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A Work of CNC Love!

The is ebook is a collaboration in the truest sense of the word. I have contributed some of the information here, but it was mainly a work of multiple people. These are special people that love CNC enought to write about it. You are the benefactor of their love.

Check out this ebook!

It is free! Free to all members of CNC Information as they are really the authors as well. Join in the project and the next revision may have your name it in.

CNC Machines

By Stuart Simpson

What is a CNC Machine? CNC stands for Computer Numeric Control. Sounds complicated, but it isn't. Years ago, it was just NC, or Numeric Control. Since, they've added computers to control the machine.

In the simplest of terms, think of a drill press. It's a machine that drills holes. But before you can drill the hole, you have to loosen the chuck, install the correct drill bit, drill the hole in the correct place, turn off the drill, and remove the drill bit. Manually, this could be time consuming and cause fatigue over the course of numerous parts. This is a simple example, but throw in some lathe or milling machining and you have a greater chance for error.

With the CNC machine, all of this drilling can be done automatically instead of the manual process listed above. Machining has to be precise, and whether you use a CNC lathe or milling machine, you have to make sure the part is right. The computer takes a lot of the guesswork out of the machining of these parts. In fact, a CNC programmer can sometimes get bored watching the machine do all the work.

But there is more programming for the machine than you would think. The operator has to enter a set of instructions. The programming uses about 50 words and tells the machine how fast, how deep, and location for machining.

What can you do with a CNC machine? In manufacturing, you can use this tool for milling, drilling, reaming, boring and counter boring. You can also groove and thread parts in a CNC turning center. You may have several setups including CNC lathes, CNC drill and tap area, CNC milling, or even CNC grinding.

EDM (electrical discharge machining) can also take advantage of CNC operations. EDM can be either vertical or wire. A vertical EDM machine uses an electrode to make a cavity for a plastic injection-molding machine. A wire EDM machine uses a wire to cut metal for a tooling operation for fabrication. EDM is more closely related to making tooling for other machines, people often overlook the use of CNC with these machines.

CNC machines can also be used with routers in the wood industry. CNC can also be used with lettering and engraving.

I hope this gave you some basic information about what a CNC machine is and what they are used for.

Stuart Simpson

http://www.cnc-machine-review.com

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Why turn to CNC grinders?

Enk, Randall

Job shops that switch from manual to CNC systems find they improve productivity and compensate for lack of operators with traditional skills

Not only is following the path of least resistance human nature, it's also good business. Take, for example, the tendency of progressive machine shops to replace manual grinders with CNC grinders.

Unlike the machining and turning center industry, which has embraced CNC technology, the grinder industry has been a decade behind, due to grinding's lack of priority on the shop floor. It's hard to believe, but the majority of grinder sales are still conventional machines.

Okamoto was the first to develop CNC profile grinding, introducing it at IMTS in 1968. As Technical Services Manager for Okamoto, I can say that every one of our customers who has replaced manual grinders with CNCs has had positive results-typically results that exceeded their expectations.

Take a good, long look around the grinding shops in this country, and you will see the graying of America. Manual grinding is, sadly, a dying art, and one that has more variables than any other machining process. It takes years of dedication to understand its nuances. True grinder artisans know intuitively how to compensate for variations in room temperature or humidity. Grinding in the morning can differ from grinding in the afternoon. Grinder operators continually adjust the process by dressing the grinding wheel and repositioning the infeed. Without accurate compensation, the tolerances required today would be difficult to achieve.

Because grinding is the final operation in many manufacturing processes, the tolerance relationships between different surfaces on the same workpiece are critical. Being able to grind all of these areas in a single setup ensures proper accuracies. CNC grinding achieves this objective more easily, quickly, and accurately than conventional grinding.

In today's job market, it's rare for a machine shop to find a young apprentice eager-and patient enough to learn the art of grinding, which can take many years. Someone just out of high school has cut their teeth on computers, electronic games, and automation. Programming CNC grinders is a more natural progression for them.

Talented grinder hands can be very costly due to their knowledge and experience. This high labor cost creates a challenge when competing with low-cost overseas labor. One of Okamoto's customers, Bill Kushmaul, president and CEO of Tech Mold (Tempe, AZ,) is passionate about this topic.

"We need to reduce the labor portion of our jobs in order to compete in the new global economy. A global economy brings many benefits. It also brings plenty of foreign competition. For us to compete in this economy today, and for years to come, we must reduce the cost of our products," says Kushmaul.

"Every shop owner has a fantasy of getting the most out of his capital by having a full talented night shift. As we know, talented people often do not like working nights. This is unlike our offshore competition. I have several colleagues in the Pacific Rim that report a full labor force 24 hours a day, seven days a week. The people there are highly motivated. They know that it took hard work to build America so in a sense they are driven to accomplish the great things we did. That is precisely why, in order to be successful we need to work smarter, not harder." These observations explain why Kushmaul has become a CNC user.

He purchased an Okamoto ACC-7-18DXNC seven years ago. Since that time, he has expanded with the purchase of four ACC-8-20DXNCP machines, one of which incorporates autoloading. The machines at Tech Mold have working envelopes of 6 x 18" (150 x 457 mm) and 8 x 20" (203 x 508 mm) chuck sizes, 2hp (1.5-kW) grinding-wheel spindle motors, and 8" (203-mm)-diam grinding wheels. All of their machines have standard Fanuc controls, which allow two-axis simultaneous motion, as well as indexing devices.

Tech Mold makes precision injection molds for the medical, packaging, and high-end consumer electronics industries. Kushmaul employs 155 people in a mold-building facility.

At Okamoto, we've found there is no typical CNC grinding customer. They can vary from mold shops, to high production manufacturing, to job shops. CNC grinders can't be pigeon-holed.

Boston Centerless (Woburn, MA) is a job shop that discovered CNC grinders' versatility. Three months ago, we installed our IGM-15NC internal CNC grinder, which has a Fanuc control and linear motion guideways (which enable contour grinding and precise axis positioning). A very compact machine, the IGM-15NC can grind internal diameters as large as 6" (150 mm) with lengths as long as 5" (127 mm).

Len Pagliaro, engineering manager for Boston Centerless, says, "We do cylindrical and ID grinding specialty work. We can grind jobs on a conventional machine, but we aren't always able to grind to the necessary tolerances and production quantities."

One source of relief for Pagliaro is the positive reaction of his team to the new CNC grinder. "Our manual grinding people like the CNC. Even our oldtimers want to learn it. It took a good month before the guys felt comfortable using the CNC, but once you get the control down, it's an easy machine to run."

Edge Manufacturing (Pevely, MO) is another Okamoto user discovering the benefits of a CNC grinder. We installed their PRG-6XNC CNC rotary surface grinder in January. Edge Manufacturing employs around 50 people who make meat-cutting tools for the food-processing industry. Prior to acquiring the new CNC grinder, they had problems meeting orders. "We were in perpetual backorder mode," recalls design engineer John Woehler. "Our customers were getting pretty mad, which prompted us to make the CNC upgrade.

"We've gained about 50% in orders over last year, in addition to new business we previously turned away, as a result of the CNC. We've realized an 80-100% increase in throughput. Unlike the manual machines that have a person attending them at all times, this machine runs untended, minus loading and unloading.

"Since the wheel compensates automatically, we use it a lot longer. I was able to upgrade to a harder, wider wheel, which benefits me, because I can hold the profile longer."

Operators at Edge Manufacturing have accepted the new technology. "One of my oldest grinder operators has run manual grinders his entire life. Now that he's on the CNC side, he doesn't want to use the manuals anymore. For him to buy into the CNC philosophy, that's huge," says Woehler.

Fairway Mold (Cypress, CA) has also made the upgrade to CNC grinders. The company employs 98 people who specialize in creating molds for medical components, cosmetic lines, dispenser lines, and personal care products.

"The software that came with the ACC-8-20DXNCP CNC grinder used conversational programming. In two weeks, I was making good parts," says Fairway's Steve Pottberg. Fairway's throughput and rejection rates have improved, according to Pottberg. "Some jobs we've done in one-third the time it used to take. I ran hand grinders for 20 years, and when I went to the CNC, the accuracy and repeatability really surprised me."

Fairway's president, Tom Smith, believes the new grinder has improved morale. "We feel it makes for better employees. They learn programming and they come to work with more enthusiasm. They get to do the setup, and they can keep a couple of machines going at one time."

Want More Information?

For information on Okamoto grinders Circle 380.

On October 4, SME sponsors the Third International Machining and Grinding Conference in Cincinnati, OH. Tabletop exhibits will be included. SME publishes several books on grinding and related subjects. Grinding Technology is intended to educate as well as serve as a shop-floor reference. Cutting and Grinding Fluids helps readers match the performance and properties of fluids to the demands of equipment, parts, and tooling. In Principles of Abrasive

Processing topics covered range from the production and evaluation of abrasive particles to the theory of comminution. Processes such as internal, external, creepfeed, centerless, belt, and nontraditional grinding are covered. For information on the Conference, or to order books, contact SME's Customer Service Department at 800-7334763, 8 am to 5 pm, Monday through Friday.

CNC Machines - The Leaders In Precision Technology Machines

By Christine Macguire

The evolution of computer numerically controlled technology, leading to higher speeds and more reliability allowed the development of machine controllers adapted to new production systems. Most of the controllers are developed in agreement with the CNC technology of the correspondent machine tool manufacturer. As a consequence; the characteristics of the CNC and the microcomputer are combined. Some researchers have addressed a flexible structure of software and hardware allowing changes in the hardware basic configuration and all control software levels.

Camware software is an integrated program to execute certain functions in these CNC systems. Today, CNC technology is a major contributor to the production capacity of industrial companies. A complex network of post-processors is therefore needed for the basic functionality of CNC systems. The necessary knowledge transformations from the vendor specific software domain to the conceptual model space are essential. This will eliminate the requirement for postprocessors. Consequently, resources will be interchangeable and interoperable, adding to the strategic agility of the manufacturing network.

CNC tool cutter and grinder chosen by leading industries are high precision tools and reliability is paramount. Whether you manufacture standard high precision cutting and drilling tools, need to sharpen standard or special tools or manufacture parts for very special applications, the camware software provides the toughness and flexibility you require. This software enables application support in all markets and can offer services that will allow you to accept special projects and deliver results in a short period of time. You can be confident that as your business expands into new application fields. Again Flexible manufacturing systems (FMS) can be created by combining any of this CNC machines with any of vertical articulated robots. The robot can be mounted on a linear slide base to provide mobility and increase its work area. Additional devices, such as storage systems and part feeders, can be added to expand the range of tasks performed by the system. FMS station in CIM system Enriched with advanced technologies generated by the company's industrial activity, and supported by effective didactic methods.

Regardless of how advanced a technology is it can only fully benefit from its advantages when the user masters it perfectly. Increasing competitive pressure demands optimized production. But how can the productivity be increased significantly? How can setup times and machine downtimes be minimized and any fault analyses and fault corrections be made as easily as possible? The solution: CNC technology. CNC machining allows you to integrate your machine tools faster and more securely in your production network - for the smooth planning, scheduling and execution of your production using data that is always current. This gives you the decisive information for significant, increased productivity. Ideal solutions for every functional area Motion Control Information System provides a complete spectrum of powerful software modules for the acquisition and optimization of your production processes. These software modules guarantee simple integration of the machines in your ERP environment. The software is modular and uniformly matched with each other. This allows the system to always be customized to your production -independent of the size and requirements profile.

Christine is an expert Internet marketing professional with years of experience in various industries such as: Business, Finance, Real Estate, Web-Design, Health & Medicine and many more.cnc machining - CNC machine

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Inexpensive PCs as CNC Machine Controllers

By Dan Staber

Part I, Utilizing an off the shelf PC as a CNC Controller

There are two main groups that can take advantage of today's low cost PCs as an effective and inexpensive CNC controller.

• Retrofits to existing CNC machines with outdated or proprietary controls in need of service.

• Shop built and home built CNC machines.

Inexpensive PCs can cost as little as $150.00 and yet provide a dependable and effective CNC machine controller. Some sources to consider for obtaining such a system are outpost.com and dell.com. Oupost.com is an outlet for Fry's electronics. They have one PC on sale ranging from $150.00 to $199.00. Several have successfully used this PC in conjunction with MACH2 CNC controller software.

Tradeoffs: Price vs. Quality. With the lowest cost PCs there a tradeoff in performance, quality, and reliability. The manufacturers of these machines use low cost hardware in their manufacture and they make compromises in the design of the systems to keep their costs down. Inexpensive hardware translates directly to a higher failure rate and more difficult to obtain manufacturer support. This can be a deciding factor by itself if you rely on this machine for production.

Design compromises which are common in low cost PC have an impact on performance. The primary concerns are: insufficient memory, the use of shared memory, and on-board graphics devices. The primary hardware requirements for a PC based CNC controller are sufficient memory, and sufficient processor speed. You can see that the compromises present in these systems are in direct opposition to the requirements for CNC controller.

At the bottom end of the Inexpensive PC market there are off the self solutions that will function well as a PC based CNC controller. As with all things, you tend to get what you pay for, so the buyer is advised to be aware of the requirements and limitations that are in play.

Part II in this series of articles will examine an alternative to buying an off the shelf solution and explore building a PC to meet your specifications.

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Computer Aided Design Applications

By Jennifer Bailey

Computer Aided Design (CAD) is a type of computer-based tool used for drafting and designing. CAD is useful in various designing fields such as architecture, mechanical and electrical fields being some of them. This is a type of software, which enables users to create rapid and precise drawings and rough sketch plans of main products. It provides a flexible pattern in the drawing process that users can alter as according to their required dimensions with minimal efforts.

CAD is not only made for artists specifically but has the diversity to entertain all kinds of designing enthusiasts. This software has all built in features as per users need and come with many templates and symbols, for designing and drafting purposes, which gives it a wide area of application. It is the primary geometry-authoring tool used for all 2D and 3D designing purposes. It is useful for engineers, architects, and other designing professions.

CAD is applied in mechanical, automotive, aerospace, consumer goods, machinery, and shipbuilding applications. In this field, it is used for designing various machinery and tools that are useful for manufacturing purposes. In the field of electronics, it is used in manufacturing process planning, digital circuit design, and other software applications. In the field of architecture, it is used as an effective tool for designing all types of buildings and assessing the integrity of steel-framed buildings. It enables them to design buildings in 2D and 3D models to give almost a real replica of the original work. It is useful in engineering processes in conceptual design, and laying out and analyzing components in manufacturing methods. Computer Aided Software Applications are now available on personal computers to facilitate users to work from home.

Many professionals use the CAD software because of its precise and creative benefits. Lower product development costs and reduced design cycles are some other attributes of the CAD software. Many educational institutions are nowadays indulging in teaching CAD to their students to make them aware of the latest technological advancement in the field of designing.

Computer Aided Design provides detailed information on Computer Aided Design, Computer Aided Design Software, Computer Aided Design and Manufacturing, Computer Aided Design and Engineering and more. Computer Aided

Design is affiliated with Cam And Computer Aided Design.

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Computer Aided Manufacturing Software

By Kevin Stith

Computer Aided Manufacturing (CAM) is one of the software automation processes that directly convert the product drawing or the object into the code design, enabling the machine to manufacture the product. The CAM system is used in various machines like lathes or milling machines for product manufacturing purposes. It allows the computer work instructions to communicate directly to the manufacturing machines. This saves on time and money, in that the controls can all be routed directly to a computer or laptop system, where changes can be made with the click of a button.

It provides compatibility with any CAD file format including DXF, DWG and DGN Professional 2D Mechanical drafting and design. It allows easy 3D modeling and rendering options. The CAM software provides complete support for milling, drilling and lathing operations. It includes the setup wizard, the tool database and a dialog-free CAM palette.

CAM software has developed in such a way that it has become quick, flexible machining with effective simulation. The 2D and 3D simulation is developed in the real time environment - a major advantage of the software. Load factor compensation for machine and tool, tool paths, automatic optimal tool paths and cumulative time are also major benefits in this CAM software.

Several software vendors like AutoDesk, EDC, PTC, GibbsCAM and CamSoft offer you the software with factors involving high quality, ease of use, and a reasonable price. EDS e-factory, EDS e-Vis, EDC FactoryCAD, PTC Pro/ENGINEER Advanced Assembly, and the API Toolkit are a few of the major software applications that are used in the CAM system.

Computer Aided Manufacturing provides detailed information on Applications of Computer Aided Manufacturing, Cam And Computer Aided Design, Computer Aided Design, Computer Aided Design Scanners and more. Computer Aided Manufacturing is affiliated with Computer Aided Design and Manufacturing.

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Ever Wondered About CAD?

By Sandy Cosser

Unless designing or drafting is in your line of work you might not necessarily know what CAD is. You're not alone. Even in today's world where it seems that every second person is a computer genius, there are still plenty of people for whom a lot of jargon travels way over their heads. I share their pain or embarrassment, because its no joke being the only one in the room who doesn't get the computer hacker joke and as result ends up smiling with a dull blank expression on her face and nodding like an idiot.

CAD stands for Computer Aided Design, it used to stand for Computer Aided Drafting but was changed because as it improved, it evolved to do more than just drafting. It is also know as CAID - Computer Aided Industrial Design and CAAD - Computer Aided Architectural Design.

The programme was created to design and develop products, which can be goods used by consumers. It is also used in the design of tools and machinery that manufacture components, as well as in the drafting and design of buildings. It is used throughout the entire engineering process from the onset of conceptual design and layout all the way through to the definition of manufacturing methods of components. Another important way in which it can be used is in the detailed engineering of 3D models and 2D drawings of physical components.

An area where CAD has gained significant importance is Computer Aided Technologies. The advancements in this field have included a reduction in product development costs and shorter time spent on the design cycle.

CAD can be used in a number of different ways, depending on the task at hand, the profession of the user, as well as the type of software that is run. CAD comes in a variety of systems, and each requires a different pattern of thought on how to use it to maximum benefit. In addition, each system's virtual components must also be designed in a different way.

CAD generally operates on computers that are Windows based, although some systems run on hardware that uses Unix operating systems and a few work with Linux. There are a few CAD systems e.g. Ocad and NX that provide multi-platform support and these include Windows, Linux, UNIX, and Mac OSX.

In order to use CAD it is generally not necessary to obtain any special hardware other than a high-end OpenGL based Graphics card. If you are going to be doing complex designs then you will need computers with high speed CPUs and large amounts of RAM. A computer mouse is used as the human-machine interface, although a pen and digitising graphics tablet can also be used.

Once a programme like this has been created and become so well used and mainstream, it is difficult to imagine a time when it wasn't used. What did people do before CAD? They had to do everything by hand. It was painstaking work. At times it could be frustrating because even the smallest mistake could set you back days. I wonder what their level of job satisfaction was like? These days CAD developers strive to make future work on the project as simple as possible. They need a very good understanding of the system in order to do this. After all, extra time spent now could mean great savings later.

Recommended site:

http://en.wikipedia.org/wiki/CAD

Sandra wrote this article for the online marketers AO Copy London business printing one of the leaders in the field of business printing and copying in the UK

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CAD for Beginners

By Rudradatta Rath

In the 21st century technology has expanded its wings in almost every sphere of knowledge and life style. Hence with the enhancement of technology has empowered Engineers and Designers to get the power to excel with CAD.

Due to the advancement of CAD (computer aided design) there is no painstaking workout of the engineers and draughts-men standing near the drawing board with a huge drafter and trying to draw their concepts.

Recreation of designs & drawings has become so easy today that it takes only an unimaginable fraction of a second. Sharing of a single platform helps the draughts man to divide the time consumption and hence increases the productivity.

A completely new drawing can be created with a base drawing and slight modification of some part of it and unlike in paper drawings where a draughts man has to redraw again the whole drawing which, consumes not only his time but also reduces productivity and interest in work.

Once converted to CAD format, the drawings can be copied any number of times, any part can be added/removed to a drawing without disturbing the original one. Various engineering data can be retrieved as well from the drawings without doing any further calculations manually.

What is CAD?

CAD is the short term for "Computer Aided Designing" or sometimes spelled as "CADD" which refers to "Computer Aided Designing and Draughting". It's the process of conversion of design data into digital format that enable the data handling easier, quicker and safer. Through CAD technology, almost any type of designs and drawings can be done. Designers from various fields such as Engineering, Architecture, Fashion, Textile, and Graphics are now days highly dependent on CAD technologies.

CAD is a computer-assisted technology, used for making various types of graphics designs. It has inherited its base technology from Co-ordinate Geometry and Mathematics. Further developments have been made to suit different domains and their related design requirements. The basic entities used in any CAD environment are point, line, polygon and text. These entities have been further modified to create circle, ellipse, parabola, hyperbola, mesh and 3D objects like Sphere, rhombus, cube, cylinder and so on.

Software in Use

Based on the concept of CAD technology, many CAD software have been developed by software giants like Auto-desk Inc, Bentley, Dassult Systemes, Some of the leading software in the industry are Auto-CAD, Micro-station, CATIA, Pro-Engineer, Uni-graphics, Solid-Edge, STAAD Pro, Auto-Civil, Auto-desk Inventor and the list goes on and on.

It is frequently seen in use for engineering fields, although it is also applied for other vector graphics designs in no fewer manners. Due to CAD facilities, the repetition of work are minimized, exact accuracy can be achieved; reproduction is not a problem now days. After conversion into digital format it can also be sent through electronic mail to any part of the world as an editable file. Due to availability of a lot of file formats, the same file can be opened and used in a variety of CAD software.

Computer aided design (CAD) Process:

In CAD, generally the drawings are done according to the dimensions given either in a hard copy like paper or it may have been mentioned in a raster or image file, which is a scanned copy of the paper drawing. If the source drawing is a hard copy, then putting the hard copy by the side and referring to the same does the drawings. But this is a cumbersome process. So another process has been developed in which, the hard copy is scanned and the same is attached into the drawing platform say, Auto CAD. Then it becomes easier to draw the elements. This type of draughting is called as on-line draughting.

Area of Use:

As it is easy to work with cad software the authorities, engineers, draughts-men in many part of the world have already begun to work with the most advanced facilities and technologies like CAD (Computer Aided Designing) for creation, modification, reproduction, safely store and enhancement of dynamism in their drawings, such as: Civil Engineering, Mechanical Engineering, Electrical Engineering, Electronics, Engineering, Architectural Engineering, Aerospace, Automobile, Manufacturing, Production, Plumbing, Piping, HVAC and Fashion Design etc...

Prospects:

From this inception, it has been human nature to innovate, discover, invent new things and so has been his creation. Design may be pronounced as the synonym for creation. So there is no end to man's creation, design and hence CAD. By passage of time it'll be even smarter, quicker and sophisticated.

This article was provided courtesy of orisysinfotech.co.uk Specializing in CAD services SEO, E-commerce website design and development

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http://EzineArticles.com/?CAD-for-Beginners&id=703084

CNC's fast moves

Noaker, Paula M

Rarely is the control the limiting factor in a high-speed machining application. More common productivity roadblocks are machine tool dynamics, long NC programs, and the wrong speeds and feeds. optimize metal removal rates, you can often use the CNC to navigate around the machining system's limitations.

The CNC functionality you require may not cost as much as you think. One reason, says Steve Manolis at control manufacturer Heidenhain (Schaumburg, IL), is that advances in functionality often offer lean-frog levels of productivity that far outpace the cost of a new control.

Additional savings come from using aids, such as distributed numerical control to feed programs to controls and real-time process monitoring technology. These help controls react fast to changes in the manufacturing process to reduce scrap and improve part quality. There also may be an advantage to rethinking the way you machine parts, for example, by using fewer, more versatile tools to hog out complex contours in aluminum blocks.

TIME TRIALS

Heidenhain's latest high-speed control is the TNC 426. Besides digital servo control, it has a block processing time of 4 msec and look-ahead capability of 126 NC blocks for feed adjustment. This is a substantial gain in functionality over the company's TNC 407, which offers 30-block look ahead and 25-msec block processing time. The specifications are impressive, but they aren't worth much if the machine tool isn't dynamically capable of moving at high speeds and feeds--or you don't know how to use them to improve processing efficiency.

For example, most control builders recommend examining several characteristics when specifying a control for high-speed work. Block processing speed is a good place to begin, but it shouldn't be the only variable used to compare controls. (Manolis defines a basic block in an NC program as the bytes of information required to control all the functions forne machining position or operation. A single program will contain a variety of block sizes.)

According to Bill Griffith at GE Fanuc Automation North America (Charlottesville, VA), control builders may provide two different block processing times, with the first measured from when the control accesses a part program from its resident memory and the second measured from when the CNC accesses a part program from an external device. "The first value is easier to determine than the second," says Griffith. "You must also understand how block processing time will vary based on how many simultaneous axes will be programmed in a block and other programmed conditions, such as cutter radius compensation."

Griffith suggests that end users also ask control vendors about other specifications that can bottleneck processing, such as the following:

* Servo sample time. The sample time of the servo velocity feedback and the position feedback must be faster or equal to the system's maximum block processing time.

* Maximum position feedback pulse rate. The maximum feed rate at which the axis can be programmed depends on both feedback resolution and the maximum position feedback pulse rate.

* Interpolation rate. This is the cyclical rate at which the main CNC processor passes commands to axis processors. If block processing time is 2 msec and the interpolation rate is 10 msec, there is a bottleneck.

Digital servo control also promotes high-speed control. "Some controls still provide analog output to the motors and servodrives," says Manolis. "In analog systems, there are two loops between the control and machine interface. The controller monitors the position loop. The velocity loop is monitored by tach feedback between the servoamplifier and the servomotor. The result can be slow response times in telling the servomotor to speed up or slow down."

With digital control, NC monitors both the position and the velocity loop. Manolis reports response is faster and resolution finer, especially in contouring. Heidenhain's TNC 426, for example, can maintain resolution of 0.1 micron, 10X better than analog-controlled NC.

When specifying a control for a new machine tool or for a retrofit, you should understand the two types of acceleration and deceleration provided by controls. According to Griffith, high-speed and high-precision machining applications require a combination of the two.

"To get the best path accuracy with Fanuc's Series 15 M," says Griffith, "the control must calculate acceleration and deceleration before doing any interpolation. Preprocessing this data is necessary to look ahead to detect a part's comers and curvatures.

"Acceleration and deceleration after interpolation are important to eliminate shock on the machine. Think of turning a corner. At the transition point, you need acceleration and deceleration to smooth the comer. Older machine tools require more of this acceleration and deceleration because they really aren't designed to accelerate at the rates required for high-speed machining."

Parallel processing also is important. On Fanuc's Series 15 MB, most control functions, such as graphics, communications, individual axis control, and PLC functions, have their own processor. These work in parallel with the 32-bit main processor and communicate over a common 32-bit bus. The reason is simple. Too many serial functions on a processor would slow it down.

An option on the 15 MB is to have a 64-bit RISC processor working in parallel with the 32-bit processor. The 64-bit processor is a requirement when you need block processing rates of 2 msec or faster and more precision than a 32-bit processor can provide. "The 64-bit processor won't resolve problems with machine tool and servo systems, though," says Griffith. "A conventional servo, for example, still requires a fast enough interpolation time and update rate."

EXPLORING MACHINE DYNAMICS

High-speed processors, combined with features such as real-time dynamic compensation of the machine tool, allow end users to rethink how they machine parts. LeBlond Makino promotes use of high-speed, high power machining centers, fast controls and data communications, as well as Geometric Intelligence software, which can predict and compensate for machine dynamics on the fly. This permits high feed rates, as well as high speeds through corners and geometry changes--for example, cutting a 1/2" (12.7 mm) boss at 630 ipm (1600 cm/min) with roundness to within 0.00058" (0.0147 mm).

By zeroing out the effects of axis reversals, geometric control capability on LeBlond production machines allows end users to interpolate holes with a small-diameter end mill. They can form holes to different diameters and depths, even chamfered and counterbored, in one operation--LeBlond calls it the Tornado Process.

User-friendly macros provided by the company allow end users to generate entire interpolation routines for holemaking, as well as threading (with a special tool), from a few input parameters.

According to LeBlond engineers, interpolation can achieve higher removal rates and faster cycle times than conventional drilling. Other benefits include the following:

* Coolant flooding and chip removal improve because the tool doesn't fill the hole.

* Edge contact with the metal is as little as 30deg per rev for greater heat dissipation, allowing high spindle rpm without burning up the tool.

* The interrupted cut breaks chips to prevent bird nests, particularly with aluminum and stainless steel.

Interpolating the end mill also addresses the problem that speed at the center of a drill is always 0 sfm. By generating cutting action at every point on the tool, helical interpolation removes much of the cutting resistance. You may then be able to create holes in difficult work materials that conventional drills have trouble penetrating.

FEEDING THE BEAST

DNC communications technology provides a key link in high-speed machining applications, such as moldmaking. First, mold machining programs are often too long for the memory of the CNC, requiring an outside file server and communications processor. Second, communication speed must keep pace with the machine control. If data flow to the machine is too slow, the control will suffer from data starvation, which will show up as dwell marks on the finished core or cavity surface.

"DNC systems can use a PC as a communications processor for drip-feeding programs to the CNC," explains Carl Billhardt, president, FMS Technology Services (Westerville, OH). "This often costs less than adding CNC memory, while removing any file length limitations."

Billhardt reports the communication rate is critical with 3-D sculptured surface machining. For example, assume the data required to define a single-axis move is 9 characters, and 27 for a three-axis move, a DNC system with 19,200-baud communication can only support a maximum block cycle time equal to 1920 characters/sec divided by 27 character/block or 71 blocks/sec. Complex NC programs for moldmaking can require instantaneous communication rates beyond 100,000 baud.

"The program size determines whether programs can be downloaded in batch form directly into the memory of the CNC or whether the program must be drip-fed," says Billhardt. "The DNC solution for drip-feeding long files depends on the control. Some controls require a special interface card consisting of a large, volatile buffer memory and control logic.

"When executing short moves, the control may want to process data faster than the communications: system can send it. Executing long moves allows the system to supply data faster than required. As long as the average rate of data execution is less than the communications rate, the CNC will never starve for data. The size of the buffer determine the period over which the difference between communication input and execution output can be averaged. The larger the buffer, the less likely the control will be starved." Billhardt says some controls permit operation in a direct tape mode with input taken from an EIA 232 port rather than the tape reader. Starvation is more likely because of the very limited buffer between input and the point of execution. For this reason, he recommends avoiding direct tape mode processing without an extended buffer when programs have a lot of short increments that must be processed at high feed rates.

When evaluating the DNC capabilities of CNCs, Billhardt recommends asking the following questions:

* What is the error detection and recovery mechanism? With simple software interfaces, Billhardt says that communications stop when a parity error is detected. High-level DNC interfaces can request that the sender retransmit the

bad packet. If the same packet has data transfer errors after several tries, the system will signal an alarm.

* What mechanism handles data flow control?

*What must the CNC operator do to initiate a file transfer?

* Can the operator upload and download files between CNC and host system and drip-feed long files?

* When drip-feeding, what other control features are available? Block search, restart, or program execution?

"Evaluate these factors as a system," says Billhardt. "One control may permit drip-feeding of long programs with the standard hardware but only with DC1/DC3 flow control and no error detection and correction. A second control may require a special hardware option for drip-feeding in addition to providing a high-level software interface with error detection and correction."

FINETUNING FEEDBACK

Ideally, says Professor Tlusty, head of the University of Florida's Machine Tool Research Center (Gainesville), the NC programmer should know about the limitations of each high-speed machine and its tooling when writing programs. Often this isn't the case, yet these data are just as important as recommended cutting speeds and feeds in maximizing metal removal rates in high-speed machining.

With spindles providing 20,000 or 40,000 rpm, for example, chatter is a major detriment. "The best combination of depth of cut' and speed occurs when machining is chatter-free," says Scott Smith at the Machine Tool Research Center. Manufacturing Laboratories Inc. (Gainesville, FL), which is conducting high-speed, high-power spindle research with Manufacturing Laboratories Inc. (Gainesville, FL). "Mapping this zone of stability isn't easy without real-time monitoring and control of the manufacturing process."

Manufacturing Laboratories makes a chatter-recognition and control (CRAC) system that Smith helped develop as a graduate student at the University of Florida. Using the CRAC system, engineers start cutting at the maximum spindle speed and a stable depth of cut, then increase depth of cut incrementally until chatter occurs. The CRAC system then commands a spindle-speed change to another stable cut, and automatically increases axial depth of cut until the cut is again unstable. The process repeats until the system can no longer find a stable cut. The metal removal rate that results for the last stable cut is often higher than that for initial cutting conditions.

A test of a milling cutter machining aluminum illustrates CRAC results. The two-fluted, 19.05-mm-diam tool extends 57.0 mm from its toolholder. For the test conditions, maximum spindle speed of 36,000 rpm and chatter-free slotting DOC of 1 mm produced a metal removal rate of 274 cm sup 3 /min with a 0.2 mm/tooth chip load. Working with the CNC, CRAC regulated cutting to 26,582 rpm and 4.45 mm DOC. This boosted the metal removal rate 128% to 900 cm sup 3/ min at the same chip load.

Tlusty reports chatter-recognition and control also can produce results in high-speed, high-power machining of cast iron. In both work materials, the search for optimum cutting conditions can be done on the work material before making the required cuts to produce a part shape. Since cutting conditions are then optimized before part machining begins, less adverse forces act on fixturing and tooling.

WANT MORE INFORMATION?

SME offers video-based training courses called "Machining Center CNC Programming" and "Custom Macro Programming." Call SME Customer Service at 1-800-733-4SME 8 am to 6 pm Eastern time Monday through Friday.

The PC's CNC transformation

Noaker, Paula M

Will a PC be the soul of your next machine tool? Control vendors can't seem to agree on the answer. Some believe its place is as a front-end interface for a conventional CNC. Others say the control of preference in coming years will be a PC with a CNC motion control board inside. Both groups, though, agree that most future controls will probably be one or the other.

Fueling the growth of PC-based control software is a recent, major initiative by the Big 3 automakers to develop an open, modular architecture controller. The automakers are working with control manufacturers to promote development of economical control technology that is:

* Open, integrating off-the-shelf hardware and software components into a de facto standard control environment.

* Modular, permitting plug-and-play of components to best meet a specific application's control needs.

* Scalable, allowing easy and efficient reconfiguration as control needs change.

* Maintainable, supporting maximum machine tool uptime, expeditious repair (minimum downtime), and easy maintenance.

"Various levels of openness can be achieved with machine tool controllers," says C. Jerry Yen, NAO-Machining Centers/Manufacturing Controls Dept., GM (Warren, MI). "The ultimate level is a software-based controller, with a variety of functional modules that can be easily added or interchanged. At this level of openness, the control will be hardware-platform independent. Along the way, though, we are targeting use of PC-based controls to provide a more open control environment--using the current PC platform and operating system standards and trying to integrate off-the-shelf components.

"We see the initial step in GM's efforts to use open-architecture controls as being the open-environment control. Controls will use PCs with the Microsoft Windows operating environment, which has become an off-the-shelf de facto standard. Moreover, a control will be open in the sense that you can pick and choose the application components that you need. The problem is that you need a lot of engineering time to integrate all these components, which aren't designed to come together easily. They may all run within the Windows environment, but that doesn't mean they will automatically interact as needed to control the process when I load the software into a system."

CNC Inside the PC

When control vendors say they have a PC-based control, they usually mean that the motion control board or complete CNC unit with integrated programmable logic control will fit into a standard slot of an IBM or compatible PC.

Thomas Glynn, CFO, CNC Software & Systems Inc.(Wells, ME) reports that its multitasking CNC-PC software for Windows, which emulates GE Fanuc in both screen functionality and G code input style, uses a Galil motion control board to handle all machining movement. This frees the PC's CPU for other uses, such as tool management, programming, and statistical process control. Because of this, if the PC Windows environment were to lock up, the motion control board would shut the system down in an orderly fashion.

Henry Glick of Mitsubishi Electric Industrial Controls Inc. (Mount Prospect, IL) adds that PC-based CNC users no longer need worry about sacrificing servo update times for position feedback that could limit the speeds demanded by some precision machining applications. In Mitsubishi's MeldusMagic PC-based control, servo update times are comparable with conventional CNCs.

An obvious benefit of PC-based controls is their cost. Consider Wizdom Controls Inc.'s (Naperville, IL) Wizdom Paradym-31 Version 2.6 Windows-based industrial programming, simulation, and control software, which works with a Delta Tau PMAC (motion control) board. A ladder-logic-only version of the software costs about $695 for programming, monitoring, and execution.

A complete control, simulation, monitoring, and execution package ranges from $2995 to $3995. (Prices don't include the controller board.)

Price/performance ratios for PCs continue to improve. Technology Automation Services (Englewood, co) notes in its recent "Technology Trends in CAD/CAM" report that $3000 worth of PC packs a lot more processing power than in 1992--one computer vendor now offers 16 MB of RAM instead of 8 MB, 1 GB of disk drive capacity vs. 200 MB, and 256 kB of cache memory vs. 64 kB. Controls also benefit from the rapid and inexpensive upgrading of today's PC technology.

Still, the key benefit of PC-based controls is their flexibility to run a variety of user-specified software programs, in addition to providing machine control. For example, with FlexMate Inc.'s (Fren Park, FL) PC-based control with Windows 3.1, an AcadView option allows viewing standard AutoCad drawings and control schematics directly from the control display. Minimum system requirements are 4 MB of memory, DOS 6.22, and a 486 DX33 PC with a mouse or trackball.

As another example, CNC Software & Systems's CNC-PC software operates concurrently with a range of shop-floor control software, such as solid modeling, SPC, tool crib inventory, and PLC graphical user interface. It also accommodates using touch probes for part inspection and location, automatic tool offsets, and SPC data collection; as well as tool changers, video cameras, coolant control, and systems for part handling or inspection.

PC-based software's customizable interface also is more user-friendly than a standard CNC. Ease of networking PC-based controls via the Novell network, another de facto standard, is a further benefit.

PC-based controls also can eliminate G-code programming, adds Bill Gibbs, president of shop-floor programming software manufacturer Gibbs Q

Associates (Moorpark, CA). Programs can be built graphically, reducing the programming learning curve dramatically.

Pros and Cons

Don't expect all control vendors to replace their conventional CNC technology soon, though. PC-based controls still face hurdles. For instance, while some reportedly can control up to 10 axes, applications requiring complex five-axis machining still will demand some conventional CNC technology. Moreover, most end users will probably not be running heavy-duty CAM work with the PC-based control while the machine tool is cutting metal. In addition, retrofitting the PC-based controls can take time. One retrofit of a PC-based control required four to six weeks. The end user reports three weeks of this required machine tool downtime.

For companies that want PC processing flexibility, but don't want to or can't give up conventional CNC technology, several control manufacturers offer a PC front end. John Turner at GE Fanuc Automation North America (Charlottesville, VA) reports that the control vendor provides several variations. One is its Machine Management Control-IV PC-compatible computer embedded in a common backplane bus with a GE Fanuc Series 15B, 16B, or 18B CNC. Users can easily replace their control's CRT with another option, the Intelligent Terminal. Turner says this combines the functionality of the first option with a high-speed serial bus for high-speed data transfer. GE Fanuc also makes it easy to link any PC in the shop with their CNCs through the Open System CNC option. This contains the serial cable, and two interface cards, as well as all interface libraries and screen generation software needed.

The PC interface is only one option in Siemens's (Elk Grove Village, IL) modular approach to CNC. Its Sinumerik 840D machine tool control allows you to plug-in power as needed. For example, if you need a fifth axis, you simply add a feed module and motor to the system. Users can decide between the MMC 101 interface with an integral Windows-based PC, the MMC 100 standard operator interface, and the MMC 102 interface, which can be used for 2-D and 3-D simulation. NC control units include the following: The NCU 571, with a 960 RISC processor, 128-kB CNC, and 64-kB PLC user memory for up to five axes and two spindles; the NCU 572 with its 486/DX33 processor, 256-kB CNC, and 96-kB PLC user memory for up to eight axes and five spindles; and the NCU 573, which builds on the NC 572 model by adding a high-speed 100-MHz Pentium processor.

As another example, the PCNC from NUM Corp. (Naperville, IL) merges an IBM PC with a multitasking OS/2 2.1 operating system with the model 1060 23-bit CNC. The PC is compatible with Microsoft Windows and OS/2 Presentation Manager and handles user and manufacturer-specific applications, including programming and machine supervision.

Future Facts

Least you attempt to downplay the impact PCs will have on machine tool control in the future, consider this. Cincinnati Milacron's (Cincinnati) control of the future, its Acramatic 2100 (A2100), is PC-based and runs on the Microsoft Windows NT operating system. According to Ron Pieper at the Electronic Systems Div., the CNC will eventually supersede both the 850SX and 950 series controls. At present, though, those wanting complex five-axis control will still see an advantage in using the 950 control.

Pieper reports the Acramatic 2100 control differs from other PC-based units because it is a dual-PC platform. One PC motherboard controls workstation functions such as shop-floor programming and database work. The other handles real-time servo control. Upgrading will be easier and less costly than with a specialized motion control board, says Pieper. The user also pays for no more capability than needed. For example, the two PC buses are linkedvia a proprietary bridge board, which holds I/O cards, and servo control cards, and leaves slots available for options such as an Ethernet adapter, as your needs grow.

Pieper sees an advantage to using Microsoft Windows NT for control. Unlike Microsoft Windows, which resides above the DOS operating system, Windows NT is its own operating system. Pieper reports this operating environment offers more protection against crashes. It also assigns different priority levels to various tasks, which ensures that CNC software has priority over other application software. Windows NT also is platform independent, allowing a company to move to other hardware as needs dictate.

The 2100's three basic components include an operator CRT, the control box, and a hand-held pendant that provides all CNC push buttons and controls required for standard operation. The pendant eliminates the need for the operator to stretch and strain to keep one hand on the feed hold button and one eye on the machine, notes Pieper. Also gone are the constant back and forth motions between part and CNC during setup and programming of a job.

Moreover, the pendant's LCD readout allows the operator to observe the machining cycle from almost any angle without losing access to major CNC functions.

Programming also is simplified using a resident assistant programmer. This allows programming a variety of cycles without G codes. Instead, operators touch an on screen icon of the desired machining function, then enter information when prompted by the system. The control's Gibbs shop-floor programming system, for example, has an option that allows the user to verify the part during programming.

Judging CNC machine utilization levels

Mike Lynch

It's no secret that CNC machines are highly productive. In fact, this is one of their greatest benefits. But this important benefit can lead to a problem. If you are thoroughly satisfied with the productivity of your CNC machine tools, how can you tell when they are being under-utilized? I define CNC machine utilization as the effectiveness level of your CNC machine tools. You can contrast your judgment of machine utilization against many factors, making the judgment of machine utilization level very subjective.

Don't confuse utilization with application. A machine's application is simply what you are using the machine to do. A vertical machining center that is being used as little more than a glorified drill press is every bit as important to its owner as an identical machine being used to produce three-dimensional shapes in molds.

Also, don't confuse machine utilization with personnel utilization. You may think you're making the best use of your CNC machine tools when in reality, you're making better use of your CNC people. For example, you may have one person running two or more CNC machines. Or you may have a CNC operator performing secondary operations during the CNC cycle. These are common practices, but they lead to under-utilization of CNC machine tools. It is likely that CNC machines will often sit idle--waiting for a CNC person to do something.

Because machine-time cost (shop rate per hour) is usually much greater than the hourly wage of a typical CNG operator, you should be more willing to have a CNC person waiting on a CNC machine than a CNC machine waiting on a CNC person. As human beings, we can't stand to see anyone sitting idle, waiting for a machine to complete its task. If your goal is to keep people busy, assign them tasks that are unrelated to the operation their CNC machines are performing. But be sure they understand that the CNC machines are the top priority.

Things have been changing in the CNC environment that are making companies take a closer look at machine utilization. Among other things, lot sizes are getting smaller, quality expectations are higher and lead time are shorter.

Sticking with current methods will lead to severe problems. Fortunately, most companies have built-in potential for improvement. Again, maybe you've been so satisfied with the performance of your CNC machines that you've never questioned utilization. It's likely that at least some of your machines have been under-utilized, allowing room for improvement.

My first suggestion for judging a CNC machine's utilization level is simple: look at the percentage of time per shift, day, week or other period that a CNC machine is in cycle. If, for example, you find that during an 8 hour shift, the machine is in cycle 7 hours (not in cycle for one hour), this machine's utilization level is 87.5 percent (seven divided by eight). Acceptable machine utilization levels will vary from company to company. A product-producing company will have higher expectations than a contract shop.

Unless your company has already implemented some kind of improvement program, there probably will be room for improvement. Fortunately, improvements in this area will be relatively easy. Just come up with ways to keep machines running. It may take rethinking your company's personnel utilization (teaming up on jobs as opposed to having one person do everything). It may require better organization (why does the operator have to go all the way to the tool crib to get more inserts?). It may require more work in preparation, getting managers and lead people more involved with scheduling.

My second suggestion for judging CNC machine utilization level is to consider bottlenecks. Is there one machine or department that's always behind? Is there a machine or department that has an unusually high scrap rate? Is there a machine or department that has unusually high turnover? Bottlenecks of any kind are an important symptom of under utilization. Improvements will likely be more challenging, often requiring an overhaul in processing, workholding, and cutting tools, generally re-thinking how the job is done.

My last suggestion for judging CNC machine utilization level is to examine the number of mistakes (especially repeated mistakes) being made. If a mistake causes scrap, the time it takes to run the scrap workpiece cannot be counted as part of the machine utilization level calculation given above. But even if mistakes don't cause scrap, it's likely that they do cause a decrease in machine utilization level. Repeated mistakes should be a signal that you need to increase skill levels through training or decrease the skill level required to perform the mistake-causing task through task simplification.

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Ask This Expert

See Mike Lynch on MODERN MACHINE SHOP Online at www.mmsonline.com/experts/lynch.html

CNC maintenance training - computer numerical control - column

Golden E. Herrin

CNC Maintenance Training

Most of today's major machine tool builders in conjunction with the CNC supplier offer a wide variety of end-user training on CNC machines. Some of the training is informal, some formal covering a wide variety of technologies such as: programming, machine maintenance, operation, servo drive maintenance, and CNC maintenance. Each of these categories of training plays an important role in the successful installation of a new machine and each imposes a different set of discipline on instructors and students. The following focuses on just one of these categories of training CNC maintenance.

The training methods used in CNC maintenance classes have changed significantly from the class conducted in the early years of NC largely due to the developments of new diagnostic tools in the controls. During the early years of hardwired NC, built-in diagnostic tools were almost non-existent and consequently maintenance training was based on teaching the theory of operation. In fact, control builders provided either a "Theory of operation" manual or a very thick chapter in their maintenance manual on "theory." This philosophy was greatly influenced by the fact that the first instructors as well as the first manual writers were often the engineers who participated in the design of the control since formal training departments as we know them today, had not yet evolved.

Today's CNCs have a high level of built-in diagnostic features and as such the maintenance training classes over the years have gradually been restructured to reflect their use. The amount of theory now taught in the classroom has been scaled down to just enough to provide the student with an overall understanding of the control's operation. Consequently a significant amount of the training time is devoted to understanding and using the diagnostic tools provided in the control. The emphasis has changed from "how it works" to "how to fix it."

Basic CNC maintenance courses offered by almost all control builders today last approximately one week, four and one half days on the average, with many offering in-depth or extended courses lasting two weeks or more. Classes are normally held at the control builders plant where adequate facilities and equipment for hands on experience are available, but a certain percentage of users request that the control builder bring the class to their facility. One control builder for example indicates that forty percent of their training (based on number of students trained) is done at the user's plant. The advantage of on-site training is obvious in that the user can send more employees since there are no travel expenses. The disadvantage is often inadequate training facilities and equipment for lab training. In addition the students are subject to being called out of the class to perform a routine maintenance job, breaking the continuity of the class.

Instructors all agree that adequate lab time with hands on experience is important for a successful CNC maintenance class. Even though instructors would like to see a ratio of one student per control for lab exercises, this is seldom possible. Generally instructors target the CNC maintenance classes for eight students with enough equipment to allow two students per control. Instructors all seem to agree that a class size of 12 with three students per control are numbers that should not be exceeded.

The practice of control builders differs when it comes to testing students. Some control builders require students take written exams, others do not. Cincinnati Milacron is one company that requires student testing and issues certification only when a student meets the requirements. The instructors evaluation of the student is based on both classroom work and lab exercises. The results are sent to the students supervisor since it is felt that companies are entitled to this information so they can properly assess their maintenance resources. But, "what is good for the student is good for the instructor." The student gets a chance to evaluate the instructor by filling out an evaluation form hich is reviewed by the instructor's manager. This permits the training manager to assess the effectiveness of the training programs.

In the early years of CNC the most important prerequisite for a good control technician was a sound electronic background. Today a good understanding of electronics is still important but the ability to understand the control from a system standpoint (interrelationship of hardware and software) may have replaced electronic background as the most important factor. With today's diagnostic tools, faults are diagnosed to the module level. The service technicians today replace an entire plug in module rather than replacing individual components within a module. This has led to less emphasis being placed on the function of each electronic component and more on the control as a system.

One problem faced by all training departments is how to get a beginner student up the learning curve so that he does not slow down the class with elementary questions or even worse, not ask questions and stay confused. General numeric addresses this problem by providing a book on request to students titled "Introduction to NC." Other companies have recommended levels of expertise and experience that a student should be at before they attend a specific class and recommend courses or books for achieving those levels.

It has been well established that training plays a major role in the success of any new NC machine installation and as such, control builders have devoted significant resources to this segment of their operations. However, it is the end user's responsibility to take full advantage of this service.

Bridging the gap between CAD and CNC

Derek Korn

The postprocessor is the last software link between an ideal CAD model and a "real" machined part. To what degree the postprocessor can take advantage of a CNC's capabilities, and vice versa, determines the number of available programming options and degree of programming difficulty. CNC/postprocessor rapport is particularly important for high speed machining (HSM).

There isn't a comprehensive, unifying solution that marries all CNCs and postprocessors in such a way. However, Siemens and ICAM have made a step in that direction by developing the CAM-Post Sinumerik 840D postprocessor, which is tailored specifically to the Siemens 840D control. This dedicated postprocessor speeds and simplifies programming, while taking some of the mystery out of accessing the control's high end HSM features.

"High speed machining, in particular, brings into play a lot of new CNC features that are not necessarily intuitive from the perspective of some CNC users," says Siemens' Norman Bleier. "Help in the postprocessor is another step in advancing the CNC concept to address the new challenges of high speed machining."

The Sinumerik CAM-Post version is an adaptation of ICAM's universal CAM-Post. It supports 840D control features such as:

* Local coordinate system programming, to allow 2 1/2-D cycles to be performed from any tool axis orientation

* Rotating Tool Center Point (RTCP) programming based on the 840D's transformation orientation (TRAORI) tool-tip programming capability, which is designed to simplify 5-D programming and tool compensation

* Circular Intermediate Point (CIP) and dual curve NURBS interpolation.

According to ICAM's Malcolm White, this CAM-Post version is also helpful for programming special Cycle832 and Cycle800 commands used by the 840D for high speed machining and coordinate frame transformation. It does this by providing an intuitive dialog box to choose parameters such as exact stop, acceleration pattern, feed forward control, and data compression, and then combines these into a single cycle command.

LEARN MORE

For more Information from Siemens, call (847) 640-1595 or enter HHS code 329FF at www.mmsonline.com

For more information from ICAM Technologies Corporation. call(514) 697-8033 or enter MMS Direct code 152UF at www.mmsonline.com

Is manual programming really important?

Mike Lynch

I am often questioned about the scope of this column. The most common question is: "Why do you continue to discuss manual programming techniques when almost all companies are using CAM systems?" Aside from the fact that other columnists are addressing issues related to computer Integrated manufacturing, I believe that a firm understanding of manual programming is of paramount importance to all CNC people. It is important not only for short term issues and specific applications, but for the long haul in every CNC environment--from a person's first acquaintance with CNC through their attainment of expert status.

For entry-level CNC programmers, course related to manual programming pro. vides an excellent platform to address some important CNC issues--issues that form the foundation of a person's understanding of CNC. Features such as program zero, coordinate systems, absolute versus incremental, motion types, the various compensation types and special programming features are best presented during a discussion of manual programming. Trying to present these features to entry-level students while they're trying to learn a CAM system will confuse them and have limited success. Starting at CAM system level without understanding the basics of manual programming is like learning to use an electronic calculator without understanding basic arithmetic.

Entry level CNC setup people and operators must eventually understand at least some manual programming techniques if they will be expected to edit programs at the machine during a program's verification. While not all companies expect this, the more setup people or operators understand about manual programming, the better they can perform.

Consider what it takes to run the first workpiece using a new program. The setup people will place the machine in single block mode and step through the program. As they do so, they must be sure that each upcoming command is correct. Regardless of whether the program is originally created manually or with a CAM system, how can they safely do this without understanding manual programming?

An understanding of manual programming is important far beyond a person's introduction to CNC. Some of the best machine utilization enhancements (reducing setup and cycle time, for example) can only be accomplished with manual programming techniques.

Indeed, utilization enhancements--and the manual programming techniques that allow them--have been the topic of many past CNC Tech Talk columns. Efficient range changing on turning centers and machining centers (September & October 1998), shortening a program's execution time with G01 for positioning (February 1999), programming trial machining operations (April 1999) and using secondary offsets (March 2001) are a few examples of techniques that are best applied with manual programming techniques.

Programming method is of utmost importance when it comes to cycle time reduction. One factor that contributes to bare minimum cycle time is how the program is formatted. While CAM systems are getting more powerful in this regard, no other programming method beats the intimacy that can be achieved with manual programming. As production quantities grow, every second of program execution time becomes more critical. Again, CAM systems have come a long way, but it can be difficult, if not impossible, to cause some CAM systems to output CNC programs as efficiently as can be done with manual programming techniques.

Manual programming is also important if you have any interest in applying parametric programming techniques. All applications for parametric programming require a firm understanding of manual programming.

Admittedly, there are people who rely exclusively on their CAM system to prepare programs and have little or no understanding of manual programming. Yet they successfully create programs, machine good parts and meet production schedules. Maybe they have extremely complicated work that can only be programmed with a CAM system. Maybe lot sizes are so low that cycle time is of little importance. Maybe there is very little repeat business, so every program must be created before the job can be run. In these cases, cycle time may not be critical.

But if you don't know manual programming, how can you be sure your CAM system is outputting programs in the most efficient manner? The first step to making any improvement is knowing what's possible.

CNC export regulations - computer numerical control equipment

Golden E. Herrin

There are not many things in life that get more complicated than export regulations, and any company that exports CNC controls or CNC controlled machines has had to deal with the difficult issue of interpreting and applying them.

In addition to machine related issues (such as accuracy) which can cause a machine shipment to be restricted, there are three CNC features that will also cause the CNC to be restricted - and, when the CNC is attached to a machine, the entire package (machine and control) becomes restricted. This article discusses U.S. export regulations on machine controls and examines why they exist.

What Is Restricted? There are three machine control features, or capabilities as referenced in the export regulations, that will cause a control to be restricted. All deal with path control and therefore target the more capable CNCs.

Functions restricted are:

* More than four axis of simultaneously coordinated axes of motion.

* Real-time processing of CAD data in the CNC for tool path generation.

* Adaptive control with more than one machine condition monitored and fed back to the control for modifying the machining process.

The above restrictions existed under COCOM (Coordinating Committee for Multilateral Export Control) and were retained when the export regulations were restructured under the Wassenaar Arrangement effective November 1, 1996. The name Wassenaar comes from the city in Holland where the final agreement was signed. In the transition from COCOM to Wassenaar, the changes took emphasis off the control hardware and redirected it to the software.

The result however is still the same, any CNC having one or more of the restricted capabilities is controlled and as such is subject to export licensing depending on the receiving country.

Why Are There Restrictions? The Wassenaar Arrangement was created by a multination group to replace the procedures that existed under COCOM. COCOM, which expired March 31, 1995, was also a multinational agreement formed in 1949 primarily to prevent U.S.S.R. and its satellite nations from obtaining sophisticated products that could be used to enhance its weapons capability. In its 46 years of existence COCOM had become grossly out-of-date as the landscape of our allies and enemies changed.

Under the Wassenaar Arrangement, Russia has become a member country and the targeted countries, which are not explicitly defined, are essentially pariah countries or "countries of concern." Each Wassenaar participating country is permitted to create its own actions based on "National Discretion." Presently the U.S. pariah countries are: Iran, Iraq, Libya, and North Korea.

What Technology Are We Protecting? Obtaining a U.S. export license for a CNC or a CNC controlled machine that has one or more of the restricted capabilities is a time consuming process that often causes delayed shipments and unhappy customers. In some cases, foreign customers have even stopped soliciting quotations from U.S. machine tool companies for the higher tech machines because of previous bad experiences consisting of delays and licenses turn downs. Instead they have gone to foreign manufacturers where the export rules are interpreted more liberally.

Why is it that the U.S. government risks the loss of export business by applying stricter interpretations to export regulations? It appears that the U.S. Department of Defense (DOD) is the motivating agency in this matter. DOD maintains that all three CNC restrictions are valuable capabilities when it comes to making small, very accurate parts associated with manufacturing nuclear weapons. DOD has been very consistent in their position that the machines with one or more of the three restricted capabilities would be of significant value to non-friendly countries for manufacturing weapon systems that are a threat to our national security.

It is up to the industries affected by export regulations to keep the pressure on government. One of the organizations involved in providing advice to government is the Department of Commerce's Materials Processing Equipment Technical Advisory Committee (MPETAC) which has been working for the past few years to educate government regulators about the changes and the availability of CNC controls. This committee referred to as a TAC committee is sponsored by the Department of Commerce and is chaired by Charles Carter, Vice President of Technology for The Association of Manufacturing Technology (AMT). The industry representatives serving on the TAC continue to work toward achieving a more realistic set of export regulations that will level the playing field with our allies when it comes to international trade.

The role of a CNC coordinator - The Best Technology on the Planet

Mike Lynch

The CNC environment is any portion of your company that in some way affects or is affected by your CNC machine tools. Based on this broad definition, there are very few people in your company that are not part of your CNC environment. The most important role of your CNC coordinator is first to identify the elements of your own CNC environment, and then to facilitate smooth interaction among the people involved. Optimum CNC machine utilization is the most basic criteria upon which any decision is based.

There are three basic element types in any CNC environment. Core elements are those easily identified people, machine tools, and accessories that form the heart of your CNC environment. People in this area include CNC programmers, operators, setup people, and instructors. They're the ones working with CNC on a daily basis. Since they are so easily identified, and since they have the largest impact on how well the CNC environment performs, most companies place a high emphasis on the core elements. In fact, some companies concentrate so heavily on core elements that other important elements are completely overlooked.

Satellite elements are those people, machinery, and accessories that affect the way CNC machine tools function, though to a less tangible degree. Yet they are still very important and, if overlooked, can have a devastating impact on the CNC environment. Among the people in this category are design engineers, tool engineers, process engineers, quality control engineers, production control people and even the company's sales force.

Target elements are those people, machinery, and accessories that are in some way affected by what the CNC machine tools do. Some of the people in this category are assembly people and operators of machines performing secondary operations.

Identifying CNC-related areas in need of improvement is actually very easy. Simply schedule a meeting and invite representatives from all three areas to attend. You may be surprised at what the meeting renders. It is likely that you'll turn up a great deal of confusion, duplication of effort and waste. Even within one element type, you may locate problems caused by communication breakdowns. When it comes to core elements, for example, you may find that your setup people waste time searching for hand tools, cutting tools and gages needed during each setup due to poorly documented setup sheets. You may find that your CNC operators are consistently having problems holding size due to poorly formatted CNC programs. You may find that your operators require more training in given areas.

As you expand the discussion to include all three element types, you will surely turn up even more problems that can be improved. You may find that simple changes in the way design engineers dimension and tolerance work-pieces will minimize the calculations required of programmers, operators and inspectors - saving time and minimizing mistakes. You may find that your company's sales people have been unaware of your company's true capabilities and have not been offering all of the available products and services. You may find that if your production control people order workpieces in a more logical order (for workpieces made of the same stock size, requiring the same tooling and run on similar machine tools), a great deal of setup time can be saved while still adhering to just-in-time principles.

You may learn that assembly people prefer that certain important tolerances be held on the high or low side in order to facilitate easy component assembly.

As stated, finding areas within the CNC environment in need of improvement will be easy. However, determining the best methods for improvement and actually implementing them will be more challenging. You'll need help from the same people that helped identify problems. In most cases, they will be the best people to make suggestions for improvement. However, you must make it clear that improving CNC machine utilization is the most important goal. In some cases, the improvements you implement will mean more (or different) work for the people involved. Be on the look-out for human nature-related problems like complacency (we've always done it that way), pride of authorship (my way is the only way) and personality conflicts (us versus them). As long as your people have your company's best interest at heart, you should be able to motivate them to a high degree of cooperation.

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CNC data interfaces

Golden E. Herrin

CNC Data Interfaces

It is not surprising that CNC Data interfacing is a source of confusion in many plants. The many names by which CNC data interfaces are specified have been a contributing factor. Some of the more common terms are: data port, serial port, communications interface, behind-the-tape-reader interface

(BTRI), DNC interface, and parallel port, to name a few. These terms are often combined with vague definitions and written into equipment specifications. For example, the following definitions are taken from actual specifications: * "A serial data port is required for future connection into a DNC or FMS system." * "A serial or parallel data port is required. A BTRI is acceptable." * "The control must have MAP communications compatibility." * "An RS-232 interface is required." * "A DNC interface is required."

The ambiguity of the above statements allows the CNC vendor to comply without defining what capability will be provided. For example, an RS-232 interface can include a very sophisticated protocol that provides error checking and status reporting capability, or it may not have any of these capabilities.

One way to minimize confusion is to use the International Standards Organization (ISO) seven-layer network architecture for local area networks (LANs). Even though this architecture is a model for open systems interconnection

(OSI) for LANs, it can also provide a common base of understanding for serial interfaces as well. The seven layers consist of: (1) physical, (2) data link, (3) network, (4) transport, (5) session, (6) presentation and (7) application.

When specifying a serial data interface there are three functions to be considered: (1) the connection, (2) the data-handling protocol and (3) the capability to be provided. The ISO seven-layer structure is used in the following description to explain these three functions:

Connection--This is the most basic part of the specification. It is the way the data is to be transmitted. Examples of the connections for serial interfaces are RS-232, RS-422 and RS-423. The speed or baud rate should also be stated at this level. Keep in mind however that even though each of the above standards provides a choice of baud rates, the distance which the data is to be transmitted becomes a limiting factor on achievable rates. Also, if error-checking protocol is to be employed, speed is usually sacrificed.

Protocol--Is a set of rules governing the exchange of messages between two communicating processes. For LANS like Manufacturing Automation Protocol (MAP) there is a protocol assigned for each of the seven ISO layers. For serial interfaces, the protocol normally only deals with starting and stopping the data flow, performing error checking if required and initiating the etransmission of a segment of data when there is an interruption. Example of protocols for serial interfaces are RS-491, RS-484, KERMIT, DDCMP and SNA. These may be isolated to ISO layer 2 functions or spread across multiple layers.

Capability--This layer is one that is most often ignored in users specifications. At this level the user should state what capability he expects the interface to have. Examples are: upload/download part programs, upload/download tool data, upload/download probe data, upload machine status, handle cycle start/stop over the data line, upload specified machine fault messages, and upload specific CNC fault messages.

In order to create an adequate interface specification it is necessary to define your requirements accurately. Include only the capability that is required since "standard" interfaces can add as much as $20,000 to the basic price of the control. Custom-designed interfaces can cost $100,000 or higher. This fact-of-life is the reason to stay with existing standard interfaces.

The above discussion was intended to address only the most significant points of serial data interfaces in CNCs. It is worth noting that all of the capability expected at the CNC data interface must also be implemented in the host computer if there is to be meaningful communications. It therefore becomes of utmost importance for the user to coordinate the communications requirements at both ends of the data line so that the proper interface tools exist when the time comes to use them.

COMPUTER-AIDED DESIGN (CAD) AND COMPUTER-AIDED MANUFACTURING (CAM)

Computer-aided design (CAD) involves creating computer models defined by geometrical parameters. These models typically appear on a computer monitor as a three-dimensional representation of a part or a system of parts, which can be readily altered by changing relevant parameters. CAD systems enable designers to view objects under a wide variety of representations and to test these objects by simulating real-world conditions.

THE ORIGINS OF CAD/CAM

CAD had its origins in three separate sources, which also serve to highlight the basic operations that CAD systems provide. The first source of CAD resulted from attempts to automate the drafting process. These developments were pioneered by the General Motors Research Laboratories in the early 1960s. One of the important time-saving advantages of computer modeling over traditional drafting methods is that the former can be quickly corrected or manipulated by changing a model's parameters. The second source of CAD was in the testing of designs by simulation. The use of computer modeling to test products was pioneered by high-tech industries like aerospace and semiconductors. The third source of CAD development resulted from efforts to facilitate the flow from the design process to the manufacturing process using numerical control (NC) technologies, which enjoyed widespread use in many applications by the mid-1960s. It was this source that resulted in the linkage between CAD and CAM. One of the most important trends in CAD/CAM technologies is the ever-tighter integration between the design and manufacturing stages of CAD/CAM-based production processes.

The development of CAD and CAM and particularly the linkage between the two overcame traditional NC shortcomings in expense, ease of use, and speed by enabling the design and manufacture of a part to be undertaken using the same system of encoding geometrical data. This innovation greatly shortened the period between design and manufacture and greatly expanded the scope of production processes for which automated machinery could be economically used. Just as important, CAD/CAM gave the designer much more direct control over the production process, creating the possibility of completely integrated design and manufacturing processes.

The rapid growth in the use of CAD/CAM technologies after the early 1970s was made possible by the development of mass-produced silicon chips and the microprocessor, resulting in more readily affordable computers. As the price of computers continued to decline and their processing power improved, the use of CAD/CAM broadened from large firms using large-scale mass production techniques to firms of all sizes. The scope of operations to which CAD/CAM was applied broadened as well. In addition to parts-shaping by traditional machine tool processes such as stamping, drilling, milling, and grinding, CAD/CAM has come to be used by firms involved in producing consumer electronics, electronic components, molded plastics, and a host of other products. Computers are also used to control a number of manufacturing processes (such as chemical processing) that are not strictly defined as CAM because the control data are not based on geometrical parameters.

Using CAD, it is possible to simulate in three dimensions the movement of a part through a production process. This process can simulate feed rates, angles and speeds of machine tools, the position of part-holding clamps, as well as range and other constraints limiting the operations of a machine. The continuing development of the simulation of various manufacturing processes is one of the key means by which CAD and CAM systems are becoming increasingly integrated. CAD/CAM systems also facilitate communication among those involved in design, manufacturing, and other processes. This is of particular importance when one firm contracts another to either design or produce a component.

ADVANTAGES AND DISADVANTAGES

Modeling with CAD systems offers a number of advantages over traditional drafting methods that use rulers, squares, and compasses. For example, designs can be altered without erasing and redrawing. CAD systems also offer "zoom" features analogous to a camera lens, whereby a designer can magnify certain elements of a model to facilitate inspection. Computer models are typically three dimensional and can be rotated on any axis, much as one could rotate an actual three dimensional model in one's hand, enabling the designer to gain a fuller sense of the object. CAD systems also lend themselves to modeling cutaway drawings, in which the internal shape of a part is revealed, and to illustrating the spatial relationships among a system of parts.

Other limitations to CAD are being addressed by research and development in the field of expert systems. This field derived from research done on artificial intelligence. One example of an expert system involves incorporating information about the nature of materials—their weight, tensile strength, flexibility, and so on—into CAD software. By including this and other information, the CAD system could then "know" what an expert engineer knows when that engineer creates a design. The system could then mimic the engineer's thought pattern and actually "create" a design. Expert systems might involve the implementation of more abstract principles, such as the nature of gravity and friction, or the function and relation of commonly used parts, such as levers or nuts and bolts. Expert systems might also come to change the way data is stored and retrieved in CAD/CAM systems, supplanting the hierarchical system with one that offers greater flexibility.

One of the key areas of development in CAD technologies is the simulation of performance. Among the most common types of simulation are testing for response to stress and modeling the process by which a part might be manufactured or the dynamic relationships among a system of parts. In stress tests, model surfaces are shown by a grid or mesh, that distort as the part comes under simulated physical or thermal stress. Dynamics tests function as a complement or substitute for building working prototypes. The ease with which a part's specifications can be changed facilitates the development of optimal dynamic efficiencies, both as regards the functioning of a system of parts and the manufacture of any given part. Simulation is also used in electronic design automation, in which simulated flow of current through a circuit enables the rapid testing of various component configurations.

The processes of design and manufacture are, in some sense, conceptually separable. Yet the design process must be undertaken with an understanding of the nature of the production process. It is necessary, for example, for a designer to know the properties of the materials with which the part might be built, the various techniques by which the part might be shaped, and the scale of production that is economically viable. The conceptual overlap between design and manufacture is suggestive of the potential benefits of CAD and CAM and the reason they are generally considered together as a system.

Recent technical developments have fundamentally impacted the utility of CAD/CAM systems. For example, the ever-increasing processing power of personal computers has given them viability as a vehicle for CAD/CAM application. Another important trend is toward the establishment of a single CAD-CAM standard, so that different data packages can be exchanged without manufacturing and delivery delays, unnecessary design revisions, and other problems that continue to bedevil some CAD-CAM initiatives. Finally, CAD-CAM software continues to evolve on a continuing basis in such realms as visual representation and integration of modeling and testing applications.

Computer-aided design - employment outlook

Michael Stanton

From the smallest computer microchip to the tallest skyscraper, every product must first pass through a painstaking process of design and analysis. Computers are making this process easier.

Computer-aided design (CAD) joins the power of the computer with the creativity and skills of the engineer, architect, designer, and drafter. The National Science Foundation suggests that CAD "many represent the greatest increase in productivity since electricity." This article examines some of the applications of this technology, its implications for the workers who use it, and opportunities it may offer for jobs in the future.

Computer-aided design is not a new technology. The aerospace and automotive industries developed their own software packages to assist in product design and development over 20 years ago. And commercial CAD systems have been available since 1964. These early systems, however, used expensive mainframe computers that only the largest companies could afford. But recent advances in computer technology, particularly the introduction of mini-and microcomputers, have brought this technology within the reach of a host of potential users. The electronics industry, from computer makers to component manufacturers, is already a major user of CAD systems, and architectural, engineering, and construction firms are increasing their use of these systems to prepare designs, maps, and technical illustrations.

In the simpler forms of CAD, the drafter, working from an engineer's or architect's rough sketch, creates drawings on a computer screen. The pens, inks, compasses, and other tools used by drafters for generations are replaced by a keyboard, graphics tablet, digitizer, and light pen. Instead of a line of ink on paper, a line of glowing phosphorus appears on a video console. Through a series of programmed commands, the drafter can produce finished drawings in much less time and of a higher quality than those produced manually.

People frequently call CAD systems word processors for drafters. And, in fact, many of the word processor's advantages find counterparts in CAD systems. John Murray, an engineer with General Motors, jokes that, as with word processing equipment, "one of the things that works the best is the eraser." An error on the computer screen can easily be corrected with a few keystrokes. To correct a manual drawing takes much longer. To simplify this process still further, some of the more advanced CAD software packages are programmed to detect errors during the drafting process and inform the user that the data or design is incorrect.

Most CAD systems, irrespective of the particular industry for which they are developed, offer four basic functions that greatly enhance the productivity of the drafter or designer.

* Replication--the ability to take part of an image and use it in other areas when the design or drawing has repetitive features; * Translation--the ability to transfer features from one part of the screen to another;

* Scaling--the ability to change the size of one part of the design in relation to another;

* Rotation--the ability to turn the design on the screen so that it can be examined from different angles and perspectives.

When drafters and designers do their work on a CAD system, the drawings are stored in a central data base. The advantages here are several. First, the handy reference to previous drawings enables the operator to recall and modify a design whose features closely resemble a present assignment rather than start from scratch. Secondly, the data base encourages communication between the designa and production staff. Working from the same data will greatly reduce the paper flow within a factory or office. Several sources interviewed for this article referred to the paperless factory of the future that CAD will permit. Thirdly, these stored designs serve as the basis for more complex applications of computer-aided design.

These applications generally fall under another acronym--CAE--or computer-aided engineering. Using the same hardware that is used to draft a design, engineers are able to subject these designs to a battery of tests and analyses.

The computer enables the engineer to simulate a variety of conditions or stresses to which a product may be subjected. For example, a designer or drafter in the automotive industry may design an axle according to an engineer's rough sketch. The engineer, working at another computer work station, will subject the axle to varying combinations of simulated conditions and weights. These computer simulations can cut the time between design and production; under older technologies, an actual prototype of the product or part would be fabricated, tested, redesigned, and reproduced until the engineer was satisfied with its performance. This reduction in development time should decrease costs and increase productivity.

Another likely outcome is improved quality. Tom Gumbala, an engineer with Boeing Aerospace, says, "We will be able to build a better product because CAD gives us the opportunity to analyze the heck out of it."

Markets and Applications

The market for CAD hardware and software has experienced substantial growth since the early 1970's. The Office of Technology Assessment (OTA) of the U.S. Congress states, "Between 1973 and 1981, the CAD system market grew from under $25 million in annual sales to over $1 billion," a fortyfold increase. The years ahead may be even more promising. The Yankee Group, a Boston-based market analysis firm, predicts that sales may reach $6.9 billion annually by 1987, with an average annual growth rate of over 40 percent.

At present, the principal mechanical for CAD are within the mechanical manufacturing industry. Aerospace and automotive companies are the heaviest users, but other segments of the industry, such as machine tool manufacturers, are incorporating CAD into their operations.

Within these enterprises, CAD is only one member of a family of computerbased technologies that is altering the nature of American manufacturing. Computer-aided manufacturing (CAM) is usually mentioned in the same breath as computer-aided design. This juxtaposition, CAD/CAM, refers to the capability of systems to design a part or product, devise the essential production steps, and transmit this information electronically to manufacturing equipment, such as robots. These design and manufacturing tools may, inturn, be linked to management information systems (MIS), which enable managers to monitor closely all aspects of a company's operations.

While mechanical applications of CAD account for nearly one-half of the systems sold today, other industries recognize the benefits it affords. For the electronics industry, CAD offers considerable advantages, particularly in the design on printed circuit boards and integrated circuits. The design of these components can be tedious and time consuming. And so many lines and cross lines must be drawn that errors are not easily detected. CAD not only speeds up the drawing but detects errors as well.

Architecture, engineering, and construction applications offer the greatest potential for growth in sales, according to a recent industry survey. Although the construction and electronics industries each represent about 16 percent of the CAD market now, the penetration is far less extensive. However, both simple drafting applications and more complex design and analysis are evident within the industry. Architectural drafters will be able to complete drawings of a higher quality in much less time. Architects and engineers will be able to submit their designs to more exhaustive structural and stress analyses. Piping and electrical layouts will be made easier and the design and allocation of interior space will be facilitated as well. As a management tool, the data base created during the project will provide an effective means of inventory control enabling contractors not only to speed construction but to reduce costs.

CAD is also having an impact upon cartography. Geographers use CAD systems to help them draft maps used for environmental impact analysis and land use planning and for charting landfill contours for strip mining. Some software packages are available that aid in extraterrestrial mapping.

Process industries, such as oil and gas refineries and chemical manufacturers, as well as power and utility companies, must plan, construct, operate, and maintain electrical grid and pipeline networks. CAD makes these complex tasks easier. CAD even has applications in landscape design, interior design, andd fashion design. Some high fashion couturiers use CAD systems to lay out patterns on expensive fabrics as a way to minimize waste.

Implications for Employment

Technological innovations invariably prompt questions as to how these changes will affect employment. Implicit in many of these questions is the notion that the introduction of new technologies will lead to the elimination of certain jobs or at least to significant changes in the way these jobs will be performed. Among those occupations directly affected by CAD, concerns focus upon drafting and design jobs.

Drafting shops are traditionally a bottleneck in many industries. Pen and ink drawings take a long time to produce. Once complete, the drawings must be presented to the engineer or architect for review and analysis. The ability of CAD systems to produce drawings much faster than manual techniques would seem to reduce the need for drafters in the long run. Dr. Donald Hecht, president of the California College of Technology in Anaheim, a technical school that trains students in computer-aided design and drafting, urges a more cautious appraisal. "I hesitate to make such straight-line predictions," he says, "particularly when dealing with computer-based technologies." Hecht believes that the reduction in drafting time and the consequent increases in productivity that CAD affords may foster a greater emphasis upon new product design and development. "I see CAD giving us the opportunity to create more and better products, perhaps even new industries which today we cannot even imagine."

The possibility has also been raised that CAD will enable engineers to take over the entire design process, from initial concept to final drawings, thereby eliminating the need for drafting and design staff. This contention is not widely supported by industry sources. Don Manor, manager of computer graphics for John Deere, says doing away with drafters would be an ineffective use of engineers. "it's the engineer's job to provide the concepts while the drafter or designer produces the documentation. This division should not change."

That CAD will increase productivity is not in question. But its effect on creativity is an issue raised in discussions of CAD's impact upon the labor force. Some people suggest that, as the technology matures, a point may be reached where software packages programmed with artificial intelligence will diminish the opportunity for individual creativity in design. John Duvalle, an engineer with CALMA, a major manufacturer of CAD systems involved in training operators in CAD techniques, rejects this thesis. Rather than seeing CAD as a replacement technology, Duvalle views it as an enhancement technology, a powerful new tool that will enable the drafter or designer to do more creative work.

This appraisal is shared by manufacturers who have installed CAD sytems. Jerry Licht is Director of Management Information Services for Lamb-Technicon Corporation, a Michigan machine tool manufacturer. "CAD is an intelligence amplififer," says Licht. "The talents and skills of a capable designer or drafter can only be enhanced by CAD." Reiterating a theme raised by many familiar with the technology, Licht emphasizes that CAD is simply a powerful new tool that can provide positive results when in the hands of a capable operator.

Some studies examining the impact of office automation on clerical staffs have focused attention on the increased incidence of stress attributable to the use of video display terminals. The OTA study addressed this issue and found that the possibility may exist, but increased stress is much less likely in situations where workers retain autonomy and make their own decisions. Those who assert that CAD acts as a stimulus to creativity believe that stress-related maladies would be less likely to occur among these operators than among other workers.

But the question of autonomy is an important one, particularly as it relates to engineers. Some evidence from cases studied by OTA suggests that jobs will be broader and more challenging at early stages in the design process, but that, farther along, jobs will be less flexible. OTA quotes the director of a CAD/CAM transition team in one of the companies studied, "Once the system is in place, most of the decisions are made. Whoever's involved downstream is working in a much more controlled environment."

The computer's ability to monitor workers also affects autonomy. Monitoring is not a new issue, at least for hourly workers, but it is for professionals. Computer-based systems that enable managers to supervise their operators more closely may alos be used for monitoring the amount of time spent at terminals by each engineer.

New Jobs and Opportunities

Enthusiasm runs high among CAD manufacturers and users, reflecting the advantages of the technology. But, like Dr. Hecht, others urge caution in making straight-line predictions. Tom Lazear of T&W Systems, a California manufacturer of CAD, believes that an increase in CAD sales depends to a large extent on what happens in the economy as a whole. During periods of slow growth, less design work is undertaken.

Nevertheless, the increased use of CAD systems will generate new occupations. Some companies that have incorporated CAD into their operations have begun hiring "CAD operators" to run this equipment. Lazear suggests that the need for these operators may reach 100,000 by 1990, a projection based upon the number of CAD work stations expected to be in use by that year.

Women and minorities are entering this field in greater numbers. Educators who run CAD training programs and engineers who hire workers affirm this trend. Ron Krimper, who oversees the drafting and design program at Fullerton Community College in Fullerton, California, says that one-third of the nearly 700 CAD operators who have been trained in the last few years at Fullerton have been women. A third of those presently enrolled are from minority groups.

Rockwell International, the aerospace giant, is a heavy user of CAD. Robert McKechnie, a Rockwell engineer who heads a department in electrical design, employs several women on his staff.

Computer-aided design presents some heartening prospects for the handicapped. Where their physical disabilities may have prevented them from mastering the manual skills necessary for drafter or designer positions, CAD may open the door to these opportunities. In the spring of 1985, a pilot project for the training of paraplegics will be initiated at San Jacinto Community College in Pasadena, Texas. Dr. Steve Horton, Chairman of the Engineering and Drafting Technology Department at the college, believes that CAD offers the chance for intellectually challenging employment for th disabled. "With a firm grounding in drafting and design theory and training in CAD techniques, a handicapped person can be as productive as any other drafter or designer," says Horton.

Education and Training

How quickly a person achieves proficiency in these new tools depends upon personal capabilities, the type of system involved, and its particular applications. Increases in productivity are noticed in a relatively short period. An article in the November 1983 issue of IEEE Computer Graphics Applications affirms this. The initial assumptions of a CAD training program at a midwestern tool manufacturer were that, after 24 weeks, students would be as productive as drafters working with manual techniques. Parity was actually reached after only 4 weeks. Within 32 weeks, the CAD operator was three times as productive as the manual drafter.

For these productivity gains to be realized, operators must receive the proper training. A number of avenues for this training are available.

As with other computer-based technologies, instructional programs are offered by manufacturers or vendors. Vendor training is generally included as part of the package when a system is purchased. Usually, two or three workers receive instruction; they then train their fellow employees. These vedor programs, however, will probably be unable to meet the ned for trained operators; they are also unavailable to students preparing to enter the market.

Therefore, schools at all levels, from junior high schools to universities, are incorporating CAD into their curriculums. At the university level, nearly all engineering and architectural schools offer some courses in computer graphics, and many computer science departments offer electives in CAD. However, only one major university, Brigham Young, offers a bachelor's degree in design technology. Schools in regions where CAD has become a major industrial tool--the automotive centers in Michigan and the high-tech bases in TExas and California--offer the widest variety of instruction. Many community colleges and technical/vocational schools, the traditional training ground for drafters, have begun to offer CAD instruction.

Although each school takes it own approach to training, some general comments can be made regarding those schools which have initiated CAD training. Students are eligible to study CAD only after obtaining a solid base in design and drafting fundamentals. As with any advanced tool, an understanding of basic concepts is essential. It's good job training as well. Over 90 percent of drafting is still done manually, and, while more and more of the work will be done on CAD systems, manual skills will still be in demand.

After a student has successfully completed introductory courses in drafting and design, the next step is specialization in such fields as electrical or architectural drafting. The introduction to CAD comes once these prerequisites are fulfilled.

While a drafting or design background is essential for CAD studies, computer literacy is not. Most CAD systems on the market are "user friendly" and can be understood by those with no background in computers. For persons involved in more complex applications, some familiarity with computers would be helpful.

In some school districts, particularly those in regions where CAD is extensively used, instruction is moving along steadily. The Oakland County Community School District, located in the heart of the automotive industry in Pontiac, Michigan, has budgeted over $300,000 to purchase CA/CAM equipment. Dr. James Hannemann, director of vocational education, says, "CAD is generating as much excitement as robotics, with interest growing by leaps and bounds." The district offers CAD instruction as part of the drafting courses at two of its four vocational education centers.

Litchfield, Minnesota, is another community that makes CAD instruction available to public school students. Industrial arts education is mandated by State law for all students in Minnesota, as is home economics. CAD will be incorporated into the vocational curriculum. Sid Herrick, coordinator of the pilot program, is excited. "It's important that we introduce that kids to what's being done in industry. I feel our program is really going to take off."

Many schools are confronted with the same obstacles that business and industry encounter when considering the purchase of CAD systems--money. Some avenues may be available to counter this difficulty. One is time sharing with local businesses and industries that have the equipment. Time sharing offers advantages to both parties. The students gain familiarity with business and industrial settings, handson experience, and the chance to meet possible employers. The participating companies contribute to the community and enhance their public image.

At the university level, several foundations have made funds available to schools for the development of computer graphics laboratories. Other possible sources of funding or equipment are CAD manufacturers. A recent survey conducted by Computer Graphics World magazine found that approximately one-third of computer graphics companies have contributed hardware or software to university-level programs.

Industry sources say that computeraided design systems have penetrated only 10 percent of their potential market. This percentage is certain to grow because CAD has proven its value as a tool, both in design and analysis. But all tools, from the simple to the complex, need skilled hands to use them effectively and creatively.

CAD/CAM system fast and hardware independent - computer aided design/computer aided manufacturing – column

First there was NC (numerical control), basically a CAM (computer aided manufacturing) function. Then along came CAD (computer aided design). Unfortunately getting from CAD to CAM often involved a lot of manual effort. The next step was having the two on the same computer. Even then the process could be slow.

All that is now changing. If the design is done on one computer based CAD system, and the NC programming is done on another, the difference in hardware platforms and software systems is no longer a factor in quickly getting the design data into an NC program to machine the part. And it can be done quickly.

One company that has bridged the two functions into an integrated whole is Adra Systems, Inc., 59 Technology Drive, Lowell, MA 01851. Their design/drafting package is called CADRA-III and it may be implemented on MS-DOS personal computers and industry standard workstations. Because of its software capabilities it may accept CAD data from other systems. This means that a die, mold, or machine shop with CADRA-III may accept design data from a customer with an entirely different CAD software language.

While CADRA-III is a design software package, its main function is not to serve the product designer. Its purpose is to take the designer's information and put it in drafting form for dimensioning, layering, study, revision, and especially the generation of NC part programs. Full coloring is available so that any layer or element may be shown in its own assigned hue. Thus, the package does not have solid modeling, kinematics, finite element analysis, and so on that the designer uses. Its drawings are limited to wire frame type, but they supply all functions needed for computer assisted drafting and part programming.

The part program is generated by the CADRA-NC software package. It has two-through five-axis capabilities, post processor libraries, verification and simulation routines, parametric geometry creation, family of parts programming, menus, and tool and material libraries as some of its functional capabilities.

Not only are the software packages able to be put in personal computers or workstations, but one of the main features is the speed at which the software will flip from programming back to a design element or visa versa. As fast as a single pen command can be entered, the results will flash on the screen. Thus, the CAD/CAM package offers not only integration with other systems, but an extremely fast processing and toggling back and forth to aid either the drafts person or the part programmer.

Included in the whole CADRA functionality is the ability to develop CAD drawing from scanned images of paper drawing.

Among the data exchange solutions are DXF for exchanging data with AutoCAD based systems, IGES for data exchange with other CAD/CAM systems, Ethernet for local area networks, CALS 28001 and CCITT Groups 3 and 4 formats for handling raster data, and ADT for direct translation between CADAM format and CADRA.

This trend of data exchange and hardware independent software plus the toggling speed between CAD and CAM will offer excellent possibilities for closing the gap between design and manufacturing while improving the speed and flexibility of NC part programming.

Integrating CAD and CAM - computer-aided design; computer-aided manufacturing - Scanning the Horizon

In today's competitive environment, many shops are feeling the pressure to take on greater CAD (computer-aided design) capabilities. This is due in a large part to the growing desire among manufacturers to exchange part designs in the form of CAD files, rather than paper prints, and suppliers must be in a position to deal with the medium. With this increasing use of CAD data, and with the greater geometric part complexities which it often enables, CAM (computer-aided manufacturing) software is also becoming more a necessity than luxury, especially in the generation of CNC part programs for multiple-surface machining.

The decision on what software to buy has become more complicated as the line between CAD and CAM has blurred--some people have come to regard the terms as synonymous--even though each is intended to serve a different purpose. CAD is the science of creating a part drawing, a process usually driven by functional or aesthetic objectives, and often executed with little awareness of the problems it might create for manufacturing. CAM is the science of creating code that drives tools to remove unwanted material easily and efficiently from a solid block of stock, leaving the intended design.

In this sense, CAD and CAM are not at all the same thing, though they still must work in harmony whenever a design is to be machined. And that can be a challenge particularly when part features deemed necessary by the designer--such as sharp corners or many small surfaces--prove difficult to replicate in tool path code.

The issue gets most interesting when it comes time to put the CAD and the CAM together. Most vendors grew up on one side of the fence or the other, and then developed the additional functionality later. And though virtually everyone refers to their offering as CAD/CAM these days, more often than not the strength of the system still lies on the side of its developer's original mission.

One CAM developer, Olmsted Engineering Company (Traverse City, Michigan), took a different approach. They continued to concentrate on their strengths--CAM, IGES file translation and shop floor integration--while applying new development efforts toward integration with established CAD systems.

Olmsted's stand-alone CAM, ACU.CARV, was developed from the machinist's perspective, incorporating functions for contour milling, climb milling and so on, and outputting contouring code in form of circular and linear interpolation commands (rather than the numerous point-to-point moves typical of most CAM systems). As part of their CAD integration process, Olmsted created a new product, ACU.CARV ADS, that runs all CAM functions directly from within AutoCAD. The user gets both functions through a single interface. Olmsted contends that by integrating the system in this manner, and at the same time keeping the CAD and CAM philosophies separate, users get the benefit of both. The system supports CNC milling, turning and wire EDM.

For CAM milling functions, the system manages three of the most difficult aspects of multi-surface machining--avoiding gouges, inserting constant or variable radii between surfaces, and automatic roughing. On the CAD side, users can create a design and specify all geometry using the same interface. Moreover, all data input for machining parameters--including stock allowance, shrink factor, and cusp height--are made using the AutoCAD dialogue boxes.

One of the system's strengths is its ability to generate 3D contours by using planar machining (constant Z), which Olmsted contends allows cutters to be driven at the optimal speeds and feeds. It does this by combining any number of complex surfaces, or types of surfaces, into a composite tool path, permitting the path to proceed from surface to surface without gouging. This way, roughing can be accomplished with flat-bottomed cutters, even if islands are present, since the system knows the composite layout of the level being cut. Add the ability to automatically control the size of cusps (or scallops) to a user-specified tolerance, and the system is capable of generating efficient part programs that create very smooth 3D surfaces right on the machine tool.

This drive toward CAD/CAM integration has helped Olmsted strengthen their existing interfaces to CAD systems, such as CADKEY and AutoCAD, in addition to the fully-integrated ACU.CARV ADS product. The company also emphasizes a strong IGES translator to import files from the range of CAD systems shops must accommodate these days.

CAD capability bears fruit - computer-aided design

Belinda Jones

By being able to work closely with its customers' industrial designers and engineers, this shop helps customers improve the patterns and prototypes it machines for them. The value of this design input has made the shop a key manufacturing resource for a growing list of clients.

Like most shops involved with CNC machining, Apple Pattern finds the CAM part of CAD/CAM extremely important. CAM (computer-aided manufacturing) is virtually synonymous with "computer system for CNC tool path generation" for most of these users. But unlike a lot of shops that do CAD (computer-aided design) just because it's an inescapable part of what they need to do effective CAM, Apple Pattern saw the strategic value of CAD for its own sake, and is reaping some big benefits from giving its employees greater CAD capability. Not the least of those benefits is better machining.

A Model Shop

Apple Pattern is a model shop in Sterling, Massachusetts. It manufactures patterns and prototypes and has specialized in rapid prototyping--both in the service of producing prototypes very rapidly by whatever means, as well as in the specific technologies identified by this term, such as stereolithography. But NC machining has been a key part of its capabilities, so NC programming was a necessity. Hence, investing in a CAM system was easy to justify.

However, when Jack Haley, president of Apple Pattern, took a hard look at the direction of his company several years ago, he came to a fundamental insight. The shop could not remain in the business of making patterns, models, or prototypes, without automating the process. It had to get into the business of servicing its customers' special design needs. These design needs may very well require a CNC-machined pattern or a prototype produced by stereolithography, he realized, but most of all, it was knowledge and expertise that customers were looking for. It seemed to him that investing in CAD was the best way to develop the knowledge and expertise of his employees—and make this knowledge and expertise accessible to customers.

So in 1990, Mr. Haley made three key decisions based on this insight. He purchased 3D CAD software for all design work, he began to promote his company's "consulting" services, and he added CNC machining capability. This strategy paid off. His company grew from six to 22 employees and doubled revenues in two years. Neither just a pattern shop nor a design house, it has created a niche for itself and is prospering. But the pivot point for this turnaround has been the shop's CAD capability.

Today, Apple Pattern works closely with its customers' industrial designers and mechanical engineers to troubleshoot designs, discuss alternative prototyping methods, review tooling, and provide precision CAD data. CAD has helped the shop attract and keep high-caliber employees, whose attitude and first-rate service attract and keep good customers. And CAD offers the speed, accuracy, and data translators the shop needs for its rapid prototyping equipment and CNC machining centers.

Transitions

Jack Haley had his start as a foundry pattern maker and moved into machining work. In 1981, he started his own business in Leominster, Massachusetts. Mr. Haley soon realized that contract machining was declining in this area.

He decided to move into creating tracing masters for mold makers, where some of the same skills were utilized, yet involved greater accuracy. From here, it was a natural progression to move into making model parts, rapid prototyping and short-run molds.

Another prominent figure at Apple Pattern is Ric Perry, senior sales engineer. Originally from the Detroit area, he worked throughout high school and college in the mold-making shop his father owned in the suburbs. His personal goal was to become proficient in CNC machining and programming, and then advance into the area of 3D surface machining.

Before joining Apple Pattern, he worked for a larger corporation as a manufacturing engineer. He focused mainly on plastic parts, but had experience in sheet metal and die casting. A manufacturing engineer for 12 years, he joins Jack Haley with the same dedication to supporting industrial and mechanical designers on part design and to helping bring their products to market in a timely fashion.

Introducing CAD

Apple Pattern entered the world of CAD in 1990, with four seats of Cadkey software from Cadkey, Inc. (Windsor, Connecticut). A fifth seat was purchased in 1992. One of the main reasons this software was chosen was the strength of its data translators, a feature the shop would need in order to work with design files from many sources. Cadkey is a 3D, PC-based system, so the hardware and software investment was not a major budget item. A much more crucial issue was the effect introducing CAD would have on the people on the shop floor.

Not long ago, many companies in the industry had the perception that a computer in the office would replace an employee. That was certainly not the case at Apple Pattern. Their employees realized CAD was a vital "tool" that would enable them to make a better job of the one they currently had and to grow on the job as the company expanded its business. Employee turnover has been extremely low and the company has been able to attract the new talent it has needed to maintain this growth.

Initially, all employees were invited to learn CAD and understand how it would effect the way they work in the future. Every one of their employees accepted the challenge and attended CAD training courses at night. A roving CAD system was placed on the shop floor and today, virtually every model maker on the floor can, at the very minimum, pull up a CAD database and generate a 2D tool path. Over half of the model makers can produce a tool path for 3D surface machining.

Employees train on new equipment and are encouraged to help each other to come up to speed. "The term model maker has taken on a new meaning," says Mr. Perry. "A few years ago it referred to a person who created aesthetic models. Now model makers are proving CAD databases and substantiating designs for manufacturability. It's a much higher level of service."

The Best Design, The Best Machining

Apple Pattern's business model is an engineering approach backed by the intent to offer not just a design, but the best design with rapid prototyping. As Mr. Haley sees it, "This is absolutely a service business. It's not just 'here's your model and on to the next project.'"

Mr. Perry adds, "You have to be committed to the industry. Just having an order come across Jack's desk for a master mold and ten copies is not enough. We want to get on the phone with the engineer and try to find out what they are attempting to accomplish. We can look at a project with ten parts in it and see that some of them should be CNC machined. Other parts must be fabricated and CNC machined or made with stereolithography. Each project heavily depends on part complexity, the geometry, and what the engineer is trying to achieve. It should be more of a team effort than merely a sales quote."

By proving out CAD design files, helping customers get past limitations, critiquing problems and reviewing tooling, their services go far beyond merely producing a model. Apple Pattern acts as a facilitator between design and manufacturing. For example, a designer at Apple was consulting with a customer on a few design modifications. The 3D model was brought up in CAD and the designer explained his proposed alteration to a corner radius of a part.

He easily modified the surfaces and proceeded to shade the model for better visualization. The customer could clearly observe the improvement and authorized the change right on the spot.

Users at Apple Pattern report that editing in 3D is so easy that real-time changes with clients are extremely helpful in shortening the product development cycle. Mr. Perry remarks, "There's no excuse not to design in 3D with the price of personal computers and CAD software like this."

Since 1992, Apple Pattern has added eight CNC machines. Four of the machines are two-axis milling machines. The other four are three-axis milling machines. Because of this addition alone, companies who had not considered them in the past are sending them work today. This technology also enabled them to broaden their geographic market.

They receive data from a wide range of customers and CAD systems. Cadkey is their primary vehicle to read in CAD part files, prove the databases and transfer data into their PC-based CAM system (SurfCAM from Surfware Inc., San Fernando, California). With the Cadkey software, they verify part files by correcting geometry that does not properly connect, rebuild wireframe models for surface generation, and modify conditions that cause problems downstream in machining.

The company maintains a total of 12 personal computers that are fully networked in a client/server environment. Apple Pattern communicates with customers and transfers CAD part files through a high-speed modem. For key accounts, direct lines have been installed for faster response time.

Since enhancing its CAD capability, the shop has witnessed an interesting trend. Two years ago, 100 percent of their work was derived from blueprints. One year ago, half of their jobs came from prints, and the other half from computer diskettes. Today, 80-85 percent of their work comes in a CAD data format, and 50 percent of that work is transferred to their business via modern. In the past, Apple's customer base was geographically sensitive. Now, engineering data changes hands quickly and opportunities come from all over the globe.

Faster Designs

Equipping the model makers with CAD and getting them involved in the product design cycle early often means that a customer's product can go to market earlier than otherwise. A good example is a modem casing prototype created for Microcom, Inc., a company that develops and markets high-speed modems and other PC accessories. The manager of mechanical design at Microcom, Wayne Norwood, had the challenge of creating a new modem casing as part of a new product release.

An industrial design consulting firm, also a Cadkey user, was contracted to do the design. Because the casing had to house a printed circuit board and other internal electronics, with properly positioned hard switches and light-emitting diodes, the modem casing was essentially designed in 3D from the inside out.

In the very early stages of the project, the team at Apple Pattern met with the designers to discuss producibility, the design for the mold and possible changes in the prototype casing. The shop took the Cadkey part file, produced an IGES file, and read it into SurfCAM for tool path generation. Within two weeks, a CNC-machined master was produced and tested to see how well snap-fit features would work.

A few modifications were decided upon at that point. The casing master was also changed slightly so it could be used directly for a silicone rubber mold made from it. These changes facilitated the production of polyurethane prototypes. These polyurethane parts were used by Microcom's sales department for sneak-preview presentations to key overseas distributors. Meanwhile, their marketing department used other parts in photo sessions for data sheets, documentation, and promotional literature. They could also use the prototypes for packaging design. In the meantime, Mr. Norwood initiated regulatory testing of the electronics earlier than usual, confident that any emission problems would be disclosed in time for prototypes to be metallized or shielded and submitted for additional testing. Mr. Norwood believes that his company gained a 12 to 20 week advantage by being able to "design out" problems using master models and prototypes to visualize the product far in advance of the release date. Working interactively with the model makers as part of the design effort helped get functional prototypes into the right hands early enough to exploit this time advantage.

Moldability

Another project recently taken on by Apple Pattern was a very complex lead paint detector gun, a product being developed by Radiation Monitoring Devices (RMD) of Watertown, Massachusetts. Paul Stoppel, engineering manager, contracted the design work and asked Apple Pattern to produce the prototype. The first round of prototyping was done in stereolithography. The part's complexity led to many changes. The model's wireframe geometry was originally constructed in Pro/Engineer, Parametric Technologies Corp., (Waltham, Massachusetts), then read into Cadkey using its IGES translator.

Alex Yawor was the model maker assigned to this project. Apple Pattern set up an initial meeting to discuss the moldability of the five parts that completed the design. Quickly, he was able to make a few suggestions that would result in a less expensive mold. Using CNC machining, Mr. Yawor made a master from ABS plastic. Another meeting was held to discuss the tooling and final changes. Mr. Yawor found a few undercuts and corrected those conditions. A large portion of his time was spent designing jigs in Cadkey that would hold the master for the remaining changes.

The final plastic prototype faithfully captured the sharp lines that stereolithography does not generate. "With a stereolithography part, you sometimes lose tolerances when you have to sand down the model. With a CNC-machined part, the precision is right on the money," noted Mr. Yawor.

"We had a continuous line into Paul Stoppel, the engineering manager at RMD and the designer on this project. This was one of our most complex projects," stated Mr. Yawor. "The organic shapes of the overall design gave us a few problems. There were 52 changes made on this part consisting of a couple of hundred surfaces. The client wanted all of the modifications on the CAD file to make sure the geometry was perfect for the mold maker."

Re-Engineering

At first glance, putting CAD tools in the hands of model makers and machinist may not seem a very likely way of improving the parts-making capability of a shop. For Apple Pattern, however, it re-defined the way they could service their customers. These CAD tools turned its model makers into service engineers, facilitating the prototyping process for both design shops and mold makers. In short, CAD allowed Apple Pattern to re-engineer their traditional processes, merging new and old technologies, and opened new market opportunities.

Stewart D. Siebell

Trends In CAD/CAM That Will Shape The Future

The rest of this decade will see continued advances in techniques for creating and manipulating workpiece geometry. Standards for user interfaces, data transfer, and computer architecture will give users new flexibility. All of these developments promise to have a significant impact on numerical control and other manufacturing applications.

Where are numerical control (NC) and computer-aided design/computer-aided manufacturing (CAD/CAM) headed? What current trends are influencing the direction these key manufacturing technologies are taking? The answers to these important questions should help us anticipate and plan for the future.

For years, manufacturing companies in the United States have been criticized for a lack of long-range planning. Intense pressures to meet short-term goals are usually blamed for this situation. But another factor has also been at work. Long-range planning means accepting a certain degree of uncertainty. Technology changes so rapidly that it is very difficult to predict what techniques, processes, or systems will predominate or become obsolete.

But decisions about technology are not like dropping an anchor. They are like spreading a sail. Leaders of a manufacturing enterprise must set a course toward a destination, then be ready to shift with the winds.

The following pages are meant to be a breezy review of the major currents blowing us toward the future. They represent the forces that will both guide and propel the decision-making process.

Capture And Share Knowledge

The collective knowledge of individuals within a company is a clear corporate asset. In the 90s, CAD/CAM systems will provide the tools to electronically capture this knowledge and apply it to the design and manufacture of components. Current CAD/CAM technology is related primarily to the dimensional characteristics of a component. However, other properties, such as material, cost, manufacturability, inspectability, assembly fit, tolerances, and so on, are equally important. Design standards, rules, and constraints also impact the design.

Today, manufacturing know-how is mainly locked in the minds of a few individuals at each company. CAD/CAM systems will be extended to capture and utilize this knowledge. This will be accomplished by direct coupling with dedicated knowledge-based engineering systems or by adding that capability to the base CAD/CAM functionality. Knowledge-based engineering will become an integral component of a CAD/CAM system.

New software tools will help these experts record the information and thought processes with which they make decisions. Once captured, these records become readily available to those making the actual design decisions on future projects. These tools will have a major impact on automation of the design and manufacturing process.

Simultaneous Engineering

Sharing information is another urgent issue where new techniques and methodologies will have an impact. One of the most important of these is simultaneous engineering. Simultaneous engineering (or concurrent engineering) can be defined as a methodology in which the design of the product is accomplished simultaneously with the design of the process to produce the product. In this methodology, design engineering works together with manufacturing engineering and other related functions during the design phase to incorporate downstream manufacturing considerations into the product design (Figure 1).

Companies that have implemented simultaneous engineering have typically experienced fewer design changes, shorter lead times, lower manufacturing costs and improved quality. This concept not only applies within a company, but can be extended to the supplier network. As a company better understands the issues being faced by the supplier, and the supplier offers design suggestions based upon manufacturing knowledge, a more effective process results. The inclusion of suppliers and customers into the manufacturing process creates a "virtual factory." Different companies will work so closely together as a team that it will be as if they were actually a dedicated organization under one roof.

Acceptance of Industry Standards

Proprietary computing systems were commonplace from the 1970s to the mid-1980s. Mainframe- and mini-based systems employed proprietary architectures, operating systems, data managers and data communication networks.

Early workstation systems also employed proprietary architectures. Proprietary systems contributed to the "islands of automation" that developed in the 1980s.

In the 1990s, open architectures employing industry standard components will be demanded by users and provided by vendors. Here are some important formal and de facto standards that reflect this trend:

* UNIX has become accepted as the de facto standard operating system for engineering workstations. Although variants of UNIX remain, efforts are underway to move to a common system. * C has become the standard programming language for development of CAD/CAM application systems. Its object-oriented variant, C++, is likely to evolve in the 1990s as a de facto standard as object orientation becomes commonplace. The main concept behind object orientation is that repetitive programming code should be written only once and shared by a number of other programs.

Object orientation provides a natural grouping of all characteristics associated with an object. An object contains both data and procedures or actions. A part can be defined as an object as opposed to a set of related lines, arcs, circles, surfaces, or solids. This simplifies the programming task for the developer and will provide an efficient system for the user. * Initial Graphics Exchange Specification (IGES) has become an ANSI standard data format to facilitate digital exchange of database information among computer-aided design systems. IGES will remain a widely used and supported standard. * Product Data Exchange Specification (PDES) supports the exchange of full product models. In addition to geometric information, PDES supports non-geometric information like manufacturing features, tolerance specifications, material properties and surface finish specifications.

Upon implementation, it is likely to evolve as an industry standard. * Standards for Exchange of Product Model Data (STEP) is an international activity to move the PDES draft forward into a formal standard established by ISO, the world standards-making body. * Programmer's Hierarchical Interactive Graphics System (PHIGS) is a functional specification of the interface between an application program and its graphics support system. Graphics Kernal System (GKS) is a related specification that provides uniform graphics input and output independent of the hardware. * Network File System (NFS) has become the de facto standard for remote access to files within a local area communication network. *

Ethernet-TCP/IP is a network based on evolving ISO standards utilizing TCP/IP formats. It has become the de facto standard for a local area network. * X Window is a specification that allows information from several databases to be accessed and displayed on one screen at the same time. Since both Open Look and the Open Systems Foundation/Motif graphical user interfaces comply with X Windows, it has become a de facto standard for the development of UNIX user interfaces. * NURBS (Non-Uniform Rational B Spline) has evolved as the standard mathematical technique used to define complex curves and surfaces.

Transparent Computing

With the acceptance of industry standards, transparent computing within heterogeneous computing environments becomes possible. In other words, computers work together to solve problems as if they were all part of a single integrated system. The user does not "see" nor is concerned with which processor does the work (hence the term "transparent"). Thus, users have ready access to all relevant computing resources within an environment (Figure 2).

Personal computers and workstations will be organized into work groups. This concept recognizes the economic value in sharing a file server, printer, and plotter among users within a given work group.

At a higher level, computing architectures will be implemented that include the networking of a range of processors from personal computers to supercomputers and supporting equipment such as file servers, printers, plotters, scanners, and so on.

Users will be able to "mix and match" to obtain the most effective application system to accomplish the task. For example, the most appropriate NC programming system can be installed with the most appropriate drafting system.

Enhanced Geometry Creation

The 1990s will see substantial enhancements in geometry creation, including solid modeling, feature-based geometry, associativity, inference systems, parametric design, and variational geometry functionality. Moreover, system architectures of the 1990s are likely to have a separate geometry subsystem that will serve all applications.

Geometry subsystems are now being independently developed and marketed in the same manner as database management, graphics, and data communication systems. They will provide a geometry toolkit to be utilized by all applications.

Advanced geometry software systems will provide an architecture in which wireframe, surface, and solid representations can be intermixed within the same model. Such a system will support applications that involve time, the fourth dimension. For example, this capability will permit direct computation of potential collisions between two solid objects moving through space, as in robotic or machining applications.

Solid models provide a complete and unambiguous representation of a real object. They permit a more direct and accurate computation of mass properties. Internal characteristics of the object can also be included in the model.

Solid product models will form the core for a single product definition in a CAD environment. All functions will reference this model. NC machining systems, now under development in some firms, will be introduced to machine directly off a solid model.

Feature-based or form-feature-based modeling is a higher level of design. It recognizes that designers and engineers generally think in terms of blind holes, through-holes, slots, shafts, chamfers, ribs, rounds, fillets, and so on, rather than lines, circles, arcs, or Boolean manipulation of solid objects such as boxes, cylinders, or cones. Furthermore, the direct creation of a feature, as opposed to a buildup of the feature, improves the productivity of designers.

A related capability is associativity. In associative systems, relationships are established between models and dimensions in such a way that changes in the model or its dimensions result in an automatic update of other related models or dimensions. Further, a change to a part within an assembly can trigger a corresponding change to that part in other assemblies.

In an inference system, the CAD system infers the next step by the operator. It automatically generates the next line, arc, circle, and so on. This is usually done by placement of the mouse pointer or other input device. By so doing, design productivity is increased. If the system inference is incorrect, it can be undone and re-entered.

Parametric design systems were introduced in the 1980s. In these systems, parameters are established as opposed to actual dimensions. Relationships can also be established among the parameters. For example, one side of an object is always twice that of another side of an object. When combined with an associativity capability, a powerful system results. A change in one dimension can also change other dimensions and update the geometric model.

A similar but somewhat more powerful capability is that of variational geometry. A variational design system completely defines the problem with a series of simultaneous equations. Thus, it offers greater flexibility by removing restrictions on interdependencies and solves all the values at once. If engineers change any type of condition or vary any design parameter, the variational design system can still adjust all other design parameters to arrive at a new solution that accounts for interactions among all the conditions defined.

A word about rapid prototyping is appropriate here. Prior to full-scale production, most manufacturers produce multiple prototypes in order to see and touch a part directly, to hold and examine the thing without recourse to abstract geometry. This step can involve significant time and cost.

Technology has been and is continuing to be introduced that reduces this time and cost substantially. The original technology is termed stereolithography but other approaches such as fused deposition modeling (Figure 3) have also appeared. In all cases, systems utilize the geometry from a CAD model as the starting point. Typically, the model is then mathematically sliced to obtain the geometry at a given elevation. Material is then deposited, layer by layer, to build the physical model.

Changes In User Interfaces

Significant changes will take place in user interfaces to a graphics-based computing system. These changes will make the computer more like an extension of the user's mind. The impact of a new user interface was made strikingly clear with the introduction of the Macintosh family of personal computers by Apple Computer Corp. A totally new look and feel for the user was created by the mouse input, windows, pop-up menus, icons, and so on that were introduced with the Mac.

Proprietary graphical user interfaces (GUI) are giving way to pseudo standard solutions for UNIX-based systems. At the lowest level, the X windowing system serves as the clear standard. At the next higher level, where the look and feel is created, the Open Software Foundation's Motif and the UNIX International's Open Look are the two primary competitors for a de facto GUI standard. Stand-alone GUIs based upon these standards are likely to become available and serve as common front-ends to CAD/CAM systems that incorporate a variety of different applications.

Other innovations on the near horizon include multimedia, voice input and virtual reality. In multimedia systems, documents or files will be created with audio, animation, and/or video, as well as the conventional data, text, and graphics. This combination is then simultaneously presented on the display. Multimedia input will allow the user to absorb greater quantities of information by using more than one sense to process information. A message could include voice comments, animation, text, and full-motion color video--even music.

Voice input is likely to become practical in this decade. The user can then enter commands to a CAD/CAM system by voice as opposed to keyboard, mouse, tablet, and other input forms.

In a virtual reality system, the user is placed within the environment of the computer visualization. An architect can walk around inside a virtual building that is being designed. An NC programmer can "walk" along a tool path. A doctor can explore a patient's heart before surgery. In virtual reality, one can directly manipulate the simulation by grasping, moving, and changing elements of the simulation with a gloved hand. This may be the ultimate intuitive user interface.

Product Data Management

Many organizations using CAD/CAM now have thousands of files representing drawings, engineering analysis results, and other information related to product definition. Managing these collections has become a problem. Product Data Management (PDM) software is emerging as a solution.

A PDM system collects, organizes, files, accesses, and controls any type of data about a company's products. Typical information managed by a PDM system includes specifications, drawings, geometric models, models produced by finite element analysis, process plans, NC programs, and so on. Although product definition data could be in hard copy form, it is generally in digital files.

PDM software is provided by CAD/CAM vendors and independent suppliers. Good capability is now available in homogeneous environments and, in the 1990s, management of files in distributed, heterogeneous environments will be commonplace. PDM systems will soon become more closely integrated with both CAD/CAM and standard management information systems.

A related technology is image management systems. In image management systems, paper documents, such as drawings, are scanned into electronic form. The documents can then be indexed, manipulated, accessed within a network, and managed as in a PDM system.

Maturity

The CAD/CAM industry has become a multibillion dollar industry. In the 1990s, it will become relatively mature. Industry growth rates, although substantial by most standards, will ease. Acquisitions, mergers, and alliances will accelerate. The trends noted, for the most part, are evolutionary and not revolutionary. Yet CAD/CAM in general, and automated manufacturing in particular, will remain an exciting field.

New technologies will continue to emerge, and for the most part, will be introduced by niche companies. User organizations will become more sophisticated and hence, more inclined to implement the best product for the task at hand. World class manufacturing demands the appropriate utilization of advanced technology. It is essential for those firms striving to remain competitive in a worldwide marketplace.

PHOTO : Fig. 1--Simultaneous engineering will be greatly facilitated by access to shared databases that capture the expertise of those who make decisions about marketing and manufacturing.

PHOTO : Fig. 2--Access to all relevant computing resources will be a cornerstone of systems architecture in the 1990s. Acceptance of industry standards makes this possible.

PHOTO : Fig. 3--CAD/CAM systems will give users powerful new tools for creating geometry, not only in the abstract on a computer screen but also in physical reality. The computer image on the left was transformed into its 3D counterpart by a rapid prototyping technique called fused deposition modeling, which was developed by Stratasys, Inc.

PHOTO : The graphical user interface defines how a user responds to and interacts with a CAD/CAM system. For example, pop-up menus (the various boxes that seem superimposed on this view of a mold cavity being designed with CAMAX software) list choices available to the user without disturbing the design image on the screen. In this case, the user defines machining parameters by simply making the appropriate selection from each menu.

Stewart D. Siebell, Chief Executive Officer CAMAX Systems, Inc.
Minneapolis, Minnesota

Ken M. Gettelman

CAD/CAM Beats Cheap Labor

It's no secret that many mold and other tooling orders have left for the low-cost labor areas of Southest Asia.

How is the business won back by domestic shops where skilled mold makers and toolmakers earn ten times that of their Third World counterparts? The answer, as shown by Beach Mold & Tool of New Albany, Indiana, is not found in working harder by using traditional methods. It comes from completely changing the process by which such tooling is designed and made. The new processes instituted by Beach wring out direct labor hours and excessive lead times while adding new levels of quality assurance and product performance.

The key has been integrating computer-aided design (CAD), computer-aided manufacturing (CAM), and electrical discharge machining (EDM), both wire and ram, into a unified and disciplined production process.

The company was founded in 1972 by Bill Beach. It had three employees. Today, the organization has more than 250 people, in three functional groups, under one roof. The first group makes molds for plastic injection machines.

The second operates a battery of 23 injection molding machines with capacities ranging from one to 165 ounces per shot. The third group coordinates an extensive assembly area where complex products, including complete sub-assemblies for the computer industry, are put together.

Contoured Surfaces

A pair of plastic speaker grilles for portable radios demonstrates the strategic value of Beach's integrated manufacturing capability. These grilles feature a curved surface that flows smoothly across the face of the radio and merges into its case. The clean, sweeping lines were an essential aesthetic element of this design.

Achieving the smooth surface contour and having it cleanly blend into the contour lines of the case were the prime challenges in designing and building the mold set. The finished grille, after shrinkage, had to have dimensional tolerances within a [+ or -]0.002-inch band around the entire curved periphery for easy assembly and an acceptable fit. Without CAD/CAM, these objectives could not be met (Figure 1).

Phil Kiesler, Chief Engineer, and Gary Wilson, CAD Manager, recall that the original drawing received in the request for a quote did not contain detailed dimensioning. Several points, radii, and matching curves were described and detailed, but smooth blending of surfaces was left to this mold shop.

The design work was done on a Calma CAD system by starting with the defined dimensional data and then using a series of splines and Bezier curves (curves drawn through points so no sharp junctures or cusps appear where they meet). One spline line must flow smoothly into the next. It turned out that this was no small task, because the rate of curvature slightly changes across the face of the grilles. In addition, blending had to be smooth in all directions. To make matters worse, the original specification called for hundreds of holes in each grille that had to be normal to the surface of the workpiece. The pattern easily could be defined, but some sophisticated math routines were needed to orient each one normal to the grille surface. This orientation would also greatly increase the mold cost. After a discussion, the customer agreed that the holes could be parallel. Again, the computer assisted in working out the various patterns for study and comparison.

Programming

The design database was generated in about four days, but it was only the beginning. The design showed the final shape of the workpiece and gave a thorough description of it in coordinate axes dimensions. But two mold halves also were needed, with the appropriate cavity, mounting surfaces, ejector pins, coolant connections, plastic flow channels, and all the other features inherent in the complete mold set.

One of the principal considerations in plastic mold design is allowing for shrinkage. Although some mathematical routines can be worked out, they are not infallible. There is no substitute for experience in this area. Plastic shrinkage during cooling is not the only problem. A decision had to be made about machining the critical cavity areas. Mr. Wilson and Mr. Kiesler chose to machine all mold elements except for finishing the cavity, then use ram EDM to finish. The cavity, in 420 stainless steel, was roughed out to within 1/16 inch of its finish dimension, and then hardened. It was then turned over to the ram EDM unit for the final finish cut. Individual NC part programs had to be generated to rough the mold cavity, machine the EDM electrode, and even machine a prototype part for visual inspection and checking.

Working from the basic design resident in the CAD computer, Mr. Wilson entered the desired machining sequence (the logical sequence of machining operations), the tooling that was to be used, and the offsets and shrinkage factors that were critically important. For example, EDM requires an offset to allow for the dielectric fluid and spark gap. It must be stated in the proper direction for either the male or female half of the mold. When using a ball nose milling cutter to rough out a cavity, the cusp height allowances must be stated to leave enough material for the finish cuts.

Single Data Source

Once this information is entered, the CAD system will generate the appropriate NC party programs for the mold components and the prototype part. One CAD file is the source for all of these programs, including those for programming a coordinate measuring machine (CMM) and analyzing the data from inspection routines.

The CAD database also is often used to generate NC programs for the wire EDM. Some mold features require more than one electrode to sink them. Wire EDM may be used to shape these electrodes in either graphite or copper.

For the grille mold sections, one shaped electrode was used to generate the female mold surface. Another, with holes drilled in it, was used to plunge down over a solid steel section to form the die pins.

EDM is used to generate the finish cut in the mold cavity because of its ability to generate surface finishes somewhere around an 8 AA (arithmetical average expressed in millionths of an inch) or better. This gets close to a mirror finish and greatly reduces the final job of mold polishing. Before any mold work was done, a prototype was machined from hard plastic on one of the CNC machining centers. After the roughing cuts were taken, a finish pass was made with a fine diamond cutter to get the curve and finish of the final contour. The machined model provided an excellent example of how the molded part would look and function. The model was taken to the customer for approval. Next, the mold manufacturing process needed to be determined. The process centered around the CNC machining centers and the CNC ram and wire EDM units.

The heart of the mold is the shaped cavity. But a mold also includes the base, top, fittings, flow channels, cooling passages, and so on (Figure 2). Standard fitting designs used by Beach have been entered into the CAD software.

Calculations for coolant passages and plastic passages have also been made part of the software base. Thus, these do not have to be reprogrammed for each job. They can be called from the file and entered into the workpiece program.

For the grilles, several workpiece programs were generated. One program was used to rough out the mold cavity, and others were generated to machine the EDM electrodes that would finish the cavity. Another program was generated to compare CMM data against the finished part and the design data to assure conformance.

In each instance, the basic CAD part data served as the reference. Skilled mold makers determined the allowances for tool offset, electrode gap allowance, and shrink factors. These people also had to enter feeds and speeds, the desired sequence of machining operations, methods of fixturing and setup, and cutting tool or electrode selection that are vital components of any working part program. The computer made the thousands of calculations and specified coordinate points.

The final results were just what the customer wanted. The mold produced the parts to specification. Total time from design to machined prototype was four weeks. It could have been done in one week if serveral days had not been spent in conferring with the customer and presenting the prototype for his study and approval.

Data Exchange

Beach Mold & Tool, Inc., notes that many of its major customers are doing their design work on CAD systems. They are also using their CAD systems for engineering analysis, quality determination, geometric dimensioning and tolerancing, and group technology. It is essential to have expertise in these areas in order to secure work from such customers. Beach has had to wrestle with the process of translating data, whether received by wire or by tape, from the customer's CAD system to their own.

Beach has two basic approaches to this problem. One uses an IGES (Initial Graphics Exchange System) software package that is currently a standard and bridges the gap between different CAD software packages. However, software development is moving so fast that the IGES effort is hard-pressed to keep up. As a result, it will handle about 80 percent of the conversion on the average. The second approach consists of specific conversion software or direct translator packages. These direct translators often will do a better job of handling Bezier curves and some of the more complex geometry. Translator software packages are available from either the CAD vendors or independent software houses.

Not only does the CAD/CAM approach generate part programs, but it also enables Beach to develop detailed engineering drawings for the customer. These drawings can be used for manufacturing mating parts, assembly fixtures, and so on.

By constantly adding to the CAD/ CAM database, Beach is building its own expert systems software. The complete catalog of one of the major mold component suppliers has been entered. Thus, the specifications for standard bases, fittings, ejector pins, and so on quickly can be called up and entered into a specific mold design. Such components easily can be ordered by the computer. In 15 minutes, Mr. Wilson can design a mold base from standard components. This allows him to devote his creative efforts to designing the critical cavity for each job. In addition, tooling and fixture components for Beach's own CNC machine tools have been entered into their database. Feeds and speeds for machining various mold and die steels have also been included. Standard processing routines are being added as they are developed.

EDM

CAD/CAM is not an isolated entity, but a method of integrating all shop functions into a coordinated whole. Rich Shirley, Superintendent of the EDM department, has offered a lot of feedback to the design people to help them implement the particular processing for each individual job. Mr. Shirley has taken both ram and wire EDM to their limits with two Mitsubishi EDM units (one wire, one ram). He can use the wire to shape complex electrodes for the ram unit. With automatic electrode changing on the ram unit, he can use several different electrodes to sink complex geometric features (Figure 3).

Modern EDM has advanced to the point that the shop can hold tolerances to within a [+ or -]0.0005-inch band with wire in normal cuts and even to within [+ or -]0.0002-inch tolerance with successive skim wire cuts. The Mitsubishi wire machine has control over the U and V axes (secondary axes movements parallel to the primary X and Y), which are employed to generate tapers. Although the machine builder rates the maximum taper capability at 20 degrees, Mr. Shirley has been able to achieve slopes as high as 26 degrees.

Many ram EDM electrodes, whether graphite or copper, are machined on one of the CNC machining centers. An Okamoto VMC 800 machine is equipped with an indexing head, for a fourth axis, and a powerful suction system that enables it to control the graphite dust (Figure 4).

Not A Cure-All

With the speed and versatility of CAD/CAM, the Beach organization pulls in a lot of prototype mold work. Appliance and other manufacturers often order molds made of aluminum or other lower cost alloys simply to build a prototype run. The important considerations are fast turnaround and design integrity. CAD/CAM provides them both.

CAD, CNC, and EDM are not remedies that will cure everything with the push of a button. The professionals at Beach have worked hard to master the benefits these individual technologies have to offer. All three technologies have gone through at least two generations of development. What Beach has done is integrate the people and the technology so that they can perfect a design and quickly develop it into a finished mold. The mold creates a precise image of the actual design.

Behind it all is the overall business strategy to which everyone is committed: Design it well in the shortest possible time and quickly translate that design into a working mold with an assurance of quality, integrity, and performance that wins business.

It is formula that defeats the low-cost labor challenge.

PHOTO : Fig. 1 - The design of this grille for a portable radio features clean sweeping lines. Beach Mold & Tool's CAD system allows them to view the contoured surfaces from any angle.

PHOTO : Fig. 2 - Mr. Kiesler with the female mold half and the part. CAD/CAM was the key to moving quickly from concept to finished design to NC programs that generated the mold.

PHOTO : Fig. 3 - A closeup of many standard mold cavity graphite electrodes used to sink standard cavity shapes on the ram-type EDM unit. Many of these electrodes were profiled with the wire EDM.

PHOTO : Fig. 4 - Some electrodes are produced on a CNC machining center equipped with a fourth axis. On this machine, an indexing unit mounted on the machine table provides that fourth axis. It is also equipped with a powerful suction system that controls the graphite dust.

Mold & die making advances: use of CAD-CAM improves the product, but the industry is slow to adapt - computer-aided design, computer-aided manufacturing

Minoru Inaba

HIROSHIMA CITY, Japan--Through the introduction of computer-aided design and computer-aided manufacturing (CAD/CAM) in the production of its dies, Mazda Motor Corp. Has been able to improve product quality. And now, Mazda, which depends on outside die makers for 80 percent of its die supply, would like to expand its CAD/CAM ability to produce its own dies.

Generally, though, only a few mold and die makers in Japan are computerized and able to receive computer data from the automakers.

"Good or no good, we can determine (quality and dimensions on the computer) before we start making production dies," said Hisao Yamazaki, manager of the company's Stamping Manufacturing Engineering Department.

With that, Yamazaki and other Mazda engineers can determine the quality improvement aspect of CAD/CAM that is usually interpreted as a means to cut lead times and reduce costs.

Mazda engineers indicated that CAD/CAM's savings are obvious, although they cannot be measured in exact amounts of time. Officials reported that the company's capability to manufacture front-fender dies increased from 15 sets per month five years ago to 77 sets per month currently.

They had been doubtful about the cost benefits which CAD/CAM is supposed to bring about. Initial investments were said to be tremendous. Mazda uses International Business Machines 3084 and 3081K mainframes and 160 graphic terminals, IBM's 3250 and 5080, which serve more than 1,000 users at Mazda plants.

However, CAD/CAM's impact has been most obvious and immediate in quality improvement, Mazda engineers explained. Mazda computerized a good part of the flow of car design and manufacturing: front-fender imaging, clay model measurement, structural analysis, cabin package layout, engine parts drawing, engine room layout, plastic trim panel data processing, stamping die patterns, stamping die numerical control (n/c) cutting path and stamping die n/c milling.

With stamping die information stored in a computer data base, simulated for structural analyses and used for machining at an accuracy of 0.05 millimeter, a drastic improvement from a 0.2-millimeter accuracy previously available, Mazda engineers said they no longer need to make dies by trial and error.

Mazda's CAD/CAM also was instrumental in expanding its model offerings. The GLC, Mazda's best selling passenger car, had only two models in 1977, but engineers promised to offer five models of the car in the next model change.

With CAD/CAM, Mazda engineers can prepare two clay models for every candidate car model, for executives' scrutiny. Mazda only had been able to make one while larger car makers made three, engineers said.

Also, Mazda, which depends on outside die makers for 80 percent of its die supply, would like to expand its CAD/CAM to do this work in-house.

Meanwhile, of Japan's 700 mold and die makers, only a few have become computerized and are able to receive computer date from automakers. The majority still need physical models from which to copy.

One of the computerized few, Ogihara Iron Works Co. Ltd., Ota City, Gunna Prefecture, receives digital data from a number of United States and European car makers, but still is in the talking stage with local car makers. Ogihara, according to Ichiro Shuzui, managing director, supplies stamping dies for "every car maker in the world which you can name."

With the Univac 1100-71 and 1106 models, as well as Data General's Eclipse 5230, under which four Calma systems work, an elaborate CAD/CAM system put together at an investment of $4 million, Ogihara performs a quarter of its die drawing on its CAD/CAM, shuzui said.

But the company's CAD/CAM investment hardly is paying off, Shuzui added, saying that it will have to computerize half of its work before CAD/CAM makes money.

From a car maker's point of view, Shuzui explained, there is little incentive in giving out piecemeal orders for die making in digital form, and also it is very difficult to make minor changes on digital data. "It's so much easier to play with physical models--put a piece of clay on here, and take another piece from there," he added.

All in all, Shuzui predicted that it will be another five years before Japan's automotive die making eliminates the use of physical models.

The lead times at Ogihara were said to be 18 months five years ago and 12 months, at the longest, now. Shuzui said Ogihara is working to reduce its lead times to six months, and the key to this is to develop both "male and female" dies from the same computer data.

Automotive apparently is the local leader in CAD/CAM. CAD/CAM vendors, like Fujitsu Ltd. see little business opportunity left there for them. Fujitsu, according to Eiichi Hashimoto, manager of the company's Mechatronics Systems Engineering department, instead is targeting plastic mold manufacturers estimated to be worth 31 percent of Japan's $3 billion mold and die output in 1981 and growing at a rate of 20 percent per year.

Pressing dies, according to Hashimoto, who cited government statistics, totaled 44 percent of 1981 output. Its growth rate is estimated to be 13 percent a year.

As a first step, Fujitsu in December will begin shipping CAD/CAM systems starting at $406,000 each, including a large Fujitsu mainframe.

Based on an injection mold CAD/CAM systems originally developed by Matsushita Electric Works Ltd., Fujitsu's new partner in this business, the new systems can automatically design the mold plate from the input of the core and cavity designs. It automatically manufactures n/c tapes for drilling, milling and wire cutting and ties in with Lockheed Corp.'s "CADAM" software for core and cavity designs.

Hashimoto said the CAD/CAM system, which has boosted Matsushita's design productivity three-fold, can be used in the production of home appliances, audio equipment, precision machinery and electronic devices.

Hashimoto said even small mold manufacturers purchased n/c machines in the 1981-1982 period, but their inability to supply n/c tapes quickly enough has resulted in idle n/c machines.

These mold makers, however, began ot realize that they should introduce CAD/CAM rather than merely try to raise the n/c's operational ratio, Hashimoto explained.

But high prices may become the stumbling block for Fujitsu's CAD/CAM business, targeted at mid-sized mold companies with 20 to 99 workers, a group accounting for 33.8 percent of the industry. Fujitsu officials pay less attention to smaller companies, a 51.5-percent factor, as well as larger companies, a 14.7-percent factor.

Making The CAD To CMM Interface More Effective

The Dimensional Measuring Interface Specification (DMIS) was developed as a standard to allow inspection data to be transferred between computer-aided design (CAD) systems and dimensional measuring equipment such ascoordinate measuring machines. An inspection program created on any CAD system, when formatted following the DMIS standard, can be downloaded to any CMM that has a processor for accepting programs in this format.

Inspection data can also be transferred from the CMM to CAD systems with equal facility using DMIS.

Creating programs for a CMM at a CAD system has certain pitfalls, however, that are now being addressed by software developers. One of these pitfalls arises from the fact that the CMM programmer at a CAD system may not haveaccess to vital information that ensures successful execution of the inspection routine. Likewise, the CMM operator has no assurance that an inspection program created on a remote CAD system takes into account essential details, such as fixture location or part alignment, that may not be available to the programmer.

An example of a product designed to help overcome this problem is EDGES, an Expert DMIS Graphical Editor and Simulator. This software product takes a DMIS file as its input and then graphically displays the CMM inspection program in 3D on the computer monitor. This display allows the CMM operator to visualize the intent of the programmer and verify aspects of the programmed inspection routines.

EDGES, as it first reads in the DMIS file, checks the actual wording or syntax. It will point out spelling errors or prompt for a missing command, a feature especially useful for shops that have "handwritten" DMIS programs. This step verifies for the operator that the DMIS program will run the CMM. Assuming the file does not have any "fatal errors," the display will proceed to show nominal features defined in the DMIS file and the path of the probe.

The next step is to check for possible collisions. A program created on a CAD system that is not located near the CMM might include a path for the probe to follow which intersects the position of the fixtures or even another part mounted on the CMM. The CMM operator who lacks the graphical means to display the inspection path must either blindly trust the CAD operator to have anticipated fixturing needs correctly or use a text editor to check the file for problems.

The simulation features of EDGES allow the operator to preview the path of the probe in animation or one step at a time. The view of the part may be rotated, translated, or zoomed to enhance visualization of the path. Editing features help the CMM operator add position points to move around a fixture, delete necessary position points to speed program execution, or change the probe. The system acts as the DMIS expert because it modifies the DMIS files by generating the necessary commands to achieve the CMM operator's intent.

Probably the most difficulty CAD users have had in programming CMMs has been in the area of alignments. This aspect of CMM programming is highly specific to the CMM and considerable variation exists from vendor to vendor.

The CMM operator is generally more familiar with the peculiarities of the CMM in use from experience programming in the machine's native programming language and best understands the correct features to select for a given alignment. EDGES interprets the intended alignment of the CAD programmer, graphically displays the existing coordinate system and allows it to be modified easily.

DMIS defines formats for return of inspection results to the CAD system. EDGES can display simultaneously the nominal and actual values, and will highlight out-of-tolerance features in contrasting colors on a color monitor. This software runs on any IBM PC or clone with 512K of memory.

Applied Automation Technologies, Inc., 19852 Haggerty Road, Livonia, MI 48152.

PHOTO : CMM programs prepared on CAD systems using the DMIS format can be previewed by the CMM

PHOTO : operator using a software package called EDGES. Errors or possible collisions can be

PHOTO : detected and corrected more easily using this product.

Delivery times cut 50 percent with CAD/CAM - computer aided-design/computer aided manufacturing

The A. J. Rose Mfg. Co., Cleveland, Ohio is a manufacturer of products for the automotive and truck industries. In an effort to better position itself in today's competitive automotive supplier environment, the company has undertaken a massive program of computerization to manage its data more effectively and drive down lead times.

The company chose Hewlett Packard, 19091 Pruneridge Ave., Cupertino, CA 95014, as the hardware vendor for both its general processing and CAD/CAM requirements. An HP 3000 Series 925 LX drives the data processing and information systems; four HP 9000 workstations are networked in a cluster to handle the CAD/CAM functions.

The results have impressed A.J. Rose. Data processing speed has been increased up to an order of magnitude of 12 on some jobs and many die delivery times have been cut by 50 percent. In addition, Rose has met its primary business objective: it can now react more quickly to its customers' orders and change requirements. Today, the company's general data processing requirements are handled by an HP 3000 Series 925LX, built around HP's

Precision Architecture-a computer technology based on Reduced Instruction Set Computing (RISC).

Rose currently runs inventory control, purchasing management, general ledger and accounts payable software on the HP platform.

For the computer-aided design (CAD) end of the business, Rose has set up a four-station network consisting of HP 9000 series machines. An HP 9000 370 Turbo SRX Server hosts a 360 SRX Client, a 360 CH Client, and a 319 Client as nodes on the CAD cluster. The production process at A.J. Rose begins with a customer order. The company reports that most of the material releases come in over the phone line. Rose has established X. 12 Electronic Data Interchange (EDI) communications with a number of its customers, including General Motors, Ford, Chrysler, Caterpillar, and Cummins.

Rose technical personnel wrote order entry software-a release accounting program-to handle customer data.

The first step after receipt of the material release is an update routine that outputs required shipment dates, schedules work flow, and retrieves relevant manufacturing files. Manufacturing requirements are automatically compared against on-hand inventory to determine what is to be used.

The 925LX has the added horsepower to meet these requirements. Reports and batch updates that were taking 10-15 minutes to process are now being accomplished in 75 seconds. HP's Precision Architecture and its use of RISC technology is a key factor in achieving the processing speeds Rose now requires. As orders are processed at the computer, hard copy reports are provided to engineering to initiate design, development and detailing process. Rose is studying the implementation of an electronic link-up between the 925 LX and the workstations in the CAD cluster.

The CAD cluster replaced a manual design environment of drawing boards and slide rules. The company states that its initial goal for the computerized installation is to decrease die lead time by one-half, and that, according to initial measurements, is an achievable goal.

Already, project engineers say, the company has dramatically decreased the time it takes to make design changes. For example, when engineers need to change the size or location of a line, the system automatically updates all other related dimensions, much as a spreadsheet does for bookkeeping.

A.J. Rose also reports that the 3D solids capabilities of the McAuto/Hp software and hardware combination is enabling its engineers to conceptualize their designs so they can anticipate problems and possible interferences.

Consequently, prototypes and die detailing are both developed more quickly.

The CAD workstation cluster has resulted in the quicker assembly of dies. Troubleshooting is accomplished up front, at the computer screen, so problems are identified and solved prior to the manufacturing process.

The HP workstations, with the Motorola 68000 chip, provide the needed graphic processing power. Real-time, fully-shaded, 3D solid modeling is facilitated by the system's high clock speeds.

Currently, die designs are output on an HP electrostatic plotter and passed along to the toolroom. NC programming of the machine tools that turn, mill, and grind the die sections is done at the CNC machine controllers.

A.J. Rose plans to purchase two additional HP stations for the CAD cluster so the toolroom programmers can boot up the McAuto NC programming system. This will link CAM directly to the CAD output so the flow of data from geometry creation to tool-path instruction is accomplished in a true CAD/ CAM mode. For more data circle 47 on Postpaid Card

Include setup as part of CAD/CAM - computer-aided design; computer-aided manufacturing

Chris Koepfer

It makes sense to program within the context of the total setup--including machine and fixture--to save time in the shop.

Often, machine setup is analogous to "mop-up," those pre-production loose-ends, usually relegated to the shop floor for remedy. But, many of those loose ends can be handled off-line with a software package that integrates setup--machine selection, workpiece holding and fixture machining--with workpiece programming, taking much of the setup burden off the machinist.

Some of the setup chores like finding clamps, getting stock, locating T-bolts, dialing in the fixture and more still must be performed on the shop floor. However, many of the decisions such as what size stock, how long the T-bolts need to be, what size clamp and where to position the fixture relative to machine zero, can be done off-line.

Computer-aided setup (CAS), does for setup what the other C-acronyms do for design and manufacturing, moving many time-consuming setup adjustments off-line. The goal of CAS, like computer-aided design (CAD) and computer-aided manufacturing (CAM), is to keep the machine tool cutting. Tying up a machine tool for extensive setup is a poor use of a valuable resource.

The output of most CAD/CAM systems is a workpiece print and an NC program. The print is a picture of the workpiece with its mathematical description. The NC file is a program that instructs the machine how, with what tool, and in what order the workpiece should be processed.

But output from the CAD/CAM system only gets the process started. Everything else is left for completion on the shop floor, such as:

* what is the actual work zone of the table

* where hold-down clamps locate

* what size and type of clamps are needed

* interference zones

* a program for machining a subplate, when needed

* a plan for holding the workpiece

* how to locate the part

* location of work zero point

These setup questions can be readily answered, off-line, using CAS. In some cases, setup time reductions of 75 percent have been reported. And with such significant savings possible using CAS software, setup is being reconsidered for inclusion as an integral part of workpiece programming.

Why CAS?

The idea behind CAS is to incorporate setup into planning the machining of a workpiece--from the start. It works hand-in-glove with CAD and CAM to answer most setup questions off-line, before they are asked on the shop floor. But how is it done? Sky Eastin has an answer that he uses in his job shop.

Mr. Eastin operates Ejay's Machine Company Inc., a 26-year-old, family owned job shop located in Fullerton, California. The company is known for producing high-quality, geometrically complicated parts, generally in small quantities. Although they occasionally work with ferrous materials and titanium, aluminum is used for most jobs. Much of the credit for Ejay's success goes to Mr. Eastin's common-sense manufacturing approach and proficiency as a machinist but he is aided by a CAD/CAM system configured to consider setup in the workpiece programming process.

Mr. Eastin bought into CAS about four years ago with a system from Aura CAD/CAM Inc. (El Segundo, California). It runs on an Apple Macintosh computer and features fully integrated CAD, CAM and CAS functionality. No translator is needed between the databases. Mr. Eastin can draw a workpiece in CAD, create a program to machine it in CAM and configure the workholding fixture in CAS, all during one sitting at his PC. Because the system is integrated, work from one area, CAD for example, can be directly accessed for programming in CAM--it is all part of the same system. And bundled into the system is setup software (CAS) that can give the shop floor the additional benefit of a picture of the setup that shows how to hold the workpiece.

Testimony to Ejay's success as an aerospace supplier is a pair of framed documents hung in the front lobby. One, from Boeing, attests to Ejay's inclusion in the D1-9000 total quality program. A second plaque is from the company's major customer, McDonnell Douglas. It identifies Ejay's as one of a very select number of companies to receive DAC-SQS certification from McDonnell Douglas.

Pick A Table

To illustrate how the CAD/CAM/CAS system works, Mr. Eastin takes us through the steps he uses to manufacture a landing gear bracket for the McDonnell Douglas C-17 aircraft. The workpiece is an L-shaped bracket made from aluminum and the production run is nine pieces. The bracket blank is created from aluminum sheet stock, rough cut on a band saw.

The first process decision is which machine will run the bracket. The decision is aided by calling up schematics of the shop's machining center work-tables, resident in the system database. This library contains worktable configurations for the shop's machining centers. In the case of the bracket, since two can be machined in one setup on the shop's 20-inch by 40-inch Amura vertical machining center, it is the machine of choice for this job.

Initial input for the bracket, like many of Ejay's jobs, is a blueprint. Other parts may arrive in the form of floppy disks, or scaled vellums that can be digitized. Whatever format the input uses, with the exception of floppy disk inputs, the workpiece is redrawn in CAD.

In this case, with the machine table display on the computer screen, Mr. Eastin opens a window on the screen and redraws the part as a separate CAD file. To simplify mounting the bracket on the fixture, Mr. Eastin draws three tabs on the workpiece. These tabs will be used to clamp the workpieces. After the workpiece is machined, the tabs will be removed at another station.

The windowing feature of the system lets him draft the workpieces in CAD while keeping the table display on the screen. When finished, he simply merges the two files--the workpiece drawing and the machining center table display.

At this point, he can manipulate the workpieces on the machining center table to arrange them in the most efficient manner for machining. Now, with the workpieces positioned on the table, the fixture can be detailed.

Each machining center table in the CAS library is displayed two-dimensionally, complete with T-slot locations. Also illustrated, inside the table perimeter, is a smaller rectangle that represents the live area or usable work zone of the machine tool. Anything outside this live area is out of the spindle's reach for machining. Seeing this graphically helps assure the workpieces are correctly positioned within the machine's cutting range. Otherwise, the machine could over-travel trying to cut outside its live area and necessitate re-fixturing the workpiece before proceeding. CAS allows confirmation of this positioning information off-line, at the computer.

With the workpieces positioned on the table, Mr. Eastin draws a box around them with the computer mouse, creating the fixture subplate. The CAS software automatically dimensions this plate so the exact size material can be ordered or cut from stock.

Catalogs In A Computer

Detailing the subplate is simple with CAS. Resident in the library is the entire Carr Lane (St. Louis, Missouri) catalog of clamps, fixtures, and component parts. Selecting a clamp, holder, bolts or other hardware from the library requires simply entering the catalog part number into the computer. A family of parts is displayed on the screen and, with the mouse, Mr. Eastin picks out the components he needs. His selections are transferred graphically to the subplate drawing where he positions them, again using the mouse. A hard copy of this library transaction can be generated and used by the stockroom for processing, or serve as a bill of materials for an outside vender to fill. A quick check of the inventory determines what is available from stock and what needs to be ordered.

Dimensions for the workpiece program and fixture feature locations are taken from the machine tool home position (X-O, Y-O) which is shown on the CAS-generated table illustration. The setup drawing, NC program and machine tool all use the same reference point.

Putting It In A Program

Creating a program to machine the fixture is the next step in the process. To help the programmer, the Aura system shows both a top view and side view of the fixture with the workpieces in place. Seeing these relative positions helps identify potential tool path interferences so they can be avoided before the program goes to the shop floor. And seeing the setup arrangement lets a safety buffer be programmed into the tool's path.

First, Mr. Eastin programs the fixture. A library of machine speeds and feeds is resident in the CAM software. The programmer defines type of material and selects the tools and the speeds and feeds are automatically calculated.

These speeds and feeds can be modified.

Essentially, once the tools are selected and the material specified, all that is left is assigning bolt hole locations for the two part blanks, spotting the locating pins for the second side and specifying the subplate hold-down bolt holes.

All of the holes are co-bored except the part hold-down holes, which get tapped.

The workpiece gets programmed next. He generates the NC program using the merged CAD and CAS files, which let him see the workpiece, subplate, and fixture clamps all mounted on the machine table. The program for the first side calls for end milling the workpiece perimeter in two passes, milling five asymmetrical pockets, and milling three flats. For the second side, the workpiece is turned over and positioned against the locating pins. With the exception of milling the perimeter, the second side machining sequence is the mirror of the first.

Both programs are next downloaded to the machining center CNC. Since the machine home position is used to locate the subplate, no fixture offsets are needed the first time the job runs.

On The Shop Floor

The off-line work is complete. Part blanks are ready. The machine is tooled. Clamps are in-house. The subplate is on the machine. It's time to machine the fixture and workpieces--less than a day from the initial CAD input.

The machining of the subplate is straightforward. A spot drill starts the cycle by locating the subplate hold-down bolt holes, workpiece holding and locating pin holes, and setting ball hole. The tapped holes for the workpiece, pins and setting ball get pilot drilled. A half-inch drill prepares the holes for the subplate bolts. Next, a quarter-twenty tap finishes up the workpiece, locator pin and setting ball holes. The drill work is complete with a co-bore of the half-inch holes.

An end mill cleans up the back side of the subplate with a skim cut creating a surface to simplify alignment with the machine's X-axis the next time the plate is used. On subsequent setups, Mr. Eastin only needs to square the subplate with the machine's X-axis, establish an X-Y location using the setting ball, and enter a G-55 offset between the ball and the machine home position and he is ready to run the brackets again.

In about half an hour, the fixture is machined complete. The workpieces are machined alternately (as detailed above), side one workpiece one, turn it over and locate it against the pins for side two, load a blank workpiece for side one, and so on until the order is complete.

Is It For You?

Automating the production process to include machine setup has helped Ejay's compete and succeed. Many of the benefits Ejay's enjoys from its CAD/CAM system are transferable to most job shop operations:

* increased throughput of work

* shortened leadtimes from order entry to shipment

* reduced in-process inventory

* better documentation of each job

* improved spindle utilization

By improving his operation, Mr. Eastin is better able to serve his customers. In the competitive environment that job shops must operate, how fast you can hold a part may determine how long you can hold an order.

For more information on Aura CAD/CAM systems, circle 38 on Postpaid Card.

Designing on the fly - numerical control and computer-aided manufacturing

Tom Beard

This captive shop designs prototypes and fixtures right in CAM. A strong graphic visualization capability helps them develop the workpiece and machining process simultaneously.

Machine shops have been making things from sketchy design information for a long time. A customer describes what he wants, the machinist does his best to make it, and then the process of refinement begins. Once there's something solid to look at, they can get specific about what the real product should be. It's a time-consuming process, but at least there's little question as to physical appearance of the product.

Today, however, few companies can afford such a protracted development cycle. You still have to get it right, but the work has to get done in a fraction of the time.

This is one area where CAD technology has been particularly helpful. With CAD, designers more quickly and easily flush out their concepts, and get varying degrees of visual feedback as to what a mechanical part really looks like.

This way, the design can be scrutinized to a much greater degree before anything is machined, and then when the first prototype is produced, it's much closer to the desired result.

But CAD is really aimed at people who design all the time. CNC machinists think mostly about the manufacturing process, and what they want first is a tool to help them turn their process plan into a workable part program. But, increasingly, they also want the ability to visualize that machining process, much like the designer, to proceed with a higher degree of confidence that what happens on the machine tool is as close as possible to the intended result.

An interesting question is, when the machinist also occasionally functions as a developer of prototypes and a designer of tooling, how much CAD and how much CAM does he really need? One answer can be found in the machine shop of Nuclear Research Corp. (Dover, New Jersey), a manufacturer of radiation monitoring systems. This is one versatile shop. They do a limited range of CNC production machining. They make prototypes of those parts, as well as for parts that will eventually be cast. And they create a variety of fixtures both for their production machining and for the plant's printed circuit board assembly machines. To compress the development process of both fixtures and prototypes, shop manager Dennis Teske does his design work right in CAM. Besides being a more efficient way to go about these tasks, it provides the ability to clearly visualize both part and process, which frequently are developed simultaneously. That's helping NRC develop new designs faster and improving the efficiency of their own production work as well.

The Shop

Nuclear Research Corp. (NRC) designs and manufactures radiation detection instruments for both commercial and military use. Their equipment is just as likely to be found on the belt of an infantryman as the bench of a laboratory.

Reliability in harsh environments is critical, which puts a special emphasis on consistency and quality in their manufacturing operations, which meet MIL-Q-9858A and MIL-STD-2000 quality standards. The most critical components of their instruments are, of course, the radiation sensors themselves, along with the necessary circuitry. But virtually all the housing and internal mounting components are made of metal, and they, too, must be made to exacting standards.

Though NRC has a line of standard products, much of their work is made to order. That creates a steady stream of work coming through the machine shop for prototypes, fixtures, and ultimately for low- to medium-volume production machining. In addition, the shop manufactures tooling for NRC's printed circuit board assembly operations. These are the fixtures that hold the boards as the various components are being inserted. Thus, machining processes can range from a fairly complicated quantity of one, to relatively simple machining of several thousand parts. All the milled parts are produced on a Fadal vertical machining center. CNC turned parts are produced on a Miyano twin-spindle turn/mill center.

Actually, CNC is a relatively new addition to the shop. They historically produced tooling and prototypes on manual machines, and sent all the production work out. The Fadal was added two years ago (as was the turning center, later) primarily as a lower-cost means for production machining, but it plays a very large role in the development work as well. The other key resource is CAM; it is the Virtual Gibbs system (Gibbs and Associates, Moorpark, California), which is run on an Apple Macintosh computer (the system also runs on IBM-compatible PCs) located right in the shop.

The variety of work creates an interesting mix of design and programming challenges for Mr. Teske. With prototypes, he's most concerned with quickly getting the geometry to a state where he and the original design engineer can agree on the details. With production work, he's focused on getting the most efficient process possible, which certainly requires the ability to quickly create and verify all tooling motions, but also involves the creative design of the workholders. And in all cases, he has to be able to make changes quickly and accurately.

A Better Picture

There are several reasons why this particular CAM system makes sense for this particular application, but clearly the most critical is its ability to graphically render a part and/or process as it is being constructed. Quite literally, Mr. Teske gets a realistic picture on his computer screen that pays dividends in the time it takes to get the right results on the table of his machining center.

Looking at a prototyping process helps explain why. Though NRC's design engineers are an extremely competent group at dealing with demanding technical tasks, their primary concerns are not closely focused on the mechanical component parts of their instruments. They are expert at the application of radiation sensors, and at the design of the circuit boards that deliver the desired functionality of the product. They do care very much that these components are adequately protected, and they generate drawings and specifications to that end, but detailing the mechanical parts is something they are happy to leave to the machine shop. And, historically, it was only after the first rough cut of a prototype that they got a really good feel for the physical characteristics of a design.

Now when Mr. Teske begins such a project, he first constructs the geometry in CAM. At this point, he is generally working in two dimensions at a time. However, once he has the basic construction done, the system provides the ability to show that image as a realistically rendered solid model that can be rotated and viewed from any angle.

To Mr. Teske's machinist's mind, visualizing a part in three dimensions is second nature, so at this stage of the process, a 3D rendering may be helpful, but not critical, to his own work. However, it can be extremely valuable in discussion with an electrical engineer who has an entirely different frame of reference. The rendering provides a model that he and the product design engineer can view together to ensure they have the same understanding as to the design intent and execution. It also provides the opportunity to discuss some elements of design optimization, for example, to address manufacturability issues that the 3D visualization of the part brings to light. Any problems that can be corrected at this early phase of the prototyping process will save time down the road.

For parts they will machine in house, it may make sense to go ahead and create tool path code to more completely evaluate the manufacturability of the part. The CAM system provides a real-time solid model rendering of the machining process, which can be revealing as to its efficiency. This way, they can evaluate the design not just as a theoretical three-dimensional shape, but as a part created by a specific machining process. It's a tool that permits NRC to think about part and process at once, and still before anything is committed to metal. If, through this simulation, Mr. Teske detects areas where slight design modifications can help reduce cycle times or the number of required tools, they can seize the opportunity for process optimization well before the design is finalized.

Such preprocess evaluations can be done with a part in its entirety, or a feature at a time, which is perhaps the defining strength of the Virtual Gibbs system. Graphic verification packages typically require that simulation come at the end of the programming process. Here, it is fully integrated so that a full simulation can be viewed of each machining process step as it is created. Moreover, steps can easily be modified or resequenced, which is particularly important while the design is still in a fluid stage. Early on, Mr. Teske can run a range of "what-if" scenarios, or go ahead and create the entire program, yet still be able to go back to the program and make whatever necessary changes emerge.

Efficient Processes

This ability to work through part and process simultaneously is no less important to Mr. Teske's work in designing and building fixtures. Being a MIL-spec supplier, they have to think about building quality into their processes, and that applies just as much to the setup as to the machining process itself. Also, like any other business these days, NRC must contend with downward price pressure on their products, so they must find ways to lower processing costs. This, too, motivates the shop to make the most of their limited resources.

A key technique Mr. Teske employs is to machine multiple parts in a single setup. The idea is to use as much of the machine table as possible, reduce the load/unload time to the bare minimum, and design in a high degree of process consistency. Moreover, multipart machining reduces the requirements for attendant manpower by combining the cycle times of even simple parts (with short cycle times) into an hour or more, therefore freeing the operator enough to execute additional tasks.

All of these considerations are built into the fixture, which Mr. Teske also designs in CAM. And here, too, he takes the broader view of thinking at once about the total process picture, rather than developing it in a linear chain, one step at a time. The idea is to visualize the entire setup in order to design the fixture and the machining process together.

The beginning premise is that as many parts as possible will be held on a base plate, the mounting dimensions of which are common to every production fixture in the shop. Mating reference pins are permanently mounted on the table of the machine so that location of a fixture within the machine coordinate system is known at the outset, and is consistent among each fixture they use.

That established, Mr. Teske begins to think about which features can be machined in a given part orientation, and then how many parts can be crowded within the space defined by the baseplate to do that portion of the job. He will first decide what is required to hold a single part, and what space is required for tool clearance. Because he has the real part and baseplate geometry with which to work, and because they can be viewed from a 3D perspective, he is quite certain that what he is creating in CAM is workable within the physical constraints of the real machining environment.

Once the general fixture design is established, and the basic part program written, he runs a simulation of the complete machining process on a single part. Satisfied that it works, he then goes about flushing out the entire program

for all parts on the plate. Initially, that's a matter of establishing the location of each part. He might just step and repeat the entire machining process, part by part. However, it's more efficient to combine them all to minimize tool changes--so that, for example, the first operation is done to all parts on the pallet, then the second, and so on. This can be accomplished by changing a single default in CAM, and further, the system can apply a degree of its own intelligence by automatically selecting the most efficient sequence. Mr. Teske may then elect to simulate the entire process, or just portions of it where he wants particular confirmation or suspects there may be additional opportunity to optimize the routine. And finally, the fixture is cut.

Critically important, this entire process has been developed within the context of the actual machine, tooling and workholder with which it will occur. This is rather different than the typical programming scenario where a theoretical part is machined in space, and then it's left up to the operator to locate that process within the real-world coordinate system of the machine tool, and to contend with the often under-considered constraints of the workholder. At NRC, however, the whole process has been considered and verified in their CAM system well before the real setup begins.

Perhaps that's a subtle distinction to some people. But it can make a big difference in the time it takes to get new parts into production, and in the efficiency and quality of the production process itself.

Impact of CAD surface modeling on CNC machining

Golden E. Herrin

There is little debate among the manufacturing community that the surface modeling techniques provided in today's CAD systems are an essential design tool and will play an ever increasing role in part designs of the future. There are a number of modeling methods designers can choose from including: interpolating splines (cubic splines); basis-spline (B-spline) of which there can be rational B-splines and non uniform rational B-spline (NURBS); and Bezier mathematics. Some forms of splines appear to offer significant benefits to manufacturing when applied to the interpolation method in the CNC.

Splines in the most general sense can be viewed as a certain type of mathematical representation of curves and surfaces in 3-dimensional space. One of the key properties of splines is that they can be used to represent smooth free form surfaces. In the design phase, the designer incorporates spline representations to generate sculptured 3-dimensional surfaces that define the shape of a part. Before the surface can be machined, it must be converted to tool centerline (CL) path data. This path data traditionally is presented to the control as a series of short straight line segments for execution by linear interpolation. The shorter the lines, the more accurate the part surface definition - but with better definition also comes enormous amounts of data for the control to process which often causes even the fastest controls to become data bound.

Additionally, when executing a contour using straight line segments with linear interpolation, a corner exists at every segment (or block) boundary. These corners are normally smoothed thanks to the affect of corner rounding and following error until feed forward is applied. Feed forward is a servo feature that is gaining popularity with users doing high speed machining. Its function is to close up the following error, thus causing the machine to track the programmed path more accurately. When feed forward is active, the segment boundary becomes more pronounced in the machined surface and unacceptable levels of vibration are generated in the machine structures due to discontinuities in axis feed rates.

Circular interpolation, the other traditional interpolation method, provides an excellent way to define a very accurate circle or circular segment with a very little amount of data but unfortunately it is limited to a single plane that can not effectively address 3-dimensional freeform shapes. An alternative method to both of the traditional types of interpolation (linear and circular) is to utilize spline interpolation in the control. This will invoke a continuous smooth curve - no segment or axis velocity discontinuities.

The following are two approaches to utilizing spline interpolation in the CNC:

* The first method starts with the part being developed as a spline representation on a CAD/CAM system. After the part is designed, a spline representation of the tool centerline path is made.

The cutter path curve is then transformed from the part based coordinate system to a machine tool based coordinate system while maintaining the spline representation of the curve. This is accomplished by an advanced postprocessor. The part program will contain axis positioning information in terms of spline parameter representation.

As the part program is run, the CNC unit interprets the spline representation of the cutter path and uses this to interpolate a sequence of discrete time axis position commands for the given feed rate.

* A second approach is to use a part program generated the traditional way, processed for linear segments, but have the control interpolate between the points using interpolating splines. This would allow smoother axis command sequences at the segment boundaries. This method could be further enhanced by additional off-line processing to eliminate unnecessary

segments, thus reducing the amount of data while maintaining the smoothness.

As the manufacturing community moves to higher and higher feed rates and demand more accurate cutter paths for competitive reasons, machines and controls are both being taxed to keep pace. For controls, the data throughput has become a major technology challenge to control builders as well as the ability to command the machine to accurately follow the programmed path at high feed rates. To address these issues some CNC builders already support spline interpolation, others are considering it.

There are good reasons why users want CNC builders to provide interpolation methods based on spline representation but which method is most appropriate? The cubic spline method offers the advantage of a smooth curve passing through a series of points and good matching at the intersection of each curve - a characteristic needed to meet the requirements of accurate path following at high speeds. NURBS on the other hand offers all of these advantages plus it also allows the designer to create parts with fewer surfaces than other modeling systems making it more efficient for the designer, It is also viewed by many in the CAD/CAM field as the de facto worldwide standard for representation of curves and surfaces. Users are in a good position today to steer the CNC builders in the direction that best meets their future manufacturing needs.

J.D. Whelan

CAD/CAM having a revolutionary impact on forgings industry

As is the case with so much technology in the 1980s, forging technology is undergoing a rapid transformation. The driving forces are the usual customer demands for lower costs, higher quality, and greater customer responsiveness.

Many of the solutions that are being investigated have a double-barrelled effect. That is, often solving a quality problem leads inevitably to better customer responsiveness. The introduction of a new technology or methodology to solve one problem tends to impact on all of them. This article will touch on the major technical changes that are occurring and attempt to put them into perspective.

Forging customers in general are making renewed demands on their suppliers. In the area of quality many customers are no longer satisfied to accept the assurances of their suppliers regarding the effectiveness of their final inspection procedures. Instead, they are demanding that their suppliers institute meaningful statistical process control (SPC) procedures throughout their whole facilities. Their expected end result is that their suppliers will do a reduced level of final inspection, and that the customer will do no incoming inspection, other than for a statistical sampling. A rejection in the statistical sampling rejects the whole lot that it represents.

Rather, in-process SPC controls the process so that there are no deviations to be found later. They are found as they are created and rejected on the spot. Or, it is recognized that the process is out of control and the process is shut until the cause of the deviations is identified and corrected. This can be thought of as building a fence at the edge of the cliff, rather than having an ambulance standing by waiting for casualties at the bottom.

Pratt & Whitney division, East Hartford, Conn., of United Technologies Corp. has recognized the importance of SPC and makes a program available to its suppliers. The firm not only asks its suppliers to implement SPC but also offers a set program complete with training if required.

In the area of customer responsiveness, inventory control and the worldwide competitive climate that exists for all engine builders places a premium on fast delivery and rapid response to the call for schedule changes. At the Medium Gas Turbine division of General Electric Co. a senior executive has remarked that their inventory thrust is away from "just-in-case' toward "just-in-time'. He added that they are looking for suppliers who are prepared to respond to schedules that may change at will. Their customers demand it, and so they must require it of their suppliers. The implications for the superalloy forging supplier are clear. Be prepared for smaller order quantities delivered with less lead time. In return there may be more room for multi-year sourcing, but that's no promise.

Superalloy customers are demanding and expecting higher quality, greater flexibility in scheduling, and along with all of that, they are placing a great deal of pressure on lower prices. It is the classic case of wanting more for less.

The only meaningful response for forging suppliers is to improve their technology dramatically. There is little room left for choice. And as one last parting shot, users of superalloy forgings are still looking for improved overall performance; longer fatigue lives, lighter weights, greater strengths, and so on. The growing trend toward worldwide competition is hastening the technology transformation in the U.S. forging industry.

The emergence of computer-aided design and computer-aided manufacturing (CAD/CAM) systems along with the introduction of low cost microprocessor controls is having a revolutionary impact on the forging industry. The incentives for the forgers of superalloys to introduce this technology are very strong. The acceptance of this new technology along with the increasing supply of engineers who know how to integrate computers, engineers, operators, equipment and processes into one unified approach to the design and production of high quality forgings at the lowest possible cost is remarkable.

CAD/CAM systems can be used to coordinate the complete process of design and manufacture of forgings including the important technical consultation phase with the end customer. The following outline is a view of how CAD/CAM systems will be working in the not-too-distant future. A customer will send an inquiry to his supplier by simultaneously contacting the appropriate sales department personnel and also downloading his technical requirements to the supplier's engineering department via their CAD/ CAM systems.

The supplier will have his own decisions to make regarding how far he carries his design at this inquiry stage. But assuming he ultimately receives the order for the job in question whatever level of design work he did is now readily available to use in the final design phase. There is no reason to lose any engineering effort between the estimating phase and the final engineering phase. The forging outline will be determined on the CAD/CAM system and using this design and with very little additional effort the process for die design, forging parameters, and numerical control (n/c) machining also will be finalized. If required, consultation with the customer at the design phase can take place via the CAD/CAM system.

One of the frustrations of engineers and metallurgists through the years has been the difficulty of ensuring that their design ideas get carried out in the shop exactly as they had envisioned them when they developed the process.

The addition of micro-processor controls to the equipment in the shops and the linking of these computer controls to the CAD/CAM system is closing the process control loop in many forge shops. The kinds of machines that can be linked, and the way that they are linked to the CAD/CAM system, is limited only by the imaginations of the managers and engineers in the industry. This author is aware of machine shops (for both production forgings and forging dies), forging presses, and furnaces for heating and heat treating that are being fitted with micro-processors and then being linked to CAD/CAM systems either for direct down-loads or for control via tapes or cassettes, depending on the needs and limitations of the shops involved.

The Air Force is sponsoring a computer-aided engineering project to evaluate a number of forging parameters. A computer model will be developed to integrate experience-based knowledge with the existing finite-element analysis program. The object will be to develop parameters which will lead to a capability to do computer modelling of forging and/or extrusion parameters such as material plasticity and lubrication characteristics, which in turn lead to the development of particular properties or metallurgical structures.

It is also of interest to develop computer models of how the metal flows in a particular die set to determine in advance of an actual trial whether the dies will fill properly. All of this will aid in the proper design of forging sequences, die designs, temperatures, and lubricants to yield the desired shape, properties and structures the first time. Again, the beneficiaries are better quality, faster reaction times, and thereby lower costs. None of this is possible without the computer-based technology which is developing in the industry.

Key changes occurring on the presses themselves involve more and more hot die and isothermal forging. Of course, for some time now powder alloy forgings have been produced on isothermal presses using thorium dispersed molybdenum (TZM) dies. The thrust is for more and more alloys to be forged isothermally or on hot dies, where the forgings are run on dies that are not TZM but are run at temperatures well above traditional die temperatures. Die materials include a variety of superalloys, either cast or wrought. The objective is to eliminate cracking completely and to produce a forging which is as close to the customer's final shape as possible, without the high cost of TZM dies and the slower run rates experienced on isothermal presses. Close tolerances also are required to optimize the effectiveness of the increasingly automated machine shops that the forgings move into.

Die change times have for years been a driving force to keep forging run sizes high. When a large piece of equipment is down for several hours to make a die change, it is imperative that a sizeable number of forgings be run to amortize the set up cost over. More and more we are hearing about presses being installed with automated die change systems. Many companies are looking at existing equipment and doing retrofits. The driving force for this change comes from the high cost of inventories and the fact that customers are increasingly saying that they want to change schedules at will, and take only small quantities of forgings at a time.

The future for superalloy disk producers might include isothermally forging disks complete with integral blades. Work has been going on in this area for a number of years. Of course, the incentive for the engine manufacturer is the high cost of machining and the assembly cost associated with fitting disks with blades. The designer is relieved of the problems associated with possible failure in the blade roots.

Certainly, there is any number of new things going on in the forging industry. However, these are some of the most significant technological developments that are shaping the forging of superalloys in the 1980s.

Photo: The future for superalloy disk producers might include isothermally forging disks complete with integral blades.

Douglas Betts

CNC Machine Tool

Background

CNC or "computer numerical controlled" machines are sophisticated metalworking tools that can create complicated parts required by modern technology. Growing rapidly with the advances in computers, CNCs can be found performing work as lathes, milling machines, laser cutters, abrasive jet cutters, punch presses, press brakes, and other industrial tools. The CNC term refers to a large group of these machines that utilize computer logic to control movements and perform the metalworking. This article will discuss the most common types: lathes and milling machines.

History

Although wood-working lathes have been in use since Biblical times, the first practical metalworking lathe was invented in 1800 by Henry Maudslay. It was simply a machine tool that held the piece of material being worked, or workpiece, in a clamp, or spindle, and rotated it so a cutting tool could machine the surface to the desired contour. The cutting tool was manipulated by the operator through the use of cranks and handwheels. Dimensional accuracy was controlled by the operator who observed the graduated dials on the handwheels and moved the cutting tool the appropriate amount. Each part that was produced required the operator to repeat the movements in the same sequence and to the same dimensions.

The first milling machine was operated in much the same manner, except the cutting tool was placed in the rotating spindle. The workpiece was mounted to the machine bed or worktable and was moved about under the cutting tool, again through the use of handwheels, to machine the workpiece contour. This early milling machine was invented by Eli Whitney in 1818.

The motions that are used in machine tools are called "axis," and are referred to as "X" (usually left to right), "Y" (usually front to back), and "Z" (up and down). The work-table may also be rotated in the horizontal or vertical plane, creating a fourth axis of motion. Some machines have a fifth axis, which allows the spindle to pivot at an angle.

One of the problems with these early machines was that they required the operator to manipulate the handwheels to make each part. Besides being monotonous and physically exhausting work, the ability of the operator to make identical parts was limited. Slight differences in operation resulted in variation of the axis dimensions, which, in turn, created poorly fitting or unusable parts. Scrap levels for the operations were high, wasting raw materials and labor time. As production quantities increased, the number of usable parts produced per operator per day were no longer economical. What was needed was a means to operate the motions of the machine automatically. Early attempts to "automate" these operations used a series of cams that moved the tools or worktable through linkages. As the cam rotated, a link followed the surface of the cam face, moving the cutting tool or the workpiece through a series of motions. The cam face was shaped to control the amount of linkage movement, and the rate at which the cam turned controlled the feedrate of the tool. These early machines were difficult to set correctly, but once set, they offered excellent repeatability for their day. Some have survived to this day and are called "Swiss" machines, a name synonymous with precision machining.

Early Design to Present Day Operation

The modern CNC machine design grew out of the work of John T. Parsons during the late 1940s and early 1950s. After World War II, Parsons was involved in the manufacture of helicopter rotor blades, which required precise machining of complex shapes. Parsons soon found that by using an early IBM computer, he was able to make much more accurate contour guides than were possible using manual calculations and layouts. Based on this experience, he won an Air Force contract to develop an "automatic contour cutting machine" to produce large wing section pieces for aircraft. Utilizing a computer card reader and precise servomotor controls, the resulting machine was huge, complicated, and expensive. It worked automatically, though, and produced pieces with the high degree of accuracy required by the aircraft industry.

By the 1960s, the price and complexity of automated machines had been reduced to the point where they found applications in other industries. These machines used direct current electric drive motors to manipulate the handwheels and operate the tools. The motors took electrical instructions from a tape reader, which read a paper tape approximately 1 in (2.5 cm) in width that was punched with a select series of holes. The position and sequence of the holes allowed the reader to produce the necessary electrical impulses to turn the motors at just the precise time and rate, which in effect operated the machine just like the human operator. The impulses were managed by a simple computer that had no "memory" capability at the time. These were often called "NC," or Numerical Controlled machines. A programmer produced the tape on a typewriter-like machine, much like the old "punch cards" used in early computers, which served as the "program." The size of the program was determined by the feet of tape needed to be read to produce a specific part.

CAD CAM - What Is It?

By John Lombaerde

The words CAD CAM are tossed around quite a bit in manufacturing circles, but what is it really? When we say CAD/CAM, do we really know what we are talking about? In my experience many of us do not. A simple definition is a good place to start. Computer-Aided-Design, and Computer-Aided-Manufacturing.

Look around you, whether you are at home, or in the office. Almost everything you see around you was probably designed on a computer. With the exception of buildings that were made before the 1970’s and any antique furniture you may have around you at home, a very high percentage of the things we use everyday were designed using CAD.

Automotive and Aerospace Design were responsible for the development of early CAD systems in the 1960’s and 1970’s. They were very expensive systems that cost over $ 100,000.00 per station. With the development of the PC, all that has changed, and CAD systems can be procured roughly anywhere from $ 500.00 to $ 5,000.00.

Even with costly additional options, it is rare for a single CAD seat to cost more than $ 20,000.00, unless it is being used for some very high-end specialized function. The development of CAD CAM software has paralleled the rise of personal computers, which made this type software affordable for the average manufacturer.

So what about CAM ? I guess you could say that there really is no CAM without CAD. Without an electronic design, no CAM system can function. Sometimes design is done within a CAM system, but without electronic information, CAM is limited. I know many machinists say they program CNC machine tools at the control without a CAD system, but chances are that the blueprint they work from was made using a CAD system.

There are probably 100 people who know what CAD is for every 2 who know what CAM is. In the same way there really is no CAM without CAD, there is also no CAM without CNC machinery. A CNC machine is simply a computerized machine that depends on a series of commands or programmed instructions that include position information to accomplish a particular task. This is usually, but not always, some kind of cutting motion, using a particular type of cutting tool.

Technically, this program code format is designated as RS-474, but most people refer to it as G and M Code. Since FANUC is the most popular type of CNC control, often CNC code is referred to as “FANUC compatible”, which means standard G and M code.

CNC machines are not limited to the typical CNC Milling and CNC Turning machines that have been used for nearly 50 years in machine shops across the country, they come in all shapes and sizes. Grinders, turret punches, lasers, plasmas, water jets, wire edms, shears, brakes, coordinate measuring machines, embroidery machines, welders, routers, jig bores, and robots used for most any job imaginable, are just a few of the hundreds of types of CNC machines used in manufacturing today.

I am reminded of a quote from Gotfried von Leibniz, a 17th century mathematician, who once said: “It is unworthy of excellent men to lose hours like slaves in the labor of calculation, which could be safely relegated to anyone else if machines were used. He also strongly advocated the use of a binary system of numbers which is the foundation of modern computer numerical calculation.

CNC manufacturing technology is the inevitable result of the application of computer technology to manufacturing. It has allowed manufacturing to progress beyond the dependence on “excellent men” to produce parts manually. CAD CAM and CNC technology has produced manufactured parts and assembled products at speeds and accuracies that could only be dreamed of a generation ago. The complexity of modern manufactured parts was simply impossible to achieve in previous generations. Although the same level of skill is required in these industries, as in earlier days, the limitations and inherent inefficiencies of manual methods have largely been overcome.

John Lombaerde is a CAD/CAM/CNC Specialist with over 20 years experience in advanced manufacturing technologies. He is a Designer, CNC Programmer, CNC Machinist, a CAD/CAM consultant, and SEO Strategy consultant.

For additional information contact:

For more information, see CAD CAM Consulting or CAD CAM Conference

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http://EzineArticles.com/?CAD-CAM---What-Is-It?&id=566074

What Is Computer Aided Manufacturing?

By Kevin Stith

Over the past decade, manufacturing processes all over the world have undergone some dramatic changes. The introduction of automated systems and computer technology has allowed industries to significantly increase their productivity. CAM is the abbreviation for Computer Aided Manufacturing. Computer aided manufacturing accurately converts product drawing or the object into a computer readable code format, enabling the machine to manufacture the product. Computer aided manufacturing can be used in different machines like lathes and milling machines for manufacturing the related product.

A computer aided manufacturing system allows the manufacturer to systematically communicate work instructions to the machine. CAM has evolved from a technology referred to as the Computer Numerical Control (CNC), invented in the 1950s. CNC performed a set of coded instructions in a punched paper tape.

Computer aided manufacturing facilitates effortless and quick computer programming and faster execution of design changes. The computer aided management system integrates the computer aided design systems and controls tasks that involve order placement, scheduling, and replacement of tools. The implementation of CAM system leads to overall increase in efficiency of the manufacturing process. CAM systems are used in the automotive, aviation and furniture manufacturing sectors and areas such as mechanical engineering and electronic designing. Another significant benefit of using the computer aided management system is that it allows customization of the manufacturing process for creating client specific designs.

A computer aided manufacturing system requires a 3D environment for making it compliant with CAD systems. The CAM system can cost $18,000 or more along with the appropriate software. CAM allows automated integration of the manufacturing procedure with other mechanization systems such as Computer-Integrated Manufacturing (CIM), Integrated Computer-Aided Manufacturing (ICAM), Flexible Manufacturing System (FMS), Direct Numerical Control (DNC), and Manufacturing Process Management (MPM). Repetitive tasks involved in the manufacturing process are delegated to machines using the CAM system, allowing workers involved to concentrate on quality control and productivity.

Computer Aided Manufacturing provides detailed information on Applications of Computer Aided Manufacturing, Cam And Computer Aided Design, Computer Aided Design , Computer Aided Design Scanners and more. Computer Aided Manufacturing is affiliated with Computer Aided Design and Manufacturing.

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Computer Aided Manufacturing Applications

By Kevin Stith

Computer Aided Manufacturing (CAM) refers to an automation process, which accurately converts product design and drawing or the object into a code format, readable by the machine to manufacture the product. Computer aided manufacturing complements the computer aided design

(CAD) systems to offer a wide range of applications in different manufacturing fields. CAM evolved from the technology utilized in the Computer Numerical Control (CNC) machines that were used in the early 1950s. CNC involved the use of coded instructions on a punched paper tape and could control single manufacturing functions. CAM controlled computer systems, however, can control a whole set of manufacturing functions simultaneously.

CAM allows work instructions and procedures to be communicated directly to the manufacturing machines. A CAM system controls manufacturing operations performed by robotic milling machines, lathes, welding machines and other industrial tools. It moves the raw material to different machines within the system by allowing systematic completion of each step. Finished products can also be moved within the system to complete other manufacturing operations such as packaging, synthesizing and making final checks and changes.

Some of the major applications of the CAM system are glass working, woodturning, metalworking and spinning, and graphical optimization of the entire manufacturing procedure. Production of the solids of rotation, plane surfaces, and screw threads is done by applying CAM systems. A CAM system allows the manufacturing of three-dimensional solids, using ornamental lathes with greater intricacy and detail. Products such as candlestick holders, table legs, bowls, baseball bats, crankshafts, and camshafts can be manufactured using the CAM system. CAM system can also be applied to the process of diamond turning to manufacture diamond tipped cutting materials. Aspheric optical elements made from glass, crystals, and other metals can also be produced using CAM systems.Computer aided manufacturing can be applied to the fields of mechanical, electrical, industrial and aerospace engineering.

Applications such as thermodynamics, fluid dynamics, solid mechanics, and kinematics can be controlled using CAM systems. Other applications such as electromagnetism, ergonomics, aerodynamics, and propulsion and material science may also use computer aided manufacturing.

Computer Aided Manufacturing provides detailed information on Applications of Computer Aided Manufacturing, Cam And Computer Aided Design, Computer Aided Design , Computer Aided Design Scanners and more. Computer Aided Manufacturing is affiliated with Computer Aided Design and Manufacturing.

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Custom Designing Your Jewelry Using 3D-CAD Technology

By Andy Moquin

For years custom designed jewelry has been created using old world techniques dating as far back as the 1800's. Until recently, almost all-custom designed jewelry was created using these methods. The introduction of Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) has changed all that and in it's wake ushered in a whole new universe of possibilities. Designs that were never thought possible can be made to the highest quality standards.

How is Custom Designed Jewelry Made? Before learning about the benefits of 3D-CAD you'll need to know more about the custom jewelry design process. Most jewelry is made using a method called lost wax casting. A skilled artisan/jeweler hand carves a jewelry prototype out of jewelers wax using small scalpels and knives. This wax prototype also known as a "model" is placed in a flask and plaster called "investment" is poured all around the model.

Once the investment hardens an exact impression of the model is formed inside of the flask. The wax model is burned out of the flask leaving a cavity of the jewelry design.

Next molten metal is injected in the flask mold using vacuum or centrifugal casting. When the metal cools and hardens the investment is broken away revealing the un-finished jewelry casting. This casting is filed, polished and prepped for assembly, which may include setting the gemstones or welding other precious metal parts to the casting.

The process of hand carving the wax prototype has always been the accepted process for creating custom jewelry. The problem with this process is that the human hand can't be as precise as a computer-aided machine when carving the model. Precision equates to more design possibilities and much higher quality jewelry production. In the end you'll have a product that looks crisper and won't be prone to stone loss or breakage.

What is Computer Aided Design? Computer Aided Design is a sophisticated modeling process using advanced software to plot coordinates for mechanical drawings. These drawings can be exported to various types of prototyping machines called CNC mills or growing machines. CNC mills cut-away material from a block of wax to make the jewelry model. The growing machines layer material from side to side much like a printer to build the model, samples of this process can be viewed at design your engagement ring The precision of these models exceeds what any human could do while hand carving the jewelry model. Design possibilities become limitless because the 3D-CAD software enables the designer to create parts and design elements that aren't possible using outmoded tools and methods.

Another benefit of 3D-CAD jewelry design is the ability to see a computer rendering before the final completion of the jewelry. In old methods the jeweler would create crude counter sketches of your concept and the rest would be left to your imagination. Now the designs that the jeweler creates in 3D-CAD can be rendered to photo-realistic images for you to view before making your final decisions.

Choosing a Jeweler for Custom Jewelry Design Like any other occupation or trade there are good jewelry craftsmen and there are bad ones. It is important to pre-screen your jeweler to determine if he/she is skilled at making custom designed jewelry. Ask to see their portfolio and examine their designs to determine if the flair they have for jewelry design matches your style requirements. Also, pay close attention to their communication and interpretation skills because much can get lost in the translation of your ideas if you're not careful. Once the jewelry is made its too late to make changes and the typical jeweler will not re-make it again without added fees.

At this point higher qualified and better skilled custom jewelry designers have moved to using 3D-CAD to create their designs. If you feel 2 jewelers are equally matched in aptitude and skills then you should choose the one that is using 3D-CAD design. You'll pay a little more to have your jewelry created in 3D-CAD but the final results will be amazing. The jewelry will look 1000% better than if it were hand carved and it will last much longer because of the precision of the jewelry model.

Andy Moquin President Andrews Jewelers Inc.

Andy Moquin has spent 20 years in the jewelry business buying and selling over $20,000,000 in diamonds, engagement rings and custom designed jewelry. He as traveled to Belgium and Israel to work with international diamond dealers and works as an advisor for DBC Diamonds an international consortium of diamond dealers. His experience in the jewelry business has become invaluable to consumers and business owners. He can be contacted at learn about diamonds or 716-630-7091

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Managers must understand CNC responsibilities! - CNC Tech Talk

By: Mike Lynch

It should go without saying that CNC people directly affect the productivity of the machine or machines on which they work. Because a company's productivity is directly related to the productivity of its CNC machine tools, GNC people should be considered among the most important people in a company.

This said, I'm amazed in my visits at how many companies there are in which management is unfamiliar with the responsibilities of the company's CNC people (and the CNC process as a whole). While managers don't actually have to program, set up or operate CNC machine tools, they should know enough about the related responsibilities to be able to communicate intelligently with CNC people. More importantly, they should be able to make informed decisions that solve the problems that arise in the CNC environment.

One common misconception, for example, is that a programmer's responsibility is limited to creating CNC programs. While this may be among the most basic tasks a programmer performs, programming involves much more than running a computer aided manufacturing (CAM) system.

The programmer makes almost all decisions related to the jobs her or she programs, including those related to process development, workholding device and cutting tool selection, cutting conditions selection, and documentation for the job. Of course, the quality of these decisions, as well as the quality of the CNC program, will directly impact the productivity of CNC machine tools. Indeed, the quality of a company's programmers, in turn, affects the productivity of setup people and operators.

Because the programmer's job is so very important, managers should know the various tasks a programmer must perform. Again, managers may not have to develop a process for a job, but they had better be able to determine whether the process used by a programmer is appropriate for the job. Managers may not have to develop cutting conditions, but they should know enough to be able to determine if cutting conditions being used are safe and efficient. Managers may not have to choose workholding devices and cutting tools, but they had better be able to tell if those being used are appropriate for the job.

Ill-informed managers will not be able to correctly diagnose problems in the GNC environment. In one company I know of, management was convinced that the excessive scrap coming from a particular CNC turning center was being caused by its operators. Management thought that these operators weren't skilled enough and needed more training.

In reality, these operators were highly skilled. The reason for the scrap was related to the process. The process was so poor that even highly skilled operators couldn't hold size.

Ill-informed managers tend to attribute problems to a person when the problem is, in fact, beyond the person's control. Consider, for example, a CNC operator who is having problems with tool breakage. It's easy to jump to the conclusion that the operator is unskilled when, in fact, the material being machined is inconsistent.

Conversely, a good manager should be able to spot problems that are within the control of the company's CNC people. It is possible that programs must be changed each time they are run because cutting tools are not set up in the same manner every time the job is run. If the programmer provides more explicit documentation, the setup person will be able to set up tools consistently.

Maybe the most important reason why managers must understand CNC responsibilities has to do with training. A manager decides how much training is required for each position in the company. How can a manager make an appropriate training-related decision if he or she doesn't understand the responsibilities of the people involved?

There are any number of ways in which managers can learn more about the CNC environment with in their company. Probably the easiest is to talk more with the people in the CNC environment. It's amazing how much people are willing to share when they know that the boss is interested. Or, there are numerous technical schools that offer courses in CNC. There are also many books available that explain CNC usage from the ground up.

Given the benefits that can be achieved by ensuring that CNC machines are being appropriately used (and the problems that can arise when they aren't), all managers should he willing to do whatever it takes to learn about the responsibilities of the company's CNC people.

Ask This Expert

See Mike Lynch on MODERN MACHINE SHOP Online at Expert www.mmsonline.com/experts/lynch.html

Another look at CNC web sites - CNC Tech Talk

Mike Lynch

Every so often, I like to present a few Web sites I've come across that are of special interest to CNC users. While some of the Web sites I mention have products to sell, they also have free information about CNC.

It's getting easier and easier to find CNC-related Web sites. A search in Google (or any other search engine) for "CNC,", "CNC training," "CNC Programming," "Parametric programming" or just about any CNC-related topic will render countless results. Here are a few of my favorites.

* The Virtual Machine Shop (gatecity.ampcenter.org): Funded by the U.S. Department Of Labor, this learning site has great animated articles about many facets of manufacturing, including CNC. You'll need a fast connection (DSL or faster) to view the animated articles. Current major categories include milling machines, engine lathes, other machines and manufacturing

processes, CNC/CAM, measurement, and machine shop processes. There are currently about 40 active articles, but according to the site, this will eventually grow to more than 180.

* techspex online (www.techspex.com): This comprehensive machine tool database (the Web site claims more than 7,000 models provides specifications for machine tools built by hundreds of machine tool manufacturers. Nicely categorized by machine type, this database should be one of the first places a new machine buyer goes to compare key features and specifications. In addition to machine tools, other main categories include tooling and accessories, software, controls, inspection, and machinery dealers. While you must register to get in, this service is free to CNC users.

* CNC Freeware, Shareware and Trialware (www.wokingham.demon.co.uk): As the name implies, you'll find free and share software to help with CNC usage. Categories include CNC text editors, multifunction software (such as Mr. Machinist, Machinist Toolbox, Machinist's Companion and Machinist's Mate), program manipulation software, visualization (verification) software, communications software, and mathematics and calculation software.

* Programming Unlimited (www.programmingunlimited.com): This site has some great free information about custom macro B and user tasks 2 (Fanuc and Okuma versions of parametric programming). Anyone wanting to know more about parametric programming should check out this site. From this Web site you can also buy inexpensive manuals and text editing software for custom macro.

* alt.machines.cnc: This is one of my favorite Internet stops. In this newsgroup, you'll find discussions related to just about any conceivable CNC topic. Many knowledgeable CNC people participate, asking and answering questions, exchanging ideas and, in general, discussing CNC. Not every post

is appropriate, but it's nice to know what others in your position are talking about. Are you thinking about buying a new CNC machine? Do you wonder what people think about that CAM system you're about to buy? Do you have a question your machine tool builder can't answer? Post a question to this newsgroup; I can almost guarantee you'll get a response. Note that this is not a Web site.

Again, it is a newsgroup. If your Internet service provider does not give you access to newsgroups, you can access the group from the Google Web site (among many others). From Google's home page (www.google.com), click the link for "groups". From the search page that comes up, enter alt.machines.cnc as the search criteria. You'll see the 2 5 most recent posts.

I've excluded my company's own site (www.cncci.com) from this list. We also have some great information for CNC users, including a schools page, a jobs page, two free downloadable technical newsletters, tips for CNC users and articles related to CNC. Other CNC Web sites to check out:

* CNC Gurus (www.cncgurus.com/forums): This site features great forums for CNC users. Included in the "Programming" forum, you'll find discussions on CNC-related software and macro (parametric) programming.

* CNC Times (www.cnctimes.com): This is an online periodical containing articles of interest to CNC users.

* Deepak Manuel's CAD/CAM/CNC Web site (www3.sympatico.ca/deepak/cadcam): This is the ultimate CNC links page! Categories include CAD systems, CAM systems, CNC machines, CNC controls, post processors, NC verification, jobs and miscellaneous.

* Cadem Technologies Pvt., Ltd. (www.cadem.com): While this company sells CNC-related software, you'll also find free software for a distributive numerical control (DNC) system.

Verify CNC program correctness

Mike Lynch

All CNC programs must be verified. While new programs present more challenges than proven programs, operators must be careful and alert during every step of a program's verification.

Step 1: Verify the correctness of the CNC program. This step is required for new programs or for programs that have been modified since the last time they were run (possibly because of engineering changes). It is also necessary to do this step if there is any doubt as to whether you are working with the current version of the program (after making changes at the machine the last time the job was run, perhaps the setup person forgot to save the program).

The objective of Step 1 is solely to confirm the correctness of motions commanded in the program. Other potential problems will require further verification at the machine; however, when Step 1 is successfully completed, the setup person will have confidence in the motions made by the program.

Some operators perform this step on the CNC machine during setup, which requires time. Many current model CNC machine tools have built-in toolpath displays, and as long as you verify the new program while the machine is running, you won't interfere with production. Not all CNC machines allow you to view one program's toolpath while another program is running. In this case, Step 1 will add to the setup time. If mistakes are found, the time it takes to correct them will also add to setup time.

Not all CNC machines provide toolpath display, and it is difficult to see a program's true motions by watching a CNC machine run a program. You may not be able to achieve the objective of Step 1 in this case because there might be serious mistakes to be found and corrected in Steps 2 and 3.

With the affordable off-line G-code level toolpath verification systems available, Step 1 can be performed for upcoming jobs, while the machine is running production shortly after a CNC program is created or modified. With these desktop computer-based systems, users can gain a better view of the program's movements than they could by watching the machine move.

If using an off-line system, the programmer is usually responsible for this step. They will perform this step shortly after the program is created. While most CAM systems have toolpath verification that is done as the CNC program is created, if changes are made to the G-code level program, many CAM systems cannot display the changes.

Even if changes are not made to the G-code level program, I recommend using a G-code level off-line program verification system to check the program's motions. If nothing else, this gives the programmer another way to see the motions a program is going to make before it is run on the CNC machine.

It takes a watchful eye to catch mistakes with an off-line system. Because the job is not currently on the machine, there is no real urgency, so mistakes can slip by. It might help to have someone else perform this step (another programmer or a setup person). Because the original programmer is so familiar with the job, he or she might not catch obvious mistakes. A setup person can be the best bet, since he or she will be responsible for actually running the program at the machine.

Many off-line systems don't show the location of clamps and other obstructions, so the person verifying the program must be able to visualize the placement of workholding components around the workpiece. The more problems they catch, the fewer problems there will be for the setup person to find and correct.

There may still be problems with the program's motions alter Step 1 is completed, but these problems should not be severe. Even with a toolpath display, it can be difficult to catch small motion mistakes. Some solid model-type program verification systems allow performing measurements on the virtual workpiece machined in the system; however, you must suspect that a problem exists before taking a measurement. For instance, with a mistake of less than 0.01 inch, it is likely that you may not suspect that anything is wrong.

After completing Step 1, the setup person can proceed to Step 2, which will be explained in next month's column. They must still be extremely careful, but there will be no big problems in the program's motions.

Ask This Expert

See Mike Lynch on MODERN MACHINE SHOP at www.mmsonline.com/experts/lynch.html

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Four types of CNC users

Mike Lynch

Almost every important CNC feature can be applied in at least two ways. For example, program zero can be assigned in the program or through some form of offset. Tool length compensation offsets can be specified as the tool's length or the distance from the tool tip to program zero in Z. Cutter radius compensation offsets can be specified as the cutter radius or the deviation from the planned cutter size. And many CNC words can be specified with or without a decimal point.

Additionally, there are those CNC features that have been developed for a niche market. Conversational CNC controls that are programmed on the shop floor make it easy to develop programs when programming must be done during setup. Tool length measuring probes are designed to measure tool lengths during setup for those applications when tool lengths cannot be measured off-line. Apparatus such as bar feeders, automatic loading systems, in-process and post-process gaging systems, and tool breakage detection systems all facilitate unattended operation.

The choices related to each CNC feature make for a great deal of flexibility. The same CNC machine tool and/or control can be applied to a variety of applications. However, with flexibility comes the potential for confusion, controversy, and misapplication. During my CNC courses, students often get into heated discussions regarding the pros and cons of even the most common CNC features. What makes perfect sense to one person seems wasteful or unfeasible to another.

The most basic reason for the controversies that surround certain CNC features has to do with company type. Knowing the subtle differences among company types will help you understand why there are so many ways of handling certain CNC features and will give you an appreciation for another company's differing ways of handling applications.

Product producing companies get their revenue from the sale of a product. In almost all cases, the actual cost of operating CNC machines is one step removed from how the company makes money. In fact, it may be difficult for manufacturing people in some product producing companies to determine each CNC machine's shop rate (the hourly cost for machine usage). Product producing companies commonly have the luxury of adequately tooling up for the component workpieces they run. Most perceive machine up-time (productivity time) as the highest priority. For this reason, they commonly staff their CNC environments with enough people to ensure that their CNC machines run workpieces for as great a percentage of time as possible. Product producing companies tend to have the most complicated CNC environments since they often employ a wide range of CNC machine types for a variety of processes.

Many also have CNC machine tools in their toolrooms and research and development departments.

Companies that produce production workpieces for other companies, commonly called contract shops or job shops, generally get their revenue from product producing companies. Manufacturing costs are directly tied to the workpieces being machined, and job quotes are based on the shop rate for the specific CNC machine tools to be used. While up-time is still important, most job shops have a slightly different set of priorities. Since most are quite small (under 50 people), they tend to expect their CNC people to perform many tasks required to get and keep their CNC machines running. It is not uncommon for the person operating a CNC machine to program, set up, verify the program and run every workpiece in the lot. Since they tend to specialize in specific machining operations, job shops often have simpler CNC environments made up of but a few different machine types.

Tooling producing companies specialize in the manufacturing of tooling needed for all forms of production machinery. Die shops, mold shops and companies that produce cutting tools and fixturing are among the tooling producing companies. Like job shops, since tooling producing companies tend to specialize in a certain kind of tooling, they commonly have simple CNC environments made up of only a few different machine types. Also like job shops, they tend to expect their people to perform many CNC related tasks. Many do not place near the emphasis on machine up-time as job shops and product producing companies. It is not uncommon to see expensive CNC machines sitting idle for days if they are not currently required.

Prototype producing companies relieve product producing companies of the need to permanently staff a research and development department to make the prototype component workpieces and assemblies needed to test a new product design. For this reason, more and more companies are specializing in the production of prototypes.

CNC Simulators provide safe training environment

Providing realistic operation, part programming, and maintenance environment, NC Guide and NCGuidePro can simulate lathes, machining centers, and compound applications. Operators, programmers, and maintenance personnel can repeatedly practice complex actions and develop Custom Macro B subprograms without risks to people or machine tool assets. Simulators also enable development of complex machine troubleshooting scenarios that are not feasible on real equipment.

Products Provide Authentic Simulation For Realistic Operations Training At A Lower Cost

CHARLOTTESVILLE, VA, JUNE 12, 2007 GE Fanuc Automation, a unit of GE Industrial, today announced two new products: NC Guide and NCGuidePro CNC Simulators for authentic GE Fanuc or FANUC CNC simulation. The new units provide a realistic operation, part programming and maintenance environment at a fraction of the cost of using a real CNC hardware or a production machine tool, therefore lowering training costs.

"The key to unlocking the full potential of operators, programmers and maintenance engineers lies in a company's ability to train them to use the many productivity tools incorporated into the equipment they have purchased," said Tomoake Ishibe, Executive Vice President, GE Fanuc Automation. "Using actual CNC equipment or machine tools to deliver the hands-on experience that is vital to acquiring and demonstrating competence is often too expensive both in investment and lost production costs."

NC Guide and NCGuidePro can simulate a wide range of CNC configurations, including lathes, machining centers and compound applications. Multiple display and keyboard configurations can be selected and saved to match each of the CNCs being used in an organization.

As a training environment the NCGuide and NCGuidePro provide:

o Enhanced comprehension and increased speed of development by performing hands-on exercises in a ergonomically-friendly office or training-room environment;

o Increased safety and productivity by allowing operators, programmers and maintenance personnel to repeatedly practice complex actions and develop Custom Macro B subprograms without risks to people or machine tool assets;

o Reduced training equipment cost by emulating multiple CNC and machine combinations using the Machine Composition setting tool, the Option Setting tool, keyboard and screen size selections, and actual CNC parameter settings, and by integrating custom screens developed and provided by the machine tool builder;

o Expanded training opportunities for more employees and reduced testing bottlenecks by allowing distributed access to the CNC simulator using a 10, 20 or 30-seat concurrent-user network license;

o Development of complex machine troubleshooting scenarios that are not feasible on real equipment by using the machine I/O signal simulation ladders and I/O operation panel and

o Increased productivity by allowing users to attain "expert" level through repeated practice on the simulator before running the actual equipment;

"The fact that the complete CNC environment can now be simulated in a single, affordable product is a great asset to the industry," said Ishibe. "In addition, the ability to add the machine tool builder custom screens and operator panel makes this a very useful distributor training tool. And, the concurrent-user network licensing makes it very affordable for larger companies to allow of their resources access."

GE Fanuc is launching this product at MD&M East medical design and manufacturing show. NCGuide and NCGuidePro are available now. Click on www.gefanuc.com/cnc for more information.

About GE Fanuc Automation

GE Fanuc Automation, a joint venture between General Electric (NYSE:GE) and FANUC LTD of Japan, delivers automation hardware and software designed to help users reduce costs, increase efficiency and enhance profitability.

With solutions and services for virtually every industrial segment, GE Fanuc Automation provides a diverse array of capabilities and products, including controllers, embedded systems, advanced software, motion control, CNCs, operator interfaces, industrial computers, and lasers. Headquartered in Charlottesville, VA, GE Fanuc Automation is a part of GE Industrial and combines the diverse global strengths of the GE family with the local presence customers need to design, develop and maintain their automation investments.

For more information, visit www.gefanuc.com or contact: GE Fanuc Information Center, P.O. Box 8106, Charlottesville, VA 22906, Phone: (800) GE FANUC (800-433-2682), Fax: 434-978-5205, e-mail: gefanuc@gefanuc.com.

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Finding qualified people for CNC - computer numerical control

Mike Lynch

In many of the CNC courses I teach, one question keeps coming up. "How do I find qualified people to work in the shop?" Since most of my students are at least partially responsible for the finding, hiring, and training of people for their CNC departments, they are commonly faced with the problem of locating qualified applicants. Though there are many factors that contribute to how easy it will be to find good people (your company location, how close you are to technical schools, the manufacturing base in your area, the wage you are willing to pay, and so on), this brief article will give a few suggestions as to where you can begin your search.

Employee referrals - One of your best sources for finding new people is to encourage your current staff to help. Possibly someone in your company has a relative, friend, or acquaintance that has the qualifications you seek. Many companies even offer a reward to employees that make successful referrals. Employees hired through employee referrals usually work out quite well since they not only feel the need to satisfy their new employer, but also to make the employee making the referral look good.

Local newspaper want-ads - Depending upon the job market in your area, your response to want-ads may meet with mixed results. While they almost always render some applicants, it can be difficult to adequately screen these applicants without holding an interview. You may find that many of these applicants simply do not have the qualifications you seek. For this reason, we recommend using some kind of proficiency test to ensure that applicants have the CNC experience they claim to have. This test can be given at the time the applicant fills out an application. Of course, you'll only schedule interviews with those applicants that score highest on the proficiency test (more on how you can attain a sample proficiency test later).

Regional newspaper want-ads - Depending upon the size of your community, you may wish to enlarge your search area by including ads in the newspapers of larger cities in your area. Trade journals - Many trade journals (including Modern Machine Shop's Business Opportunities) offer a classified ad section in which you can place a reasonably priced want-ad. Since this will give your ad national (even international) coverage, you may wish to use this avenue only when hiring higher level people.

Temporary services and employment agencies - There may be employment services available in your area that cater specifically to the manufacturing sector. Good ones will provide screening of applicants (based on your requirements) and will work for a small percentage of the new-hire's wage. Temporary services provide the additional benefit of a prolonged evaluation period prior to actually hiring the person to work for your company.

Technical schools in your area - One of the best ways of handling your long term CNC hiring problems is to work closely with the technical schools in your area. While students completing the school's standard CNC curriculum may have the qualifications you need, many technical schools will work closely with local industry to fine tune their programs to specifically suit the needs of manufacturing companies in the area they serve. In fact, some will even custom tailor in-plant training for your current employees as well as new-hires. In this manner, you can reap many of the benefits of an apprenticeship program for a very small investment.

Sales people that visit your company - Another excellent source for finding people is the group of sales people that call on your company. Machine tool and cutting tool sales people, for example, commonly call on many companies in your immediate area. They often know who is hiring and who is laying-off. Additionally, they may know of high level people who are unhappy in their current position. Since all sales people are highly motivated to satisfy all needs of their customers, most will be willing to share this information if you simply ask.

More on the proficiency test - As stated earlier, you can use this test to determine how much CNC expertise people really have. Since your want ads will be specific enough to relate precisely what you want in the new hire, anyone applying is indirectly saying they have the necessary skills. This test will prove them right or wrong. Unfortunately, space does not permit us to include the entire four page test in this short column. To receive the test, simply request it from CNC Concepts, Inc. at the address given under the CNC Tech Talk heading.

As you decide whether to use this test, keep in mind that proficiency is but one of three important attributes a new hire should possess. Of equal or greater importance are motivation and aptitude. These attributes will ensure that the new hire will overcome any problems with proficiency. Additionally, your screening may determine that there are currently no qualified applicants in your search area. In this case, you will either have to expand your search area or be prepared to train new people after hiring.

CNC Router Machine

By Peter Vermeeren

The CNC router machine cuts in three directions at once. The precision of the router's cutting relies on the design software, software that provides a two-fold advantage to the router operator.

To begin with, the CAD software gives the operator of the CNC router machine the ability to create the design that will be cut into the solid plate.

After the operator creates the design, that same operator relies on the computer to send the proper operating instructions. The instructions from the software send signals to the router motor drive. These signals, termed tool path files, allow the motor controls to direct the precise motion of the router drive system.

The router bits perform the cutting of the CNC router machine. These bits are similar to drill bits. As mentioned above, the cutting can proceed along three different axes simultaneously.

The CNC controls cause the movements of the drill bits to take place in small and precise increments. The cutting along the x-axis moves from front to back. The cutting along the y-axis moves from left to right. The cutting along the z-axis moves up and down. The ability of the CNC router machine to move in 3 directions at once leads to the creation of interesting patterns and shapes.

The use of a CNC router machine guarantees savings in time and money. The CNC router machine produces each of its elaborately shaped products in a very small amount of time. In addition, the CNC router machine eliminates the need for an employee to stand at the router. A computer controls the operation of the router. Either the computer linked to the router can stand adjacent to the manufacturing devices, or it can sit at the desktop of the operator.

In other words, the operator of the CNC router machine can sit at his or her desk and direct the movement of the device that holds the router bits. The operator maintains control of this device, a machine part that is called a gantry.

The benefits of a CNC router machine increase steadily, spurred in large part by the increasing need for the manufacture of prototypes. Prototypes are test versions of a product. The creation of prototypes provides the manufacturer with a way to detect those places where an error in production could occur.

The precision of the router allows the operator to detect the scale of any possible manufacturing error. The computer can inspect a prototype and then alert the operator to the precise degree of expected changes in the routed product. The benefits of this precision are magnified by the potential for offline simulation of manufacturing processes. Without access to such precision, the manufacturer would not be able to use the creation of prototypes by the CNC router machine. Thanks to the precision of the router, the manufacturer can use the prototype to plan the needed strategy for an efficient full-scale production.

The CNC router machine enables manufactures to utilize the latest technologies in order to achieve their business needs more effectively. More information about CNC machines can be found here: CNC Woodworking Machine - CNC Grinding Machine- Kamikaze News and Articles

Article Source: http://EzineArticles.com/?expert=Peter_Vermeeren

http://EzineArticles.com/?CNC-Router-Machine&id=176086

The Mini CNC Machine

By Peter Vermeeren

The mini CNC machine gives the manufacturer a way to reduce cycle time. The mini CNC machine helps the manufacturer to avoid a long void between the end of one operation and the start of the next operation. The manufacturer who decides to purchase a mini CNC machine has chosen to apply the principles of cycle time to the area of production machinery.

The nature of the mini CNC machine creates three ways by which miniaturization can pave the way for cycle time reduction. This article will list three ways by which a manufacturer can reduce cycle time. It will also provide details concerning how the mini CNC machine permits the manufacturer to apply the principles of cycle time reduction to the operation of the mini CNC machine, and ultimately to the process of machine production.

The effort to reduce the manufacturers cycle time begins with an attempt to minimize the amount of time that operators spend loading and unloading various materials. The operator of a CNC machine will work more efficiently if he or she is able to minimize the workplace loading and unloading. This minimization is achieved through use of the mini CNC machine.

The operator of the mini CNC machine can save time by using large bed sizes and a small footprint. The operator of a mini CNC machine will save money by loading into the machine a wide piece of material and then limiting each process (cutting, engraving, routing, and drilling) to a small footprint.

The operator of a CNC-based piece of equipment can reduce cycle time by reducing the tool maintenance time. Such a reduction is made possible by the mini CNC machine. The small size of the miniaturized machines facilitates the creation of multiple design options. The large number of options leads to creation of a generous number of spare parts. Meanwhile the surplus of spare parts guarantees the ready replacement of any malfunctioning parts.

The operator of a mini CNC machine also reduces cycle time by decreasing the program execution time. The clamping of small elements to the mini CNC machine and the automation of the tiny machine parts leads to a lowering of operator intervention. Whenever operators can afford to devote less time to matching the quality of a previous result, then the manufacturer saves money.

It thus becomes obvious that the characteristics of the mini CNC machine guarantee the application by the operator of the principles of cycle time. Three aspects of any CNC program fall under the control of the product manufacturer.

1) The time required for workplace equipment to accomplish the loading and unloading of the material that requires a transformation (a cutting, drilling, routing or engraving),

2) The length of the program execution time,

3) The length of the tool maintenance time.

The ability of a mini CNC machine to substantially alter any of the above three aspects could lead to a reduction in cycle time. A reduction in cycle time could improve performance of the process machinery.

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http://EzineArticles.com/?The-Mini-CNC-Machine&id=121438

What is a CNC Router?

By Eric B. Slarkowski

What is a CNC router? This machine is used to cut wood, plastic or metal and is generally used for routing out letters for signs, etc. Besides routing and signage, these machines can act as engraving machines, so you can get a lot of usage from one machine.

Many small fabricating shops, and even individuals are finding the accuracy and versatility of a CNC router very useful. As used equipment becomes available, more and more will be in demand since the price is lower for used equipment.

But they are still an expensive addition to the home shop, and plans to make your own have now become available in sizes as small as 15X15 to 50X60. The use of the machine would determine the size. A CNC router allows a worker to create many projects that would be very time consuming and sometimes almost impossible to do otherwise. Cutting a complicated design into wood or even putting inlays into it are difficult for even the most skilled of carpenters, but with a CNC machine, these are done easily and accurately.

This makes CNC routers ideal for furniture making. The software for the machine allows you to design patterns or to do signs, once you know the software, and learning the software is not difficult. The smaller machines, typically for the home shop worker, only require 120 voltage and can therefore be run on household current. These smaller table top machines only require 1 or 2 HP motors and are within the range of a hobbyist. A large machine can cost upwards of $20,000 while these smaller ones are about $7,000. Used machines are usually half the price of new ones, so for an investment of $3500, a home shop can have a very versatile machine. If someone were interested in making furniture for sale, it would pay for itself in no time.

A used CNC router therefore is quite a bargain. At half the cost of a new one, it is a very attractive option. Just make sure you shop around and determine the best machine for the type of machine work you will be doing. The used machines are older, and therefore not as fast as the newer machines. For the home shop this may not be as important an issue as price.

Used machines are available that have been rebuilt and these are a very good value as a rule. After a thorough inspection any worn or damaged parts of the machine are replaced and the result is a machine that is so good that many of the companies who do this are able to offer a warranty on the machine. It is also important to have support available from the company.

This will allow you to get installation instructions, and may also entitle you to free training on the software. If you are buying and using such a machine for the first time, this may be very important. You will want to make sure you are dealing with a company that can give you help and support in case you need it. A manual is important to have, but it may not answer all of your questions.

Eric Slarkowski works primarily for http://www.insidewoodworking.com , an online publication with information about cnc machines , wood router and other topics. His publications on cnc router are published on http://www.insidewoodworking.com and other web pages.

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http://EzineArticles.com/?What-is-a-CNC-Router?&id=444215

CNC Cutting Machine

By Peter Vermeeren

A good quality CNC cutting machine has a cutting table that covers the area bounded by a length of four feet and a width of eight feet. A quality table can handle satisfactorily a standard 4 x 8 plate of metal, wood, plastic, glass, or stone. A table that lacks a sufficient length or width will make it necessary for the operator to repeatedly reposition the plate.

Operators of the CNC cutting machine refer to such repositioning as indexing.

A good basic CNC cutting machine does both plasma and oxyfuel cutting. Refinements on a basic cutting machine might provide it with the ability to perform other functions, functions such as:

-spotting holes for drilling

-drilling aluminum

-cutting a shape in the sides or end of tubing

-routing wooden shapes

Other modifications on a CNC cutting machine might be directed at installation of the equipment for laser or water jet cutting.

The selection of a CNC cutting machine will be primarily determined by the nature of cutting that will be performed by the machine operator. For some operations, it will be necessary to do only straight cutting. For other operations, the cutting machine must perform bevel cutting. Bevel cutting allows the operator to trim, reduce, shave, and pare the material in the plate.

Both types of cutting will subject the CNC cutting machine to a fair amount of wear and tear. The manufacturer therefore needs to purchase a machine with adequate customer support. Such support should include the availability of spare parts. An absence of spare parts could require that the electronics of the CNC cutting machine undergo a retrofitting.

A need for retrofitting would deprive the operator of important production time. The need for retrofitting would diminish the quantity of goods that could be sold to the consumer. The need for retrofitting leads to a decrease in the amount of time that the operator will be spending at the CNC cutting machine. That is why the availability of spare parts for a malfunctioning CNC cutting machine remains one of the two chief concerns of the manufacturer. A second prime concern is the size of the cutting table.

The operator of a CNC cutting machine that needs to spend a large percent of time indexing will not have much time to spend on the actual cutting. Hence, the manufacturer will have much less product. Fewer products from the manufacturing facility translate into fewer products on the shelf. Consequently, the need for operators to spend time indexing can prove a detriment to the company's bottom line. A good sales volume reflects the well-planned purchase of a CNC cutting machine.

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http://EzineArticles.com/?CNC-Cutting-Machine&id=116473

CNC Router Buying Guide

By Kenneth Morris

CNC router tables are used for cutting wood, plastic, or metal, depending on the machine. They can be used for sign making or general routing jobs. The router doubles as engraving equipment. This versatility allows you to get more from one machine.

The interest in these machines for home use and small shops has grown rapidly in recent years. As people become aware of the accuracy and versatility, this demand will surely increase.

Many people are choosing used equipment in an effort to save money, while owning this machinery.

Although they are still expensive for most users, there are plans available on the internet to make your own table. These save money and allow you to choose sizes from 15 by 15 to 50 by 60 inches, according to your needs.

Uses of a CNC Router

With cnc routers, you can do projects that would otherwise take too much time or be too difficult to accomplish. This includes cutting elaborate designs and creating metal inlays in wood.

Complex designs come out smooth and accurate. You can do things that you could never do by hand.

These machines are great for furniture making. You will get professional results every time. The software allows you to program the depth per pass for even better results. You can engrave anything from a large sign to very small lettering. These machines are versatile and easy to use, once you've been trained on the software.

Smaller machines work on 120 voltage and can be run on typical household current. These are the best choice for the home workshop. The motors are generally either one or two horsepower.

These smaller, table top models are more affordable, costing about $7000 new, as opposed to $20,000 for a larger machine. A used machine is even more affordable, costing about $3500. This is still very expensive, but can be cost effective if you are making furniture that you will sell.

Buying a Used CNC Router

Purchasing a used cnc router is a great value for the money. You can save 50% or more compared to the cost of a new machine. Take your time when shopping. Do some research to find the best machine for your needs. Keep in mind that a used machine will probably not be as fast as brand new. However, in a small shop, this may not matter.

Many used machines have been reconditioned. The machine is inspected and any damaged parts are replaced. Ask about the work that was done to your router. Find out what was repaired or replaced. Ask about a warranty. Many come with a one year warranty, which is a big plus.

Find out about the support that is offered by the company. Many will offer help with installation and train you for using the software. This is important if you've never used one before.

Look for professional advice and support. Whenever possible, choose a dealer that offers on going support. Make sure to get a manual for your router. You will need the information contained in the manual for operation and maintenance.

Ken Morris distributes lots of information to http://www.inside-woodworking.com a website with resources. The writer is writing on subjects such as cnc router.

Article Source: http://EzineArticles.com/?expert=Kenneth_Morris

http://EzineArticles.com/?CNC-Router-Buying-Guide&id=156986

Different Types of Metal Lathes

By John Russel

A metal lathe is general description for a hard machine device made to remove material for a workpiece, by the way of a cutting tool. They were intentionally intended to machine metals; any how, with the start of plastics and other substances, and with their inherent versatility, they are used in a huge varieties of applications, and a broad range of materials.

You can find might variations of lathes within the metalworking field. You will feel that some variations are not really that obvious, and other are more to a niche area. For example, a centering lathe is a double head machine where the work stays fixed and the heads move towards the workpiece and machines a center drill hole in every end. The appearing workpiece might then be used between centers for another operation. The usage of the term metal lathe might as well measured to some extent outdated these days, plastics and other composite materials are in huge use and with appropriate modifications, the same principles and methods might further be applied to their workholding machining as used for metal.

Center lathe

A center lathe is other called engine lathe it might be considered the basis for the metal lathe and is the kind of most normally used by the general machinist or hobbyist.

Capstan lathe

The fresh name for a capstan lathe used in workholding industry is a ram-style turret lathe. A capstan lathe is a manufacturing machine, which combines the features of the basic lathe along with a capstan style tailstock.

Turret lathe

A turret lathe is a manufacturing machine, which to all appearances is alike as the capstan, any how the turret slides straightly on the bed rather than being fixed.

Combination lathe

A combination lathe might introduce drilling or milling operations into the plan of the lathe. These machines uses the carriage and topslide as the x and y axis of the machine.

CNC lathe

CNC lathes are now fast replacing the older production lathes such as multispindle, etc) due to their simple method of setting and operation. They are intended to use modern carbide tooling and fully uses modern processes.

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Wire EDM Machines: An Overview

By Josh Riverside

While there are many brands and models of Wire EDM machines available today, the three most prominent manufacturers are Elox, Japax, and Mitsubishi.

While each of these companies manufacture similar products, there will always be some varying features such as the User-interface with the CNC controller, the numbers of wires, be it a 4-axis or 5-axis Wire EDM machine, type of electrical current (AC vs. DC), and the gauges of wires that can be used. Another very big difference will be the size of the tank in which the manufacturing is accomplished.

Some examples of specifications for one model from each of these companies are:

Elox Fanuc Model M - (the Fanuc indicating the type of CNC controller that is a component of the Elox Wire EDM) has an X-axis path of 20”, a Y-axis path of 14”, and a Z-axis path of 10”

Japax Wire EDM Model LDM-S - has a Y-axis path 13.8” and capable of machining a work piece with the measurements of 15.7” x 19.7” x 5.9” and a table that moves 7.9” x 13.8”

Mitsubishi Wire EDM Model DWC 110 H-1 - has an X-axis of 12”, a Y-axis of 18”, and a Z-axis of 10”

Each of these models only represents one of many different models offered by their respective manufacturer. Variations will be observed from model to model with some differences including the distance that each axis wire can travel, the size of product that can be manufactured and the CNC controller.

When selecting a wire EDM machine, one must take into consideration the product that will be manufactured, the degrees of tolerance and variances that are allowed, how detailed the cut will be, and not least importantly, the funds available for purchasing the wire EDM.

While Elox, Japax and Mitsubishi are three prominent manufacturers of wire EDM machines, remember that there are also other manufactures of wire EDM machines.

Wire EDM Info provides detailed information about wire EDM machines, machining, heat affected zone, technology and more. Wire EDM Info is the sister site of Metal Stamping Web.

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http://EzineArticles.com/?Wire-EDM-Machines:--An-Overview&id=66869

Water Jet Machining

By Ross Bainbridge

Water jet machining technology involves the use of high-pressure water jets for cutting parts out of different types of material such as soft rubber, foam, extremely thin stuff such as foil, carpet, paper, cardboard, soft gasket material, candy bars, diapers, and soft wood. Its use is limited, as it cannot cut harder materials such as metals, glass, and hard wood.

The water used in water jet machining systems is pressurized between twenty and sixty thousand pounds per square inch (PSI) depending on the type of material being cut. The highly pressurized water is released through a tiny hole called "jewel" which is typically 0.007" to 0.015" in diameter, creating a very high velocity beam of water capable of cutting soft materials.

Water jet machining process is controlled with the help of computer numeric control (CNC) software that guides the water jet nozzle according to the lines and arcs of a computer aided design (CAD) drawing. The CAD drawing is a three dimensional (3D) graphic representation of parts that are to be fabricated. The technology has many advantages such as easy to use components, quick assembly process, reduced turn around time on the machine, complementariness to other machining techniques, and cutting without heating the material.

One major drawback of water jet machining is that the nozzle often gets blocked due to dust particles that might be present in the water. The other problem with water jet assemblies is that they are prone to constant wear and tear caused due to high-pressure water flowing out of tiny nozzles.

These drawbacks are however ignored, as water jets are the most environment friendly and safe machining technology used in the present era. It does not produce fine particles that might get into the human body and cause fatal diseases such as cancer. Particles if any are swept away with the strong force of the water jet and do not pollute the surrounding environment.

Machining provides detailed information on Machining, CNC Machining, Casting Molding Machining, Precision Machining and more. Machining is affiliated with Automotive Machine Shop Services.

Article Source: http://EzineArticles.com/?expert=Ross_Bainbridge

http://EzineArticles.com/?Water-Jet-Machining&id=429865

What Kind of Plastic Foams Are Best for Your Needs

By Ispas Marin

Nowadays, when you are thinking about accomplishing your hobbies generally consisting of model building, you couldn't have missed the basic materials for it, which are called foam plastics. They can be used even in boat modeling, yet there are many things you should not forget when thinking about using them because there are several types, each one having different characteristics.

We can name three types of these foam plastics: the rigid Styrofoam, the rigid polyurethane foam and the beaded Styrofoam. The rigid Styrofoam and the rigid polyurethane foam have similar properties and can be given many shapes, while the beaded Styrofoam can be used only to shape angled and squared forms. You may recognize it whenever you buy an electrical device as this comes covered in the third type of the foam plastics: the beaded Styrofoam.

The second type of the foam plastics, the rigid polyurethane is a material of a light-brown color; it is alike the Rigid Styrofoam ,yet there are two main differences between them: this one will not dissolve whenever coated with polyester resin, and the second difference is that it is impossible to be cut with a hot wire cutter(a specific tool used by modelers in their

work).

The first type of foam plastics, the rigid Styrofoam presents the opposite characteristics of the rigid polyurethane: it can easily be dissolved when coated with polyester resin and a hot wire cutter can be used to give different forms of this material. Moreover, the beaded Styrofoam cannot be altered by means of carving but a hot wire cutter can be used to obtain carved shapes.

There were several doubts regarding the way you find these materials and the purpose of the article is also to clarify this aspect: the rigid polyurethane is generally sold in panels of 4X8 foot sheets; this is the case of the beaded Styrofoam too. The Rigid Styrofoam can be found in pink and blue(the pink type is less dense than the blue one and easier to carve with a hot wire cutter), its thickness being 1 or 2 inches.

In what concerns the price of the materials, you should know that Beaded Styrofoam is the cheapest as its properties are limited, while the Beaded Styrofoam is the most expensive(can be found only at commercial plastic suppliers). The rigid Styrofoam has a medium price as it combines the properties of the other two foam plastics: it can be sanded, carved, sawed or cut with the hot wire cutter mentioned above. This tool is similar to a scroll saw consisting of heated nichrome wire replacing the saw blade, enabling you to cut in any direction.

All in all, the three materials come in hand when performing your task: both advantageous and easy to work with, these foam plastics represent the key elements of model-building. In addition, the hot wire cutter is an advantage to your work as it can easily deal with the foam plastics and it is accessible to everyone. This way, the satisfaction of your work is guaranteed.

For quality hot wire foam cutters, architectural foam, foam coatings, eps foam cutter, styrofoam hotwire manufactured and supported in the U.S.A. just visit http://www.hotwiredirect.com

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http://EzineArticles.com/?What-Kind-of-Plastic-Foams-Are-Best-for-Your-Needs&id=71045

Challenges in Metal Cleaning for Tube and Pipe Benders

By Jamie Knapp

Tube benders experience more challenges when it comes to cleaning their product than most other metal formers. Tubes present a challenge for cleaning, due to the viscosity of the lubricant used to protect the metal during the bends as well as the variations in shapes, tube diameters and orifice orientation. By using antiquated aqueous dip tanks or fixtured spray impingement systems production will be slowed to a crawl by the inability to clean tubes in a standard aqueous wash process. Solvent cleaning systems are able to solve these problems in a quick and cost effective manner.

A closed-circuit, hermetically sealed, industrial washing system that uses solvent, is the ideal technology for applications where the aim is to achieve the highest possible, repeatable cleaning and drying results together with inexpensive operation. The thickest, hardest contaminants can be successfully removed during treatment in these systems. By utilizing a sequence of heated sprays, immersions, the application of ultrasonics during submersion and vapor rinsing sealed solvent systems clean tough parts effectively and efficiently. In addition, through the application of heated blowing cycles and vacuum drying, the parts leave the process chamber absolutely bone dry to the touch regardless of orientation within the system.

Washing with solvents such as Perchlorethylene is ideal for tube applications because perc is able to break the surface tension between soil and metal up to 6 times more effectively than heated water and alkaline soap. This allows the ultrasonic action applied to the solvent while in submersion to break that surface tension of contaminant on the part even more effectively and allow it to be rinsed away. Each cycle in the cleaning process takes place inside the same sealed chamber, where one or more baskets of tubes, loaded in any orientation that is convenient, have been loaded.

When the cycle begins, the door is closed and a spray impingement washing process is performed using hot solvent. The solvent is applied through moderate pressure spray jets directly onto the parts. This stage removes up to 90% of the soil from the parts. The soil laden solvent is drained from the process area while the continued spraying takes place and is delivered to a distilling device within the system, which boils the solvent into a vapor. The soil remains in the still for subsequent removal while the vapor is directed to a chiller which condenses the clean solvent into liquid for subsequent use.

This distillation process continues to occur throughout the entire operation of the equipment.

The second cycle involves complete submersion of tubes within the process chamber, during which ultrasonic mechanical action favors the detachment of the remaining contaminant from both the interior and exterior diameter of the tubes.

In the final stage of the cleaning cycle, direct vaporization is performed on the parts using solvent vapors inside the chamber. These vapors come from the still, but rather than being sent to the chiller for immediate condensation, they are directed to the process chamber for a final rinsing where they condense on the parts and cause removal of any remaining pollutants. Then the parts move to the drying stage, which allows for virtually total recovery of the solvent from the parts. Charcoal filters are necessary in some machines to ensure compliance with environmental regulations.

Heater cores, refrigeration tubes, cooling system tubing, exhaust manifolds or any other types of tubes can be more effectively cleaned and dried using a sealed solvent system than those systems that use soap and water. This is true mainly because soap and water systems cannot clean interior diameters adequately, but it is also a reality due to the inefficiencies of water based systems.

In sealed solvent systems the solvent comes to the process chamber therefore the parts do not need to be transported from one bath to the next for submersion. By effectively bringing the same, yet freshly cleaned solvent to the parts for each cycle, there is no concern of bath contamination nor is there any carryover from one bath to the next.

In fixtured indexing conveyor systems where nests hold each part in a particular orientation so the spray impingement can be directed down the throat of the tube, fixtures need to be made for each specific tube. Different tube designs require different nests to hold each individual tube in the proper orientation. This is necessary to allow not only for proper spray cleaning, but also for proper draining to facilitate adequate drying. When submersion is used, the surfactant package in the alkaline cleaner needs to be intense enough to release the lubricant that it can harm the tubes made of softer metals. There the issue becomes how to drain the water from inside the tubes prior tobasket of tubes move from one bath to the next for cleaning, rinsing and drying. When single piece flow is attempted, the differing fixture nests create change over time that fails to allow production rates to be maintained. In addition As demonstrated in these cases, solvent closed circuit cleaning systems are versatile and effective. They can be employed in many applications, including tube cleaning, with excellent results.

Midbrook Cleaning Systems is a minority owned provider of parts washer and parts cleaner systems, custom metal fabrications, CapSnap water bottling systems, and production cleaning services.

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Laser Machining

By Ross Bainbridge

Laser machining technology uses high intensity laser beams of varying widths for a variety of applications such as slotting, cutting, and creating holes. It can be used in fabrication of

different types of materials such as metals, plastics, vinyl, glass, marble, and graphite. Other materials that can be fabricated using laser machining include nylon, ceramics, carbon fiber, composites, soft rubber, and thin metal foils.

Laser machining systems are used in conjunction with computer numeric control (CNC), which makes it ideal for use with thin walled tubing, boasting beam widths down to .0005'. In this process, the machining operator uses computers to control machine tools for manufacturing complex and intricate parts in metal and other materials.

A laser machining process involves the use of conventional as well as fiber optic beam delivery systems, which allow precision positioning while cutting metal or other materials. It is used to cut burr-free parts that are required in a number of industries such as aerospace, automobile, shipping, and others. The process is fast, efficient, and can be repeated any number of times depending on production volumes. It is used to create grooves that are cut to a specific depth with one pass of a laser beam without severing any material from the work piece.

Laser machining is used for producing a knurled or roughened surface on hard materials such as metals and fragile materials such as ceramics and glass. The technology is also used for marking material surfaces. In the process a high intensity laser beam is passed through a stencil of a mirror and onto the area of the material or work piece that is being marked.

Research is underway to develop advanced laser machining techniques that will allow the production of microscopic devices for use in medical industry. This will help in fighting deadly diseases such as cancer in the near future.

Machining provides detailed information on Machining, CNC Machining, Casting Molding Machining, Precision Machining and more. Machining is affiliated with Automotive Machine Shop Services.

Article Source: http://EzineArticles.com/?expert=Ross_Bainbridge

http://EzineArticles.com/?Laser-Machining&id=429192

Wire EDM 101

By Josh Riverside

Wire EDM refers to wire electrical discharge machining. It uses a wire electrode that travels through the conductive work piece. The electrically charged wire is monitored by a Computer Numerically Controlled system or CNC.

Wire EDM removes a part of the material from the work piece, by spark erosion. In this process the wire never comes in contact with the work piece. The electrically charged wire leaves a path on the work piece, which is slightly larger than the wire itself.

The gap between the wire and the work piece generates high voltage electrical pulses. The high voltage and the controlled spark melt and vaporize a small part of the work piece. Each spark produces a temperature of 10000 C, where the energy turned out by the power supply decides the size of the spark penetration into the material.

Wire EDM are basically developed for the tool & die industry. The improvement in the cutting speed, reliability, unattended operation and accuracy is making it very popular in many industries, such as the aerospace, automotive, defense and electronics.

The dielectric fluid acts as an insulator and a flushing agent, during the cutting process. Further through the process of flushing, the dielectric fluid is emitted through the upper and lower heads of the machine. The pressurized fluid also helps in removing the eroded material produced by sparks.

Wire EDM promises high precision as it produces a profile accuracy of 0.00004'. It depends on the quality of the EDM and enables high finish standards obtaining surface finishes 8 micro inches.

The multiple work piece set- up and unattended operation saves a lot of time, which can be utilized on other job functions. The wire EDM system is very cost effective and can be operated at around $4 per hour, in normal cutting conditions.

Wire EDM provides detailed information on Wire EDM, Wire EDM Machining, Wire EDM Machines, Used Wire EDM and more. Wire EDM is affiliated with Shock And Vibration Testing.

Article Source: http://EzineArticles.com/?expert=Josh_Riverside

http://EzineArticles.com/?Wire-EDM-101&id=407713

Wire EDM Costs

By Josh Riverside

Wire EDM machine technology has progressed rapidly in recent times and a strategic investment in the technology can greatly enhance the accuracies and surface finishes, reducing cycle times.

The EDM machines are available in different brands with varying capacities and features. Often, investing in a wire EDM requires a huge capital and the cost varies. All leading companies in wire EDM manufacturing business have their websites. These websites provide detailed information of the different wire EDM machines manufactured by the companies. The prices can be accessed, by making an online request for a catalogue. A catalogue contains detailed information of the machines with the price and shipment details.

For a company with less capital, a used Wire EDM proves a convenient investment. Often used Wire EDM's are available in all models and brands and at reasonable rates. A1996 model of a submerged auto threaded wire EDM, equipped with 27.62' X-axis travel, 15,75' Y-axis travel and 15.75' Z-axis travel, would cost around $24,500.

A1988 model of a wire EDM machine featuring 9.82' X-axis travel, 5.89' Y-axis travel and 4.71' Z-axis travel, would cost around $22,000. A 1998 evolution 3- model wire EDM, equipped with 19.65' X-axis travel, 13.75' Y-axis travel and 9.82' Z-axis travel, would cost around $ 50,000.

Wire EDM has played a crucial role in growth of the manufacturing sector. The technology has been greatly improvised for attaining higher efficiency and to reduce the operational costs.

The latest wire EDM's are incredibly capable, but are approaching their practical limits in speed, accuracy and finish, reducing the scope of further improvisation. Many mold makers are opting for advanced machines such as the twin wire EDM machines because though these machines are costly, they are extremely efficient and very cost effective. They have enhanced the process of metal cutting and designing.

Wire EDM provides detailed information on Wire EDM, Wire EDM Machining, Wire EDM Machines, Used Wire EDM and more. Wire EDM is affiliated with Shock And Vibration Testing.

Article Source: http://EzineArticles.com/?expert=Josh_Riverside

http://EzineArticles.com/?Wire-EDM-Costs&id=407711

Used Wire EDM Machines

By Josh Riverside

The oscillating of the U.S. economy has provided many great deals for used wire EDM machines, which include all major and reputed brands. Primarily, before investing in a used Wire EDM it is essential to verify the integrity and reputation of the business. In the same vein, one must be sure that the company he is doing business with, is trustworthy. It is advisable to decide what product is to be manufactured, the quantity, size and capacity of the tank required and the details of the cuts required. Different machines allow different axis paths through which the wire can travel. It is advisable to purchase a wire EDM that would suit the specifications and requirements.

Prices of the wire EDM greatly varies, depending on the age, up keep and features. It is always good to check the maintenance records of the considered wire EDM and the last date of servicing. The person should also verify when the wires were last replaced. Many times the wires need to be replaced soon after the purchase of the wire EDM, which is very expensive for the purchaser. It is advisable to buy a wire EDM with recent replacements.

Used wire EDM are available in all leading brands and configurations, such as, 16' x 10' x 10', auto threaded and a chiller with submerged capacity. Even a 17.7X, 12.6Y, 6.4Z, auto thread, taper 3R tolling wire machine is available.

The businesses that have commenced with a limited capital find the used wire EDM's practical. Often it requires a lot of initial footwork in deciding the quality of the EDM, but if the company is trustworthy and the specifications are met, there is no harm in investing in the system. A little research goes a long way in determining and identifying a good deal.

Wire EDM provides detailed information on Wire EDM, Wire EDM Machining, Wire EDM Machines, Used Wire EDM and more. Wire EDM is affiliated with Shock And Vibration Testing.

Article Source: http://EzineArticles.com/?expert=Josh_Riverside

http://EzineArticles.com/?Used-Wire-EDM-Machines&id=407707

Wire EDM Supplies

By Josh Riverside

Wire electrical discharge machining has played a crucial role in development of the manufacturing sector. Since it is very popular even in the allied sectors, many companies have joined the league of manufacturing wire electrical discharge machining systems. Many entrepreneurs have chosen the supplies department.

Various kinds of supplies are needed for wire electrical discharge machining, such as de-ionizing resin and services. Good water quality is very essential for maximum productivity and consistent results from any wire EDM. A wide range of de-ionizing resin products are available for operators for the maintenance and modification of the de-ionizing systems on their machines. The range includes regenerated resins, virgin resins and a variety of accessories that are used to configure and support the systems. There are a number of other options are also available in resin systems, which are used to add to the capacity or upgrade an existing system. They are used to replace an existing system and to configure a system for new machine.

A large selection of EDM wires is available, with a choice of brands, type, diameter, spool size and spool weight, for almost all machines and their application. A complete line of economy brass wires is available for cost conscious operators. Though economical, these wires are consistent, clean and straight. Likewise, a range is available in high performance brass wires. These contain a higher percentage of zinc that promotes the cutting speed. Many other types of high performance coated EDM wires are developed for speed such as the D-Kut, Gamma-X, Gamma-Z, SZR, XI and Z-Kut. EDM wires are also available in copper, molybdenum and tungsten. An extensive choice is available in filtration products. Various kinds of filter cartridges are available with the reputed brands. A choice is also available in filter cleansing and disposal and filter systems.

Wire EDM provides detailed information on Wire EDM, Wire EDM Machining, Wire EDM Machines, Used Wire EDM and more. Wire EDM is affiliated with Shock And Vibration Testing.

Article Source: http://EzineArticles.com/?expert=Josh_Riverside

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An Introduction To Wire EDM

By Josh Riverside

EDM refers to wire electrical discharge machining. Wire electrical discharge machining or EDM is a metalworking process with the help of which a material is separated from a conductive work piece, by means of electrical erosion. The wire never comes in contact with the conductive work piece. The wire electrode leaves a path on the work piece, which is slightly larger than the wire. Most often a 0.010' wire is used which creates a 0.013' to 0.014' gap. The wire electrode once passed through the work piece cannot be reused.

Wire electrical discharge machining is mainly used to cut intricate shapes and designs into hard metals, which are otherwise difficult to form, mold or manipulate. It is most useful in the electronics and aerospace sectors for prototyping and manufacturing various parts. Most often, steel and titanium are processed with help of wire electrical-discharge machining.

Jewelry designers are using the system for cutting intricate shapes. Even artists working with metals find the machining very convenient and practical to use.

Many manufactures are profiting from the production of wire electrical discharge machining systems. There is a large selection available in EDM wires, providing a choice of optimum brands, typed, diameter, spool size and spool weight for almost any machine and application.

Joseph Priestly invented the Wire EDM in 1770, but it was very imprecise and prone to failures in the initial stage. It soon became popular and is now a key component in the manufacture of injection molds and metal stamping dies. The purchase of a new wire electrical discharge machining system requires a huge capital. Many invest in used wire EDM's, which are available in all types.

There are people who have ventured to create the complex systems at home too. This ensures them the ability to be self- employed.

Wire EDM provides detailed information on Wire EDM, Wire EDM Machining, Wire EDM Machines, Used Wire EDM and more. Wire EDM is affiliated with Shock And Vibration Testing.

Article Source: http://EzineArticles.com/?expert=Josh_Riverside

http://EzineArticles.com/?An-Introduction-To-Wire-EDM&id=407706

What is Wire EDM?

By Josh Riverside

What exactly is wire electrical discharge machining, also referred to as Wire EDM? Wire EDM is the process whereby hard metals, those that previously could not be machined or manipulated by traditional methods, could now be machined, manipulated and designed by electrical charges in order to cut away the unwanted metal into heretofore unattainable shapes and designs with greater tolerances and precision.

The one limiting requirement for wire EDM is that the material must be electrically conductive. An example of traditional machining is putting a metal pipe on a lathe and turning it while cutting it with a carbide tip or some other similar cutting tool; in much the same way that wood is lathe-cut. While this is a pretty elementary example and shows how wide variances can be from product to product, wire EDM can allow companies to now manufacture much more elaborate items from metals heretofore incapable of being worked, even cutting shapes into 3D and extremely intricate Jewelry designs.

There are two general types of Electrical Discharge Machining, ram EDM and wire EDM. For the scope of this document, we will only discuss the latter – wire EDM.

Observed originally by Joseph Priestly in 1770, electrical discharge machining had its start but was very imprecise and prone to failures. However, it was not until it was fully developed and commercially available in the mid-1970s that wire EDM began its rapid rise and came into its own in the 1980s when it migrated into a machine tool and became much more widely available and attractive over the traditional machining processes. In attempts to work with metals that were harder and to increase the precision of the cut, wire EDM allows just for that ability and precision.

Some of the types of industries that benefit from utilizing wire EDM include jewelry designers, metal shops, automotive manufacturing plants, artists who work with metals, as well as plants that specialize in wire EDM to supply parts to various industries, to name a few benefactors.

Because of wire EDM, we have automobiles whose engines are much more efficient as well as appliances that long surpass the life expectancy of those built before the advent of wire EDM.

Because of wire EDM, we are much more capable of producing durable goods while best utilizing raw natural resources, which is good for everyone.

Wire EDM Info provides detailed information about wire EDM machines, machining, heat affected zone, technology and more. Wire EDM Info is the sister site of Metal Stamping Web.

Article Source: http://EzineArticles.com/?expert=Josh_Riverside

http://EzineArticles.com/?What-is-Wire-EDM?&id=66867

Homemade Wire EDM Machines

By Josh Riverside

EDM in an engineering term referring to electrical discharge machining. Wire electrical discharge machining or EDM is a metalworking process with help of which a material is separated from a conductive work piece, by means of electrical erosion. In this process, the wire never comes in contact with the conductive work piece. The wire electrode leaves a path on the work piece, which is slightly larger than the wire. Most often a 0.010' wire is used, which creates a 0.013' to 0.014' gap. The wire electrode once passed through the work piece cannot be reused.

Wire electrical discharge machining is a complicated assembly, but efforts have been made to build this system at home. While building a wire electrical discharge machining system at home the biggest problem is breaking the wire. Often engineers use the full power of 70 volts, which the wire cannot withstand. If a VARIAC is used, it can vary the alternate current output,

producing varying voltages. It can also control and vary the direct current out put. If the voltage is maintained at 55Volts, a spark is produced without breaking the wire electrodes.

In the home made wire electrical discharge machining system, the reducing gear doubles as an encoder and drills 50 holes of equal space. Mainly a ½ - 20 threaded rod acts like a feed screw. The counts go to a PLC, which is outfitted with starts, reverse and stop functions. It is equipped with an appropriate motor, which enables easy rectangular movement. The homemade wire electrical discharge machining system is also supplemented with manual switches for free burning.

The homemade systems can only be used for working on small work pieces. However, the developments have been encouraging and ensure an ongoing process that will definitely create a market for the home built systems.

Wire EDM provides detailed information on Wire EDM, Wire EDM Machining, Wire EDM Machines, Used Wire EDM and more. Wire EDM is affiliated with Shock And Vibration Testing.

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http://EzineArticles.com/?Homemade-Wire-EDM-Machines&id=407705

Wire EDM FAQs

By Josh Riverside

Wire electrical discharge machining is a method of cutting conductive materials with a traveling wire that separates material in a controlled manner. The wire used is electrically charged and actually arcs with the part to be cut.

The purchase of a wire electrical discharge machining system is a heavy investment and it should be made only after all queries are answered. The initial queries regarding the wire electrical discharge machining are concerned with its working. The system uses a thin brass wire as an electrode. This is controlled on a computer and runs close to the part to be cut, without touching it. The small gap produces sparks of 10000 C that vaporize the small particles of the piece, as the wire moves.

Simultaneously, the dielectric fluid flushes away the disintegrated particles, enabling the wire to advance further. The movements of the wire are operated with help of a computer program. The other query that comes up is concerned with the materials that can be cut using wire electrical discharge machining. The system works on the principle of electricity and virtually any conductive metal can be processed.

It is advisable to confirm with the dealer if it is required to pay for special industrial tooling or fixtures, when using wire EDM to cut the pieces. Some enquire about the kind of tolerance that can be expected while using the wire electrical discharge machining.

Similarly, queries do come up about the finishing of the output, after it is worked upon and machined, using the wire electrical discharge machining. The queries may also include the doubts regarding the range of finishes that can be achieved for typical surfaces. There are queries on the specification and capacity of the system and its ability to assist in production and manufacturing of the prototype parts.

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A Guide To Wire EDM

By Josh Riverside

Wire EDM has become very popular in the manufacturing industry and many workshops are emerging. In order to gain larger and more complex wire jobs, modular work piece fixtures play a crucial role.

Many mold makers have realized that the trick of winning the wired game lies in being different from competitors. They have realized that it is not about doing intricate work and cutting large pieces, which even their competitors do, but it is more important to figure out the different processes and practices, which can provide with a profitable niche. More owners are paying premiums for advanced machines, as they know that the returns would surely pay in the long run.

Wire EDM has an unusual hollow center section that allows the head to guide the wire through the cuts. This is very beneficial, as the cutting wire cannot reach the portion of the work piece that is in contact with the table. This means that the work piece has to be flipped off again for the second time, to cut the previously inaccessible area. Incase of large and long parts, there is no alternative but to clamp the work piece directly on the table. Smaller components, on other hand can be worked upon modular pallet fixturing systems, which produce good results. The cutting time for each machine is highly increased as the quick-change system offers a way to change the function in a matter of seconds.

Proper gripping of the work piece is very crucial for providing efficiency and pace in cutting .The decision whether to grip the work piece vertically or horizontally largely depends on the geometry involved, profile to be cut and the amount of extra stock that has been provided by the mold maker. The system makes the process very cost effective and precise.

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http://EzineArticles.com/?A-Guide-To-Wire-EDM&id=407710

Reducing Wire EDM Costs

By Josh Riverside

Wire EDM technology plays an important part in the competitive manufacturing sector. A strategic investment in wire EDM machinery and technology can greatly enhance the accuracies and surface finishes, reducing cycle times.

Many mold makers are opting for this more advanced application. Most of them are manufacturing parts, which cannot be made in low-cost labor countries. The twin wire technology assists greatly in manufacturing these intricate parts and proves to be of great help in reducing the operating cost and increasing autonomy. The twin wire technology enables the user to roughly cut the work piece with a larger diameter wire and then automatically switch to the smaller diameter wire. The twin wire technology is highly recommended for making intricate parts.

Similarly, with the use of the advanced filtration process, operating cost can be reduced significantly. The use of an integrated filter capacity and new filter designs reduces the downtime of the wire EDM and enables it to run longer, unattended. This improvisation is very important for high-speed cutting generators that are capable of manufacturing more parts per hour.

The latest development is the five-axis wire EDM, which is also called the turn and burn technology. It has opened up many new avenues for designing complex 3-D mold components.

The latest wire EDM s are capable of accomplishing the limits desired in speed, accuracy and finish, thus reducing the scope for further improvisation. Currently mold makers are focusing on finding better ways to make their existing equipment more efficient. Most of them are opting to run one machine in a three-shift workday, instead of running three machines on a one-shift working day. Simultaneously, with the integration of robotic tools and work changers that allow an unattended, lights-out operation of the additional two shifts, a significant increase in fixed overheads is achieved.

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Where To Buy Wire EDM Machines

By Josh Riverside

Wire EDM machines have become very popular in the manufacturing sector and have been very significant in the growth of the tooling and dying industry. A number of manufactures, mainly from China and Taiwan, have come up with quality wire EDM machines.

All these leading companies have hosted their websites on the Internet, which provide with all information on the company products. The websites give detailed information of the products, including the features, specification and cost. The information often includes tips for operators that can be helpful in improving efficiency and reducing operational costs. Often a detailed brochure on the price and features of a particular machine can be availed of online. The purchase process becomes much more easier, after visiting the sites. The buyer becomes aware of all the options available in all leading brands. These sites also help the buyer to find the appropriate wire EDM machine that can meet his particular needs. As these sites illustrate detailed images, buying becomes easier.

As the suppliers and manufacturers of Wire EDM machines are limited to a few countries, Internet is a crucial marketing weapon. There are many websites that provide links to all major manufacturers and suppliers of wire EDM machines and parts. Very often mold makers purchase used machines. There are many websites where these machines are auctioned. The websites provide all details regarding the history of use, features, specification and utility. The websites also provide detailed images of the machine and information on the seller.

Wire EDM machine trade fairs can be the ideal place for a satisfactory purchase. Trade fairs are often organized, throughout the year, in different countries. These trade fairs facilitate good deals with demonstrations. An investment in a Wire EDM is advisable only after a careful study of manufacturing needs and machine capacity.

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Article Source: http://EzineArticles.com/?expert=Josh_Riverside

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How to get started in CNC grinding

Rob Murnyack turned his professional life upside down in this quest to get into CNC machining. Rob had worked for his father for more than 20 years and was eager to get into CNC grinding when he launched his own business, Absolute Grinding (Mentor, OH).

"Maybe it was a long time coming, but we just couldn't find a solution that would work to get my father to move [into CNC]," Murnyack says. "And I can't blame him. At 65 years old, would you want to go into debt for $150,000 or $200,000?"

In May 1994, Murnyack took some employees, customers, and four manual grinding machines from his father's shop and began operations. Four months later, Murnyack found himself at the International Manufacturing Technology Show (IMTS) in Chicago, looking at CNC grinders.

"I wasn't even taking a paycheck at that point, and I was looking at machines that cost $200,000," Murnyack says. "I thought I was nuts, but I decided I needed one of those machines. I started saving money from day one to have a down payment."

Obviously, Murnyack had a lot riding on his plunge into CNC. He has not regretted his choice of an S35cnc from Studer Inc. (Brookfield, CT) for a minute.

Because none of Absolute's employees were familiar with CNCs, it was important that the machine be simple to operate. "We literally taught ourselves on this machine," Murnyack says. "It had the simplest form of conversational programming that I saw on the market. It teaches you as you go along. For all of my operators, it's still the easiest machine to set up, program, and run."

The machine still runs 24 hours a day at Absolute. Murnyack has also added a Studer S36cnc universal cylindrical grinding machine for medium-sized workpieces. The latter machine gives Absolute the ability to tackle more complicated assignments using complex wheel configurations.

The latest addition to Absolute's CNC lineup is Studer's S31cnc. Purchased in 2001, the newer machine is even more flexible than its predecessors. It's equipped with a Fanuc 16i CNC, and can grind IDs, ODs, and tapered IDs.

Time savings realized with the S31cnc are critical for Murnyack. "We do four or five setups a day here," Murnyack says. "This is a job shop. We can't spend four hours on a setup. My guys can switch over from an ID operation to an OD operation on a different part in an hour with the S31. With other machines, I heard from people out in the field that they might spend four hours just writing the program. It takes us just five minutes to write these programs on the Studers." Circle 223.

CNC tool grinders get friendly

Mason, Frederick

The overworked term "user-friendly" really means something when it comes to controlling the motions of five and six-axis CNC tool and cutter grinders. This class of machine tool was introduced in 1977 and became quite capable of producing and regrinding all the basic round-shank fluted cutting tools. Yet, the software and control were definitely not friendly and ranked up there with five-axis mills in the difficulties involved in programming and controlling them.

The major news about CNC tool grinders today is that they are simpler to operate. The software requires only a page or two of data input for all the basic round-shank fluted cutting tools. User interfaces have advanced from writing command lines to graphical fill-in-the-blank formats. Operators can enter operating parameters and tool geometry with less time and trouble. And the Pentium, 486, or other fast computer chips calculate the paths of the tools and grinding wheels in seconds rather than minutes.

Whether machine builders use their own or industry-standard controls, they have all written their own grinding software for a wide variety of tool types. It is still true, however, that some data input formats are easier to work with than others. This is important when there can be more than a dozen questions to answer or a data screen or page. Setup time minimization is particularly critical for regrind shops or in-house cutter grind departments doing small lot of tools.

The other significant development is that the designs of the CNC grinder hardware have incorporated more years of experience. They have moved away from the lightweight machine designs inherited from manual cutter grinders and become more rigid and productive for grinding tools at high stock-removal rates.

On some models, coolant pressure is up to 100 psi (690 kPa) or more, coolant filtration is more sophisticated, the grinder's moving elements are well protected, sometimes with positive air pressure to repel dirt and liquid. Several models now come with polymer-composite or cast-granite bases to minimize vibration. The latest axis drives and encoders provide many of these models with positioning accuracy and repeatability equal to or greater than the needs of most tool manufacturers and resharpening shops.

Most CNC tool grinders are designed to use wheel packs with two, three, or four wheels to grind most tool types. This eliminates individual wheel changes but creates some complexity in getting wheels to the tools without interference. A wheel pack may consist of an OD wheel, a cup wheel, and probably a third wheel.

Popular New Design

Walter Grinders (Fredericksburg, VA) introduced its five-axis Helitronic Power double-ended spindle CNC tool grinder at IMTS a year ago. Aimed at both cutting tool manufacturing and regrinding, the fully enclosed, compact machine is fast and rigid, grinding a 3/4" (19 mm) diam four-flute carbide end mill from a solid blank in 5 min, 15 sec.

The software package has a data-bank with the commonly required tools to provide faster setup. Screens for the operator interface are nearly identical regardless of tool type, reducing the learning curve and simplifying data input. Normally only two screens of data entry are required, although up to eight can be used if additional data are required for special customer applications.

The data--such as primary and secondary clearance angle, rake angle, etc.--for HSS and carbide tools now reside in the database. The same goes for operating parameters such as feeds and surface footage, thus optimizing wheel performance. When the operator enters the wheel diameter, the rpm is automatically selected--according to the surface footage in the file. The machinist may, of course, override the supplied data without affecting the data residing in the database.

The machine's work envelope is an 8" (300 mm) grind diameter and tool length of 11" (280 mm). The double-ended grinding spindle on the cross-slide and the +200' C-axis rotation of the workhead give this circular machine design great flexibility. This was demonstrated by grinding 16 different tools (cylindrical and tapered end mills, step drills, and other step tools) with changeover times ranging from 1 to 3 min.

For automated tool certification, Walter is developing (with a partner) a three-axis and four-axis tool measuring machine employing lasers and cameras to measure rake angles and primary and secondary clearances on the OD and on the end teeth. This could, potentially, be coupled with a loader to transport tools from the grinder to the tool checking machine, for automatic tool verification and feedback to the grinder. This Helicheck device uses some of the same software as the Walter grinder data-bank.

Fast Tool Manufacturing

The Model 4000 five-axis Super Truflute from Unison Corp. (Ferndale, MI) is built for fast cutting-tool production and incorporates all the company has learned in the last forty years.

The five-axis machine has hydrostatic round ways on the X, Y, and Z axes and a 22" (560 mm) cross roller bearing for the wheelhead swivel, providing extreme rigidity. This allows it to flute solid carbide at very high rates--

perhaps twice what was possible even five years ago. For example, a standard 1" (25 mm) carbide four-flute square end mill is manufactured complete from the solid in 5 min, 15 sec. A 1" four-flute carbide ballnose end mill takes 7 min 30 sec from the solid.

The spindle drive is 10 hp (7.5 kW), speeds are from 2200 to 7500 rpm, and the maximum wheel diam is 10" (25 mm). The grinder takes tools up to 12" (305 mm) diam and up to 14" (355 mm) long.

Unison's own control employs an Intel 90 MHz Pentium processor for very fast calculations--the first Pentium chip in a machine tool control, says Unison President Fred McDonald. For example, the calculation for a tapered ball-nose end mill takes no more than 30 sec, compared to minutes on older-generation controls with slower processors. A large-type fill-in-the blank approach characterizes the new software, making it clearer for operators to use. Standard data pages, with a uniform format from tool to tool, can be filled in to program standard tool types.

A touch probe is standard on the Model 4000 for tool remanufacturing, although for tool resharpening alone, Unison offers a less costly, less powerful Model 2700. Its motor is 3.5 hp (2.6 kW) and revs to 7200 rpm. The 2700 carries the same software system as the 4000.

Bramac (Tucson, AZ) is another builder specializing in machines for the rotary cutting tool manufacturing industry. Its five-axis Model 038 CNC tool grinder can have up to five wheels in its wheel pack and has spindle options of either a standard 7.5 hp (5.6 kW) unit or a 20 hp (15 kW) high-speed unit for four-times faster feed rates cutting with CBN. It is offered by

Ameri-Swiss (Scottsdale, AZ). The standard spindle revs from 100 to 7000 rpm.

Windows-Like Software

The five-axis CNC cutter grinding Quinto software package from J. Schneeberger (Elgin, IL) represents a considerable improvement over the software for their first CNC cutter grinders of a decade ago. It is in today's software mainstream of creating grinding programs by entering the tool data and wheel data into screen pages for given tool types. The screens do not confuse the operator with questions or data slots unrelated to the program at hand.

A helpful software tool is the flute simulation program, it displays the cutting tool, and the program may be adjusted interactively on screen if the flute parameters are not what the operator would have expected. This is not unusual, since even an expert can make only a rough guess as to what a flute will look like, given the combination of several tool and wheel parameters.

A standard database is supplied and is further expanded with user-defined tool designs. Database values or sensor-measured dimensions, such as the spiral pitch, are displayed in the editor window for verification. The CAD drawing of profile tools and step tools may be imported into Quinto, and the software calculates the grinding motions required, with the necessary compensations for spiral pitch, slot shape, or axial angles.

New among the line of Schneeberger CNC cutter grinders is the five-axis Gemini model, with Fanuc control, using a moving column design for good operator access. The wheelhead will swivel 360+' to achieve any desired helix angle. The machine is designed for resharpening, with a 5.3 hp (4 kW) water-cooled motor and double-ended spindle, capable of holding six wheels at a time. This reduces setup time if standard wheels are used.

Still another five-axis cutter grinder sporting a new windows-type graphical user interface is the Alfred H. Schuette WU 400, from Grinding Technology Inc. (Shelton, CT). It carries a NUM control, with Schuette's software. The multi-window software system "is pretty intuitive, with the screens showing you what you are changing on the tool or on the grinding wheel," says

Rick Huston, GTI applications engineering manager. The probe can automatically determine effective tool length, tool diameter, lead, and radial position of the tool. The design of this double-ended spindle machine rotates the spindles around the cutting tool, rather than vice versa. There are three spindle options, with top speeds of 7000 or 12,000 rpm.

New Graphical Interface

Stan Huffman, founder of Huffman Corp. (Clover, SC), introduced a multiaxis CNC tool and cutter grinder for ball and radius end mill grinding in 1977. His designs used superabrasive grinding wheels, high-pressure flood coolant, and an off-line programming system to produce accurate and repeatable geometries on ball nose and corner radius end mills. Huffman's H150 series is, says David Drechsler, manager for grinding systems, "better, faster, and cheaper." The HS 150 series uses GE/Fanuc controls, drives, and motors.

The entire machine--including its cast iron base--has been optimized with finite element analysis. The rails and ballscrews are twice the size of previous models. Three different single-spindle models, and a dual-spindle model for high production, are available. A 10 hp (7.5 kW) spindle motor is standard. On the HS-155, the maximum wheel diam is 6 (150 mm) and the wheel spindle reaches 6000 rpm.

"Our graphical interface software is mouse driven, displays a graphic of the cutting tool, provides a menu for entering numerical and geometric data, and greatly reduces changeover and setup times," says Drechsler. Windows-style screens lead the: operator through sequential choices: identifying the part or type of part, retrieving a data file, probing the part, making a finished part program, and downloading the program. Also aiding setup, he adds, are the quick-change HSK toolholders and wheel arbors, and the integrated probing. Software optimization and increased axis rapid travel rates have reduced grinding cycle time.

Unusual Six-Spindle Approach

The six-axis Ewamatic 106 from Ewag Corp. (Lincoln, RI) is one of the CNC tool grinders for grinding fluted tools to offer a radically new design. Up to six grinding spindles are arranged in a circle and driven from a central 10 hp (7.5 kW) motor, one at a time. Each spindle is capable of carrying up to three wheels.

However, the real benefit of this design is less the increased number of wheels that may be carried and more that each spindle has unfettered access to the tool with a single wheel, rather than a conventional three-wheel pack, says Sam Lerch, Ewag president. Spindles are shifted in two seconds. The table carrying the grinding spindles may be inclined +25' to -15'.

The control is the NUM 1060 Series II.

The machine grinds tools from the solid in the size range of 0.5 to 25 mm. The standard spindle speed range is 2000 to 12,000 rpm. For special procedures, one grinding spindle may be a high-speed 75,000 rpm spindle to drive small diamond wheels.

For controlled automatic production of tools, a 3-D measuring system is mounted on the grinding head to take up to nine measurements of the workpiece. The measuring system compensates for wheel wear and temperature-based deviations. For cutting tool production, the machine may be equipped with a robot arm to load/unload tools automatically. The controls for the arm are installed in the standard machine control panel.

Cutters to Tool Grinders

Star Cutter Company started as a cutter manufacturer in 1927 and branched out into building CNC cutter grinders about a decade ago. The Star CNC tool grinders have Allen-Bradley or Fanuc controls and are manufactured by Elk Rapids Engineering (Elk Rapids, MI).

The spindle of the six-axis, 5 hp (3.7 kW) ATG grinder takes a cup wheel, an angle wheel, and two OD wheels. The maximum diam wheel is 6" (150 mm) and wheel speed is 1000 to 5275 rpm. Star provides dual-probe technology, with one probe for tool location and geometry verification, and a second probe for wheel data verification. Both are interactive with the other software programs, minimizing non-grinding time.

Tool setup is much easier than on earlier models. The operator selects the program for the type of tool to be sharpened and then fills in data for tool geometry, diameter, length, primary clearance angle, secondary angle, etc. Once tool geometry data has been entered, it is stored under a tool ID number for recall later.

Five Star six-axis CNC grinders, as well as a five-axis model dedicated to broach grinding, are used at the Chrysler Trenton Engine Plant (Trenton, MI). Two of the grinder operators in the cutter grind area, Mike Pittiglio and Paul Hacker, report that they generally work on holemaking tools in small lots, from three to a dozen tools being typical, and they can do the setups fairly rapidly with the software system.

In fact, they report, the CNC cutter grinders allow some tools to be completed in a single setup that formerly required three setups on the manual cutter grinders.

If a tool has been sharpened before, says Pittiglio, then all that is needed for proper positioning is to set up the right bushing, if it is a long drill or reamer, and probe a single flute. If the tool had not been run before, then all the flutes must be probed to tell the control the position data. He reports that the present control, with a 486 computer chip, can calculate much faster than two older model Star machines the shop also has.

Some Advantages of CNC Cutter Grinding

CNC tool and cutter grinding produces more consistent tools than manual grinding and is the only reliable way to grind matched sets of identical cutters. Diameters, angles, and lengths can be held more accurately than an expert toolgrinder can produce consistently on a good manual tool grinder. The teeth of a cutter that is CNC-ground are concentric, so that all carry an equal cutting load. The absence of runout yields tool life increases of 1.2 to 4 times that of manually ground tools. CNC-ground tools may yield productivity gains on multispindle CNC machines on the shop floor that outweigh any productivity gains in the toolroom itself.

Further, CNC grinding is much faster than manual tool grinding in part because it operates under flood coolant in an enclosed cabinet, maximizing the speeds employed with the diamond or CBN wheels without burning the tools. The edge quality of CNC-ground tools is superior because the wet grinding eliminates any edge softening from grinding heat Speeds and feeds in end-milling o holemaking operations may be raised 10 to 35% over those used with manually ground tools. It is also possible to achieve more regrinds per tool with CNC grinding because all the teeth were initially ground more uniformly and thus wore evenly.

The CNC tool grinders are expensive, however, ranging from $150,000 to over $400,000, but if they provide quality service to machining departments and minimize downtime and other losses due to tooling problems, they will more than pay for themselves.

A Challenge: Producing a Constant Helix on a Ball Nose End Mill

When milling with a ball end mill, most of the work is done with the end cutting edges, rather than the side edges. The optimum end-cutting tooth geometry is a positive rake angle to the axial center of the tool. The notch rake angle should be positive and blend, without change of direction, with the side cutting edge positive rake at the point of tangency between the ball end and the side cutting edges. In this "perfect" geometry, according to Unison Corp., the primary relief would be the same all around the tool from the straight side cutting edge to and through the ball to the axial center. Because of the constant helix on the ball, full eccentric relief can be obtained providing such benefits as a longer cutting edge, uniform shearing action, increased chip removal rate, good dimensional accuracy, and good surface finish.

Unfortunately, until now this superior geometry has not been attainable in practice. Gary Vasher of Unison Corp. says the company has developed the machine and software to generate this geometry. "We have three methods of calculating the position of each point on a spherical ball nose," he explains, "and the result is the same with each method. We have also compared each to determine a grinding wheel path that truly produces a constant helix and positive hook around the spherical end of a ball nose end mill."

Control systems for CNC grinding

John Liverton

Perhaps the most exciting developments in CNC grinding are in the controls themselves. Here, one builder explains just how far this technology has come.

The development of CNC systems for precision grinding machines has revolutionized their use both in the toolroom and in the production environment. Today's very versatile software enables fully-automatic, precision grinding of simple or complex parts as one-offs or in batch production. Profiles can be generated directly on the workpiece or performed on the grinding wheel.

Various dressing and grinding cycles can be combined into a single automatic sequence that grinds a workpiece complete with minimum operator intervention. In addition to the grinding and wheel-dressing operations, the same CNC system is used to control a wide range of ancillary equipment, such as rotary tables, gaging units, automatic loading devices, and so on. The result is a production unit capable of high levels of productivity, accuracy and repeatability.

A Case in Point

A factor that delayed the general acceptance of CNC grinding, particularly in smaller organizations, was the need to learn and understand complex programming languages. The requirement for a programming system that is easy to understand on the shop floor was obvious, and that capability is now readily available in a range of grinding machines. Jones & Shipman worked closely with one of the leading CNC suppliers, Allen Bradley, to achieve this with its Format range of software running on the Allen Bradley 8600 series. Certain Format machines now also use GE Fanuc's Series 18 system.

In either case, operational software is menu-driven and incorporates clear graphic displays for both grinding and wheel-dressing cycles. When necessary, an operator can use his skill and experience to override the control program, for example, to give an extra wheel-dressing cycle or gage the workpiece.

Another advantage to the user is when similar control systems can be applied to different processes. This is demonstrated by the close similarity of the surface and cylindrical grinding programming procedures illustrated in Figure 1. Thus, it is relatively easy for an operator trained on one machine to operate the other, allowing better utilization of the production machine and greater flexibility in the scheduling of work and labor. And where required, special programs can be written for non-standard applications to supplement the standard features.

Process Specific

Today's CNC grinding machines are designed as a single integrated unit, rather than adding a control system to an existing machine, which was the normal practice when control systems were first applied to the grinding process. Unique software is developed by engineers experienced in the grinding process. Programming is logical and easily understood and carried out by machine operators on the shop floor, or off-line by production engineers. Rapid setups are possible, some as quick as five minutes.

The control system simply asks the operator for the data required for grinding the workpiece on a particular machine. The software then calculates and displays the optimum grinding parameters, including incremental or plunge feed rates, divided into coarse, medium and fine sections; table traverse speeds; spark-outs; and (in the case of cylindrical grinding) speeds at which the workpiece should be rotated. The operator then has the opportunity to either accept or edit these parameters.

An example of the use of combined cycles to give a highly versatile operation is shown in Figure 2. This is on a Format 15P ID/OD cylindrical grinding machine, which has a powered and programmable wheelhead swivel and is capable of both external and internal grinding. Seven combined cycles are used in an automatic sequence that includes grinding four external diameters, three external faces, two internal diameters, and one internal radius, all in one workpiece chucking.

The machine is fitted with a 350-mm diameter external wheel and a 38-mm diameter internal wheel. A quick setting in-process gage is used on one of the diameters.

Contouring Control

One of the more recent developments, made available through the introduction of CNC, is contour generation grinding on both surface and cylindrical grinders, that enables the grinding of profiles many times wider than the wheel width, using simultaneous movements of the machine's two axes. Such profiles can include a combination of radii, angles, sharp corners, parabolic or inverse curves, as shown in Figure 3. In some applications, contour generation on a surface grinding machine gives better results than wire erosion methods for both cycle time and surface finish.

New Possibilities

With advancing microprocessing technology, and with 32-bit processors in particular, have come much more powerful CNCs. This, in turn, allows more sophisticated control systems, both in terms of hardware and software.

For example, Jones & Shipman now has a cylindrical grinding control system that takes advantage of the enhanced capabilities of the new Allen Bradley Series 9/360 control. Compared with previous models, the 32-bit 9/360 is considerably more powerful with increased storage capacity on hard disk drive, and incorporates specially-developed, easy-to-use color graphic screens and menus to further simplify setup and programming. The system can control up to 12 axes, which means many items of ancillary equipment can be integrated when required, such as automatic loading/unloading, post-process gaging with SPC, and so on.

While the machine is carrying out an automatic grinding sequence on one component, the operator is able to program a new component, edit an existing program, or exchange information with external computer systems running applications such as CAD or work scheduling. The 9/360 control incorporates a personal computer with an MS-DOS operating system that enables it to be used as a workstation in a network. The MS-DOS partition can be accessed while grinding so, for example, it could be used for such real-time functions as adaptive control. Communication between the control and the rest of the machine is by high-speed fiber optics.

Programs are developed on the powerful graphic editor by selecting macros and geometric elements that appear on the screen, and adding the required part dimensions. A comprehensive "Help" facility is available to help the operator with all the necessary information about the current process, as shown in Figure 4.

In addition to the standard surface grinding machines, advanced new CNC systems with 32-bit processors bring new advantages to the high-tech range of creep-feed grinding machines as well.

User-friendly software--incorporating menus, macros and graphical programming--further simplifies and speeds up part programming.

Linear scales are fitted to all four axes to give highly accurate positional accuracy. This is particularly important on applications where interpolation is used to generate profiled components. This permits resolution of 0.0001 mm on all axes.

Development of CNC systems for grinding machines is an on-going process aimed at providing additional facilities and simplifying programming still further. At the same time, quality and productivity are improved, and optimum use made of existing skilled labor.

Threading on a lathe: the right choices in tooling and technique can optimize the thread turning process - Emphasis: Cutting Tools

Stuart Palmer

Tools for turning threads have benefited from the same improvements in coatings and material grades that have improved turning tools overall. In addition, there have been design improvements in thread turning inserts resulting in better chip control. In spite of these changes, however, manufacturing engineers tend to spend little time optimizing their threading operations, seeing the thread machining process as a "black box" that doesn't lend itself to incremental improvement. In fact, the thread machining process can be engineered for better efficiency. The first step is to understand some basic topics in thread machining.

Why Thread Turning Is Demanding

Thread turning is more demanding than normal turning operations. Cutting forces are generally higher, and the cutting nose radius of the threading insert is smaller and therefore weaker.

In threading, the feed rate must correspond precisely to the pitch of the thread. In the case of a pitch of 8 threads per inch (tpi), the tool has to travel at a feed rate of 8 revolutions per inch, or 0.125 ipr. Compare that to a conventional turning application, which may have a typical feed rate of around 0.012 ipr. The feed rate in thread turning is 10 times greater. And the corresponding cutting forces at the tip of the threading insert can range from 100 to 1,000 times greater.

The nose radius that sees this force is typically 0.015 inch, compared to 0.032 inch for a regular turning insert. For the threading insert, this radius is strictly limited by the allowable radius at the root of the thread form as defined by the relevant thread standard. It's also limited by the cutting action required, because material can't be sheared the way it can be in conventional turning or else thread distortion will occur.

The result of both the high cutting force and the more narrow concentration of force is that threading inserts see much more stress than what is typical for a turning insert.

Partial Versus Full Profile Inserts

Partial profile inserts, sometimes referred to as "non topping" inserts, cut the thread groove without topping or cresting the thread. (See Figure 1.) One insert can produce a range of threads, down to the coarsest pitch--that is, the smallest number of threads per inch--that is permitted by the strength of the nose radius of the insert. This nose radius is designed to be small enough that the insert can machine various pitches. For small pitches, the nose radius will be undersize. This means the insert will have to penetrate deeper. For example, a partial profile insert machining an 8-tpi thread requires a thread depth of 0.108 inch, while the same thread produced with a full profile insert requires only the specified depth of 0.81 inch. The full profile insert therefore produces a strongerthread. What's more, the full profile insert may produce the thread in up to four fewer machining passes.

Multi-Tooth Inserts

Multi-tooth inserts feature multiple teeth in series, with a given tooth cutting deeper into the thread groove than the tooth that went before it. (See Figure 2.) With one of these inserts, the number of passes required to produce a thread can be reduced by up to 80 percent. Tool life is considerably longer than that of single-point inserts because the final tooth machines away only one half or one third of the metal in a given thread.

However, because of their high cutting forces, these inserts are not recommended forthin-wall parts--chatter can result. Also, the design of a workpiece machined with one of these inserts needs to have a sufficient amount of thread relief to allow all of the teeth to exit the cut.

Infeed Per Pass

The depth of cut per pass, or infeed per pass, is critical in threading. Each successive pass engages a larger portion of the cutting edge of the insert. If the infeed per pass is constant (which is not recommended), then the cutting force and metal removal rate can increase too dramatically from one pass to the next.

For example, when producing a 60-degree thread form using a constant 0.010-inch infeed per pass, the second pass removes three times the amount of metal as the first pass. And with each subsequent pass, the amount of metal removed continues to grow exponentially.

To avoid this increase and maintain more realistic cutting forces, the depth of cut should be reduced with each pass.

Infeed Methods

At least four infeed methods are possible. (See Figure 3.) Few recognize how much impact the choice among these methods can have on the effectiveness of the threading operation.

A. Radial infeed

While this is probably the most common method of producing threads, it is also the least recommended. Since the tool is fed radially (perpendicular to the workpiece centerline), metal is removed from both sides of the thread flanks, resulting in a V-shaped chip. This form of chip is difficult to break, so chip flow can be a problem. Also, because both sides of the insert nose are subjected to high heat and pressure, tool life will generally be shorter with this method than with other infeed methods.

B. Flank infeed

In this method, the infeed direction is parallel to one of the thread flanks, which normally means the tool feeds in along a 30-degree line. The chip is similar to what is produced in conventional turning. (See Figure 4.) Compared to radial infeed, the chip here is easier to form and guide away from the cutting edge, providing better heat dissipation. However, with this infeed, the trailing edge of the insert rubs along the flank instead of cutting. This burnishes the thread, resulting in poor surface finish and perhaps chatter.

C. Modified flank infeed (recommended)

This method is similar to flank infeed except that the infeed angle is less than the angle of the thread--that is, less than 30 degrees. This method preserves the advantages of the flank infeed method while eliminating the problems associated with the insert's trailing edge. A 29 1/2-degree infeed angle will normally produce the best results, but in practice any infeed angle between 25 and 29 1/2 degrees is probably acceptable.

D. Alternating flank infeed

This method alternately feeds the insert along both thread flanks, and therefore it uses both flanks of the insert to form the thread. The method delivers longer tool life because both sides of the insert nose are used. However, the method also can result in chip flow problems that can affect surface finish and tool life. This method is usually only used for very large pitches and for such thread forms as Acme and Trapeze.

Clearance Angle Compensation

Some threading insert and toolholder systems provide the ability to precisely tilt the insert in the direction of the cut by changing the helix angle. This feature provides a higher quality thread because it tends to prevent the insert from rubbing against the flank of the thread form. It also provides a longer tool life because the cutting forces are evenly distributed over the full length of the cutting edge.

An insert that is not tilted in this way--one that holds the cutting edge parallel to the centerline of the workpiece--creates unequal clearance angles under the leading and trailing edges of the insert. (See Figure 5.) Particularly with coarser pitches, this inequality can cause the flank to rub.

Adjustable systems permit the angle of the insert to be tilted by changing the orientation of the toolholder's head, generally using shims. Precise adjustment results in leading and trailing edge angles that are equivalent, ensuring that edge wear will develop uniformly. Miniaturization And Spedalizatian

Inserted tools are available to permit internal thread turning of bores down to about 0.3 inch in diameter. Producing the threads for these small bores through turning offers many advantages. The quality of the thread formed is usually higher, the insert design allows chips to flow out of the bore with little damage to the thread, and the ability to index the tooling results in a lower cost for tooling.

The carbide used for these applications is generally a grade that permits machining at low surface speeds. For an internal threading application in a small hole, machine tool limitations generally leave anything other than a low surface speed out of the question.

Technology improvements have expanded the application range of thread turning tools, and the move to internal thread turning of small bores is one example of this. In spite of the expanded range of standard tools, however, manufacturers continue to encounter special problems that justify custom tooling. (See Figure 6.) Special tooling developed in cooperation with the tool supplier is an option that shouldn't be overlooked when searching for the right threading tool for a particular job.

For more information about threading tools from VNE Corp., call (608) 756-4930, enter 32 at www.mmsinfo.com to visit Online Showroom, or write 32 on the reader service card.

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Turning turning on end

Destefani, Jim

Verticals put a productive twist on machining of round parts Chances are, you haven't given much thought to vertical turning. But flipping your typical horizontal lathe on end has multiple advantages compared to conventional turning machines, including a relatively small footprint, easy chip disposal, and a gravity boost for loading of large, heavy parts. The configuration also facilitates automation and has excellent spindle accuracy.

The market for vertical turning machines consists of two distinct segments. Inverted verticals are chucker machines that are primarily aimed at relatively mid- to high-volume, automated applications in the automotive and other industries.

On the heavy-duty end of the market, large vertical turret lathes (VTLs) feature high-horsepower spindles and tables that can handle workpieces weighing thousands of pounds. Traditional applications for VTLs include production of components for jet engines, oil and gas exploration, military and off-road vehicles, pumps, and compressors. Suppliers report that current applications are about the same, but the customer base has evolved from OEMs to their first and second-tier suppliers.

The machines have evolved, as well. Most VTLs now feature toolchanging and live tooling capability. Becoming more common are four-axis machines, which allow complete machining of components such as railroad wheels in a single setup. Some machines are also equipped with pallet changers that allow operators to set up the next part while the current job runs.

Exemplifying the current crop of VTLs is the VTC series of machines from Giddings & Lewis (Fond du Lac, WI). Four models cover a size range from 1700 to 2700 mm maximum swing and from 1250 to 2500 mm table diameter.

All the machines feature a 75-kW AC motor coupled to a two-speed table drive. The system generates torque of 24,550 N*m for the two smaller machines and 41,144 N*m for the larger models. All also use a hydrostatic ram.

Perhaps more important, all have been re-engineered to reduce part counts and eliminate parts that are prone to failure such as limit switches. A 50% reduction in part count has improved reliability and allowed G&L to offer the machines at about 2/3 the price of previous generation.

VTC machines also use the company's proprietary Wedge-Lock modular tooling system, which is based on a taper system much like a boring mill or machining center. Rather than pulling the tool in from the rear like on a conventional tapered tool, the system uses hydraulic wedge assemblies on each corner of the ram that force the tool into the tapered socket. G&L says the system allows placement of electrics, hydraulics, and coolant through the tool, and is relatively easy to manufacture compared to a Hirth coupling or cross keys.

A relatively new player in the heavy-duty vertical market is Haas Automation (Oxnard, CA). Introduced in 2002, the company's Vertical Turning Center (VTC) allows single-setup turning and live-tool milling of parts to 48'' (1220 mm) diam, 28'' (710 mm) tall, and weighing up to 10,000 lb (4500 kg). Features include a 48'' diam T-slot table and 50-taper milling head. The table is powered by a 30-hp (22.5-kW) drive system through a two-speed gearbox for turning and a servomotor for C-axis positioning and interpolation with accuracy of + or -30 arc-sec.

Live-tool operations are via a 50-taper spindle with 30-hp vector drive system that yields 450 lb-ft (610 N* m) of torque and speeds to 5000 rpm. The machine features a 30-station side-mount toolchanger that can hold 21 milling and drilling tools, two turning tools, and one boring tool. Additional turning and boring tools may be added, but require empty adjacent pockets.

Inverted vertical turning machines feature a spindle that also serves as part of the machine's material handling system. The spindle grabs workpieces from an external conveyor system, takes them to the machining area, and presents them to a fixed tool turret. After machining, the spindle returns the finished part to the conveyor, which moves the next workpiece into position.

The arrangement has advantages over conventional turning machines, which require full-time operator attention, and over machines equipped with gantry robots and other external operator's role is reduced to loading blanks on the conveyor and removing finished parts. The operator's role is reduced to loading parts on the conveyor and removing finished components. Depending on parts and cycle times, this may be every couple of hours or even only once or twice per shift.

Eliminating an external robot or gantry reduces cost and floor space requirements. Users save not only the initial cost of the robot, but also the cost of programming and tooling. The conveyor arrangement also simplifies setups, although at the cost of some of the flexibility of a robot or gantry system. Typical of the breed are VL series machines from Hardinge Inc. (Elmira, NY), which are built in Germany by Hardinge-Emag GmbH, a joint venture with German machine builder Emag Maschinenfabrik. The VL3 features a 21-hp (15.6-kW), 7500-rpm spindle; storage capacity for 20, 3.1''

(79-mm) or 14, 5.1'' (130-mm) diam workpieces; and a 6'' (152-mm) chuck capacity. The VL5 uses a 29.9-hp (22.3-kW), 4500-rpm spindle, a circular parts conveyor that can accommodate up to 28 workpieces, and a chuck with either 8 or 10'' (204 or 254-mm) capacity.

Both machines have spindle Z-axis traverse rate of 1181 ipm (30 m/min) and X-axis rate of 2362 ipm (60 m/min). Both feature rigid disk-type, 12-station VDI 40 bidirectional tool turrets that can handle live tooling in any position. GE Fanuc's 21-iT control is standard; machines with live tooling and C axis get Fanuc's 18i-T control.

Inverted machines also lend themselves to cellular manufacturing arrangements. Simple part conveyors can link units to create flexible transfer lines that can be reconfigured to handle changing production requirements. And, the machines' small footprint means cells based on inverted turning take up less floor space than horizontal turning cells.

Mazak Corp. (Florence, KY) markets its IVS 200 inverted vertical machine as a solution for medium to high-volume production of automotive and similar parts. The company has displayed two of the two-axis machines set side by side, with connecting automation to allow machining of opposite sides of a turned part. The machines are said to have a very small footprint, and feature an automatic tool presetting arm. When the tool tip is brought into contact with the Tool Eye, the machine control automatically registers offset and other tool characteristics. The device also monitors and compensates for tool wear.

Also touted as an expandable platform for cellular applications is the CTV 250 from DMG America Inc. (Schaumburg, IL). The machine features a linear motor drive for the X axis, which results in 1-g acceleration and rapid traverse rates of 3936 ipm (100 m/min) in X. A 33.5-hp (25-kW) motor drives the spindle at speeds to 5000 rpm. A 10" (254-mm) chuck, Y axis for eccentric drilling and milling operations, and Siemens 840D control round out the package.

Forgings and castings are commonly used workpiece forms for all types of machining processes, and variability in workpiece dimensions and geometries can be a challenge to process automation. Mori Seiki's latest inverted machine, the Pick-up Turn CS200B, was developed specifically to handle short castings and other low length-to-diameter ratio parts such as brake rotors, motor housings, and compressor rotors.

With spindle speeds to 5000 rpm and peak power output of 15 hp (11.2 kW), the machine can handle workpieces up to 15.7" diam x 5.9" long. Machine ballscrews and linear guide-ways are permanently lubricated using phenolic pads impregnated with mineral oil, eliminating the need to add oil. Doing away with oil lubrication also helps keep coolant free from problems caused by tramp oil.

An example of how productive vertical turning can be-and how the technology can replace not only horizontal turning but also perform milling, drilling, and other operations-is provided by applications at a couple of European automakers.

The job involves complete machining of differential cases. Advantages of the turning-based approach include single source for machines and simplified tooling and workholding requirements, according to machine supplier Hessapp Div., Cross Huller (Port Huron, MI).

Relationships between key machined features of the nodular cast iron parts are critical. For example, the tolerance on concentricity and position of an inner machined spherical surface to cross holes is 60 [mu]m. Perpendicularity between bored and reamed trunnion IDs and the cross holes also is 60 [mu]m. C^sub pk^ requirement was 1.33 for all dimensions.

The first operation happens on a Hessapp DVT 300 machine with dual spindles, cross slides, and tool turrets. After the part is chucked on the body OD, the first spindle roughs the trunnion ID and flange OD. For operations on the second spindle, the part is chucked on the machined flange OD and located off the machined face for semifinish boring of cross holes and reaming of the trunnion ID.

Next, the part is transferred to a Hessapp VDM 300-12L with a vertical spindle for machining the internal sphere and a horizontal reaming spindle. The part sits horizontally on the chuck with the window facing up to allow boring bars to enter, then moves on the machine cross slide (X axis) to allow semifinish and finish machining of the inner sphere.

This operation is followed by reaming of trunnion IDs and finish boring/reaming of cross holes. Machining all these features in a single chucking assures that the critical dimensional tolerances and relationships between the holes and the inner sphere are held.

A single-spindle VDM 250R machine with cross slide and horizontal turret completes machining and establishes critical dimensions on the part OD. The part is chucked on the finished trunnion ID using an arbor and a tailstock. Then three tools finish-turn all critical OD dimensions, which also have a specific relationship to the inner sphere and trunnion ID. Longest cycle time in the cell is 2.5 min, so the process is capable of producing 20 parts/hr at 85% efficiency. All the machines are built using modular Hessapp components and are connected by a palletized conveyor. Hessapp has delivered half a dozen of the cells in Europe, and has quoted the process to tier suppliers in the US. Jim Destefani

Senior Editor

Henry Stier

Millturning

When turning softer materials, such as low-carbon steels, it is sometimes impossible to break up chips even with special inserts. The resulting "bird's nests" of long stringy chips can cause damage to both the cutting tool and the workpiece. Production interruptions and short tool life are often the result. In fully automatic turning operations, positive chip breaking is essential.

A relatively new manufacturing process called "millturning" has emerged in Europe. It is the use of a milling cutter in place of the single-point tool normally used on a lathe and it assures the formation of short chips.

The powered milling cutter, in the station of a tool turret, rotates against the turning direction of the part as established by the lathe spindle. Thus several milling cutter teeth are cutting in succession and removing short chips.

With different diameters and types of face milling cutters, or by changing the cutting angles, a wide range of part configurations and surfaces may be machined and finished. Surface finishes of Ra 3 to 8 and part roundness of 0.00005-inch can be achieved by this approach with a rigid setup.

Cutting depths of 1/8 to 5/8-inch with small feed rates per revolution are the norm. Feed rates of 3/8 to 2.0 inches per minute are possible with a combined cutting speed of the part and cutter adding up to 800 to 1500 surface feet per minute.

With this combined turning milling approach, rigidity is essential in the entire setup. Both the lathe and milling spindle must be stepless and adjustable so that the turning and milling rotations oppose each other. This means that when the lathe spindle turns in a normal right hand mode, the milling spindle must rotate against the part surface direction.

With this type milling, the chips are thin at the cutting tooth entry, thick at the middle, and thin at the exit. The chip width also varies throughout. As the speed of part rotation increases in proportion to the cutting tool rotating speed, the length of the chip increases proportionally.

Some users in Europe have been able to match all the variables to finish to size in one cut, thus avoiding the roughing/finishing sequence. The process is especially economical when large amounts of material must be removed and rough forgings are either too expensive or lead times are too long for short runs.

Millturning is a relatively new process, it is not widely known or used in the United States, but the process of millturning shows great promise for the shops that run fully automatic operations.

Henry Stier 4126 Sheppard Drive, Spartanburg, SC 29301

Metalcutting: Turning Machines

Complex parts, quality demands drive technology

Without doubt, the most significant trend driving turning technology is the need to machine more complex components. Manufacturers faced with the need to produce complex parts have several options, and not all of them are pleasant. Multiple operations on both a lathe and a mill or machining center can require too much time and too many setups. A shop that is strictly a lathe shop could be faced with the choice of subcontracting the milling work or turning down the job. A third option is use of multitasking machines (see the section "Multitasking" in this issue), which are becoming very capable but require both a significant capital investment and a learning curve on the part of shop personnel.

"The simple jobs are gone," sums up Jon Schaudies of SNK America Inc. (Elk Grove Village, IL). "Our customers now have to be able to do more complex parts and more complete machining operations per setup." The capability to drill and mill off center and/or on the side of parts is becoming more important, he adds.

According to Schaudies, quick changeover capability and more powerful CNCs are also in demand. To meet all these requirements, SNK America is offering its Prodigy GT-27 gang-tool lathe. Built in the US, the machine features a Fanuc control, a standard third indexing axis, high spindle speed, and a polymer bed that reduces vibration at high machining speeds and feeds.

Frank Ramirez of Haas Automation Inc. (Oxnard, CA), echoes the assessment of Schaudies. "More complex part designs are driving changes in the way round parts are machined today," he says. "Parts are being designed to have many of the features of a casting-holes, ports, and others-but with the requirement of being machined from billet stock. This provides more strength while saving time and cost for the designer."

Ramirez says producing such components requires an investment in lathes with live tools, C axis, and subspindle capabilities. "This allows production of complex parts in a single setup on one machine, thus reducing part handling and the cost per part." At IMTS, Haas: will show a range of machines with live tooling and subspindle capabilities, as well big-bore, options, high-speed spindles, and rapid rates up to 1200 ipm (30 m/min), he says. Driving down cost per part is also the focus at Mori Seiki (Irving, TX). The comp-. any will exhibit its new NL series of lathes that are said to provide milling capability as robust as a machining center.

The machines feature a milling motor inside the turret directly coupled to the milling tool. The patent-pending design cuts transmission losses and inherent vibration associated with use of gears and/or belts for milling capability. Mori says the direct-coupled milling motor reduces tool spindle acceleration time by 2/3 and diminishes vibration and noise by 1/2. The NL line will launch at IMTS with 30 new models.

Also beefing up the multitasking capabilities of its turning centers is Mazak Corp. (Florence, KY), which will launch its Nexus QTN-350M machine. Features include integral spindle/motor technology on the 40-hp (30-kW), 3300-rpm main spindle and a rotary tool spindle with 10-hp (7.5-kW) output and 4000-rpm maximum speed. Rotary tools and turning tools can be mounted at any position of the machine's 12-station drum turret. Other features include a fully programmable NC electric tailstock and Mazak's Tool Eye automatic tool presetting arm.

The trend toward single-setup production of more complex components is not lost on venerable lathe supplier Hardinge Inc. (Elmira, NY), which will display the Quest GT27SP gang-tool lathe with a two-axis programmable subspindle. The 6000-rpm, 3-hp (2.2-kW) subspindle allows machining of complex arcs and angles on parts up to 1'' (25.4 mm) in diameter, facilitates part transfers with the main spindle, and can handle canned machining cycles. It features five back-end working stations for tools to 0.625'' (16 mm).

A new player in the turning machine market is Hurco Cos. Inc. (Indianapolis). The company's Bob Albaugh believes movement to JIT and demand pull manufacturing operations places a premium on system integration and programming flexibility. "The ability to handle part data in a variety of formats, and to network both internally and within the supply chain while using a simple, easy-to-operate control, has contributed to a movement toward shop-floor programming and editing in job shops and contract manufacturers," Albaugh says. "Flexibility is key to meeting the demands for the fast turnarounds required by the global manufacturing economy."

At IMTS, Hurco will introduce the TM line of two-axis CNC slant-bed lathes. All the machine's feature the company's MAX conversational control and knowledge-based programming software. The CNC allows programming in any of 31 languages using Hurco's graphical user interface. Initial launch of the turning line will be with three models, with chuck sizes of 6, 8, and 10'' (152, 203, and 254 mm). All three models can be equipped with bar feeders, parts catchers, tool presetters, tailstocks, chip conveyors, and collet chucks. Future plans call for addition of live tooling and C-axis capability.

Mill/drill capability with fast programming and setups are key technologies for contract manufacturers. For mid to high-volume production of turned parts, automation is playing a critical role, according to Laurence Pelligrini, Director of Operations, Murata Machinery (Charlotte, NC).

"Our customers are asking for automated solutions to their production applications to drive labor cost to a minimum," he says. "Automated part handling must be flexible, robust, integrated, 'smart', and relatively simple. This includes automatic part input to the machine staging area, automated part orientation, automatic load/unload to and from the machine workholding, automated turn-around for second operation, and an automated device to convey finished parts to the next operation."

Pelligrini says Murata's high-speed, three-axis gantry loader provides "an integrated, robust, flexible, and 'smart' automated part load/unload device." The company has an installed base of more than 5000 automated, twin-spindle machines, he adds.

Another absolute, according to Pelligrini, is part quality. "No out-of-tolerance parts can be shipped or leave our customer's dock. As part tolerances become tighter and tighter, post-process gaging becomes a requirement. On challenging tolerances, the gage measures every part as it comes off the machine, and automatically adjusts offsets when necessary." Nearly a third of machines Murata delivers now have post-process gaging systems, he says.

In Chicago, the company will feature its MW series of four, twin-spindle CNC chuckers. The machines range from the MW100GT, with a 6'' (152-mm) chuck, to the MW400G, which features a 15'' (380 mm) chuck.

A different spin on high-volume turning comes from Mazak, which will show its inverted vertical turning machines. The company claims a relatively small number of inverted verticals can replace numerous conventional two-axis turning centers to handle increasing part volumes. Visitors to IMTS will see a vertical cell that uses pre-engineered automation to provide automatic load/unload.

Following is a sampling of turning machines scheduled for display at IMTS.
Swiss Multispindle Center

Newest addition to the MultiDeco Family, the MulitiDeco 20/8b is configured to machine parts as large as 20-mm diam. It has eight spindles and will be shown with the MSF 522/8 integrated bar feeder. The machine can be configured as a traditional eight-spindle machine or a two four-spindle (2 Ã— 4) machine. As an eight-spindle it can produce more complex parts. In the 2 Ã— 4 configuration, the machine can produce two relatively simple, separate parts at the same time.

Tornos USA

Ph: 203-775-4319

Circle 230

Twin-Spindle CNC Chuckers

The MW series of twin-spindle CNC Chuckers includes the MW100GT, which is designed to meet a minimum cycle time of 11 sec for two parts. It has a 6'' (152-mm) chuck standard and can handle a maximum part size in automatic mode of 60-mm diam Ã— 40-mm long. The manufacturer will also exhibit three other chuckers in the series, the MW120GT, the M200GSMC, and the largest model, the MW400G. The machines offer chuck sizes of 8, 12, and 15'' (203, 305, and 380-mm) respectively.

Murata Machinery USA Inc.

Ph: 704-394-8331 ext. 229

Circle 231

Twin-Spindle Lathe

Model 2SP-10HG miniTwin from Okuma & Howa is a twin-spindle lathe that offers four-axis simultaneous or individual production of rotational parts to 100-mm diamby 100-mm long. The 50-5000-rpm spindle (60-6000-rpm optional) features a stepless speed range shift, and is powered by a 7.5-kW motor. Each spindle is serviced by an eight-tool magazine, and the machine can be equipped with a gantry loader for automated operations. When used in a manual mode, it's equipped with pedal-operated chuck loading.

KGK International

Ph: 847-465-0160

Circle 232

Vertical Chucker

A pick-and-place vertical chucker with built-in automation, the VturniV200 employs inverted vertical chuck clamping to - reduce the likelihood of chip scratching on part surfaces. A pick-and-place spindle by the traveling headstock couples turning and part-loading by one machine. A servodriven turret with hydraulic clamping shortens tool changeover time and ensures cutting rigidity. Three work-feeding packages-A, B, and C-make possible the creation of a flexible turning cell.

Fortune International Corp.

Ph: 732-214-0700

Circle 233

Facing, Centering, Chamfering Machine

Double-end part-machining system can face, center, chamfer, and turn both ends of bar stock or tubing. Material previously cut to length by any method can be loaded into the machine magazine for transfer through the system and finish machining of both ends of the part. Displayed machine has a capacity of 1-4'' (25-102-mm) OD and part lengths of 6-60'' (152-1520 mm).

Tooling is quick-change mounted on a taper holder. Operations such as part gaging can be added to the base unit.

Bardons & Oliver

Ph: 440-498-5800

Circle 234

Swiss-Style Turning

Maier CNC Swiss turning centers are available in five different series with configurations ranging from four axes and 11 tools to 11 axes with up to 30 tools. Able to handle bar stock to 32 mm diam, the machines feature 6000 or 8000-rpm, 5-hp (3.8-kW) main spindles; 6000 or 8000-rpm, 3.5-hp (2.6-kW) subspindles; and 1260-ipm (32 m/min) rapid traverses. Several models offer simultaneous processing with two or three tools, and are capable of secondary milling . and drilling using a 2-hp (1.5-kW) front drilling spindle. A

Fanuc control is standard. Also shown will be the Nakamura-Tome Super NTJ turning center, which uses a B axis to allow complete multi-face angular machining and contour milling in a single setup.

Methods Machine Tools Inc.

Ph: 978-443-5388

Circle 235

Self-Loading NC Lathe

A 6'' (152-mm) chuck machine with an A2-5 nose, the HS-01 machine uses a fixed turret and a traveling spindle. Parts load directly to the spindle, reducing loading time and boosting overall productivity. The machine features a 10-hp (7.5-kW) spindle with a maximum speed of 6000 rpm. A 12-station, servo turret has an index time of 0.5 sec to the opposite tool. Control is via a Fanuc 0iTB CNC, and rapid traverse rates in X and Z are 1200 ipm (30.5 m/min). Also shown will be vertical turning lathes, as well as cost-effective lathe packages that include a CNC turning center, short-bar feeder, parts catchers, chip conveyors, and other accessories.

Tong Tai Seiki USA Inc.

Ph: 845-267-5500

Circle 236

Robust Milling Capability

New NL series lathes feature a direct-coupled milling motor that eliminates bevel gears, belts, and pulleys to cut associated transmission losses and vibration. The result is more power delivered directly to the tool, reduced vibration, increased tool life, and better accuracy. The machines also offer a rigid toolholder said to give the lathes milling capability that rivals that of 40-taper machining centers. For example, the machines can use 80-mm diameter face mills and perform rigid tapping at 3600 rpm. Encompassing a total of 30 variations on the basic NL design, the machines feature either 10 or 12-station turrets and digital tail-stock driven by a servomotor and ballscrew. Models include 6, 8, 10, and 12'' (155, 205, 255, and 305-mm) chuck versions with turning lengths to 49.6'' (1260 mm) and ability to handle bars to 3.54'' (90 mm) diam.

Mori Seiki USA Inc.

Ph: 972-929-8321

Circle 237

Gang Tool Subspindle

A new two-axis programmable subspindle on the Quest GT27SP Super-Precision gang tool CNC lathe allows machining of complex arcs and angles on parts up to 1'' (25 mm) diam. The 6000-rpm, 3-hp (2.2-kW) subspindle facilitates exacting part transfer with the main spindle, is canned cycle capable, and features a complete Fanuc motor, drive and I/O system. It includes five back-end working tool stations for tools up to 0.625'' (16-mm) diam. Finished parts are spring ejected into the machine's parts chute, with cut-off provided by an air-over-oil actuated vertical cut-off slide. The machine itself has either a 5C or 16C collet and interchangeable tool top plates that reduce setup time. The patented main spindle is said to maintain 0.000015'' (0.4-Aμm) part roundness at high feeds and speeds.

Hardinge Inc.

Ph: 859-342-1700

Circle 238

CNC Turning Centers

New TM series single-spindle, slant-bed turning centers are aimed at machining of small to medium lot sizes. The company's user-friendly control allows quick setup and programming on the shop floor using knowledge-based software, direct conversion of CAD drawings into programs, and downloading of CAM-generated programs. The TM6, TM8, and TM10 turning centers (with 6, 8, and 10'' [152, 204, and 254-mm] chucks, respectively) have spindle speeds up to 6000 rpm and up to 12-station turrets. Users can select a variety of options for the compact machines, including tailstocks, chip conveyors, tool probes, parts catchers, and bar feeders.

Hurco Cos. Inc.

Ph: 317-298-2622

Circle 239

Automated Turning

The model ANW-3000 is a high-efficiency, twin-spindle lathe equipped with a new robot controller for producing high-volume precision parts with speed and accuracy. The Max SP1 robot controller is independent of the machine CNC, and its programming capabilities are said to reduce robot cycle times significantly. The controller drives a built-in, four-axis rack-and-pinion swing arm robot with traverse speeds of 3937 ipm (100 m/min). Standard equipment on the machine includes twin eight-station turrets, 15-hp (11.2-kW) continuous spindle motor, 8'' (204-mm) chuck, auxiliary loader, 12-pallet work stocker, hinge-type chip-conveyor, and Fanuc 180i-TB CNC.

Fuji Machine America

Ph: 847-821-2445

Circle 240

Portable Turning

The OL-1 Office Lathe is a compact machine small enough to fit through a standard 36'' doorway and easily moveable from one location to another. Designed for medical, dental, and research facilities; schools and training facilities; or even hobby shops and jewelry manufacturers, the machine runs on single-phase power. It features a 5-hp (3.8-kW) peak spindle that spins to 6000 rpm, and a 5C threaded spindle nose that accepts a number of optional chucks. A high-speed cross slide features travels of 8'' (204 mm) in X and Z and accepts a variety of gang-style tools. Users can also select a setup for use of air-driven live tools, including M-code activated air-supply, all associated plumbing, and toolholders that accept standard pneumatic tools.

Haas Automation

Ph: 805-278-1800

Circle 241

Turning + Milling

The Nexus QTN-350M features integral spindle/motor technology on the main turning spindle that is said to allow heavy-duty metal removal and high-speed cutting of aluminum and other nonferrous materials. The 40-hp (30-kW), 3300-rpm main spindle features a 12'' (305-mm) chuck; the machine also has a rotary tool spindle with 10-hp (7.5-kW) output and 4000-rpm maximum speed. A 12-station drum turret can handle rotary or stationary tools at any position, and quick-change toolholders can be loaded or unloaded with a single turn of a wrench. The machine uses the Mazatrol Fusion 640T Nexus control, and features a programmable NC electric tailstock, and "Tool Eye" automatic tool presetting arm.

Mazak Corp.

Ph: 859-342-1700

Circle 242

Lathe lets users move between manual and automated operation

A surprising (and some would say a disconcerting) number of shops in this country have no numerically controlled (NC) machine tools at all. Machine tool builders are now recognizing these shops as an important but overlooked market and are introducing products specifically designed to attract these first-time buyers. Bridgeport Machines Inc. (Bridgeport, Connecticut) for example, is marketing a Romi-built lathe with a Bridgeport control that it believes addresses the issues that have held these shops back.

Apparently, the idea is to overcome resistance to this technology and make entry into the world of CNC (computer numerical control) turning an easy one. The new lathe is even being called the EZ-Path.

So what has been causing some shops to stay away from CNC turning? Although the benefits of CNC turning for quality and throughput improvements are generally understood and accepted, the decision to move up to CNC turning can be a difficult one for a shop owner. First, there are the costs associated with new equipment. For a shop operating on a small margin, the prospect of any major capital expenditure is not appealing, particularly in a slow-moving economy.

Another consideration is CNC technology. There are lingering misconceptions in the machine tool market that CNC equipment is difficult to operate, and may even require highly trained, and costly, computer programmers to develop turning programs.

Yet customers are forcing the decision by demanding tighter tolerances, faster deliveries, and lower costs. Can a shop stay in business today if the owner doesn't move to CNC?

Bridgeport's new lathe is designed to break this dilemma by resolving concerns about ease of use and cost. The new lathe lets users turn parts manually or automatically, or in combination, for what the company calls an operator-paced move into automated turning. It is priced in the mid-$30,000 range, or roughly half what many CNC turning centers would cost.

Switching between manual and automated operation is not difficult so operators unfamiliar with automated turning can learn the system as they go and proceed at a pace commensurate with

their skill level. As turning skills grow, more of the operation can be automated. Key features are the dual electronic handwheels. These handwheels connect to encoders and servomotors which move the tool. Using the handwheels, which are located on the lathe apron, the user can turn, face, bore, as well as cut a taper, chamfer, or radius by hand.

Using the same concept, automated sequences can be overridden at any time by the operator when manual turning is judged more appropriate to the application. For example, when machining a casting, the inside of the workpiece might be turned using full automatic operation. Because casting dimensions vary slightly, even in the same lot, automated turning may not be appropriate for the outside of the casting because of the set-up time required. Each casting is, in effect, a different workpiece. Cutting a chamfer or radius on the outside of a workpiece like this is more efficiently done manually.

As the operator moves up the learning curve at his own pace, the lathe's programmability facilitates advancement. For fully automatic operation, the operator answers screen prompts on a nine-inch monitor. A fill-in-the-blank format simplifies the entering of part dimensions and machining data. The control system has a number of built-in routines for automatic turning, facing, grooving, drilling, and boring without the need to enter each cutting pass.

A teach mode allows the operator to first cut a workpiece manually, then automatically thereafter. By hitting one of two dedicated keys for a feed move or rapid move after each cut, the machine's position is stored in the lathe's two-axis microprocessor-based digital readout (DRO) controller. This controller calculates, stores, and displays part shapes, and provides a graphic preview of stored operations for program verification.

To keep costs down, the lathe is constructed using an H-bed design. The H-bed construction consists of four castings (base, headstock, bed, and tailstock support) that are bolted together. These castings are less costly to produce separately and assemble than a single large casting typically used for a slant-bed lathe. In addition, the H-bed design accommodates a workpiece up to twice as long as that expected on a traditional slant-bed. Clearly, the company recognized that the acquisition cost of the EZ-Path had to be attractive for short-run production, which is characteristic of the shops this machine is aimed at.

The EZ-Path lathe has infinitely variable power feeds and a rapid traverse rate of up to 250 inches per minute. The spindle motor provides a constant eight hp through a geared headstock. Finally, the company notes that the EZ-Path is compatible with its EZ-CAM part programming software, so it should be easy to integrate into existing computer-aided production set-ups.

When to use a collet chuck

Michael Minton

The three-jaw powered chuck is the standard workholding device for most CNC lathe users. This type of chuck is versatile enough to be used in a wide range of turning applications.

However, it's not the best chuck for all jobs. The collet chuck is an alternate workholding device that, like the jaw chuck, also uses mechanical force to hold the part being turned.

While a collet chuck lacks the capacity for the same wide range of workpiece sizes that a jaw chuck can accommodate, it offers advantages related to speed, accuracy and productivity that may be crucial for certain jobs.

Several factors figure into the determination of which type of chuck would work better. When evaluating a collet chuck versus a jaw chuck for a given lathe application, take all of the following factors into account.

Spindle Load Capacity

The lathe spindle has a maximum allowable weight based on bearing load capacity. If the combination of the chuck and the work accounts for too much weight, the bearings may be overloaded.

In applications where there is a danger of exceeding this limit, this very danger may dictate the choice of workholding. Jaw chucks tend to be more massive than comparable collet chucks, making the collet chuck an appropriate choice where weight control is needed.

Spindle Speed

A collet chuck tends to be the better choice for turning at particularly high levels of spindle rpm. There are two reasons for this.

One reason relates to the mass of the chuck. Given the same spindle horsepower driving a jaw chuck and a collet chuck, the more massive jaw chuck would take longer to accelerate up to speed. The acceleration time would extend cycle time and reduce productivity.

Another reason relates to centrifugal force, which becomes a significant concern at high speeds because it increases as the square of rpm. For example, doubling the spindle speed causes centrifugal force to quadruple. This force pulls chuck jaws out from the center and tends to reduce clamping force. But with a collet chuck, centrifugal force does not have a significant effect. Therefore, clamping force is more constant across the speed range.

Operation To Be Performed

A collet chuck applies clamping force all around the circumference of the part instead of just at select contact areas. The result is tight concentricity. This can be particularly significant for second-operation work where accuracy relative to the first operation is a concern. Even when a jaw chuck is used for the first operation, a collet chuck may be used for the second operation because of its precision clamping. A jaw chuck with bored soft jaws repeats within 0.0006 to 0.0012 inch TIR. A collet chuck typically provides repeatability of 0.0005 inch TIR or better. The collet chuck can also be adjusted for concentricity during installation to further improve secondary operation accuracy.

Workpiece Dimensions

Collet chucks are best suited to workpieces smaller than 3 inches in diameter. A collet chuck may also impose a limitation on the workpiece length. Specifically, a collet chuck limits the machine's range of axial (Z-axis) travel, because its length is longer than that of a jaw chuck. When the machining length of a workpiece is so long that just about all of the available travel of the machine is needed to cut it, then this requirement will probably dictate the use of a jaw chuck.

Lot Size

Very large and very small lot sizes both help make the case for a collet chuck. Where there are small lot sizes and lots of them, the collet chuck's advantage relates to changeover time. Swapping jaws takes around 15 to 20 minutes for a standard jaw chuck or 1 minute on a jaw chuck specially designed for quick change, but the collet in a quick-change collet chuck can be changed in l5 to 20 seconds. The time savings add up where changeovers are frequent.

Similar time savings related to clamping add up where lot sizes are large. A collet chuck takes less time to open and close than a jaw chuck, shaving cycle time by reducing the non-cutting time from one piece to the next.

Workpiece Size Range

Part of the reason a collet chuck opens and closes more quickly is that its actuation stroke is shorter. Compared to a jaw chuck, a collet chuck is more limited in the range of workpiece sizes it can accommodate.

Collet chucks essentially trade flexibility for speed. If part size is consistent, a collet chuck is faster. But where workpieces vary significantly in size, it may take a jaw chuck to accommodate the complete range of work.

Types Of Materials

For hot rolled steel, castings, forgings and extrusions, standard jaw chucks tend to work better because of the diameter variations inherent in all of these types of parts. On the other hand, cold rolled material tends to be more consistent in size and therefore better suited to collet chucks.

However, the absence of any diameter measurement is not necessarily an obstacle to using a collet chuck. Collets designed for non-round cross sections can be provided for extruded bars that are made to custom shapes.

Find these related resources on the Web:

Glossary of Chuck Types For basic information on the range of workholding available for lathes, this is one place to start. The list of chuck types and their definitions is the one used by AMT--The Association for Manufacturing Technology. On MODERN MACHINE SHOP ONLINE, the glossary is supplemented by links to lists of supplier companies offering the various chuck types.

Article Archive On Chucks

This collection of articles details unusual chuck types, chuck selection criteria and instructive examples of chuck applications.

For links to these articles, visit

www.mmsonline.com/articles/050203.html

For more information about chucks from ATS Workholding, call (714) 688-1744, enter 40 at www.mmsinfo.com to Visit Online Showroom, or write 40 on the reader service card

Collet Chuck Advantages

Light weight

Fast acceleration

Less affected by centrifugal force

Tight concentricity

Fast clamping

Fast collet change for part changeover

Collet Chuck Drawbacks

Limited range of workpiece sizes

Large axial dimension

Better suited to small parts

Better suited to workpieces with consistent diameter

The Subspindle Scenario

Turning machines with subspindles are often used in the kinds of high-volume applications where collet chucks can realize significant savings. With their ability to machine all of a part's faces in one cycle, these machines are often coupled to bar feeders for unattended production of a continuous succession of workpieces. In these applications, the savings in chuck

actuation time, which may be small for one piece, may add up to considerable time savings when multiplied across the production run as a whole.

The Chuck Arsenal

When choosing the most appropriate workholding between jaw chuck and collet chuck, a third option is also important to consider. It may be cost-effective to keep both chuck types on hand and change from one to the other as circumstances warrant. Changing from a jaw chuck to a collet chuck, or vice versa, should take no more than 20 minutes. The jaw chuck can remain on the machine to handle an unpredictable range of parts. But when the machine is to run a large batch, or several batches of parts that are consistent in size, then the productivity gain from a collet chuck may more than make up for the time spent on changing chucks.

Workholding Maintenance

Proper maintenance of workholding systems is important. In fact, it may be more important than machine tool maintenance. Most modem CNG machine tools have extensive logic programs

designed to watch and protect the machine tool from machine-related problems. But similar automatic safeguards for machine accessories generally don't exist. What's more, a failure of the workholding system--whether due to operator error or damage from some past crash--can be catastrophic to the machine and work, and dangerous to the operator. Standard practice should include a brief check of the workholding, making sure everything is tight and nothing has moved, every time a new component is loaded into the workholding device.

About the author: Michael Minton and Michael Sullivan work for ATS Workholding of Anaheim, California. Mr. Minton is eastern regional sales manager. Mr. Sullivan is vice president.

Powerful Potential of Peel Grinding

Aronson, Robert

A grinding wheel "lathe"

Why consider peel grinding? Among the reasons: high precision; ability to make complex, small features; works well on hard materials conventional machining can't handle; and the falling cost of CBN.

Peel grinding is one of those techniques that has been around for some time-usually applied to rather specialized tasks. But, changing industry needs have recently given it more prominence.

Basically, peel grinding uses a narrow grinding wheel, usually 0.25" (6.4 mm) or less in width, to grind a part. Because the process is much like cutting with a conventional lathe, it is a major competitor to hard turning.

The advantages of peel grinding include:

* Dramatically reduced cycle time.

* Combined operations.

* Decreased throughput time. Only software needs to be changed to accommodate different parts, as opposed to tooling changes.

* Ability to grind dissimilar metals on one platform.

* Complex shapes can be formed without a profile wheel. The thin wheel functions like a single-point tool under CNC control. Therefore it's simple to change profiles without changing wheels.

Grinding-wheel manufacturers also see a positive side to peel grinding. Mike Hitchiner, Vitrified Product Manager St. Gobain (Romulus, MI) notes, "Since China has become a major supplier of CBN grit, the prices have dropped for this material," notes Hitchiner. "Therefore, wheel prices are lower, and this encourages more use of peel grinding.

"In addition, more economical wheel bond technologies have made it practical to use peel grinding. For our wheels, the bonding material is mainly vitreous but with some use of metal.

Typically the wheels are 350-450mm diam with widths of 10-15 mm. The new bond technology also helps make peel grinding cost effective.

"At the same time, US manufacturers are being influenced by international companies that use the process with oil lubricants. Lubrication is a big factor. In the US, most manufacturers

were going to water-based fluids because of environmental issues. But Europe stayed with oil, which can improve wheel life from three to 20 times. Now the US is slowly migrating back to oil even though with oil you have to have mist-extraction devices."

Automotive is one of the major growth industries for peel grinding because of the growing interest in transmission manufacturing. Precision requirements are greater both because of increased complexity of six-speed transmissions and the need for greater efficiency and quieter running. There is particular emphasis on gear grinding.

"Finish with peel grinding is in the 0.24-0.4 Ra range, and because of the cutting speed this process can be quite a bit faster than conventional grinding," says Hitchiner.

The physics of peel grinding also brings advantages. "You concentrate all the grinding force in one small area with peel grinding," says Hitchiner. "This tends to drop the forces on the part as compared to straight plunge grinding.

Therefore, you don't use the same horsepower and part changeover is easier.

"With force concentrated like that, you can cut a lot of material with a small wheel. The actual power required per unit volume of metal removed goes down by a factor of two or three. So you can remove the same amount of metal with a 10-hp [7.5-kW] spindle in peel grinding as you can with a 20 or 30 hp [15 or 22.5-kW] spindle in plunge grinding operations with a much wider wheel. The larger wheel needs more power to turn and has more coolant drag.

"In selecting a machine for peel grinding, you want overall high stiffness and a good bearing system. Wheel speed should be in the 90-140 m/sec range with rpm in the 1000 to 10,000 range," he concludes.

"Two features have changed in peel-grinder performance in the last few years: increased surface speed, to accommodate greater production speed, and shorter dressing intervals, because of improved wheels," explains Denis Fritz, vice president and COO, Erwin Junker Machinery Inc. (Elgin, IL).

"But the amount of improvement can't be linked to a specific number. Any production estimate is productspecific. But we have seen cases of 75,000 to 100,000 parts per wheel.

"We have machines with a B axis and up to three spindles. This provides a lot of versatility. So a single machine can, for example, provide OD peel grinding, a snap-ring slot, and special grooves. We recently introduced a machine with two independent wheelheads that enables the user to grind two crankshaft pins at the same time.

"Another advantage is that we can grind lead free. (Lead free means that there is no directional pattern left by the wheel, this is important for seal diameters, as lead would carry oil out through the seal).

"It's important to keep the grit as sharp as possible, but dressing frequency is not commonly done on a fixed interval. It's usually necessary to evaluate a part's surface. When grit gets dull, it rubs rather than cuts, and this is obvious from a look at the part.

"One of our clients, a drill manufacturer, formerly made his products in a five-step operation that included profiling, tapering, cutoff, centerless, and chamfering. We were able to do the same job in one grinding machine, using two wheels with a singlesetup operation.

"In another case, a client was responsible for making 250 different transmission shafts. He formerly did this with 10 machines. We replaced them with two of ours. Part change only required a readjustment for shaft length and calling up a different program.

"It is sometimes a tossup between hard turning and peel grinding, but hard turning cannot achieve diameter tolerances better than 10Aµm holding a high Cpk.

"We have noticed that US manufactures still hesitate to use CBN. They are content to stay with what they are familiar with. But in the rest of the manufacturing nations, this market is taking off. In some cases, India is surpassing China in some areas of technology. US manufacturers have to wake up and start looking at the new technology, or they are going to be replaced," Fritz concludes.

Flexibility is one of the main attractions of peel grinding, and greatly responsible for its growing popularity. This is particularly true among manufacturers who are faced with reduced lot size and the need to minimize changeover time.

"Another key advantage is that there are no driver dogs," explains Nelson Beaulieu, United Grinding Technologies (Miamisburg, OH). "Typically, this is a ring mounted on one end of the part. You use only center pressure to drive the components. Male or female centers can be used, and for some specific applications it's possible to use synchronous workheads and tailstocks to drive the parts. This eliminates a lot of up-front cost when trying to orient a part. There is no workholding prerequisite.

"For our machines, we recommend sintered, galvanic bonded wheels. Only about 25% of applications use vitrified bonded superabrasives. Wheel speed is typically in the 80-110 m/sec range. "We offer a number of peel grinding machines. For example, our Studer line is available with linear or digital drives, and can carry a variety of powered wheels, in either a single fixed wheelhead design or using a turret style on a twin-wheelhead platform.

"Offering a platform with the ability to use one or two wheelheads and a turret gives the customer maximum flexibility by providing the ability to call up subroutines and apply a grinding wheel that is specifically matched to a batch of components or shapes.

"One of our fastest growing applications is peel grinding of multiple-diameter shafts, such as those in automotive transmissions. They can be ground in a single setup using a single or multispindle machine. Typically, when grinding at a speed of 3 mm/sec lateral feed, we can remove 1 mm of material at full depth. Often we replace plunge grinding or conventional machining where interrupted cuts and multiple diameters eat up a lot of cutting tools and setup time.

"Our newest machine is the Kairos, which combines conventional part turning and peel grinding. It's particularly effective when working with sintered metal parts. This material tends to pit, and you get a feathering on a face or an edge with conventional turning."

Cutting-tool manufacture is a key peel-grinding application for Rollomatic (Mundelein, IL). "We notice a strong trend to carbide tooling and small parts that require a diamond wheel," says Eric Schwarzenbach, president. "RPM is also up to 8000 and wheel surface speed is now in the 16,000-20,000 fpm [4876-6096 m/min] range.

"We have found an increasing number of applications for our machines in small [1/4-3/8" or 6.35-9.5-mm] diam injection molds, because of the precision and automation we offer. Parts can be ground automatically on one machine instead of multiple machines with multiple setups.

"To accommodate the newer feeds and speeds, we have modified our machines. Our newest model will have an increased surface speed capability in the 12,000-20,000 fpm [3658-6096 m/min] range. Prebalancing is essential for operation at those speeds.

"With standard abrasive wheels, you don't need those speeds because of their larger diameter [around 16-20" or 400-500 mm]. Their surface speed is high. With diamond and CBN wheels, maximum diameter is abouti O" [250 mm]. The reason is cost. It would be very rare for someone to buy a 20" [508 mm] diamond or CBN wheel.

"One of our key features is pinch grinding, a process in which we 'pinch' the workpiece between a roughing wheel and a finishing wheel. This allows the user to rough and finish in the same setup. Metal-bond wheels work better than resin bond for roughing, while we suggest a polyimide resin wheel for high-gloss finishing.

"The machine uses a V-block shank-guidance system, instead of a tailstock holder, which is a Swiss-turn-like 'through-feed bushing.' This provides constant support until the workpiece form is completed. It also simplifies part handling for automated work.

"The corner area of the peel-grinding wheel is critical in peel grinding. You want to minimize the contact area to be able to cut small features and to minimize heat generation. Our wheels are relieved 10Â° radially and 3Â° axially, so that the wheel does not drag and a good surface finish is achieved. Any new wheel has a true single-point edge, but this quickly wears into a radius. With our wheels, that's about 0.001" [0.03 mm], which is a small area of contact."

The two major markets for peel (and pinch) grinding are grinding components and cutting tool blanks. Pinch grinding is suitable for grinding products such as precision punches, micro pins, and mold components. The purpose is to have minimal contact between the wheel and the workpiece in order to reduce the introduction of heat.

With pinch grinding, part deflection is minimized. It can do both roughing and finishing operations simultaneously. Examples are the Rollomatic ShapeSmart 148P4 or NP4, both of which are cylindrical grinders that utilize pinch grinding. The pinch grinding process with a roughing and finishing wheel is patented by Rollomatic.

Europeans have widely accepted peel grinding," explains Denny Rowe, Weldon Solutions (York, PA). "Now US manufacturers are starting to show an interest in peel grinding in two primary areas:

* As an alternative to conventional formed-wheel plunge grinding to reduce setup time by eliminating grinding wheel and dresser-roll changes between parts.

* As an alternative to hard turning for improved statistical control, lower tooling cost-per-piece, and as a better way to handle interrupted cuts as on keyways and slots that can be difficult to address with singlepoint turning tools."

Peel grinding with vitrified CBN abrasives, has also been proven to be much more productive on difficult to cut materials such as Inconel and soft stainless. This is accomplished by "scrubbing" the wheel during the grind cycle with high-pressure wheel-cleaning systems.

Weldon began its peel grinding effort in 1997 while working with the aerospace industry. "We found that the peel-grinding process was perfectly suited for grinding complex forms in exotic, tough materials that tended to 'load' the grinding wheel when using conventional abrasives and plunge-grind processes," says Rowe. "For example, removing up to 0.030" [0.8 mm] stock from the diameter of an Inconel shaft in a conventional process would require that the cycle be interrupted twice to dress the wheel for every part. Peel grinding with vit-CBN allowed us to grind up to 20 parts without dressing.

"This same process was found to be successful for high-stock-removal applications in hard steel such as 52100 and D2, allowing very short cycle times without burning or cracking the surfaces. We have found that high-speed CBN peel processes grind much cooler and with greatly reduced forces."

Weldon is currently developing peel-grinding processes for mild-steel automotive components to take advantage of the quick changeover from part to part and long-term tooling cost savings for the customer.

Weldon has concentrated on developing these processes using water-soluble coolant. Although CBN wheel life is better when using straight oil coolant, the poor heat dissipation properties of oil make it difficult to hold the close tolerances required in grinding applications. "Water-soluble coolant allows us to maintain high levels of part quality at faster rates, which more than offset the tooling costs. We have also found that the US customer base is hesitant to accept the environmental and safety problems associated with straight oil processes," Rowe states.

Requirements for successful peel grinding:

* Machine tools must have a higher static and dynamic stiffness than that typical of conventional grinders designed for use with aluminum oxide abrasives.

* Grinding spindles must be designed to handle wheel speeds up to 140 m/sec.

* Rigid electric rotary dressers are required for wheel conditioning.

* Size-control gaging (post-grind) with feedback to the machine control is required primarily where automation is used for machine tending.

* Coolant temperature control is required for maximum process stability."

* Acoustic emissions sensor systems are required for automatic "touch dressing" in increments of approximately 1 pin. (2.5 Aμm).

* High-pressure wheel scrubbers are required to prevent wheel "loading" that can be detrimental to CBN grinding wheels.

WANT MORE INFORMATION?

Circle these numbers on the reader service card for more details on the equipment mentioned in this article.

Robert Aronson

Senior Editor

Plasma cutter lets fabricator's business grow

Kirk & Blum (Lexington, KY), an industrial sheetmetal enclosure and process-piping system fabricator, had always relied on shearing equipment, saws, presses, grinders, notchers, punchers, and welders foi many types of custom sheetmetal and steel plate fabrication projects. Recently it found that its mechanical tools could not handle the complex designs, precise specifications, and just-in-time delivery schedules custom orders required.

It began declining manufacturing contracts or transferring work to other K&B locations to meet product specifications and schedules. It was also reluctant to pursue new custom-parts manufacturing contracts aggressively. "New clients needed their orders filled on demand," explains R.J. Blum, K&B's president. "Before we could bid on these contracts, we needed to increase our accuracy and speed up deliveries to within 24 hours."

Drawing on the shop's previous experience with plasma cutters and the advice of Kentucky Utilities Company (KU), the company's power supplier, and the Electric Power Research Institute's Center for Materials Fabrication, K&B decided to install a computerized plasma cutter at its Lexington facili ty. The cutter made fabrication on demand possible for KAB.

K&B's high-definition plasma cutting systems have an 8 X 20' (2.4 X 6 m) cutting area. A single moving head supports two torches that can cut through 2" (51 mm) of material with accuracy within +/-0.01" (0.25 mm) on most materials 3/8" (9.5 mm) or thinner. For materials 1" (25 mm) or thicker, an air drill with scribing and etching capabilities pierces a starting point. The cutting table has special exhaust dampers, allowing all air used in the plasma cutting process to be captured, cleaned, and recycled.

K&B's 200 amp plasma equipment draws 20-30 kW and averages 480 kW per day, for an average cost of $19 per day. The company runs the cutting operation two shifts a day, occasionally operating three shifts to meet increased demand. Ongoing maintenance costs are primarily nozzle and electrode replacement, at a cost of $8 tc $15. Each replacement is good for 700-1000 ignitions.

Today, says Bill Wells, K&B vice president and manager of the Lexington facility, "When customers provide us with schematic diagrams and engineering specifications, we load them into the computer and cut the parts. Using the computer to work directly from customer specification sheets or drawings also helped cut our delivery time from roughly three days to under 24 hours."

Computerized plasma cutting simplifies business, says Wells, because the cutters tackle unique geometries with ease and store specifications on disk. With computer memory, it's fabrication on demand. Parts need not be warehoused for repeat orders. The $250,000 investment in the plasma cutter has improved overall cost effectiveness. "Computerized cutting lets us nest parts more closely, which boosts the number of parts we get per sheet," says Wells.

Since KAB manufactures control panels for Kentucky Utilities, KU has been able to observe the results "Using the plasma cutters, K&B has been able to deliver control panels in a fraction of the time it took us to produce them ourselves," said Phil Roberts of KU. As for K&B, it's no longer in a no-growth mode. Blum is now aggressively pursuing new business because he knows the company can meet any product specifications and delivery schedules a new customer throws at him.

Bar feeder cuts shop costs

Installing bar feed systems to complement turning operations helped reduce manufacturing costs and improve controls over the machining process for a large Tennessee job shop.

Southern Fabricators (Memphis) manufactures steel components, ranging from the size of a quarter up to 30' (9.1 m) and longer for OEM products, such as parts for trailers and rail cars, and large oil pans for locomotives. The job shop employs a wide range of machine tools with more than 230 machines, including 30 CNC machine tools, plasma and laser cutters, mechanical presses, and programmable press brakes ranging from 45 to 2000 tons (400 kN to 18 MN).

In order to meet demand, Southern Fabricators had subcontracted some parts to local machining vendors. Growing order levels, however, prompted management to expand its machining capability. "We needed to install a new lathe," says Norris Roberts, Southern Fabricators' tool engineer. "To justify the new expenditure, we had to bring those subcontracted parts back in-house."

With the majority of those parts machined from round stock, the company decided to install the lathe and the first of seven Rhinobar heavy-duty, hydraulic bar feed systems from LexairInc., (Lexington, KY). The Rhinobar systems handle 12' (3.7 m) stock and the bar feed systems are available in tube sizes ranging from 0.25 to 2.75" (6.4-70 mm) in quarter-inch increments.

Southern Fabricators paired the Rhinobar bar feed systems with Cincinnati Machine (formerly Cincinnati Milacron) CNC turning centers-a Cinturn, two Falcon 400s, two Falcon 200s, and two Hawk 150s. It produces a wide variety of parts, including dies, spacers, pins, form tooling, dowels, and bushings, on the turning centers.

Complexity is the watchword for Southern Fabricators, as the shop bores, turns, or faces many types of parts. Production parts include those with turned contours, angles, or steps, machined out of materials such as cold-rolled and hot-rolled stainless steel, brass, and D2 tool steel. Part sizes range from 4 to 18" (0.1-0.5 m) diameter form tooling to pins that are 0.25-0.35" (6.4-8.9 mm) in diameter and 0.5-8" (12.7 mm to 203 m) long. Typical operations include turning shafts and drilling a center hole, and after the part is cut, the bar feed system advances another increment of stock into the turning center, with the whole operation taking about 45 seconds.

"We've been able to reduce our manufacturing costs by about 50% by machining these parts ourselves," notes Roberts. Once the machine operator loads the bar and starts the operation, he or she is freed for other duties, reducing the need for additional labor, adds Roberts.

With the installation of the turning centers and bar feeders, Southern Fabricators' turning output has tripled. And because the bar feed system eliminates chucking and rechucking of the workpiece, the turning centers can run untended for long periods of time. An endof-bar signal and auto pusher retraction alerts the operator when the Rhinobar is empty.

Since the bar feed system provides a high degree of stabilization to the round stock, the quality of machined parts has improved, says Roberts, who adds that the basic print tolerance at the shop is 0.0005 (0.013 mm). In the Rhinobar's design, oil fills the gap between the bar stock and feed tube, acting as a noise-damping support that provides a high degree of stability.

As the bar begins to turn, hydrodynamic forces move it toward the center of the feed tube, and centering forces increase as bar speed increases. The system's oil recuperator also features a bearing-mounted revolving support bushing that helps stabilize the bar stock, eliminating vibration. This support, working with a dynamic bearingmounted pusher cone that maintains contact with the bar chamfer, allows much higher turning speeds than other bar feed systems, according to the company. At Southern Fabricators, application speeds typically range from 200 rpm to 4000-5000 rpm, according to Roberts, and the front swing-out mechanism includes a large barrel clamp to further reduce vibration.

The expanded capabilities have allowed the job shop to perform more secondary turning operations for customers, and enabled the company to add significantly more production work for manufacturers that are seeking to do less machining and fabrication and more assembly operations. Circle 224.0

CNC, 3-Axis Tube Bender meets basic industry requirements

Powerbend machines employ hydraulically-powered mandrel tube benders capable of handling carbon steel tube from 50-125 mm dia. With respective maximum bend angles and CLR of 180[degrees] and 250 mm, units feature externally mounted hydraulic valves and filter; plug-in electrical connections to valves with position indicators; and hydraulically powered, direct acting reaction arm. Allen-Bradley alphanumeric keypad offers 1,000 program storage with 16 bends max per program.

World-leading tube-bending and end-forming technology specialists, AddisonMckee, of Preston, UK, and Wilmington, USA, have developed a high-performance, lower cost tube bending range aimed specifically at the more basic requirements of the tube bending industry.

Benefiting from AddisonMckee's reputation for quality, precision and reliability, at an exceptionally competitive price, the new Powerbend range combines years of proven design techniques to provide the high levels of accuracy, repeatability, prompt tool change and ease of operation as required by today's manufacturing industries.

High quality solution of international standards

"As the leading innovator and provider of tube bending technology," commented AddisonMckee Sales & Marketing Director, Peter Chapman, "we have been able to use our expertise to provide a high quality solution for those companies who would ideally like to invest in AddisonMckee equipment, but have not always been able to justify the sophisticated capabilities that some of our machines offer. In the new Powerbend range we have created a choice of exceptionally durable models of international standards and revolutionary design, each with the added advantage of an exceptionally attractive price point. From launch, there will be a choice of 50mm, 75mm, 100mm and 125mm diameter capability models."

Impressive capabilities

Hydraulically-powered mandrel tube benders, capable of bending carbon steel tube from 50mm diameter to 125mm diameter, the models in the new Powerbend range offer maximum bend angles and CLR of 180[degrees] and 250mm respectively.

Machine beds and tanks are of one integral assembly. Hydraulic valves and filter are externally mounted for easy access. Electrical connections to the valves are of the plug-in type with position indicators. And the bend head is mounted to the bed on slideways and is adjusted laterally for CLR setting by means of a lead screw.

Main spindle

Mounted on heavy-duty taper roller bearings, the main spindle carries the bend arm. Rotation is by hydraulic cylinder connected to the spindle by chains. The angular position feedback to the servo is by encoder, through instrumentation grade gearing from the main spindle.

Simple to locate bend die

Easily located on the bend arm on double drive keys, the bend die is retained by a single nut if a tool spindle is used or bolted directly to the tooling platform for small CLR bending.

Clamp die mounting slide

The clamp die mounting slide is hydraulically powered with toggle mechanism for maximum gripping pressure and operated in a rise and fall motion to clear the tube on subsequent Y axis feeds. The clamp block moves across the clamp slide by lead screw for CLR adjustment. Clamp tooling is drop-in type with simple height adjustment. Reaction arm / follower slide

Hydraulically powered and direct acting, the reaction arm carries the follower slide which takes the pressure die and is infinitely variable for speed via valve adjustment. The drop-in pressure die has simple screw adjustment for ease of alignment with the bend die.

Wiper die mounting

A rigid mounting post with three axis adjustment for easy set-up ensures good quality bends and long die life.

Plane of bend unit

On all models, the tube carriage (Y axis) moves along the machine bed on precision low friction bearings. Linear motion is by AC motor drive, with position feedback by absolute encoder. The collet is carriage mounted, with rotary motion (B axis) provided by AC motor, with absolute encoder position feedback for precision and repeatability. The master collet is designed to accept segments for the required tube diameters, clamping is by hydraulic cylinder actuated mechanism.

Mandrel unit

Fitted as standard with hydraulic actuation, the mandrel unit includes one 22mm diameter quick-change rod. Anticipated mandrel retraction is standard for high bend quality. Additional rods and automatic mandrel lubrication are offered as optional extras.

Allen-Bradley control

Programming of all Powerbend models is provided by an Allen-Bradley alphanumeric keypad. The many simple routines and features available include: tool monitoring to prevent collision; inch/imperial data input; 1000 programme storage; maximum 16 bends per programme capability; Y, B, C axis data input and automatic release of tube prior to final bend to prevent follower die / collet collision. AddisonMckee Powerbend features at-a-glance:

o Allen-Bradley Control Unit

o Allen-Bradley Drives & Motors

o Rexroth Hydraulics

o Foot pedal cycle start

o Clockwise Rotation of Bend Arm

o Recapture Software

o Anticipated Mandrel Retraction

o Safety Scanner & Barrier Rail

o Operator manual and Circuit Diagrams

o CE Mark

Powerbend 75 technical data

Axis data

Y = distance between bends, B = angle between bends, C = angle of bend

Axis speeds

Y 60m / min

B 50 rev / min

C 13 rev / min

Axis accuracy

Page 15

Y +/-0.1mm

B +/-0.1[degrees]

C +/-0.1[degrees]

Operational parameters

Maximum outside diameter 76mm

Minimum outside diameter (guide) 20mm

Maximum wall thickness (carbon steel) 2.5mm

Maximum CLR 250mm

Minimum CLR 0mm

Maximum bend arm rotation 193[degrees]

Maximum tube length over mandrel 3000mm

Working height 1015mm

Tooling centre line height from bend arm 50mm

Mandrel stroke 150mm

Follower stroke 450mm

Reaction stroke 100mm

Hydraulic tank capacity 530l

Hydraulic system pressure 140 Bar

Length rearwards 5200mm

Bend arm radius 700mm

Length forwards 150mm

Reaction arm protrusion 1300mm

Overall width 1930mm

Height 1800mm

Weight 4.5 tons

C axis stall torque 11.5kNm

Safety equipment

Conforms to relative territory statutory requirements

Optional equipment

Mandrel automatic lubrication

Slide-way lubrication

Air-conditioning

12mm dia. mandrel rod

16mm dia. mandrel rod

Need a light touch?

Noaker, Paula M

The force isn't with you during laser processing, but the impact can be significant. Permanently mark titanium pacemakers to a depth less than 0.001" (0.03 mm) without damaging internal electronics. Slice through abrasive composite materials without high tool wear or delamination. Cut, drill, and weld with one laser, one setup. Use simple fixturing since cutting forces are infinitesimal.

Three to five-axis laser machining centers routinely outpace processes such as CNC milling or electrical discharge machining on the "difficult" parts, those that chew up conventional cutting tools or have complex geometries requiring multiple setups and long cycle times. Key benefits of 3-D laser machining include the following:

* Flexible part processing. For example, the Bystar CNC three-axis laser system from Bystronic Inc. (Hauppauge, NY) has a 5 x 10' flying optics format-stationary workpiece, moving cutting head that accommodates flat sheets and round or square tubing and profiles. Changeover to 3-D cutting takes 5-15 min (depending on the part) because the CNC rotary axis is integrated into the machine frame. High-speed cuts are consistent irrespective of part size. Less floor space is necessary than with a moving table and a stationary laser head, and there are no clamp dead zones.

Improved laser control. The laser on the 3020HT five-axis CNC laser processing machine from MC Machinery Systems Inc. (Wood Dale, IL) provides rectangular-waveform pulsing up to 3-kW peak power. Better pulse control--including control of pulse on and off times-means faster cuts, capability to make sharp points, improved small-hole drilling in thick work materials, and reduced heat-affected zones (HAZ). The 3020HT's cross-axial-flow resonator design also targets "maintenance-free" operation and lower operating costs-consumable costs are as low as $0.02/hr. In addition, there is no warm-up time, and the laser can begin producing parts in 45 sec (see Managing Editor Jim Koelsch's article, "Be an Enlightened User" in this issue for more about the reliability and uptime of production lasers).

Programming flexibility. Programming options for Prima US Inc.'s (Farmington Hills, MI) laser systems range from on-machine teach pendant programming, the drawback being the machine isn't cutting, to an off-line simulator that can mate with a tracing machine and Prima's Forma CAD/CAM system, designed specifically for 3-D laser cutting machines. This allows building the 3-D cutter path trajectories directly from the CAD files.

High accuracy and repeatability. Consider the TLM Series of five-axis carbon-dioxide (CO sub 2) laser cutting systems from NTC Laser Machine Group, Marubeni America Corp. (Southfield, MI). Positioning accuracy for the TLM-404, 408, and 608 is 0.001 ipf (0.08 mm/m) in X, Y, and Z axes and 0.01deg in Alpha and Beta. Repeatability is 0.0005" (0.013 mm). Accuracies are slightly higher for the TLM-G10, which has a work envelope of 74.80 x 122.04'. Laser options include Rofin-Sinar (Plymouth, MI) switch-mode CO sub 2 lasers-the 1500W model RS-1200-SM with 5-kW peak power or the 1950-W model RS-1700-SM with 10-kW peak power.

THE SHAPE OF THINGS

Three to five-axis laser machining systems provide more access to part surfaces, even complex geometries, than conventional machine tools. On flying-optics (moving beam) three-axis systems, laser movement typically provides the major axes of movement: X, Y, and laser head rotation (include Z and tilt for a five-axis system). Tom Burdel at Bystronic reports gantry systems, which typically have the largest work envelopes, provide flexibility to gang several part setups on one table or to replace the table with a shuttle-type positioning system or custom workholding. This can allow processing a larger part than might seem possible based on axes dimensions. Rotary tables can add 3-D contouring capability.

The midsize machine is often a moving-beam cantilever-type system with the laser mounted at an angle to the part instead of above it. For example, Prima US's five-axis Optimo laser centers are flying-optics, gantry laser robots with working volumes up to 160 x 88 x 40" (X, Y, Z). The company's Rapido 5 cantilever machine provides 125 x 60 x 24" (X, Y, Z).

Lumonics Eden Prairie Div. (Eden Prairie, MN) provides three Laserdyne five-axis machining configurations: gantry, cantilever, and composite. The smallest machine has three moving-beam axes and two that are moving table or part. It has a smaller footprint, with one part loaded at a time?, and is aimed specifically at processing small, intricate 3-D parts requiring high accuracy.

"We use CO sub 2 and Nd:YAG [Neodymium Yttrium Aluminum Garnet] lasers from a variety of manufacturers, including Lumonics," says Lumonics' Ron Sanders. "YAG systems are more common on the composite frame, followed by the cantilever. Rarely have we mounted them to large gantry systems." High-power carbon-dioxide (CO sub 2) lasers remain the production workhorses, but continuous-wave (CW) Nd:YAG lasers have reached 2-kW average power. Another plus in harsh manufacturing environments is their capability for fiber optic beam delivery. The laser source stays in a clean, protected environment, while the light traverses along fiber optics to the shop floor. For example, the CW Nd:YAG laser from Hobart Lasers & Advanced Systems (Troy, OH) can transmit up to 2.4 kW through a 150-m-long, 0.6-mm fiber optic cable, using computer-controlled motion systems or articulated-arm robots, for applications ranging from cutting and welding to surface treating.

To help defray high costs associated with Nd:YAG lasers, fiber optic beam delivery allows two workstations to share one Nd:YAG laser beam using a production-rate multiplexer for beam switching. A station processing a thick work material also can draw power from two lasers with little loss in working volume.

Engineers at Motoman Inc. (West Carrollton, OH), a Hobart-Yaskawa joint venture, report CW Nd:YAG transmissive efficiency (the percent of loss along the fiber optic) is now better than 90%. A typical C02 beam delivery system requires a minimum of one beam bender per articulated axis. Transmissive efficiency of clean benders is generally 98-99.5%, but cutting efficiency drops as they accumulate dust and other contaminants. CW Nd:YAG lasers don't have this efficiency loss because the beam delivery system is sealed.

COMPARISON SHOPPING

The capital equipment outlay for a high-power Nd:YAG laser is till, one estimate, almost 20% higher than for a mutikilowatt CO sub 2 unit. Operating Costs also are higher. One reason is flashlamps required to produce the beam must be replaced after so many thousand operating hours. Nevertheless, the decision to buy an Nd:YAG or CO sub 2 laser depends more on the application: work material, part thickness, processing rates, even accuracy.

Both lasers produce a monochromatic, coherent light beam in the infrared spectrum that bombards the part surface to create localized heating, melting and resolidification as in welding, or complete vaporization required for cutting. The Nd:YAG wavelength is 1.06 microns. The CO sub 2 wavelength is 10.6 microns. To comply with safety standards, Rofin-Sinar Vice President Richard Walker says both lasers require shielding. The only difference is you can shield the CO sub 2 with materials like plexiglass. YAG systems require more costly shields.

Walker notes typical production YAG lasers provide 300-500-kW average power, while it is more common to have multikilowatt CO sub 2 systems. YAGs can cut and drill thicker materials because they provide more peak power and energy per pulse than CO sub 2 systems with the same average power. For instance, a 500-W YAG may generate 10-kW peak power. A CO sub 2 laser able to pulse will probably reach two to four times average power. Unlike CO sub 2 systems, however, YAG's often don't have adequate average power for production welding. And CO sub 2 processing rates are usually higher.

A YAG laser also can look through the focusing lens in real time to find a specific detail on the part, so locating required features before cutting is faster than with a CO sub 2 system.

Expect CO sub 2 referencing capability to begin improving, however. Lumonics, for example, recently introduced CO sub 2 systems with Teach Vision, where small television cameras aid part location.

Comparing a 2-kW YAG to a 2-W CO sub 2 beam is a little like comparing apples to oranges. The wavelength is shorter, yet the YAG laser's mode structure is such that it will not focus to as small a spot. A 400-W YAG laser might produce a spot of 0.008-0.10" compared to the 0.004-0.006" spot produced by a CO sub 2 laser. According to Lumonics's Sanders, this translates to a large difference in processing capabilities.

Nonmetals absorb beam energy better from a CO sub 2 laser than an Nd:YAG because of the high absorption characteristics at the 10.6-micron wavelength. Both lasers slice through common metals, but the YAG can also process certain reflective materials like gold, silver, copper, brass and a few other highly conductive, reflective materials. There also are less problems with HAZ. For instance, Steven Dolan, vice-president, HGG Laser Fare (Smithfield; RI), which specializes in laser processing, estimates a 0.010"

(0.25 mm)-diam beam will create approximately 0.002" (0.05 mm) HAZ (20% of beam diameter) on either side of the cut.

DRILLING BITS

While high-power CO sub 2 lasers do most laser welding, Nd:YAG systems see a lot of use drilling high-precision, small holes. While percussion drilling expends a lot of energy, it can outpace electrochemical machining and electrical discharge machining in some applications. In material less than 0.100" thick, the laser uses three to four pulses to break through it and the remaining bursts for sizing the hole and reducing taper. Operators also can produce holes at an angle close to the horizontal and in areas inaccessible to other machining methods.

Trepanning to make a hole uses a tightly focused beam and the motion system or rotary tables to start a hole in the middle of the circle (sometimes by percussion drilling), and then cut the circle perimeter. Orbiting, an outgrowth of trepanning, rotates the focusing mirror to make the hole. The drilling process required depends on the hole specifications, work material, and volume to be removed, notes Dolan. For instance, drilling a composite with conventional machining techniques can be difficult due to the work material's inhomogeneous composition and its hardness and abrasive nature. Other potential problems are excess tool wear and delamination.

Laser processing melts and seals the material not vaporized, leaving an unfrayed hole or edge. In one application, HGG Laser Fare had to trepan 8800 0.125" (32-mm)-diam holes in a slightly bowed Kevlar noise-suppression panel. At first, engineers used a 1200-W CO sub 2 laser in pulse mode, with 300 W overall power output. The laser beam was stationary while the part moved under it. This method had several drawbacks. First, the 6 hr/panel cycle time was too high.

Tooling configurations limited cutting speeds, and inertia problems caused occasional over-travel and slightly elliptical holes. To solve the problem, engineers attached an orbital cutting nozzle to the lens focusing assembly. This allowed rotating the lens to focus on a stationary part. Cutting speed increased because the nozzle assembly can move faster than the tooling table. Engineers also designed an autofocus device for the orbital lens assembly. Since conventional capacitance-measuring techniques only work on conductive materials, they used a HE-NE laser beam to triangulate positions and automatically adjust focal distance from the Kevlar part.

Manufacturing engineers can now make holes in 0.25 sec. Setups are less complex, so what once took six hours is now done in two. Higher cutting speeds also reduce beam exposure time to help eliminate part damage such as charring.

Another application involved percussion-drilling thousands of 0.001-0.002" (0.025-0.05 mm)-diam holes in a titanium-based composite. Here, Dolan's company used a YAG laser fitted with special optics. To be cost effective, processing had to be done on-the-fly (by synchronizing pulses with work material movement, and having each pulse vaporize a hole). To avoid repeatability problems related to synchronizing positioning equipment with the laser controller, the engineers developed software to coordinate beam pulse speed (pulses/sec) with travel parameters, such as speed and distance, while accounting for laser firing.

DOING MORE WITH LESS

F&B Manufacturing Co. (Phoenix, AZ), which makes hydroformed parts and assemblies for aerospace, computer, and medical applications, also received substantial productivity gains with laser machining. On a 625 Inconel detail part that used to require CNC milling of the flange perimeter, Engineering Manager John Stewart reports boosting feed rate by 60:1. "The transition to laser machining went smoothly," says Stewart. "We were making parts the first week and in full-scale production within a couple months. We justified the system by identifying the parts that would derive the most benefit from it. As a result of this evaluation, we now target the following parts for laser machining: hard-to-machine high-temperature alloys such as Inconel 718; complex trim geometry; parts requiring pierced holes smaller than one stock thickness; parts requiring cutting, drilling, marking, or welding; and parts requiring expensive dies or next-day turnaround."

One part benefiting from laser processing is an aerospace combustion liner. Before, it required turning, milling, and drilling. Pierce and slot dies were necessary; setups were numerous and time-consuming. The process flow involved trimming, refixturing, hole drilling, often at shallow angles to the surface, and then cutting complex shapes. Another operation serialized the part. According to Stewart, the company now machines and marks this part and others on a five-axis Lumonics Laserdyne 780 BeamDirector(TM) with a T-slot table, rotary index table, a 1.5-kW CO sub 2 laser, and standard clamps.

Programs control all axis motions and laser process parameters. Feed rates average 30-60 ipm (760-1520 mm/m). Most applications involve making 0.015 to 0.020" (0.38-0.51-mm)-diam holes in 0.020-0.032" (O.81-mm)-thick stock, although operators have cut 0.125" (3.2 mm)-thick aluminum, 0.5" (13 mm)-thick cold-rolled. steel, and 0.375" (9.5-mm)-thick stainless.

"Most aerospace work has rigid specifications controlling edge conditions, including allowable taper and recast layer," says Stewart. "F&B checks and proves these conditions by sampling macro cross sections of the laser cut. Edge conditions and cutting parameters are recorded and maintained in the laser cutting schedule. During first-article inspection, operators can keep the tooling set up on the work table, while we machine another part. This boosts machine uptime dramatically."

Lasers and the job shop fabricator

Terry VanderWirt

There is a growing trend among job shops to invest in multi-axis laser systems. With a need for flexibility from project to project and their willingness to challenge this non-contact manufacturing technology, job shops are finding new ways to get jobs done. In fact, part designs that were never before possible are rapidly developed as laser processing permits these companies to innovate in surprising ways.

The software advancement of lasers--plus the ability of contract manufacturers to get the most out of this software--is really at the heart of why these job shops are increasingly successful with laser.

Good examples of these trends can be found at Meco, Inc., of Paris, Illinois, a precision metal fabricator who uses two laser systems along with an array of other CNC equipment, and at laser system manufacturer, Laserdyne, the laser systems division of Lumonics, of Minneapolis, Minnesota. Meco is a 200-employee job shop and specializes in manufacturing parts like turbine engine combustors for leading aerospace manufacturers. Laserdyne designs and builds standard laser systems and performs in-house contract laser machining and welding.

Laser's Real Worth Is Doing The Difficult

Meco began its experience with laser systems in 1984. As a specialized fabricator of turbine engine parts for major aerospace and turbine manufacturers, it regularly experienced heavy trim-die maintenance costs as high as $150,000. Laser processing was the logical solution to reducing these costs. Moreover, Meco began envisioning what it could do with a multi-axis system beyond simple trimming operations.

As it turned out, it did a lot beyond flat-trimming and this is the heart of the real story behind both Meco's success and Laserdyne's. It has also been the key to the growth of laser systems in many job shops. Meco looked beyond the obvious application and provided input to Laserdyne for development of multi-axis laser system features which it needed for its aerospace projects and which later became a standard in the aerospace and automotive industries.

Meco's first system was a five-axis Laserdyne 780 BeamDirector. They used the five-axis laser system to work with complicated contoured metal shapes--from trimming edges, cutting holes and welding sections of formed, thin-metal parts made of stainless steel as well as other materials. The system provided flexibility and speed for both production and prototype runs, requiring only the simplest tooling so setups were very fast and tooling costs were small. But this is the old news--Meco has been doing this kind of laser processing work on three shifts now for over eight years.

More interestingly, a recent development in turbine engine combustor design created a need for development of new laser system hardware and software. The old methods would work for this new part design.

The new combustor design allows for more laminar air flow to create more efficient cooling. However, Meco had no effective production method for producing the hundreds of small (0.019-inch) holes set at shallow angles over the entire contoured surface with the required precision. Conventional methods and standard user techniques were unreliable and inconsistent.

A solution to the small hole-drilling problem didn't come easy. The combustors were roll-formed and welded out of 0.04-inch and 0.06-inch thick high-temperature, oxidation-resistant alloy. Holes were 0.019-inch diameter ([+ or -]0.001 inch) and set at a 15-or 20-degree angle to the contoured surface. The imprecise nature of the roll-form process resulted in parts that were out-of-round by 0.01 inch to 0.02 inch, enough to create major difficulties in controlling both hole diameter and hole location. Besides these obvious positioning difficulties, the existing C[O.sub.2] laser wasn't capable of drilling small holes at shallow angles.

Laserdyne and Meco set out to solve this hole drilling problem with a new generation five-axis Laserdyne 550 BeamDirector equipped with a Lumonics JK704 Nd:YAG laser. Through an intensive development process, Laserdyne designed new hardware and software to go with the system.

Because the surface variations in combustor parts were not consistent from one combustor to the next, automatic focus control allowed the beam focal point to be maintained at a constant location relative to the surface. Meco found very quickly that without focus control, the focal point would change, resulting in variation in hole diameter. Hole location would also vary.

The latter phenomenon is called "Abbe Error."

Since the holes were cut at 15- or 20-degree angles, the positioning error was compounded. For example, with a hole cut at 45 degrees, the error in hole location when offsetting along the axis of the beam would be approximately 1:1. In other words, the error would be equal to the amount the part deviates from its ideal surface. On the other hand, when holes are angled at 15 degrees, the error in hole location is nearly four times the surface deviation. (Actual error is one/tangent of the angle or 3.7 times the deviation in the surface location.) The result was that a 0.01-inch deviation in the location of the part surface would result in a 0.037-inch hole position error.

To correct this Abbe Error positioning problem, Laserdyne designed a new feature for its automatic focus control, known as "Selectable Seek." This provides the ability to define the direction of the offset of the system, within the part program, responding to any deviation in the gas assist/automatic focus control nozzle which targets the laser beam. This was made possible by locating part features independent of part distortion.

With Selectable Seek, the system is programmed to offset in a direction parallel to the reference plane of the workpiece. Like earlier Laserdyne systems, the nozzle moves along the beam line when cutting holes perpendicular to the workpiece surface. When cutting angled holes, the software enables the system to distinguish the correct axis for compensating motion. When special cases arose, Meco changed the direction through the software.

Meco quickly found more than enough work to justify the new laser, much like it did with its first system, not just in the manufacture of new generation engine combustors but also in other aerospace parts it produces which require high-volume hole drilling.

The pressure Meco was getting from its customers brought about by shorter production leadtime requirements--nothing new in the job shop industry--was relieved by its laser system processes. Because tooling was either unnecessary or relatively simple with the laser system, there were fewer tool development delays. Some of the more routine operations done with

Meco's laser systems were also speeded up. Trimming went from 30 to 200 inches per minute. Edge finish was burr-free and consistent. With fewer "secondary operations" needed, there were fewer part setups needed and fewer errors.

According to Will Magers, Executive Vice President of Meco, all of these features made Meco more competitive in its bidding for work. The laser systems' flexibility gave them an extra way to be creative in their problem-solving processes.

Meco found other bonuses with their laser systems, too. One of these was the ease with which in-process gaging could be handled and changes could quickly be made in the software programs when needed. Statistical process control (SPC) was made a lot easier over old handchart methods. Data could be gathered electronically on a real-time basis, not some time after the fact.

Meco says the documentation improvements alone have saved their company and customers thousands of dollars. It's facilitating an important part of their ISO 9000 effort, according to Mr. Magers, and helped them survive in a number of vendor base reduction efforts by their aerospace customers.

According to Mr. Magers, "For us, laser machining is not just a new manufacturing process, it is leading all of our manufacturing processes because we're able to produce new part designs because of it." It's been pretty good for Laserdyne too. Laserdyne sold its 130th system earlier this year and over 65 percent of the machines have been purchased by aerospace manufacturers and aerospace suppliers like Meco. For more information on laser systems from the Laserdyne Div. of Lumonics Corp., circle 36 on the Postpaid Card.

Laser Cutting Thicker Materials

Laser machining is not limited to thinner materials as proven by Aero-Fab, an Indianapolis-based manufacturer of aerospace components. Pictured here is a cutaway of one Aero-Fab part—a 17-inch long by 14-inch high by 1-inch thick (432 x 356 x 25 mm) cooling frame made of Nimonic and used in General Electric land-based turbine engines. It presented manufacturing difficulties because of the material hardness and thickness. The part required 194 0.060-inch (1.5-mm) diameter holes drilled at 12-degree angles, each with a tolerance of [+ or -]0.003 inch ([+ or -]0.075 mm).

Aero-Fab originally produced the part by hand-drilling the holes, a costly and time-consuming process that caused frequent and expensive tool breakage, plus required substantial part rework. Typical processing time for one handdrilled part was 16 hours.

Laserdyne then began producing the parts in its job shop on a contract basis, on a 550BeamDirector laser. Once the process was proven, Aero-Fab bought the same model, and moved the process in house, saysDaryl Grubb, Laser Department Manager at Aero-Fab.

The process involves laser piercing into the part, trepanning or contour cutting the 0.060-inch diameter holes, and then forcing the minute slug through the exit hole. This process provides much straighter and cleaner holes than percussion drilling.

Mr. Grubb says the laser operates at 50 joules-per-pulse with a 250-mm focal length lens, which allows easy and fast deep-hold penetration of the part. Repeatability has been a consistent [+ or -]0.003 inch ([+ or -]0.075 mm) and part production increases have been recorded at up to 200 percent.

Aero-Fab's Laserdyne 550 Beam-Director is equipped with a Lumonics JK704 Nd:YAG laser. The system has axis travel of 25 by 25 by 24 inches (635 x 635 x 610 mm). It has a 360-degree continuous rotary table and [+ or -]135 degrees of full motion using the Laserdyne Beam-Director as an alternate to using conventional tilt tables. The direct drive Beam-Director axis provides precise point-to-point or contouring motion, and speeds as high as 32 rpm. The system is capable of processing a 29-inch diameter by 24-inch high (737 x 610 mm) cylindrical part.

How capable is your machine tool?

Gregorig, Ian

Machine tool builders routinely use laserinterferometry to check equipment during assembly and automatically compensate for CNC machine and coordinate measuring machine (CMM) positioning errors. Now, some companies working toward ISO 9000 certification, even those with as few as 10 CNC machine tools, are using it to "map" their shop-floor process capability.

Though ISO 9000 doesn't specify how often to check machine tools, manufacturing engineers must monitor equipment process capabilities on an ongoing basis. Demands for high part quality often preclude using conventional gages, making laser interferometry or a more costly calibration technique the only option. Measurement intervals will vary. Some machines must be calibrated monthly or quarterly, others annually. Timing depends on the equipment's working hours, stability, required accuracies, and historical processing performance.

Laser interferometry also allows grading machine tools based on accuracy. This strategy allows manufacturing engineers to assign high-precision work only to the most accurate machines, using the others for routine applications. It also reduces scrap.

WAVELENGTH ACCURACY

Coupled with application-specific PC software and appropriate optics, a laser interferometer can provide accuracy and convenience unmatched by gages or indicators. Common applications include calibrating machine tools and CMMs, quality control, preventive maintenance, error mapping, automatic linear error compensation, and a range of geometric measurements. Unlike a laser alignment system, which measures beam position on a target with resolution near 0.0001" (0.003 mm), the interferometer can measure linear distance to an accuracy of +/- 1.1 ppm.

Interferometry is made possible by the fact that a laser beam is coherent light, with all rays at the same wavelength and phase (peaks and valleys are in sync). During linear-distance measuring, the equipment shoots a beam through a small optical device made up of a beamsplitter and a retroreflector, which always reflects a beam parallel to the source beam. The beamsplitter sends a reference beam back to a detector on the laser source and allows a second beam to strike another retro-reflector, which returns another beam to the detector. The detector counts how many wavelengths of light one optical element moves relative to another and displays the corresponding distance measurement on a PC screen. When measuring a long axis, the interferometer usually is stationary, and the second retroreflector is on a moving element such as a machine spindle. The interferometer is separated from the laser source to prevent distortion due to heat buildup. As a result, the measurement is independent of laser source position.

A typical interferometer uses a stabilized helium-neon laser with a 0.633-mum nominal wavelength and a long-term wavelength accuracy (in vacuum) better than +/- 0.1 ppm. The laser light wavelength depends on the laser tube length, which quickly heats to a specified temperature (stabilizes), allowing full accuracy ten minutes after laser startup.

Though a beam of light never wears out and laser frequency is constant, the air surrounding the beam can cause measurement error. While environmental conditions have little impact on accurate measurement of angle, velocity, or flatness, they must be compensated for to achieve accurate linear displacement measurements. For example, there will be an error of about 1 ppm for each of the following changes: 1.8deg F in air temperature, 0.1" (3 mm) Hg in air pressure, and 30% in relative humidity. The machine tool's temperature also impacts laser accuracy. A change of just 1deg F in hardened steel, for instance, can introduce error of +/- 7 ppm.

To correct for extraneous influences, the interferometer's environmental compensation unit continually monitors all factors affecting the refractive index of air, automatically compensating for them. The system also has inputs for up to three material temperature sensors to normalize the machine under test to 68deg F (20deg C).

Historically, straightness has been difficult to measure due to sensitivity to air turbulence and poor optical design of the measuring equipment. Interferometer optics are now designed to reduce this sensitivity. While similar in principle to linear optics, they allow measuring straightness in almost the same time required for linear measurements. A typical system, including an interferometer and reflector, can measure straightness of travel, parallelism, and perpendicularity of machine axes. The straightness retroreflector forms an optical straight edge, allowing measurements in the two orthogonal planes perpendicular to the travel axis. A squareness pentaprism allows measuring in two axes nominally at 90deg to each other, allowing perpendicularity assessment. By measuring straightness of colinear axes such as Z and W with a common optical straight edge, operators can also derive parallelism measurements.

Straightness can be measured by stopping the machine and recording the data point or by taking data automatically while the machine is moving. The second case reduces machine tool downtime because the calibration test time is now limited by velocity capabilities of the machine tool or CMM.

Systems can provide short or long-range straightness measurement, but there is a slight tradeoff in accuracy for the second option. For instance, with a straightness range of 0.1-4 m, the measurement range is +/- 2.5 mm, resolution is 0.01 mum, and accuracy is a +/- O.5%. For a system with a straightness range of 1-30 m, measurement range is +/- 2.5 mm, resolution is 0.1 m, and accuracy is +/- 2.5%.

DISPELLING MYTHS

Two misconceptions about lasers persist today. One is the science fiction image of the laser as a weapon of mass destruction. However, the interferometer's Class II He-Ne laser source only uses a maximum power of 1 mW. It also conforms to federal safety regulations. Although operators shouldn't stare directly into the beam, they can safely view it from the side. In normal use, a shutter mechanism on the front of the laser source can automatically shut off the beam when the system isn't measuring. The second misconception is that a PhD is needed to operate a laser. The laser interferometer is often easier to use than the machine tool it calibrates. A trained operator can unpack a portable laser and begin' taking measurements in 15 min. Its PC-based control provides simple, menu-driven interfaces (often the user simply buys an expansion card for an IBM-compatible PC already in house). The PC links directly to the CNC, allowing the operator to communicate with both the machine tool and the laser.

These software features also facilitate laser interferometer operation:

* Automatic data capture. In a typical linear displacement measuring run, the operator aligns the laser with two optical components on the machine and keys in the start and stop points.

The laser software then monitors the machine's programmed, incremental moves, taking measurements at each position. The software then automatically analyzes and plots the results according to various international standards, including ISO 230, ANSI, BSI, B89, and AMT.

* Automatic linear error compensation. The software, which supports Fanuc, Siemens, Allen-Bradley, Heidenhain, and Acramatic controls, can generate and download an "exercise" program to a

CNC, monitor the machine tool moves, capture measurement data automatically, revise the CNC's internal error compensation values as necessary, and retest the machine. This evaluation step now takes just a few minutes instead of hours and requires little operator intervention.

* Automatic beam-break recovery. Much like automatic tool recovery on a CNC machine tool, this feature allows the laser to resume a calibration run after a beam break without having to start over.

JUSTIFYING LASER TECHNOLOGY

A complete laser calibration system, including a kit of linear measurement optics, the laser source, environmental compensation unit, and software to run the user's PC costs about $20,000-$25,000. A system can be disassembled and carried in two or three carrying cases rugged enough to be checked as airline baggage, facilitating its use in manufacturing or the research lab, as well as at another manufacturing location. Portability also allows some companies to expand laser calibration into a profit center by offering calibration services to external customers.

Measurements are traceable to national standards. To calibrate the laser and environmental control unit, Renishaw uses a certified iodine laser calibration system and certified temperature, pressure, and humidity measurement equipment. Where traceability to a national standard is required, laser manufacturers can arrange calibration at the National Institute of Standards and Technology (Gaithersburg, MD) or another accredited calibration facility.

A study on torch path planning in laser cutting processes Part 1: Calculation of heat flow in contour laser beam cutting

Han, Guk-Chan

Abstract

Conductive heat transfer in contour laser beam cutting is analyzed by using a transient, two-dimensional finite difference model, and the result is combined with a simple analytic model. From the calculation results, the

correlation is derived between workpiece temperature and opening angles at a corner in contour cutting. As a result, a modified analytic solution is developed to predict if excessive workpiece heating occurs for given cutting contours in a nested plate. The main objective is to use the computation results in the optimization of torch path planning to provide fully automated CNC programming software for laser cutting. To efficiently apply the analytic model in torch path planning, the critical temperature that should be avoided during the cutting sequence is considered. This leads to an improvement of the cutting quality in the automatic cutting process.

Keywords: Contour Laser Beam Cutting, Finite Difference Method, Nonstationary State Heat Conduction, Opening Angle, Critical Temperature,

Torch Path Planning

Introduction

Recently, the major objective of laser processing in a production line is the precision or shape-cutting of metallic and nonmetallic thin sheets.' The cutting process is carried out by melting and/or evaporating a material with a focused Gaussian laser beam as a heat source. For a detailed description of the physical mechanism, the theory of laser cutting is given in the references.2-4 Compared with conventional cutting tools, the advantages of using the laser beam are small kerf width and high cutting velocity combined with a narrow heat-affected zone. In combination with a computer-controlled CNC machine, the laser beam can easily produce complex part geometries; however, in the case of complex workpiece geometries, undesirable reduction in cutting quality may result. One cause of this is workpiece preheating as a result of heat conduction. With useful tools or guidelines for determining optimum cutting parameters and sequences in the production line, improvement in cut quality and automation of cutting processes can be expected. For this purpose, numerical calculation methods such as the finite element and finite difference methods can be adopted; however, the simulation of total cutting sequences using these numerical methods is ineffective because of the exhaustive computing time.

Most of the theoretical works on heat transfer in laser cutting have centered on the solution of the classical heat conduction equation for the stationary or quasi-stationary state. The most significant previous work on the analytic solution of heat flow in welding/cutting was done by Rosenthal for a point heat source in three-dimensional analysis or a line heat source in two-dimensional analysis.5,6 The modeling of temperature distributions induced by a distributed heat source was pioneered by Eagar and Tsai7 for a traveling Gaussian intensity distribution and by Ashby and Shercliff8 for a traveling hypersurface line heat source. With the growing interest in laser processing, these models have been investigated further. Most of the theoretical descriptions of the heat conduction are often connected to the Rosenthal solution, and even today some of the solutions obtained by Rosenthal are widely used; however, analytic solutions of the heat conduction equation are inadequate for the temperature profiles within a finite plate or for the cutting of particular contours. Therefore, the temperature field occurring during the contour cutting with the laser beam should be calculated by using a numerical model.

In investigations of the numerical model of the laser cutting process, a three-dimensional heat transfer model was developed by Mazumder and Steen9 for a laser striking the surface of an opaque substrate moving with uniform velocity. The model was solved by the finite difference method, and its results were presented for the temperature distribution and melt depth. Kim and Majumdar10 developed a two-dimensional finite element model based on the transient heat conduction to analyze the material removal process using the laser beam. The numerical experimentation was carried out for mesh refinements and the rate of convergence in terms of groove shape and temperature. Hillebrand, Decker, and Wohlfahr11 solved the workpiece heating

during contour laser cutting by using the finite element method. The calculation results showed a possibility of the cutting sequence optimization for complex part geometries and also of the quality assurance. Although these computational models are considerably precise, investigations to optimize the cutting path problem concerning the heat effect have not been presented in the literature.

When the main goal is to examine the temperature distribution along a simple cutting contour, it is convenient to use a simple analytic model. Unfortunately, analytic models of heat conduction are unsuitable for solving the cutting problem of complex contours because the heat-affected zone and/or kerf previously produced affects the current heat conduction.

Therefore, the objective of this paper is to develop a modified analytic model for laser beam cutting of complex contours based on the finite difference model. The modified analytic solution should provide a reasonable temperature prediction having a margin of safety for a given cutting contour. This mathematical model can be applied as a tool for avoiding the critical temperature that causes workpiece overheating during the laser cutting process, and then can be applied for carrying out torch path optimization incorporating the heat effect.

Numerical Approach

Physical Definition of Laser Cutting Process

For the cutting contour illustrated in Figure 1, the temperature field is calculated using the finite difference method, and the results are combined with the analytic solution. To develop the mathematical model, the laser cutting process is physically defined as follows:

1. The cross section of a laser beam, moving with uniform velocity, is assumed to be square, having a constant power distribution striking the surface of the workpiece. The laser beam contributes the energy to the workpiece.

2. Heat conduction in the direction of depth is negligible because the workpiece is a thin sheet having a finite width and length.

3. Constant material characteristics, such as thermal conductivity, specific heat, and density, are adopted during the change in temperature.

4. Absence of convective and radiative heat flow is assumed in the formulation.

5. After removal of the molten material along the cutting line, the side walls of the kerf produced are treated as an adiabatic boundary.

6. Influence of the material cooling caused by the cutting gas jet is neglected in calculations.

The advantages of laser cutting can be described by a very simple calculation based on the geometry shown in Figure 1 and the physical definitions given above.

Finite Difference Formulation

The transient heat flow in a two-dimensional workpiece with internal heat generation is governed by the energy conservation equation in the Cartesian coordinate system, as follows:

Analytic Solution

Most of the analytic solutions conducted so far on the heat flow in the workpiece have been on the temperature distribution in the quasi-stationary state. In the quasi-stationary state, in which the temperature distribution is stationary in a coordinate system that moves with the heat source, the mathematical analysis is simple because the problem can be treated as a steady heat flow problem for the moving coordinate. In the area near the start and end of a cut, however, the heat flow is in the nonstationary state. When the cutting is performed over a short length, therefore, the quasi-stationary state is never reached.

In this paper, the nonstationary state heat conduction equation is used as the basic principle. Under the assumptions that the cutting velocity is fast enough, the laser power is high enough, and the heat transfer is only in directions perpendicular to the cutting direction, a useful analytic solution can be derived from the solution presented by Carslaw and Jaeger.12

Figure 4 shows the comparison between the heat flow model in a thin rod and the typical laser cutting model with the laser beam moving at a speed of V. The solution of the temperature distribution at time t, T (xi, t), produced by an instantaneous heat source in a thin rod is expressed as follows (Figure 4a): where T^sub o^ is the initial temperature, Q' is the net energy input per unit area, xi is the shortest distance between the heat source and point selected to be calculated, and h is the heat flow factor by convection effect on the surface. Because the traveling line heat source can be treated as an instantaneous plane source (Figure 4b), the incident energy density Q' is written as q/Vd in the thin plate cutting, where q is the net input energy per unit time. Also, based on the assumption that there is no convective heat flow through the upper and lower surface, the nonstationary state solution for the temperature distribution in laser beam cutting can be expressed as follows:

The surface temperature distribution around the laser beam obtained by Eq. (3) is presented in Figure 5. The assumptions used in this analysis include the moving line heat source and the constant average thermal properties.

Result of Calculations

Type 304 stainless steel with 1.0 mm thickness is considered as the material for simulations, with the cutting speed of 2 m/min and the laser output power of 250 W The material properties are listed in Table 1. To demonstrate the cutting simulation, opening angles of beta = 180 deg, beta = 135 deg, beta = 90 deg, beta = 63 deg, and beta= 45 deg are selected. Each cutting model for a given opening angle adopts the same cutting condition and cutting length.

The temperature profiles around the laser beam obtained by the finite difference model for beta = 180 deg are compared with the solution of the nonstationary state heat conduction equation [Eq. (3)] in Figure 6. The simulation results obtained by the numerical and analytical model showed very similar temperature gradients for the same cutting condition, except at the side regions of the plate. This difference of temperature gradient may result from the fact that the finite difference model is applied to a finite plate, while the analytic model is applied to an infinite plate. The effect of these differences may decrease as the size of the solution domain increases.

Figure 7 shows the calculation results of isothermal lines for different opening angles. When the laser beam changes its cutting direction at a corner, two types of heat flow are expected. At small opening angles, the burnoff of the corner may take place. This is due to the reduced dissipation of heat caused by two adiabatic sides of the kerf. After the advance of the heat source and a change in the cutting direction at the corner, the fusion zone moves through the workpiece region at higher temperatures. Consequently, the applied heat is dispersed less in the right-hand side than in the left-hand side because two adiabatic boundaries of the kerf have the blocking effect against the heat flow. As a result, the heat accumulation occurs in the side of small opening angles, and a steep temperature gradient is formed. Consequently, a reduction in the cutting quality must be expected at the corner with small opening angles. At the region of large opening angles, however, there is no reduction in the cutting quality along the kerf because the heat applied by laser beam can be easily dispersed in the plate. Simulation results (Figures 7a-7d are in good agreement with the theoretical background mentioned above.

Application of Calculations

On the basis of the finite difference and analytic analysis, a modified analytic model can be introduced to predict the temperature field in laser cutting of complex part geometries. A possible use of this tool is the determination of optimized cutting sequence plans. Figure 8 shows the temperature profiles calculated from the numerical and analytical model for the identical cutting path and cutting parameters. It can be used also as a typical example of illustrating the modification procedure of the analytic model. The temperature profiles plotted by solid lines are simulation results obtained by the finite difference model for an opening angle of beta = 90 deg, while the dashed lines denote the results by the simple analytic model for beta = 180 deg. The black point in the figure is located on the 400 deg C isothermal line for the numerical solution, while it is on the 300 deg C isothermal line for the analytic solution. In this case, the temperature determined by the numerical model is 1.33 times as high as that determined from the analytic model. One of the methods of efficiently considering the heat accumulation effect in the contour cutting process is to use the modified temperature obtained by multiplying a factor to the calculation result of the nonstationary state heat conduction equation [Eq.(3)]. The analytic temperature distribution can be modified for various opening angles as follows:

Critical Temperature

A great number of variables affect the results of laser cutting. They can be divided into materialrelated, laser-related, and process-related variables. The other cutting variable that affects cutting quality is the initial plate temperature. In general, workpiece preheating can result in several advantages for laser cutting. It can improve the cutting operation by an increased cutting speed and reduced temperature gradient in the plate; however, when many contours with complicated shapes are nested and cut with a constant cutting speed and laser output power, workpiece preheating may cause cutting quality deterioration. This is due to the fact that the contour to be cut in the complicated nested plate can be excessively preheated by the heat accumulation from the previous cutting contours.

In this paper, the allowable increase of kerf width is considered as a criterion to judge cutting quality because kerf width is one of the most important factors in precision cutting of small parts. To determine the critical temperature for a given material and cutting condition, a simple lumped heat capacity equation [Eq. (4)] based on the heat balance of the material removed in fusion cutting is used as shown in Figure 10, for which the heat balance equation can be written as follows:

Concluding Remarks

By comparing the results of the numerical and analytical model of heat conduction, a useful tool was developed to predict the temperature rise for various opening angles in contour laser beam cutting. To calculate the temperature field in the cutting of contours, the two-dimensional finite difference model based on the transient heat conduction was introduced. As a basis of the analytic solution, the nonstationary state heat conduction equation was adopted to develop the modification factor. The modified analytic solution was then used for temperature predictions in contour cutting, especially for small opening angles. The critical temperature was defined as an allowable kerf width that increases with the increasing initial temperature of the plate. This approach is used in Part 2 of this paper to optimize the cutting sequence planning, which can be further used in efficiently developing an automated CNC program for the laser cutting process.

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On the beams: lasers and abrasive waterjets - Emphasis: EDM and Lasers

Chip Burnham

A major benefit of cutting with a beam--[CO.sub.2] and YAG lasers, abrasive waterjets (AWJs) and plasma arc--is the ability to respond quickly to demands for small quantities of custom parts cut from a variety of materials. As tooling costs and just-in-time production demands increase, these alternative cutting methods become increasingly attractive for independent and manufacturers' machine shops.

The beam-cutting tools are usually integrated into CNC machines. Operators merely change programming and process parameters to respond to requirements for different parts and materials.

As with any new technology, much has been written about the comparative advantages and disadvantages between beam-cutting and traditional machine tools, and between one kind of beam cutting and another. Everyone would like to have a machine that can cut everything, and a lot of machine manufacturers would like you to believe that their machines will cut everything.

Material processors who consider purchasing new beam-cutting systems to upgrade, add to, or replace existing equipment need to analyze carefully the type and volume of work they want to do. Then they need to evaluate which of the methods will do the majority of the work within the boundaries of costs, productivity and profits they expects.

Lasers and abrasive waterjets are known for their speed, accuracy and versatility in cutting a wide variety of materials. Plasma arc cutting is fast as well, but is used primarily for metals. This discussion compares the capabilities and costs of lasers and AWJs.

Capabilities

In general, lasers do a superior job cutting many materials less than 0.25 inch (6.4 mm) thick. a survey of 156 job shops, which was reported in the September, 1990, Proceeding Of The Marketplace For Industrial Lasers, showed that 88 percent of them were using [CO.sup.2] laser to cut mild steel of 0.25 inch (6.4 mm) or less, and 65 percent were using [CO.sup.2] lasers to cut stainless steel of 0.125 inch (3.2 mm) or less. At these thicknesses, the heat-affected zones (HAZs) that lasers produce are small. At metal thicknesses greater than 0.25 inch (6.4 mm), the use of lasers designed to cut thin sheet metal becomes increasingly impractical, and AWJs may be a better choice, especially if the material is heat-sensitive.

Laser-cutting thicker metals tends to produce larger HAZs. Sometimes this is acceptable for the final part application, but at other times, costly grinding operations are required to remove these areas. Also, the laser power required to cut thicker metals is greater, and therefore, the cutting process is more expensive.

The AWJ cuts to tight tolerances without HAZs, mechanical stresses, or warping. The fine, sand-like abrasive removes material by high-speed erosion, and the AWJ-cut surface looks sand-blasted. Even for thin materials, the AWJ's "cold" cut can sometimes make a big difference in part production costs when it eleminates finishing steps.

The cutting speed of a laser for a given thin material is higher than the AWJ. Cutting speed, however, is not always determined by the cutting process itself. If the motion control positioning equipment can contour a complex shape to required tolerances at 50 inches per minute at best, then either process will do. Almost any gantry-type machine can travel fairly quickly in linear moves (over 300 inches per minute is not uncommon), but, to contour a small, intricate shape, the same machine may have to slow to 1/10 its linear speed.

Although sheet metal cutting is a major application for beam-cutting technology, lasers and AWJs are also being used in plate metal and custom material processing. Those who purchase beam-cutting technology for a specific application or customer base soon discover other areas where lasers or AWJs can reduce part production costs or allow diversification into new markets.

Not all these applications are for two-dimentional parts. Three-dimensional work requires five to six axes of programmable articulation provided by multi-axis machines with delicate wrists and low payload capacities. Both the AWJ and laser have relatively light cutting heads, which makes it easy to integrate them with these sophisticated CNC systems. The lighter the cutting head, the faster the manipulator can move with accuracy.

Both AWJs and lasers produce very low cutting forces. The AWJ usually exerts less than one pound of force onto the workpiece; the laser virtually none. When the workpiece and fixturing do not have to withstand high cutting tool forces, the result is simplified, less expensive and more flexible fixturing.

Material Examples

* Aluminum: Aluminum up to 0.25 inch (6.4 mm) can be cut with an inert assist gas (nitrogen), but its high thermal conductivity limits practical cutting to thicknesses less than 0.125 inch (3.2 mm). Any HAZ is small and quickly removed if necessary. AWJs cut aluminum up to 8 inches (203 mm) thick, although most production work is 1.5 inches (38 mm) or less.

One-inch-thick materials can be cut at speeds up to 13 inches (330 mm) per minute. AWJs produce no HAZ and edge quality is in the range of 125 rms (on thicker materials), depending on cutting speed and other process parameters.

* Mild And Carbon Steels: Lasers cut mild carbon steels up to 0.5 inch (12.7 mm) thick with some HAZ, but mild steels (1010-type materials) do not harden, so the HAZ is easy to remove. Beyond 0.5 inch (12.7 mm), laser cutting requires higher power and slower cutting speeds and it becomes increasingly impractical. AWJs cut mild and carbon steels up to 6 inches (152

mm) thick, although most users are cutting in the range of 0.25 to 2 inches (6.4 mm to 50.8 mm). AWJ cutting speed for 1-inch (25.4-mm) steels is 5 inches (127 mm) per minute.

* Stainless Steel And Inconel: With a nitrogen assist gas, lasers cut stainless steel up to 0.5 inch (12.7 mm) thick and Inconel up to 0.125 inch (3.2 mm). At this thickness, the HAZ is small and relatively easy to remove with sanding wheels. AWJs cut stainless steel and Inconel in the same thickness ranges as any other ferrous metal--typically 0.25 to 2 inches (6.4 to 50,8 mm), 6 inches (152 mm) maximum. One-inch-thick stainless steel can be cut at speeds up to 4.5 inches (114 mm) per minute. With no HAZ, there is no need for any secondary removal processes.

* Titanium: It is possible to laser-cut titanium as thick as 3/16 inch (4.8 mm), but it is expensive. Laser-cutting of titamium requires argon or argon/helium assist gases. One user reports that he routinely cuts 0.060-inch (1.5-mm) material at 120 to 150 inches (3048 to 3810 mm) per minute. Without assist gases, the AWJ cuts 0.060-inc (1.5-mm) titanium at 50 to 80 inches (1270 to 2032 mm) per minute, and AWJs can cut titanium up to 3 inches (76.2 mm) thick. With no HAZ to remove, the AWJ cut is often the final cut, which also saves material costs.

* Stack Cutting: It usually is not practical to cut stacked materials with a laser because it is diffuclt to prevent hot gases and molten material from blowing between the layers. AWJs, on the other hand, easily cut stacked sheets of material such as shim stock.

Costs

A 1.2- to 1.5-Kw X-Y laser system that will cut thin sheet metal fast and accurately can be purchased for as little as $ 249,000. For the ability to cut thicker materials--up to 0.5 inch (12.7 mm) for some metals and up to 1.0

inch (25.4 mm) for non-metals--with reasonable speed and accuracy, costs range between $ 325,000 and $ 375,000 for 1.2- to 1.5-Kw systems. For routine cutting of thicker (0.5 to 1 inch) material such as plate metal, prices start at $ 450,000 for 1.5- to 2.5-Kw systems. Sophisticated multi-axis systems for prototyping start at $500,000 and can exceed $1 million for trim-line die cutting systems such as those used by automobile manufacturers.

In general, a laser system consists of the laser, a cooler, a fume extractor, and various assist gases (oxygen, nitrogen or argon, depending on the material being cut). The laser system may also require a separate foundation--usually a 10-inch (254-mm) "floating" concrete slab.

Equivalent AWJ systems start at $100,000 for a small system. Prices for a turnkey two- or three-axis NC-controlled shapecutting system that is 6 feet by 9 feet (1.8 by 2.7 meters) range from $130,000 to $220,000. Five-axis gantry systems range from $280,000 to $1 million.

An AWJ system consists of an intensifier pump to pressurize water to 55,000 psi, a water booster and filtration system to supply clean water to the pump, an abrasive delivery system, and an AWJ cutting head. The AWJ system may require a 6-inch (152 mm) rebar-reinforced concrete pad. For either system, a large percentage of the cost is in the motion control equipment.

Lasers and AWJs use similar techniques for material support. As mentioned above, the low cutting forces do not require elaborate part support structures. The supports themselves are often sacrificial--they wear out druing cutting and must be replaced occasionally. Examples of support media (both sacrificial and permanent) include pins, slats, grating and rollers. Special applications may use other techniques.

The laser does not require an elaborate catcher system because the beam's intense heat is concentrated at its focal region. Typically, a small catcher or tray is needed to collect the molten globules of material for disposal. A bigger concern is the fumes that are given off when melting (cutting) the material. Most laser systems are completely enclosed and vented to remove fumes from the cutting area.

AWJs do require some form of a catcher device to dissipate the residual kinetic energy of the stream and collect the slurry. The slurry consists of spent water, abrasive and the kerf material of the cut part. Most X-Y systems use a tank catcher that also supports the workpiece. These tank catchers may be "self-cleaning," where the slurry is automatically removed from the tank. The remaining waste and process water is easily disposed of. Multi-axis systems use a point catcher that follows the AWJ nozzle as it cuts. The virtually heat-free cutting produces no fumes, so no ventilation is required.

Although AWJs generate no fumes, they can be noisy. Some systems are partially enclosed to reduce the noise level. A properly designed catcher also decreases the noise to levels that are well within state and federal requirements. Many such noise-suppressing designs are available for two- and five-axis systems.

Operating costs vary, depending on the process parameters (including assist gases, if any) for a given material, desired cutting speed and edge quality. When a laser system is operating at power levels greater than 2 Kw (the level needed for most exotic metals), costs can run as high as $90 per hour, excluding labor and fixed costs. For most applications, however, the operating costs range from $25 to $40 per hour. Operating costs for AWJ systems range from $15 to $35 per hour, with most applications running about $18 per hour.

Downtime and maintenance are other costs to consider. Most laser installations experience downtimes of 10 to 20 percent per year. AWJ systems typically experience 5 to 10 percent annual downtime. This is because AWJ technology is relatively simple. In-house maintenance people quickly learn everything they need to know about the filtration unit, pump and abrasive delivery system. The mixing tube (sometimes called a focusing nozzle) on the cutting head must be replaced every 100 hours or so. Pump seals, valves and water filters also require occasional replacement.

Laser technology is less familiar to most machine tool maintenance technicians. As a result, the user often is dependent on the manufacturer for maintenance and repairs. The mirrors, lenses and tips must be cleaned or replaced periodically.

Conclusion

The primary advantages of lasers over AWJs are faster cutting speeds and tighter tolerances in cutting materials less than 0.125 inch (3.2 mm). The primary advantages of AWJs over lasers are the ability to cut thicker materials, the ability to cut heat-sensitive materials, and the absence of a HAZ on the cut surface. Part tolerances are a product of manufacturers such as positioning equipment and cutting process accuracy, fixturing and material flatness. Startup costs for AWJs are less than those for equivalent laser systems. Operating, downtime and maintenance costs are generally less for AWJs than for lasers. In the final analysis, the method to choose is the one that provides the most flexibility for the least overall cost for a given volume of material and customer requirements.

Is it a mill, a waterjet cutter or both?

Derek Korn

If you remove the cutting head and high-pressure pump from a waterjet cutter, then you'd be left with essentially a machine frame and computer numerical control motion. A CNC vertical machining center also possesses both of these things.

With that in mind, Ward Jet (Kent, Ohio) recently developed its compact, enclosed M-Series waterjet module that, when installed on a shop's existing knee mill or VMC, temporarily turns that equipment into a waterjet cutter. According to the company, the conversion takes 20 minutes and requires only sources of water and compressed air at the machine for operation. The module can be removed as simply as it installs, turning the mill back into a mill.

It's easy to imagine the inevitable damage that would occur if a waterjet's abrasive liquid cutting media happened to splash upon vital mill components such as ballscrews. That's why the M-Series provides a self-contained waterjet cutting environment, isolating the entire cutting operation in a sealed "tent" module to keep harmful media from contacting mill components.

The module bolts to a mill's T-slot table as would a fixture or vise. The mill must be capable of supporting the entire waterjet assembly's weight of approximately 600 pounds and provide at least 23 inches of Z-axis clearance to accommodate its height. The base of the module is a shallow tank filled with ball bearings. These dissipate the waterjet stream's cutting energy, which, on a typical cutter, is accomplished by a deep tank of water. A toolchanger plate in the top of the tent installs in the mill's spindle. The system's waterjet cutting head then attaches to the underside of the plate inside the tent. Once water, air and abrasive lines are connected, then the mill becomes a waterjet cutter.

Two tent versions are available with X-Y work envelopes of 16 by 30 inches and 24 by 48 inches. The larger model allows a standard 4-foot by 8-foot sheet of material to be cut in fourths and loaded into the tent. The workpiece material is supported by grates inside the tent and held in place with a clamping system that accepts workpieces from 0.5 to 4 inches tall.

A 20,000-psi pneumatically powered intensifier pump permits waterjet cutting using existing shop compressed air. This pump, along with an abrasive hopper and electrical box, is mounted on a cart located next to the machine. Larger pumps are also available in 40,000 psi and 60,000 psi versions.

The M-Series is perhaps best suited for shops that currently don't have a waterjet cutter, possibly because of a lack of available floorspace. The package not only works for mills, but it can also be applied to lasers, wood routers, robotic arms, oxy-fuel cutters, plasma cutters--virtually any type of CNC equipment.

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Wire EDM goes horizontal

Mark Albert

Wire EDM (electrical discharge machining) has been configured with the wire in a vertical orientation for decades, so the appearance of a wire machine that orients the wire horizontally is truly a novel development. One such machine, the UPJ-2 horizontal wire EDM, was introduced to the North American market at IMTS by Makino (U.S. headquarters: Mason, Ohio). However, looking beyond the novelty of its wire orientation, the machine is more properly noted for being designed to meet the special needs of micro-miniature machining applications. This is not a general-purpose wire machine reconfigured to hold the wire in an unexpected position. Rather, the company says, it is a piece of equipment specifically engineered for the machining of micro gears used in miniature molds, fiber optic components, inkjet nozzles and medical instruments. The demand s of these applications dictated the horizontal wire and other features.

Although the horizontal wire is the most conspicuous feature of the machine, its ability to handle extremely fine wire may be more significant. Wire as small as 0.00078 inches (0.02 mm) in diameter can be effectively used. (As John Shanahan, a product manager at Makino's Auburn Hills, Michigan, technical center points out, wire this small is only two and a half times the diameter of a human blood cell.)

Working with wire this fine posed two main mechanical challenges for the machine's designers. Automatic wire threading is particularly difficult with wire this fine. The challenge was met with a tubular system that uses positive and negative air pressure to automatically thread a 0.00078-inch wire through a 0.0019-inch (0.05 mm) diameter start hole. Essentially, a vacuum force sucks the wire into the start hole. V-type wire guides, rather than round guides, enhance threading reliability.

The other challenge for designers was wire tensioning. The machine uses a system that automatically applies weights to the wire. Thus, the unvarying force of gravity ensures that tensioning will remain constant during operation.

According to Mr. Shanahan, these solutions do not make the machine complex or difficult to run. The machine, he says, is as simple to set up and operate as a conventional wire machine. Nevertheless, the horizontal wire provides major benefits in fine-wire, ultra-precision applications. It allows workpieces to be held in an inverted position in the C-axis spindle mounted in the head of the machine. Workpieces can be mounted on standard holders, such as the Erowa pallet system, which lend themselves to automated or robotic loading and unloading.

More importantly, the C-axis rotary motion can be coordinated with X and Y moves to cut intricate geometries. Likewise, slug and core management (a perennial headache in conventional wire EDM) is greatly simplified. An automatic core and slug removal unit allows material to fall away from the workpiece without interfering with the cutting action of the wire or damaging the workpiece. Because fine wire has a limited current carrying capacity, its metal removal speed is proportionately paced, making automation essential for extended operation.

The machine has a granite base like that of a coordinate measuring machine to damp vibration and minimize thermal effects. The machine is fully enclosed to provide a machining environment that can be controlled to within 1[degrees]F (0.5[degrees]C). Travels in X, Y and Z are 7.87 by 7.78 by 2.36 inches (200 by 200 by 60 mm), with U- and V-axis travel at [+ or -]

0.394 inch ([+ or -] 10 mm) Maximum weight of workpiece and holder is 44 pounds.

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Where Wire EDM Is A Workhorse

Mark Albert

This shop finds the process practical, productive and predictable, an indispensable technology that supports all of its manufacturing capability. By its nature, wire EDM (electrical discharge machining) attracts a lot of attention. Using an energized strand of brass wire to slice through difficult-to-machine materials and create intricate profiles and tapers as the wire follows its programmed path is quite remarkable. In the last 25 years, novel and inventive applications for this process have been appearing constantly. At the same time, builders of wire EDM equipment have been constantly improving and speeding up their models. It's no wonder that most discussions of wire EDM gravitate to the latest and greatest.

The message that gets lost is that wire EDM is not just for the extreme or esoteric applications. Wire EDM is a workhorse, too. Hi-Tek Manufacturing, Inc. in Mason, Ohio, (northeast of Cincinnati) is a good example of wire EDM doing its job, day in and day out, proving to be highly practical, productive and predictable. Wire EDM is an outstanding performer in a shop that depends on outstanding performance from all of its machine tools.

Hi-Tek is a contract machining and precision component manufacturing company. It produces precision components for a variety of industries but has its roots in the aerospace industry.

Hi-Tek offers laser cutting; CNC machining and grinding; EDMing; and testing services. Small hole drilling of cooling holes for workpieces in high temperature applications is one of the company's major specialties. In every case, the ability to offer customers a "one-stop advantage" based on combinations of these processes is a key part of the shop's overall strategy.

Deep EDM Roots

The company that became Hi-Tek was originally founded in 1980 as System EDM, Ltd. The founders, Cletis Jackson and Jack Cross, had extensive experience at General Electric's Aircraft Engine Group in Evendale, Ohio, with the use of EDM for drilling airfoil cooling holes. Their expertise in this area helped the young company to become a major supplier of these specialized drilling services as well as allowed it to move into the drilling of fuel injection holes and other fluid flow applications. To this day, work that is related to cooling hole production is a major portion of Hi-Tek's business. More than 60 EDM machines are dedicated to cooling hole work.

In 1985, Gary Griessmann, an associate of Mr. Jackson and Mr. Cross, joined them to start a new business as a sister company to System EDM. This company, named Hi-Tek Manufacturing and located near System EDM's original building, was dedicated to conventional machining as a full-service, high-precision manufacturing facility. Hi-Tek also built tooling and fixturing for its own operations and for its customers on a contract basis. System EDM provided EDMing to Hi-Tek.

In 1990, with the retirement of Jack Cross, Mr. Jackson and Mr. Griessmann decided to consolidate the two companies under the Hi-Tek name and move into a new manufacturing facility constructed near System EDM's original site. At this time, the company acquired new CNC machining centers, CNC slant bed lathes, CNC grinders, and five-axis laser machines.

The new Hi-Tek, however, never lost its focus on EDM as a critical enabling technology. lathe mid-1980s, wire EDM had been introduced to enhance the company's growing R&D work for jet engine manufacturers, primarily Pratt & Whitney. Wire EDM proved to be the best way of cutting small intricate components, of doing small detail work, and of fabricating electrode holders for its hole drilling operations.

Even this very small sample of wirecut workpieces shows the diversity of applications Hi-Tek finds for wire EDM. "Wire machines were slow, not easy to program, and at best could hold a tolerance of a little better than one thousandth," recalls operations manager Scott Stang, who joined the company around that time. "But wirecut soon proved to be so useful for so many projects that it quickly became indispensable."

Today, the shop has nine wire EDM units from several builders, including Brother, Fanuc EDM and Mitsubishi. With the wire machines fully occupied in support of the complex, high-precision, difficult-to-machine aerospace projects that Hi-Tek was known for, the company has rarely sought wire EDM job shop work. Rather, the company has always looked for ways to utilize wire EDM to complement other machining processes and thereby find a competitive edge.

An EDM Mindset

According to Mr. Stang, this has been the pattern Hi-Tek has followed over the years. "About 80 percent of the work in this shop involves some wire

EDM," he says. "Sometimes wire is the only way to do a job. Certain features or tolerances can't be produced any other way. We've had many jobs that were produced entirely on a wire machine. Other times wire is required to machine the fixturing, the gages, or the cutting tools and special toolholders. We use wire whenever we can."

Wire EDM is often used to enhance EDM. A good example is a 3-foot diameter ring that requires a series of dovetail shapes to be cut on the ID, along with slots cut at a 10-degree angle. This part is larger than the worktable on the Mitsubishi 300-Hi machine assigned to this job. No commercial indexing unit could be adapted, so Hi-Tek engineers designed their own indexing unit to rotate the ring and maintain the 10-degree angle. The plate for this special indexer and other components were cut from steel right on the machine that they would eventually be installed on.

Mr. Stung believes that Hi-Tek integrates wire EDM into its work more often, more thoroughly and more effectively than most other shops simply because EDM has been part of the mix from the company's earliest days. "EDM isn't a technology we moved to. We started with EDM and added laser and conventional CNC machining later," he says.

He explains that utilizing wire EDM in process plans is a routine habit for designers, engineers and production planners. "We can always count on the results of wire EDM. The quality and accuracy are a given. Using wire EDM takes a variable out of every process plan it's involved in," says Mr. Stang.

Enhancements to other machining processes often come from wire EDM. For example, the company designs and fabricates its own specialized coolant nozzles for its CNC grinders, especially in creep-feed and superabrasive grinding operations. Both types of grinding require precisely directed, high pressure coolant flow for optimum efficiency. Nozzles shaped to the contour of the grinding wheel are cut with wire EDM, as are electrodes used to form the nozzle's internal ducts and orifices. This attention to detail is often the difference between a highly effective operation and a merely adequate one. "in our business," says Mr. Stang, "merely adequate isn't good enough to stay alive."

Opportunities And Transitions

Wire EDM has played a key role in Hi-Tek's ability to adjust quickly to shifts in the marketplace. Aerospace work dominated the shop's activities for the first 10 years of its existence. But in the early 1990s, the aerospace industry was in recession as military budgets were reduced and commercial aircraft production slowed. However, power generation equipment was in an upswing.

Deregulation of the power companies had encouraged competition while a strong economy spurred increased energy usage. At the same time, tight emission controls forced turbine manufacturers to redesign equipment for cleaner, hotter-burning, more fuel-efficient operation.

Power generating equipment resembles jet engines in many ways but is built on a larger scale. The turbine blades and nozzles are similar, and many of the requirements are the same. Many of the same high temperature alloys are found in both applications. Both applications require complex workpieces requiring large numbers of cooling holes.

Hi-Tek saw an opportunity to develop new business and further leverage its expertise in cooling hole production.

The shift from jet engine work to power turbine work required many new workholding fixtures to be designed and built. New gage stands and other test and measurement fixtures were constructed. Wire EDM was heavily utilized not only because of its versatility and ability to handle hardened materials, but also because wire EDM does not introduce heavy forces during machining. "Surfaces that act as datum reference points are EDMed whenever possible," Mr. Stang explains, "because they don't move when the clamps come off." He considers this a key aspect of the company's rapid response in this situation.

Hi-Tek was also able to reposition itself in the design and engineering of cooling holes. Wire EDM was critical in several ways. The ability of air to remove heat from a surface is highly dependent of the way the air flows. By shaping cooling holes to diffuse the exiting air so that it forms a consistent "film" across the surface, heat can be removed more efficiently, allowing a workpiece to withstand higher temperatures.

The company uses wire EDM to cut prototype copper electrodes to generate the hole shapes and hole placement in test parts. Hi-Tek also designs and builds the pressurized fixtures used in the testing procedures. Wire EDM is used to produce the ports and sealing surfaces on these fixtures.

Finally, when a new film cooling hole design has been approved for manufacturing, wire plays an essential role. Before 1994, Hi-Tek relied on an outside supplier for the stamped copper electrodes used on its EDM hole drilling machines. When that shop left the business, Hi-Tek decided to manufacture the electrodes in house. So the company set up its own in-house stamping facility, acquiring a number of coil-fed stamping presses.

In the meantime, it chose to produce its own closely toleranced progressive dies to be used in these presses. "This option was attractive to us because of our confidence in wire EDM," says Mr. Stang. All of the punches and dies are wire cut, as are most of the strippers and punch holders.

Dies typically have ten to 40 stations that pierce, blank and form the copper strip into electrodes with as few as one single tooth to as many as 25 teeth.

Each finished electrode produces as many holes at a time as it has prongs, usually in multiple workpiece setups. The electrode tooth and diffuser areas have shaped cross-sections and must be within [+ or -]0.0003 inch of nominal dimensions.

Larger, comb-like electrodes are also wire cut from pre-ground copper plate. Whenever possible, two electrodes are cut at the same time with the teeth intermeshed to reduce raw material usage. Cutting these electrodes is ideal for the shop's smaller Brother or Fanuc wire units. These machines feature submerged cutting, which solves the flushing problems created by the terraced surfaces of the copper plate.

Hi-Tek now produces all of its diffuser hole electrodes and is the single-source supplier of such electrodes to the major jet engine and turbine OEMs for certain projects. Whereas aerospace work accounted for almost 90 percent of the company's business in 1990, power generation work represents 60 percent of its business today.

Looking Ahead

As Mr. Stang puts it, "For us, wire EDM is like a Bridgeport in a toolroom. It's a basic metalcutting technology we couldn't do without." He sees that reliance continuing in the future as the company pursues new approaches to high speed, high precision small hole drilling. For example, Hi-Tek has developed its own proprietary EDM drilling machines, which are custom-built in the shop. Numerous components are wire cut, including those that are essential to patentable design features. "Let's just say these new machines couldn't do what we wanted them to without wire EDM as a manufacturing resource," says Mr. Stang in summary. The one constraint that he sees is the shop's need for talented wire EDM operators. Automation from the EDM builders will help, he believes, particularly in the areas of streamlined programming and setup. The shop uses wire EDM in so many ways for so many projects that there is little opportunity for untended operation. "Getting jobs up and running faster makes our wire EDM specialists more productive." And that, he insists, is a good thing because the wire EDM workhorse will be busier than ever in the future.

A wire EDM kind of guy - electrical discharge machining

Mark Albert

If you could be a machine tool, what kind would you be? A lathe? A mill? A grinder? An EDM? (A wire EDM would be my choice). This question isn't as silly as it sounds.

An affinity with machines and other inanimate objects is a hallmark of our industrial culture, just as an affinity with plants, animals and other natural objects is a hallmark of other (not necessarily primitive) cultures. As it is, we consciously or unconsciously identify with the equipment we use and see it as an extension of ourselves.

If you are working with a machine tool that matches the one you might fancy yourself being, the work is probably more enjoyable and you are probably better at it. You'd have more respect for your machine and for yourself.

A wire EDM would be my choice because it has the qualities I'd most like to see in myself.

Wire EDMing is a remarkable process. Imagine cutting metal with a thin wire that is giving off electrical energy. It's in a category all its own. I like that. I've never wanted to fit any stereotypes and resent it when people try to pigeonhole my personality.

Wire EDMs are patient. They take their time getting things done - not that they waste time, but there's no rushing them either. They'll work all night or over the weekend if you let them and often you have to. That's how my mind seems to work when it is looking for an idea. My best thoughts come to me during periods of reflection in the untended mode.

The results of wire EDMing can be very subtle. I've seen wirecut workpieces where the clearance between the mating parts is invisible until you move the parts. I wish all of my writing had that kind of seamless integrity.

A wire EDM has work habits I admire. No shower of flying chips, no blast of coolant against the machine cover, no whining of spindle motors, just quiet steady operation. Wire EDMs appeal to the imagination. The most original and creative applications in metalworking seem to be on these machines.

I've seen many different kinds of machine tools over the years but wire EDMs are the ones I relate to the most. If I could own my own shop, I'd want it to be a wire EDM shop, naturally. Picturing yourself as one kind of machine tool or another is a simple mental exercise. For a moment, you can see yourself, and the machines around you, in a whole new light.

Mark Albert

High Performance EDM

Spectrum Manufacturing is clearly the leading pioneer of high performance wire electrical discharge machining (EDM). This Wheeling, Illinois, job shop routinely cuts two or three times faster than most shops using standard wire EDM units, even those with the latest generation of equipment. And it does so without compromising accuracy or surface finish.

Doubling, and in many cases, tripling cutting speed is a remarkable feat in itself, but that is not the most remarkable thing about Spectrum as a leading EDM user.

What is outstanding is how the shop has taken EDM in entirely new directions. Extremely small parts. Extremely large parts. The one-of-a-kind "impossible" parts. Parts by the hundreds of thousand. They are using wire EDM as an advanced tool that calls for new thinking about how many parts can now be manufactured.

High cutting speed is only part of this phenomenon. In fact, Bill Fricke, president of the company and one of four partners that make up Spectrum's management team, would rather talk about efficiency when discussing high performance EDM. "You can't think in terms of just speeding things up," he explains. "Programming, fixturing, power settings, flushing - every aspect of the EDM process - has to be part of a strategy to machine work-pieces at higher quality and lower cost than by any other method." In many cases, he points out, that strategy may include other technologies in creative combinations. Spectrum has been innovative with laser cutting, multi-axis ram EDM, and computer-aided design/computer-aided manufacturing (CAD/CAM). Every one of its 25 ram and wire EDM units has computer numerical control, and all are linked to a shop-wide data network. "We are not afraid to experiment, to modify our equipment, explore every possibility, or develop our own systems and software." Mr. Fricke points out.

Not Afraid To Experiment

In fact, the development of high performance EDM sprang from Spectrum's willingness to change procedures and try new things. About four years ago, Spectrum was asked to take on a project for an aero-space contractor. It involved cutting 168 rectangular openings in tungsten alloy billets, 7.5 inches thick. Each opening had very precise geometry. The job was completed on a heavily modified wire machine. These modifications eventually became the basis for a high-speed cutting system that is now sold as a product line by a Spectrum subsidiary, T-Star Industrial Electronics (see box).

High Performance On The Market Fast-Track is T-Star's family of enhancement modifications for various wire machines. This package is typically retrofitted in the field on existing equipment. How big of a difference does it make? According to Tom Truty, T-Star's president, a two- to four-fold improvement in cutting performance is common for the various Fast-Track models. And, he notes, surface finish will be much improved because a patented feature allows smaller amounts of material to be removed in larger numbers, with less energy per spark.

In addition, T-Star and Spectrum have been conducting a joint development program with Charmilles Technologies Corp. The result of this project is FAST-CUT, an enhancement package tailored to Charmilles machines. This package is now standard on certain models.

T-Star's research and development efforts are continually producing a variety of electronic and mechanical modifications or inventions, all related to enhanced wire and ram EDM. It has numerous patents to its credit. Many of these products can be traced to experiments originating on Spectrum's shop floor.

The results of the original modifications hinted at their potential. Because the billets were made of a tungsten alloy that is extremely dense, cutting the openings was equivalent to cutting a steel plate almost 16 inches thick. To get the required accuracy at cutting speeds then available, it would have taken about nine months of machine time to complete each of these extraordinary work-pieces. After modification, however, each piece could be produced in three months of machine time.

Spectrum has since equipped all of its wire machines for high performance, where typical jobs are measured in hours or days. A similar three-to-one speed improvement is not uncommon.

Essentially, this system is a package of electronic, mechanical, and flushing enhancements. Together, they create a synergy of effects that makes high-speed wire cutting both possible and practical.

The chief electronic enhancement is patented circuitry that energizes the wire separately at upper and lower wire guides, effectively doubling the number of sparks that can be discharged at any given time. The servo system is also modified for greater performance.

The chief mechanical enhancements include redesigned wire guides that are mounted very close to the workpiece, interchangeable cartridge units for fast changeover of wire diameters, and passages for high-pressure flushing.

The chief flushing enhancement is a high-pressure pump and nozzle delivery system. Dielectric fluid is delivered to the spark gap at higher pressure but under greater control. Unwanted particles are removed faster and the fluid is ionized for the next spark sooner.

New Possibilities

Routinely doubling wire cutting speed has opened up a new world of possibilities - and a whole new set of challenges - for this job shop. Exploiting this new capability meant adopting new strategies for applications that were once beyond the scope of wire EDM. But efficiency, not speed, is the thrust of these strategies. Bill Fricke stresses that efficiency must be multi-leveled. Metal removal by the wire, setup and workpiece fixturing, workflow and scheduling must all be efficient. It is Spectrum's ability to achieve efficiency on every level routinely that makes the difference.

Efficiency For High Production

A good example of an application that typifies Spectrum's multi-level approach to efficiency is an advanced computer component made of a special alloy. The geometry of this workpiece is both complex and tightly toleranced ([+ and or -]0.00025 inch). Wire EDM is the ideal method of machining such a workpiece, but the production run numbers in the hundreds of thousands.

Wire EDM is only cost effective if production rates can meet the customer's time constraints. To perform the work economically, Spectrum teamed the principle of double-head wire cutting with submerged machining in a small overflow tank as shown in Figure 1. The double-head concept uses a single wire that follows a U-shaped route (Figure 2). This unusual routing allows the wire to cut twice as many workpieces simultaneously in side-by-side setups. Workpieces can be ganged in multiples on special fixtures, as in the case of this computer component, or stacked so that numerous workpieces are cut at once by a single wire (the number depends on the thickness of each piece). Shuttle fixturing principles are typically used with this concept. Quick release clamps are also used at the machine to speed fixture exchange, thus minimizing downtime.

The small overflow tank fills and empties quickly for fast changeover, yet provides all of the advantages of submerged cutting. The front wall of the tank is transparent, allowing clear observation of the cutting process. The job runs on two machines around the clock, seven days a week.

Interestingly, automation isn't always useful in the pursuit of efficiency. For example, the double-head arrangement with manual threading yielded substantially more parts per shift than possible with one of the shop's single wire units with automatic wire rethreading.

Laser/Wire EDM Combination

Sometimes drawing on the strengths of several processes in one application is most efficient. A particularly promising combination is laser and wire EDM.

At one time, Spectrum concentrated its development efforts on laser cutting, producing precision high-speed cutting systems that were successfully marketed for several years. Although the company no longer sells laser systems, it still uses them extensively as a high-precision production tool. Expertise in laser cutting is particularly valuable for engineering high-production applications that take advantage of both technologies.

A family of parts produced for a well-known armaments manufacturer exploits the speed and accuracy of laser cutting as well as the speed, accuracy, and fine surface finish of the shop's wire EDM. Blanks are cut from steel strips, as shown in Figure 3, at 50 inches per minute using a synchronous pulsing [CO.sub.2] laser. Individual pieces remain attached to the parent strip by a small web. The laser brings the pieces to within 0.002 inch of final size, with an excellent edge by laser standards but not sufficient to meet the customer's requirements.

The strips are then stacked twelve high on the wire machine. Using a high-speed trim cutting mode and double heads, the stacks are recut to gain the accuracy and surface finish wire EDM can produce. The wire trims at 80 square inches per hour. A simple milling operation produces a beveled cut from end to end along the tab to complete the strip. Individual pieces are then broken away from the strip to finish.

In less than two and a half weeks, Spectrum produced 5,000 pieces. Laser alone could not meet the accuracy and finish specifications; wire EDM alone could not meet required production rates. Together, they were quite cost-effective.

Unique Fixturing

Production jobs are not the only area where unique fixturing and special modifications pay off. Spectrum cut the barrel-shaped workpiece shown in Figure 4 by modifying a relatively small wire unit. This workpiece, a large bearing component weighing 3500 lbs and standing 30 inches high, had to be cut into two identical halves for assembly around other components. Because the guide system developed for high performance is modular, it could be configured to clear the full height of this workpiece.

To cut this part effectively, special flushing fixtures also had to be designed and the electronics from its high performance system were modified for additional fine tuning.

Prototype Of The Future

Spectrum is one of a handful of job shops that might be considered prototypes of the future. Contract manufacturing is clearly undergoing a metamorphosis, and the shape of things to come can be glimpsed here. To prosper in the face of competition that often comes from around the world, shops will have to push the state of the art ahead for themselves. Like Spectrum, they will not only be expert users of some technology, but also inventors and developers of that technology, as well as leaders in innovative applications of their own discoveries.

Given the nature of wire and ram EDM at the time of its founding, Spectrum virtually had no choice but to pursue a course as both user and developer of this technology. Indeed, the prospect of being pioneers was a primary motive for the shop's co-founders.

As Bill Fricke puts it, "We could all see that EDM, especially wire, had tremendous potential. And we all recognized the technical barriers that were holding things back. But we didn't let those barriers give us preconceived notions about what it could or couldn't do. We didn't let them limit our imaginations."

While no shop can claim the future, it certainly appears that the future belongs to those with ingenuity and imagination.

PHOTO : The shop floor at Spectrum Manufacturing is both production center and "laboratory". Top management encourages its skilled employees to explore new ways of doing things, to experiment and tinker, with the goal of improving quality and efficiency.

PHOTO : Fig. 1 - Efficiency is more than high cutting speeds. By ganging workpieces, cutting with a double head, and using a small overflow tank, a special alloy computer component is produced by the hundreds of thousands.

PHOTO : Fig. 2 - The wire electrode feeds from top to bottom at the left, rounds two wheels, then feeds in the opposite direction at the right. This double head concept allows two workpieces or two groups of workpieces, to be cut at once.

PHOTO : Fig. 3 - This strip of break-away parts is cut on a laser (for speed), then finished on a wire EDM (for accuracy and fine finish).

PHOTO : Fig. 4 - A 30-inch high wire cut makes this application remarkable. Numerous modifications to the machine's electronics, flushing system, and wire guide were required.

A highly complementary combo: wire EDM and abrasive waterjet go together well, especially for cutting aluminum

Mark Albert

Wire EDM and abrasive waterjet (AWJ) are increasingly seen as highly complementary processes. The combination takes advantage of the speed of AWJ and the high accuracy of wire EDM. AWJ is used for rough cutting and wire EDM is used for finish cutting to tight tolerances and very fine surface

One of the most promising applications for this combination is cutting aluminum because the advantage of roughing with AWJ and skim cutting with wire EDM are particularly strong for this material. Complex, close-tolerance aluminum components are proliferating in many key industries such as electronics, aerospace and defense. OEMs are looking for shops that can make these parts quickly and economically, and production strategies that use wire EDM and AWJ to reduce the number of process steps and to streamline individual steps are bound to be winners. Advances in the latest generation of waterjet equipment further enhance this effect.

To get a glimpse of how the combo of wire EDM and AWJ can improve productively with wire EDM, we asked MC Machinery Systems Inc. (Wood Dale, Illinois) to examine and discuss a sample study part, shown above. MC Machinery Systems is the North American source for wire and ram EDM technologies from Mitsubishi EDM and the line of AWJ machines branded as Waterjet Powered by Mitsubishi Electric. The same part was produced entirely on a wire EDM and then again on an AWJ machine. The table on the next page compares the two processes and summarizes the results.

The sample part is half-inch thick 6061 aluminum. The part's outside dimensions measure 2.5 by 3.0 inches. The inside shape is a scaled-down version of the outside contour with 0.020-inch inside radii. The outside radii are sharp.

The EDM test cut was performed on a Mitsubishi FA10S using 0.010 brass wire. The machine's travels are 10 by 14 by 8.6 inches. To replicate results that the typical user could expect in the field under normal operating conditions, machining parameters were derived from the set of standard technology settings resident in the control software. The achievable surface finish is 50 microinch Ra in aluminum with four skim cuts. Two start holes were needed, one for the inside and one for the outside shapes. A similar test was performed in steel, achieving 10 microinch Ra with the appropriate technology.

The AWJ test cut was performed on a Suprema 1200 Waterjet Powered by Mitsubishi Electric. The machine travels are 48 by 48 inches with 6-inch cutting height in Z. This model is equipped with a 60-hp waterjet pump designed to create as much as 60,000 psi of cutting pressure. The Suprema also has a standard feature called Intelligent Tapering Control (ITC) that allows faster cutting while maintaining side wall straightness. Similar to the wire EDM test cut, this test cut used machining parameters that would be applied in a typical user application.

At first glance, it might seem that the speed of the AWJ for roughing in this case is the whole story. However, according to Steve Szczesniak, national waterjet product manager for MC

Machinery Systems, there is more to it than that. For one thing, he says, AWJ has benefits that may help shops overcome reluctance to wirecut aluminum. For another, not all rough cutswith AWJ are the same. Users can select the parameters that help them optimize the results in conjunction with wire EDM skim cuts.

The Trouble With Aluminum

Because cutting aluminum with wire EDM has some undesirable drawbacks, some shops try to avoid the process, especially if they also wirecut steel or graphite. One problem with wirecutting aluminum is the large volume of debris particles created during the process. It can quickly clog an EDM filtration system.

These particles are an unavoidable by-product of EDM, which is a thermal process. In a sequence that occurs thousands of times a second, EDM uses the extremely high temperature created by the flow of electrical current in each "spark" to form a microscopic bubble of vaporized material just below the work-piece surface. When this bubble expands and bursts, it expels molten bits of the parent workpiece material into the dielectric fluid, where they solidify. The particles created by wirecutting aluminum are very small and very hard. They shorten the life of certain types of filter media and cause the filter cartridges to be changed more often. Disposal of filters containing these particles is costly, and they are not easily recycled. In addition, if these particles remain in the wire EDM dielectric system, they can interfere with the wire cutting of other materials or contaminate the workpiece surfaces.

Because rough cutting a part from a solid blank with EDM removes considerably more material than subsequent skim cuts, finding an alternative process for this step is very attractive.

Laser cutting is a possibility, but cutting aluminum in thicknesses greater than 1/2 inch is difficult. Laser cutting also creates a heat-affected zone that is not easily removed with skim cutting on a wire EDM unit.

Why Rough Cut With AWJ?

AWJ does not face these difficulties. AWJ uses a high-pressure stream of water containing an abrasive grit (usually pulverized garnet) that aggressively wears away the workpiece material as it blasts across the surface. AWJ does not heat or distort the material it is cutting. Chunks of material cut away by AWJ are perfectly suitable to be used for other jobs. Also, AWJ does not need a start hole--it can create its own by piercing the material directly.

However, cutting with a high-pressure steam of water differs in several critical ways from cutting with an energized wire as EDM does. The cutting action of AWJ changes with distance from the nozzle, whereas the cutting action of the wire is virtually the same throughout the full length of its engagement (assuming that flushing conditions are uniform.) With AWL the stream begins to lose pressure and spread out as it leaves the orifice. It also deflects away from the direction of travel as a function of axis travel speed. All of these factors degrade the accuracy and surface finish, and the effects are more noticeable depending on the height of the cut.

Overcoming "Jet Lag"

Recent developments in waterjet technology are able to provide considerable compensation for these natural tendencies in the cutting action of AWJ. For example, the intelligent tapering control system on the Suprema model used in the test cut tilts the high-pressure waterjet as much [+ or -] 6 degrees to correct for the spread of the stream. This system hinges on the

machine's four-axis configuration. According to Mr. Szczesniak, this feature allows faster cutting speeds in a contour and is the key to moving directly to skimcutting.

The company's five-axis Evolution 3D System includes a further refinement that enhances AWJ results. This system uses a self-positioning device that references a rotation point on the surface of the workpiece near the cutting nozzle, thereby maintaining a constant distance between the surface and the nozzle when following 3D geometry.

These developments help AWJ create a smoother, straighter and more consistent surface that may require fewer skim cuts to achieve the desired accuracy and surface finish.

Additional Cutting Tips

Mr. Szczesniak has the following recommendations for maximizing the value of rough cutting with AWJ as a prelude to wire EDM:

* Use the correct nozzle and orifice for the geometry detail required. This will allow you to rough out as much detail as possible during the waterjet cutting process and avoid re-roughing on the EDM. The smaller the orifice size, the smaller the attainable radius. However, cutting speeds have to be decreased accordingly.

* Wall straightness affects the number of skimcuts needed on the wire EDM. Taper control is necessary to cut parts as straight as possible on a waterjet. It also minimizes total cut time.

* The finer the abrasive used in AWJ, the finer the finish achievable with the process. However, finer abrasives cut less aggressively and increase cutting time proportionately. In most cases, the best strategy is to use the finest abrasive on the waterjet and the least number of skimcuts on the EDM.

For more information from MC Machinery Systems, call (630) 860-4210 or search MMSOnline.

Wire EDM And AWJ Test CutsMaterial: 1/2-inch thick aluminum. Total length of cut is about 16inches.EDM Cut Information Cut Time Surface FinishRough Cut 24.24 minutes 190 [micro] inch RaSkim 1 25.4 minutes 90 [micro] inch RaSkim 2 24.24 minutes 82 [micro] inch RaSkim 3 26.22 minutes 58 [micro] inch RaSkim 4 28.57 minutes 50 [micro] inch RaTotal Cut Time 2 hours 8 minutesAbrasive Waterjet Cut Cut Time Surface Finish Information60,000 psi with 120-mesh 6.4 minutes 85 [micro] inch Ra abrasiveThe results of the test cuts show a significant reduction in roughcutting time with AWJ. In this case, a 73-percent time savings wasachieved with AWJ, not counting time saved because no start holes were needed.

Wire EDM cuts a new path - electrical discharge machines - Emphasis : Electrical Discharge Machining

Andrew White

This job shop knew it had to change direction and offer more than just precision milling and turning if it wanted to keep its current customers and attract new ones. Adding wire EDM gave the shop a new range in capabilities along with a better balance in its operations.

When an electrical discharge machine (EDM) is introduced to a conventional mill-and-turn job shop, it can't just take up floor space. It has to earn its keep, and the machine will be under the scrutiny of many skeptical eyes to do just that - and to do it quickly.

So when a wire EDM made its way to the pine woods of northern Massachusetts and settled into a far corner of the work floor at Lavelle Machine, Inc., the staff of 40 looked on with keen interest. Would this machine become a problem-solver, or just a headache-generator?

For 30 years, Lavelle Machine has grown steadily and quietly, building up customer trust in its capabilities as a precision milling and turning shop. By diligently focusing on the areas it knows best, the company has been steadily rewarded with contracts to handle prototype machining assignments as well as small production runs for medical, military and commercial applications.

But the management team at Lavelle sensed they couldn't live forever tightly burrowed within this niche. Often the programs on which Lavelle worked required that the company subcontract out secondary operations such as laser welding, EDM, or product assembly. Some projects requiring additional processes weren't even being offered to Lavelle by existing customers for bid. "We knew we had to increase the scope of our capabilities," said Ed Lavelle, Jr., vice president and general manager. "We needed more things to ask a customer to let us bid on."

A Strategy Emerges

To get that additional business, he decided, the company needed to bring new production capabilities in-house. Assembly work seemed to be the least intrusive to the shop's existing operation, so a portion of the shop floor was set aside for limited assembly work, and flexible staffing arrangements were made so that the company could handle product assembly on an "as needed" basis.

Getting into EDM was a tougher decision. From its earliest years, EDM has had a reputation for "black magic," of being more of a science than a technology - one that also required large capital investment and specially trained personnel. While Lavelle certainly was not wary of advanced technology - its shop floor is comprised almost totally of high precision CNC milling and turning machinery - it had heard enough stories of other machine shops getting in over their heads with EDM.

For Mr. Lavelle, though, a little time spent researching today's EDM equipment showed a pleasant surprise: The industry has changed dramatically in recent years, primarily due to truly quantum leaps in control technology. While computers have simplified processes in countless fields of industry, the gains are most apparent in the more delicate and complex of production operations. Such is EDM. It now seemed possible to run a small EDM operation using existing plant labor - without the expensive and specialized operators and programmers of days past.

One Lavelle employee who last worked in EDM over a decade ago, machinist Harry Haynes, agreed to become the company's EDM supervisor. When he saw the state of today's equipment, he said, "I was literally blown away.

"Programming [an EDM machine today] is a breeze, using plain English and minimal keystrokes. While the job is underway, the display can show the operator a diagram of the cutting path, and then continually show exactly where the cutting is being performed throughout the job."

For Mr. Lavelle, two major factors in the decision-making process were when he learned that most EDM equipment has decreased in price in recent years - even though the control and cutting technology has dramatically improved - and that one of his most trusted machine tool suppliers had recently begun marketing a line of wire EDMs. If we are going to get into this, he thought, now is the time.

Setting Up For EDM

Lavelle already had strong relationships with several customers producing medical components, and often served as primary contractor for jobs requiring EDM operations. The jobs varied in the complexity of EDM work required, and Mr. Lavelle realized his shop would not be able to perform all of the EDM work that might be required with just one machine on-site. But acquiring two EDM machines was out of the question at this early running. Narrowing the decision to either ram-type EDM or wire EDM, the company chose the latter for what amounted to an utterly practical reason. "With ram EDM, you have to make your own electrodes," Mr. Haynes said. "With wire EDM, all you need to do is buy a spool of wire."

Not interested in making their first EDM experience more complicated than it needed to be, the Lavelle managers determined that a control unit that was powerful yet still easy to use would be the major factor in their purchasing decision. They gave the nod to a Fanuc flushing-style wire EDM. Familiar with Fanuc CNCs, they felt confident that the control unit of the new EDM would live up to expectations. Likewise, managers had the additional reassurance of working with a machine tool supplier, Methods Machine Tools of Sudbury, Massachusetts, from whom they had acquired other machines in the past. Methods distributes the Fanuc line of wire machines in the United States but what was important to this shop was confidence that they would receive the appropriate support, training and service as they got started.

"We found the EDM control easy to understand," said Peter Oberto, operations manager. "It wouldn't be unreasonable to expect even an inexperienced operator to be programming and cutting within days."

The machine was placed in the company's prototype department. "It was a cleaner environment in there," said Mr. Oberto. "And in the beginning, at least, we expected most of the cutting we did would be for prototypes or for our own tooling."

Harry Haynes programmed his first job: a modification for a carbide collet used on a turning center in-house. The operation was completed successfully on the first try. "I knew we were on our way," he said.

As the shop began to use wire EDM for prototypes and for small runs, Mr. Haynes and the supervising staff in the shop were especially surprised to find the finished parts not only measured well within specification, "but visually they looked terrific," said Mr. Haynes. EDM has a history of being a less-than desired production method when it comes to producing parts that must be visually appealing. But today's generation of digital AC power supplies, such as that on the model that Lavelle had acquired, greatly reduces discoloring and tarnish by supplying the charge through a non-electrolysis method. "When we saw the quality of the output," Mr. Oberto said, "we knew the range of potential jobs for this machine had just been greatly expanded." Since much of Lavelle's work is in the medical field - where a highly polished, unblemished finish is required for instrumentation - this unexpected benefit of using EDM appeared to be a godsend.

Discovering Production Efficiency

Turning its attention now to obtaining larger work orders for its new capability, Lavelle management suggested to its customers that they could achieve some excellent economies of cost and time by keeping their total job - from milling to turning to drilling to EDM - within a single shop. In addition, job accountability, responsibility and overall quality assurance would be tighter - all key benefits for precision machining jobs.

"It makes sense for our customers to funnel their work into a single shop they know and trust," said Mr. Oberto. "It's better for both the customer and for us."

The customers seemed to agree. One project brought into Lavelle early on, a surgical inserter made from 303 stainless, required four precise operations - milling, turning, EDM and laser welding. The handle for the inserter was milled on a Matsuura CNC vertical machining center. Meanwhile, the shaft was turned on a Nakamura-Tome CNC lathe. Before the two could be laser welded together, however, the handle needed an extremely precise cutting operation to provide three narrow slots. On the prototype, these slots were cut manually with a circular slitting saw. This was an extremely labor-intensive and expensive process. Plus, "we would have needed to do significant deburring on every piece in production," said Mr. Oberto.

With what Mr. Haynes called "a minimum of set-up," the wire EDM took care of the slotting process for four pieces set on a fixture in one cycle, with a cutting time of three minutes for each part. No skim cuts were needed, the accuracy level was 0.0002 inch, and the finished pieces required no deburring or polishing.

Another medical application, a mini-anchor assembly made of 17-4 PH, would have proved even more daunting without secondary EDM capability. Here, the required processes included turning, milling, welding, EDM, assembly, passivating and laser marking. For a machine shop to handle only the milling and turning in-house and then send the other processes outside would have created a nightmare of logistics and quality control issues. But with Lavelle's newly added capabilities including EDM, the only process that needed to be handled out-of-shop was the passivating. Again, the EDM work required for the part was primarily to create three precision slots. On the new wire EDM, the single-cut operation took four minutes per part, with 24 parts per cycle.

For a bushing for a computer printer that had the most demanding specs yet, a blank was turned out of tool steel using a Nakamura-Tome six-axis dual spindle turning center, which also performed a secondary milling operation to create the flange. After heat treatment, the part was brought to the wire EDM, where a rough cut followed by a series of skims took the ID to within a tolerance of 0.0001 inch.

The new EDM received its most vigorous test when Lavelle Machine was asked to produce a prototype for a medical sliding gripper block. The job called for a complex mix of milling, turning, EDM, heat treating, passivating, laser marking, hard coat anodization, and manual assembly using 300 series stainless steel. The most critical operation was the precision cutting of angular teeth 0.040 inch in height that required an extremely sharp point - yet also needed to be absolutely free of burrs for use in holding human tissue during surgical operations.

The wire EDM succeeded in meeting the specs, and upon completion of the prototype, the company was assigned a production run for this component.
EDM And JIT

For Mr. Haynes and Lavelle's EDM operators, the time and cost benefits gained from their EDM setup go beyond the simplified control and ease of use. Several jobs can be left within the control's memory at any given time - and the tooling and fixturing for those same jobs often can be left set up within the machine's working area even while another job is underway. This means a setup for a job that is in frequent production on the EDM can be left intact while another job or two jobs are run during a break in the machine's production schedule. These benefits can be significant ones on a hectic shop floor.

"Our shop has a strong JIT emphasis, and this EDM fits in perfectly," said Mr. Oberto. To keep production changes moving quickly, the Fanuc machine is hard-wired to the shop's central DNC computer, and programs can be downloaded quickly for jobs. For classically trained machinists like Harry Haynes, there are other enjoyable benefits to EDM. "If I set up a job for 1000 pieces, I'll never have to change the offset number," he said. It didn't take very long for Lavelle's new EDM to be booked solid for its two daily shifts and beyond. At the end of the day's second shift, the operator often sets up an "overnight job" and programs the controller to wait until the early morning hours to start the cycle. This way, the job is finished shortly before the first shift operator arrives at 7:00 a.m., and the finished pieces are not sitting wet for an extended period. The first shift operator unloads the finished job, and goes on to prepare the next cycle.

Once the setup is complete and the run button is pushed, the EDM operator rarely needs to stay near the machine. "I can set up 25 parts for a two-hour cycle," said Mr. Haynes. "I can walk away for those two hours and have confidence that everything is running smoothly." If he does decide to wander back to the machine to check the status of a job, all the details of the progress of the run are displayed on the control monitor. "The nice thing about the control is that it graphically shows what I'm cutting at any given moment," said Mr. Haynes. "I always know what path my tool is following."

To create an even greater level of automation, the Fanuc control can be programmed to use its own artificial intelligence capability. The machine can be set so that the controller can be allowed to make its own "decisions" about how to adjust cutting conditions and operations. These guidance functions also can be applied to automatic power recovery, restarting, and even machine maintenance.

At Lavelle Machine, typically the machine's primary operator is working nearby at the shop's laser marking machine, which requires continual operator attention. When the EDM cycle is finished, he simply shifts over to the Fanuc to unload and prepare the next job.

"The two machines complement each other well with their cycle times," said Mr. Oberto. The EDM also allows Lavelle to maintain flexibility among staffing assignments. The company has several veteran CNC milling and turning machinists who have found little difficulty stepping in to operate the EDM - simply by using basic machining principles. The control unit on the EDM is similar to the controls they're already used to working with, and a quick look at the display during programming or at run time shows the data they require to get the job done.

Bringing "Balance" To Operations

Lavelle Machine has always held as one of its goals the objective of being a balanced job shop. In recent years, Ed Lavelle had sought to create such a balance by installing the equipment and recruiting and training the staff necessary to handle complex jobs involving conventional as well as third and fourth axis milling, along with turning capabilities ranging from the conventional to multi-spindle, multi-function operations. "But I had always been eyeing EDM as well," he said. "We wondered if it might be the missing link." "If we were sending the EDM operations on a job out to an EDM shop," said Mr. Oberto, "we had to contend with time delays and quality issues. Jobs were costing more due to our additional administrative and management time. And we were not fully in control."

Now that Lavelle Machine has been up and running with EDM capabilities for over a year, Mr. Lavelle and Mr. Oberto note that they are able to quote lower costs and shorter deliveries on their job bids. They have better control over the jobs that are in the engineering stage or in production, and they have reduced the chances of running into unhappy surprises from outside vendors.

And, they say, they have once again confirmed what they have always believed to be a fundamental tenet of the business: that a machine shop can make itself more versatile and responsive to its customers' needs when it has a broad range of capabilities. "We never want to be in a situation where we cannot accommodate the customer," said Mr. Lavelle.

The customers have noticed. Mr. Lavelle said his company has solidified its relationships with its existing customers as well as opened up new avenues of business in recent months. "In today's market, the company that is going to be the most successful is the one that is the most self-sufficient," said Mr. Lavelle.

One measure of success is growth, and at Lavelle Machine plans are underway for a 10,000 square-foot expansion to the facility, which Ed Lavelle said will certainly include significant additional EDM capability.

And no longer is anyone at Lavelle Machine casting a wary glance at the little white machine in the corner.

How to handle tall wire EDM work: modular workpiece fixturing plays a vital role in this shop's quest to win larger, more difficult wire EDM jobs

Derek Korn

Do what the others can't. That's been Extreme Wire EDM's mantra from the get-go. Its owners realized that the key to succeeding in the EDM game was not only taking on the intricate jobs and large workpieces that their competition couldn't handle, but also figuring out the processes and practices to make this a profitable niche. The owners have no qualms about paying a premium for advanced equipment because they know the payoff comes in the long run in the form of improved production. The strategy is working, as the company's sales have increased by 25 percent every year since its start in 1998, and its customer list continues to grow.

Over the years, Karl and Brian Bernt, co-owners and brothers, have purchased machines with successively larger table sizes, noting a trend toward larger-sized mold work in the United States. However, having machines with the capacity to accommodate these workpieces is only one piece of the puzzle. Effective fixturing and quick job change-overs are equally vital, because an idle machine isn't making money.

Reducing setup time is a common quest regardless of the machining process. Wire EDM, though, is unusual in that the center section of the machine's worktable is hollow, allowing the heads to guide the wire through its cuts. The significance of this is that the cutting wire can't reach the portion of a workpiece that's in contact with the table. That means the workpiece will have to be flipped around and set up a second time to cut the previously inaccessible area. As Karl Bernt notes, such subtle nuances are lost on some mold makers who often think wire shops can just slap a mold block in a machine and start cutting.

For extremely large or long parts, there may be no alternative to clamping the workpiece directly on the table. Smaller components, on the other hand, lend themselves to a modular pallet fixturing system that Extreme uses with good results. This quick-change system offers a way to change out jobs in a matter of minutes, which increases the amount of cutting time for each machine. It also offers a way to extend the parts away from the table to allow, in some cases, complete machining in one setup.

Getting A Grip

Karl Bernt is a 15-year wire EDM veteran who, after working at a few different die shops, decided to start his own company. Extreme has classic garage roots: in this case, it was a functioning auto repair garage. In those days, it wouldn't have been surprising to find Mr. Bernt spending the night there to wring more burn time out of the Robofil 290 that he purchased new from Agie Charmilles (Lincolnshire, Illinois). He soon bought out his partner, the garage's owner, and moved to Grandville. Michigan. Mr. Bernt has leased the company's current facility for the past 8 years and has no immediate plans to purchase his own building. As he explains, his rent is affordable and his machines are paid off, so he chooses to spend money on that which will make money.

Extreme currently has five Charmilles Robofil wire EDM units and one HD20 hole popper. Three of the machines are networked to allow fast part program loading and off-site machine monitoring. Four of the five wire machines have automatic wire threading and submerged cutting capabilities. No two machines are the same size, providing a means to best match part to machine.

The modular fixturing system from Hirschmann Engineering USA (Buffalo Grove, Illinois) can be used on any of these machines. Its three main components are clamping unit, pallet and vise. The clamping unit secures to existing tapped holes located around the machine's table. The vise jaws, which install in the pallet, clamp the workpiece from the side (in the case of a horizontal vise) or on top and bottom (vertical vise). A locking mechanism in the clamping unit secures the pallet/vise/workpiece on the table to a positioning accuracy and repeatability of 0.002 mm (0.00008 inch). One or more clamping units can be located at any point around the table. When clamped, the pallet extends the part into the center of the table, where the cutting heads have a better chance of reaching the entire workpiece.

Each new job that will use the pallet fixturing system starts at Extreme's tooling setup station. A fixturing system clamping unit is installed on the station's granite table (shown in the photo on page 84). During setup, a pallet with vise is locked into the clamping unit and the vise jaws are tightened to grip the workpiece.

The vertical vises use twin jaws that adjust independently to clamp workpieces of various heights. Because the two jaws install into the pallet separately, they can also secure parts that may have different thicknesses at the clamping points. Mr. Bernt has worked with Hirschmann over the years to develop taller vertical jaws to hold thicker workpieces. Current versions can secure parts as tall as 115 mm and are rated at 66-pound capacity (though Extreme has installed parts as heavy as 100 pounds). Mr. Bernt is currently testing jaws that can secure workpieces as tall as 160 mm.

The decision whether to grip the part horizontally or vertically largely depends on workpiece geometry, profile to be cut, amount of extra stock the mold maker provided for clamping and where the part must be indicated. Clamping the workpieces vertically sometimes allows better access to a pick-off corner when indicating a new job. Horizontal vises may interfere with the machine heads and prevent the wire from accessing that location. This can also affect how much cutting can be completed, as heads must stop short of the vise to avoid collision. In this case, two setups would be required to machine the part. There are similar instances in which vertical jaws could obscure a section of the workpiece that requires machining, so horizontal jaws might be a better choice.

Burn Time

The shop schedules short-burn-time jobs for the daytime, then sets up jobs that have long burn times to run during the evening or weekend. A number of fixture clamping units can be installed around the table to allow setup of multiple jobs, but this typically isn't done during the day. That's because the programming time for multiple jobs would take much longer than a single job. The fixturing system makes it quicker to pull a completed job, drop in another, load a new part program and begin cutting. Off-hours unattended work, on the other hand, does lend itself to multiple parts set up around the table.

Some of the difficult jobs the company is going after involve drastic cutting angles, commonly required for slides in mold blocks or variable lands on dies. Sine tables mounted directly on the machine table could be used to deliver these angles, but then the benefits of the modular fixturing system would be lost. Mr. Bernt has modified the heads of three of the company's wire machines to perform 45-degree cuts, which is approximately 15 degrees more than the machines originally offered.

The repeatable workpiece positioning of the pallet fixturing system is helpful when a customer has a "hot" job that must be turned around quickly. Extreme is able to stop a job that's currently in process on a machine, drop in and cut the new job, and then install and finish the interrupted job. The shop added a mounting plate on its hole popper on which it could mount a fixturing system clamping unit. One way quick-change fixturing capability on the hole popper comes in handy is when, after starting a job on a wire machine, it is noticed that the customer forgot one of the start holes. Rather than removing the workpiece from the vise jaws and losing part position in the machine, the entire pallet/vise/workpiece assembly can be removed from the wire machine's table and loaded into the clamping unit on the hole popper. Once the hole is added, then the entire pallet assembly can be dropped back into the clamping unit in the wire machine to complete the cutting job.

The hole popper has also been fitted with a universal rod guide to eliminate the need to buy dedicated guides for specific rod diameters, which would be expensive. The universal guide adjusts to various rod sizes, allowing Extreme to stock 40 different rod diameters (but not 40 different dies). To adjust for a new rod size, three rod fingers lock into position around the rod to guide it as it drills a hole.

Bigger Work

Extreme does machine workpieces that are too large to be used with the modular fixturing system and require conventional clamping methods. For unusually long parts, the company has removed the robot access panel from its Robofil 440 machine and fabricated an enclosure so that the machine can accept parts much longer than the table's width. The quest to machine large parts is also one reason that nearly every wire machine has automatic threading capability. In cases such as the part shown above, threading by hand would be impossible. Automatic threading is also beneficial for workpieces that require multiple cutting operations to allow unattended machining.

Extreme uses stratified wire in three of its machines and recommended CC wire in its two CC machines. Though it is more costly than brass, stratified wire is used for most jobs because it cuts faster. Brass wire is used for parts taller than 6 inches because it can better maintain a straight, precise wall. Large-diameter wire typically allows the machines to cut faster, too, so the company uses 0.010-inch diameter wire for a variety of jobs. Wire thickness is limited by feature radius size.

Because taller parts create more debris and cause filters to clog faster, Extreme is a stickler for routine machine maintenance. In addition, cutting speed should be reduced and flushing pressure increased to flush out cutting debris. Mr. Bernt believes the secret to effective wire EDM is proper flushing. First of all, it washes away the waste material to better allow the wire to burn new material away. Second, it helps maintain wire straightness while cutting. Finally, it eliminates dry sparking conditions on non-submerged machines. Submerged cutting also helps in the flushing process to allow steeper taper angles and accurate contoured parts.

Friendly Advice

Mr. Bernt suggests that mold makers discuss the wire EDM portion of their project with their wire shop so that workpieces are prepped to facilitate the EDM operation. Some mold makers think they are doing wire shops a favor by removing a good deal of material from workpiece edges. This can actually do more harm than good. A wire cutting close to a part's edge tends to vibrate, causing poor wall surface finish and drastically reduced cutting speed. At minimum, there should be 0.1 inch of stock around the edges to allow good flushing conditions for a quality finish, Mr. Bernt suggests. Also, it's best that block sides be ground or machined at the very least. Saw cuts, he says, won't cut it.

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* On The Path To Automation Implementing an integrated tooling system proved to be this mold shop's first step toward automated operation of its ram EDM equipment and graphite mills.

Find a link to this at www.mmsonline.com/ articles/050602.html

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Applying wire EDM to moldmaking: accuracy and autonomy - electrical discharge machines

Wire EDM is still a relatively underutilized technology in the field of moldmaking, but when faced with a mold that was impossible to grind, Peter Fedorko, president of Parm Tool in Erie, Pennsylvania, got a close look at its potential. The results led him to further apply the technology in ways and for operations that previously were impossible for him.

In Parm Tool's 50,000 square foot facility, Mr. Fedorko turns out a variety of workpieces but his specialty is the complex injection molds such as those used for electric connectors. In 1987, a customer brought him a complex part drawing. Mr. Fedorko agreed to take it on for the manufacturing challenge and because he will not say "no" to customers. The mold called for 164 slots with a width of seven thousandths (with a taper).

"At that time, we could grind slots down to eleven and a half thousandths wide but there was just no way a grinder could touch the job," he states. Mr. Fedorko asked around and found another shop using an Agie machine (Agie USA Ltd., 839 Rohlwing Road, Addison, IL 60101) and sent the drawing to them. He goes on to say, "When I got the finished piece I inspected it closely, and within a month Parm Tool had its first Agie machine, an AgieCut 100." The company went on to produce as much as three and a half million parts for that particular project.

Parm Tool is said to be the single largest user of Vectra A130, a liquid crystal polymer. The polymer is said to be a more stable material to mold with better flow for finer centerline parts. "Using EDM from Agie, we can create molds for parts with seven thousandths walls." He goes on to say that his operator can even hold 50 millionths on the work he does. "One little secret is that we keep the room tightly temperature controlled. On the core pin blanks we're cutting out, we can hold a tolerance of 50 millionths by keeping the room at 67 |degrees~."

Today, Parm Tool uses the original AgieCut 100 and a newer AC100D wire EDM system, and both operate 24 hours a day, seven days a week.

"At first, we were using the Agie machines for the accuracy they provided. But the more we worked with them, the more we were able to take advantage of features such as the automatic wire-threading (which rethreads the wire, even in the taper) and programming, to get outstanding productivity. My operator, Gary, runs both machines but spends only 30 percent of his time doing that. The other 70 percent of the time, he spends doing some mold repair in another part of the plant. We could put another machine in there and only impact his job by another ten percent, they really are that autonomous."

How good are the parts they produce from their molds? In February 1991, they produced their highest volume of plastic parts ever and maintained a CPK level of 1.51 or six sigma for over one and a half million parts.

Mr. Fedorko describes the changes at Parm Tool by saying, "Our first priority is getting the tool right. Having a good quality tool is 85 to 95 percent of the molder's job. If you have a good tool, a molder can make a good or a bad part. But if you have a bad tool, even the best molder in the world can't do anything about it." What began as an alternative to grinding has become an essential part of Parm Tool and its success.

Wire EDMs in vanguard of tool, die progress - electrical discharge machines

Audrey Lipford

NEW YORK--Tool and die makers are making innovative use of electrical discharge machines, while the use of lasers and programmable computer numerical control (cnc) machines use is not expected to dramatically exceed that of conventional machining methods in the immediate future, interviews with officials at several companies found.

Among the innovations now being seen are work with helical parts for aircraft, prototype and short-run jobs, mold making changes, and various applications of vectoring, orbiting, tapering and undercutting, the officials said.

The use of programmable UV axes is one significant innovation making tool and die makers strong competitors for that more diverse work, particularly in aerospace industry areas, according to David Smith, secretary and treasurer of Dayton Wireburn Inc., dayton, Ohio.

Dayton Wireburn does subcontract electrical discharge machine (EDM) work for companies in cases where volume does not justify the high cost of the purchase of such machines or the employee training and investment required to get maximum usage from the EDM technology.

The UV axes, which move independently of one another, facilitate the ability to produce different contours on the top and bottom of the workpiece, and chemical configurations, Smith said.

This capability allows the tool and die maker to do more diversified work involving more than one contour, such as in aircraft work.

For example, some aircraft components require helical patterns, the creation of which is facilitated by the UV axes. Use of the Z axis, generally limited to machining a workpiece of four inches, is expanded to 10 inches with the programmable UV axes.

Micro-Cut Engineering, a job shop in Streamwood, Ill., which does contour cuting work, late last year acquired a laser cutting tool which it expects will allow it to move into areas outside those of machine tools. According to Rich Binning, owner of Micro-Cut, the $250,000 machine will allow his company to do short-run production and prototype parts for the stamping industry.

"With the laser we're looking to make a dent in the (stainless steel) signmaking business, prototype dollhouses, and plastic artwork (such as mosaic tiles)," Binning said.

While Binning acknowledged the part accuracy of the laser is not as great as that achieved from a wire EDM, he said the new areas his company plans to move into do not require the same tight dimensional accuracy of machine tools.

In the building of a die, for example, the die clearance between the punch and the die must be strictly maintained, but the part accuracy may not have to be adhered to as strictly, he said. Gaskets, for example, can have a part accuracy of plus or minus 0.005 or 0.0001 inch.

What the laser tool lacks in that accuracy, it makes up in cutting time, Binning said. A part that would take 48 minutes to cut, for example, would take 42 seconds with the laser. As a result, a six-week delivery time can be dropped to perhaps one to two weeks. The accuracy of the tool of the laser ranges from 0.0006 inch to a foot, Binning said, while its part accuracy is not that close.

The problem of controlling the laser's so-called burst of energy can be controlled by changing the pulsing mode, using a non-continuous rather than a continuous ray, Binning said. The laser tool was manufactured by Laser Lab Sales, Inc. of Farmington Hills, Mich. Basic characteristics of the tool include a table size of 63 inches by 80 inches, a positioning accuracy of 0.0006" per foot of travel, a maximum positioning rate of 800 inches per minute and a maximum cutting rate of 400 inches per minute. Control specifications include a 16-bit micro-processor, up to nine axes of control, and advanced programming and hardware features.

Just last month, Micro-Cut initiated its first who paying cutting jobs with its recently acquired laser tool. One is a prototype part insulator out of a hard fiber material for International Business Machines Corp., White Plaines, N.Y. The second involved the cutting of gasket material for Dana Corp., Toledo, Ohio, a maker of power transmission equipment.

"The main reason I bought the (laser cutting) machine was to get into more diverse work," Binning said. "We'd like to have three or four more of them within the next few years."

Micro-Cut's wire EDM business has been "unbelievably fantastic; I like to think it is due to the quality of our work, and delivery times," Binning said. About 60 to 70 percent of Micro-Cut's business is moldmaking, the remaining 30 to 40 percent is tool and die.

The designing of molds today includes tooling which incorporates more of the capabilities of wire EDM than in the past, Binning said.

Irving Trygg, vice president of Eltee Pulsitron of West Caldwell, N.J., a builder of conventional electrode EDMs and vendor of wire cut machines, said there are about 5,000 wire cut EDMs and about 15,000 conventional EDMs currently in use in the United States.

The wire cut machines are sold at the rate of about 500 to 600 units per year, he said, adding that he expects that rate to increase by about 50 to 100 annually over the next five years after which the rate will start to slow.

Predicting a "more sophisticated operator" in the future, Charles Peterson, vice president of marketing at the Elox division fo Colt Industries, said "the bottom line is we're moving into cnc" as a result of substantial strides and demands for unattended factory operation.

A wire shop's outlook

Mark Albert

What does a wire EDM shop look like in 2007? What does a wire EDM shop look jot in 2007? I called Milt Thomas, president and founder of Wire Cut Company, Inc., in Buena Park, California, to find out. Milt started his shop almost 30 years ago to specialize in wire EDM. I've known Milt for many years and wrote about his shop in 1997 (www.mmsonline.com/articles/099702.html). At the time, I considered Wire Cut a good "role model" for other shops interested in EDM.

Milt has always taken EDM very seriously. When he started his shop in 1978, EDM was not the mainstream process it is today. Milt not only mastered the technical complexities of wire EDM, but he also pioneered new applications for it, especially those involving very tall workpieces. Milt soon added ram EDM and CNC machining, but has kept his focus on the wirecut process and its expanding capabilities. Given his background and history in this technology, I was interested in Milt's thoughts on the current prospects for wire EDM and in his outlook for the coming year. First, I checked his shop's Web site (www.wirecut-co.com) and then had a nice chat. Here are some of the observations that I took away from this conversation.

Wire EDM still has unique capabilities that make it indispensable as a manufacturing solution. Engineers are designing parts (especially in aerospace) to take advantage of what wire EDM can do. He expects this trend to continue.

That said, a shop such as Milt's has to have complementary processes that leverage creative use of EDM. He's added four-axis CNC machining, small hole EDM drilling, several more sinker machines and a large coordinate measuring machine just in the last year. Because wire EDM lends itself to complex, close-tolerance parts, having advanced machining and inspection capability naturally follows.

Palletizing workpieces to move seamlessly from process to process is important. Wire Cut is investing in this area and emphasizing the necessary shop disciplines to leverage the benefits. "It's the way forward," Milt says.

Further gains in wire cutting speed don't get Milt very excited, but he highly values the extreme accuracy that today's wire machines can deliver. "We can split a tenth but keeping the entire shop environment exactly right is the challenge," he says. "That includes air temperature, water condition, de-ionzing and most of all, having machines that are clean and well maintained."

Milt is pleased to see EDM builders introducing wire machines for larger and heavier workpieces. Wire cutting very small workpieces is a growth area but Milt sees unexplored territory and radical possibilities in large, monolithic workpiece applications. Looking for new frontiers is still a key part of his EDM experience.

Running all of his machines around the clock and mostly without much operator attention is a routine fact of life for a shop such as Wire Cut. It has to be, he says. Milt keeps his work in diversified applications. Medical, aerospace, and semi-conductor make most of the current mix. He's particularly vigilant about this because he got caught when a bubble in lucrative semi-conductor jobs burst a few years ago. Technical prowess has to be guided by good business sense, he says.

High speed EDM hole drilling is a capability that Milt is going to grow in 2007. He's looked at laser and waterjet cutting but would rather pursue high-end machining center capability as an asset. He thinks it will do more to attract more profitable work in less crowded markets.

Because wire EDM is a technology that keeps changing, looking ahead has to be a habit for shop owners such as Milt. That has made him mindful of the on-going need to develop new talent for the industry. Over the years, he's maintained an in-house apprenticeship program and has been a strong supporter of training efforts, both on the local and the national level. He won't let up in 2007, he says.

I'd say Milt is still a good role model for shops committed to making the most of wire EDM.

MARK ALBERT

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EDM continues to evolve

Chalmers, Raymond E

New technical developments and custom applications drive change

11 puns aside, the electrical-discharge machining (EDM) market is hot. Many suppliers of wire-cut and sinker EDM machines describe last year as the best sales year ever, with total sales for the category exceeding $1.5 billion. Analysts predict sales will rise 7% annually through 2004, fueled by advances in machine reliability, productivity, and programming; all this despite EDM still being categorized as "alternative" or "special" machining equipment.

In fact, new bywords for describing EDM processing ought to lead with "productivity, in the literal sense of the word," says Gabriele G. Carinci, president, AGIE Ltd. (Davidson, NC). "One of the biggest myths that needs dispelling is that one man is needed to operate one machine," he says. With such options as multiple parts in one setup, including parts of different heights and materials, EDM processing can certainly help parts manufacturers control high labor costs while keeping prices low and quality high for customers. Doing so, Carinci says, requires "a dual level of integration-the machine being a system integrating with the operational system of the company. The single biggest area where Agie plays a pivotal role is systems thinking. You can't just drop a machine into a shop."

Other suppliers concur. Greg Langenhorst, EDM division product manager for MC Machinery Systems Inc., a Mitsubishi Corporation (Wood Dale, IL), describes the EDM marketplace as "a forum for constant customer education." Because EDM equipment is not cheap-even low-end equipment goes for $125,000-and erosion rates still require overnight jobs and untended operation, manufacturers take machine reliability and operating efficiency as givens. Education plays a role in teaching manufacturers not only to recognize advances in machining speed, but to exploit them to improve total process speed. A variety of options come into play here, including new developments in EDM, as well as a growing array of programming and automation choices.

On the wire side, one advance speeding EDM processing is the antielectrolysis power supply. Formerly an option on Mitsubishi equipment, the patent-pending development is now offered by the manufacturer as standard. In machines lacking this feature, stray voltage leaking off the wire produces rust, which must be removed by polishing. Electrolysis also causes excessive bluing in titanium parts and microcracking in carbide tooling, causing carbide dies or punches to chip during machining or break down more quickly in production.

Version 3 of the company's antielectrolysis power supply, called AE3, uses fine-pulse control circuits to precisely control machining currents in the discharged energy field. This feature minimizes reductions in surface hardness due to electrolytic deterioration or corrosion, helping prevent workpiece chipping even during extended machining. When machining ultrahard alloys, including carbide and other sintered materials, almost no strength reduction occurs because of binder depletion after machining, according to the company. When used on a machine that produces plastic molding dies, the antielectrolysis power supply can greatly reduce grinding and polishing; when used on iron-based materials, it minimizes rust and oxidizing zones. With its Isopulse generator's surface-integrity feature, Charmilles (Lincolnshire, IL) even guarantees no microcracking when machining carbide, along with a uniform surface finish featuring a recast layer less than 0.000040' (0.0010-mm) thick. Running costs may decrease as well, since with such efficient power supplies, antirust agents may no longer be necessary.

Mitsubishi research also indicates a nearly threefold increase in the service life of the ion-exchange resin used in standard submerged machining because of the more efficient power supply.

On the sinker side, adaptive controls using "fuzzy logic" to variably control acceleration and deceleration rates are another hot topic. Understanding why fuzzy logic helps improve EDM operation requires understanding two basic processes in sinker EDM: sludge creation and sludge removal.

Basically, the energy released by the sinker creates a sludge that's usually made up of resolidified workpiece material, electrode material, and tars from the dielectric fluid. Machine builders usually remove sludge by flushing or machine-controlled jump strategies in the discharge area so the discharge remains stable. Balancing sludge creation and sludge removal yields stable machining. Make too much sludge relative to sludge removal and an unstable process results. Too little sludge relative to sludge removal means slow machining. You need adaptive controls to adapt or modify discharge control parameters to keep the system in balance.

Also necessary is a jump strategy that addresses the machine's jump-up, jump-down, and jumpspeed parameters. The jump-up parameter defines the set distance that the electrode retracts for removing sludge particles, either by the retracting action itself or by auxiliary flushing. Applying through-electrode flushing can greatly diminish the need for jump actions during roughing.

The jump-down parameter defines the amount of time electrical discharge pulses can occur. Jump speed is the acceleration and deceleration rate required to attain the jump height and return distance defined by the jump-up parameter. Although typically linear, these rates can be nonlinear. Large electrodes that generate greater hydraulic forces usually mean slower speeds.

When adequate flushing conditions exist, a conventional jump strategy does very well. A new jump strategy that allows a greater retraction distance at a faster acceleration rate can address marginal or no-flush conditions that would severely test a conventional power supply. At IMTS '98, Mitsubishi unveiled its Fuzzy Pro II upgrade, an adaptive control system incorporating this new jump strategy. It uses a variably controlled acceleration and deceleration rate that can retract the electrode from the burn by as much as two inches. The company predicts marked processing-- time improvements for deep rib or cavity burns, small undersize applications, and marginal or no-- flush conditions.

Three things help the Fuzzy Pro draw maximum performance out of a sinker EDM's fine-pulse power supply: a processing-area sensor that automatically recognizes the area being machined; another sensor that detects hydraulic reaction force; and an adapter that recognizes changes in gap stability in microseconds. Fuzzy Pro contains a function that automatically recognizes the electrode's contact area with the workpiece during discharge. Because the previous method of adaptive control made decisions based only upon gap stability, adding measured contact area as a factor means achieving optimum machining depth conditions much faster. Power level increases can only occur after detecting sufficient contact and appropriate gap stability.

Also, since the control can measure electrode geometry and contact area, Fuzzy Pro automatically sets burning conditions during machining of the electrode's leading edge. This automated action reduces what is normally a very complicated set of programming steps to an automatic operation.

Controls and related programming advances of this sort not only speed and sometimes automate machine setup and operation, they give users the possibility of incorporating EDM knowledge and know-how into their systems and equipment. Also at IMTS, Agie unveiled its Futura V SuperStar control for its Mondo Star die sinking systems. Working in Windows 95, the control has a wizard-based job setup function with EDM and erosion-- specific knowledge built in. Operators can program an elaborate four-cavity mold with complex orbits and measuring cycles in about 10 minutes compared to more than an hour in other systems. An automatic erosion-programming feature allows the programmer to click on an icon for the necessary erosion complexity. After running the calculations, the control recommends erosion settings, number, and best undersizes for electrodes that meet the required part accuracy and finish specifications.

An optional feature, StarView, employs a camera and modem so the control can use the Internet for remote monitoring. With a phone line and Web browser, users can ask Agie support personnel to dial into the system and walk them through any setup or service problems.

Recently, Agie's EDM equipment also received acclaim for its design. Earlier this year at the CeBit show in Hannover, Germany, the Agiecut Classic and Evolution wire EDM systems and the Agietron Innovation diesinking system received Best Products status in the Industry category of the Industrie Forum Design awards program. These were not simply aesthetic awards; they recognized EDM technical advances as well. Screens punched into the machines' doors and sides, for example, are not simply design elements, but also dissipate heat and emissions. Custom applications drive advances in some areas. Raycon, a TransTec Advanced Machines company (Ann Arbor, MI) recently launched a new EDM four-head drilling machine, capable of precision-drllling microholes in a variety of fuel injectors. Capable of machining holes of 0.1 mm in diam and as deep as 1 mm, the new system can drill as much as 25% faster than previous machines. Part of the speed increase is due to the company's flow measurement technology. The flow system measures the total flow of each nozzle and generates a statistical process control analysis of the last 32 parts measured.

Next, the system generates the deviation of average flow from the specified mean, and uses the software database to keep the system in control, making absolute electrode size less vital than it was. Fuel injectors needing drilling can be mounted on individually programmable stations on the A axis. The A-- axis assembly is in turn mounted on a servo-driven U axis, and EDM electrodes and servoheads on a linear X axis. A resident database helps simplify part programming, and a warning indicator automatically advises when an electrode falls below usable levels.

Where will EDM's continuing evolution lead? More and more often, EDM intelligence will be resident in the equipment. Machining speeds and overall part processing speeds will certainly increase. Given the ability to take advantage of automation and untended operation, EDM systems should continue to help manufacturers meet productivity and part accuracy goals reliably and cost-effectively

Want More Information?

SME's Fundamental Manufacturing Processes video series includes a program on EDM, describing and explaining both ram and wire-cut processes. For information, contact Customer Service toll free at (800) 733-4763, 8 am-6 pm, Eastern Time, Monday through Friday. For more technical information on EDM systems, use the following numbers on the reader service card.

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Raymond E. Chalmers

Special Projects Editor

A secret weapon—again

Mark Albert

There was a time, 20 or 25 years ago, when electrical discharge machining (EDM) was a mysterious and misunderstood process mastered by but a few shops. For these shops, EDM was their "secret weapon." It could do things that other metalworking processes couldn't do. Working with EDM required patience and persistence. It could be tricky and unpredictable. In those days, EDM was often characterized as "non-traditional" or "exotic," but that characterization wasn't entirely inaccurate.

Yet the ability to erode the highly detailed shape of a formed electrode into a hardened piece of metal or slice an intricate path barely wider than the diameter of a fine electrode wire opened up all kinds of new manufacturing possibilities.

Then, year after year, the equipment became more reliable, more capable and easier to use. It became more affordable. Breakthroughs in solid-state electronics made the process much more controllable and predictable. Cutting speeds and metal removal rates went up. Computer numerical control made a high degree of automation possible. Advances in CAD/ CAM improved programming. EDM was gradually joining the mainstream of metalworking processes.

But in the last few years, EDM seemed to lose ground to other processes in certain quarters. Advances in milling, turning, grinding, laser cutting and abrasive waterjet began encroaching on EDM's territory. Hard milling, for example, has been displacing EDM as an effective way to machine certain mold and die cavities. At a recent machine tool show, exhibitors were demonstrating how five-axis milling with extremely small end mills could produce corners as sharp as those once only attainable with a ground EDM electrode. "Eliminates EDM" has become a selling point for a variety of processes.

As some shops make a strategic retreat form EDM, others should be re-examining what the latest in EDM technology can do. The process continues to become faster, more efficient, cleaner and more automated. EDM has always rewarded those who approached it with imagination and creativity. Fortunately, that hasn't changed. The kind of manufacturing that seems to have the brightest future in this country might loosely be described as "nontraditional" and "exotic"--the work that is too daring, too demanding or too vital for off-shoring.

This could be exactly the situation that calls for "secret weapons" in the hands of imaginative and creative manufacturing companies. I'll bet that EDM will be part of that arsenal.

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US MANUFACTURERS GAIN AN EDGE

Lorincz, Jim

Small, delicate parts challenge processing

It's not a stretch to say that wire and sinker EDM technologies are cutting faster and putting a finer finish on products that are smaller, more delicate, and more complex than ever before.

Chief beneficiaries of these advances in EDM technology are US manufacturers in the mold and die, medical device, and electronics industries, among others searching for a competitive edge against their global competitors, principally from Asia. It's not too surprising, then, that many of the advances in technology are aimed at taking the EDM process deep into the realm of micromachining.

"To survive and compete US manufacturers must come up with new ideas and concepts to work with the very smallest parts," says Gisbert Ledvon, Charmilles (Lincolnshire, IL). Ledvon explains: "Electrodes are required for parts that are so small that you have to rely on your ability to cut the part perfectly, because they are difficult to measure."

Charmilles has adopted a two-pronged approach in developing its Roboform 350Î¼ MicroTEC technology for micromachining delicate, complicated parts. "First we have focused on developing application-driven technology that addresses the customer's requirements, for example, to produce a deep rib or produce a finish of a certain quality rather than to cut graphite into steel. Secondly, we have developed the MicroTEC generator to fine-tune power settings to match the complex details of smaller electrodes," Ledvon states.

The purpose of the MicroTEC discharge circuitry is to provide the EDM process the flexibility necessary to maximize material removal, while allowing a reduced electrode undersize of less than or equal to 0.002" (0.05 mm). "In this way," says Ledvon, "higher machining outputs are achieved, while maintaining the geometry of the electrodes due to an extremely low wear rate."

Machine accuracy is critical in small-cavity work or for positioning the electrode in multiple locations. Charmilles has replaced the former approach of using a drop tank and circulating dielectric flow around the table with a double thermostabilization system. The Robofbrm 350Aμ's main frame and X, Y, Z axes are enclosed and cooled by pulsed air, cooled in real time by the dielectric, which is circulated through holes drilled in the table. The result is that the whole machine tool is cooled by one chiller to one temperature.

"For micromachining, manufacturers need a lot more electrodes for all the small details of a mold. Having access to a lot of tools in the ATC is important, especially because tool changers for EDMs are fairly slow compared with those for milling machines," says Ledvon.

Charmilles has developed an ATC which is faster than previous models and has a storage capacity of 160 electrodes. The ATC has a double gripper that reduces toolchanging time from about 2 Â½ min to 55 sec. The ATC is a much less costly alternative to robotic tool changing, and it is integrated in the machine's control with collision protection.

A Renishaw optical transmission probe that's readily available can ensure positioning accuracy within a micron and is managed by the Roboform 350Aμ. Optical transmission of measurements allows dimensional inspection of machined cavities, as well as the taking of part references without having to remove it from the machine. All the measurements are sent back to the CNC, which then generates a complete inspection report.

"This is an important feature for medical and aerospace industries that require part-tracing information that the DPControl can generate automatically," says Ledvon. The DPControl interface offers a wide choice of machining strategies developed on the basis of the new MicroTEC settings, and generated automatically based on the data entered by the operator.

A lot of production work has shifted offshore, but there is still a great deal of work that's likely to remain, especially if the right technology is available. Jeff Kiszonas, EDM product line manager, Makino's Die/Mold Technologies (Auburn Hills, MI) explains: "There is still a lot of work staying here in the US in microminiature, medical, aerospace, and telecommunications applications, as well as prototyping and short-run mold or stamping-die work," he says, noting that "aerospace and DOD work tends to stay here."

"There is a movement, though not very strong yet at this point, to micromachining whether for miniature connector molds, miniature stamping dies, or miniature parts for medical implants, and telecommuncations products," says Kiszonas. "Drives for IPODs, and handheld video are getting smaller all the time, as are cell phones."

At IMTS, Makino introduced its EDAC1 ram EDM machine to the microconnector mold market for such products as cell phones and charger connectors. The EDAC1 is designed to deliver machining accuracy of Â±2Aµm and a corner radius of 5Aµm. "The ability to execute the tiny corner radii required by precision dies/molds for making connector parts and other components is increasingly in demand," says Kiszonas.

The EDAC1 ram EDM features an oil-cooled system that removes heat from the Z axis for improved depth accuracy. The SPG machining circuit provides surface finish of 0.5 Aµm R^sub y^ for carbide and 0.6Aµm R^sub y^ for SKD-61.

Introduced at IMTS 2004, the UPJ2 horizontal wire EDM has about 100 installations worldwide, and has been launched in North America for electronics, medical, telecommunications, and fiber-optic applications.

"The market for this type of machine is small but growing," says Kiszonas. "The machine can automatically thread tungsten wire to 0.0008" [0.020-mm] diam. In Japan, I recently saw one being used for plastic injection molds for gears that weigh about one millionth of a gram," he says. Makino has introduced its HEAT, or High Energy Applied Technology, to enhance cutting speed and accuracy for its SP-43 and SP-64 wire EDM machines in production job shops, and aerospace and medical applications.

Using 0.010 or 0.012'' (0.25 or 0.30-mm) diam wire, HEAT can achieve part straightness of 0.0005'' TIR (0.013 mm) per side in one-pass machining and 0.0002'' TIR (0.005 mm) with two passes. HEAT technology can be used with both standard brass and coated wires (paraffin, nonparaffin, and high zinc).

Kiszonas explains: "HEAT greatly increases cutting speed in poor flushing conditions with detached upper and lower nozzles. Applications where the flushing nozzles are not sealed on the parts, or uneven part thicknesses, inherently cause problems with speed and wire breakage throughout the burn. Applications include medical hand tools and piece parts, as well as aerospace, electronics, fiberoptics parts and tooling, and contoured shapes, or where there are cross holes or counterbores."

Although the HEAT technology was developed specifically for tool steels, it has produced advantages in cutting stacked titanium plates. "We've seen some advantages to using HEAT for titanium because titanium burns like steel in a lot of applications. It has even been tried on Inconel with some good results, though there isn't much of an advantage for high-nickel chromium alloys used in aerospace."

MC Machinery Systems Inc. (Wood Dale, IL) has introduced two wire EDM machines, the Mitsubishi FA-PS and the Mitsubishi FA-VS, that advance the technology and capability of two existing machines, the FA-P and FA-V, the former noted for its accuracy, the latter for its speed.

* The FA-PS wire EDM is aimed at high-accuracy, small-wire fine finishing typical of the microtechnology world of miniaturization for connector tooling and small medical parts,

* The FA-VS wire EDM combines the speed of the FA-V machine with the accuracy and finish of the FA-S machine to reduce total part processing time through increased high-speed, rough-cut machining and improvements in finish machining.

"The FA-PS wire EDM is capable of running with wire from 0.002 to 0.012'' [0.05-0.30 mm] with start holes from 0.007'' [0.18-mm] diam with 0.002" [0.05-mm] wire," explains Greg Langenshorst, technical marketing manager, Mitsubishi EDM. "The previous FA-P machine ran a minimum wire size of 0.003'' [0.08 mm]. Most other standard machines, some requiring options, are capable of reaching just 0.004'' [0.10 mm]," he says.

The significance of this small-wire capability is that, in combination with the digital FS control, surface finishes to 3.0Î¼ in Ra, which is twice as good as previously attainable, are possible.

"The FA-PS brings a new level of customer work to the company," says Langenhorst. "Workpieces that require both high accuracy and fine finish, including carbide work, electronic connector tooling, or microchip-type tooling, as well as cutting tips of medical devices that need the finest burr-free surface finish, are leading candidates for the FA-PS," he says.

"Previously, for small-wire work you would have to use molybdenum or tungsten wire, but wire technology has advanced so that brass alloy wire to 0.002'' [0.05 mm] lends itself to faster cutting speeds, less expense, and is easier to use with machine technology," says Langenhorst.

The FA-PS isn't necessarily limited to using the smallest diam wire, either. Langenhorst remarks: "Machine movement has been smoothed out with AFC2, advanced friction control.

Disturbances during high-precision feed and machine reversal are suppressed to produce a high level of roundness and pitch precision with a circularity error of 0.00005'' [0.0013 mm].

Precise positioning and Â±3Aµ machining accuracy are achieved."

Langenhorst compares the new FA-VS wire EDM machine to a race car, combining the high speed of the V machine with the accuracy and surface finish of the S machine. "The high-speed V500 power supply produces machining speeds to 500 mmVmin and improved machining performance for difficult-to-cut materials, like titanium alloy or heat-resistant high-nickel alloys." For piecepart production machining the FA-VS can automatically thread 0.36-mm-diam V wire.

"Some of the key features in the V500 power supply lend it to cutting PCD or CBN and graphite like POCO EDM 200, a very popular grade of graphite for sinker use," says Langenhorst: "It's a less-expensive grade than, say, EDM 3, being a coarser-grain material with high tar levels. It has a tendency to heat-fracture and stress-crack more from high spark intensity. The V500 sails right through it with no signs of micro-fracturing. It also works better in high-temperature materials like Hastelloy, Waspaloy, and Inconel, among others."

"Total part processing time is improved by 20% or more by the FA-VS through increased high-speed, roughcut machining and improvements in finish machining. Surface finish to 9-10Aµ in R^sub a^ is twice as good as the previous FA-V model. High-speed, high-accuracy machining with 3Aµm straightness is possible with a minimum number of finish cuts," Langenhorst says.

The FA-VS also benefits from the Corner Master 2 control that attains a uniform electrical discharge gap regardless of the corner shape. The control improves radial shape error and total part accuracy. The Power Master PM4 control enables full automation from rough to finish machining, allowing stepped shape capabilities for processing multiple parts with different shapes and thickness to be machined without setting specific electrical conditions.

Jim Lorincz

Senior Editor

SlantBed v/s Flat Bed CNC Turning Centres

Slant bed design offers some reduction in theeffects of cross-slide backlash. Ithelps in making Z axis motion more straight and stable. With the bed tiltedupward, and with a machine's moving parts "hanging" on the uppermost surface ofthe uppermost ways, the force of gravity helps in stabilizing motion andimproves accuracy.

In case of a slant bed lathe, the slant position ofthe guide way relative to the spindlecenter line and the positioning of the ball screw causes major cutting forcesto be absorbed directly into guide way thus promoting maximum load capacity andfurther enhancing long term accuracy, rigidity and wear characteristics. Inaddition, the design removes the mechanical couple associated with the forcesgenerated between cutting tool, guide way and ball screw -nut which tends to'crab' the carriage, thus, cutting and drive forces are in equilibrium.

In the slant design, a permanent cavity/gap in thebed has been accommodated to allow for extra 'gap-swing' without the usual lossof slideway support. By utilizing a 30 degree slant bed design andinstalling protective covers over the linear guide ways, swarf debris cannotaccumulate on the bed way or in swarf 'traps'. With the slant bed design, there is dramatic improvement in the abilityto get hot chips off the machine and to let them directly accumulate in a chipconveyor before they could ruin machine accuracy by transferring heat toslideways and castings.

Slant bed offers some ergonomic advantages as well.When the cross slide , or the whole machine bed, are tipped up off the floor,the turret is naturally tipped toward the operator, making tool mounting,inspection and maintenance some what easier than the flat bed lathe. The slant of the bed presents the work areaat a much better angle for the operator with regard to loading, access andvisibility.

Jasmin C.Shah

CNC Application Engineering Consultant

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A CNC Router Can Be Useful At Home

By Kurt A. Schefken

You can use a cnc router table for cutting various types of materials. Depending on what kind of machine you buy you can cut, plastic, metal, or wood with your CNC router. You can use your machine for basic routing work or to make signage. Since your router also does engraves, it can be very versatile. So if you can only buy a single machine, you should be able to get many different uses from it.

In the past few years many people have considered purchasing a used cnc router or a new one for their home use. Some smaller shops have also bought them for a variety of purposes. You can save a lot if you go for a used machine instead of a new one.

You can also follow certain plans online that can teach you how to create your own. You can make one to suit your purposes from 15 x 15 up to 50 x 60 inches. Using a cnc router can help you complete projects that you wouldn't be able to on your own. You can create patterns and lay down metal inlays onto wood. Your creations will be smoothly done and correctly done. It will help you accomplish tasks you couldn't do by hand alone.

If you want truly pro results when it comes to crafting furniture then a cnc router can help you out. Using special software will help you to program things exactly so you get the cuts you want. Use for engraving anything you want from a outdoor sign to the smallest cnc lettering. Once you know how to operate the machine and software, you can create virtually anything.

You can find a small machine that can be operated in your home with just a normal 120 voltage. This type of machine would be good for home use. These kind of machines have motors that range from 1-2 horsepower. These small models run about $3,500 used or $7,000 new. This makes buying a used machine a great option for your home. If you wanted to get a large machine this could cost $20,000! This is more than most people want to spend on their home equipment. If you are buying one for a potentially profitable business, then this might be a consideration.

You can save about half if you buy a router used. You can get all the power from it, a save twice as much! When you are looking around for a router shop carefully. You should determine your exact needs and then find a machine that will handle them. If you get a used router you should remember that it may be a bit slower than a new one, but if you don't have large volume then it should be OK for you.

The free-lance writer Kurt Schefken is passionate about ideas relating to cnc machines. You might find out more about his writings on cnc router over at http://www.insidewoodworking.com/cnc/cnc_router.html and different sources for cnc router news.

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http://EzineArticles.com/?A-CNC-Router-Can-Be-Useful-At-Home&id=551533

CNC Machines Get The Job Done

By Greg K. Hansward

If you need a machine that will improve your speed and accuracy then try a CNC machine when you are getting large jobs done or doing very repetitive tasks. You can get a used one for half the cost of a new one since most individuals wouldn't want to spend their money on a new one. CNC equipment can be found in woodworking shops or industrial settings. Add them to your collection that includes a milling machine as well.

If you need to drill holes than consider a CNC router. Some of them can hold more than one tool too. This makes it possible to do more than one procedure at a time. This will help you cut back on the tie you spend working and help you become more accurate.

Computer Numerated Control is the full name for CNC. In the 1970's this technology was first created. These machines are easy to run and operate after they have been initially set up.

They also need to be set up correctly and programmed before they are operated. They can be made so you can drill a hole automatically. This can be much more accurate and quicker than manual drilling. You will get more uniform results. If you have a large job that needs a lot of drilling then this can be a good choice for you. You might get more inconsistent results when you are doing manual drilling and if the operator gets tired.

If you want a good thing to cut wood with then try a CNC lathe. You can buy one that ranges from 15-40 horsepower. You will choose the lathe power you need depending on the type of wood you use. You can get a model that comes with more than one mode. You can one that is totally manual or CNC. You can rig each machine for your individual project.

If you want the best in milling technology then try a Bridgeport mill. You can find a mill in both a small shop or a large one. If you want a mill that will last forever than try a Bridgeport mill. They are very pricey and more so than most people can afford.

A CNC mill use a special type of instrument that uses a combination of robotics and computer programming. You will get great results better than anyone could ever want. These are the kind of mills that the airline companies use. The CNC decides which tool is need for an operation and changes as it goes.

Since CNC equipment is so pricey it means most people can't afford it. If you get a used machine you may find that you can afford it. You may be able to save about half on a used machine compared to a new one.

Being really passionate about cnc machinery and woodworking tools, Greg Hansward authored different summaries in this specific area. With his detailed writings on cnc machines and tools and cnc machinery the reviewer showed his deep knowledge on the topic.

Article Source: http://EzineArticles.com/?expert=Greg_K._Hansward

http://EzineArticles.com/?CNC-Machines-Get-The-Job-Done&id=551529

The Keys to Getting the Perfect TV Stand

By Ray K. Walberg

So, you've gotten yourself into a new HDTV so that you're entertainment life at home will change. Well, now you're also going to have to change some of your decorating, including a new TV stand to accommodate for the bigger set.

Now that the new HDTV sets are bigger, heavier, and a bit pricier, you have to go that extra effort in remodeling your home for these new toys. However, if forking over a few hundred bucks for a stand is beyond your intentions, there are some alternatives for you to consider.

You can go ahead and grab a steel kit for about $100 bucks. These are strong kits that come in many sizes, and you can construct it in about an hour, even if you're not a professional handyman, or even a mediocre one at that. Usually, these will hold the TV, a DVD player, and a cable box. A lot of times the newer HDTV sets are equipped with a slot for a cable card, which eliminates the need for a separate, external box.

Stands will typically hold about 200 pounds quite easily, and this is sufficient for most models of TV's. If you're more into the modern look, some stands come with stylish glass shelving for all three devices, the TV, DVD player, and cable box. If you're looking for a clear shelf for the TV itself, you'll need to get strong acrylic or Plexiglass to hold it. This is a bit more expensive, but also a lot safer.

Another idea is to build your own stand out of wood. You can find tons of plans for this for free online. Here's one style that you might consider, which has list of cheaper parts. Go out and buy two ninety centimeter by sixty centimeter (3 ft x 2 ft) planks of cedar wood, 2.5 centimeters (1 inch) thick. Cedar is naturally beautiful and doesn't need staining, even though you can use a semi-transparent stain if you like to finish the wood.

Use a saw and, starting at the bottom, cut a curved pattern. Go for a shape similar to a folk guitar. The curve makes for a great design and will add strength for support. Now you need to sand the edges smooth.

Next, groove the wood a centimeter and a quarter (half an inch) deep, more than a few centimeters (a few inches) from the top. These are what's known as 'dadoes'. Now you'll make additional grooves for shelves that will hold the DVD, etc. You can make the grooves the old-fashioned way with a gouging tool or with a router.

Buy the shelves at the width you need for your TV. Wood is probably best and cheapest. Simply slide the shelves in, then screw in four L-shaped supports below each shelf for added support. Basically, that's all there is to it. Now you can hide the wires using tape or by adding an extra compartment if necessary.

Building your own stand is definitely the way to go if you're looking to get one on the cheap, as well as one that is customized best to your liking. The essayist Ray Walberg is very excited about themes related to cnc machines. Writing for documents such as ttp://www.insidewoodworking.com/cnc/cnc_router.html, the reviewer expressed his capability on areas dealing with cnc router.

Article Source: http://EzineArticles.com/?expert=Ray_K._Walberg

http://EzineArticles.com/?The-Keys-to-Getting-the-Perfect-TV-Stand&id=449503

CAD/CAM plays large in small shop - computer-aided design/computer-aided manufacturing

Tom Beard

This small mold maker has made CAD/CAM an integral part of its array of technical tools - and secured its position as a high-tech manufacturer of complex tooling.

Not so long ago a successful formula for a die and mold shop was a relatively small dose of technology and a huge measure of know-how. If a journeyman toolmaker couldn't make it with a print and a Bridgeport, well, then it just couldn't be done.

The formula is vastly different today. Enter the age of CNC, CAD/CAM, EDM, digitizing, TQC and more. Shops need both excellent knowledge and excellent tools in order to keep up with rapidly advancing standards for quality and efficiency, all the while having to deal with ever more complex workpiece designs. An day.

What's a small shop to do in this environment? The answer is as straightforward as it is harsh: Keep up, or perish.

Fehrman Tool & Die, a small shop in Byesville, Ohio, has chosen the latter course of action. With just ten toolmakers, they make some of the more complex molds you'll find anywhere. Is this shop remarkable? In some ways, yes. But the truth is they are mostly just flexible - willing, that is, to apply new technology as it becomes available and affordable, and particularly CAD/CAM. This has elevated the shop's capability to compete with virtually anyone in the mold making business. And armed with good tools, their small size becomes a major strategic advantage; it makes the company all the more nimble in responding to new challenges. Here's how the formula works in Fehrman's shop.

Rapid Change

Fehrman Tool & Die was founded in 1977 by two brothers, one expert in mold and die design, the other in machining. Today, Ron Fehrman continues as president, while his son Eric leads the engineering department.

Well, actually, the engineering department consists of just two people, but that doesn't mean the company is short on either its technical skills or tools. What they have is an efficient team, both in the office and in the shop, that is well tuned to serving the demands of some rather demanding customers that include (directly or indirectly) Honda, London Industries, Hoover, Ford, General Motors, Evenflow and Grief Brothers. Suppliers don't do business with these kinds of companies without having the house in order. Fehrman does, and in fact stakes its reputation on the ability to do the most complex work. But much has changed at the company in order to be able to keep up with their ever more challenging customer requirements.

Initially Fehrman was a typical tool and die shop, making a little bit of everything, but over time they grew increasingly focused on making molds. Today they make more plastic injection molds than anything, but also make tooling for thermoset injection molding, die casting, and some stamping dies. They can handle just about anything within a 30-inch square, and some things up to 40 inches, a limitation determined only by the size of the shop's two Hurco vertical machining centers.

Also typical, they began making their tooling mostly on manual mills - indeed doing things on those machines that many less experienced people today would think impossible - and doing the more complex cavity work with patterns and tracer mills. Then in 1988, Ron Fehrman decided to take a major leap into a new era. Within the span of a month or so, he acquired the shop's first CNC machining center, an Elox ram-type EDM, and CAD and CAM systems. The need for all this technology stemmed from the dramatic changes happening all around the mold and die industry: higher quality standards combined with significantly more complex part designs; the upsurge in parts being designed entirely in CAD by the original equipment manufacturers; the reduction in lead-time allotted to build new tooling; and more frequent design changes.

As such, Fehrman's production concept rapidly shifted from a hand-skills orientation, where process plans were conceived on the fly in the shop, to an engineering orientation, where it all had to be planned beforehand, and ultimately captured in part programs for intricately milling mold cavities or electrodes. Growing comfortable with CAD/CAM was central to making this transition possible.

Creating Tool Path

Eric Fehrman, who one day may inherit the shop, first inherited the job of getting the CAD/CAM system functional. With expensive new CNC and EDM equipment on the floor, clearly the first priority was to get out the programs to keep those machines running. It was, as he says, "CAM by fire," working both on his own to figure out how to use the system and with the experienced machinists to determine how best to cut the mold cores and cavities. After six months or so, the function was beginning to live up to their expectations in terms of productivity.

Initially, the shop purchased a Cadkey (Windsor, Connecticut) 3D CAD system and a separate CAM system, both running on personal computers. The CAM system's methodology for doing cavity work was primarily to generate 2D cutter paths across sections of a 3D wireframe representation of the form. Though not a true surfacing system, the CAM system proved quite functional for most of Fehrman's CNC work at the time. In more time, however, the limitations of the system became increasingly evident. Part geometry was growing more complex, and then Fehrman finally took a job that simply could not be programmed with the existing CAM system.

After five weeks of frustration with that part, Fehrman decided to upgrade the CAM capabilities to a true surfacing system from Surfware, Inc. (San Fernando, California). This term, "true surfacing" is an important distinction for die and mold making. Lower level systems typically approximate a free-flowing 3D form with a cloud of data points, a set of cross sections, or a grid of intersecting curves. With true surfaces, however, the entire skin of the form is mathematically defined.

Moreover, a higher functioning system provides wide latitude in manipulating surfaces. Individual surfaces can be created from scant input, such as a few cross sections or defining edge curves. Multiple surfaces can be smoothly blended together. Then these simple or complex forms can be modified later. And finally, the tool path code can be generated from this composite definition of even a very complicated cavity form.

The ability to work with multiple surfaces is critical. It's not at all unusual for a single cavity to be constructed from 300 or more individual surfaces that must be pieced together to create a smooth, continuous form. Also, Mr. Fehrman must be able to slice through that model in the appropriate place in order to create a proper parting line for a mold.

And just as important by Mr. Fehrman's reckoning is the control he must have in generating the tool path. First of all, the system must not gouge. With the prior system, he says, the cutter "would follow an individual section, but be totally oblivious to others around it," which was particularly problematic in sharp internal corners or with sheer vertical walls. In such cases, tool paths or specific geometry had to be individually edited in order to prevent the violation of adjacent surfaces. Subtle gouges were difficult to detect, and sometimes could only be discovered by trial cuts in wax.

Also, he now has the flexibility to flow cuts with surfaces of his own choice, rather than machine in successive straight sections. He can machine in continuous cuts over multiple surfaces, yet also establish boundaries for such cuts. This allows him to confine a specific machining method to a portion of a mold where it makes sense, but not be locked into that method for the entire job. He also can rough in constant Z depths, allowing the use of much more efficient flat-bottom end mills, and then move to ballnose cutters for the semi- and final-finishing passes.

The Front Door

As indispensable as CAD/CAM is for creating machining programs, it holds similar value in providing Fehrman with a tool to compile and manage critical workpiece information, and do this work in a way that inspires a high level of confidence from the shop's important customers. It is the tool by which customers' sometimes specific and sometimes sketchy requirements are interpreted and defined for Fehrman's own manufacturing process.

The shop must be prepared to accept job information in a variety of ways. As Mr. Fehrman puts it, "We get everything from old, washed-out cavities to IGES files." Between those extremes are prints, old patterns, previously molded parts, and sometimes a combination of two or more of the above.

As for the jobs that come in the form of some sort of physical model, Fehrman has also secured the capability to digitize those forms. The surface measurement is done on a Starrett (Athol, Massachusetts) coordinate measuring machine, which feeds data points to a PC running RevEng data collection software from Design Automation (Raleigh, North Carolina). The RevEng software allows a great degree of flexibility in gathering data. In addition to being able to simply collect an ordered cloud of points, the software can go the next step and create surface geometry using ordered or random clouds of point data.

Once the geometry is captured, it is exported either into the Cadkey or Surfware systems where it can be further manipulated - to clean up or detail the form, and finally to place it into a block of material along with all the other form features that together comprise a working mold. From this point forward, the process is essentially the same, whether the geometry was entered from digitizing, an IGES file, or created entirely from scratch on the shop's CAD or CAM systems.

Besides allowing Fehrman to get a handle on part geometry for their own purposes, CAD/CAM makes Fehrman easier for their customers to do business with. If customers want electronic data exchange - and some demand it - Fehrman can easily comply. With one customer, for example, the only paper they use are the prints for shop floor documentation. Or, if the customer is at a loss to fully describe what they need, the shop can help realize the customer's dimly defined objectives.

Ironically, Fehrman's tool makers are skilled enough that not all this electronic assistance is always necessary, at least in terms of creating a quality product. "We have the kind of people that you could just hand a print to, and they'd be able to get the job done right," says Mr. Fehrman.

But such a system no longer lives up to customer expectations, particularly the kinds of blue chip companies the shop does business with. "Customers can't see your skills," says Mr. Fehrman, "but they can see the equipment and the kinds of controls a shop has on its manufacturing processes."

In addition, the shop can do these things in much less time than they once required, which may be the most important benefit of all. Anyone who makes dies and molds these days knows what's happened to turnaround time, and tools that help compress the engineering cycle are very welcomed indeed. Moreover, the shop must be prepared to accommodate the much more frequent prototype and design changes common today. That's much easier and expeditious to deal with electronically in CAD and CAM files.

Balance

All these things said, Mr. Fehrman is quick to point out that "CAD/CAM won't solve all your problems." If anything, it's now a necessary tool just to stay even with rising customer expectations for quality, service and particularly for quicker delivery cycles. Increasingly, says Mr. Fehrman, their "biggest hurdle is fighting the clock." That means the shop can ill afford mistakes, creating all the more pressure on engineering to get it right the first time. Which returns the discussion to the shop's resident body of know-how. To achieve the highest levels of performance, the shop can't afford to lean too heavily on any single tool. They must marshal all their resources, human and technical, to the greatest effect. Some work still does belong on the manual machines. Not every CNC job should be programmed off-line. And tool makers must be free to apply their expertise on the shop floor, even if the job was planned another way in the office.

One of the major advantages a small company enjoys is the ability to accommodate this level of flexibility without having to create some elaborate management structure to make it happen. The company barely has any supervision; training is imparted in the traditional mentoring process; and everyone is permitted - indeed, expected - to pursue improvements in tool design or manufacturing wherever they see an opportunity. When it comes time to execute changes in the shop's procedures, there's no red tape to wade through. "We just call in all the guys," says Mr. Fehrman, "talk about it, and that's it. It's done."

Maybe it's a eliche, but the company really does have a family environment, and this extended family seldom loses any of its members. But just being nice guys is not nearly enough to remain competitive in today' s environment. "You can' t have limitations," says Mr. Fehrman, and that means both in terms of your people and your tools.

For more information on surfacing CAM from Surfware, Inc., circle 35 on the Postpaid Card.

John Staudinger

Keeping Your Precision-Machining Contract Shop Competitive

This 25-year-old contract shop's recipe for success includes CNC, coordinate measuring and computerized scheduling.

If you operate a precision-machining contract shop today, you know how tough the competition is. Fortunately, technology can help.

After starting 25 years ago with an $875 lathe in a basement, Arlington Machine had quickly grown to a 25-man shop with manual machines and one NC (numerical control) milling machine.

However, business was drying up because prices for machining were being slashed by the competition. They were using computer numerical control (CNC).

This situation provided the impetus to plunge into CNC with a big investment in machining centers and CNC lathes. As more CNCs were installed, business increased accordingly. The CNCs allowed machining of workpieces ranging in size from the very small up to 80 by 30 by 25 inches and up to five-axis complexity.

By 1983, there were a total of eight CNCs. A coordinate measuring machine (CMM) was added to simplify and speed inspection. Today, there are eleven machining centers running two shifts, six CNC lathes, and it is clear that a second CMM is needed to keep up with steadily increasing business. In fact, the new CMM will require the added capability of CNC to preserve and continue the shop's growth.

Based on lessons learned through experience, three ingredients are necessary to succeed as a precision-machining contract shop. These are versatile CNC machining, a CMM for in-house coordinate-measuring capability, and computerized scheduling CNC Machining

The first ingredient, computerized machining, requires more than one or two CNC machines. Only with multiple CNC machine tools will there be enough sales volume to support a methods department and a QC department (just as it takes more than one house in a community before the community can support a fire department and a police department.)

When a key CNC machine is down and switching to a manual machine is necessary to fulfill a delivery promise, the value of CNC stands out. For instance, it was discovered early that a gear housing with circular grooves could be machined for $360 each by CNC, but cost $1200 with manual machining.

The eleven machining centers equipped with pallets are important to Arlington Machine because a job can be set up once, the workpieces run, and the setup saved for running another lot later without repeating an extensive setup. This is particularly effective for those customers using just-in-time (JIT) production scheduling. Pallets also permit one job to be run while another is set up and multiple pallets can be loaded so the machining centers can run unattended.

A Schlumberger (Applicon) system provides programming for the CNC machines. It includes the Equinox computer graphics package. This combination allows work-pieces with difficult contours to be programmed easily, and is beneficial on jobs consisting of as few as one or two pieces. To machine an outside contour, for example, part boundry is described indicating whether it requires inside or outside contouring, and a G-code program is generated automatically.

Another advantage of this programming system is adaptability to machine tools and control units from various vendors. It produces a source program which, after post processing, runs any of the machining centers, regardless of brand.

Direct numerical control (DNC) is used where applicable, giving direct-line access to the CNC machines--punched tape can be run directly from the computer to the CNC machine.

Inspection with CMM

The answer to the question "You can make it. But can you measure it?" illustrates the second ingredient for success and demonstrates the importance of a coordinate measuring machine.

One example is a high-precision government job run on three CNCs at one time. Forty castings valued at $500 each were involved. Each had varied reference surfaces.

With manual inspection, four days were required to verify the first piece. The job could not proceed until verification.

At an average rate of $50/hour for CNC machining time and 10 hours of lost time daily for each machine, total cost of lost time on the three CNC machines was $6000. However, with the CMM, first-piece inspection takes 3 hours, for a total machining-time loss of only $450. With CNC CMM, first-piece inspection can be reduced to a half hour.

For another customer, 100 complex workpieces were received and machined with many compound angles having intersections located to [plus or minus] 0.001 inch. Thanks to inspection by the CMM, all 100 workpieces were shipped, and all 100 were accepted. With manual inspection, this job probably could not be completed successfully, with all pieces passing.

Over a two-year period, the company studied CMMs and analyzed various designs before purchasing a FJ1006 CMM from Mitutoyo. No problems have been experienced in the four years since installation.

A CMM can astonish workers only familiar with mechanical inspection methods. Yet, learning to use a CMM is easy.

Although a three-day training period is normal for an inexperienced CMM inspector, one inspector at Arlington took the manual home overnight and used the CMM the next day.

Generally, the output of one CMM is equivalent to the output of seven or eight inspectors checking manually. The machine has the ability to check to within 0.0002 inch. As for repeatability, the CMM gives an identical numerical readout when the same measurement is made six or seven times.

At present, the CMM does first-piece and final inspection.

The new CNC CMM will be dedicated to in-process and final inspection. On repeat jobs, the CNC CMM will contain the program for the previous job, and so a first piece can even be checked in less time than now needed. Later, the CNC CMM will be connected with the methods department, and the one program will be used for both making and measuring the part.

Computerized Scheduling

The third ingredient for success is computerized scheduling. For Arlington Machine, computerized scheduling is essential for locating open time for rush jobs and determining profitability of a job for a given number of workpieces.

A Profitkey International job-shop scheduling system is in use. It is capable of both forward and backward scheduling.

With forward scheduling, what-if modeling forecasts the match between jobs and capacities, and then establishes priorities.

Backward scheduling proceeds in a reverse time-line from desired completion date.

Before computerized scheduling, conventional cost accounting provided after-the-fact information, such as setup time and cycle time, only when it was too late to do anything about a particular job. Computerized scheduling provides before-the-fact information, which may indicate that reducing times by modifying fixtures or increasing speeds and feeds may be necessary.

Today, many customers are consolidating their vendor bases. To remain on their list, a shop must have a variety of CNC equipment; be able to supply CMM documentation; and use computerized scheduling.

Precision-machining contract shops which hope to compete today and survive tomorrow have to keep on top of technology. [Fig. 1 to 3 Omitted]

Control of Stepping MotorsA Tutorial

byDouglas W. Jones

THE UNIVERSITYOF IOWADepartment of Computer Science

Thismaterial expands on material originally posted to the rec.railroadnewsgroup in 1990. Significant parts of this material have beenrepublished as sections 5.2.10, 10.8, 10.9 and 10.10 of the Handbook of Small Electric Motors edited by W. H. Yeadon and A. W. Yeadon, McGraw-Hill, 2001, and as Applications Note 907published by Microchip Inc in 2004.

Abstract

This tutorial covers the basic principles of stepping motors andstepping motor control systems, including both the physics of steppers,the electronics of the basic control systems, and softwarearchitectures appropriate for motor control.

Introduction

Stepping motors can be viewed as electric motors without commutators.Typically, all windings in the motor are part of the stator, and therotor is either a permanent magnet or, in the case of variable reluctancemotors, a toothed block of some magnetically soft material. All of thecommutation must be handled externally by the motor controller, andtypically, the motors and controllers are designed so that the motor maybe held in any fixed position as well as being rotated one way or theother. Most steppers, as they are also known, can be stepped at audiofrequencies, allowing them to spin quite quickly, and with an appropriatecontroller, they may be started and stopped "on a dime" at controlledorientations.

For some applications, there is a choice between using servomotorsand stepping motors. Both types of motors offer similar opportunitiesfor precise positioning, but they differ in a number of ways. Servomotorsrequire analog feedback control systems of some type. Typically, thisinvolves a potentiometer to provide feedback about the rotor position,and some mix of circuitry to drive a current through the motor inverselyproportional to the difference between the desired position and thecurrent position.

In making a choice between steppers and servos, a number ofissues must be considered; which of these will matter depends on theapplication. For example, the repeatability of positioning done witha stepping motor depends on the geometry of the motor rotor, while therepeatability of positioning done with a servomotor generally depends onthe stability of the potentiometer and other analog components in thefeedback circuit.

Stepping motors can be used in simple open-loop control systems; theseare generally adequate for systems that operate at low accelerations withstatic loads, but closed loop control may be essential for high accelerations,particularly if they involve variable loads. If a stepper in anopen-loop control system is overtorqued, all knowledge of rotor positionis lost and the system must be reinitialized; servomotors are not subjectto this problem.

Stepping motors are known in German as Schrittmotoren, in Frenchas moteurs pas à pas, and in Spanish as motor paso paso.

Other Sources of Information

Web Sites

Other Motor Control Web Pages

- Advanced Micro Systems Stepper Motor Basics

an excellent tutorial from a maker of motors and controllers.

- motioncontrol.com

a commercially operated gateway to motion control resources on the web

- Ian Harries on Stepping Motors

with a nice set of information on reverse engineering salvaged motors and a number of example applications.

- Euclid Research MotionScope demo

excellent illustrations of physical behavior of some real motors.

Motor Manufacturers

- Advanced Micro Systems (1.8 degree per step, large permanent magnet motors)

- Astrosyn. (UK)

- Donovan Micro-Tek Inc. (very small motors)

- Eastern Air Devices Inc. (midsize motors and linear actuators)

- MyMotors & Actuators The Faulhaber Group (very small pancake-format motors)

- Gunda Electronic GmbH (German) (Google's English translation)

- Haydon Switch and Instrument, Inc.

- IntelLiDrives (high-resolution linear and 2-d planar stepping motors)

- Lin Engineering (100 to 800 steps per revolution)

- MicroMo Electronics (very small motors)

- Mitsumi (Japan)

- Parker Hannifin Corporation (motors and controllers)

- Phytron, Inc. (motors and controllers)

- Portescap Inc.

- Shinano Kenshi Corp. (SKC)

- Micro Precision Systems (remarkably small motors and controllers)

Controllers

- Advanced Micro Systems

- Astrosyn. (UK)

- Advanced Micro Systems Inc.

- Alzanti Limited (UK)

- Arrick Robotics

- Control Technology Corporation

- E-Lab Digital Engineering, Inc.

- GreenSpring Computers

- Simple Step LLC

- Netmotion

- StepperControl.com

Distributors

- ACP&D Limited (UK) (UK version) (distributor for COLIBRI integrated motor/controllers and maker of COBRA linear and planar stepping motors)

- Alzanti Limited (UK)

- Electro Sales Inc. (northeast USA)

- Flexible Technologies, Inc. (Southwest USA)

- MESA Systems Co. (USA) (distributor for COLIBRI integrated motor/controllers)

- Motionex (southeast USA)

- Smart Motion Control Inc. dba ABC Motion Control (northeast USA)

- Technovation Systems Ltd. (UK)

Surplus and Hobbyist Suppliers

- ALL Electronics (new and surplus)

- DIY Electronics (kits, Hong Kong)

- EIO's Stepper Motor Page (surplus)

- PC Gadgets (the Gadgetmaster interface)

- Hi-Tech Surplus

- Surplus Center (mostly heavy industrial surplus, Nebraska)

- Vorlac (Surplus, australia)

- Wirz Electronics (Hobbyist oriented, controllers)

Motor Design, Selection and Prototype Fabricaton Services

- Yeadon Engineering Services, (Michigan)

YES is the contact for the Small Motor Manufacturer's Association.

Other Web Pages

- The Art of Motion Control;

Bruce Shapiro's stepper-controlled machine-shop and artist's studio.

- EIO's Stepper Motor Page;

a surplus dealer, but listed here because of their extensive index of information about stepping motors.

- Fractional Horsepower Motor Manufacturers;

an index maintained by Industrial Quick Search.

- Schmitz Engineering Liaison;

a rotary shaft position encoder distributor offering consulting services on encoder use. Roger Schmitz wrote Encoder Output Choices for System Designers for MOTION Magazine.

Books

Handbook of Small Electric MotorsWilliam H. Yeadon and Alan W, Yeadon, eds.

McGraw-Hill, c2001.

LC number: TK2537 .H34 2001

Stepping motors: a guide to modern theory and practiceAcarnley, P. P.

P. Peregrinus on behalf of the IEE, 1984, c1982.

LC number: TK2537 .A28 1984

A third edition has recently been released.

Stepping motors and their microprocessor controlsKenjo, Takashi

Oxford University Press, c1984.

LC number: TK2785 .K4 1984

Stepping Motor Types

Part of Stepping Motors

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Introduction

Stepping motors come in two varieties, permanent magnet andvariable reluctance (there are also hybrid motors, which areindistinguishable from permanent magnet motors from the controller's pointof view). Lacking a label on the motor, you can generally tell the twoapart by feel when no power is applied. Permanent magnet motors tend to"cog" as you twist the rotor with your fingers, while variable reluctancemotors almost spin freely (although they may cog slightly because ofresidual magnetization in the rotor). You can also distinguish betweenthe two varieties with an ohmmeter. Variable reluctance motors usuallyhave three (sometimes four) windings, with a common return, while permanentmagnet motors usually have two independent windings, with or withoutcenter taps. Center-tapped windings are used in unipolar permanent magnetmotors.

Stepping motors come in a wide range of angular resolution. Thecoarsest motors typically turn 90 degrees per step, while highresolution permanent magnet motors are commonly able to handle 1.8or even 0.72 degrees per step. With an appropriate controller,most permanent magnet and hybrid motors can be run in half-steps, and somecontrollers can handle smaller fractional steps or microsteps.

For both permanent magnet and variable reluctance stepping motors, if justone winding of the motor is energised, the rotor (under no load) will snapto a fixed angle and then hold that angle until the torque exceeds theholding torque of the motor, at which point, the rotor will turn, tryingto hold at each successive equilibrium point.

Variable Reluctance MotorsFigure 1.1

If your motor has three windings, typically connected as shown in the schematicdiagram in Figure 1.1, with one terminal common to all windings,it is most likely avariable reluctance stepping motor. In use, the common wire typically goesto the positive supply and the windings are energized in sequence. The cross section shown in Figure 1.1 is of 30 degree per step variablereluctance motor. The rotor in this motor has 4 teeth and the stator has6 poles, with each winding wrapped around two opposite poles. With windingnumber 1 energised, the rotor teeth marked X are attracted to this winding'spoles. If the current through winding 1 is turned off and winding 2 is turnedon, the rotor will rotate 30 degrees clockwise so that the poles marked Yline up with the poles marked 2. Ananimated GIF of figure 1.1 is available.

To rotate this motor continuously, we just apply power to the 3 windings insequence. Assuming positive logic, where a 1 means turning on the currentthrough a motor winding, the following control sequence will spin the motorillustrated in Figure 1.1 clockwise 24 steps or 2 revolutions:

The section of this tutorial onMid-Level Controlprovides details on methods for generating such sequences of control signals,while the section onControl Circuitsdiscusses the power switching circuitry needed to drive the motor windingsfrom such control sequences.

There are also variable reluctance stepping motors with 4 and 5 windings,requiring 5 or 6 wires. The principle for driving these motors is thesame as that for the three winding variety, but it becomes important towork out the correct order to energise the windings to make the motorstep nicely.

The motor geometry illustrated in Figure 1.1, giving 30 degrees per step,uses the fewest number of rotor teeth and stator poles that performssatisfactorily. Using more motor poles and more rotor teeth allowsconstruction of motors with smaller step angle. Toothed faces on eachpole and a correspondingly finely toothed rotor allows for step angles assmall as a few degrees.

Unipolar MotorsFigure 1.2

Unipolar stepping motors, bothPermanent magnet and hybrid stepping motors with 5 or 6 wires are usuallywired as shown in the schematic in Figure 1.2, with a center tap on eachof two windings. In use, the center taps of the windings are typically wiredto the positive supply, and the two ends of each winding are alternatelygrounded to reverse the direction of the field provided by that winding. Ananimated GIF of figure 1.2 is available.

The motor cross section shown in Figure 1.2 is of a 30 degree per steppermanent magnet or hybrid motor -- the difference between these twomotor types is not relevant at this level of abstraction. Motor windingnumber 1 is distributed between the top and bottom stator pole, whilemotor winding number 2 is distributed between the left and right motorpoles. The rotor is a permanent magnet with 6 poles, 3 south and 3 north,arranged around its circumfrence.

For higher angular resolutions, the rotor must have proportionally morepoles. The 30 degree per step motor in the figure is one of the mostcommon permanent magnet motor designs, although 15 and 7.5 degree per stepmotors are widely available. Permanent magnet motors with resolutions asgood as 1.8 degrees per step are made, and hybrid motors are routinelybuilt with 3.6 and 1.8 degrees per step, with resolutions as fine as0.72 degrees per step available.

As shown in the figure, the current flowing from the center tap of winding1 to terminal a causes the top stator pole to be a north pole while thebottom stator pole is a south pole. This attracts the rotor into theposition shown. If the power to winding 1 is removed and winding 2 isenergised, the rotor will turn 30 degrees, or one step.

To rotate the motor continuously, we just apply power to the two windingsin sequence. Assuming positive logic, where a 1 means turning on thecurrent through a motor winding, the following two control sequences will spinthe motor illustrated in Figure 1.2 clockwise 24 steps or 2 revolutions:

Note that the two halves of each winding are never energized at the sametime. Both sequences shown above will rotate a permanent magnet onestep at a time. The top sequence only powers one winding at a time, asillustrated in the figure above; thus, it uses less power.The bottom sequence involves powering two windingsat a time and generally produces a torque about 1.4 times greater thanthe top sequence while using twice as much power.

The section of this tutorial onMid-Level Controlprovides details on methods for generating such sequences of control signals,while the section onControl Circuitsdiscusses the power switching circuitry needed to drive the motor windingsfrom such control sequences.

The step positions produced by the two sequences above are not the same; as aresult, combining the two sequences allows half stepping, with the motorstopping alternately at the positions indicated by one or the other sequence.The combined sequence is as follows:

Bipolar MotorsFigure 1.3

Bipolar permanent magnet and hybrid motors are constructed with exactlythe same mechanism as is used on unipolar motors, but the two windingsare wired more simply, with no center taps.

Thus, the motor itself issimpler but the drive circuitry needed to reverse the polarity of eachpair of motor poles is more complex. The schematic in Figure 1.3 showshow such a motor is wired, while the motor cross section shown hereis exactly the same as the cross section shown in Figure 1.2.

The drive circuitry for such a motor requires an H-bridge controlcircuit for each winding; these are discussed in more detail in thesection onControl Circuits.Briefly, an H-bridge allows the polarity of the power applied to eachend of each winding to be controlled independently. The control sequencesfor single stepping such a motor are shown below, using + and – symbols toindicate the polarity of the power applied to each motor terminal:

Note that these sequences are identical to those for a unipolar permanentmagnet motor, at an abstract level, and that above the level of the H-bridgepower switching electronics, the control systems for the two types of motorcan be identical.

Note that many full H-bridge driver chips have one control input to enablethe output and another to control the direction. Given two such bridgechips, one per winding, the following control sequences will spin themotor identically to the control sequences given above:

To distinguish a bipolar permanent magnet motor from other 4 wire motors,measure the resistances between the different terminals.It is worth noting that some permanent magnet stepping motorshave 4 independent windings, organized as two sets of two. Within eachset, if the two windings are wired in series, the result can be usedas a high voltage bipolar motor. If they are wired in parallel, theresult can be used as a low voltage bipolar motor. If they are wiredin series with a center tap, the result can be used as a low voltageunipolar motor.

Bifilar Motors

Bifilar windings on a stepping motor are applied to the same rotorand stator geometry as a bipolar motor,but instead of winding each coil in the stator with a single wire,two wires are wound in parallel with each other. As a result, themotor has 8 wires, not four.

In practice, motors with bifilar windings are always powered as eitherunipolar or bipolar motors. Figure 1.4 shows thealternative connections to the windings of such a motor.

Figure 1.4

To use a bifilar motor as a unipolarmotor, the two wires of each winding are connected in series and thepoint of connection is used as a center-tap. Winding 1 in Figure 1.4is shown connected this way.

To use a bifilar motor as a bipolar motor, the two wires of each windingare connected either in parallel or in series.Winding 2 in Figure 1.4 is shown with a parallel connection; this allowslow voltage high-current operation.Winding 1 in Figure 1.4 is shown with a series connection; if the centertap is ignored, this allows operation at a higher voltage and lowercurrent than would be used with the windings in parallel.

It should be noted that essentially all 6-wire motors sold for bipolaruse are actually wound using bifilar windings, so that the external connectionthat serves as a center tap is actually connected as shown for winding 1in Figure 1.4. Naturally, therefore, any unipolar motor may be used asa bipolar motor at twice the rated voltage and half the rated current asis given on

the nameplate.

The question of the correct operating voltage for a bipolar motor run asa unipolar motor, or for a bifilar motor with the motor windings in seriesis not as trivial as it might first appear. There are three issues: Thecurrent carrying capacity of the wire, cooling the motor, and avoidingdriving the motor's magnetic circuits into saturation. Thermal considerationssuggest that, if the windings are wired in series, the voltage should onlybe raised by the square root of 2. The magnetic field in the motor dependson the number of ampere turns; when the two half-windings are run in series,the number of turns is doubled, but because a well-designed motor has magneticcircuits that are close to saturation when the motor is run at its ratedvoltage and current, increasing the number of ampere-turns does not makethe field any stronger. Therefore, when a motor is run with the twohalf-windings in series, the current should be halved in order to avoidsaturation; or, in other words, the voltage across the motor winding shouldbe the same as it was.

For those who salvage old motors, finding an 8-wire motor poses achallenge! Which of the 8 wires is which? It is not hard to figurethis out using an ohm meter, an AC volt meter, and a low voltage ACsource. First, use the ohm meter to identify the motor leads that areconnected to each other through the motor windings.Then, connect a low-voltage AC source to one of these windings.The AC voltage should be below the advertised operatingvoltage of the motor; voltages under 1 volt are recommended. The geometryof the magnetic circuits of the motor guarantees that the two wires of abifilar winding will be strongly coupled for AC signals, while thereshould be almost no coupling to the other two wires. Therefore, probingwith an AC volt meter should disclose which of the other three windingsis paired to the winding under power.

Multiphase Motors

Figure 1.5

A less common class of permanent magnet or hybrid stepping motor is wired withall windings of the motor in a cyclic series, with one tap between eachpair of windings in the cycle, or with only one end of each motor windingexposed while the other ends of each winding are tied together to aninaccessible internal connection. In the context of 3-phase motors, these configurations would be described as Delta and Y configurations, but theyare also used with 5-phase motors, as illustrated in Figure 1.5.Some multiphase motors expose all ends of all motor windings, leaving itto the user to decide between the Delta and Y configurations, or alternatively,allowing each winding to be driven independently.

Control of either one of these multiphase motors in either the Delta or Yconfiguration requires 1/2 of an H-bridge for each motor terminal. It isnoteworthy that 5-phase motors have the potential of delivering more torquefrom a given package size because all or all but one of the motor windingsare energised at every point in the drive cycle. Some 5-phase motors havehigh resolutions on the order of 0.72 degrees per step (500 steps perrevolution).

Many automotive alternators are built using a 3-phase hybrid geometry witheither a permanent magnet rotor or an electromagnet rotor powered througha pair of slip-rings. These have been successfully used as stepping motors insome heavy duty industrial applications; step angles of 10 degrees perstep have been reported.

With a 5-phase motor, there are 10 steps perrepeat in the stepping cycle, as shown below:

With a 3-phase motor, there are 6 steps perrepeat in the stepping cycle, as shown below:

Here, as in the bipolar case, each terminal is shown as being eitherconnected to the positive or negative bus of the motor power system.Note that, at each step, only one terminal changes polarity. This changeremoves the power from one winding attached to that terminal (becauseboth terminals of the winding in question are of the same polarity) andapplies power to one winding that was previously idle. Given the motorgeometry suggested by Figure 1.5, this control sequence will drive themotor through two revolutions.

To distinguish a 5-phase motor from other motors with 5 leads, note that, ifthe resistance between two consecutive terminals of the 5-phase motor is R,the resistance between non-consecutive terminals will be 1.5R.

Note that some 5-phase motors have 5 separate motor windings, with a totalof 10 leads. These can be connected in the star configuration shown above,using 5 half-bridge driver circuits, or each winding can be driven by itsown full-bridge. While the theoretical component count of half-bridgedrivers is lower, the availability of integrated full-bridge chips may makethe latter approach preferable.

Stepping Motor Physics

Part of Stepping Motors

byDouglas W. Jones

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Introduction

In any presentation covering the quantitative physics of a class of systems,it is important to beware of the units of measurement used! In thispresentation of stepping motor physics, we will assume standardphysical units:

EnglishCGS MKS MASS slug gram kilogram FORCE pound dyne newton DISTANCE foot centimeter meter TIME second second second ANGLE radian radian radian A force of one pound will accelerate a mass of one slug at one foot per secondsquared. The same relationship holds between the force, mass, time anddistance units of the other measurement systems. Most people prefer to measureangles in degrees, and the common engineering practice of specifying massin pounds or force in kilograms will not yield correct results in theformulas given here! Care must be taken to convert such irregular units toone of the standard systems outlined above before applying the formulasgiven here!

Statics

For a motor that turns S radians per step, the plot of torque versusangular position for the rotor relative to some initial equilibriumposition will generally approximate a sinusoid. The actual shape of thecurve depends on the pole geometry of both rotor and stator, and neitherthis curve nor the geometry information is given in the motor datasheets I've seen! For permanent magnet and hybrid motors, the actualcurve usually looks sinusoidal, but looks can be misleading. For variablereluctance motors, the curve rarely even looks sinusoidal; trapezoidaland even assymetrical sawtooth curves are not uncommon.

For a three-winding variable reluctance or permanent magnet motors withS radians per step, the period of the torque versus position curve will be3S; for a 5-phase permanent magnet motor, the period will be 5S. For atwowinding permanent magnet or hybrid motor, the most common type,the period will be 4S, as illustrated in Figure 2.1:

Figure 2.1

Again, for an ideal 2 winding permanent magnet motor, this can bemathematically expressed as: T = -h sin(((/2) / S))Where: T – torque h -- holding torque S -- step angle, in radians = shaft angle, in radiansBut remember, subtle departures from the ideal sinusoid described hereare very common.

The single-winding holding torque of a stepping motor is the peakvalue of the torque versus position curve when the maximum allowed currentis flowing through one motor winding. If you attempt to apply a torquegreater than this to the motor rotor while maintaining power to onewinding, it will rotate freely.

It is sometimes useful to distinguish between the electrical shaft angleand the mechanical shaft angle. In the mechanical frame of reference,2 radians is defined as one fullrevolution.

In the electrical frame of reference, a revolution is definedas one period of the torque versus shaft angle curve. /S)gives the electrical angle for a motor with 4 steps per cycle of the torquecurve.

Assuming that the torque versus angular position curve is a good approximationof a sinusoid, as long as the torque remains below the holding torque of themotor, the rotor will remain within 1/4 period of the equilibrium position.For a two-winding permanent magnet or hybrid motor, this means the rotor willremain within one step of the equilibrium position.

With no power to any of the motor windings, the torque does not always fall tozero! In variable reluctance stepping motors, residual magnetization in themagnetic circuits of the motor may lead to a small residual torque, and inpermanent magnet and hybrid stepping motors, the combination of pole geometryand the permanently magnetized rotor may lead to significant torque with noapplied power.

The residual torque in a permanent magnet or hybrid stepping motor isfrequently referred to as the cogging torque or detent torqueof the motor because a naive observer will frequently guess that there isa detent mechanism of some kind inside the motor. The most common motordesigns yield a detent torque that varies sinusoidally with rotor angle, withan equilibrium position at every step and an amplitude of roughly 10% of therated holding torque of the motor, but a quick survey of motors from onemanufacturer (Phytron) shows values as high as 23% for one very small motorto a low of 2.6% for one mid-sized motor.

Half-Stepping and Microstepping

So long as no part of the magnetic circuit saturates, powering two motorwindings simultaneously will produce a torque versus position curve that isthe sum of the torque versus position curves for the two motor windings takenin isolation. For a two-winding permanent magnet or hybrid motor, the twocurves will be S radians out of phase, and if the currents in the twowindings are equal, the peaks and valleys of the sum will be displacedS/2 radians from the peaks of the original curves, as shown in Figure 2.2:

This is the basis of half-stepping. Thetwo-winding holding torque is the peak of the compositetorque curve when two windings are carrying their maximumrated current. For common two-winding permanent magnet or hybridstepping motors, the two-winding holding torque will be: h2 = 20.5 h1where: h1 -- single-winding holding torque h2 -- two-winding holding torqueThis assumes that no part of themagnetic circuit is saturated and that the torque versus position curvefor each winding is an ideal sinusoid.

Most permanent-magnet and variable-reluctance stepping motor data sheets quotethe two-winding holding torque and not the single-winding figure; in part,this is because it is larger, and in part, it is because the most commonfull-step controllers always apply power to two windings at once.

If any part of the motor's magnetic circuits is saturated, the two torquecurves will not add linearly. As a result, the composite torque willbe less than the sum of the component torques and the equilibriumposition of the composite may not be exactly S/2 radians from theequilibria of the original.

Microstepping allows even smaller steps by usingdifferent currents through the two motor windings, as shown in Figure 2.3:

Figure 2.3

For a two-winding variable reluctance or permanent magnet motor, assumingnonsaturating magnetic circuits, and assuming perfectly sinusoidal torqueversus position curves for each motor winding, the following formula givesthe key characteristics of the composite torque curve: h = (a2 + b2)0.5 x = (S / (/2)) arctan(b / a) Where: a -- torque applied by winding with equilibrium at 0 radians.

b -- torque applied by winding with equilibrium at S radians.

h -- holding torque of composite.

x -- equilibrium position, in radians.

S -- step angle, in radians.In the absence of saturation, the torques a and b are directlyproportional to the currents through the corresponding windings.

It isquite common to work with normalized currents and torques, so that thesingle-winding holding torque or the maximum current allowed in one motorwinding is 1.0.

Friction and the Dead Zone

The torque versus position curve shown in Figure 2.1 does not take intoaccount the torque the motor must exert to overcome friction! Note thatfrictional forces may be divided into two large categories, static or slidingfriction, which requires a constant torque to overcome, regardless ofvelocity, and dynamic friction or viscous drag, which offers a resistance thatvaries with velocity. Here, we are concerned with the impact of staticfriction. Suppose the torque needed to overcome the static friction onthe driven system is 1/2 the peak torque of the motor, as illustrated inFigure 2.4.

Figure 2.4

The dotted lines in Figure 2.4 show the torque needed to overcome friction;only that part of the torque curve outside the dotted lines is available tomove the rotor. The curve showing the available torque as a function ofshaft angle is the difference between these curves, as shown in Figure 2.5:Figure 2.5

Note that the consequences of static friction are twofold. First, the totaltorque available to move the load is reduced, and second, there is adead zoneabout each of the equilibria of the ideal motor. If the motor rotor ispositioned anywhere within the dead zone for the current equilibrium position,the frictional torque will exceed the torque applied by the motor windings,and the rotor will not move. Assuming an ideal sinusoidaltorque versus position curve in the absence of friction,the angular width of these dead zones will be: d = 2 (S / (/2)) arcsin(f / h) = (S / (/4)) arcsin(f / h)where: d -- width of dead zone, in radians

S -- step angle, in radians

f -- torque needed to overcome static friction

h -- holding torque

The important thing to note about the dead zone is that it limits the ultimatepositioning accuracy! For the example,where the static friction is 1/2 the peak torque, a 90° per step motorwill have dead-zones 60° wide! That means that successive steps may beas large as 150° and as small as 30°, depending on where in thedead zone the rotor stops after each step!

The presence of a dead zone has a significant impact on theutility of microstepping! If the dead zone is x° wide, then microsteppingwith a step size smaller than x° may not move the rotor at all. Thus,for systems intended to use high resolution microstepping, it is very importantto minimize static friction.

Dynamics

Each time you step the motor, you electronically move the equilibriumposition S radians. This moves the entire curve illustrated in Figure 2.1a distance of S radians, as shown in Figure

2.6:

Figure 2.6

The first thing to note about the process of taking one step is thatthe maximum available torque is at a minimum when the rotor is halfwayfrom one step to the next. This minimum determines the running torque,the maximum torque the motor can drive as it steps slowly forward. For commontwo-windi curves and holding torque h, this will be h/(20.5).If the motor is stepped by powering two windings at a time, the runningtorque of an ideal two-winding permanent magnet motor will be the same asthe single-winding holding torque.

It shoud be noted that at higher stepping speeds, the running torque issometimes defined as the pull-out torque. That is, it is the maximumfrictional torque the motor can overcome on a rotating load before the loadis pulled out of step by the friction. Some motor data sheets define a secondtorque figure, the pull-in torque. This is the maximum frictionaltorque that the motor can overcome to accelerate a stopped load to synchronousspeed. The pull-in torques documented on stepping motor data sheets are ofquestionable value because the pull-in torque depends on the moment ofinertia of the load used when they were measured, and few motor data sheetsdocument this!

In practice, there is always some friction, so after theequilibrium position moves one step, the rotor is likely to oscillatebriefly about the new equilibrium position. The resulting trajectorymay resemble the one shown in Figure 2.7:

Figure 2.7 " align="middle" height="127" width="390" />

Here, the trajectory of the equilibrium position is shown as a dottedline, while the solid curve shows the trajectory of the motor rotor.

Resonance

The resonant frequency of the motor rotor depends on the amplitude ofthe oscillation; but as the amplitude decreases, the resonantfrequency rises to a well-defined small-amplitude frequency. Thisfrequency depends on the step angle and on the ratio of the holdingtorque to the moment of inertia of the rotor. Either a higher torqueor a lower moment will increase the frequency!

Formally, the small-amplitude resonance can be computed as follows:First, recall Newton's law for angular acceleration:

T = μ AWhere: T -- torque applied to rotor

μ -- moment of inertia of rotor and load

A -- angular acceleration, in radians per second per secondWe assume that, for small amplitudes, the torque on the rotor can beapproximated as a linear function of the displacement from the equilibriumposition. Therefore, Hooke's law applies: T = -k where: k -- the "spring constant" of the system, in torque units per radian -- angular position of rotor, in radiansWe can equate the two formulas for the torque to get: μ A = -k Note that acceleration is the second derivitive of position withrespect to time: A = d2/dt2so we can rewrite this the above in differential equation form: d2/dt2 = -(k/μ) To solve this, recall that, for: f(t) = a sin btThe derivitives are: df(t)/dt = ab cos bt

d2f(t)/dt2 = -ab2 sin bt = -b2 f(t)Note that, throughout this discussion, we assumed that the rotor isresonating. Therefore, it has an equation of motion something like: = a sin (2 f

t)

a = angular amplitude of resonance

f = resonant frequencyThis is an admissable solution to the above differential equation if weagree that: b = 2 f

b2 = k/μSolving for the resonant frequency f as a function of k andμ, we get: f = (k/μ)0.5 / 2It is crucial to note that it is the moment of inertia of the rotor plusany coupled load that matters. The moment of the rotor, in isolation,is irrelevant! Some motor data sheets include information on resonance,but if any load is coupled to the rotor, the resonant frequency willchange!

In practice, this oscillation can cause significant problems when thestepping rate is anywhere near a resonant frequency of the system;the result frequently appears as random and uncontrollable motion.

Resonance and the Ideal Motor

Up to this point, we have dealt only with the small-angle spring constantk for the system. This can be measured experimentally, but if themotor's torque versus position curve is sinusoidal, it is also a simplefunction of the motor's holding torque. Recall that:

T = -h sin(((/2)/S))The small angle spring constant k is the negative derivitive of T atthe origin. k = -dT / d = - (- h ((/2)/S) cos(0)) = (/2)(h / S)Substituting this into the formula for frequency, we get: f = ((/2)(h / S) / μ)0.5 / 2 = (h / (8 μ S))0.5Given that the holding torque and resonant frequency of the system areeasily measured, the easiest way to determine the moment of inertia ofthe moving parts in a system driven by a stepping motor is indirectlyfrom the above relationship! μ = h / (8 f2 S)For practical purposes, it is usually not the torque or the moment ofinertia that matters, but rather, the maximum sustainable accelerationthat matters! Conveniently, this is a simple function of the resonant frequency! Starting with the Newton's law for angular acceleration: A = T / μWe can substitute the above formula for the moment of inertia as a functionof resonant frequency, and then substitute the maximum sustainable runningtorque as a function of the holding torque to get: A = (h / (20.5)) / (h / (8 f2 S)) = 8 S f2 / (20.5)Measuring acceleration in steps per second squared instead of in radians persecond squared, this simplifies to: Asteps = A / S = 8 f2 / (20.5)Thus, for an ideal motor with a sinusoidal torque versus rotor positionfunction, the maximum acceleration in steps per second squared is a trivialfunction of the resonant frequency of the motor and rigidly coupled load!

For a two-winding permanent-magnet or variable-reluctance motor, withan ideal sinusoidal torque-versus-position characteristic, thetwo-winding holding torque is a simple function of the single-windingholding torque:

h2 = 20.5 h1Where: h1 -- single-winding holding torque

h2 -- two-winding holding torqueSubstituting this into the formula for resonant frequency, we can findthe ratios of the resonant frequencies in these two operating modes: f1 = (h1 / ...)0.5

f2 = (h2 / ...)0.5 = (20.5 h1 / ...)0.5 = 20.25 (h1 / ...)0.5 = 20.25 f1 = 1.189... f1This relationship only the stepping rate varies between these two frequencies.

In general, as will be discussed later, the availabletorque will tend to remain relatively constant up until some cutoffstepping rate, and then it will fall. Therefore, this relationship onlyholds if the resonant frequencies are below this cutoff stepping rate.At stepping rates above the cutoff rate, the two frequencies will be closer toeach other!

Living with Resonance

If a rigidly mounted stepping motor is rigidly coupled to a frictionlessload and then stepped at a frequency near the resonant frequency, energywill be pumped into the resonant system, and the result of this is that themotor will literally lose control. There are three basic ways to deal withthis problem: Controlling resonance in the mechanism

Use of elastomeric motor mounts or elastomeric couplings between motor andload can drain energy out of the resonant system, preventing energy fromaccumulating to the extent that it allows the motor rotor to escape fromcontrol.

Or, viscous damping can be used. Here, the damping will not only draw energyout of the resonant modes of the system, but it will also subtract from thetotal torque available at higher speeds. Magnetic eddy current damping isequivalent to viscous damping for our purposes.

Figure 2.8 illustrates the use of elastomeric couplings and viscous dampingin two typical stepping motor applications, one using a lead screw to drivea load, and the other using a tendon drive:

Figure 2.8

In Figure 2.8, elastomeric moter mounts are shown at a and elastomericcouplings between the motor and load are shown at b and c. The end bearingfor the lead screw or tendon, at d, offers an opportunity for viscous damping,as do the ways on which the load slides, at e. Even the friction found insealed ballbearings or teflon on steel ways can provide enough damping toprevent resonance problems.

Controlling resonance in the low-level drive circuitry

A resonating motor rotor will induce an alternating current voltage in themotor windings. If some motor winding is not currently being driven, shortingthis winding will impose a drag on the motor rotor that is exactly equivalentto using a magnetic eddy current damper.

If some motor winding is currently being driven, the AC voltage induced bythe resonance will tend to modulate the current through the winding. Clampingthe motor current with an external inductor will counteract the resonance.Schemes based on this idea are incorporated into some of the drive circuitsillustrated in later sections of this tutorial.

Controlling resonance in the high-level control system

The high level control system can avoid driving the motor at known resonantfrequencies, accelerating and decelerating through these frequencies and neverattempting sustained rotation at these speeds.

Recall that the resonant frequency of a motor in half-stepped mode will varyby up to 20% from one half-step to the next. As a result, half-steppingpumps energy into the resonant system less efficiently than full stepping.Furthermore, when operating near these resonant frequencies, the motorcontrol system may preferentially use only the two-winding half steps whenoperating near the single-winding resonant frequency, and only thesingle-winding half steps when operating near the two-winding resonantfrequency. Figure 2.9 illustrates this:

Figure 2.9

The darkened curve in Figure 2.9 shows the operating torque achieved by asimple control scheme that delivers useful torque over a wide range of speedsdespite the fact that the available torque drops to zero at each resonancein the system.This solution is particularly effective if the resonant frequencies aresharply defined and well separated. This will be the case in minimallydamped systems operating well below the cutoff speed defined in the nextsection.

Torque versus Speed

An important consideration in designing high-speed stepping motorcontrollers is the effect of the inductance of the motor windings.As with the torque versus angular position information, this is frequentlypoorly documented in motor data sheets, and indeed, for variable reluctancestepping motors, it is not a constant! The inductance of the motorwinding determines the rise and fall time of the current through the windings.While we might hope for a square-wave plot of current versus time,the inductance forces an exponential, as illustrated in Figure 2.10:

Figure 2.10 " align="middle" height="134" width="251" />

The details of the current-versus-time function through each winding dependas much on the drive circuitry as they do on the motor itself!It is quite common for the time constants of these exponentials to differ.The rise time is determined by the drive voltage and drive circuitry, whilethe fall time depends on the circuitry used to dissipate the stored energyin the motor winding.

At low stepping rates, the rise and fall times of the current throughthe motor windings has little effect on the motor's performance, but athigher speeds, the effect of the inductance of the motor windings is toreduce the available torque, as shown in Figure 2.11: Figure 2.11

The motor's maximum speed is defined as the speed at which the availabletorque falls to zero. Measuring maximum speed can be difficult when there areresonance problems, because these cause the torque to drop to zero prematurely.The cutoff speed is the speed above which the torque begins to fall.When the motor is operating below its cutoff speed, the rise and fall timesof the current through the motor windings occupy an insignificant fractionof each step, while at the cutoff speed, the step duration is comparable tothe sum of the rise and fall times. Note that a sharp cutoff is rare, andtherefore, statements of a motor's cutoff speed are, of necessity,approximate.

The details of the torque versus speed relationship depend on the detailsof the rise and fall times in the motor windings, and these depend on themotor control system as well as the motor. Therefore, the cutoff speedand maximum speed for any particular motor depend, in part, on the controlsystem! The torque versus speed curves published in motor data sheets occasionally come with documentation of the motor controller used to obtainthat curve, but this is far from universal practice!

Similarly, the resonant speed depends on the moment of inertia of the entirerotating system, not just the motor rotor, and the extent to which thetorque drops at resonance depends on the presence of mechanical dampingand on the nature of the control system. Some published torque versus speedcurves show very clear resonances without documenting the moment of inertiaof the hardware that may have been attached to the motor shaft in order tomake torque measurements.

The torque versus speed curve shown in Figure 2.11 is typical of the simplestof control systems. More complex control systems sometimes introduceelectronic resonances that act to increase the available torque above themotor's low-speed torque. A common result of this is a peak in the availabletorque near the cutoff speed.

Electromagnetic Issues

In a permanent magnet or hybrid stepping motor, the magnetic field of themotor rotor changes with changes in shaft angle. The result of this is thatturning the motor rotor induces an AC voltage in each motor winding. Thisis referred to as the counter EMF because the voltage induced in eachmotor winding is always in phase with and counter to the ideal waveformrequired to turn the motor in the same direction.Both the frequency and amplitude of the counter EMF increasewith rotor speed, and therefore, counter EMF contributes to the decline intorque with increased stepping rate.

Variable reluctance stepping motors also induce counter EMF! This is because,as the stator winding pulls a tooth of the rotor towards its equilibriumposition, the reluctance of the magnetic circuit declines. This declineincreases the inductance of the stator winding, and this change in inductancedemands a decrease in the current through the winding in order to conserveenergy. This decrease is evidenced as a counter EMF.

The reactance (inductance and resistance) of the motor windings limits thecurrent flowing through them. Thus, by ohms law, increasing the voltagewill increase the current, and therefore increase the available torque.The increased voltage also serves to overcome the counter EMF induced in themotor windings, but the voltage cannot be increased arbitrarily!

Thermal,magnetic and electronic considerations all serve to limit the useful torquethat a motor can produce.

The heat given off by the motor windings is due to both simple resistivelosses, eddy current losses, and hysteresis losses. If this heat is notconducted away from the motor adequately, the motor windings will overheat.The simplest failure this can cause is insulation breakdown, but it can alsoheat a permanent magnet rotor to above its curie temperature, the temperatureat which permanent magnets lose their magnetization. This is a particularrisk with many modern high strength magnetic alloys.

Even if the motor is attached to an adequate heat sink, increased drivevoltage will not necessarily lead to increased torque. Most motors aredesigned so that, with the rated current flowing through the windings, themagnetic circuits of the motor are near saturation. Increased current willnot lead to an appreciably increased magnetic field in such a motor!

Given a drive system that limits the current through each motor winding tothe rated maximum for that winding, but uses high voltages to achieve a highercutoff torque and higher torques above cutoff, there are other limits thatcome into play. At high speeds, the motor windings must, of necessity, carryhigh frequency AC signals. This leads to eddy current losses in the magneticcircuits of the motor, and it leads to skin effect losses in the motorwindings.

Motors designed for very high speed running should, therefore, have magneticstructures using very thin laminations or even nonconductive ferrite materials,and they should have small gauge wire in their windings to minimize skineffect losses. Common high torque motors have large-gauge motor windingsand coarse core laminations, and at high speeds, such motors can easily overheat and should therefore be derated accordingly for high speed running!

It is also worth noting that the best way to demagnetize something is toexpose it to a high frequency-high amplitude magnetic field. Running thecontrol system to spin the rotor at high speed when the rotor is actuallystalled, or spinning the rotor at high speed against a control systemtrying to hold the rotor in a fixed position will both expose the rotorto a high amplitude high-frequency field. If such operating conditions arecommon, particularly if the motor is run near the curie temperature of thepermanent magnets, demagnetization is a serious risk and the field strengths(and expected torques) should be reduced accordingly!

Basic Stepping Motor Control Circuits

Part of Stepping Motors

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Introduction

This section of the stepper tutorial deals with the basic final stagedrive circuitry for stepping motors. This circuitry is centered on a singleissue, switching the current in each motor winding on and off, and controllingits direction. The circuitry discussed in this section is connected directlyto the motor windings and the motor power supply, and this circuitry is controlled by a digital system that determines when the switches are turnedon or off.

This section covers all types of motors, from the elementary circuitry neededto control a variable reluctance motor, to the H-bridge circuitry needed tocontrol a bipolar permanent magnet motor. Each class of drive circuit isillustrated with practical examples, but these examples are not intended asan exhaustive catalog of the commercially available control circuits, nor isthe information given here intended to substitute for the information foundon the manufacturer's component data sheets for the parts mentioned.

This section only covers the most elementary control circuitry for eachclass of motor. All of these circuits assume that the motor power supplyprovides a drive voltage no greater than the motor's rated voltage, and thissignificantly limits motor performance. The next section, on current limiteddrive circuitry, covers practical high-performance drive circuits.

Variable Reluctance Motors

Typical controllers for variable reluctance stepping motors are variations on the outline shown in Figure 3.1:

Figure 3.1

In Figure 3.1, boxes are used to represent switches; a controlunit, not shown, is responsible for providing the control signals to openand close the switches at the appropriate times in order to spin the motors.In many cases, the control unit will be a computer or programmable interfacecontroller, with software directly generating the outputs needed to controlthe switches, but in other cases, additional control circuitry is introduced,sometimes gratuitously!

Motor windings, solenoids and similar devices are all inductive loads. Assuch, the current through the motor winding cannot be turned on or offinstantaneously without involving infinite voltages! When the switchcontrolling a motor winding is closed, allowing current to flow, the resultof this is a slow rise in current. When the switch controlling a motorwinding is opened, the result of this is a voltage spike that can seriouslydamage the switch unless care is taken to deal with it appropriately.

There are two basic ways of dealing with this voltage spike. One is tobridge the motor winding with a diode, and the other is to bridge the motorwinding with a capacitor. Figure 3.2 illustrates both approaches:

Figure 3.2

The diode shown in Figure 3.2 must be able to conduct the full currentthrough the motor winding, but it will only conduct briefly each time theswitch is turned off, as the current through the winding decays. Ifrelatively slow diodes such as the common 1N400X family are used togetherwith a fast switch, it may be necessary to add a small capacitor inparallel with the diode.

The capacitor shown in Figure 3.2 poses more complex design problems!When the switch is closed, the capacitor will discharge through the switchto ground, and the switch must be able to handle this brief spike ofdischarge current. A resistor in series with the capacitor or in serieswith the power supply will limit this current. When the switch is opened,the stored energy in the motor winding will charge the capacitor up to avoltage significantly above the supply voltage, and the switch must beable to tolerate this voltage. To solve for the size of the capacitor,we equate the two formulas for the stored energy in a resonant circuit:

P = C V2 / 2

P = L I2 / 2Where: P -- stored energy, in watt seconds or coulomb volts

C -- capacity, in farads

V -- voltage across capacitor

L -- inductance of motor winding, in henrys

I -- current through motor windingSolving for the minimum size of capacitor required to prevent overvoltageon the switch is fairly easy: C > L I2 / (Vb - Vs)2Where: Vb -- the breakdown voltage of the switch

Vs -- the supply voltageVariable reluctance motors have variable inductance that depends on theshaft angle. Therefore, worst-case design must be used to select thecapacitor.

Furthermore, motor inductances are frequently poorly documented,if at all.

The capacitor and motor winding, in combination, form a resonant circuit.If the control system drives the motor at frequencies near the resonantfrequency of this circuit, the motor current through the motor windings,and therefore, the torque exerted by the motor, will be quite differentfrom the steady state torque at the nominal operating voltage! The resonantfrequency is:

f = 1 / (2 (L C)0.5)Again, the electrical resonant frequency for a variable reluctance motorwill depend on shaft angle! When a variable reluctance motors is operatedwith the exciting pulses near resonance, the oscillating current inthe motor winding will lead to a magnetic field that goes to zero at twicethe resonant frequency, and this can severely reduce the available torque!

Unipolar Permanent Magnet and Hybrid Motors

Typical controllers for unipolar stepping motors are variations on the outline shown in Figure 3.3:

Figure 3.3

In Figure 3.3, as in Figure 3.1, boxes are used to represent switches;a control unit, not shown, is responsible for providing the control signalsto open and close the switches at the appropriate times in order to spinthe motors. The control unit is commonly a computer or programmableinterface controller, with software directly generating the outputs neededto control the switches.

As with drive circuitry for variable reluctance motors, we must deal withthe inductive kick produced when each of these switches is turned off.Again, we may shunt the inductive kick using diodes, but now, 4 diodesare required, as shown in Figure 3.4:

Figure 3.4

The extra diodes are required because the motor winding is not two independentinductors, it is a single center-tapped inductor with the center tap at afixed voltage. This acts as an autotransformer! When one end of the motorwinding is pulled down, the other end will fly up, and visa versa. When aswitch opens, the inductive kickback will drive that end of the motor windingto the positive supply, where it is clamped by the diode. The opposite endwill fly downward, and if it was not floating at the supply voltage at thetime, it will fall below ground, reversing the voltage across the switch atthat end. Some switches are immune to such reversals, but others can beseriously damaged.

A capacitor may also be used to limit the kickback voltage, as shown inFigure 3.5:

Figure 3.5

The rules for sizing the capacitor shown in Figure 3.5 are the same as therules for sizing the capacitor shown in Figure 3.2, but the effect ofresonance is quite different! With a permanent magnet motor, if the capacitoris driven at or near the resonant frequency, the torque will increase to asmuch as twice the low-speed torque! The resulting torque versus speed curvemay be quite complex, as illustrated in Figure 3.6:Figure 3.6

Figure 3.6 shows a peak in the available torque at the electrical resonantfrequency, and a valley at the mechanical resonant frequency. If theelectrical resonant frequency is placed appropriately above what would havebeen the cutoff speed for the motor using a diode-based driver, the effectcan be a considerable increase in the effective cutoff speed.

The mechanical resonant frequency depends on the torque, so if themechanical resonant frequency is anywhere near the electrical resonance,it will be shifted by the electrical resonance!

Furthermore, thewidth of the mechanical resonance depends on the local slope of thetorque versus speed curve; if the torque drops with speed, the mechanicalresonance will be sharper, while if the torque climbs with speed, it willbe broader or even split into multiple resonant frequencies.

Practical Unipolar and Variable Reluctance Drivers

In the above circuits, the details of the necessary switches have beendeliberately ignored. Any switching technology, from toggle switches topower MOSFETS will work! Figure 3.7 contains some suggestions forimplementing each switch, with a motor winding and protection diodeincluded for orientation purposes:

Figure 3.7

Each of the switches shown in Figure 3.7 is compatible with a TTL input.The 5 volt supply used for the logic, including the 7407 open-collectordriver used in the figure, should be well regulated. The motor power,typically between 5 and 24 volts, needs only minimal regulation. It isworth noting that these power switching circuits are appropriate fordriving solenoids, DC motors and other inductive loads as well as for drivingstepping motors.

The SK3180 transistor shown in Figure 3.7 is a power darlington with acurrent gain over 1000; thus, the 10 milliamps flowing through the 470 ohmbias resistor is more than enough to allow the transistor to switch a fewamps current through the motor winding. The 7407 buffer used to drive thedarlington may be replaced with any high-voltage open collector chip thatcan sink at least 10 milliamps. In the event that the transistor fails,the high-voltage open collector driver serves to protects therest of the logic circuitry from the motor power supply.

The IRC IRL540 shown in Figure 3.7 is a power field effect transistor.This can handle currents of up to about 20 amps, and it breaks downnondestructively at 100 volts; as a result, this chip can absorb inductivespikes without protection diodes if it is attached to a large enough heatsink. This transistor has a very fast switching time, so the protectiondiodes must be comparably fast or bypassed by small capacitors. This isparticularly essential with the diodes used to protect the transistoragainst reverse bias! In the event that the transistor fails, the zenerdiode and 100 ohm resistor protect the TTL circuitry. The 100 ohm resistoralso acts to somewhat slow the switching times on the transistor.

For applications where each motor winding draws under 500 milliamps,theULN200xfamily of darlington arrays fromAllegro Microsystems,also available as theDS200xfromNational Semiconductor and as theMotorola MC1413 darlington array will drivemultiple motor windings or other inductive loads directly from logic inputs.Figure 3.8 shows the pinout of the widely available ULN2003 chip, an arrayof 7 darlington transistors with TTL compatible inputs:

Figure 3.8

The base resistor on each darlington transistor is matched to standardbipolar TTL outputs. Each NPN darlington is wired with its emitterconnected to pin 8, intended as a ground pin, Eachtransistor in this package is protected by two diodes, one shorting theemitter to the collector, protecting against reverse voltages across thetransistor, and one connecting the collector to pin 9; if pin 9 is wiredto the positive motor supply, this diode will protect the transistor againstinductive spikes.

The ULN2803 chip is essentially the same as the ULN2003 chip describedabove, except that it is in an 18-pin package, and contains 8 darlingtons,allowing one chip to be used to drive a pair of common unipolarpermanent-magnet or variable-reluctance motors.

For motors drawing under 600 milliamps per winding, theUDN2547Bquad power driver made byAllegro Microsystemswill handle all 4 windings of common unipolarstepping motors. For motors drawing under 300 milliamps per winding,Texas Instruments SN7541, 7542 and 7543 dual powerdrivers are a good choice; both of these alternatives include some logicwith the power drivers.

Bipolar Motors and H-Bridges Things are more complex for bipolar permanent magnet stepping motorsbecause these have no center taps on their windings. Therefore, to reversethe direction of the field produced by a motor winding, we need to reversethe current through the winding. We could use a double-pole double throwswitch to do this electromechanically; the electronic equivalent of such aswitch

is called an H-bridge and is outlined in Figure 3.9:

Figure 3.9

As with the unipolar drive circuits discussed previously, the switches usedin the H-bridge must be protected from the voltage spikes caused by turningthe power off in a motor winding.

This is usually done with diodes, as shownin Figure 3.9.

It is worth noting that H-bridges are applicable not only to the control ofbipolar stepping motors, but also to the control of DC motors, push-pullsolenoids (those with permanent magnet plungers) and many other applications.

With 4 switches, the basic H-bridge offers 16 possibleoperating modes, 7 of which short out the power supply! The followingoperating modes are of interest:

Forward mode, switches A and D closed.Reverse mode, switches B and C closed.These are the usual operating modes, allowing current to flow from thesupply, through the motor winding and onward to ground.Figure 3.10 illustrates forward mode:Figure 3.10

Fast decay mode or coasting mode, all switches open.Any current flowing through the motor winding will be working againstthe full supply voltage, plus two diode drops, so current will decayquickly. This mode provides little or no dynamic braking effect on themotor rotor, so the rotor will coast freely if all motor windings arepowered in this mode.Figure 3.11 illustrates the current flow immediately after switching fromforward running mode to fast decay mode.Figure 3.11

Slow decay modes or dynamic braking modes.In these modes, current may recirculate through the motor windingwith minimum resistance. As a result, if current is flowing in a motorwinding when one of these modes is entered, the current will decay slowly,and if the motor rotor is turning, it will induce a current that will actas a brake on the rotor. Figure 3.12 illustrates one of the many usefulslow-decay modes, with switch D closed; if the motor winding has recentlybeen in forward running mode, the state of switch B may be either open orclosed:Figure 3.12

Most H-bridges are designed so that the logic necessary to prevent a shortcircuit is included at a very low level in the design. Figure 3.13illustrates what is probably the best arrangement:Figure 3.13

Here, the following operating modes are available: XY

ABCDMode 00 0000 fast decay 01 1001 forward 10 0110 reverse 11 0101 slow decay The advantage of this arrangement is that all of the useful operating modesare preserved, and they are encoded with a minimum number of bits; the latteris important when using a microcontroller or computer system to drive theH-bridge because many such systems have only limited numbers of bits availablefor parallel output. Sadly, few of the integrated H-bridge chips on themarket have such a simple control scheme.

Practical Bipolar Drive Circuits

There are a number of integrated H-bridge drivers on the market, but it isstill useful to look at discrete component implementations for an understandingof how an H-bridge works. Antonio Raposo(ajr@cybill.inesc.pt) suggested the H-bridge circuit shown in Figure 3.14;

Figure 3.14

The X and Y inputs to this circuit can be driven by open collectorTTL outputs as in the darlington-based unipolar drive circuitin Figure 3.7. The motor winding will be energised if exactly one ofthe X and Y inputs is high and exactly one of them is low. If bothare low, both pull-down transistors will be off.If both are high, both pull-up transistors will be off.As a result, this simple circuit puts the motor in dynamic braking modein both the 11 and 00 states, and does not offer a coasting mode.

The circuit in Figure 3.14 consists of two identical halves, each of whichmay be properly described as a push-pull driver. The term half H-bridgeis sometimes applied to these circuits!

It is also worth noting thata half H-bridge has a circuit quite similar to the output drive circuitused in TTL logic. In fact, TTL tri-state line drivers such as the 74LS125Aand the 74LS244 can be used as half H-bridges for small loads, as illustratedin Figure 3.15:

This circuit is effective for driving motors with up to about 50 ohms perwinding at voltages up to about 4.5 volts using a 5 volt supply.Each tri-state buffer in the LS244 can sink about twice the current itcan source, and the internal resistance of the buffers is sufficient, whensourcing current, to evenly divide the current between the drivers thatare run in parallel.

This motor drive allows for all of the useful statesachieved by the driver in Figure 3.13, but these states are not encoded asefficiently: XYE

Mode --1 fast decay 000 slower decay 010 forward 100 reverse 110 slow decay The second dynamic braking mode, XYE=110, provides a slightly weaker brakingeffect than the first because of the fact that the LS244 drivers can sink morecurrent than they can source.

The Microchip (formerly Telcom Semiconductor)TC4467Quad CMOS driver is another example of a general purpose driverthat can be used as 4 independent half H-bridges. Unlike earlier drivers,the data sheet for this driver even suggests using it for motor controlapplicatons, with supply voltages up to 18 volts andup to 250 milliamps per motor winding.

One of the problems with commercially available stepping motor controlchips is that many of them have relatively short market lifetimes. Forexample, the Seagate IPxMxx series of dual H-bridge chips (IP1M10 throughIP3M12) were very well thought out, but unfortunately, it appears thatSeagate only made these when they used stepping motors for head positioningin Seagate disk drives. The Toshiba TA7279 dual H-bridge driver would beanother another excellent choice for motors under 1 amp, but again, itappears to have been made for internal use only. TheSGS-Thompson(and others)L293dual H-bridge is a close competitorfor the above chips, but unlike them, it does not include protection diodes.The L293Dchip, introduced later, is pin compatible and includes these diodes.If the earlier L293 is used, each motor winding must be set across a bridgerectifier (1N4001 equivalent). The use of external diodes allows a seriesresistor to be put in the current recirculation path to speed the decay ofthe current in a motor winding when it is turned off; this may be desirablein some applications. The L293 family offers excellent choices for drivingsmall bipolar steppers drawing up to one amp per motor winding at up to 36volts. Figure 3.16 shows the pinout common to the L293B and L293D chips:

This chip may be viewed as 4 independent half H-bridges, enabled in pairs,or as two full H-bridges. This is a power DIP package, with pins 4, 5, 12and 13 designed to conduct heat to the PC board or to an external heat sink.

TheSGS-Thompson(and others)L298dual H-bridge is quite similar to theabove, but is able to handle up to 2-amps per channel and is packaged asa power component; as with the LS244, it is safe to wire the two H-bridgesin the L298 package into one 4-amp H-bridge (the data sheet for this chipprovides specific advice on how to do this). One warning is appropriateconcerning the L298; this chip very fast switches, fast enough thatcommonplace protection diodes (1N400X equivalent) don't work. Instead,use a diode such as the BYV27. The National Semiconductor

LMD18200H-bridge is another good example; this handles up to 3 amps and has integralprotection diodes.

While integrated H-bridges are not available for very high currents or veryhigh voltages, there are well designed components on the market to simplifythe construction of H-bridges from discrete switches. For example,International Rectifier sells a line ofhalf H-bridge drivers; two of these chips plus 4 MOSFET switching transistorssuffice to build an H-bridge. TheIR210 1,IR2102andIR2103are basic half H-bridge drivers. Each of these chips has 2 logic inputs todirectly control the two switching transistors on one leg of an H-bridge.The IR2104andIR2111have similar output-side logic for controlling the switches of an H-bridge, butthey also include input-side logic that, in some applications, may reduce theneed for external logic. In particular, the 2104 includes an enable input, sothat 4 2104 chips plus 8 switching transistors can replace an L293 with noneed for additional logic.

The data sheet for theMicrochip (formerly Telcom Semiconductor)TC4467family of quad CMOS drivers includes information on how to use drivers in thisfamily to drive the power MOSFETs of H-bridges running at up to 15 volts.

A number of manufacturers make complex H-bridge chips that include currentlimiting circuitry; these are the subject of the next section.It is also worth noting that there are a number of 3-phase bridge drivers onthe market, appropriate for driving Y or delta configured 3-phase permanentmagnet steppers. Few such motors are available, and these chips were notdeveloped with steppers in mind. Nonetheless, the Toshiba TA7288P,the GL7438, the TA8400 and TA8405 are clean designs, and 2 such chips, withone of the 6 half-bridges ignored, will cleanly control a 5-winding 10step per revolution motor.

Current Limiting for Stepping Motors

Part of Stepping Motors

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Introduction

Small stepping motors, such as those used for head positioning on floppydisk drives, are usually driven at a low DC voltage, and the currentthrough the motor windings is usually limited by the internal resistanceof the winding. High torque motors, on the other hand, are frequentlybuilt with very low resistance windings; when driven by any reasonablesupply voltage, these motors typically require external current limitingcircuitry.

There is good reason to run a stepping motor at a supply voltage abovethat needed to push the maximum rated current through the motor windings.Running a motor at higher voltages leads to a faster rise in the currentthrough the windings when they are turned on, and this, in turn, leads toa higher cutoff speed for the motor and higher torques at speeds abovethe cutoff.

Microstepping, where the control system positions the motor rotorbetween half steps, also requires external current limiting circuitry.For example, to position the rotor 1/4 of the way from one step toanother, it might be necessary to run one motor winding at full currentwhile the other is run at approximately 1/3 of that current.

The remainder of this section discusses various circuits for limiting thecurrent through the windings of a stepping motor, starting with simpleresistive limiters and moving up to choppers and other switching regulators.Most of these current limiters are appropriate for many other applications,including limiting the current through conventional DC motors and otherinductive loads.

Resistive Current Limiters

The easiest to understand current limiter is a series resistor. Mostmotor manufacturers recommended this approach in their literature upuntil the early 1980's, and most motor data sheets still give performancecurves for motors driven by such circuits. The typical circuits used tocontrol the current through one winding of a permanent magnet orhybrid motor are shown in Figure 4.1.

Figure 4.1

R1 in this figure limits the current through the motor winding.Given a rated current of I and a motor winding with a resistanceRw, Ohm's law sets the maximum supply voltage asI(Rw+R1).

Given that the inductance of the motormotor winding is Lw, the time constant for the motor windingwill be Lw/(Rw+R1).Figure 4.2 illustrates the effect of increasing the resistance and theoperating voltage on the rise and fall times of the current through onewinding of a stepping motor.Figure 4.2

R2 is shown only in the unipolar example in Figure 4.1 because it isparticularly useful there. For a bipolar H-bridge drive, when all switchesare turned off, current flows from ground to the motor supply throughR1, so the current through the motor winding will decay quitequickly. In the unipolar case, R2 is necessary to equal thisperformance.

Note: When the switches in the H-bridge circuit shown in Figure 4.1 areopened, the direction of current flow through R1 will reversealmost instantaneously! If R1 has any inductance, for example,if it is wire-wound, it must either be bypassed with a capacitor to handlethe voltage kick caused by this current reversal, or R2 must beadded to the H-bridge.

Given the rated maximum current through each winding and the supplyvoltage, the resistance and wattage of R1 is easy to compute.R2 if it is included, poses more interesting problems.

Theresistance of R2 depends on the maximum voltage the switchescan handle. For example, if the supply voltage is 24 volts, and the switchesare rated at 75 volts, the drop across R2 can be as much as 51volts without harming the transistors. Given an operating current of1.5 amps, R2 can be a 34 ohm resistor. Note that aninteresting alternative is to use a zener diode in place of R2.

Figuring the peak average power R2 must dissipate is awonderful exercise in dynamics; the inductance of the motor windings isfrequently undocumented and may vary with the rotor position.

The powerdissapated in R2 also depends on the control system. Theworst case occurs when the control system chops the power to one windingat a high enough frequency that the current through the motor winding iseffectively constant; the maximum power is then a function of the dutycycle of the chopper and the ratios of the resistances in the circuitduring the on and off phases of the chopper. Under normal operatingconditions, the peak power dissipation will be significantly lower.

Linear Current Limiters

A pair of high wattage power resistors can cost more than a pairof power transistors plus a heat sink, particularly if forced air coolingis available. Furthermore, a transistorized constant current source, as shownin Figure 4.3, will give faster rise times through the motor windings thanthe current limiting resistor shown in Figure 4.1. This is because acurrent source will deliver the full supply voltage across the motorwinding until the current reaches the rated current; only then will thecurrent source drop the voltage.

Figure 4.3

In Figure 4.3, a transistorized current source (T1 plusR1) has been substituted for the current limiting resistorR1 used in the examples in Figure 4.1. The regulated voltagesupplied to the base of T1 serves to regulate the voltageacross the sense resistor R1, and this, in turn, maintainsa constant current through R1 so long as any current is allowedto flow through the motor winding.

Typically, R1 will have as low a resistance as possible, in orderto avoid the high cost of a power resistor. For example, if the forwardvoltage drops across the diode in series with the base T1 andVBE for T1 are both 0.65 volts, and if a 3.3 voltzener diode is used for a reference, the voltage across R1 willbe maintained at about 2.0 volts, so if R1 is 2 ohms, thiscircuit will limit the current to 1 amp, and R1 must be ableto handle 2 watts.

R3 in Figure 4.3 must be sized in terms of the current gain ofT1 so that sufficient current flows through R1 andR3 to allow T1 to conduct the full rated motor current.

The transistor T1 used as a current regulator in Figure 4.3 isrun in linear mode, and therfore, it must dissapate quite a bit of power.For example, if the motor windings have a resistance

of 5 ohms and a ratedcurrent of 1 amp, and a 25 volt power supply is used, T1 plusR1 will dissapate, between them, 20 watts! The circuits discussedin the following sections avoid this waste of power while retaining theperformance advantages of the circuit given here.

When an H-bridge bipolar drive is used with a resistive current limiter,as shown in Figure 4.1, the resistor R2 was not needed becausecurrent could flow backwards through R1. When a transistorizedcurrent limiter is used, current cannot flow backwards through T1,so a separate current path back to the positive supply must be provided tohandle the decaying current through the motor windings when the switches areopened. R2 serves this purpose here, but a zener diode may besubstituted to provide even faster turn-off.

The performance of a motor run with a current limited power supply isnoticably better than the performance of the same motor run with aresistively limited supply, as illustrated in Figure

Figure 4.4

With either a current limited supply or a resistive current limiter, theinitial rate of increase of the current through the I ductive motor windingwhen the power is turned on depends only on the inductance of the windingand the supply voltage. As the current increases, the voltage drop acrossa resistive current limiter will increase, dropping the voltage applied to the motor winding, and therefore, dropping the rate of increase of thecurrent through the winding. As a result, the current will only approach therated current of the motor winding asymptotically

In contrast, with a pure current limiter, the current through the motorwinding will increase almost linearly until the current limiter cuts in,allowing the current to reach the limit value quite quickly. In fact,the current rise is not linear; rather, the current rises asymptoticallytowards a limit established by the resistance of the motor winding andthe resistance of the sense resistor in the current limiter. This maximumis usually well above the rated current for the motor winding.

Open Loop Current Limiters

Both the resistive and the linear transistorized current limiters discussedabove automatically limit the current through the motor winding, but at aconsiderable cost, in terms of wasted heat. There are two schemes thateliminate this expense, although at some risk because of the lack of feebackabout the current through the motor.

Use of a Voltage Boost

If you plot the voltage across the motor winding as a function of time,assuming the use of a transistorized current limiter such as isillustrated in Figure 4.3, and assuming a 1 amp 5 ohm motor winding,the result will be something like that illustrated in Figure 4.5:

Figure 4.5

As long as the current is below the current limiter's set point, almostthe full supply voltage is applied across the motor winding. Once thecurrent reaches the set point, the voltage across the motor winding fallsto that needed to sustain the current at the set point, and when the switchesopen, the voltage reverses briefly as current flows through the diode networkand R2.

An alternative way to get this voltage profile is to use a dual-voltagepower supply, turning on the high voltage for as long as it takes to bringthe current in the motor winding up to the rated current, and then turningoff the high voltage and turning on the sustaining voltage. Some motorcontrollers do this directly, without monitoring the current through themotor windings. This provides excellent performance and minimizes powerlosses in the regulator, but it offers a dangerous temptation.

If the motor does not deliver enough torque, it is tempting to simply lengthenthe high-voltage pulse at the time the motor winding is turned on. Thiswill usually provide more torque, although saturation of the magnetic circuitsfrequently leads to less torque than might be expected, but the cost is high!The risk of burning out the motor is quite real, as is the risk ofdemagnitizing the motor rotor if it is turned against the imposed field whilerunning hot. Therefore, if a dual-voltage supply is used, the temptation toraise the torque in this way should be avoided!

The problems with dual voltage supplies are particularly serious when thetime intervals are under software control, because in this case, it is commonfor the software to be written by a programmer who is insufficiently awareof the physical and electrical characteristics of the control system.

Use of Pulse Width Modulation

Another alternative approach to controlling the current through the motorwinding is to use a simple power supply controlled bypulse width modulaton (PWM) or by a chopper.During the time the current through the motor winding is increasing,the control system leaves the supply attached with a 100% duty cycle. Oncethe current is up to the full rated current, the control system changes theduty cycle to that required to maintain the current.Figure 4.6 illustrates this scheme:

Figure 4.6

For any chopper or pulse width modulator, we can define the duty-cycle D asthe fraction of each cycle that the switch is closed: D = Ton / (Ton + Toff)Where Ton -- time the switch is closed during each cycle

Toff -- time the switch is open during each cycleThe voltage curve shown above indicates the full supply voltage beingapplied to the motor winding during the on-phase of every chopper cycle,while when the chopper is off, a negative voltage is shown. This is theresult of the forward voltage drop in the diodes that are used to shunt thecurrent when the switches turn off, plus the external resistance used tospeed the decay of the current through the motor winding.

For large values of Ton or Toff, the exponential natureof the rise and fall of the current through the motor winding is significant,but for sufficiently small values, we can approximate these as linear.Assuming that the chopper is working to maintain a current of I and thatthe amplitude is small, we will approximate the rates of rise and fall inthe current in terms of the voltage across the motor winding when the switchis closed and when it is open:

Von = Vsupply - I(Rwinding + Ron)

Voff = Vdiode + I(Rwinding + Roff)Here, we lump together all resistances in series with the winding and powersupply in the on state as Ron, and we lump together all resistancesin the current recirculation path when the switch(es) are open asRoff. The forward voltage drops of any diodes in the currentrecirculation path have been lumped as Vdiode; if the off-staterecirculation path runs from ground to the power supply (H-bridge fast decaymode), the supply voltage must also be included in Vdiode.Forward voltage drops of any switches in the on-state and off-state pathsshould also be incorporated into these voltages.

To solve for the duty cycle, we first note that:

dI/dt = V/LWhere I -- current through the motor winding

V -- voltage across the winding

L -- inductance of the winding

We then substitute the specific voltages for each phase of operation:

Iripple / Toff = Voff / L

Iripple / Ton = Von / LWhere Iripple -- the peak to peak ripple in the currentSolving for Toff and Ton and then substitutingthese into the definition of the duty cycle of the chopper, we get: D = Ton / (Ton + Toff) = Voff / (Von + Voff)If the forward voltage drops in diodes and switches are negligable, and ifthe only significant resistance is that of the motor winding itself,this simplifies to: D = I Rwinding / Vsupply = Vrunning / VsupplyThis special case is particularly desirable because it delivers all of thepower to the motor winding, with no losses in the regulation system, withoutregard for the difference between the supply voltage and the running voltage.

The AC ripple Iripple superimposed on the running current by achopper can be a source of problems; at high frequencies, it can bea source of RF emissions, and at audio frequencies, it can be a source ofannoying noise. For example, with audio frequency chopping, most steppercontrolled systems will "squeel", sometimes loudly, when the rotor isdisplaced from the equilibrium position. For small systems, this is usuallyno more than a minor nuisance, but in systems with large numbersof high power steppers, the ripple currents can induce dangerous AC voltageson nearby signal lines and dangerous currents in nearby ground lines.To find the ripple amplitude, firstrecall that:

Iripple / Toff = Voff / LThen solve for Iripple: Iripple = Toff Voff / LThus, to reduce the ripple amplitude at any particular duty cycle, it isnecessary to increase the chopper frequency. This cannot be done withoutlimit because switching losses increase with frequency. Note that thischange has no significant effect on AC losses; the decrease in such lossesdue to decreased amplitude in the ripple is generally offset by the effectof increasing frequency.

The primary problem with use of a simple chopping or pulse-width modulationcontrol scheme is that it is completely open loop. Design of good chopperbased control systems requires knowledge of motor characteristics such asinductance that are frequently poorly documented, and as with dual-voltagesupplies, when motor performance is marginal, it is very tempting toincrease the duty-cycle without attention to the long-term effects ofthis on the motor. In the designs that follow, this weakness will beaddressed by introducing feedback loops into the low level drive system todirectly monitor the current and determine the duty cycle.

One-Shot Feedback Current Limiting

The most common approach to automatically adjusting the duty cycle of theswitches in the stepper driver involves monitoring the current to the motorwindings; when it rises too high, the winding is turned off for a fixedinterval. This requires a current sensing system and a one-shot, asillustrated in Figure 4.7:

Figure 4.7 illustrates a unipolar drive system. As with the circuitgiven in Figure 4.3, R1 should be as small as possible, limitedonly by the requirement that the sense voltage provided to the comparatormust be high enough to be within its operating range. Note that when theone-shot output (¬Q) is low, the voltage across R1 no-longerreflects the current through the motor winding. Therefore, the one-shotmust be insensitive to the output of the comparator between the time itfires and the time it resets. Practical circuit designs using this approachinvolve some complexity to meet this constraint!

Selecting the value of R2 for the circuit shown in Figure 4.7poses problems. If R2 is large, the current through the motorwindings will decay quickly when the higher level control system turns offthis motor winding, but when the winding is turned on, the current ripplewill be large and the power lost in R2 will be significant.If R2 is small, this circuit will be very energy efficient butthe current through the motor winding will decay only slowly when thiswinding is turned off, and this will reduce the cutoff speed for the motor.

The peak power dissapated in R2 will be I2R2during Toff and zero during Ton; thus, the average powerdissapated in R2 when the motor winding is on will be:

P2 = I2R Toff / (Ton + Toff)Recall that the duty cycle D is defined asTon/(Ton+Toff) and may be approximatedas Vrunning/Vsupply. As a result, we can approximatethe power dissipation as: P2 = I2R2 (1 - Vrunning/Vsupply).Given the usual safety margins used in selecting power resistor wattages,a better approximation is not necessary.

When designing a control system based on pulse width modulation, note thatthe cutoff time for the one-shot determines Toff, and that thisis fixed, determined by the timing network attached to the one-shot. Ideally,this should be set as follows:

Toff = L Iripple / VoffThis presumes that the inductance L of the motor winding is known, thatthe acceptable magnitude of Iripple is known, and thatVoff, the total reverse voltage in the current recirculationpath, is known and fixed.

Note that this scheme leads to a variable chopping rate. As with the linearcurrent limiters shown in Figure 4.3, the full supply voltage will be appliedduring the turn-on phase, and the chopping action only begins when the motorwinding reaches the current limit set by Vref. This circuit willvary the chopping rate to compensate for changes in the back EMF of themotor winding, for example, those caused by rotor motion; in this regard, itoffers the same quality of regulation as the linear current limiter.

The one-shot current regulator shown in Figure 4.7 can also be applied to anH-bridge regulator. The encoded H-bridge shown inFigure 3.13is an excellent candidate for this application, as shown in Figure 4.8:

Figure 4.8

Unlike the circuit in Figure 4.7, this circuit does not provide designtradeoffs in the selection of the resistance in the current decay path;instead, it offers the same selection of decay paths as was available inthe original circuit fromFigure 3.13.If the X and Y control inputs are held in a running mode (01 or 10), thecurrent limiter will alternate between that running and slow decay modes,maximizing energy efficiency. When the time comes to turn off the currentthrough the motor winding, the X and Y inputs may be set to 00, using fastdecay mode to maximize the cutoff speed, while if the damping effect ofdynamic braking is needed to control resonance, X and Y may be set to 11.

Note that the current recirculation path during dynamic braking does notpass through R1, and as a result, if the motor generatesa large amount of power, burnt out components in the motor or controllerare likely. This is unlikely to cause problems with stepping motors, butwhen dynamic braking is used with DC motors, the current limiter shouldbe arranged to remain engaged while in braking mode!

Practical Examples

SGS-Thompson(and others)L293 (1A)andL298 (2A)dual H-bridges are designed for easy use with partial feedback currentlimiters. These chips have enable inputs for each H-bridge that can bedirectly connected to the output of the one-shot, and they haveground connections for motor-power that are isolated from their logicground connections; this allows sense resistors to be easilyincorporated into the circuit.

The3952H-bridge fromAllegro Microsystemscan handle up to 2-amps at 50 volts andincorporates all of the logic necessary for current control, includingcomparators and one-shot. This chip is available in many package styles;Figure 4.9 illustrates the DIP configuration wired for a constantcurrent limit:

Figure 4.9

If Rt is 20 Kohm, and Ct is 1000pF,Toff for the pulse-width modulation will be fixed at20 (±2) microseconds. The 3952 chip incorporates a 10 to 1voltage divider on the Vref input, so attaching Vrefto the 5 volt logic supply sets the actual reference voltage to 0.5 V.Thus, if the sense resistor Rs is 0.5 ohms, this arrangementwill attempt to maintain a regulated current through the load of 1 A.

Note that all power switching chips are potentially serious sources ofelectromagnetic interfence! The 47μF capacitor shown between themotor power and ground should be as close to the chip as possible, andthe path from the SENSE pin through Rs to ground and back toa ground pin of the chip should be very short and with a very low resistance.

On the 5 volt side, because Vref is taken fromVcc, a small decoupling capacitor should be placed very closeto the chip. It may even be appropriate to isolate the Vrefinput from Vcc with a small series resistor and a separatedecoupling capacitor. If this is done, note that the resistance fromthe Vref pin to ground through the chip's internal voltagedivider is around 50 Kohms.

One of the more dismaying features of the 3952 chip, as well as many ofits competitors, is the large number of control inputs. These aresummarized in the following table:

BRAKEENABLEPHASE MODE

OUTa OUTb Notes 0 - - 0 0 0 Brake 0 - - 1 0

0 Limited Brake 1 1 - 0 - - Standby 1 1 - 1 -

- Sleep 1 0 0 0 0 1 Reverse, Slow 1 0 0 1 0

1 Reverse, Fast 1 0 1 0 1 0 Forward, Slow 1 0 1 1 1 0 Forward, Fast In the forward and reverse running modes, the mode input determines whetherfast or slow decay modes are used during Toff.In the dynamic braking modes, the mode input determines whether the currentlimiter is enabled. This is of limited value with stepping motors, but useof dynamic braking without a current limiter can be dangerous with DC motors.

In sleep mode, the power consumption of the chip is minimized. From the perspective of the load, sleep and standby modes put the load intofast decay mode (all switches off) but in sleep mode, the chip drawsconsiderably less power, both from the logic supply and the motor supply.

Hysteresis Feedback Current Limiting

In many cases, motor control systems are expected to operate acceptably witha number of different stepping motors. The one-shot based current regulatorsillustrated in Figures 4.7 to 4.9 have an accuracy that depends on theinductance of the motor windings. Therefore, if fixed accuracy is required,any motor substition must be balanced by changes to the RC network that determines the off-time of the one-shot.

This section deals with alternative designs that eliminate the need for thistuning. These alternative designs offer fixed precision current regulationover a wide range of load inductances. The key to this approach isarrange the recirculation paths so that the current-sense resistorR1 is always in the circuit, and then turn the switches on oroff depending only on the current.

The usualy way to build this type of controller is to use a comparator witha degree of hysteresis, for example, by feeding the output of the comparatorback into one of its inputs through a resistor network, asillustrated in Figure 4.10:

Figure 4.10

To compute the desired values of R2 and R3, we notethat: Vripple > VhysteresisWhere: Vripple = Iripple R1

Iripple -- the maximum ripple allowed in the currentand: Vhysteresis = Vswing R2 / (R2 + R3)

Vswing -- the voltage swing at the output of the comparatorWe can solve this for the ratio of the resistances: R2 / (R2 + R3) < Iripple R1 / VswingFor example, if R1 is 0.5 ohms and we wish to regulate thecurrent to within 10 milliamps, using a comparator with TTL compatableoutputs and a voltage swing of 4 volts, the ratio must be no greaterthan .00125.

Note that the sum R2 + R3 determines theloading on Vref, assuming that the input resistance of thecomparator is effectively infinite. Typically, therefore, this sum ismade quite large.

One problem with the circuit given in Figure 4.10 is that it does notlimit the current through the motor in dynamic braking or slow decay modes.Even if the current through the sense resistor vastly exceeds the desiredcurrent, switches B and D will remain closed in dynamic braking mode,and if the reference voltage is variable, rapid drops in the referencevoltage will not be enforced by this control system.

The designers of the Allegro 3952 chip faced this problem, and passed thesolution back to the user, providing a MODE input to determine whether thechopper alternated between running and fast decay mode or running andslow decay mode. Note that this chip uses a fixed off-time set by a one-shot,and therefore, switching between the two decay modes will change the precisionof the current regulator. Given that such a change in precision is acceptable,we can modify the circuit from Figure 4.10 to automatically thrown thesystem into fast-decay mode if the running or dynamic braking current exceedsthe set-point of the comparator by too great a margin. Figure 4.11 illustrateshow this can be done using a second comparator:

Figure 4.11

As shown in Figure 4.11, the lower comparator directly senses the voltageacross R1, while the upper comparator senses a higher voltage, determinedby a resistor network. This network should hold the negative inputs ofthe two comparators just far enough apart to guarantee that, as the voltageacross R1 rises, the top comparator will always open the top switches beforethe bottom comparator opens the bottom switches, and as the voltage acrossR1 falls, the bottom comparator will always close the bottom switches beforethe top comparator closes the top switches.

As a result, this system has two basic steady-state running modes. If themotor winding is drawing power, one of the bottom switches will remainclosed while the opposite switch on the top is used to chop the power tothe motor winding, alternating the state of the system between running andslow-decay mode.

If the motor winding is generating power, the top switches will remain openand the bottom switches will do the chopping, alternating between fast-decayand slow-decay modes as needed to keep the current within limits.

If the two comparators have accuracies on the order of a millivolt withhysteresis on the order of 5 millivolts, it is reasonable to use a 5 millivoltdifference between the top and bottom comparator. If we use the 5 volt logicsupply as the pull-up supply for the resistor network, and we assume a nominaloperating threshold of around 0.5 volts, the resistor network should havea ratio of 1:900; for example, a 90k resistor from +5 and a 100 ohm resistorbetween the two comparator inputs.

Practical Examples

The basic idea described in this section is also applicable to unipolarstepping motor controllers, although in this context, it is somewhateasier to apply if the reference voltage is measured with respect to theunregulated motor power supply. Figure 4.12 illustrates a practical example,using the forward voltage drop across an ordinary silicon diode as thereference voltage.

Figure 4.12

The circuit shown in Figure 4.12 uses a 2.4K resistor to provide a biascurrent of 10ma to the reference diode. A small capacitor should be addedacross the reference diode if the motor power supply is minimally regulated.

The 0.6 ohm value used for the current sensing resistor sets the regulatorto 1 amp, assuming that the reference voltage is 0.6 volts. The 1000 to 1ratio on the feedback network around the comparator sets the allowed ripplein the regulated current to around 8 ma.

The comparator shown in Figure 4.12 can be powered from the minimallyregulated motor power supply, but only if it is able to operate withthe inputs very close to its positive supply voltage. Although I havenot tried it, the Mitsubishi M5249L comparator appears to be ideallysuited to this job; it can work from a positive supply of up to 40 volts,and the input voltages are allowed to slightly exceed the positive supplyvoltage! The output of this comparator is open collector, so the hysteresisnetwork shown in the figure also acts as a pull-up network, providing apull-up current of a few milliamps. The diode to +5 shown in the figureclamps the comparator output to the logic supply voltage, protecting theand gate inputs from overvoltage.

Other Current Sensing Technologies

The feedback loops of all of the current limiters given above use thevoltage drop across a small resistor to measure the current. This isan excellent choice for small motors, but it poses difficulties forlarge high-current motors! There are other current sensing technologiesappropriate for such settings, most notably those that deliver only afraction of the motor current to the sensing resistor, and those thatmeasure the current by sensing the magnetic field around the conductor.

National Semiconductorhad incorporated a very clever current sensorinto a number of their H-bridges. This delivers a current to the senseresistor that is proportional to the current through the motor winding,but far lower. For example, on theLMD18200H-bridge, the sense resistor receives exactly 377 microamps per ampereflowing through the motor winding.

The key to the current sensing technology used in the National Semiconductorline of H-bridges is found in the internal structure of the DMOS powerswitching transistors they use. These transistors are composed of thousandsof small MOSFET transistor cells wired in parallel. A small butrepresentative fraction of these cells, typically 1 in 4000, is used toextract the sense current while the remainder of the cells control themotor current. The data sheet for the NationalLMD18245H-bridge contains an excellent writeup on how this is done.

When very high currents are involved, precluding use of an integratedH-bridge, an appealing and well established current sensing technologyinvolves the use of a split ferrite core and a hall effect sensor, asillustrated in Figure 4.13:

Figure 4.13

Simple linear Hall effect sensors require a small regulated bias currentbetween two of their terminals, and they generate a DC voltage proportionalto the magnetic field on a third terminal. The magnetic field across the gapsawed in the ferrite core is proportional to the current through the wire,and therefore, the voltage reported by the Hall effect sensor will beproportional to the current.

Allegro Microsystems and othersmake a full lines of Hall effect sensors, butpre-calibrated hall effect current sensors are available; these includethe split core, the hall effect sensor, and auxiliary components, allmounted on a small PC board or potted as a unit. Newark Electronics listsa few sources of these, includingHoneywell,F. W. Bell andLEM Instruments.

An intriguing new current sensor is just becoming available, as of 1998,based on a thin-film magnetoresistive sensor; the sensitivity of thistechnology eliminates the need for the ferrite core and the result is avery compact current sensor. The NT series sensors made byF. W. Bell use this technology.

Microstepping of Stepping Motors

Part of Stepping Motors

byDouglas W. Jones

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Introduction

Microstepping serves two purposes. First, it allows a stepping motorto stop and hold a position between the full or half-step positions,second, it largely eliminates the jerky character of low speed steppingmotor operation and the noise at intermediate speeds, and third, itreduces problems with resonance.

Although some microstepping controllers offer hundreds of intermediatepositions between steps, it is worth noting that microstepping doesnot generally offer great precision, both because of linearity problemsand because of the effects of static friction.

Sine Cosine Microstepping

Recall, from the discussion in Part 2 of thistutorial, on Stepping Motor Physics, thatfor an ideal two-winding variable reluctance or permanent magnet motorthe torque versus shaft angle curve is determined by the followingformulas:

h = (a2 + b2)0.5

x = (S / (/2)) arctan(b / a)Where: a -- torque applied by winding with equilibrium at angle 0.

b -- torque applied by winding with equilibrium at angle S.

h -- holding torque of composite.

x -- equilibrium position.

S -- step angle.This formula is quite general, but it offers little in the way ofguidance for how to select appropriate values of the current throughthe two windings of the motor. A common solution is to arrange thetorques applied by the two windings so that their sum h has aconstant magnitude equal to the single-winding holding torque. Thisis referred to as sine-cosine microstepping: a = h1 sin(((/2)/S))

b = h1 cos(((/2)/S))Where: h1 -- single-winding holding torque

((/2)/S) -- the electrical shaft angleGiven that none of the magnetic circuits are saturated, the torque and thecurrent are linearly related. As a result, to hold the motor rotor to angle), we set the currents throughthe two windings as: Ia = Imax sin(((/2)/S))

Ib = Imax cos(((/2)/S))Where: Ia -- current through winding with equilibrium at angle 0.

Ib -- current through winding with equilibrium at angle S.

Imax -- maximum allowed current through any motor winding.Keep in mind that these formulas apply to two-winding permanent magnet orhybrid stepping motors. Three pole or five pole motors have more complexbehavior, and the magnetic fields in variable reluctance motors don't addfollowing the simple rules that apply to the other motor types.

Limits of Microstepping

The utility of microstepping is limited by at least three consideraitons.First, if there is any static friction in the system, the angular precisionachievable with microstepping will be limited. This effect was discussedin more detail in the discussion in Part 2 of this tutorial, on Stepping Motor Physics, in the discussion offriction and the dead zone.

Detent Effects

The second problem involves the non-sinusoidal character of the torque versusshaft-angle curves on real motors. Sometimes, this is attributed to the detenttorque on permanent magnet and hybrid motors, but in fact, both detenttorque and the shape of the torque versus angle curves are products of poorlyunderstood aspects of motor geometry, specifically, the shapes of the teeth onthe rotor and stator. These teeth are almost always rectangular, and I amaware of no detailed study of the impact of different tooth profiles on theshapes of these curves.

Most commercially available microstepping controllers provide a fairapproximation of the sine-cosine drive current that would drive an idealstepping motor to uniformly spaced steps.

Ideal motors are rare, and whensuch a controller is used with a real motor, a plot of the actual motorposition as a function of the expected position will generally looksomething like the plot shown in Figure 5.1.

Figure 5.1

Note that the motor is at its expected position at every full step and atevery half step, but that there is significant positioning error in theintermediate positions. The curve shown is the curve that would result froma perfect sin-cosine microstepping controller used with a motor that had atorque versus position curve that included a significant 4th harmoniccomponent, usually attributed to the detent torque.

The broad details of detent effects appear to be fairly uniform from motorto motor, so in principle, it ought to be possible to adjust the tables ofsines and cosines used in a sine-cosine controller to compensate for thedetent effects. In practice, the effects of friction and the errors introducedby quantization combine to limit the value of such an effort.

Quantization

The third problem arises because most applications of microstepping involvedigital control systems, and thus, the current through each motor windingis quantized, controlled by a digital to analog converter. Furthermore, iftypical PWM current limiting circuitry is used, the current through eachmotor winding is not held perfectly constant, but rather, oscillates aroundthe current control circuit's set point. As a result, the best a typicalmicrostepping controller can do is approximate the desired currents througheach motor winding.

The effect of this quantization is easily seen if the available current throughone motor winding is plotted on the X axis and the available current throughthe other motor winding is plotted on the Y axis. Figure 5.2 shows such aplot for a motor controller offering only 4 uniformly spaced current settingsfor each motor winding:

Figure 5.2

Of the 16 available combinations of currents through the motor windings,6 combinations lead to roughly equally spaced microsteps. There is a cleartradeoff between minimizing the variation in torque and minimizing theerror in motor position, and the best available motor positions are hardlyuniformly spaced! Use of higher precision digital to analog conversion inthe current control system reduces the severity of this problem, but itcannot eliminate it!

Plotting the actual rotor position of a motor using the microstep plan outlinedin Figure 5.2 versus the expected position gives the curve shown in Figure 5.3:

Figure 5.3

It is very common for the initial microsteps taken away from any full stepposition to be larger than the intended microstep size, and this tends to givethe curve a staircase shape, with the downward steps aligned with the fullstep positions where only one motor winding carries current. The sign of theerror at intermediate positions tends to fluctuate, but generally,

theposition errors are smallest between the full step positions, when both motorwindings carry significant current.

Another way of looking at the available microsteps is to plot the equilibriumposition on the horizontal axis, in fractions of a full-step, while plottingthe torque at each available equilibrium position on the vertical axis.If we assume a 4-bit digital-to-analog converter, giving 16 current levelsfor each each motor winding, there are 256 equilibrium positions. Of these,52 offer holding torques within 10% of the desired value, and only 33 arewithin 5%; these 33 points are shown in bold in Figure 5.4:

Figure 5.4

If torque variations are to be held within 10%, it is fairly easy to select8 almost-uniformly spaced microsteps from among those shown in Figure 5.4;these are boxed in the figure. The maximum errors occur at the 1/4 steppoints; the maximum error is .008 full step or .06 microsteps. This errorwill be irrelevant if the dead-zone is wider than this.

If 10 microsteps are desired, the situation is worse. The best choices, stillholding the maximum torque variation to 10%, gives a maximum position error of.026 full steps or .26 microsteps. Doubling the allowable variation in torqueapproximately halves the positioning error for the 10 microstep example, butdoes nothing to improve the 8 microstep example.

One option which some motor control system designers have explored involvesthe use of nonlinear digital to analog converters. This is an excellentsolution for small numbers of microsteps, but building converters withessentially sinusoidal transfer functions is difficult if high precision isdesired.

Typical Control Circuits

As typically used, a microstepping controller for one motor winding involvesa current limited H-bridge or unipolar drive circuit, where the current isset by a reference voltage. The reference voltage is then determined byan analog-to-digital converter, as shown in Figure 5.5:

Figure 5.5 ------| |----- Vref |_____________|| _|_///" align="middle" height="220" width="340" />

Figure 5.5 assumes a current limited motor controller such as is shown inFigures4.7,4.8,4.10 or4.11.For all of these drivers, the state of the X and Y inputs determines thewhether the motor winding is on or off and if on, the direction of thecurrent through the winding. The V0 through Vn inputsdetermine the reference voltage and this the current through the motorwinding.

Practical Examples

There are a fair number of nicely designed integrated circuits combininga current limited H-bridge with a small DAC to allow microstepping controlof motors drawing under 2 amps per winding. TheUDN2916Bfrom Allegro Microsystemsis a dual 750mA H-bridge, with a 2-bit DAC to control the current through each.bridge.Another excellent example is theUC3770fromUnitrode.Unit rode.This chip integrate a 2-bit DAC with a PWM controlled H-bridge, packagedin either 16 pin power-dip format or in surface mountable form. The3717 a slightly cleaner design, good for

1.2 A, while the 3770 is good forup to between 1.8 A or 2 A, depending on how the chip is cooled.

The3955fromAllegro Microsystemsincorporates a 3-bit non-linear DAC and handles up to 1.5 A; this isavailable in 16-pin power DIP or SOIC formats. The nonlinear DAC in thischip is specifically designed to minimize step-angle errors and torquevariations using 8 microsteps per full-step.

TheLMD18245fromNational Semiconductoris a good choice for microstepped control of motors drawing up to 3 amps.This chip incorporates a 4-bit linear DAC, and an external DAC can be usedif higher precision is required. As indicated by the data shown inFigure 5.4, a 4-bit linear DAC can produce 8 reasonably uniformly spacedmicrosteps, so this chip is a good choice for applications thatexceed the power levels supported by the Allegro 3955.

Historical Note

It appears that microstepping was invented in 1974 by Larry Durkos,who was working as a mechanical engineer for American Monitor Corporation.The company was a medical equipment vendor, and they were using a largeSuperior Electric 1.8 degree per step stepping motors to directly drivethe 20 inch diameter turntable of their Kinetic Discrete Analyzer. Theturntable was used to bring each of 100 blood samples into position foranalysis.

That is 2 steps per sample, and the motion was so abrupt that the samplestended to spill. The system was controlled by a Computer Automation LSI 2minicomputer (today, we would use a microcontroller), and Durkos workedout how to do computer-controlled sine-cosine microstepping in orderto solve this problem. The solution was published in the technical servicemanuals for the KDA analyzer, but it was never patented.

Representatives ofSuperior Electric learned of microsteppingfrom Durkos, and that company wasthe first to market a microstepping controller.

High Level Control of Stepping Motors

Part of Stepping Motors

byDouglas W. Jones

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Introduction

The key question to be answered by the high-level control system for astepping motor is, when should the next step be taken? While thisalmost always depends on the application, the similarities betweendifferent applications are sufficient to justify the development offairly complex general purpose stepping motor controllers.

Stepping motor control may be based on open loop or closed loopmodels. We are primarily interested in open loop models, because this iswhere stepping motors excel, but we will treat closed loop models brieflybecause they are somewhat simpler. Figure 7.1 illustrates an extreme example:

Figure 7.1

In Figure 7.1, a quadrature shaft encoder is attached to the drive shaftof a permanent magnet or hybrid stepping motor, and the two phase outputof this encoder is used to directly generate the control vector for themotor driver. Rotary shaft encoders are typically rated in output pulsesper channel per revolution; for this example to be useful, for a motor withn steps per revolution, the shaft encoder output must gives n/2 pulses perchannel per revolution. If this is the case, the behavior of this systemwill depend on how the shaft encoder is rotated around the motor shaftrelative to the motor.

If the shaft encoder is rotated into a position where the output of theshaft encoder translates to a control vector that holds the motor shaftin its initial position, the motor shaft will not rotate of itself, and ifthe motor shaft is rotated by force, it will stay wherever it isleft. We will refer to this position of the shaft encoder relative to themotor as the neutral position.

If the shaft encoder is rotated one step clockwise (or counterclockwise)from the neutral position, the control vector output by the shaftencoder will pull the rotor clockwise (or counterclockwise). As the rotorturns, the shaft encoder will change the control vector so that the rotoris always trying to maintain a position one step clockwise(or counterclockwise)

from where it is at the moment. The torque producedby this method will fall off with rotor speed, but this control system willalways produce the maximum torque the motor is able to deliver at any speed.

In effect, with this one-step displacement, we have constructeda brushless DC motor from a stepping motorand a collection of off-the-shelf parts. In practice, this is rarely done,but there are numerous applications of stepping motors in closed-loopcontrol systems that are based on this model, usually with a microprocessorincluded in the feedback loop between the shaft encoder and the motorcontroller.

In an open-loop control system, this feedback loop is broken, but at a highlevel, the basic principle remains quite similar, as illustrated inFigure 7.2:

Figure 7.2

In Figure 7.2, we replace the shaft encoder from Figure 7.1 with a simulationmodel of the response of the motor and load to the control vector. At anyinstant, the actual position of the rotor is unknown! Nonetheless, we can usethe simulation model to predict, based on an assumed rotor position andvelocity, how the motor will respond to the control vector, and we canconstruct this model so that its output is the control vector generatedby a simulated shaft encoder.

So long as the model is sufficiently accurate, the behavior of the motorcontrolled by this model will be the same as the behavior of the motorcontrolled by a closed loop system!

Model Variables

In the example given in Figure 7.1, the only control variable offered isthe angle of the shaft encoder relative to the motor. In effect, this controlsthe extent to which the equilibrium point of the motor's torque versus shaftangle curve leads or follows the current rotor position. In theory, anydesired motor behavior can be elicited by adjusting this angle, but it is farmore convenient to speak in terms of other variables:

-- The predicted shaft position (radians) target -- The target shaft position determined by the application

V = d/dt -- The predicted velocity (radians per second)

Vtarget -- The target velocity determined by the application

A = dV/dt -- The predicted acceleration (radians per second squared)

Atarget -- The target acceleration, may be determined by the applicationAs in the section on Stepping Motor Physics, we willdefine the basic motor characteristics: S -- step or microstep angle, in radians μ -- moment of inertia of rotor and load

h -- the holding torque of the motorNote that here, the step angle S is not the physical step angle of the motor,but rather, the step angle offered by the mid-level motor interface; thismay be a full step, a half step, or a microstep of some size!

Models

The simplest model that will do the job is almost always the best. For someapplications, this means the model is so simple that it is hard to identifyit as a model! For example, consider the case where the application demandsa constant motor velocity:

Atarget = 0

Vtarget = ConstantIn this case, tstep = S / Vtargetwhere tstep -- time per stepThis barely looks like a model; in part, this is because we haveomitted the statement that, every tstep seconds, we advance thecontrol vector one step: repeat the following cycle forever: wait tstep seconds and then

= + S step(1)

A more interesting model is required if we want to maintain a constantacceleration. Obviously, we can't do this forever, but we'll use thismodel as a component in more complex models that require changes ofvelocity or position. In this case,

Atarget = Constantwhere Atarget < h / μIn developing a model, we begin with the observation that, for constantacceleration A and assuming a standing start at time 0, = 1/2 A t2More generally, if the motor starts at positionand velocity V, after time tthe new position'and velocity V' will be: ' = 1/2 A t2 + V t + V' = A t + VSetting =0and '=S, we solve firstfor t, the time taken to move one step, as a function of V and A: 1/2 A t2 + V t - S =

0 t = (-V ± (V2 + 2 A S)0.5) / AHere, we have applied the quadratic formula, and for our situation,this gives two real roots! The additive root is the root we are concernedwith; for this, we can use the resulting time to compute the velocity atthe end of one step: tstep = (-V + (V2 + 2 A S)0.5) / A V' = (V2 + 2 A S)0.5

We can combine this model for acceleration with the model for constantspeed running to make a motor controller that will seek Vtarget,assuming that an outside agent may change Vtarget at any time:

repeat the following cycle forever: if V = Vtarget do the following: wait S/Vtarget seconds and then = + S step(1) otherwise, if V < Vtarget, accelerate as follows: wait (-V + (V2 + 2 AaccelS)0.5) / Aaccel seconds and then = + S

V = (V2 + 2 AaccelS)0.5

step(1) otherwise, V > Vtarget, decelerate as follows: wait (-V + (V2 + 2 AdecelS)0.5) / Adecel seconds and then = + S V = (V2 + 2 AdecelS)0.5

step(1) This control system is not fully satisfactory for a number of reasons!First, it only allows the motor to operate in one direction and it failsutterly when V reaches zero; at that point, if a divide byzero operation is allowed to produce an infinite result, the program willwait infinitely and never again respond to change in the control input.

The second shortcoming of this program is simpler to correct: As written,there is an infinitesimal probability of the motor speed reaching the desiredspeed and staying there with Vtarget equal to V. Far more likely,what will happen is that V will oscillate around Vtarget, takingalternate accelerating and decelerating steps and never settling down at thedesired running speed.

A quick and dirty solution to this latter problem is to add code to recognizewhen V passes Vtarget during acceleration or deceleration; whenthis occurs, V can be set to Vtarget.

Formally, this is incorrect,but if the acceleration and deceleration rates are not too high and if thereis sufficient damping in the system, this will work quite well.

In a frictionless system using sine-cosine microstepping at speeds belowthe cutoff speed for the motor, theavailable torque is effectively constant and we can use the full torque toaccelerate or decelerate the motor, so the above control algorithm willwork with Aaccel = Adecel = h / μIf there is significant static friction, we can take this into account asfollows: Aaccel = (h - f) / μ

Adecel = (h + f) / μwhere f -- frictional torqueIf the motor is run using the maximum available acceleration and decleration,any unexpected increase in the load will cause the motor rotor to fall behindits predicted position, and the result will be a failure of the control system.As a result, open-loop stepping motor control systems are never run at theaccelerations

give above! In the case of full or half-stepping, where thereis no sine-cosine torque compensation, the available torque varies overa range of a factor of 20.5, so we typically adjust theaccelerations given above by this amount: Aaccel = ((h / 1.414) - f) / μ

Adecel = ((h / 1.414) + f) / μIf we operate consistently near the edge of the performance envelope,and if we never request a velocity Vtarget near the resonantspeed of the motor, we can safely accelerate through resonances withoutrelying on damping. If, on the other hand, we select acceleration valuesthat are significantly below the maximum that is possible, electrical ormechanical damping may be needed to avoid problems with resonance.

Note that it is not difficult to extend the above control model to account,at least approximately, for viscous friction and for the dropoff of torqueas a function of speed. To do this, we merely modify the above formulasfor Aaccel and Adecel so that h and fare functions of V. Thus, instead of treating these as constants of thecontrol algorithm, we must recompute the available acceleration at eachstep.

If our goal is to turn the motor smoothly from one set postion to another,we must first accelerate it, then perhaps coast at fixed speed for awhile, then decelerate. The decision governing when to begin deceleratingrests on a knowledge of the stopping distance from any particular velocity.Assuming that the available acceleration is constant over the relevantrange of speeds, we can compute this from:

V = Adecel t

= 1/2 Adecel t2First we solve for the stopping time, t = V / Adeceland then we solve for the stopping angle = 1/2 Adecel (V / Adecel)2 = V2 / (2 Adecel)Given this, we can outline a procedure for moving the motor from its currentestimated position to a step just beyond some target position: moveto(target) -- a function of one argument -- no value is returned while V < Vtarget and while < target - V2 / (2 Adecel) repeat the following to accelerate step(1) wait (-V + (V2 + 2 AaccelS)0.5) / Aaccel seconds and then = + S V = (V2 + 2 AaccelS)0.5 V = Vtarget while < target - V2 / (2 Adecel) repeat the following to coast step(1) wait S/Vtarget seconds and then = + S while < target repeat the following to decelerate step(1) wait (-V + (V2 + 2 AdecelS)0.5) / Aaccel seconds and then = + S

V = (V2 + 2 AaccelS)0.5 V = 0 done, and target are within a step of each other!

The control model only moves the motor one direction, it fails to plan interms of the quantization of available stopping positions, and it doesn'taccount for the cyclic nature of.

Nonetheless, it is a usefulillustration. Note that we have used Vtarget as a limiting velocityin this code, but that this will only be relevant during long moves; for shortmoves, the motor will never reach this speed.

With the above, code, so long as the acceleration and deceleration ratesare high enough to avoid dwelling for too long at resonant speeds, and solong as Vtarget is not too close to a resonant speed, a plot ofrotor position versus time will show fairly clean moves, as illustratedin Figure 7.3:

Figure 7.3

If the motor is to be accelerated at the maximum possible rate, the controlmodel used above is not sufficient. In that case, during acceleration, theequilibrium position must be maintained between 0.5 and 1.5 steps ahead ofthe rotor position as the rotor moves, and during deceleration, the equilibriumposition must be maintained the same distance behind the rotor position.This requires careful logic at the turnaround point, when the change is madefrom accelerating to decelerating modes. The above control model omits anysuch considerations, but it is adequate at accelerations sufficiently belowthe maximum available!

Hardware Solutions

Today, it is rare to find high-level stepping motor control done purely inhardware, and when it is done, it is usually only in the very simplest ofapplications. For example, consider the problem of starting and stoppinga stepping motor under load. Direct generation of the quadratic functionsnecessary to achieve smooth acceleration is quite difficult in hardware, butit is easy to generate exponentials that are adequate approximations ofthese. The circuit outlined in Figure 7.4 illustrates how this can bedone:

Figure 7.4

Here, the resistor R and capacitor C form a low pass filter on the controlinput of the voltage controlled oscillator VCO. When the input level isat run, the VCO output oscillates at its maximum rate. When the input levelis at stop, the VCO output ceases to oscillate. The RC time constant of thelow pass filter determines the rate of acceleration applied to the motor.

With such a design, the time constant RC is usually determinedempirically by setting up the system and then adjusting R and C until thesystem operates properly.

Practical Examples

The NE555 timer can be used as a voltage controlled oscillator, but I firstsaw this done with discrete components on a controller for a paper-tapereader designed around 1970.

Software Solutions

The basic control models outlined at the start of this section can bedirectly incorporated into the software for controlling a stepping motor,and this must be done if, for example, the motor is driving a load witha variable moment of inertia or driving a load against variable frictionalloadings. Most open-loop stepping motor applications are not thatcomplicated, however! So long as the inertia and frictional loadings areconstant, the control software can be greatly simplified, replacing complexmodel computations with a table of precomputed delays.

Consider the problem of accelerating the motor from a standing start.No matter where the motor starts, so long as the torque, moment of inertiaand frictional loadings remain the same, the time sequence of steps will bethe same. Therefore, we need only pre-compute this time sequence of stepsand save it in an array. We can use this array as follows to acceleratethe motor: array AV, the acceleration vector, holds time intervals

i is the index into AV

i = 0 repeat the following cycle to accelerate forever: wait AV[i] seconds and then

step(1)

i = i + 1 We may use i, the counter in the above code, as a stand-in for the motorvelocity, since stepping the motor every AV[i] seconds will move themotor at a speed of S/AV[i].

It is a straightforward exercise in elementary physics to compute theentries in the array A. If the motor is accelerating at Atarget,

i = 1/2 Atarget ti2where i -- the shaft angle at each successive stepSolving for time as a function of position, we get: ti = (2i / Atarget) 0.5If we define 0 = 0so that i = Siand t0 =

0we can conclude that ti = k i0.5where k = (2S/Atarget)0.5The acceleration vector entries are then: A[0] = (2S/Atarget)0.5and A[i] = (i0.5 - (i - 1)0.5)A[0]The following table gives the ratios of the first 20 entries in A[i]

toA[0]: 0 1.000 10 0.154 1 0.414 11 0.147 2 0.318 12 0.141 3 0.268 13 0.136 4 0.236 14 0.131 5 0.213 15

0.127 6 0.196 16 0.123 7 0.183 17 0.120 8 0.172 18 0.116 9 0.162 19 0.113

In general, we aren't interested in indefinite acceleration, but rather,we are interested in accelerating until some speed or position restrictionis satisfied, and then the control system should change, for example, fromacceleration to deceleration or constant speed operation. So long asfriction can be ignored, so the same rates can be used for accelerationand deceleration, we can make a clean move to a target position as follows: array AV is the acceleration vector

i is the index into AV

i = 0 D = target - while D nonzero do the following if D > 0 -- spin one way step(1) D = D - 1 else -- spin the other way step(-1) D = D + 1 endif

wait AV[i] seconds and then

if (i < |D|) and (S/AV[i] < Vtarget) -- accelerate i = i + 1 else if i > |D| -- decelerate i = i - 1 endif endloop Given an appropriate acceleration vector, the above code will cleanlyaccelerate a motor up to a speed near the target velocity, hold thatspeed, and then decelerate cleanly to a stop at the target position.

The above code does not take advantage of the higher rates of decelerationallowed when there is friction. In general, this should not cause anyproblems, but if the fastest possible moves are desired, a separatedeceleration table should be maintained. Here is one idea:

array AV holds acceleration intervals

array C holds coasting intervals

array T holds transition information

array D holds deceleration intervals

i = 0 repeat the following until the desired speed is reached

wait A[i] seconds and then

step(1)

i = i + 1

repeat the following to maintain the speed

wait C[i] seconds and then

step(1)

repeat the following to maintain the speed

i = i - T[i] repeat the following until i = 0

i = i - 1

step(1) In the above, the arrays A and D are constructed identically, except thatone has intervals used for acceleration, at a rate limited by friction,while the other has intervals used for deceleration, at a rate assistedby friction. Note that, after accelerating for i steps from a standing start,the motor will reach a velocity from which it can decelerate to a haltin i-T[i] steps. This relationship determines the values pre-computed inthe array T.

Simple Practical Examples

An Object Oriented Design

Stepping Motor Control SoftwareOld Part 5 of Stepping Motors

byDouglas W. Jones

Here's the code to make your motor run as if you had one of thosefancy stepper controllers. I've used Pascal for no particular reason.This code assumes only one motor, and it assumes it's attached to theleast significant bits of one parallel output port. In practice, it'snice to have one parallel output port per motor, although with a bit ofcare, you can use the high bits of a port for another motor or otherapplications, and you can multiplex one port to handle multiple motors.(The July 1993 issue of Model Railroader has plans for a parallel portmultiplexer circuit for IBM PC systems in it).

Assume these declarations and values for a three winding variablereluctance motor: const maxstep = 2;steps = 3;var steptab: array [0..maxstep] of integer;step: integer;motor: file of integer; { this is the I/O port for the motor }beginstep := 0;steptab[0] = 1; { binary 001 }steptab[1] = 2; { binary 010 }steptab[2] = 4; { binary 100 }write(motor, steptab[step]);Assume these declarations and values for a permanent magnet motor, eitherunipolar, with center tapped windings, or bipolar, with H-bridge drivecircuits: const maxstep = 3;steps = 4;var steptab: array [0..maxstep] of integer;step: integer;motor: file of integer; { this is the I/O port for the motor }beginstep := 0;steptab[0] = 1; { binary 0001 }steptab[1] = 4; { binary 0100 }steptab[2] = 2; { binary 0010 }steptab[3] = 8; { binary 1000 }write(motor, steptab[step]);Assume these declarations and values for half-step control of a permanentmagnet motor: const maxstep = 7;steps = 8;var steptab: array [0..maxstep] of integer;step: integer;motor: file of integer; { this is the I/O port for the motor }beginstep := 0;steptab[0] = 1; { binary 0001 }steptab[1] = 5; { binary 0101 }steptab[2] = 4; { binary 0100 }steptab[3] = 6; { binary 0110 }steptab[4] = 2; { binary 0010 }steptab[5] = 10; { binary 1010 }steptab[6] = 8; { binary 1000 }steptab[7] = 9; { binary 1001 }write(motor,

steptab[step]);Assume these declarations and values for control of a 5-phase motor, withan H-bridge on each of the 5 leads to the motor: const maxstep = 9;steps = 10;var steptab: array [0..maxstep] of integer;step:

integer;motor: file of integer; { this is the I/O port for the motor }beginstep := 0;steptab[0] = 13; { binary 01101 }steptab[1] = 9; { binary 01001

}steptab[2] = 11; { binary 01011 }steptab[3] = 10; { binary 01010 }steptab[4] = 26; { binary 11010 }steptab[5] = 18; { binary 10010 }steptab[6] = 22; { binary 10110 }steptab[7] = 20;

{ binary 10100 }steptab[8] = 21; { binary 10101 }steptab[9] = 5; { binary 00101 }write(motor, steptab[step]);The remainder of the code is the same and doesn't depend on the motor.The following procedure will advance the motor one step in eitherdirection, where the direction parameter must be either +1 or -1 toindicate the direction. procedure onestep(direction: integer);beginstep := step + direction;if step > maxstep then step := 0else if step < 0 then step := maxstep;write(motor, steptab[step]);end;Software control of a stepping motor is a real-time task, and you needat least a bit of feedback. One bit is enough; typically, this will bea bit indicating that a cam on the turntable (or whatever the motor isdriving) is interrupting a light beam or closing a microswitch. To avoidhysteresis problems in reading the position from this cam, you shouldonly read zero to one transitions as indicating the home position whenthe motor is spinning in one direction. Especially with switchesor where gear trains are involved between the motor and the turntable,the one to zero transition in the other direction won't usually occurat exactly the same position.

Given that you can read the sense bit and that you have a programmableinterval timer interrupt on your system, it is easy to make the timerinterrupt service routine operate the motor as follows: const maxpos = 11111; { maxpos + 1 is calls to onestep per rev }var position: integer; { current position of motor }destination: integer; { desired position of motor }direction: integer; { direction motor should rotate }last: integer; {

previous value from position sensor }sensor: file of integer; { parallel input port }beginread(sensor, last);position :=

1;setdest(0, 1); { force turntable to spin on power-up untilit finds it's home position }procedure timer; { interval timer interrupt service routine }var sense: integer;beginread(sensor, sense);if (direction = 1) and (last = 0) and (sense = 1)then position = 0;last := sense;if position <> destination then beginonestep(direction);position := position + direction;if position > maxpos then position := 0else if position < 0 then position := maxpos;end;if position <> destinationthen settimer(interval_until_next_step);end;The following procedure is the only procedure that user code should call.This procedure sets the destination position of the turntable and setsthe direction of rotation, then sets the interval timer to force animmediate interrupt and lets the timer routine finish rotating theturntable while the applications program does whatever else it wants. procedure setdest(dst,dir: integer);begindestination := dst;direction := dir;if position <> destinationthen settimer(min_interval); { force a timer interrupt }end;If you want to control multiple stepping motors, it is easiest if you haveone interval timers and one parallel port per motor. If you hardware hasonly one timer, then you can use it to simulate multiple interval timers,but this is most of the way to the job of writing a real-time executive.

A final note: If you try to step a motor too fast, it will slip and yoursoftware will lose track of the motor position. Motors typically comewith a rating that indicates a maximum number of steps per second, butyou may not be able to accelerate the motor to that number of steps persecond from a dead start without running it at a lower speed first. This is especially true if the inertia of the load is fairly large, and infact, with appropriate acceleration sequences, you can usually excede themaximum rated speed.

In the above code, interval_until_next_step is shown as a constant. Ifyou are dealing with high-inertia loads or very short intervals, you'llhave to make this a variable, using longer intervals during starting andstopping to take care of accelerating and decelerating the motor.

Midlevel Control of Stepping Motors

Part of Stepping Motors

byDouglas W. Jones

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WARNING: This material is new but fairly stableIntroduction

All of the low-level motor control interfaces described in the previoussections are quite similar, at an abstract level. Each interface has somenumber of logic inputs. Some of these inputs may be used to directlycontrol which switches are open or closed, others may be encoded, whileothers may control subsystems such as the analog to digital converter ina microstepping interface.

The states of each of these logic inputs is referred to as thecontrol vector for the motor, and a sequence of states used torotate the motor is referred to as a control trajectory for themotor.

For example, the control vector for controlling a permanent magnet or hybridstepping motor using any of the control circuits shown in Figures3.4,3.5,3.13,3.14,3.15,4.7,4.8,4.10,4.11 or4.1 2will contain 4 bits, 2 bits to control each motor winding. In each case, thecontrol vector can be expressed as<X1Y1X2Y2>, whereX1 and Y1 control the current through motor winding1 and X2 and Y2 control the current through motorwinding 2.For any interface with this control vector, the following trajectory willstep the motor through one full electrical cycle, using full stepping:

1010 1001 0101 0110 1010 Similarly, the following trajectory will half-step motor through the sameelectrical cycle: 1010 1000 1001 0001 0101 0100 0110 0010 1010 Other controllers have different control vectors. For example, the controlvector for a permanent magnet or hybrid motor controlled by a pair ofAllegro3952chips (see Figure 4.9) will be<B1E1P1M1B2E2P2M2>,where B, E, P and M are the ¬BRAKE, ¬ENABLE, PHASE and MODE controlinputs for each chip. In this case, the following control trajectorywill full-step the motor through 1 electrical cycle: 10001000 10001010 10101010 10101000 10001000 The following control trajectory will half-step the same motor through oneelectrical cycle, using dynamic braking to control resonance whenever a motorwinding is turned off: 10001000 10000000 10001010 00001010 10101010 10100000 10101000 00001000 10001000 It is worth noting that, while dynamic braking on disconnected motor windingsis an excellent way to control resonance during low speed operation, this willreduce the available torque at higher motor speeds.

The control vectors required for microstepped motors are more complex, butthe basic idea remains the same. The problem we face here is to develophigher level control systems that will generate appropriate controltrajectories, moving the motor one step, half-step or microstep each timethe higher level control system requires a move.

Hardware Solutions

Early solutions to the problem of generating appropriate control trajectoriesfor stepping motors were almost always based on direct synthesis of thecontrol trajectory in hardware. Such solutions are still appropriate forsome applications, but these days, when programmable interface controllerchips are commonly used to replace random low-speed logic and when moststepping motor applications are ultimately controlled by computer systemsof one kind or another, it is common to use software to generate thecontrol trajectory.

All hardware solutions to generating the control trajectory are subsumedby the general model illustrated in Figure 6.1:

The next-state and create-vector blocks in Figure 6.1 arecombinational logic functions, while the state block is a register.Depending on how the state is encoded, the create-vector functionmay be trivial; for certain applications, the next-state functionis also trivial, but in the general case, next-state becomes anup-down counter while create-vector becomes a ROM holding thesequence of state vectors needed to form the control trajectories.

It is worth noting that some stepping motor control systems include addtionalinputs to the mid-level control system. Common additions includehalf-step and brake inputs. Braking control is meaninglessin full-step mode but it is of some use in half-step mode. In the lattermode, shorting unused motor windings at low speed is an excellent way tolimit resonance while at higher speeds, unused motor windings should beleft open for efficiency. Finally, some motor control systems include adisengage input that removes power from all windings; in this case,if brake is asserted, it typically shorts all motor windings.

Practical Examples

Amature astronomers frequently need very slow motors to turn their telescopes,and in recent years, stepping motors have taken the place of synchronous motorsand gear trains for many applications, particularly forbarn-door or Scotchmounts, a class of extremely simple camera mounts used in astrophotography.For this application, circuits as simple as that shown in Figure 6.2 arecommon:

Figure 6.2

The circuit shown in Figure 6.2 only operates in one direction, generatingthe signals needed to turn a permanent magnet or hybrid motor one full stepfor each pulse on the take-step input.

In terms of the general model inFigure 6.1, the next-state and create-vector functions are trivial and requireno logic to generate so long as each flipflop in the state register has outputsavailable in both straight and complemented form.

Modifying this circuit for bidirectional operation is straightforward, as isillustrated in Figure 6.3:

Figure 6.3

The circuit shown in Figure 6.3 uses two exclusive or gates to compute twodifferent versions of the next-state function, depending on the value of thedirection input. Each flip-flop presents both inverted and non-invertedoutputs to the world; this allowsan equivalent circuitto be made by substituting a double-pole double-throw switchfor the exclusive-or gates, andano ther equivalent circuit can be derivedfrom this by substituting a pair of 2-input 1-output multiplexors for theswitch.

A number of manufacturers of stepping motor control circuitry make integratedcircuits that include slightly more complex logic allowing both full and halfstepping modes. For example, them otorola(and others)MC3479chip includes a 16 volt350mA H-bridge and control logic with step, direction, and mode inputs tocontrol half-stepping.

TheSGS-Thompson(and others)L297includes just the mid-level control logic for full or half-step control ofa pair of H-bridges used to control a permanent magnet or variable reluctancemotor. This chip is specifically designed to control theL298dual 2 Amp H-bridge, and in addition to the mid-level control logic, itincludes the one-shots and comparators required to use this H-bridge as acurrent limited chopper.

Software Solutions

If a microprocessor, programmable interface controller or other computersystem is used to control a stepping motor, the computer can directly generatethe control vector in software and present it to the motor interface througha parallel output port, as shown in Figure 6.4:

Figure 6.4

In this software-centered model, the basic problem of mid-level control isreduced to how the step function is implemented. Each call tostep(d)causes the control vector to advance along the control trajectory in thedirection specified by dir. The call step(+1) causes the motorto step forward, while the call step(-1) causes it to take onestep back.

The control trajectory for any motor can be described as a circular arrayof control vectors. The simple full-stepped trajectory given in theintroduction can be represented as:

t, a 4 element array where t[0] = 10

t[1] = 9

t[2] = 5

t[3] = 6 Similarly, the corresponding half-stepped trajectory for the same motorinterface would be: t, an 8 element array where t[0] = 10 t[1] = 8

t[2] = 9

t[3] = 1

t[4] = 5

t[5] = 4

t[6] = 6

t[7] = 2 Similar definitions, differing only in the size of the trajectory arrayand the values of each entry, will suffice to describe one complete cycleof the control trajectory for any stepping motor interface!

The step routine itself does not depend in any way on the control vector.For all of the above examples, the step routine is: p, a statically allocated integer variable, initially zero. step(d) -- a function of one argument d

-- where d must be either +1 or –1 -- no value is returned p = p + d (mod size(t)) output(t[p]) Here, we assume that the output function sends one controlvector to the motor. The details of this function will depend on thecomputer, the interface used, and the operating system, if any. The abovepseudocode also assumes a size function that returns the size ofthe array holding a cycle of the the trajectory; how this is done willdefinitely vary from one programming language to another.

Note that, when translating the above code into real programming languages,the simple use of the mod operator above can rarely be preserved.Mathematicians generally agree that y > x (mod y) > 0but the designers of programming languages frequently depart from thisdefinition when x is negative. As a result, in languages suchas C, C++, Java and

Pascal, care must be taken to avoid negative valueson the righthand side of the mod (or %) operator!

Simple Practical Examples

The following C code will control a single 3-phase variable reluctancemotor taking its control vector from the three least significant bitsof the parallel port of a Unix or Linux system, assuming that the parallelport has been opened in the correct mode using the file descriptorpp:

#define STEPS 3int t[STEPS] = { 1, 2, 4 };int p = 0;void step(int d){char c;p = (p + STEPS + d) % STEPS;/* output t[p] using low-level Unix I/O */c = t[p];write(pp, &c, 1

);}Rewriting the first few lines of the above code allows us to convert itfor use with a permanent magnet or variable reluctance motor operated inhalf-step mode from the 4 least significant bits of the parallel port: #define STEPS 8int t[STEPS] = { 10, 8, 9, 1, 5, 4, 6, 2 };

An Object Oriented Design

Things are more complex if multiple motors are in use! Although ad-hocsolutions can are common, a systematic approach is appropriate, andeven in languages with no support for object oriented methodology, theeasiest way to describe such solutions is in object oriented terms.

After initialization, which may depend on many low level details, thehigh level software isn't interested in how the motor works. Therefore,for each motor object, the visible interface needs only the stepfunction. The class of motor objects is polymorphic because the detailsof how step operates for one motor may differ considerably fromthe details of how it works for another.

The following code is given in Java; translation to C++, Simula 67 orother object oriented languages should be straightforward: abstract class StepMotor{public abstract void step(int d);// step the motor in direction d (+1 or -1)}This is an abstract class; that is, objects of this class cannot beinstantiated because we have yet to specify any of the details of howthe motor or interface works. Each useful stepping motor interface mustbe supported by an extension or subclass of this abstract class! Theclass below illustrates this, incorporating the code discussed in thesections above: class UniversalStepMotor extends StepMotor{private int s; // the size of the trajectoryprivate int[] t; // the trajectory for this motorprivate int p; // motor's position in trajectoryprivate OutputStream o;// the output port to usepublic void step(int d)// step the motor in direction d (+1 or -1){p = (p + s + d) % s;o.write(t[p]);}public UniversalStepMotor(int[] table, OutputStream out)// initializer{s = table.length;t = table;p = 0;o = out;o.write(t[p]);}}The above code assumes that the interfaces to motors are accessible throughoutput streams of type java.io.OutputStream, and the initializernot only builds the data structure but sends an initial control vector tothe motor.

Given that MotorPort is an object of typejava.io.OutputStream, the following Java code will createa UniversalStepMotor object m for a 3-phase variablereluctance motor: StepMotor m = UniversalStepMotor(new int[]{4,2,1}, // step table for the motorMotorPort // OutputStream for the motor);With this declaration and initialization in place, the call m.step(1)will turn the motor one step.

For many applications, the class StepMotor defined above will needto be extended with a reset procedure, used to reset both the motorobject and the motor interface. This procedure should probably be incorporateddirectly into the definition of the StepMotor class, as opposed to adding itby class extension. This procedure would typically be called as the firststep in recovering from an error detected at higher levels in the controlhierarchy.

When Objects Won't Do

For programmers who can't use object oriented design, for any reason, thefollowing example illustrates an appropriate mid-level design that avoidsthe use of such features. Using Pascal, the following types can beused to describe each motor: typedirection = -1 .. +1;trajectory = array [0 .. MaxTrajectorySize] of int;StepMotor = records: integer; { size of this motor's trajectory }t: trajectory;p: integer; { this motor's position in trajectory }o: port; { the output port to use for this motor }end { record };The StepMotor record type given here corresponds exactly to anobject of the class

UniversalStepMotor defined in Java above.The array type trajectory is explicitly named so that a trajectory maybe passed, as a formal parameter, to an initializer procedure for recordsof this type. The subrange type direction allows Pascal's subrangerestriction mechanisms to check the correctness of parameters to the stepfunction, a desirable feature that is missing in languages descended from C.

Given the above definitions, we can now construct a general purpose stepprocedure: procedure step(var m: StepMotor, d: direction);{ step motor m in direction d }beginwith m do beginp = (p + s + d) mod s;output(o, t[p]);}end { step };In all of the above, we have assumed that variables of the type portare used to describe output ports to which motors may be attached, and thatthe procedure output outputs one vector to the indicated port.

In effect, in abandoning programming languages with direct support forobject orientation, we have had to chang our notation from:

motor.step(dir);to: step(motor, dir);This is not a major sacrifice in a system where there is only one type ofmotor interface, but when there are multiple motor types, support for theobject oriented model will be useful. If this must be done in a languagelike Pascal, the declaration for the type StepMotor mustbe modified to allow for all types of motor interfaces, for example, bydeclaring it to be a variant record, and the step procedure mustbe modified to check the motor type and act appropriately.

A Worked Stepping Motor ExampleOld Part 6 of Stepping Motors

byDouglas W. Jones

Perhaps some of the most commonly available stepping motors, for theexperimenter, are the head positioning motors from old diskette drives.These can be found at electronics swap meets, in computer surplusoutlets, and even in trash dumpsters. In addition to a stepper, a typicalfull-height 5.25 inch disk drive includes a 12 volt DC motor withtachometer and motor control circuit board, two microswitches, and amatched LED-photosensor pair.

A common stepper to find in a full-height IBM or Tandon 5.25 inchdiskette drive is the type KP4M4 made by either Japan Servo Motors orTandon; this is a permanent magnet motor with 3.6 degrees per step and150 ohms per winding, with the center-taps of each winding tied to acommon lead. Many half-height 5.25 inch diskette drives use very similarmotors, although there is much more variety in newer drives, includingsome that use bipolar steppers.

Another stepper sometimes found in half-height drives is the `pancake format'motor from a 1/2 height 5.25 inch diskette drive; for example, a permanentmagnet motor made by Copal Electronics, with 1.8 degrees per step and96 ohms per winding, with center taps brought out to separate leads. Theleads on these motors are brought out to multipin in-line connectors, laidout as follows:

Figure 6.1

When the center-taps of these motors are connected to +12 and one end ofeither winding is grounded, the winding will draw from 170 mA to 250 mA,depending on the motor, so any of a number of motor drive circuits can beused. The original IBM full-height diskette drives used a pair ofUDN3612N or UDN5713 chips; these are equivalent to chips in the SN7547Xseries (X in 1,2,3).

TheULN2003darlington arrays fromAllegro Microsystemsis probably the most widely available of the applicable chips, so it willbe used in this example.

Consider the problem of controlling multiple steppers comparableto those described above from an IBM compatible DB25-based parallel outputport. The pinout of this connector is given in Figure 6.2, as seenlooking at the face of the female connector on the back of an IBM PC(or equivalently, as seen from the back of the male connector that mateswith this):

Figure 6.2

The IEEE 1284 standard gives the best available definition of the parallelport, but as an after-the-fact standard, nonconformance is in the net. There is an extensive set oftutorial material available on the web discussing the IBM PC Parallelport. Another index of parallel port information is available fromIan

Harries.

There is some confusion in the documentation of this connector aboutthe labels on the SLCT and SLCTIN lines (pins 13 and 17); this is becausethese names date back to a Centronics printer design of the early 1970's,and the name SLCTIN refers to an input to the printer, which is to say,an output from the computer.

The names of some of these lines are relics of the original intended purposeof this I/O port, as a printer port. Depending on the level at which you wishto use the printer, some may be ignored. If the BIOS printer supportroutines of the IBM PC or the parallel port driver under various versions ofUNIX sare to be used, however, it is important to pay attention to some ofthese signals:

The BIOS handles reinitializing the printer by producing a negative pulseon INIT (pin 16). We can use this as a reset pulse, but otherwise, it shouldbe ignored! In the reset state, all motor windings should be off.

When no output activity is going on, the BIOS holds the output signal linesas follows:

- STROBE (pin 1) high, data not valid.

- AUTOFD (pin 14) high, do not feed paper.

- INIT (pin 16) high, do not initialize.

- SELCTIN (pin 17) low, printer selected.

To print a character, the BIOS waits for BUSY (pin 11) to go low, if it isnot already low, and then outputs the new data (pins 2 through 9). Followingthis (with a delay of at least 0.5 microsecond), STROBE (pin 1) is pulsedlow for at least 0.5 microsecond. The BIOS returns the inputs ACK,BUSY, PE and SLCT (pins 10 to 13) to the user program after printing eachcharacter.

The computer is entitled to wait for ACK (pin 10) to go low for at least 5microseconds to acknowledge the output strobe, but apparently, IBM'sBIOS does not do so; instead, it relies on device to set BUSY to preventadditional outputs, and it leaves the output data unmodified until the nextprint request. While neither MS/DOS nor the BIOS use the interrupt capabilityof the parallel port, OS/2 and various versions of UNIX use it. A risingedge on ACK (pin 10) will cause an interrupt request if interrupts areenabled. This interrupt design is only useful if, in normal operation,the trailing edge of the ACK pulse happens when BUSY falls, so that findingBUSY high upon interrupt signals an error condition.

Note that all input output to the parallel port pins is done by writingto various I/O registers; so as long as interrupts are disabled and the I/Oregisters are directly manipulated by application software, all 5 inputpins and all 12 output pins may be used for any purpose. To maintaincompatibility with existing drivers, however, we will limit our misuse ofthese pins.

If we only wanted to support a single motor, it turns out that the logicon the standard 5.25 inch diskette drive can, with an appropriate cable,be driven directly from the parallel port.

Documentation on this approachto recycling motors from old diskette drives has been put on the web byTomy Engdahl.

Since we are interested in supporting multiple motors, we will useDATA lines 4 to 7 to select the motor to control, while using the leastsignificant bits to actually control the motor.

In addition, becausealmost all stepping motor applications require limit switches, we willuse the PE (12) bit to provide feedback from limit switches. The IEEE 1284standard defines the PE, SLCT and ERR signals as user defined when in eitherEnhanced Parallel Port or Compatibility mode, so this is not a bad choice.Unfortunately, the BIOS occasionally checks this bit even when it is awareof no printer activity (for example, when the keyboard type-ahead bufferfills); thus, it is a good idea to disable the BIOS when the parallel portis used for motor control!

Note that fanout is not a problem on the IBM PC parallel port. The IEEE 1284standard defines the parallel port outputs as being able to source and sink14 milliamps, and older IBM PC parallel ports could sink about 24 milliamps.Given that a standard LS/TTL load sources only 0.4 milliamps and somedevices (comparitors, for example) source 1.2 milliamps, an IEEE 1284port should be able to handle up to 10 of motor interfaces in parallel.

A Minimal Design

As mentioned above, we will use the ULN2003 darlington array to drive thestepping motor. Since we want to drive multiple motors, the state of eachmotor must be stored in a register; while many chips on the market canstore 4 bits, careful chip selection significantly reduces the parts countand allows for a single-sided printed circuit card!

With appropriate connections, both the 74LS194 and the 74LS298 can use apositive enable signal to gate a negative clock pulse; we will use the 74LS194because it is less expensive and somewhat simpler to connect. Finally, wewill use the 74LS85 chip to compare the 4 bit address field of the outputwith the address assigned to the motor being driven.

Figure 6.3 summarizes the resulting design:

Figure 6.3

The 74LS194 was designed as a parallel-in, parallel-out shift-register withinputs to select one of 4 modes (do nothing, shift left, shift right, andload). By wiring the two mode inputs in parallel, we eliminate the shiftmodes, converting the mode input to an enable line. The unused right and leftshift input pins on this chip can remain disconnected or can be grounded, tiedto +5, or connected to any signal within the loading constraints.

Here, we show the 74LS194 being loaded only when bits 4 to 7 of the outputdata match a 4-bit address coded on a set of address switches. Thecomparison is done by a 74LS85, and the address switches are shown inFigure 6.3 as an 8-position DIP-switch. The cost of a DIP switch may beavoided in production applications by substituting jumpers.

One interesting aspect of this design is that the LS-TTL outputs drivingthe ULN2003 chip are used as current sources -- they pull up on the inputsto the darlington pairs. This is a borderline design, but careful readingof the LS-TTL spec sheets suggests that there is no reason it should notwork, and the ULN2003 is obviously designed to be driven this way, withmore than enough forward current gain to compensate for the tiny pull-upcapacity of an LS-TTL output!

The Zener diode connected between pin 9 of the ULN2003 and the +12 supplyincreases the reverse voltage on the motor windings when they are turnedoff. Given the 50 volt maximum rating of the ULN2003, this may drop asmuch as 50-12 or 38 volts, but note that power dissipation may actually bean issue! At high frequency with unconventional control software, the powertransfer to this diode can be quite efficient! With the stepping motors fromold diskette drives, it may be possible to push a 12 volt zener toon the order of 1 watt. I used a 15 volt 1 watt

zener, 1N3024.

If this motor is to be driven by software that directly accesses the low-levelparallel port interface registers, directly loading data and then directlyraising and lowering the strobe line, no additional hardware is needed.If it is to be driven through the BIOS or higher level system software,additional logic will be needed to manipulate ACK and BUSY.

Although the 74LS85 and the 74LS194 are no longer stocked by some mass-marketchip dealers, they are still in production by Motorola, TI, Thompson SKand NTE. If over-the-counter availability of chips is your primary concern,adding a chipload of inverters or 2-input nand gates will allow just aboutany 4-bit latch to be used for the register, and address decoding can bedone by a quad XOR chip and a 4-input nand gate.

If over-the-counter chips are of no concern, you can reduce the chipcount even further! The Micrel MIC5800 4-bit parallel latch/driver caneasily handle the loading of small unipolar steppers and combines thefunction of the ULN2003 and the 74LS194 used here! The resulting designis very clean.

Adding One Bit of Feedback

Surprisingly, no additional active components are needed to add one bit offeedback to this design! There are 3 spare darlington pairs on the ULN2003driver chip, and, with a pull-up resistor for each, these can serve asopen-collector inverters to translate one or two switch settings into inputsappropriate for the PC!

The ULN2003 includes pull-down resistors on each input, guaranteeing thatthe corresponding output will be turned off if left disconnected. Thus,connecting a ULN2003 input to a positive enable signal (pin 5 of the 74LS85chip for example) will turn the output on only if it is both enabled andthe switch is closed. It may be necessary to add a 1K pull-up to the

LS-TTLoutput because, in addition to driving the ULN2003, it is also driving twonormal LS-TTL inputs. Adding this pull-up will do no harm if it isn'tneeded (an LS-TTL output should be able to handle even a 300 ohm pull-up).

Since the ULN2003 is an open-collector inverter, the output needs a pull-up.We could rely on the PE input of the IBM PC parallel port to pull this lineup (an open TTL input usually rises of its own accord), but it is better toprovide a pull-up resistor somewhere. Here, we provide a 10K pull up on eachstepping motor drive card; these pull-ups will be in parallel for all motorsattached to a single parallel port, so if fewer than 10 motors are in use,proportionally smaller resistors may be substituted or the pull-ups may beomitted from some of the controller cards.

Figure 6.4 summarizes these additions to the design:

Figure 6.4

Something You Can Build

Figure 6.5 shows a single-sided PC board layout for a 2.5 inch square boardthat incorporates all of the ideas given above. I have etched and tested the7/8/1996 version of this artwork.

Figure 6.5

(What's that about copyright notices? Well, put simply, if you're going tosell my design, please get in touch with me about it. You're free, however,to make a handful of boards from this design to control your own motors.)

This version of the board includes a jumper to ground the BUSY signalon the parallel port (pin 11) and it brings out the STROBE, ERROR, ACK andSELECT signals to allow for possible jumpering. These changes make itslightly more likely that this board can be hacked to work with nativeoperating system drivers for the parallel port. As is, with no specialjumpering other than the grounding of BUSY, it works under Linux.

To use the artwork in Figure 6.5 for etching a board, reproduce it at100 pixels per inch (a slightly finer version,using 150 pixels per inch, is also available). Both versions are positiveimages of the foil side of the board; depending on how you transfer theimage to the resist for etching, you may need to flip it left-to-rightand/or invert the black and white.

Most GIF viewers allow for suchtransformations.

Figure 6.6 shows the component side of this board, with jumpers and partsin place.

Figure 6.6 Note that this layout does not show mounting holes for the board, but that4 corner pads are provided in appropriate locations. The layout also doesn'tshow a power connector, but the standard 4-pin Molex connectorsused with 5.25" diskettes will fit the pads provided. The 26 pin header iswired so that it can be directly wired to a 25 pin DB-25 plug using ribboncable and insulation displacement connectors. If multiple motors are to beused, a single ribbon cable can be made with multiple 26 pin connectors onit, one per motor.

Figure 6.6 shows 4 capacitors, 3 between +5 and ground, and 1 between +12and ground. The two capacitors farthest from the power input connectorcan be .01 or .1 microfarad capacitors; it may be better to use largercapacitors at the power input pins, 1 microfarad or more.

The plug from the stepping motor goes on the the top header shown inFigure 6.6, with the center-tap lead(s) topmost. The board is arranged so thateither a 5 or 6 pin header may be used here, compatable with the plugs onthe motors shown in Figure 6.1. The limit switch goes on the bottomheader. The latter is wired so that it can be used with either microswitchsalvaged from a full-height Tandon 5.25 inch diskette drive.

The address may be hard-wired using 4 jumpers, or it may be set using aDIP-switch, as shown in Figure 6.6. Each bit of the address is set bytwo switches or jumper positions, the topmost pair of these sets the mostsignificant of the 4 bits.To set a bit to 1, close the top switch and open the bottom switch in thecorresponding pair (or put the jumper in the top position of the pair); toset a bit to 0, close the bottom switch and open the top one (or putthe jumper in the bottom position of the pair). If it is at all likely thatsomeone will change the address switches while power is applied to theboard, use a 47 ohm resistor in place of the jumper directly above theswitches! This will protect your power supply from the accidental shortcircuits that can result from improper switch settings.

Testing the Board

Under Linux

The standard Linux line printer driver attaches the device /dev/lp0to the standard parallel port found on most PCs, and /dev/lp1 and/dev/lp2 to the optional additional parallel ports.

The line printerdriver has many operating modes that may be configured and tested withthe tunelp command. The default mode works, and the followingtunelp command will restore these defaults:

tunelp /dev/lp0 -i 0 -w 0 -a off -o off -c offThis turns off interrupts with -i 0 so that the board need not dealwith the acknowledge signal, and it uses a very brief strobe pulse with-w

0, sets the parallel port to ignore the error signal with-a off, ignores the status when the port is opened with-o off, and does not check the status with each byte output with-C off.

The settings of the tunelp options -t and-c should not matter because this interface is always ready andthus polling loop iteration is never required.

Given a correctly configured printer port, the C routines allow outputof motor control bytes to the port:

The comments above indicate a critical section! This is only a concernif the parallel port is shared by multiple processes, perhaps with oneprocess in charge of each of a number of motors. In that case, a semaphoremust be used to guard the critical section (see the UNIX semctl()kernel call), or a file lock using F_LOCK and F-ULOCK fcntl() commands,preferably through the lockf() function with a very large size. Thelatter approach (file locking using lockf()) is probably preferable.

Given these routines, the following main program should spin the motor ata few steps per second in a direction that depends on the sense switch setting:

Under Quasic

To test your board, use the following little basic program. This was developedunder Microsoft's Qbasic (C:DOS/QBASIC on a typical off-the-shelf PC) underbare MS/DOS (no version of windows running). This code has been tested withthe prototype hardware for the design given above.

The first subroutine in this program outputs the data D to motor M attachedto printer port P, and reads the status into S. 100 OUT P, D + (16 * M)OUT P + 2, &HDOUT P + 2, &HCS = INP(p + 1)RETURNThe second subroutine updates D, the motor control output, to rotatethe motor one step, then uses the first subroutine to output D. 200 IF D = 9 THEND = 10ELSEIF D = 5 THEND = 9ELSEIF D = 6 THEND = 5ELSEIF D = 10 THEND = 6END IFGOSUB 100RETURNThe main program connects the second subroutine to the real-time clock anduses it to step the motor once per second, then repeatedly prints the statusreported by the motor. P = &H378M = 15D = 10ON TIMER(1) GOSUB 200TIMER ON305 LOCATE 5, 5PRINT "STATUS: "; S; " "GOTO 305Unfortunately, QBASIC doesn't give you access to the high resolution of thehardware real-time clock, so this prototype code is only good for testingthe hardware. While this code is running, the status of the microswitch(if connected) will be displayed on the screen, embedded in the rest of theI/O port status word.

Essential guide to 2D CAD publishing: what you need to know for successful sharing, archiving

Ron LaFon

Once designers invest time and energy into creating a drawing, it can be used for a variety of purposes beyond the original intent. Repurposing that drawing can at times be difficult, but help is at hand with a variety of applications designed just for this task. For this 2D publishing article, we elected to focus on file repurposing--how to get a drawing file into another form to share with non-CAD users, be it to present a design for client approval, to convey design information to salespeople or others within your organization or to illustrate a detailed aspect of a project.

Although PDF (portable document format) is the most widespread file format used for such communication, it's far from the only way to distribute design information. Other file formats, created by a number of different applications, are often more compact, more quickly produced and offer more extensive security features to protect privileged or valuable information.

File size. If your goal is to distribute information electronically, file size is a consideration--the more compact the file, the faster it transmits. Recipients of the file might not have DSL, cable Internet or a T1 line at their disposal, so decisions about the appropriate software may come down to final file size. The amount of time required to generate such documents should also be brief.

Security. Whenever design information leaves the company, security becomes a concern. Many applications provide some means of password protection or, in the case of drawings included in the document, the ability to turn off or hide layers that contain proprietary information. Typically there's a way to limit printing or viewing to further protect the design information.

We've noted the available security features for each application in the feature table that accompanies this article online at www.cadalyst.com/0505cadpub.

Adobe Reader. The advent of the new Adobe Reader has made markup, redlining and commenting much easier for those who use the PDF file format. PDF files created in Adobe Acrobat 7

Professional can be flagged so that anyone with the Adobe Reader can mark them up and send their input to the originator of the file. For more on Adobe Acrobat 7 Professional, see Cadalyst's review in the March 2005 issue, p. 40, or online at http://management.cadalyst.com/0305acrobat/.

Design Details

Cadalyst contacted appropriate vendors to request software used to publish and repurpose 2D design content for this issue. We'll cover 3D publishing later this year.

We used the willhome.dwg file that ships with AutoCAD to test the submitted applications, with the exception of the flangedvalve.dgn MicroStation drawing used to test Net-It CAD for MicroStation from Informative Graphics. Conversion file sizes and time required for each conversion are noted in the text and in the online feature table. The feature table also notes the availability, file size and URL where users can download free viewers. Depending on the depth of features required, prices for the applications reviewed here vary from $99 to $4,995—a very broad range.

Several of the applications we looked at were in beta testing at the time of our tests, including applications from Informative Graphics and CADzation. CADzation plans to release its server-based solution, AcroPlot Auto, by the time you read this. Development is an ongoing process, with new features continually being added and old features extended. Several applications, including the latest version of Autodesk's DWF Composer, were not ready for testing at this time. We plan to cover those products at a later date.

Two sidebars accompany this article. Bluebeam Software's Pushbutton PDF (p. 24) creates PDFs and many other file types. In addition, Bluebeam recently released its Bluebeam Conversion Server for enterprise-level document generation. The latest version of Bentley Systems' MicroStation V8 2004 Edition (p. 20) generates PDF files and the 3D U3D files used by Adobe Acrobat 7 Professional.

Whatever your needs, a wealth of capable software applications is available to aid in publishing and repurposing drawing and design data while protecting your interests.

[Editor's note: The company says that its AcroPlot Jr. program translates the same DWG in about half the time with a resulting file size of 123KB.]

Ron LaFon, a contributing editor for Cadalyst, is a writer, editor and computer graphics and electronic publishing specialist from Atlanta, Georgia. He is a principal at 3Bear Productions in Atlanta.

Types of Manufacturing Software

By Eric Morris

Currently, a large variety of software is available to the manufacturing industry. The software helps the industry to improve a multitude of manufacturing as well as organizational functions.

Firstly, software has been developed to control and monitor machines used in manufacture of products. Each type of machinery works in a different way and therefore requires a specifically designed software program.

Computer-aided manufacturing (CAM) is software used to generate the codes to give instruction to CNC machines to enable them to form shapes designed in a computer-aided (CAD) system. This helps the modern manufacturing plants to meet their high volume high accuracy production requirements.This also simplifies the job of the person who is watching over the machines and makes it significantly less strainous.

The second important function of a software programs is to facilitate better control on financial and personnel management. The software for this purpose is usually applicable to all types of industries and institutions. Nevertheless, minor changes may be necessary to tailor the general software for a particular industry or institution.

Thirdly software programs are able to streamline and improve management functions within the manufacturing industry. Because computers control the machines, time and motion studies of various manufacturing operations, and stages can be more easily undertaken. It is possible to stay up-dated and effectively control the status of critical items, such as raw materials, inventory and order status, goods in-process status, finished goods inventory, and delivery status. Planning and scheduling software enables the industry to monitor manufacturing activity, through time and action calendars that track key milestone events and create alerts. Activities such as packing and labeling can be controlled, by getting real time status on exact quantity of pieces packed for different orders, per quantity, per color, and per size, to reduce possible back charges.

Manufacturing Software provides detailed information on Manufacturing Software, Manufacturing Inventory Software, Manufacturing Business Software, Manufacturing Management Software and more. Manufacturing Software is affiliated with Free CAD Software.

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http://EzineArticles.com/?Types-of-Manufacturing-Software&id=408172

Manufacturing Control Software

By Eric Morris

Manufacturing control software has existed in a rudimentary form since the advent of Computer Numerical Control (CNC) machines. The term CNC refers to the computerized control of machine tools, to facilitate the repeated production of complex parts in all kinds of materials. CNC was developed in the late 1940s and early 1950s in the M.I.T.

Early CNC machines used a software program written in a notation called G-Code. In the early days, the computers were very large in size and were power guzzlers. Despite their huge presence, the 1950 computers had very limited processing or data storage power. Therefore, computers were not used in the manufacturing industry, till the appearance of Personal Computers (PCs) and suitable Operating Systems in the 1980s.

With The PC explosion in the 1980s, CNC manufacturers started shifting to PC-based controls running Microsoft Windows or O/S 2 operating systems, which can be linked to the existing networks using standard protocols. Manufacturing companies began to move away from, expensive minicomputer and workstation based CAD/CAM which usually ran on G-Code, towards the more cost-effective PC-based software solutions. PC-based systems which can accomplish complicated tasks, using standard network protocols are available at minimal or no cost. In most cases, the Manufacturers do not need an 'expert' to implement shop floor networking, and can do the implementation themselves.

The demand for sophisticated manufacturing software has grown tremendously, over the last fifteen years and affords a lot of new and exciting functionality, to a variety of machines in the manufacturing industry.

Many software developers write and provide proprietary software systems. These are for manufacturing companies, employing computer control of machine tools such as milling machines, cutting machines, robots, hexapods, and lathes. However, these software programs are supplied for a fee, and are subject to Copyright Act provisions. Free open source CNC control software is also available on Internet.

Manufacturing Software provides detailed information on Manufacturing Software, Manufacturing Inventory Software, Manufacturing Business Software, Manufacturing Management Software and more. Manufacturing Software is affiliated with Free CAD Software.

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Definition of Computer Aided Design (CAD) Software

By James Hunt

CAD is computer aided design. CAD is used for designing objects such as architectural designs, mechanical designs, and electrical designs. When you use this type of software tool you'll be able to get results that are perfect each time and that look very professional. Most software packages will come with a multitude of graphics that are already built into the system.

All you need to do is choose what you want and add them to the design that you're working with. You don't need to be an artist to use a CAD tool. The features that are built into this type of software will do all the aligning for you. You'll be able to have all the design power that you need when you use CAD software.

Most CAD software programs will also come with many templates that you can use, as well as the symbols that you need to create designs that are readable and 100% useable. Besides using the CAD tool to create designs for your architectural or mechanical business you can use it to create floor plans to design your new home, landscaping designs for your garden, circuit diagrams for your electrical needs, and block diagrams.

There are many CAD software packages that you can choose from. The best thing is to know exactly what you want from the software so that you're not disappointed with your purchase. CAD software doesn't come without a high price and most times will be un-returnable once you've opened it and installed it on your computer. If you're unsure about what CAD software package to buy you may be able to try a free download that many software manufacturers will offer to try and get your attention. This will allow you, for a short period of time, to work with the CAD software to be sure it's what you want and does what you want it to do.

James Hunt has spent 15 years as a professional writer and researcher covering stories that cover a whole spectrum of interest. Read more at http://www.cad-software-center.com

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http://EzineArticles.com/?Definition-of-Computer-Aided-Design-(CAD)-Software&id=117506

Discover The Benefits of Using CAD Software

By Kelly Hunter

Different fields of study involve different aspects of training that are necessary in order for people to make a difference in the career which you wish to place yourself. In the fields of engineering most practitioners will be involved in the design of new parts and components that are meant to aid the quality of life that people currently enjoy. Other people who are involved in design include architects who design houses, interior designers and other people who are involved in the design and construction of different things associated with different fields of learning. All of these careers are careers which require a level of skill and dedication in their study.

For people involved in design, the difficulty in drawing components which are part of whatever it is that they design is all too real. A lot of designers run through many sheets of paper in order to come up with concepts that they want to bring to life. People incessantly complain of not only the time it takes to design such components but the lack of flexibility in such designs. On the completion of such projects they also have to create real life models in other to text for aesthetics as well as the functionality of their designs.

CAD stands for Computer Aided Design; Computer Aided Design involves the use of computers in order to create drawings without the associated stress that is involved with the use of paper and other similar materials. With Computer Aided Design you can come up with varying level of designs by using a computer and a specialized input device. The resulting design will be flexible and can easily be turned into a 3D model whose aesthetics and functionality can easily be tested for on the computer without having to spend additional time creating a real life model.

CAD is beneficial to engineers, designers as well as architects, as can be clearly seen from the description of what it provides for these people. The flexibility and the ease at which they can create easily maneuverable models and diagrams that they can test for aesthetics as well as functionality. You can also easily modify any diagrams that you create without having to create entirely new drawings from scratch. The overall benefits that are derived from CAD drawing make the very concept and usage of paper drawings somewhat outdated and unnecessary.

Furthermore learning how to use CAD will save you from most of the stress of other methods of conceptualization.

Training can be got from various sources. People tend to do better with training delivered in video formats such as training given through videos on certain DVD products. Online means are also a great way to learn because these methods of learning are quite interactive and flexible as well. You can interact with the trainers delivering the learning that you need to derive through these methods of online instruction. Other aids to reading and studying CAD courses include the use of books and literature associated with studying the subject.

Kelly Hunter operates http://www.cad-software-help.com and writes about Cad Software.

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Drafting Tools in AutoCAD - Snap and Grid

By Jos Van Doorn

We've got snap and grid in AutoCAD. Let's talk about snap and grid. Let's see how we can use it and why we would use it.

Snap restricts the cursor movements to specified intervals. That is handy. Lines will have a specific length.

Still. If you're using object snaps than you can pick a point that is not on an interval that has been specified. We'll talk about object snap later.

With grid switched on dots are displayed in the screen. The dots help to visualize distances. Often the grid interval is the same as the snap interval.

That is important. You can have grid dots displayed in the screen. Now you want to print your drawing. The dots are not printed.

OK. We know what snap and grid are. But we want to know more. We want to know how we can set the intervals and how we can switch it on and off.

Let's start with setting the intervals. There are two ways for doing that. Whatever way you choose. You do it over the Drafting Settings dialog box.

Click on Tools in the menu bar. A pull down menu shows up. In the pull down menu click on Drafting Settings. The Drafting Settings dialog box is displayed.

There are four tabs in the Drafting Settings dialog box. The Snap and Grid tab is in front. That's exactly what we want.

In the dialog box we see two check boxes and we see four areas. The checkboxes can be used for switching on or off snap and grid.

Let's have a look at the Snap area and the Grid area. First the Snap area. In that area you can enter values for the spacing.

You can enter a value for the X spacing and you can enter a value for the Y pacing. The spacing set the interval I was talking about.

There is more you can do in that area. You can enter an angle, an X base, and a Y base. The angle gives the angle of the snap intervals.

Most of the time you do not change the angle. You leave the angle at zero. But the X base and the Y base. What's that?

The X base and the Y base gives the starting point of the snap. As before. Do not change it. Leave it as it is. At zero.

You now know how you can do the settings for the snap. You do it in the Snap area of the Drafting Settings dialog box.

But we can also do something with the settings of the grid. That is done in the Grid area of the dialog box. This time we can do less.

We can only change the X spacing and the Y spacing. We cannot change the angle or the X base and Y base of the grid.

This is what is done most of the time. Most of the time the spacing for the grid is the same as the spacing for the snap.

That is what is happening. The grid follows the snap settings for angle and the X base and Y base. So there is no need to change those settings.

This is what we now saw. You can do the settings of the snap and the grid in the Drafting Settings dialog box. And you can switch them on and off.

Before I continue. I must tell you about the third area in the Drafting Settings dialog box. It is the Snap style and type area.

For the snap type we can set Grid snap and we can set PolarSnap. If we go for a Grid snap type then e can select a rectangular snap or an isometric snap.

If you're creating isometric drawings, then you want to go for an isometric snap. The snap will have the isometric angles.

I'm not going to talk about PolarSnap now. I will do that later. I will do that as we're talking about Polar Tracking. In the next article.

But there is another way. Look at your screen. Do you see the status bar? In the status bar there are two buttons.

In the status bar there is the Snap button and there is the Grid button. You can click on the buttons. To have snap and grid switched on and off.

Something else you can do with the buttons. You can right click them. If you do a short cut menu is displayed.

If you right click the Snap button then you'll find the following options in the shortcut menu:

- PolartSnap On

- Grid Snap On

- Off

- Settings

If you right click on the Grid button then you'll find the following options in the shortcut menu:

- On

- Off

- Settings

You can imagine where the on and off options stand for. Those options can be sued to switch snap and grid on or off.

But we already saw. There is a quicker way. We can also click on the Snap and Grid buttons in the status bar. In fact. There is another quick way.

You can press the F7 function key to switch grid on or off. And you can press the F9 function key to switch snap on or off.

Oh. In the shortcut menu under the Snap button you also see the PolarSnap On option. As I said before. We'll talk about it alter.

But there is the Settings option in the shortcut menus under the Snap button and the Grid button. Click on that option.

If you do the Drafting Settings dialog box is opened. We already have seen what can be done in the Drafting Settings dialog box.

But this is what we now know. Using the shortcut menu under the Snap and Grid button. That is a quicker way to open the Drafting Settings dialog box.

This is it for today. Now you know everything that you need to know about snap and grid. Tomorrow we're going to talk about polar tracking.

See you tomorrow.

This is the first article in a series of five articles. F- R- E- E. Written by Jos van Doorn. To get the other articles. Send a blank e- mail to:

draftingtools@aweber.com

There are more AutoCAD articles. Would you like to know? You can find them here:

http://www.autocad-articles.blogspot.com

Jos van Doorn. AutoCAD specialist and AutoLISP programmer.

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Drafting Fundamentals - How to Bisect an Angle Using Autocad 2004

By Larry Shumate

This article will explain how I use AutoCAD to bisect an angle into two smaller but equal angles. I currently work in a cabinet shop where we make custom cabinets and the counter tops that go with the cabinets. when we have a counter top that makes an “L” shape that is to say that the counter top is on two walls and joins together with a miter cut that is to say both pieces of the counter tops are cut at equal angles that then joined together make the necessary angle for the counter tops to fit the walls they are up against.

Whatever the reason for needing to bisect an angle the basic process is the same whether the angle is more than 90º (obtuse angle) or less than 90º (acute angle). The first thing that I would need to do is go to the tools pull down menu and select drafting settings. I would make sure that the check boxes beside endpoint and midpoint are selected.

After having my angle drawn that needs to be bisected I would draw a circle at the vertice of the angle. This circle would need to cross each leg of the triangle at about the half way point of one of the legs on the angle. Then I would use the legs of the angle as cutting edges and use the trim command to trim the outside part of the circle off. So now what I am left with is an angle with an arc inside it. The next step to bisecting the arc would be for me to draw a line from the vertice of the angle to the midpoint of the arc. I could then erase the arc and be left with two angles that are the equal. All that would be left to do is extend or trim the bisector to the desired length.

About the Author:

Larry Shumate has worked as a drafter for 14 years. He graduated with honors from Kentucky Tech. Corbin Campus drafting class in 1993 he also graduated with honors from Somerset Community

College with an Associates degree in Mechanical drafting and he has been certified by the National Occupational Testing Institute in Mechanical drafting.

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http://EzineArticles.com/?Drafting-Fundamentals---How-to-Bisect-an-Angle-Using-Autocad-2004&id=681907

Top Ten AutoCAD Tricks for New AutoCAD Users

By Nancy Fulton

AutoCAD is used by professionals world-wide to create the drawing files that define the buildings, equipment and products we use every day. If you are looking for a job in design or construction, you need to know AutoCAD in order to command high wages and job security. These easy tips will help new users get up to speed fast.

Use the Pull Down Menus

If you look at the top of the AutoCAD screen you will see menus like Draw, Edit, Modify, etc. Use these menus to launch AutoCAD commands. As you become more familiar with AutoCAD you may elect to use the toolbars and the command prompt to issue commands, but new users learn and work faster if they use the pull down menus.

Keep Your Eye on the Command Prompt

At the bottom of the screen you will find the Command prompt. Keep your eye on this space when you issue commands. You will find that every command you issue puts its options on this line. So, if you start the CIRCLE command, you will find you can type D to indicate that you want to specify a diameter for the circle you want to create.

Learn How to Identify Points

New AutoCAD users struggle with the many ways in which they can enter points in AutoCAD. You can type them (3,4), you can click your mouse to select them, you can use Object Snaps to pick up points on existing geometry (hold down the shift key and right-click to see the Osnap menu). You can Also select a point, move your mouse up or down, right or left and type a distance.

Take 30 minutes and learn all the ways you can select points in AutoCAD by reviewing its Help files. you will save yourself hundreds of hours of work and create better drawings.

Never Ever Draw What You Can Copy

New AutoCAD users spend too much time drawing. If you've ever drawn something, you should never need to draw the thing again. Learn how to use the BLOCK and WBLOCK commands to create named geometry you can use over and over again. Learn how to use the INSERT or DESIGN CENTER and EXPLODE commands to place editable geometry in your drawing.

Learn How to Use Model Space/Paper Space or Layouts

Its really very simple. You Click the MODEL tab. You draw your objects at full scale (one inch in the real world is one inch in AutoCAD's model space). Select a Layout to toggle into paper space. Specify the size of your paper. Use the MVIEW command to “cut a hole” in the paper and display the objects in model space. Select the edge of the hole, right-click and choose a scale for the view. Double-click inside the hole and pan the view so its centered. Double-click outside the hole. From the File menu choose Plot to plot your scaled drawing. The instructions for using Layouts vary slightly based on which version of AutoCAD you are using, but the basic technique is always the same. Draw full scale in model space. Create scaled drawings in Layouts.

Be Organized

If you don't know how to create and navigate to folders in Windows, life with AutoCAD will be a misery. It will scatter your files all over your hard disk or network. you will never be able to find anything. There are a million books and websites that review Windows fundamentals, take a moment to master the basic skills they review. you will spend less time looking for things.

Use External References

If you are working as members of a team, put the geometry you need in one file. Everyone can then create new files which externally reference that file. The result is, multiple people can work on the same project at the same time. You use the XREF command to place one drawing inside another. You can also use Design Center to insert external references.

Learn How to Use Dimension & Text Styles

To define text fonts that you use in your drawings, use the STYLE command. To define how dimensions look use the DIMSTYLE command. If you don't use dimension and text styles, you spend a great deal of time tweaking each and every dimension and text block you create. If you define a style changing the style updates all the text and dimensions.

Back Up All The Time

If you don't know how your drawings are being backed up, go find out right now. Every drawing represents hundreds or thousands of man hours. A lost, deleted or corrupt drawing file can mean lots of lost revenue. Small design shops using AutoCAD are the worst offenders. They rarely back up, they often lose data. You need to back up in such a way that you can go back four or five versions of your drawing, because often problems in a drawing aren't noticed for a long time. So many lines, so little time . . .

Find Out What Other Folks In the Office Do

Don't be the lone wolf in your AutoCAD office. Use the templates, title blocks, text styles, dimension styles, plot styles and block libraries everyone else uses. It saves everybody time.

Your drawings are easier for others to edit and plot. You can edit and plot the drawings of others. Its always better to ask questions (even multiple times) than do something no one else in the office will understand later.

I hope these ten tips will help make you a better AutoCAD user, and that you will learn to love the application as so many have. As complex as it is, as confusing as it can be, there's almost nothing you can't do in AutoCAD one way or another. You can't say that about every CAD application.

Nancy Fulton owns and operates the http://www.Complete-Support.com training site which has hundreds of free AutoCAD tutorials currently online.

Article Source: http://EzineArticles.com/?expert=Nancy_Fulton

http://EzineArticles.com/?Top-Ten-AutoCAD-Tricks-for-New-AutoCAD-Users&id=309823

If You Have Always Wondered What Dynamic Input of AutoCAD Is

By Jos Van Doorn

This is something they have added to AutoCAD 2006. In AutoCAD 2006 you now have dynamic input. It helps to stay on focused on the screen. You're not in a command. You move the cursor over the screen. The X position and the Y position of the cursor are displayed. Even better. You're in a command. What normally is displayed in the command window is now displayed next to the cursor.

Suppose you want to draw a line. You click on the Line button in the Draw toolbar. The first prompt of the line command is displayed. Next to the cursor. Behind the prompt are two numbers. Those numbers give the X position and the Y position of the cursor. Click to get the first point. The first prompt is no longer displayed. Now the next prompt is displayed. We now have two numbers. Not exactly behind the prompt.

The first number gives a distance. From the cursor to the point that we picked. And the second number gives an angle. From the first point to the cursor. We pick another point. We now come to the next prompt. That prompt is displayed next to the prompt. We can pick another point. But there is something in the prompt. There is something in each prompt that is displayed.

We see the icon of a down arrow displayed in the prompt.

Press the down arrow on your keyboard. A shortcut menu shows up. All available options are in the shortcut menu. Press the down arrow again. A black dot is displayed next to the first option. If you want to invoke that option, then press the Enter key. Of course. You can keep on pressing the down arrow. You go to another option. And press the Enter key to invoke that option. Do you see? With dynamic input you can keep your eyes on the screen of AutoCAD. No need to look down into the command window.

OK. I gave an example. Using the LINE command. But if you use another command. Still the same. The prompts are displayed in the screen. There is much more to dynamic input. We will talk more about dynamic input in the other articles in this series. But allow me to make another remark. This is the first article of a series of four articles. The subjects of all articles are:

1. What Dynamic Input is.

2. Status bar. Switching on. Switching off.

3. Settings

- Enable Pointer Input

- Enable Dimension Input

- Dynamic Prompts

4. Settings

- Appearance

- Options

Jos van Doorn. AutoCAD specialsit and AutoLISPO programmer. Also writer AutoCAD articles and AutoCAD books.

If you want to have the other articles, then send an e- mail to:

dynamicinp@aweber.com If you do you'll get the article in consecutive days.

About the author:

Jos van Doorn. Get the IntelliCAD newsletter. About IntelliCAD and about free stuff for AutoCAD and IntelliCAD. To subscribe send a blank email to: intellicadnewslettersubscribe@yahoogrou ps.com

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Architectural Software - Auto Cad Software - What Are My Options?

By Jud Leonard

Architectural software comes in many different types, prices, features, and quality. I won't talk about all of your options here, as there are literally dozens of different small, inexpensive programs available at your local software depot.

Instead, I will focus on the major players in the architectural software market for design professionals. This will also be useful for beginner designers...especially those who may want to share (or pass-on) their files to an architect or engineer without having compatibility issues.

Here are some of the most popular architectural software programs available, along with my comments, based on my 13 years of experience working with some of them. These programs are widely used in design firms all over the nation, but can also be used by everyday consumers, as well.

- Microstation

- Archicad

- Chief Architect

- SketchUp

- AutoDesk Products, such as AutoCad, AutoCAD LT, Revit, VIZ, 3ds Max, AutoSketch, Maya, and other plugins and add-ons.

Below are some descriptions and comments about the list above...

Microstation

Many who are die-hard microstation users will quickly point out that it is a much more stable platform to work with, as opposed to the industry standard AutoCad. Many suggest that it is much easier to deal with, and that the programmers did many things much more intelligently in their architectural software design, as it relates to user experience.

One glaring problem is this... Even IF microstation is a better program than AutoCAD, it's still got some major flaws for the end user. The first and most critical flaw, is the fact that it only comprises about 5-10% of the architectural software market. Therefore, if the software is not COMPLETELY compatible in BOTH DIRECTIONS, this poses workflow problems for our design team...and yes, it has some serious compatibility issues with AutoCAD.

No matter how much Microstation users want to deny it, there ARE compatibility issus, especially if you use x-refs and images/OLE objects in your AutoCAD drawings. When someone opens your AutoCAD files in Microstation, often the x-ref's become unviewable, and the user will then need to contact the architect to either "bind" his drawings into one drawing, or other similar method. OR, they will have to convert the drawings themselves. As an architect, this is not practical.

You can find more information about Bentley's Microstation on their website at http://www.bentley.com.

Archicad

Archicad is more of an all-around 2d/3d application that is intended to provide a total project output, including modeling & rendering, as well as 2 dimensional construction documents.

Changes made to the model are updated in all views, such as plans, elevations, 3d model, etc.

Archicad stores all the information about the building in a central database; changes made in one view are updated in all others, including floor plans, sections/elevations, 3D models and bills of material.

Although I do not personally have experience with Archicad, they are definitely making an impact in the architectural software industry, however still only occupying a very small percentage of the market. One thing I am not so sure about, is the single database file structure.

My concern is that I need to be able to delegate different responsibilities to different team members, and if only one person can be working on the file at a time, then this poses a major workflow problem. It is possible that Graphisoft (the makers of Archicad) has addressed this, you can find out more information about their product on their website at http://www.graphisoft.com.

Chief Architect

Chief Architect is one of the leading software products for residential design. Since my business is 99.9% marketed the product well. The graphics are limited, with respect to the more expensive competition, but it seems to provide a very acceptable output from that perspective.

I tried a demo about 12 years ago, and quickly realized it's limitations in architectural software design for commercial projects, so I have not pursued it for our design purposes.

You can find more information here at their website... http://www.chiefarchitect.com.

SketchUp

SketchUp is becoming extremely popular and more well-known, especially now that Google has purchased the software rights. We use SketchUp often to convey design ideas to our clients, as well as within our design team.

It's ease of use, and ability to quickly generate 3-dimensional representations of building design, make it a very useful piece of architectural software. It's rendering capabilities are limited, compared to 3ds Max, but the price tag is proportional. SketchUp will not break your bank account, whereas 3ds Max is only affordable if you are really making some good money from your 3d modeling efforts

I highly recommend this product. You can get more information at www.sketchup.com.

AutoCAD

AutoCad, by AutoDesk, is the standard by which all CAD software programs are compared...not because it's necessarily a better program, but because it occupies, by far, the greatest market-share for professionals than any other CAD software program available.

In fact, for the 13+ years that I've been using AutoCad (since version 10), only about 5% of our consultants or other design professionals have used anything other than AutoCad, or other AutoDesk products. You can find a link to a large selection of AutoDesk products at http://architecturalsoftware.jdlarchitects.com/.

Now, of course, AutoDesk will tell you that this IS because their program is superior to the others. This may be the case, but you will get differing opinions from all sorts of designers, architects, and engineers. Many of the complaints, including my own, are that AutoCad is not very user-friendly. This is definitely the case.

The program is so powerful, that it could take someone decades to master it's features. Often, it is so much easier to just use the features you know, than to keep digging into it's vast feature sets...you could literally spend all of your time trying to learn all of the programs features, but you would never get any real work done.

That being said, I have used AutoCad for 13+ years now, and if it is used correctly, with the proper sheet setups and reference files, your workflow can be as efficient as with any architectural software product.

In Conclusion

In conclusion, even if there are debatable issues about architectural software quality and user-friendliness, it just doesn't make sense to me, to use anything other than AutoDesk's products. I may not be enthused about it, but I have to ensure that my workflow is efficient. The unnecessary hoops to jump through when using CAD software that only 5% of the world is utilizing, is not practical.

I want my file structure to be maintained on my consultant's end, and since the design process requires back-and-forth transferring of files throughout the process (sometimes dozens or even hundreds of times on large projects), it is obviously an unacceptable solution if you have compatibility issues to deal with.

Yes, there are plenty of design teams fighting their way through this process, but the problem is that their upper management, on the average, are not savvy enough to current software applications to care about "how" their production happens...they just care that it gets done. What they don't realize, is that if they implemented proper workflow usage of architectural software, they could save literally hundreds of man-hours on each job.

Jud Leonard, AIA, is the President and CEO of Jud Leonard Architects, Inc., located in Dallas, TX. Mr. Leonard has over 13 years of experience using architectural software for commercial projects. You can view this article and more about his firm at http://architecturalsoftware.jdlarchitects.com

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CAD CAM Software

By Jason Gluckman

Manufacturing processes across industries has undergone a sea change thanks to the advent of sophisticated technologies like Computer Aided Manufacturing (CAM). CAM is a system which uses computer technology to assist in the manufacturing of products.

Using CAM industries have become highly automated. Modern day concepts like robotics being used in manufacturing process owe their origin to CAM. CAM enables a high degree of precision to be achieved, which is humanly impossible.

Certain sophisticated CAM systems can keep track of even the materials and automate the entire ordering process, apart from aiding such tasks as tool replacement. CAM is generally linked to CAD systems. The integrated system usually takes the computer generated design and feeds it into the manufacturing process. The entire system works under a multiple computer controlled environment, with specific computers being assigned for specific jobs for instance, like milling or drilling.

The use of CAD CAM also enables the production of custom designed products to suit particular client requirements. CAD CAM technology is the most preferred process for manufacturing customized products, because it is a relatively cheaper process and less time consuming process rather than doing the same manually.

CAD CAM software has literally changed the way tasks are done in factories, with increasing numbers of robotic arms and machines being used in factories. These machines are usually assigned to do repetitive tasks, which require a high degree of precision. A good CAD CAM system results in decreasing production costs and over heads for a manufacturing unit. It is also a cost-cutting tool, which ultimately results in increased profits to a factory. CAD CAM software is extensively used in a wide variety of manufacturing industries. They touch every facet of our lives, without us being aware of it, most of the times. Such is their impact that newer product designs and production processes keep springing up every day.

CAD provides detailed information on CAD, CAD School, CAD Software, CAD Drawings and more. CAD is affiliated with Digital Architectural Rendering.

Article Source: http://EzineArticles.com/?expert=Jason_Gluckman

http://EzineArticles.com/?CAD-CAM-Software&id=408178

CAD Software Comparisons

By Josh Riverside

There are more than 30 varieties of CAD software available in the market, which are sourced from different software developers. Apart from these, customers also have the option of downloading freeware and shareware available easily on the Internet. Customers who want to buy CAD software should conduct a comparative study analysis to select the most suitable software among available options.

CAD software can be compared using different product criterion such as cost of the software, developer's profile, after sales technical support and future upgrades. This can be done by using an excel spreadsheet or other software. Product analysis software is also available in the form of freeware, which can be used to compare and select the most cost effective CAD software.

CAD software systems are also compared based on features such as two dimensional (2D) or three dimensional (3D), CAD or CAD+CAM, operating system compatibility (windows, UNIX, Solaris, and SunOS), microprocessor requirements (Pentium, Celeron), hard disk space & RAM memory requirements, and supported formats(IGES, DXF, STL, SLA, Gerber, HPGL, CadKey & APT, CATIA CL, Excellon, Gerber).

Customer reviews can also be used to compare different CAD software. Reviews are written by CAD software users who describe their experiences about different brands manufactured by different software development companies. A number of websites are completely dedicated to provide information about CAD software reviews, which can be used to gather information on the benefits and drawbacks of different software programs.

After comparing, different brands of CAD software are rated on a scale of one to five, which is commonly known as star ratings. A rating of four and above indicates that the software is good and can be purchased. Software systems that are rated below three usually do not have advanced features and may have inherent defects. Customers who do not have in-depth knowledge about software systems should opt for CAD software that is rated in the range of four to five.

CAD Software provides detailed information on CAD Software, AutoCAD Software, Free CAD Software, CAD/CAM Software and more. CAD Software is affiliated with Manufacturing Business Software.

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http://EzineArticles.com/?CAD-Software-Comparisons&id=408193

How to Choose a CAD CAM System

By John Lombaerde

The selection of a CAD/CAM system is an important one for any design or manufacturing company. It has ramifications all the way from the beginning of the product concept phase to the end of the manufacturing process. It is likely that, only a single CAD or CAM vendor will be chosen, (although multiple stations may be procured). For most companies, a CAD/CAM software purchase decision is a one-time event. Because of this fact most companies have somewhat limited experience in the purchase of a CAD CAM system. A reliable CAD CAM consulting firm can be an important ally in the process of system selection.

This review will consider five important criteria. These criteria are listed in order of importance. Most companies place a great emphasis on initial cost and the list of features / benefits first. In this recommendation, ease of use is listed first.

1)Ease of use - productivity

2)Vendor stability and longevity

3)Features – functionality

4)Cost – total cost of system

5)Maintenance / upgrade and training costs

1) Ease of use

In practical terms, the ease of use of the system will have the most significant return on investment. It is often forgotten that design or manufacturing personnel may spend anywhere from 100 – 2000 hours per year on the system. (Estimate based on 2 hours part time per week, or 40 hours per week on a full-time basis.) The average cost of this labor is many times greater than the cost of the CAD CAM system itself. Even a 10 % reduction in time spent to complete a particular task could have a savings of over $ 5,000.00 in labor costs, the first year alone ! This is more than the entry price of most CAD systems !

Note: This estimate is based on use of the system on a full-time basis with a conservative calculation of a $ 25.00 / hour labor rate. Ease of use as it relates to productivity, is the single most important criteria to evaluate, and yet it is also the most difficult of the criteria to quantify.

Benchmarks: some companies attempt a timed benchmark between various systems, to evaluate this measure of productivity. This is problematic, however, since these types of competitive benchmarks are just as easily influenced by the individual skills of the CAD or CAM engineer, as they are by the software system itself.

It is wise to ask the vendor to demonstrate the creation of a particular part that is similar to others that you have designed or manufactured in the past. It is much easier for you to compare systems on a part that you are already familiar with than a “canned” demo on a part the vendor chooses.

2)Vendor stability

Make sure that the company chosen has a stable financial base, and has been in the industry for at least 10 years. One of the worst things that can happen to CAD/CAM customers is to lose the support and upgrade path for their software, because their CAD/CAM software vendor has gone out of business. This leaves customers stranded, and eventually their software will become relatively obsolete.

3) Features and functionality

Many prospective CAD/CAM customers try to calculate the value of their software based on a long list of features, and try to compare to other systems. The difficult of this is that the terminology used to describe certain functions varies from system to system. Vendors may also unintentionally or intentionally obfuscate this point, by claiming unique functionality which is really just a question of semantics.

For most customers, the CAD/CAM software industry is sufficiently mature to have more than enough functionality to satisfy even demanding customers. If your job requirements are highly specialized, or unique to your industry, then you may need to carefully examine specific functionality to make sure the software you choose can meet your needs. In terms of CAD software, this might be libraries of standard components particular to your industry, or it could be a unique type of warpage calculation, etc. For CAM systems, pay particular attention to specialized turning machines that are not simple 2-axis plus C-axis milling. Screw machines, multiple turrets or rotary turrets on a lathe, can be problematic. For milling machines, 4-axis and 5-axis applications can be very tricky to evaluate and can present special challenges for the machine tool manufacturer, and software vendor.

Again, a CAD/CAM consultant can be invaluable to scope out specialized requirements, and assure the the software meets the specific intended application.

4) Cost

This is the easiest criteria to evaluate, but one caveat emptor needs to be addressed. Most CAD/CAM software is sold on a modular basis. No company should purchase more CAD/CAM modules than they need. There should always be an upgrade path open for a later purchase of additional modules if needs expand or change. Buyers also take note that this industry is extremely competitive, and in general customers really do get what they pay for. Prices are stable and well established, and there really are no fire sales, or steep discounts available. One further note: it is usually wise not to purchase software that has been licensed to another company, without expressed written consent from the software vendor. Many software purchase agreements prohibit transfer of a particular license from one company to another, (unless the software has been transferred as a result of a company buyout or merger.

5) Maintenance, Upgrades, and training and support

Users should not be shocked to find that software is regularly upgraded, at additional cost. This is true across the entire software industry. Since CAD/CAM Software is generally more costly than other type of software, is should also be no surprise that software upgrades are also more expensive than other types of software. Upgrades should be available on a regular basis. It is good to ask what the time period was between the last several upgrades. Most CAD/CAM software should have an major upgrade every 12-18 months. Users should not be penalized for failure to upgrade. They may find, however, that reasonable restrictions may be placed on support for badly outdated software.

Support hours should be reasonable, and at cover business hours, with some consideration to start and finish times within the time zones. Training costs should not be exorbitant. Group training for several employees at one time, or on-site training may also be available.

The use of good buying common sense and informed decision making using the above criteria can make the difference between a smooth CAD/CAM installation and something less than desirable.

John Lombaerde is a CAD/CAM/CNC Specialist with over 20 years experience in advanced manufacturing technologies. He is a Designer, CNC Programmer, CNC Machinist, a CAD/CAM consultant, and

a Search Engine (SEO) Strategist.

For additional information contact:

For more information, see CAD CAM Consulting

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http://EzineArticles.com/?How-to-Choose-a-CAD-CAM-System&id=531120

Open CNC software adds choices

NEWS DESK SOFTWARE

PASSWORD

James R. Fall has over 20 years of operations management and marketing experience in manufacturing and high technology companies. He has continued to offer MDSI's innovative software

motion technology and OpenCNC software CNC to manufacturing companies worldwide. Fall engineered MDSI's move to globalization with the company's acquisition by Tecumseh Products Company

in April, 2002.

Manufacturing Engineering: What is open CNC software?

Fall: It's an unbundled software computer numerical control (CNC) that is independent of any hardware and includes all of the following in software as an integral part of the control:

HMI, interpolation, servo algorithms, RS-274D parser, PID and PID tuning tools, soft PLC, a defined and well-structured API, and a data server that can push data across a network. It runs on standard office-grade or industrial PCs.

ME: Why should a company use open CNC software?

Fall: The great advantage of an unbundled all-software CNC is that it gets you on a different technology curve, a software technology curve. What this means is that you can continuously improve the productivity of your machines by installing new versions of the software-a matter of simply loading a new CD-without being forced to do complete and expensive control retrofits and hardware-- swapping that is the hallmark of traditional proprietary CNCs. Another reason for moving to an unbundled software CNC is to reduce the life-cycle costs of machine tools. With a renewable software control, users avoid the steep increases in costs that occur in traditional hardware systems when hardware becomes obsolete, or when improvements can only be made by throwing out the old and starting over. An unbundled software CNC can change and grow along with your manufacturing assets and processes. Also, the performance of off-theshelf PCs continues to improve while the price drops, and unbundled software CNCs allow you to take advantage of this-once again, without incurring significant hardware costs. Finally, an unbundled software CNC benefits the user because it provides realtime data that manufacturers can use to continuously monitor and improve their processes.

ME: Can one program fit every type of machine tool?

Fall: The dream of every manufacturer is to have a common control across a broad range of machine tools. An unbundled all-software CNC can provide this capability. We designed reconfigurability into the OpenCNC product from the beginning. This capacity to reconfigure the existing control across a broad range of machine tools, axes, and job streams was recognized by the US Patent Office awarding MDSI a patent. When one program can fit every type of machine tool, manufacturers can move operators freely from one machine to another and training costs are decreased.

ME: Does it completely eliminate the control software that came with the machine tool's controller?

Fall: Yes it does. The machine tool becomes a device on a network, just like a printer is now in your office network. Device drivers pertinent to each machine tool come with the software, not with the hardware on the machine.

ME: What kind of computer equipment is needed?

Fall: Unbundled software CNCs run on standard PCs and use standard communications cards to talk to the servos and I/O.

ME: How difficult is it to run these types of programs?

Fall: With the advent of graphical user interfaces, unbundled software CNCs are more intuitive and easier to learn than traditional hardware-based CNCs and user interfaces. Furthermore, upgrades to the unbundled software CNC don't require retraining in the dramatic way control retrofits of hardware controls do. Historically, with proprietary hardware CNCs, multiple generations of different kinds of hardware controls across multiple kinds of machine tools have maximized costs, isolated each element, and hamstrung an enterprise's ability to change and adapt to new technology. Unbundled software CNCs that include HMI, interpolation, servo algorithms, RS-274D parser, PID and PID tuning tools, soft PLC, a defined and wellstructured API, and a data server that can push data across a network offer the first true way out of the Balkanization of the traditional factory.

Software Becomes The Backbone Of CNC Machining

John M. Jordan

Penco Precision (Fontana, California), founded in 1975, is a medium-sized CNC precision engineering job shop with 17 CNC machines installed. The company specializes in tight tolerance batch work for clients in the aerospace, instrumentation, medical and computer peripheral supply sectors. Batch quantities go from a few to several hundred, with a lot falling between five and 25 parts. Tolerances are held as tight as 0.0002 inch on turned diameters up to 0.75 inch and positional tolerances to 0.001 inch. Occasionally, a true position (TP) feature is required when milling, which then demands precise and careful handling.

Since Penco acquired its first CNC machine in 1984, the plant has grown to eight CNC lathes and nine machining centers. Turning capacity up to 6 inches diameter by 15 inches length and machining center capacity up to 24 inches by 36 inches by 18 inches is now available. Machines include a CNC sliding head lathe specifically for slender shaft work and one lathe with C-axis capability. Other facilities include a 3D coordinate-measuring machine and a computerized job scheduling system, while the in-house quality systems are ISO 9002 compliant.

Penco used to develop part programs using fairly basic methods, according to Glynn Pennington, president. "The only off-line facility that we had was a simple computer-based text editor," he says. "The pressure to upgrade came from two directions. First, we were being asked to machine more complicated radius and blend features; second, as the number of machines increased so did the programming workload, which was increased due to the trend for short batch demand."

Penco is an unusual company as it has abroad base of CNC skills. Out of a total workforce of 30, nearly half can perform programming, setups and operate the machines. When selecting an off-line system, the requirement was for software that could be used with multiple skill levels according to the operational needs of the job and the knowledge of the individual.

At this time, CAM software that had been developed from the ground up in the Windows environment was rare. This was a big factor in Mr. Pennington's ultimate decision to purchase EdgeCAM from Pathtrace Systems Inc. (Ontario, California). The company bought two seats and hosts one on a desktop PC while the other resides on a notebook. This allows programming to be carried out at home--a practice the company has found to be very successful.

"We've gained all of the benefits that we hoped for with EdgeCAM," says Mr. Pennington. "It has allowed us access to new markets because we are now able to tackle more complex work. In addition, the basic ability to develop programs so much faster has made us more competitive. On the technology front, the DXF and IGES file transfer capability means we can work direct from clients' latest design files rather than from drawings."

Other benefits gained since the introduction of EdgeCAM have included a reduction in the need for hand finishing of components on blends and transitions. In addition to the increased business that has been brought in, it has also acted as a confidence builder for the staff, Mr. Pennington maintains.

"We've been able to develop far more complex programs very quickly and shorten the time to produce quotes for customers. Our 'Right First Time' ability has also improved because EdgeCAM helps us to catch errors long before we start to cut metal," he adds.

"We've been able to grow with our customers in a way that would have been impossible without CAD/CAM capability," Mr. Pennington says. "Since we've had EdgeCAM the business has grown, while up to 40 percent of our revenues depend on the capabilities it provides."

UNLEASH YOUR CNC'S POWER

Koelsch, James R

You can do more with what you already have

If you're like most machine shops, you want to cut faster and hold better accuracy on your machining centers-without having to invest much money.

Well, the means for doing just that could already be sitting in your shop. One of the best-kept secrets in the industry is that most modern CNCs contain many performance-enhancing features that builders of general-purpose machines often don't use. All you need to do is turn them on.

"CNCs have a lot of capability that's not taken advantage of," says Bill Griffith, CNC product manager, GE Fanuc Automation North America Inc. (Charlottesville, VA). "You can hire a service engineer to set them up for you. Sometimes maintenance engineers learn about some features in the training classes that they take."

The availability of these performance enhancements varies widely with the make of the CNC and its manufacturer's marketing strategy. Some manufacturers, for example, activate all of the features that they offer, making them available to users from the outset to avoid "optioning" them to death. You just need to learn to use them. Others, however, price their products based on the active features, requiring their customers to pay only for those features that they use. So if the builder of your machine djd not activate a feature that you might find useful, you will need to buy it.

Although the cost of such features usually runs between $900 and $2000 each, it varies by manufacturer and type of feature. Sometimes the purchase is simply a matter of giving the CNC manufacturer your credit card number over the phone, and receiving an activation code that you punch into the CNC. Other times, however, a technician needs to come to the machine to activate and tune the feture, and perhaps even load a missing piece of software. In these cases, you'll need to add the cost of the service call, which usually requires from a few hours to a day.

Keep in mind, however, that using these hidden features isn't always just a matter of turning them on. Sometimes there is a tuning, or commissioning, process. Other times, you need to tweak cutting programs and internal software to account for the changes made by a feature. "You have to be aware of what you are doing to enhance your machine, because it might affect how the machine will operate," says Christian Kuhls, CNC product manager, Siemens Energy and Automation Inc. (Elk Grove Village, IL).

An example is the motion-synchronous actions, or synchronized actions, feature in Siemens' CNCs. This feature allows users to program instructions-such as sending output of auxiliary functions to the PLC, writing and reading of real-time variables, making on-line tool offsets, taking measurements, and calculating of function values-that are processed synchronously with the interpolation cycle. The goal is to complete tasks or to provide data in time for use. Since you integrate these actions into the machine and coordinate them with the tool motion, you might need to adjust them if any features change the machine.

To help users sort through the various features that are hiding in the CNG and to decide which would boost the performance of their machines the most, GE Fanuc's Griffith suggests organizing them into a kind of hierarchy-one that puts sound mechanics at the base. Although software and electronics might mask some mechanical defects, they cannot make an unsound machine sound. The hierarchy then builds on the base of sound mechanics, beginning with servo and positioning adjustments, continuing with features that enhance the machine's acceleration (and deceleration, which is nothing more than negative acceleration) and programming, and ending with those that add functionality to the machine.

At the lowest level, adjusting servo and positioning parameters, the first order of business is tuning the velocity loop. The process involves determining the natural frequency of the machine, which tells you the performance limits of the machine and lets you set resonance filters, velocity loop gain, feed-forward coefficient, and position gain accordingly. GE Fanuc has software called Servo Guide that leads users through this initial tuning process.

"Servo-tuning functions like feed-forward control are in every CNC, but aren't always used," says Griffith. "The feed-forward function more or less skips the position loop and sends the command directly to the velocity loop of the servo system." By bypassing the slower position loop, the feature hastens the CNC's response to any deviations from the programmed toolpath, allowing the machine to react to corners and contours much faster. Consequently, feed-forward control reduces any position errors that would result from servo-processing delays when cutting at high feed rates.

A feature called nanometer command interpolation allows Fanuc CNCs to send commands to the servo system in increments that are a thousand times smaller than before. These tiny, nanometer-size command increments not only improve accuracy by moving rounding error to smaller decimal places, but also make acceleration smoother, which allows you to cut at faster rates.

Griffith emphasizes that this feature is not a function of the positioning accuracy of the machine. "It is strictly a command unit between the CNC and the servo system," he explains. "So it doesn't need nanometer feedback on the position feedback loop." It does, however, need high servo responses to be able to handle the amount of data being processed. For this reason, GE Fanuc's CNCs? have high-response velocity feedback that samples velocity from the motor every 64 nsec.

If you are looking for a way to hold tighter tolerances and create finer finishes, you might check your CNC for error-compensation features. Many CNC manufacturers have equipped their products with optimization features that run tests to measure mechanical errors, power transmission faults, and measurement errors, and to compensate for them. "Interpolatory tests, for example, check the contour accuracy of your axes, compensating for any gap in their ability to return the tool to a particular point in space," says Siemens' Kuhls.

Besides performing these interpolatory tests for leadscrew error and beam sag, Siemens' CNCs also compensate for temperature changes, backlash, and friction, and provide dynamic feed-forward control and electronic counterweights for drives. Because these tests take only about 5-10 min to run and generate optimum compensation coefficients, Kuhls recommends running them periodically as part of a maintenance schedule to compensate for normal wear and changing conditions.

"If you do it on a regular basis, you can identify faults much earlier and schedule maintenance based on these values," he says. "You'll be performing maintenance based on the actual status of your machine, not on how long it has been operating."

Siemens' CNCs also can perform vibration analyses, and help the user filter and damp internal noise. Kuhls reports, however, that this test is more involved than the others. It not only needs much more time, but also requires a fair amount of expertise. Consequently, he recommends hiring an expert to perform it.

A machine's acceleration profile is the next level in the hierarchy of hidden features. These options can shave milliseconds off each inflection point where an axis changes its rate of acceleration. Because a typical contour has thousands of blocks, the time savings can be quite large when you add them up, especially on large parts. Moreover, controlling changes in velocity and acceleration better can reduce vibration and shock that can damage a machine at high speeds.

One way to squeeze time from tool-paths is to use a more efficient acceleration profile, which CNC manufacturers allow users to change through a feature called the ace/dec control. "Many builders set their machines' ace and dec control to follow an exponential curve during acceleration," explains GE Fanuc's Griffith. "Linear and bell-shaped curves are available too. Each has its advantages and disadvantages, but an exponential curve is the lowest base feature, and will give you the least performance."

Of these profiles, the bell-shaped acceleration curve is usually best because it avoids shocking the machine. "A linear acceleration is very sharp," Griffith notes. "A lot of machine tool builders don't build machines that are rigid enough to handle a truly linear acc and dec. If the machine can handle a linear acceleration, though, linear is just as good as bell-shaped."

If the acc/dec control feature is activated, anyone who knows the basics of the machine and has the experience can tune the machine in about an hour. Doing it right, however, requires a ball-bar test. "An experienced person can tune the gains, adjust the feed-forward coefficient, and set acc/dec profile in an afternoon," says Griffith.

Another oft-ignored feature is jerk control, a feature that controls shock from inertia, friction, and internal play by smoothing abrupt changes in acceleration. According to Griffith, true jerk control is the first derivative of acceleration at points of change. It is not a bell-shaped acceleration curve, which some CNC vendors called jerk control in the past. The advantage of true jerk control is that it is better at smoothing jerks. "It reduces shock so you can lower ace/dec constants and accelerate faster," says Griffith.

GE Fanuc offers another acceleration-improving feature called Optimum Torque. As the name suggests, this feature adjusts acceleration based on the speed-torque curve of the motors to ensure that the machine is using as much of its cutting capacity as it can. Because an intimate knowledge of the motor, amplifiers, and control loops is necessary to make this feature work, it usually requires that the CNC, drives, and motors come from the same manufacturer.

A good application for this feature is optimizing machines that cut parts that differ widely in weight. "If you set the machine for a very heavy part, you're stuck with that acc and dec," says Griffith. "With Optimum Torque Acc/Dec, the machine can accelerate faster without any adjustments when we put a light part on the machine. Because the CNC accelerates based on the torque of the motor, you no longer have to set the machine for the worst-case scenario. Now, it will adapt."

Tools for programming toolpaths are the next level in the hierarchy of hidden features. CNC manufacturers build some kind of programming software into their products, and offer a variety of alternatives as options. One is a basic CAD/CAM system called profile editors for creating electronic "blueprints" on the CNC's screen. Upon creating a profile, the operator simply saves the profile or blueprint as a program, a process that generates G-codes automatically.

This ability can come in handy for a shop cutting a family of parts containing four profiles, according to Todd Drane at Fagor Automation Corp. (Elk Grove Village, IL). It could let production bypass the CAD/CAM department and the associated trial and error; of creating a file offline. Because loading a new profile using a profile editor such as the one Fagor offers can take between one and three minutes, depending on the part's complexity, downtime for program changes is much shorter than typically required for importing and programming profiles from the CAD/CAM system.

Many CNCs also have a conversational operating system available to give the operator the option not to work with G-codes. "We recommend that users consider using one in most situations where part programs are created at the machine," says Drane. The operator simply selects the operation that he wants to perform and fills in the blanks on the graphics that appear on the screen. This lets him simulate cutting graphically or execute the program without having to know G-codes.

When using Fagor's CNCs, the operator makes his selection by pressing the key on the keyboard containing the icon that depicts the operation that he wants to perform. Drane recommends activating this feature when you order the CNC, because' the keyboard needs the keys containing the icons.

Although some kind of programming software is typically standard issue on CNCs, the tools for importing files are not always. Heidenhain Corp. (Schaumburg, IL), for example, puts a DXF converter in its CNCs, but does not turn it on. "Not everybody needs it," explains Chris Weber, product manager for controls. If you are someone who does, contact Heidenhain, pay the fee, and get the code that activates the option.

CNCs also often contain programming tools for customizing the user interface for the particular jobs that the user has or for the particular tasks that mariagement expects of the operator. These customization tools usually fall into two groups or levels. First is an elementary level that Siemens calls its expanded user interface wizard for adding setup instructions and other screens. "It enables you to develop your own screens just with ASCII files," says Kuhls. "We also have options that let you generate complex screens in higher languages like C++ or Visual Basic." This higher level of customization allows users to create screens that pull information from others, so operators need not flip through several screens to get the information that they need.

Tools for efficient and safe motion's form yet another level in the hierarchy. Bosch Rexroth Corp. (Hoffman Estates, IL) has a fast auxiliary-processing feature for activating tool changers, coolant pumps, clamps, and other auxiliary devices quickly. It's especially handy on jobs that require several tool changes or need selective use of high-pressure coolant. After configuring an auxiliary function as a "fast" function in the setup page, the programmer inserts the function early to ensure that it is on.

"Before the motion block where the function must be on-confirmed by the CNC logic controller via a switch, etc.-the user programs an auxiliary function check," says Bosch Rexroth's Karl

Rapp, branch manager for the machine tool industry. "Using this method avoids unnecessary stopping of the NC-block execution, and could reduce machining time." He emphasizes the need for diligence in ensuring that the feature activated or deactivated by the auxiliary function is truly finished before going to the next motion block.

Most CNCs also contain tools for altering the programmed feed rates as conditions permit to boost productivity. A feature in Heidenhain's CNCs, for example, adjusts the feeds automatically based on the tolerances that you set for each feature in a cut. "If you want to cut at 300 ipm [7620 mm/min] yet want to hold a micron around a corner, the cycle will override programmed feed rate and decelerate automatically as it approaches the corner so it can hold tolerance," says Weber. In Heidenhains case, the feature is free, but needs activating.

GE Fanuc takes this ability a step further with its Machine Condition Select feature. In addition to adjusting the feed rates, the feature also switches the servo gains and other parameters based on the tolerance and finish requirements. It allows users to identify as many as 10 cutting conditions, set as many as 12 parameters for each of those conditions, and have the program load them into the CNC on the fly to cut at optimum settings. "It allows you to have a roughing cut that is not as accurate, but much faster, and have a finishing ok that is very accurate but running at a feed rate corresponding to the accuracy," says Graham.

Heidenhain also offers a paid option called Dynamic Collision Monitoring that protects the machine automatically from collisions, no matter what the program tells the machine to do.

Machine tool builders can use this feature to create maps of their machines' work envelopes and link them to the kinematics of CNCs. "The controller knows where everything is and will not let you move, say, the spindle into the toolchanger," says Weber. "Even if you try to move the spindle with the handwheels to crash into a tool probe, the control will prevent you from doing it."

Because the commissioning of this feature is involved and requires a measure of expertise, it is a tool intended mostly for machine builders or integrators. Nevertheless, it is an option gaining the attention of users of five-axis machining centers. "The odds of crashing into something are fairly slim on a three-axis machine," explains Weber. "But it becomes an issue on five-axis machines capable of tilting and swiveling," in addition to moving along the three conventional linear axes.

GE Fanuc has developed a feature called Machining Point Control for damping vibration as large machines move through rapid traverses and cuts. It reads vibration at the tool tip or in moving members with a three-axis accelerometer attached to the machine much like a linear scale would be. The vibration signal goes through the velocity loop of the CNC, which adds a negative error adjustment in the opposite direction. "It damps the true vibration, not the predicted vibration," says Griffith.

He expects the first applications to be on the large machines making wing and fuselage segments in the aerospace industry. "In the past, the only way to damp vibration was to filter it through the servo system based on the machine's natural frequencies," he says.

At the highest level of the hierarchy of hidden power are the features on many of today's CNCs for streamlining the adding of functionality. Heidenhain, for example, makes its CNCs in only five and 10-input models. Machine tool builders pay for only those axes that they use, and let the others lie inactive. Consequently, CNCs often have the capacity to run more axes.

So someone who has a machine using only six of the inputs on a 10-input CNC can pay a fee to activate that dormant axis to add, perhaps, a rotary table.

Activating the axis is a simple process that requires a lead time of about a day. The user places the order through the local distributor, who then relays the CNC's system identification key (SIK) to Heidenhain. "Once we have the SIK, we know everything about the machine and can send the appropriate activation code to the customer by e-mail," says Weber. "The customer punches in the code, and his axis lights up." The CNC is then ready for the integrator to attach the table and commission the servo loops.

Another advantage of the SIK is that a user can transfer the CNC's setup parameters to another controller. If a worker were to drive a fork-lift truck into the machine and ruin the CNC, then a technician could pull out the hard drive and the card containing the SIK, and plug them into a replacement CNC. "It brings along all of the setup and commission parameters," says Weber. "The new unit now is the same as the old one."

Users also can expand the functionality of their machines by adding touch probes. Because Heidenhain makes these devices, it equips all of its CNCs with the software and communications ports necessary for installing and using on-machine probes. "Our controller has two dedicated inputs, one for spindle probes and the other for tool probes," says Weber. Because the macros for probing are already loaded on the controller, the cycles light up on the screen when you turn them on. The documentation is available for downloading for free from Heidenhain's Web site. The only cost associated wijth this feature is buying the probes.

Before you can begin probing, however, you have to commission the feature to set the approach speecs. "For example, I might want the machine to rapid traverse until the probe is within 10 mm of the part, and then slow the feed to move closter and do the actual triggering," notes Weber. He says that the commissioning is a fairly simple process that takes about two hours.

The probing software offered by Heidenhain and other CNC manufacturers like Fagor includes cycles for manual part setup and automatic inspection of both cutting tools and parts. Canned probing cycles can greatly reduce setup time too. "Users can automatically find fixture offsets, hole centers, and fixture angle offsets, and load these points directly into the zero-offset tables," says Fagor's Drane.

He also recommends to shops using on-machine probes a digitizing feature that they can activate in Fagor's CNCs. This feature can create a program automatically after sweeping a sample part with a probe in either concentric circular or in rectangular "cornrow" patterns. "A user simply fills in the blank of the pattern that he or she wishes to digitize," says Drane. He estimates that the typical user can create a digitizing cycle and begin executing it within three minutes.

James R. Koelsch

Contributing Editor

Custom CNC software - computer numerical control - column

Golden E. Herrin

Custom CNC Software

Custom CNC software - users clamor for it, machine tool builders often get stuck with writing it, control builders try to avoid it and independent software firms welcome it. When custom software cannot be avoided on a new CNC machine, who is responsible for writing it? To adequately answer this question the software must first be divided into its basic categories and each category addressed individually.

CNC Executive Software is the software embedded in the CNC providing the architectural framework and basic features of the control. This software is supplied and maintained by the CNC builder as part of the CNC unit and is considered proprietary by them. In fact, the source code for the executive software is not available from some control builders. With others, it is available under very restricted licenses agreement.

Even if the user is able to obtain a copy of the source code, they may find it of minimal value except for the secure feeling they get from ownership. The secure feeling may change to frustration if a user attempts to make modifications. They quickly discover that personnel must be trained in the proprietary architecture of the specific executive. Then the required compliers and computer hardware must be obtained which are often custom or proprietary from the control builder. In addition, any existing control warranty would be voided and future software enhancements from the control builder would most likely not be compatible with user modified software. These obstacles usually make it impractical for anyone but the control builder to make changes to the executive.

The requests for executive software changes are generated by both the user and the machine tool builder and cover a wide range of requirements. Frequently one control builder will be asked to provide a feature similar to one that is offered by another. Typically, features of this type are: 5-axis tool lenght compensation; 5-axis cutter diameter compensation; zero shift in cycle; solid tapping; retrace and so on.

Request for features may also come from the machine tool builder as a result of a unique requirement generated by the machine design, or as a result of the user's special requirements.

Features which fall into this category are: more axes error compensation points than the basic control offers; two error compensation tables for a given axis; an axis address not offered in the basic control; split or parallel axis in a control that does not provide it.

How willing are control builders to make these kind of changes? A lot depends on the market potential of the features, how many machines involved, and how much influence the user and the machine tool builder have over the control builder. Also, how responsive a control builder is to creating special features depends on whether they are a high-volume standard control builder or a low-volume custom control builder. In some cases, it may become necessary to switch control vendors in order to get a required new feature.

Application Software is provided by the machine tool builder to marry the CNC to the machine tool. It normally resides in a special partition of the CNC which functions much like a programmable controller. The basic functions performed by application software are: axis homing sequence, pallet shuttle, toolchange cycles, as well as the logic for all machine pushbottons, lights and limit switches. Today's CNCs, however, provide considerably more capability than just the basic functions. Most CNCs now provide the machine tool builder with the capability to create M codes, G codes and mnemonic codes. Also, with the power provided by subroutines and math capability, the machine tool builder can provide custom cycles for a variety of functions including custom milling, drilling, boring and probing cycles. Machine tool builders are generally very flexible when it comes to designing custom software for special machines. They are less likely to commit to changes on a standard machine.

Front End Software is a term applied to the software dealing with the management of data in and out of the CNC. It consists of such functions as transfering part programs, collecting and analyzing status information, or the matching up of unlike communications protocols. This software normally resides in a personal computer located external to the CNC. However, an increasing number of controls are providing built-in personal computer front ends which can be used by both the machine tool builder and the user.

The suppliers for this type of custom software are considerably more abundant than for other types of software providing an environment for competitive bidding. Suppliers consist of: independent or third party software houses; the machine tool builder; and in some cases, even the users own internal software department. Front end software is generally capable of being clearly defined in terms of functional requirements making it a good candidate for an independent design task.

There's a possibility that custom software in one or more of the above three categories may be required on your next CNC machine. Whatever the reason may be for requiring custom software, it does provide a valuable service for meeting the changing requirements of manufacturing in today's market.

Open-architecture CNC continues advancing

Chalmers, Raymond E

As the worldwide market for CNC grows

Not only is the market for computer numerical control (CNC) hardware, software, and services continuing to grow, it is experiencing significant shifts. According to "CNC Worldwide Outlook," a recently updated study from ARC Advisory Group (Dedham, MA), the worldwide CNC market exceeded $3.7 billion in 2000 and will exceed $5 billion in 2005.

"A market once dominated by Fanuc has now seen one of the most significant shifts in the last 15 years," says Sal Spada, senior analyst at ARC. Marking this shift are acquisitions, joint ventures, and mergers, making the CNC market no safe haven for suppliers offering a simple commodity solution. "After this period of consolidation is over, the only survivors will be niche market players and global suppliers," Spada says. "Price competition in the machine tool metalcutting and fabrication sector will continue to seek lowest-cost solutions that will allow many specialty CNC suppliers to coexist in this market. "

One technology partnership announced in May is advancing the cause of open-architecture CNC, defined as an unbundled software application (i.e., not tied into proprietary motion-control hardware) that provides unconstrained access to all data items within the control, and leverages commercially available PC hardware. Manufacturing Data Systems Inc. (MDSI, Ann Arbor, MI) announced a multiyear product development and license agreement with Hurco Companies, Inc. (Indianapolis, IN), which makes milling machines, turning centers, press brakes, and tooling, as well as control software, computerized machine systems, and industrial automation products.

The multiyear agreement consists of a development agreement and a software license agreement. Under the development agreement, Hurco will integrate MDSI's OpenCNC software as a core technology component onto its own next-generation patented openarchitecture software system. The multiyear software license allows Hurco to use MDSI's OpenCNC software on the company's SmartNet product line.

MDSI's OpenCNC product, in production since 1993, is an unbundled, open-architecture, all-software CNC that runs on Windows NT, providing a common control technology across a range of machine tool types, including single and dual-turret lathes, single- and multiple-spindle milling machines, grinding equipment, gear hobs, gantry machines, and dial index machines. The software has a three-tier architecture that isolates high-priority machine-control tasks such as trajectory planning from toolpath preparation tasks and user-interface tasks. All three layers, though, share a single, real-time database that OpenCNC dynamically configures for maximum machine functionality for a given set of tasks. As opposed to proprietary hardware-based CNCs that can require multiple processors, OpenCNC's advanced scheduling and control algorithms use only a fraction of a single Intel processor, allowing other applications to run at the machine tool on the same chip.

Moreover, the open, real-time database provides an important gateway for collecting and distributing realtime manufacturing data and rapidly integrating thirdparty applications. Called Significant Events in OpenCNC, it allows gathering production, maintenance, or quality data directly from the machine tool without operator intervention or specialty hardware. Such critical data can then be imported into a company's chosen manufacturing execution system/ materials requirements planning (MES/MRP) software. It can do this because it supports Microsoft's object-oriented standards in Windows, including Windows DNA (Distributed Internet Applications) for Manufacturing, and OLE/OPC (Object Linking and Embedding for Process

Control). Realtime data technology in OpenCNC software will be combined with Hurco's patented real-time object-oriented software to provide manufacturers not only the ability to use high-performance machining, but also to gather and broadcast machine data throughout the manufacturing enterprise via the Internet. Access to machine data that can be pushed across a factory intranet or the Internet gives Hurco the opportunity to offer additional services such as online support, online engineering, and remote machine and process diagnostics to its customers.

Open-architecture CNC also is making advances at the device level. Earlier this year, MDSI announced it has created a new digital device driver for OpenCNC software to support the Yaskawa Mechatrolink digital communications network. The new MDSI device driver makes it possible to support an open digital communications link to the Yaskawa family of digital servo drives, inverters, and I/O. This is the first time an independent third-party CNC company has been given access to Yaskawa's Mechatrolink interface and invited to integrate new technology.

Yaskawa (Waukegan, IL) is a $3 billion global manufacturer of motors and drives.

The benefits of integrating an open-architecture, all-software CNC with a digital-device communications network system include shortened setup time, as no ribbon cable or related hardware are needed. All communications can take place with a single interface cable. Improved communications between the CNC and drives means improved device performance, whether those drives exist on a spindle, robot, or machining center. "This new device driver for Yaskawa also gives MDSI access to drive technology available from one of the most dominant suppliers in the world," says ARC's Spada.

"For Yaskawa, this relationship ratifies our own approach to open architecture," says Dennis Kostrzewski, Yaskawa senior manager. "Our drive products have been 100% digital for some time, but the full advantages were only available with our own general motion and digital network solution. Having an interface into an open digital CNC software helps MDSI and Yaskawa customers realize all the performance characteristics already built into our products. There's no need for any D/A interface on the servo side."

The first people who benefit are the machine-tool builders, Kostrzewski continues. The most immediate benefits are reduction of internal wiring and the ability to gain diagnostics from the device. The user benefits in that the resulting machine is usually more compact, taking up less space on the floor. The machine controls system is tightly integrated for maximum performance and flexibility. Fewer connections also make the machine tool inherently more reliable, and faults become easier to identify. The MDSI/Yaskawa relationship is a significant step forward for machine controls and open-architecture CNC, "and we're focusing on actual motion and machine performance, and anything that improves those properties," Kostrzewski says.

While Yaskawa offers a wide selection of servos, inverters, and I/O for a complete solution, an MDSI customer can choose from more than one vendor, mixing Mechatrolink devices and DeviceNet I/O for best advantage, in keeping with the definition of open architecture.

MDSI sees the relationship with Yaskawa as advancing the cause of open-architecture CNC. "It's no longer a question of open architecture becoming the standard of choice, it's how long will it take to achieve dominance," says MDSI president and CEO Jim Fall.

This isn't the first time MDSI has interfaced OpenCNC with a device driver. Last year, the company developed an interface in collaboration with Rexroth Indramat (Lohr, Germany) and its SERCOS (Serial Real-Time Communications System) network for communicating with Rexroth servo drives and controllers. As in the Yaskawa relationship, the SERCOS interface allows controlling and monitoring servo drives from a single PC with one fiber-optic cable and a passive communication card between the PC and the drive.

Validating the rational design of the MDSI CNC software is the fact that it took less than a month to integrate OpenCNC with the Yaskawa Mechatrolink digital communications network.

Manufacturing engineers, as opposed to controls engineers, are the real beneficiaries of CNC improvements. "Even with an economic slowdown and reductions in spending, people are still looking at means of streamlining production," says MDSI's Fall. "The need for continuous improvement is even stronger today than it was 10 years ago, and manufacturing engineers are challenged constantly on this point. Open-architecture CNC provides a real tool to do this. The possibility of regularly using remote diagnostics, which MDSI's OpenCNC makes possible, goes beyond how to monitor and fix a single machine. It makes it possible to fix a broken process. The data points the way to fixing a process before it's seriously broken."

CNC software package for existing program

Lori B. Bok

The company has released JenCNC, a 3D CNC software package designed to run its SmartMotors program. It combines features of both a CAD/CAM and a motion-control software package into a graphical user interface for controlling two to four SmartMotors in 3D coordinated motion.

The software offers real-time 2D and 3D plotting to the screen, DXF-to-G-code conversion and conversational G-code building.

It also uses a serial interface to communicate and control SmartMotors. With its ability to run in a constant vector velocity regardless of changes in direction, the software is said to be useful where dispensing, glue flow rate or adhesives is needed for a given process.

The software has been built on 3 years of infield testing and customer feedback in applications including routers, hot-wire EPS foam cutting, milling machine retrofits, sign making, engraving, CNC drilling, gasket cutting and adhesive applicators.

Features that increase throughput and quality, according to the company, are that upon start-up, the software automatically detects motors and performs a system update if any motor was changed out; a machine settings window allows for customization to physical dimensions of the machining space; and machine tolerance levels can be set to ensure that no product damage occurs in the unlikely event of motor drop out or path divergence.

For more information from Animatics, call (408) 748-8721 or enter MMS Direct code 682TD at www.mmsonline.com

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Plugging into STEP NC - Emphasis: CNC - CAM software firms offer programs for CNC machines

Mark Albert

CAM software companies are offering software programs that allow their users to read STEP-NC files info their existing CAM software to generate the tool path and output for specific CNC machines. These "plugins" make many of the benefits of STEP-NC available to the average machine shop today.

The concept behind STEP NC is simple. It enables a product model database to serve as direct input to a CNC machine tool. No separate files of tool paths. No G or M codes. No post processors.

This is a radically different approach to CNC programming. It has far-reaching implications for the emerging possibilities of "e-manufacturing." Recent developments, however, promise to make it easier for CNC machine shops to make the transition to this technology Without scrapping existing machine tool and CNC programming technology, shops now have a way to implement key aspects of STEP-NC.

Several leading CAM software companies have made it possible for STEP NC files to be used with their own software. This makes their users ready to participate in supply chains that are turning to global data exchange standards to streamline the flow of digital information over the Internet.

According to STEP Tools, Inc. (Troy, New York), a leading supplier of STEP software toolsets for application software developers, design firms and manufacturing companies, STEP NC offers significant savings to machine shops and their customers. The company estimates that, by fully implementing STEP NC, machine shops can reduce the time it takes to get jobs onto their machines by 35 percent if they can seamlessly read the 3D product geometry and manufacturing instructions of their customers. Likewise, original equipment manufacturers can reduce the time they spend preparing data for their suppliers by as much as 75 percent if they can seamlessly share the design and manufacturing data in their databases.

STEP Tools also estimates that STEP NC will reduce machining time for small- to mid-sized job lots by as much as 50 percent because STEP NC compliant CNC units will be capable of optimizing speeds and feeds with very little intervention from CNC programmers or machine operators. This factor could make it easier and safer to program high speed and five-axis machines, the company says, making it more likely that they will be used for small- to mid-sized job lots.

STEP NC In A Nutshell

STEP NC is an extension to STEP, the STandard for the Exchange of Product model data. STEP is the international standard that specifies a neutral data format for digital information about a product. STEP allows this data to be shared and exchanged among different and otherwise incompatible computer platforms. STEP NC standardizes how information about CNC machining can be added to parts represented in the STEP product model.

By using STEP NC to capture instructions on what steps to follow for machining the part, the "producability" of this part would not be affected by the availability a certain brand of control unit, programming system or post processor. Figure 1 compares the key features of STEP NC to current conventional approaches to creating CNC machine tool input.

If equipped with a STEP NC compliant CNC, any suitable machine tool could be designated to make the part. Because a product model database can be made accessible through the Internet, this designated machine tool could be linked to this global network virtually anywhere on earth. For manufacturing enterprises participating in a highly competitive global supply chain, this kind of flexibility is crucial. With the Internet acting as a global DNC system, the world becomes one big job shop.

Step Rather Than Leap

The availability of STEP NC software plug-ins for CAM software puts STEP NC within the reach of many shops. Currently, plug-ins are available for Gibbs

CAM from Gibbs and Associates (Moorpark, California) and for Mastercam from CNC Software (Tolland, Connecticut). A plug-in for Esprit from DP Technology(Camarillo, California) will be completed soon. With these plugins (or "add-ins," as they are also called), a shop can take in a customer's STEP NC files and produce parts on existing CNC equipment.

A full implementation of STEP NC would involve equipping machine tools with CNCs customized with special software. This software enables the CNC to interpret the STEPNC data directly and use the information to machine the part without a conventional G-code program. This software is currently under development.

Machine tools with PC-based open architecture control systems may be able to install this software to upgrade to STEP NC compatibility rather effectively. The conventional input/output (I/O) structure and the servo system of the CNC machine do not need to be modified under STEP NC.

Of course, a great many perfectly serviceable CNC machines are not candidates for STEP NC operation. Likewise, legacy data in the form of existing G-code part programs must be preserved.

Shops are understandably reluctant to jeopardize these resources, even as they move toward STEP NC in future planning. The new plug-ins make it unnecessary to make a full leap to STEP NC.

Essentially, a STEP NC plug-in provides a bridge between conventional CNC programming and the product-model-as-input approach of STEP NC.

A STEP NC plug-in converts a STEP NC file into the data structures of an existing CAM system. Once converted, the data can be used to generate tool paths the way the CAM software would process part geometry derived from a CAD file or other source.

The resulting output would also need to be postprocessed to produce machine-specific CNC code.

One key advantage to this approach is that the shop can promote its capability to accept STEP NC files. Knowing that the supply chain is populated with these manufacturing resources will encourage OEMs and large prime contractors to implement STEP NC. Ready access to job shops with STEP NC adds to the' incentive for OEMs to adopt STEP NC as a means integrate machining instructions in the STEP product model database. As demand for STEP NC-enabled job shops grows, job shops will find it easier to justify the investment for full STEP NC implementation, which gains them all of the advantages of this streamlined approach to CNC operations.

The plug-in strategy reflects the wisdom of STEP NC developers and supporters. It tends to break the "you-first" syndrome that has stymied other standard-making initiatives. Creating momentum behind the implementation of STEP NC will speed the introduction of affordable STEP NC products to benefit both job shops and their customers.

Plug-In Demo

How a plug-in enables a conventional shop to use STEP NC files was demonstrated in February 2002, at the Industry Review Board meeting for the Model Driven Intelligent Control of Manufacturing (MDICM) project. The MDICM project, chartered to develop and deploy a digital input standard for CNC machines and awarded to STEP Tools, Inc. as the main contractor, is funded by the National Institute of Standards and Technology (NIST), an agency of the U.S. Commerce Department's Technology Administration. STEP NC is that digital exchange standard.

The Industrial Review Board--consisting of representatives from manufacturing companies, CAD/CAM software vendors, machine control builders, government and defense agencies and job shops (all stakeholders in the effort to streamline machining and manufacturing)--operates under the contract to help make sure the project truly meets its needs in a practical, realistic way. The demonstration was held at Experimental Machine Tool & Plating Company in Troy, New York. This shop specializes in precision machining of complex workpieces in small lots, often on a prototype basis. With four CNC machining centers and four CNC lathes, it typifies the advanced job shop serving the aerospace and defense industry. The nearby Watervliet Arsenal is a frequent customer.

In the demonstration, the shop read a STEP NC-formatted file into its GibbsCAM programming system using the plug-in for this software. The plug-in converted the STEP NC information into GibbsCAM data structures and then used GibbsCAM to generate the necessary tool path and output machine specific code. The part, shown on page 80, was then machined in aluminum on the shop's Mon Seiki MV-65 machining center.

The demonstration also made use of GibbsCAM's Cut Part Rendering functionality to validate the machining process, and the Reporter functionality to generate corresponding process documentation. See Figure 2.

Because this is the final year of the 3-year ATP contract, demonstrations of STEP NC technology are vital to illustrate STEP NC's viability, raise general awareness of STEP NC and move STEP NC "from science fiction to within the horizon of realization," to borrow words from STEP Tools.

Clicking To STEP NC

A review of the online STEP NC resource can be seen at www.stepnc.com. STEPTools is offering a downloadable version of its plug-in technology for GibbsCAM and Mastercam. The plug-ins are not initially available for production use. However, interested manufacturers can view and test-drive the technology as it is continuously improved in the coming years. The technology will benefit greatly from Phase One implementers who will use it to begin the process of integrating STEP-NC into their manufacturing programs and supply chain. This core group of companies will be breaking new ground in machining, and ultimately these advancements will be felt throughout the NC community.

For more information about GibbsCAM from Gibbs and Associates, call (800) 654-9399, enter 37 at www.mmsinfo.com to visit Online Showroom, or write 37 on tire reader service card.

For more information about Mastercam from CNC Software, call (860) 875-5006, enter 38 at www.mmsinfo.com to visit Online Showroom, or write 38 on the reader service card.

For more information about Esprit from DP Technology, colt (805) 388-6000, enter 39 at www.mmsinfo.com to visit Online Showroom, or write 39 air tire reader service card.

To contact STEP Tools, Inc., call (518) 687-2848 or visit www.steptools.com.

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The role of STEP NC in emerging approaches to push-button CNC programming is explained here.

For the link to these articles, visit www.mmsonline.com/articles/070203.html

RELATED ARTICLE: Key Features Of STEP NC.

STEP NC describes "what" not "how"

* Make this geometry from this stock

* By removing these features

* In this order

* With this tolerance

* And with tools that meet these requirements

The old standard described "how"

* Move tool to this location

* Move tool to this location

* And so on for millions of commands

Data For Inside And Outside

"For the [manufacturing] enterprise, STEP NC allows the same data to be used by the external and internal supply chains," writes Martin Hardwick, president of STEP Tools, Inc., in a recent white paper on automatic programming of CNC machines.

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Dr. Hardwick explains that, with STEP NC, all the data required to make apart is included in one AP-238 file. (Under the ISO STEP standard, STEP NC is designated as AP-238. It is an "application protocol," one of the sets of definitions for data related to a particular industry or type of product such as, in this case, machined parts.)

An AP-238 file contains the part geometry, geometric dimensions and tolerances of the finished part, along with the manufacturing features, the tooling and the material. Thus, Dr. Hardwick points out, STEP NC means that STEP now covers the capability of both IGES (CAD exchange files) and RS 274D (conventional G and M code CNC programs) in one specification. In the past, if a part were to be made in-house, a company sent an RS 274D program to its shop floor. If the part was to be farmed out to a job shop, the company sent out an IGES file. Whether the part is made inside or outside, STEP NC allows manufacturing to be driven from the same database.

It is simpler for a CAM system to produce AP-238 data than RS 274D data because AP238 data does not require the data to contain machine tool specific tool paths, Dr. Hardwiek notes. Any system that currently produces RS 274D data can produce AP-238 data if it understands manufacturing features. He sites Unigraphics, CATIA and Pro/Engineer as examples of such systems and predicts that these systems will be enhancedsothatAP-238 data is available from them.

AP-238 datagives designers and engineers the assurance that the digital information about machining critical components remains in a viable database and will be available for manufacturing those components throughout the product's life cycle. This contrasts with the conventional approach wherein the digital information about machining a part is locked up in RS 274D data. This data may reside only with an external supplier such as the job shop contracted to machine the parts.

Likewise, this data may be valid only as long as that shop has the original or compatible resources used to generate it. Changes to these resources-the

CAM software is no longer supported, the machine tool or its control unit are replaced, for example--are likely to occur before the product's life cycle expires, thereby jeopardizing the availability of machined parts critical to the product.

STEP NC protects machining data as a key manufacturing asset. As long as the company has its database of STEP NC files, the parts can be manufactured regardless of what happens to the external or internal supplier.

An efficient CNC programming approach based on group technology

Djassemi, Manocher

Abstract

Many studies and reports support the significant impact of the application of group technology on various aspects of product design and manufacturing. The fact that group technology is the common solution to similar problems is the main source of such impact. In this paper, one of the less frequently utilized features of CNC technology known as parametric part programming is used to implement the common solution feature of group technology in processing a set of similar parts. Using three part families, the advantages of blending the concept of group technology and parametric programming for CNC machining operations are illustrated. The efficiency improvement due to the use of parametric programming in terms of number of setups

and size of program is discussed.

Keywords: Group Technology, Computer Numerical Control, Parametric Part Programming

Introduction Group Technology (GT) is a broad concept that uses common attributes to reduce redundant work in design and manufacturing and results in shorter product development and production time. This GT feature-shorter product development and production time-provides a significant advantage for manufacturers by enabling them to respond faster to market demand/changes and run production more economically in today's highly competitive manufacturing environment.

A significant amount of research and case studies in group technology shows that GT improves productivity in one or more aspects.1,2 The application of GT covers areas as diverse as design, process planning, tooling, scheduling, part programming, and material handling. In all cases, GT is used to find a common solution to a set of similar problems, that is, designing similar products or processing similar parts. Likewise, GT is used to classify part designs, allowing the efficient grouping of similar designs that can be manufactured on the same machine or machine cell. First, the approach avoids duplication of data in a database; and second, it results in significant reduction in both number and variety of CAD files, process plans, and NC part programs. Many companies in the US and Europe have adopted GT for standardization of design and production techniques.3

This study is focused on the implementation of the GT concept to a specific aspect of computer-aided manufacturing, that is, numerical control (NC) programming of machining and turning centers. The common solution for similar problems (CSSP) feature of GT and the parametric programming capability of computer numerical control (CNC) machines will be used to develop a single NC program for each part family. For CNC machine users, the combination of CSSP and parametric programming approaches is expected to create the opportunity to generate NC codes and

operate CNC machines with greater efficiency. CNC machining or turning centers lend themselves to the CSSP concept in two ways: common tooling and common programming for a family of parts. When a family of parts is processed on these machines, tool indexing and loading/unloading are performed less frequently because most parts can be machined by a set of common tools. Similarly, the parametric programming feature of modern CNC machines allows a common program to be used for machining a number of similar parts.

Considering the potential benefits of such an application for group technology and CNC machine users, a study to link the parametric programming technique to GT system is appropriate.

Using three examples, the efficiency improvement due to the joint application of the two technologies is discussed in the following sections.

Parametric Part Programming

Traditionally, separate part programs are written for individual parts within a part family; then the programs are loaded to the machine controller one by one.

Most CNC machines have a special feature known as parametric programming, also referred to as macro,4 in which a part program can be written using variables and parametric expressions to represent the machine axis position (x, y, z, a, etc.), feed, and speed functions.s Similar to computer programming languages such as Pascal or C, computer-related features such as variables, arithmetic, logic statements, and looping can be implemented in a parametric program. This programming feature allows the user to load a single part program for a family of parts to the CNC controller.

The part program is then called up for machining a similar part or similar feature on different parts. The process involves a simple entry of parameter values into the machine controller. For example, several cylindrical parts may have two common parameters, such as diameter and overall length. A single parametric part program can be called up from a main program for machining such a group of similar parts. Upon loading the main program, the values of the two parameters are entered; then these values are transferred to parametric subprograms. This approach could minimize the number of program changeovers, reduce the redundant codes in the part program, and shorten the length of the program.

Methodology

In this study, three part families are considered to investigate the effects of blending CSSP and parametric programming in improving the efficiency of CNC operations. The efficiency improvement is determined based on two factors: (a) number of program changeovers and (b) number of NC files and size of part program. As the number of part types within a part family increases, the number of program changeovers or setups is expected to increase. The number of NC files and the size of the part program can have a significant effect on file management and memory space when the number of part types within a part family is relatively high. Based on the aforementioned factors, an efficiency improvement (EI) measure is defined as follows:

The weight factor, W, is empirically determined using a Bridgeport CNC mill and a PC. It was observed that the ratio between the times to change programs, including clearing the control memory, and locating a program to program downloading time from a PC to CNC is roughly 4:1 (W = 80%). This indicates that for the cases studied here, the effect of program length on EI is not as significant as the effect of machine stoppage for program changing (see Table 1).

Analysis of Results

Part family I consisted of five parts (n = 5), as illustrated in Figure 1. A single parametric part program for machining this part family is shown in the Appendix.

The numbers of instructions in conventional NC programs for individual part types were 66, 37, 132, 104, and 132. The number of executable NC instructions in the corresponding parametric program was 45 lines. The overall EI due to application of parametric programming was 74%. However, if the number of part types in the part family grows and the new part members are different from the old ones only in terms of values of specified parameters in the program, such as diameter and overall length, then EI yields greater efficiency in programming the CNC machine. For example, for 15 part types (n = 15) the EI increases from 75% to 85%.

Part family II consisted of four parts (Figure 2). The number of NC instructions for individual part types were 27, 53, 8, and 34 lines for this group. The number of NC instructions in the corresponding parametric program was 25 lines (see the Appendix). The use of parametric programming resulted in a 64% improvement in programming efficiency. When a larger number of similar parts (n = 15) were included by changing the value of the parameters, including external radius, thickness, diameter of center pocket, and number of holes, then the EI improved from 64% to 78%.

Part family III consisted of four parts (Figure 3). The number of NC instructions in the conventional part program remained at 53 for all part types. The number of NC instructions in the corresponding parametric program was 25 lines. The use of parametric programming resulted in a 64% improvement in programming efficiency for this part family. By changing the value of four parameters, including length, width, thickness, and number of slots, additional parts may be included in this group. Increasing the number of part types to 15 improved the EI from 64% to 85%.

Table 2 summarizes the comparison results of the two methods of NC programming applied to the three part families under study.

Conclusion The results of this study support the findings of many other reports and studies regarding the effects of adopting group technology in improving the efficiency of manufacturing operations. The parametric programming approach was used as a means to implement the common solution for similar problems (CSSP) feature of group technology in CNC machining operations where there are some similarities among the parts. The numerical results showed an improvement in efficiency of NC programming after applying the parametric programming approach to three part families. Such improvement is more signif icant when the number of part types within a part family is relatively high. It is recommended that GT users adopt parametric programming for large part families or whenever there is a growing trend in the size of the part family to minimize program changeovers and the number of similar NC files. A threshold value for part family size can be determined based on a cost-benefit analysis considering the time for program changeover and the time to write the NC program in conventional and parametric fashions.

In today's competitive economy, manufacturing companies have no alternative other than taking advantage of the new technologies in improving the efficiency of their operation. Parametric programming as the best-kept secret of modern CNC machines5 is already at the machine tool users' disposal. Surveys on successful applications of parametric part programming in group technology facilities would be an appropriate extension to this study.

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Author's Biography

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Djassemi has five years of industrial experience and is a certified manufacturing engineer. His primary areas of teaching and research are conventional and CNC machine tools, robotics, CAD/CAM, group technology, and cellular manufacturing.

AutoCAD SchoolBox has Designs for the Classroom; New Customized Package Introduces Students to Computer-Aided Design

SAN RAFAEL, Calif.--(BUSINESS WIRE)--May 4, 1995--A new, customized package of the world's most popular computer-aided design software is providing the software and curriculum resources educators need to introduce middle and high school students to the technical knowledge necessary for a skilled workforce.

Autodesk Inc.'s AutoCAD(R) SchoolBox designed for middle- and high-school classrooms, combines AutoCAD (see note A) Release 12 for Windows with a set of classroom exercises. In addition, a Bonus Pack, introduced today and available free to educators purchasing AutoCAD SchoolBox, provides an array of curriculum resources including: -0-

-- A videotape featuring successful classroom programs

-- Detailed product demonstration disks

-- A sample course overview and hands-on exercise guide

-- A subscription to Autodesk's education newsletter and the CompuServe(R) on-line service

-- Reference resources: Command Reference manual, User's Guide, Tutorial -0-

AutoCAD SchoolBox is available through Authorized Autodesk Area Education Representatives (AERs), a dealer channel dedicated to serve the education community, for a suggested retail price of US$595 per license, an 85 percent discount over the commercial price of AutoCAD software. -0-

(Note A) U.S. News & World Report named CAD the number one business tool of 1994. -0-

"I'm trying to be a guide on the side, not a sage on the stage," said Pat Vernon, an educator at Pennsylvania-based State College Area High School who has used Autodesk products in his classroom. "AutoCAD is a tool for provoking my students' imaginations and solving real-world problems. Now when the bell rings, no one gets up and leaves -- everyone just stays and works."

Students in Vernon's classroom have used AutoCAD software to plan dormitory rooms, design stage sets, and map a Norwegian valley. Other educators concur that using software tools such as AutoCAD teaches students problem solving, an important approach to learning. Their classroom projects have included modeling historic buildings, simulating the effects of a solar eclipse, and designing products such as kneepads.

"The early introduction of computer-aided design to students stimulates their imaginations and equips them for productive working lives," said Jim Purcell, director of Autodesk's Education department. "AutoCAD SchoolBox provides students access to the world's leading CAD package, and the Bonus Pack gives educators curriculum resources at an affordable price to help them in their roles as teachers."

AutoCAD SchoolBox is the latest offering from the education department, a group of 28 professionals dedicated to providing the software and services that prepare individuals for careers in design. Recognizing that educator and student needs are different from those of commercial users, Autodesk Education offers special packages and prices to educational institutions, faculty, and students, and trains users through its network of Autodesk Training Centers worldwide.

While AutoCAD SchoolBox is aimed at providing middle- and high-school students an introduction to computer-aided design, the AutoCAD Release 13 Education Special Edition gives advanced students preparing for design careers access to a comprehensive set of design tools including the latest version of AutoCAD as well as AutoVision(TM) and AutoCAD(R) Designer.
System Requirements

IBM or compatible personal computer with 80386/486 microprocessor and 80387/487 math coprocessor; Microsoft Windows(R) 3.1 and MS-DOS(R)

3.31 or higher; 8MB RAM; 8MB minimum hard-disk space; and Windows-supported VGA monitor and pointing device.

AutoCAD SchoolBox is available through an AER. AERs will work with customers to develop a complete program that meets the needs of both teachers and students. AutoCAD SchoolBox is available exclusively to educational institutions. To locate an AER, customers can call Autodesk at 800/964-6432.

About Autodesk

Autodesk is the world's leading supplier of design automation software and the fifth-largest PC software company. The company develops, markets, and supports a family of design automation and professional media software, and component technologies for use on personal computers and workstations. A global company since its founding in 1982, Autodesk markets products in 118 countries and 18 languages. Autodesk shares are traded on the Nasdaq National Market under the symbol ACAD. For more information, please call 415/507-5000 or type GO ADESK on CompuServe.

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CONTACT: Autodesk, Inc.

Carrie Bustillos, 415/507-6415

For CAD/CAM, is Windows just another pretty face? - computer-aided design/computer-aided manufacturing - Scanning the Horizon

Jon Perry

This, from Jon Perry, a senior applications engineer at Solutionware Corporation (San Jose, California), a noteworthy vendor of CAD/CAM software written for operation in Microsoft

Windows:

A graphical user interface is the most obviously visible thing about Microsoft Windows and it does make life more pleasant for most people. But is that all? Is it just a pretty face with no real substance behind it for people - like machinists - who actually work for a living?

There is, in fact, another benefit that's even more important: Thanks to the way Windows handles memory, it allows software developers to do more with their applications. With DOS limited to 640 K of memory, you can only cram in so many features before you run out of room. Prior to Windows there were ways of getting around that barrier, but there was no standard way of doing it. Each software developer took a different approach which resulted in incompatibilities.

Windows changed all that with a standard way to go beyond 640 K, giving software developers more room to work. Take, for example, Solutionware's Geopath for Windows CAD/CAM system.

Application code for CAM software that can cut 3D surfaces takes a large amount of memory no matter how you do it. With the added memory of Windows, you can build in full 3D surface support - everything from basic entities up to splines and NURBS surfaces - but also take an approach that's more advantageous to the user.

For instance, most CAM systems create 3D cuts by approximating the surface in a series of short straight line segments. Rather than compromise the geometry this way, however, it's possible to maintain full accuracy and cut true arcs. In order to do so, the shape being programmed and cut must retain its original math form, and the same form must be used to generate the CL file, and finally the form can be output from the postprocessor in the form of true arcs. The result is shorter NC programs, more accurate parts, better surface finish, and less handwork for mold makers. This is the approach taken with the Geopath system.

Another example is the integration of high speed machining capability, which requires the ability of "look ahead" in a program to slow down or accelerate feed rates for accurate cuts at corners and radii. Some CNCs have their own look-ahead capability, but others require special G-codes to do it. For the latter, it's possible to apply look-ahead functions in CAM and modify feed rate appropriate to conditions to optimize each section of the cut for maximum speed.

Another area where Windows shines, quite literally, is in its standardization of graphics display drivers for video cards. This allows the use of large, high resolution monitors, and allows software developers to let users take full advantage of these big screens. The same is true for printer and plotter drivers, and helps insure applications can accommodate just about any commonly used output device. Standardization of the interface also makes it easier for Windows users to learn new applications, whatever they be, and that applies to CAD/CAM software as well.

In fact, the ability to run multiple applications on the same computer is still another advantage. Multitasking capabilities allow users to program one part while using a DNC function to cut another at the same time. It's even possible to cut a part while checking into another application, such as your accounting software.

To take full advantage of these new possibilities brought on by Windows, however, it's necessary for developers to write applications for it from scratch. If you merely adapt a DOS application, it's basically still the same thing with a bunch of added boxes and menus, which can look fancy but can actually get in the way. That puts more burden on the software developer since DOS is somewhat more forgiving of minor variations in application programming. In our case, we felt that starting from scratch was worth the effort, and gave us a chance to completely rethink our algorithms and procedures, allowing the software to work more the way that machinists work.

The true advantage of Windows is that it gives software developers the opportunity to create applications that fit more naturally into the shop environment and let people do the things they want faster and more efficiently, if the software is well designed. And that means a good deal more than just a pretty face.

CAD Design Tools get a Little Better

All the talk about outsourcing, multiple partners, follow-the-sun design engineering, and e-business has put collaborative and interoperability technologies on everybody's checklist of features for design tools. There's good news all around. The technology is real. And it is being incorporated in computer-aided design (CAD), computer-aided engineering (CAE), product data management (PDM), and other design-related applications, in fact, creating and sharing mechanical CAD (MCAD) information is getting better all the time. See for yourself.

Better Clicks

The latest version of Pro/Engineer 2001, the flagship solid modeler from PTC (Waltham, MA), features a "direct modeling" interface (other vendors call this a "heads-up" display). This interface lets users work directly with the geometry they're creating on-screen; that is, they can click-and-drag geometry into the desired shape, as well as selecting dimensional values from a drop-down list of most recently entered values. This replaces having users punch in parameters, dimensions, and the like from the keyboard (though that option is still at one's fingertips, so to speak). The upshot, says PTC, is that mouse travel and menu navigation for common activities is as much as 40% less than in previous versions of Pro/Engineer.

Better Functionality

Pro/Engineer now lets users create multiple variations of a design for process-specific tasks, such as analysis and manufacturing. These associative "process variants" are managed independently of the original design, letting designers make process-specific changes without having to revise the original design. Pro/Engineer also includes optimization technology that makes parts automatically adapt to stay in spec and meet desired functional requirements. The examples PTC gives are: "Cam shafts seek to stay in balance, containers strive to maintain correct volume, and mechanisms adapt to maintain desired performance and clearance objectives."

While PTC, SolidWorks (see February 2001, AM&P), and other CAD vendors prefer launching new CAD releases annually, IBM and Dassault Systems prefer the Energizer-Bunny approach: The releases keep coming and coming. The latest release is Version 5 Release 6 (V5R6), which comes only four months after V5R5, which came four months after V5R4. The latest release introduces an array of CAD/CAE/CAM enhancements, plus 17 new what-they-call products" to the Catia line, which now boasts 78 what-I-call "modules." (Many of these are mainframe-based Catia modules rewritten for desktop computers running Microsoft Windows NT or Unix operating systems. Running MCAD and such on conventional desktops may be a "better" attribute in and of itself.)

One of these new modules lets users manage multiple instances of a subassembly, wherein each instance has a different positional configuration. This eliminates the need for multiple copies of a subassembly and bills of material (BOM). Moreover, users can define assembly features across multiple parts in an assembly-in one step. These features remain within the individual parts, even when manipulated independently.

Another Catia module adds the human element into product development: Users create virtual mannequins to help evaluate operational activities (lift, reach, maximum weight), comfort levels, field of vision, and other human interactions with machines.

BeTTer TransLaTIons.

While you can "adequately" translate three dimensional (3D) geometry using IGES and STEP, translating the features in the models created by feature-based CAD programs is a stumper. A real stumper. According to the National Institute for Standards and Technology, interoperability problems for the U.S. automotive industry alone cost at least $1-billion per year.

It's getting easier, though. Translation Technologies Inc. (TTI, Spokane, WA) is an Internet-based service providing native-to-native, feature-based CAD model translations. These translations look and function as though they were created in the target CAD system. The company's Acc-u-Trans translation engine currently translates to and from Pro/Engineer and Catia; translations to and from SDRC I-DEAS, UGS Unigraphics, SolidWorks, and AutoDesk products are expected by the end of the year.

Translation involves five steps--all but one is automatic. These steps include a computerized review of geometric features in the incoming file, automatic native-to-native conversion of the geometry and features in the history tree, and automatic comparison of the original and new CAD files. Then a human steps in. An expert at TTI manually corrects the discrepancies identified in the comparison step. The last step is an automated quality-assurance check.

Translations typically take 24 to 48 hours and cost about $140. (An average file, according to TTI, is between 2 MB and 10 MB and contains about 100 features of average complexity.)

BeTTer WeBs.

Solid modeling is all well and good, but seeing these models move is better. Costing $2,495, version 7.0 of IPA (Interactive Product Animator) from Immersive Design, Inc. (Action, MA) spits animations out onto the Web based on the parts and assembly information in Pro/Engineer 2000, SDRC 1-

DEAS Master Series 8 and 1-DEAS Web Access, SmarTeam version 3, Solid-Works 2000, and Solid Edge version 9.

These are not "normal" AVI animations, though you can create those, too. You can interact with IPA animations--including zoom, rotate, manual explode-and selectively hide parts of the solid model. You can view these animations on any Windows desktop using IPA WebView, a free viewer, plus Microsoft Internet Explorer (version 4.0 or higher). IPA uses streaming technology and major-league compression to squirt these animations across the Internet. (Company officials say IPA files sizes are under 3% of the size of the original CAD models.) The Pro version includes a Web-publishing wizard to help you create HTML documents that include IPA animations, plus 3D product data, hierarchical product structure or tree views, BOM, and maintenance information.

BeTTer InspecTIons.

Comparing a CAD model to reality is easy with Geomagic Qualify, a $7,000 standalone program from Raindrop Geomagic (Research Triangle Park, NC). Geomagic Qualify shows the feature and geometric differences between CAD models and built parts (or between one CAD model and another). The source data, on the CAD side, comes from IGES or STEP imports; on the physical-part side, from scanned or touch-probe data. Geomagic Qualify aligns those data to make its comparisons. The graphical results use color to show deviations--either the whole range of deviation for detailed analysis or just a green-and-red display for "go/no go" decisions.

As needed, you can add comments or deviation data to the displays, and then generate a web-ready HTML report to share with colleagues. This report can include numeric details, multiple views, user-defined and annotated views, and view-specific notes and conclusions.

BeTTer InTrgraTIons.

"People still have difficulty managing design data and going through the evolutions of the design process, admits Mark McCoy, MDA marketing manager for SDRC (Milford, OH). Hence the impetus for SDRC's I-DEAS Enterprise, which integrates the company's I-DEAS MCAD products and Metaphase PDM system together.

This integration is unusual because MCAD and PDM are typically "technologies interfaced, but separate," says McCoy. This is important because the interface approach--regardless of vendor--involves additional software, intermediate and time-consuming steps to "publish" and synchronize data, and a can of worms regarding data accuracy. Nevertheless, SDRC's Team Data Manager interface worked admirably well in groups of less than 100 people who are in the same location. However, today's virtual design environments are often much larger than that, and they are usually globally dispersed.

Enter I-DEAS Enterprise, a "large-scale environment where many contributors can collaborate in realtime without having to wait for information to be published," says McCoy. In this wide area networked system, both MCAD and PDM users see the same Windows-like views of product structure and information. Sharing data across the extended enterprise requires only a single-step data check-in (based on access privileges). Neither team nor enterprise data need reside in the same physical location. And released data can have different rules for ownership, access, and management.

Say you're not on an integrated design platform. There are other tools for data sharing. SmartBOM, from SmarTeam Inc. (Beverly, MA), creates a BOM directly from a PDM-based product structure and then packages that plus related documentation into a "self-contained, self-extracting, compressed, and executable briefcase." Think of this as a self-extracting ZIP or StuffIt file containing Everything You Wanted To Know About A BOM. Not only is the resulting file lightweight--read "small"--but it comes with its own viewer, which doubles as an editor.

So you can edit, redline, and annotate to your heart's content, compare and consolidate BOM data from different suppliers, track changes, export and import the BOM to Microsoft Excel and other applications, and then close the file and e-mail it to someone else.

SmarTeam's SmartBriefcase does almost the same thing for product design. It packages together metadata, drawings, part data, part numbers, conventions, business rules, and optional tools.

At the receiving end, a user without any pre-installed software can view and annotate the information within the briefcase using the tools bundled with the data. Upon return back to the sender, SmartBriefcase will synchronize and merge the new data with production data.

Enterprise Information Environment

Enterprise

* Enterprise space & ownership

* FormaL DaTa SHarIng

* ConTroLLeD RaTe Of CHange

* DISTrIBUTeD gLOBaL Access

Advanced Collaborative Environment

Team

* SHareD Team space & ownerSHIp

* InformaL TO FormaL DaTa SHarIng

* HIgH RaTe OF CHange

* InTegraTeD AppLICaTIonS

Engineering Authoring Environment

User

* prIvaTe user space & ownerSHIP

* CAX & DOCUMENT AUTHoring

* OPTImIZeD TOOL performance

The 3-Tier Product Development Environment

To accommodate the fact that teams are not only made up of people within one company but may stretch across the globe and include representatives from various companies, SDRC has facilitated working together with its I-DEAS Enterprise, which integrates I-DEAS MCAD and Metaphase PDM together, eschewing the technology overhead that conventional interface approaches create.

A couple of cool tools for designers: although plenty of attention gets paid to many of the more mainstream CAD-related offerings, here are a couple that may pass under your radar. Yet if you're looking for fast collaborative development, both may be gear that you can't afford to miss

Lawrence S. Gould

1 LIKE AN ENGINEERING-AWARE NAPKIN

WHAT'S THE PROBLEM?

It's one thing to scribble engineering calculations and the barest wisp of a mechanical design on a napkin. It's another thing to transfer that stream of consciousness into a solids model. Engineers think in terms of mechanical relationships and engineering calculations, not in terms of geometric descriptions and modeling constraints, such as "a shaft is a circle extruded along a line," or "a spring is a cross section extruded along a helix." This approach, what Autodesk, Inc. (Tualatin, OR; www.autodesk.com) calls "functional design," explains Brad Juhasz, Customer Solutions Manager, Manufacturing Solutions Division (MSD), "is a more direct way to design in 3D."

WHAT DOES IT DO?

MechSoft, from a Czech Republic company of the same name but recently acquired by Autodesk, automatically creates mechanically correct engineering components. Think of it as the software equivalent to an engineering-aware napkin. The software uses a multitude of wizards that contain design rules and the "smarts" to walk you through the design process based on engineering calculations and your inputs for parameters such as load, pitch, reduction ratio, torque, and space constraints. The wizards also have the smarts to check that the design doesn't violate physics or physical constraints. When all is done, MechSoft produces geometry: The solid model of that part.

AREN'T WIZARDS ALREADY IN CAD PRODUCTS?

Yes, most CAD systems have templates and wizards for part and assembly design. Some of these wizards encapsulate engineering principles and corporate design standards. However, these wizards start from geometry to create geometry; they do not start with "first principles" to create geometry.

WHAT COMES WITH MECHSOFT?

MechSoft consists of calculations, a calculation-driven parts generator, and on-line engineering references: More than 50 engineering calculators (such as for weld and solder joints, brake design, and tolerances) and component wizards (such as for bolted connections; V-and toothed belt; involute and straight-sided splines).

A drag-and-drop content library that contains more than 1.5 million parts (bolts, bearings, nuts, pins, holes, etc.) representing all prominent international standards (including ISO, DIN, ANSI, JIS, BS, NF, CSN and STN). All of these parts are parametric models. They can be edited, linked to external databases, and recalculated and updated within the assembly.

[ILLUSTRATION OMITTED]

A built-in mechanical engineering handbook that provides the calculations to create mechanically correct parts. A database containing information mainly for machine design and product design, including material properties and other information for bills of material.

HOW DOES IT WORK?

Say a designer wants to minimize the mass of a gearbox. The designer launches MechSoft's Group Manager, which contains the functional assembly of the gearbox. The designer then links the Group Manager to templates for defining the driving and goal variables for the gearbox. Launching the Behavioral Optimizer module lets the designer input parameters for driving the variables, constraints, and goal (minimal mass). The Behavioral Optimizer then generates the smallest gearbox for requested power and speed.

OTHER THINGS TO KNOW

The MechSoft add-on exists for a number of solids modelers, including Autodesk Inventor, Autodesk Mechanical Desktop, PRO/Engineer, SolidWorks, Solid Edge, AutoCAD, and AutoCAD LT. For the time being, Autodesk will be honoring "contractual obligations" regarding MechSoft as a plug-in to non-Autodesk solid modelers. In time, MechSoft's technology will be fully integrated into Autodesk Inventor Series, not as an add-on but as core Inventor functionality. Eventually, MechSoft will only be for Autodesk products.

2 COMPRESSION EXPANDS COLLABORATIVE DEVELOPMENT

SENDING 3D CONTENT OVER THE INTERNET?

Yes. Lattice3D (Los Altos, CA; www.lattice3d.com) is offering a set of collaborative utilities that are said to go beyond being "just another" compression format. The company's mouthful "eXtensible Virtual world description Language"--XVL--is a proprietary, format-neutral, compressed lingua franca. The Lattice3D applications use XVL to exchange 3D content over the Internet and to let users interactively view that 3D content on the web or in software applications from Adobe, Microsoft, and others.

HOW DOES THAT WORK?

Lattice3D is really in the business of selling a bunch of applications that take native CAD data (and digital content creation, DCC), translate those data to XVL, and then manipulate those XVL files for publication. These publications can be manuals, parts lists, marketing brochures, assembly instructions--

even parts databases. The XVL compression format lets Lattice3D squirt the massaged CAD information across the Internet without bursting the electronic pipes that make up the "information pipeline."

REALLY "SQUIRT" 3D SOLIDS DATA?

Not exactly. The Lattice3D applications are not passing around cubes and such. They only work with surface representations of the solid primitives in the solid models. Also, the squirting is one-way. Only Lattice3D applications use XVL files.

HOW COMPRESSED IS "COMPRESSED"?

According to Marc Jablonski, Lattice3D's Director of Technology and Professional Services, the XVL compression ratio is between 50:1 to 200:1. Occasionally, for example with SolidWorks files, compression is closer to 300:1.

WHAT ARE THE XVL APPLICATIONS?

The XVL applications are basically utilitarian building blocks. The applications fall into basic categories. Converters translate CAD data into XVL. The converters can be plug-ins to native CAD systems or independent applications running on a server. The latter let users convert CAD data without opening a CAD session.

XVL Studio is an authoring tool. Users can add annotations, dimensions, hyperlinks, camera views, animations, texture mapping, lighting, and layers. Users can measure the distance of vertices/edges/faces, the angle of edges/faces, and the radii and diameters of circles. XVL Studio also supports point-cloud evaluations--and more.

"Publish" is another category. XVL Notebook can combine 3D data, 2D snapshots of 3D views, structured data, text, and other graphics into Office-like documents. These are essentially

ActiveX documents with embedded XVL. XVL Web Master lets users post XVL-based documents on the web without having to know HTML.

Two viewers are available. The free version is a plug-in for Internet Explorer and Netscape, or act as an ActiveX control that can be embedded into any Microsoft Office document. It lets users browse XVL-based 3D web pages, as well as examine objects, or walk or fly through a scene. The pro version includes advanced engineering functionality, such as measurement, cross sectioning, data visualization, and analysis.

Other XVL applications handle password access, encryption, and software development.

DO I BUY ALL OF THESE APPLICATIONS?

You buy what you need. For example, explains Jablonski, creating a 2D/3D parts lists involves converting your CAD data to XVL. Then you would use Web Master to produce the 2D/3D parts list. But maybe the Purchasing Dept. needs more information about those parts. Player Pro will let them cross section and take measurements of the parts. If a design review is involved, XVL Notebook will create a lightweight document to email to other reviewers who, also using Notebook, can redline and annotate as they wish.

"This could really be a breakthrough for 3D as a means of communicating,as a common media format, in parallel with 2D images, email, andelectronic documents." Marc Jablonski, Lattice 3D's

Director ofTechnology and Professional Services.WEIGHT LOSS WITHOUT DATA LOSSSUPPORTED FORMATS COMPRESSION RATIO* CONVERSION

Search by shape: new CAD-independent search engines automatically code and classify shapes for quick retrieval

Lawrence S. Gould

Group technology (GT) is based on order arising from the structure of part families. By identifying parts uniquely and grouping similar parts together, retrieving one part can lead to finding similar parts. Great idea. Useful in concept. And yet conventional GT search methodologies--namely, alphanumeric text-based search--fail primarily because of their manual roots.

Someone has to manually determine part attributes, manually code those attributes, manually tie those codes together to make up a part's identification number, and then manually enter those codes and ID numbers into a computer. Add to this, says Abir Qamhiyah, president of iSEEK Corporation (Ames, IA; www. iseekcorp.com), "Different users, different groups, and different applications will have different interests and different classification criteria." Moreover, she says, alphanumeric-based GT has "limited value because file names are often part numbers or cryptic references to the assembly in which the part belongs."

Shape search technologies follow the same GT philosophy. The only difference is in the implementation. Shape search uses 3D part geometry as the basis for the search, it is fully automated, and predefined clusters of shapes are not required. GT finally works the way it should. People find parts, similar parts, and even redundant parts fast.

How to search

CADSeek from iSEEK and Geolus Search from UGS (Plano, TX; www.ugs.com), and other shape search products do for parts what Google does with text: They find and display parts similar to the initial inquiry. That initial inquiry can come in various ways. There's the conventional textual approach: Users simply enter all or a portion of a part name or number, using wildcard characters if necessary. Or part metadata can be searched for specific part or shape attributes. Another approach is to load an existing file of the target part, or just sketch an image of the target part in the computer-aided design (CAD) program, and then have the search engine find similar parts. Suitable matches are displayed in a web browser for further inspection.

As necessary, users can rotate these displays to better visualize the shapes. Click on the desired shape and the search engine will go find similar shapes or open that shape file in CAD.

(Users can tell the engine how many results to return.) Users can also scan through (fly over) a 3D representation of the company's CAD library. This representation shows families, or "clusters," of similar shapes and parts. By clicking on a cluster, users can drill deeper into the specific part classification. Last, users can page through a digital parts catalog. The catalog shows 3D thumbnail images of parts, as well as part characteristics as text (metadata). Again, clicking on the desired image opens it up in CAD.

[ILLUSTRATION OMITTED]

[ILLUSTRATION OMITTED]

Behind the scenes

Shape search engines classify shapes in different ways. Explains Qamhiyah, shape in 3D space can be described by its voxels, the volume it occupies, or by the surface that surrounds it.

(A "slightly more sophisticated," but simplistic, voxel approach involves "thinning" the volume into a graph model, explains Qamhiyah.) The voxel methodology has problems in scaling, changes in orientation, storage requirements, and such. The surface-based approach, which is how CADSeek works, requires less storage and is faster to process. Geolus Search uses a hybrid approach. It looks at volumes (voxels), surfaces, edges, overall size, and other attributes of shape "to figure out exactly what's going to match," says Chris Kelley, vice president partner and platform marketing for UGS.

Implementation begins with source geometries in a tessellated file format (JT and STL for CADSeek; both those and VRML for Geolus Search). CADSeek takes the surface information and creates a point cloud for each part, which is fed into the search engine algorithm. (CADSeek can even take point clouds from CMM devices. Again, it only needs the skin of a part.) The CADSeek algorithm uses statistical analysis to classify the shapes, create a hierarchy of shapes, and cluster those shapes appropriately. The shape code for each shape is "nothing but a tag," explains Don Flugrad, senior vice president and COO of iSEEK. "Once you retrieve it, you can then pull out all other related information, including production information."

Production and other metadata comes from the CAD design files. At installation, the search engine scans the CAD files and captures field and field contents automatically. New fields are added as they come up in the metadata either during initial installation or later as CAD files are created or modified.

In general, the shape search products consist of three basic pieces. Various server-side components (including connectors, indexers, and the database) "perform all the heavy lifting," explains Kelley. These components convert the source geometries into mathematical representations of the shape. The second piece are the plug-ins that let users initiate a search from virtually any major product lifecycle management and CAD system. The third part is the web browser on the client side (typically, Internet Explorer, Netscape, and Firefox) to search and view results.

According to iSEEK officials. A typical search of 20 models in CADSeek comes back within a fraction of a second. A return with 400 matches takes 2 seconds, 1000 matches takes 5 seconds, and 2000 matches takes 17 seconds. According to UGS, the average insert/update time per part in Geolus Search is 15 seconds, and each part occupies about 15 KB of drive space.

CADSeek costs $25,000/seat for a concurrent (floating) license. For smaller organizations, CADSeek is typically $5,000 per named user. According to Kelley, the price of UGS' Geolus Search is based on database size.

Lawrence S. Gould

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by Lawrence S. Gould

CONTRIBUTING EDITOR

The Cost of Redundant Parts

According to iSEEK Corporation, a paper published around 1999 by the Parts Standardization and Management Committee of the U.S. Department of Defense (DoD) estimates that adding a part to a manufacturer's parts list costs slightly over $20,000.

Activity CostEngineering and design $9,300Testing $700Manufacturing $1,750Purchasing $3,800Inventory $875Logistics Support $3,750TOTAL $20,175

The DoD analysis does not include the cost of tooling for redundant parts, which significantly adds to the cost of each part.

Using the CADseek shape search engine on 5,000 parts from a major manufacturer revealed that nearly 5% to 10% of the dataset were redundant parts. Redundant was defined as 99% to 100% similarity.

What software do you need?

Lawrence S. Gould

"What software applications do I really need to run my business? What software is truly strategic, creates a competitive advantage, and genuinely contributes directly to return on investment and profits?"

Sorry, I can't give you a definitive answer. Every business is different in terms of goals, strategies, finances, production environment, sales channel, etc., so "your mileage may vary."

However, there are some categories of software that most manufacturing enterprises do need. Granted, some of these categories overlap, especially as more and more software vendors bundle in more and more features/functions/bells & whistles/capabilities into their core products either because of technology improvements, market demand, or sales promotion.

Nevertheless, consider, if not implement, the following.

PRODUCT DESIGN

Computer-aided design (CAD) is a given. Product design starts on paper, virtual as it might be these days. Nowadays, get a solid modeler (3D CAD), which is a better lead to digital mockup, and virtual product and process modeling. Such software also leads to better design documentation, better machining, and inspection programs, and higher quality surfaces for machining. Before machining, however, there are computer-aided engineering (CAE) and its subset finite element analysis (FEA) to consider. CAE simulates and analyzes the behaviors of materials, assemblies, and finished products to help validate designs, select the better design alternative, and identify design improvements.

Closely associated with CAD is product data management (PDM). PDM is more than document management; this application captures, stores, manages, and displays product information throughout the lifecycle of the product. PDM also supports engineering workflow, configuration management, and change control--all critical processes within engineering design. Production monitoring and control

Supervisory control and data acquisition (SCADA) software typically includes data acquisition, process monitoring and alarming, regulatory or continuous control, some sort of supervisory control, an operator interface, and management reporting. The sophistication of such software runs the entire gamut from, say, simple data acquisition and process monitoring, to dynamic, adaptive, self-tuning production control with workflow and management alerting capabilities.

At the very least, this software should capture data for work-in-process (WIP) tracking, including logging process start/stop times and log movement/queue times. It should also be able to generate serial numbers, perform revision control, and slice and dice the captured data every which way you chose--on demand. Needless to say, any data acquisition application should accept data from anywhere: bar code, radio frequency identification, machine controllers, and human key entry.

Computer-aided manufacturing (CAM) software probably also falls in this category. CAM software provides the intelligence for machine tools to perform. Machine tool manufacturers typically provide CAM software.

OPERATOR INTERFACE

A good operator interface (OI) is a must for seeing exactly what's going on in manufacturing. OI software typically comes with supervisory control systems, such as manufacturing execution system (MES) and SCADA. Or it can be bought separately, which creates a wonderful work opportunity for systems integrators.

In any case, a sophisticated OI provides a window into the operation of not only software programs, but of the plant itself, including machine tools, materials handling equipment, and the production line in its entirety. Some provide advanced alarming, routing management, statistical process control/quality control (SPC/SQC), and a high-resolution graphical display for viewing everything from CAD drawings to simulations.

PRODUCTION OPTIMIZATION

On the theory that "If you can model it, you can improve it," simulation software mimics the plant floor so that users can debug control system, visualize operations off-line or in real time, analyze production strategies and options, and to monitor, optimize, and stabilize production on line. Today's simulation systems typically use advanced mathematical models to simulate and predict factory floor operations. By changing the parameters within these models, users can analyze various operating scenarios ("what if") in their attempts to optimize operations. It's far cheaper to mess up a software model than a physical plant.

ARTIFICIAL INTELLIGENCE

Expert systems, an application of artificial intelligence, are primarily a database containing rules that capture the knowledge and thought processes of a human expert. While this class of software can be purchased separately, expert system capabilities are often found deep in just about all the software you buy today. Simple example: The ability of Microsoft Word's AutoCorrect to automatically change "hte" to "the."

Now apply such "expertness" to manufacturing. Overlay data collection, data analysis, and workflow on top of manufacturing rules, and you have a software system that can predict out-of-tolerance conditions and failures, perform capacity planning dynamically, smooth material flow and machining operations, provide fault diagnosis, and perform automated startup, shutdown, and recovery procedures, to name a few expert-needed applications.

QUALITY MANAGEMENT

Quality control and monitoring software, often associated with data acquisition applications, must be integrated throughout the manufacturing enterprise. These applications collect and store test, diagnostic, and repair data either from manual data entry or from automated test equipment. This software should provide both on- and off-line SPC/SQC tools, which can range from simple control chart reporting to sophisticated design of experiments and business intelligence capabilities. In addition, the software should maintain, or be integrated with software that maintains, vendor quality records and assist in vendor rating.

Most important, these systems must be able to report, report, report--both standard and ad hoc, batch and real time--on such matters as control charts, WIP and production equipment locations, and failure codes for component parts and production equipment. Now couple reporting with artificial intelligence, workflow, and communications capabilities. The result is an application that notifies the appropriate personnel about processes and process trends that are out of tolerance.

PRODUCTION MANAGEMENT

Tops among applications that manage production is MES. MES resides in that middle layer between upper management's transaction processing business system (namely, enterprise resource planning, ERP) and production's real-time dynamic operation. MES executes the resource plan generated by ERP, and it reports plant-floor and order status back up to ERP. MES addresses operational issues such as process data acquisition and management, document control, quality management, finite scheduling, resource allocation, and labor management.

If MES seems like overkill, consider at least some form of finite scheduling. Advanced planning and scheduling (APS) is the finite scheduler du jour. APS balances customer demand against the resource constraints existing on the production floor (typically machines, materials, and labor), and all of that against a company's business and production rules. APS production plans detail when to start and finish production, ideally after anticipating resource needs and the implications of technical, financial, operational, and business decisions.

The poor, back room stepchild in manufacturing has always been machine maintenance. No longer. Computerized maintenance management systems (CMMS) and the more all-encompassing enterprise asset management (EAM) systems are mission-critical applications that focus on performing plant maintenance before things break down. These systems cover maintenance areas such as equipment, labor, service and work order requests and management, preventive maintenance, statistical predictive maintenance, inventory, and purchasing.

There are other types of mission-critical manufacturing software to consider. In the early stages of production management, consider software for product costing, quoting/estimating, production routing control, and inventory control. At the back end of manufacturing, consider applications for inventory and warehouse management, logistics support, and field service.

Of particular note in the latter category is a warehouse management system (WMS). A WMS coordinates the movement of all material from the moment it enters the warehouse to when it leaves.

WMS directs both material handling systems and people to move materials from one station to the next. Besides database building, receiving, replenishment, put away, order accumulation, and shipping, a WMS needs to account for the movement--that is, traffic control--and safety of both personnel and material, handling equipment. It also manages those operations critical to inventorying, but peripheral to warehousing, such as in-bound inspection.

ENTERPRISE MANAGEMENT

Entire forests have been cut down explaining, documenting, selling, and justifying ERP (including material requirements planning and manufacturing resource planning). It all boils down to an enterprise-level business management system integrating a company's financials with human resources with sales and marketing with manufacturing with inventory and supply. It's the whole enchilada of business information--within the four walls of the enterprise.

SUPPLY CHAIN MANAGEMENT

As much as ERP's focus is within an individual enterprise, supply chain management (SCM) and its close cousin collaborative planning, forecasting, and replenishment (CPFR) integrate disparate enterprises--and their critical software system, whether that be ERP, inventory management, CAD, quality management system, or some sort of inventory system. Software in this category spans the breadth of business functions from forecasting and demand planning, through supply chain planning and scheduling, to customer order configuration, to supply chain execution. Separate software categorized as supply chain execution involves such fundamentals as order fulfillment, distribution (warehouse, transportation, and logistics), returns, and international trade activities.

AND DON'T FORGET

There's something nagging in the back of my mind. The more I talk to manufacturing software users and vendors, the more I'm convinced that there's really only one hunk of software that manufacturing really needs: a spreadsheet. It's a database. It's an analysis tool. It's a scheduler. It's a resource planner. It's so many things--when used correctly. And therein lies the nagging. Used incorrectly, none of the software mentioned here amounts to a hill of beans if manufacturing management doesn't know how to plan, monitor, manage, communicate, and analyze.

RELATED ARTICLE: The top 10 "gotchas" in enterprise software

Regardless of the enterprise application, several mistakes are common to all of them. Here are the top 10 problems manufacturing companies should have learneo to avoid from implementing

these applications in the 1990s.

* Enterprise applications are a major asset/liability to your company.

* Too much integration is bao.

* Enterprise apps are about standardization, not flexibility.

* Project management, project management, and more project management.

* No single vendor can address all of your application needs.

* People, not software, are what cost money.

* Don't use enterprise applications Beyond their proven limits.

* Managing enterprise applications is complex, and lifecycle tools are immature.

* Erp vendors do not understand the external world.

* Be wary of vendor claims.

(Source: Erik Keller, principal of Wapiti LLC)

CAD: FROM 3-VIEWS TO PLANS

Yarrish, Gerry

THE NUMBER OF CAD-DESIGNED MODELS on the market today is amazing. The days of developing specific tooling and dies to cut kit parts are all but gone; these processes are being replaced by laser cutting and CNC machining. Modelers also use their PCs to draw their scratch-built beauties. In the September issue, I talked about using CAD and the basic drawing tools included with it. Several readers had questions, and I address some of them as we look more closely at the techniques used to transform scale 3-view drawings into construction plans!

PLAN DEVELOPMENT

At this point, I assume that you know how to use your CAD program and can create the basic geometry needed to develop model plans. I also assume that you have chosen a 3-view drawing and have scanned it into an electronic image file. This is where the fun begins!

The process always begins with importing your image file land saving your CAD document. Next, use the zoom function !to enlarge the fuselage side view to the width of your screen. Draw a centerline through the middle of the prop shaft, and extend it to the tail. Now trace the fuselage's long gradual lines using the curved-line or "Spline" tool. Also, wherever possible, use the Circle and/or Ellipse tool to create crisp, well-defined curves. Do the same for the top views of the fuselage and horizontal stabilizer. Now trace one wing panel; note that most of the lines are drawn with the Straight Line tool. Usually, the wingtip will be the only place requiring curved lines. Finally, trace half of the fuselage front view.

From here, you may be tempted to begin adding formers, ribs and other internal details, but wait! There's one more thing to do. Compare the side and top fuselage views and make sure that they are the same length and that the wing land stabilizer locations coincide. If they don't, decide which view is correct and adjust the other view to match. Also check the wing and stabilizer top views, and make sure that they match their placement in the fuselage side view. More times than not, there will be minor discrepancies in even the best-drawn 3-views.

Before adding any internal details, make sure that your basic top-, side- and front-view elements all match in height, width and length!

DRAW TO FULL-SIZE

Once everything matches, but before you draw the various reference lines, use the Enlargement tool to adjust your drawling to the size you want your plans to be. The most obvious dimension to use here is the wingspan. Once you have enlarged your drawing, save the file. Also save a copy of the file and use it as a backup in case something happens to your original.

From here, you can add internal details and draw them in full scale. In the Wing Development drawing, you can see that I have drawn a P-40 Warhawk wing panel using straight lines for the leading and trailing edges, and I used the Circle tool to develop the wingtip's shape. Since the drawing is full-size, a 3/8-inch-wide main spar, a 3/8-inch-wide seciondary spar and 3/32-inch ribs. Servo and landing-gear details have also been added-all in full-size. All that would be required now is to develop the airfoil and to size it using the wing top view as a guide to develop all the ribs.

FORMER DEVELOPMENT

To accurately develop former shapes, it is important to start with a scale drawing that has at least a few of the main fuselage cross-sections shown. Begin with the top view (horizontal) and side view (vertical) reference lines and their relative positions to the fuselage centerline. Now combine the reference lines to form the overall height and width of the cross-section's front view. Next add the basic geometric shapes and trim away any unwanted parts. What's left is the outline of the cross-section. To define the former, add an offset line inside the outline to represent the thickness of the fuselage sheeting-typically, 1/8 inch. Now you can add the internal structures such as stringers and doublers. Define the former segments and again, delete any unwanted lines to show the finished former. Do this for all the cross-sections. To develop any additional formers, you have to do some plotting using the known cross-sections as a guide. But I'll show how to do that next time! Remember my CAD rule: work only on one side of the centerline and use the Mirror Image tool to complete your symmetrically shaped parts. Developing your model-design skills is all part of the fun and challenge of using a CAD program. Until next time, grab that mouse and keep on practicing.

FILE CONVERSION

SO FAR, I HAVE DESCRIBED HOW TO use CAD to trace over your imported image file to produce your plans' geometry. A great way to speed this process and to eliminate tracing errors is to convert your image file directly into a CAD file. An image file such as a bitmap, TIF, or JPG, etc., is made up of many tiny black and white dots, or pixels, and is saved as a raster file. CAD documents are saved as vector files, and they contain the "X" and "Y" coordinate information (start and stop locations) for all the line elements in the drawing. You can use a conversion program, or you can send your scanned image to a company that offers a raster-to-vector conversion service.

DesignPresentation Associates offers a raster-to-vector conversion service, and I have used it several times. This company can take any hand-drawn sketch or scanned image and convert it into any other type of file that you may want. For our situation, that would be either a .DWG or a .DXF format. Simply scan your drawing, send your image file via email and, in a very short time, you'll receive your vector file ready to be imported into your CAD program. Once it's imported, you can save the file and enlarge it to the drawing size you want. The service costs about $50 for a standard, single-page, 3-view conversion, but considering the time this service saves, it's a great investment. You can check out what DesignPresentation Associates has to offer at designpresentation.com, or you can email Gene Kang and ask for a quote; gene@designpresentation.com. Give Gene a try. I know you will love the results.

MODELING WITH CAD

Yarrish, Gerry

A popular topic that keeps popping up in the old mail bag is Computer-Aided Design (CAD) and its use in designing big models. Today, many kits have been developed using CAD, and these files are then used to produce kit parts. Laser cutters, CNC-driven routers, milling machines and even high-pressure water cutters (for metal parts) can be driven using CAD programs. For this column, I thought it would be fun to go through some of the basics for developing a set of model plans using a CAD program!

WHERE TO START

First, you can't just buy a CAD program and expect to start drawing plans overnight. Check out the various CAD programs available online and pick one that matches your budget and computer requirements. Once you've installed it on your PC, play with it until you can draw all the basic shapes and line types, and from there, you'll learn how to develop various geometric shapes. Several programs come with helpful tutorials on the basic functions of the program. If you really want to get into CAD, you can take classes to speed the learning process. Once you've mastered the basics, you can start developing your own model airplane plans.

There are two directions to take: you can design your own models and develop unique sport planes, or you can develop scale 3-view drawings and reverse-engineer them into workable model plans. The latter is what I discuss in this column, and here are some words of advice: before you start using a CAD program, study other people's plans to see how they laid them out and how they solved basic engineering and structural issues. This will help you understand the proper size of wood to use for specific purposes, the proper spacing of formers and ribs, and other such topics. Refer to drafting and drawing books, too, so you can develop a good sense of how things should look when drawn in top, side and front views. A working knowledge of drafting is a basic requirement for using CAD, so don't put the cart before the horse.

Find good-quality, detailed, 3-view drawings and scan them into a file that can be imported into your CAD program. Try to find a drawing with a few cross-sections shown. With PC-based programs, this would be a bit map (.bmp) format, and for you Mac users, a .pict file will do. You could use other formats, but these are the most popular. With the image imported into your drawing file, you can begin tracing it with the various drawing tools at your disposal. And it is here where many wannabe CADsters run into difficulty. When I started drawing plans, I began with simple airplane designs. Old WW I biplanes and homebuilts have fewer curved lines and are relatively less complicated to draw than more modern aircraft. Start simply, and work up to the curvier designs.

Here are my rules for drawing with CAD:

* USE LAYERS. Import your image and assign it to a specific layer. With my umwingBoard program, I assign the image to Layer 1, and I rename it "3-view." Place all the other drawing and details you add on their own separate layers. I typically trace the 3-view and then place the structure (formers, ribs and outlines of other parts) on a separate layer named "Plan." Details such as the engine, servos and such go on a "Hardware" layer and so on. In this way, you can look at specific items, or you can look at them all at the same time. Using layers really helps keep things straight in your head!

* USE REFERENCES. Start all plans with a centerline or a reference line. From this, you can ensure that things like ribs or formers are drawn square with or parallel to one another.

Vertical and horizontal reference lines also are important when you develop fuselage former shapes.

* THINK SYMMETRICALLY. When it comes to things like wings and fuselages (in top view), draw only one half and then copy and paste a mirror image to it to complete the drawing. Do all the work on one side of the centerline, and then duplicate it and flip it over to produce the other half. This ensures exact symmetry and cuts the work in half!

* SAVE DETAILS. Never draw anything twice! Draw things like engines, electric motors, servos, receivers, control horns, etc. once, and then save them into a master file. Drawing these things in top, front and side views is

also a great way to hone your drawing skills. After you have saved them, you can copy and paste them into new drawings. You can also enlarge or shrink them to make new master details.

* USE THE TOOLS. The palettes included with all CAD programs have many useful drawing tools and functions. It is always easier to use these tools than to draw freehand over your imported 3-view drawing. Geometric drawing tools for circles, squares, ellipses and arcs are all easy to use, and they'll make your drawings cleaner and more precise. Wingtips, engine cowls and other parts are easily reproduced by combining segments of ellipses and straight lines.

* WORK INWARD. After you've drawn your reference and centerlines, draw the outline of a wing half top view, fuselage side view, tail surfaces top views and half of the fuselage top view.

From here, you then establish the locations of main formers, doublers, landing-gear mounts, wing spars, ribs and so on.

* AIRFOILS. Investigate the many sources of downloadable airfoil plots or consider using an airfoil-generator program. These will save you hours of tedious airfoil layout work.

Above all else, remember that this is a hobby, so using CAD should be fun! For many, drawing plans can turn into another major part of the hobby. Before you know it, you'll have a whole collection of model CAD plans to show off to your friends. The hard part will be picking which ones to build and fly!

GRAPHITE

Ashlar-Vellum's Graphite is one of the easiest CAD programs I have ever used. It's an excellent 2D drafting tool that can be used to develop model airplane plans. Marketed as a professional 3D CAD program, Graphite costs $995-obviously not intended for the general public, but it should be! My previous experiences with the DrawingBoard (DB) program made me feel that Graphite was an updated version of DB.

Graphite has a very simple workscreen layout; it looks more like a simple art/ drawing program than a powerful CAD program. The tool menu, which includes the various line, circle and polygon tools, is at the left of the screen. Finding and using the tools is simple and intuitive. The program comes with an excellent users' manual as well as a "Getting Started" booklet; combined with its program tutorials, Graphite is as user-friendly as can be.

Graphite has an awesome alignment system that allows you to very precisely move and connect lines and other objects. Known as the "Drafting Assistant," this alignment feature replaces typed command inputs and replaces them with simple mouse clicks and drag-and-drops! Graphite also has an excellent set of line-trimming tools and a large library of often-used drafting symbols.

The big difference between Graphite and DB is the additional 3D drawing tools. To create items in an isometric view requires you only to draw a top view and then to enter a menu command to tell the program that you want a "Trimetric" view or "Wire Frame." You can even move the item in all three axes; nothing could be easier!

Look for a complete review of Graphite in an upcoming issue. Until next time, use those CAD programs and practice, practice, practice!

CAD on a Budget:

great tools at a fantastic price: not every firm or individual needs or can afford a major design application, regardless of whether the economy is booming or depressed.

Justifying the cost of an AutoCAD license can often be difficult, particularly if your needs are modest. Fortunately there are alternatives that are not only less expensive, but also quite capable - Cadalyst Labs Review

Ron LaFon

It should come as no surprise, but somehow it always does, just how capable and sophisticated the low-cost CAD applications on the market are. You expect that applications that cost several thousand dollars, such as AutoCAD, would offer a broad and extensive range of features that are applicable to a wide range of disciplines. The old saying "you get what you pay for" comes to mind. There's a tendency to think that CAD applications that cost in the hundreds, rather than the thousands, of dollars can't possibly be all that good. Mistake. Big mistake.

It really is possible to get a high percentage of the functionality of such design behemoths as AutoCAD for a small percentage of the cost, with the bonus of file-level compatibility.

Whether the software is AutoCAD or Microsoft Word, chances are that you use only a fraction of its functionality. Granted that many of those unused commands are essential or extremely useful to many other users, but not all will miss their absence.

When an application such as AutoCAD dominates the 2D design market as thoroughly as it does, rather than stifle the industry, it often benefits the typical CAD user. Compatibility is one area where this is evident--most low- to mid-priced CAD applications offer a fairly high degree of file-level compatibility with the DWG and DXF file formats.

For firms with a large investment of time, information, and money tied up in drawing files, AutoCAD compatibility becomes an important consideration in protecting that investment. Aside from file formats, the use of components such as linetype and hatch patterns based on ANSI or ISO standards in these low-cost alternatives also assures a level of cross-application compatibility.

Among the feature sets found in these low-cost applications are unexpected niceties such as rendering and modeling capabilities that should prove useful for a broad range of projects.

These programs may not include more sophisticated 3D tools, the ability to handle huge and complex drawings, or extensive programmability, but many users won't find these low-cost alternatives lacking. Some offer tools that in certain areas go beyond the capabilities of out-of-the-box AutoCAD. User-level support for these low-cost applications via newsgroups and forums often offers a good reason to consider them.

Fewer applications are reviewed here compared with last year for several reasons. Autodesk, for example, hasn't released new versions of QuickCAD (v8) and AutoSketch (v8) since our last roundup (January 2003, p. 29, so they weren't eligible this time around. QuickCAD and AutoSketch continue to be among the best low-cost training tools for those just getting into CAD, and both run well on fairly modest systems.

Several applications cost just above our price limit ($600), and small price increases pushed several more above that barrier, including SmartSketch, PowerCAD, and AutoCAD LT. As a result, we are considering a mid-range CAD roundup later this year to reflect the changing dynamics of the low to intermediate-priced CAD scene.

Among the entries in this roundup is one program that had seemed to drop from the face of the earth: Generic CADD, now called General CADD. Despite the reduced number of inexpensive CAD applications surveyed here, the field continues to grow. This is good news for those of us who seek quality CAD alternatives at a reasonable price. Sometimes you do get a lot more than what you pay for.

MORE LOW-COST CAD OPTIONS

The following products didn't meet the requirements or deadlines to make it into our review, but may be just what you're looking for. Visit www.cadalyst.com to find past reviews of these products.

AutoSketch 8 Autodesk 800.964.6432 www.autodesk.com/autosketch

AutoSketch ($99) is geared to developing concept sketches, informative graphics, floor layouts, presentations, electrical drawings, and home project plans. Features include enhanced fill support, outline boxes on text entities, realistic 3D effects, customizable grids and construction guidelines, automatic snaps and locks, pan and zoom, Publish to Web tools, and libraries of symbols.

QuickCAD 8 Autodesk 800.964.6432 www.autodesk.com/quickcad

QuickCAD 8 ($49) is another Autodesk product for creating technical designs and diagrams and adding technical information to 2D drawings and presentations. It offers a familiar Windows interface, AutoSnap, and database functionality. You can also access and send DWG files.

Corel DESIGNER 10 Corel 800.772.6735 www.corel.com/designer10

Corel DESIGNER 10 ($469, $299 upgrade) is a technical graphics application used to create, manage, and share technical diagrams, illustrations, and schematics. This version focuses on meeting the workflow requirements of those who create precise technical illustrations. Features include industry improved import and export filters, CorelTRACE to convert data to editable vector images, and customizable workspaces.

PowerCAD 5.2 GiveMePower 888.977.6937 www.givemepower.com

PowerCAD Pro 5.2 ($495) offers enhanced 2D/3D design tools, new FxRAY photorealistic rendering, Leica and Hilti laser device support, and enhanced DWG/DXF support. Other new features include DWF file export and an EnterPoint Precise Data Entry System to speed up entry of 2D and 3D coordinates, angles, and distances.

Visio 2003 Microsoft 800.936.3500 www.microsoft.com

Visio Professional 2003 ($499) is a diagramming program that you can use to create business and technical diagrams. Visio 2003 automates data visualization by synchronizing directly with data sources to provide up-to-date diagrams, and you can customize it to meet your organization's needs. Features include SmartShapes symbols, tools for specific disciplines, annotations, and access to a Share-Point Services site where you can share diagrams in workspace files.

REVIEW SUMMARY

Everybody loves a good deal--getting a lot for just a little--so this month's roundup of budget CAD applications is sure to offer much to delight both the bargain hunter and those who need capable and sophisticated software tools. Whether you're looking for an inexpensive CAD seat for an established firm, a primary tool where CAD is not the main concern, or an economical seat for training new personnel, there are many affo

Bargain buys: 7 CAD packages to stretch the budget

Ron LaFon

OVERVIEW

Feature rich and flexible, these moderately priced CAD applications can serve as either a primary design tool or as an economical alternative to adding another expensive CAD seat. These impressive design applications deliver a significant portion of the features normally associated with applications such as AutoCAD and are often adept at reading and writing the DWG file format and producing visualizations. In certain areas, these applications actually go beyond out-of-the-box AutoCAD. One of these applications may very well be appropriate for your needs.

We set two basic criteria for this roundup--CAD applications had to cost less than $600 and be significantly updated from the last time we reviewed them. As capable as these applications were when we looked at them last January (p. 16), these new versions offer many improvements and new features. This is definitely not a stagnant area for application developers, much to the benefit of end users.

With AutoCAD dominating the midrange CAD market, it's not surprising that many of these applications tout their AutoCAD compatibility. Not only are many incarnations of the the DWG file format supported, DXF support is readily available. Some applications here also support DWF. It's even possible to use some of these applications to modify a DWG file that originated in AutoCAD, then open the modified drawing in AutoCAD again. Many of the applications here offer compatibility with AutoCAD commands from the command line, customization via the same AutoLISP features supported by AutoCAD, and other features that allow them to fit comfortably into a work environment that uses AutoCAD. In addition, these same features make it much easier to move to AutoCAD should that be necessary, so there's not much effort wasted in training.

Rich Feature Sets

Whenever we cover inexpensive design applications in Cadalyst, the richness of the feature sets in these entry-level applications never ceases to amaze us. In addition to the CAD features considered standard requirements, some of these programs offer sophisticated capabilities such as OpenGL hardware acceleration, rendering, antialiasing, transparency, reflectance and ray tracing. Some also include fairly extensive symbol libraries, support for VBA customization and support for external reference files. These capabilities vary by application, so for a more detailed view of a particular application's capabilities, see the feature table starting on p. 24.

All told, these applications are remarkably capable, far beyond what you'd expect for such bargain prices. And the extra features make the low cost an even greater bargain. Most of these applications benefit from avid user support, with newsgroups and forums for sharing information and resources with one another.

The Future

Vendors continue to develop these products and regularly add new features and improvements, some of which are certainly based on user input. At least one of the vendors covered here was in the late stages of beta testing a major release. The level of development activity in this category is encouraging and should speak well to those interested in an economical solution to their design needs. New features such as freely distributable stand-alone DWF viewers and audio notekeeping systems appear in this roundup, along with support for the latest versions of the DWG file format.

We've noticed some degree of specialization in budget CAD applications, which traditionally tend to be all-purpose drawing programs. For example, a low-cost tool specifically for AEC design is now available. But all of these design tools are capable of a broad array of work, whether they're destined to become a primary design tool or an adjunct to other applications.

Though new versions of many familiar products are included here, a few are missing for one reason or another. Autodesk discontinued QuickCAD last year, electing to concentrate its development energies on AutoSketch.

Also missing are IMSI's TurboCAD products, TurboCAD Deluxe and TurboCAD Professional, because we did a stand-alone review of TurboCAD Professional in December 2004 (p. 34). We do, however, cover another very capable IMSI CAD application here--DesignCAD 3D MAX v15.

With software prices climbing industry-wide, we're considering a survey of moderately priced CAD software in a future issue. Several adept design applications are priced higher than our $600 cutoff, but still substantially below applications such as AutoCAD and SolidWorks.

There are many options for CAD applications these days, depending on the feature set you require and the price you can afford or justify.

AutoSketch 9

Autodesk

Price: $129

800.538.6401, 415.507.5000

www.autodesk.com

In addition to AutoCAD, Autodesk offers design applications ranging from the entry-level AutoSketch and AutoCAD LT to such higher-end applications as Autodesk Architectural Desktop and Inventor. Autodesk recently released AutoSketch 9, a new version with tools for creating professional-quality drawings.

Autodesk last year discontinued QuickCAD, leaving AutoSketch 9 as its economy offering. AutoCAD LT has steadily crept out of the budget CAD price range--it now sells for $899. QuickCAD 8

CAD files are compatible with AutoSketch 9, so those of you who used QuickCAD are not left out in the cold as far as file support is concerned.

Included with AutoSketch 9 is a series of tutorials designed to get you up and running quickly, and the Microsoft Windows XP-like interface provides a familiar environment for basic drafting. AutoSketch 9 is, as one might expect, compatible with the Autodesk DWF file format, so you can create and share drawings with a variety of design applications, including

AutoCAD. The AutoSketch Content Librarian lets users incorporate ready-made content by dragging and dropping desired symbols and blocks into a drawing.

AutoSketch 9 comes with predrawn content such as kitchen, bedroom and bathroom symbols, as well as decks and landscaping icons, architectural graphics, mechanical parts, plumbing and electrical symbols and an assortment of hatch and fill patterns. This content covers a fairly broad range that will prove useful for the home user as well as the novice user in a business environment.

To help new users become productive quickly, a wizard automatically steps through the process of choosing the most appropriate symbols libraries, drawing scales and toolsets for the type of drawing desired. Beyond providing a basic grounding in CAD concepts, AutoSketch 9 offers customizable grids and construction guidelines, associative dimensioning, and 3D special effects--including extrusion and transformation options (though no true 3D). Other notable features include in-place text editing, automatic snaps and locks to align objects precisely and hold them in position, pan and zoom capabilities and drag-and-drop functions.

A printed "Getting Started" guide covers software installation, making the transition from paper to CAD, and AutoSketch basics. It also contains four tutorials: Create and Trim Entities, Create a Birdhouse Drawing, Create an Office Layout Drawing and Advanced Exercises, which discusses creating 3D effects, using Web tools and generating a database report. An appendix to the "Getting Started" guide includes several pages of sample drawings created with AutoSketch to give an idea of the variety of drawings that are typically created with the program.

AutoSketch 9 runs on systems with Microsoft Windows 2000/XP/XP Tablet and a minimum of 128MB of RAM. Pricing is an economical $129.

DataCAD 11

DataCAD LLC

Price: $195

860.677.4004

www.datacad.com

DataCAD LT 11 is a new, low-cost ($195) 2D/3D architectural CAD program for design professionals. It's also a great way for those unfamiliar with CAD to get started. DataCAD LT 11 is useful for everything from developing construction drawings to creating architectural presentations.

All of the fundamental architectural drawing and modeling features of DataCAD are included in DataCAD LT. It provides automatic door and window insertion, associative dimensioning and hatching, unlimited undo/redo, 23 standard and hand-lettered fonts and OpenDWG-based DXF/DWG translators. 3D models created in DataCAD LT can be exported to o2c format for Internet distribution. Comprehensive online documentation is included with DataCAD LT 11 for quick answers to questions.

Investment in DataCAD LT 11 is protected, because if after using DataCAD LT, you later decide to move up to full-strength DataCAD, you can apply a $150 credit toward the purchase. All drawings created with DataCAD LT are fully compatible with DataCAD.

DataCAD LT 11 features a 64-bit, double-precision floating point drawing database. Designers can work on much larger projects without running into rounding issues, especially when importing large models.

DataCAD 11 can now query other instances of DataCAD 11 and DataCAD LT 11 running on a network to determine whether a given file is in use or not. DataCAD LT 11 incorporates a streamlined backup and recovery system, with automatic purging of unused drawing data, welcome capabilities for those managing large workgroups.

Perhaps the most visible change is the updated user interface. DataCAD LT 11 now provides Windows 2000-style properties and support for Windows XP themes and skins. Users can position toolbars and menus anywhere on the screen by tearing them off and docking them. DataCAD LT 11 will also inherit the visual style of the current desktop theme.

This release incorporates basic system improvements such as greater precision. Improved symbol management means better tools for symbol browsing and reporting, including user-defined fields and text attributes. Symbols can be dropped directly on the surface of a polygon. The DXF/DWG translator is also significantly improved and supports symbols with layers as well as block attributes.

In addition to the comprehensive online documentation noted earlier, you can purchase a hefty 617-page printed reference manual complete with screenshots and illustrations that elaborate on given topics for $39.95. The reference manual is remarkable in its scope, but the documentation doesn't end there. Another option is the tutorial manual with some 434 pages and an accompanying CD-ROM that encompasses a broad range of topics for $49.95. The "DataCAD Essentials Tutorial," with the examples included on the CD, is spiral-bound for easy use at the computer. This makes DataCAD LT 11 the best documented of any of the applications reviewed here. If you're a fan of printed documentation, as I am, this is definitely a good thing.

General CADD v3.1

General CADD

Price: $599

607.264.8344

www.generalcadd.com

At an estimated street price of $599, General CADD v3.1 falls just shy of the $600 ceiling for applications included in this article.

As I prepared this article, General CADD was readying its release of General CADD v3.1, which I saw in regular weekly updates during the course of this review. General CADD v3.1 was released in December.

General CADD Pro, commonly called GCP by users, is a 2D CAD and drafting program that embodies the features of Generic CADD (CADD6), the DOS-based program that managed to retain its popularity even after it was discontinued some years ago. The primary goal for the General CADD application was to provide Generic CADD users with a natural and nearly painless upgrade to Windows while retaining as much as possible of the two-letter command structure of the original program.

Once General CADD accomplished moving the old Generic CADD to Windows, development began on General CADD Pro v3.1, which is nearing release. The new version will include another fifty needed, requested and useful new features. General CADD supports Windows 95/98/98SE/ ME/2000/XP.

Customers can reuse their current collection of Generic CADD drawings, components, fonts, hatches, menus and so forth. New features include AutoCAD 2004 file format import and export, user-customizable toolbars, 16-button digitizer support, several surveyor-specific commands, vastly improved fill and hatch functions and trim and extend to all objects and components.

Also new are Spell Check, AutoSave, version control, multi-break, 3-point rectangle, autopan, autosave, offset, persistent commands, image load and PDF file creation.

Version 3.1 offers a number of new two-letter commands such as UB (Multibreak), OS (Ortho Stop), OT (Offset), TJ (Text Justify) and SE (Fence Selection). Stretch commands have been added to selection options. These two-letter commands are accessible from the application's command line and drop-down menus and through small icons that appear above the drawing editor window.

General CADD is the only application included in this roundup that requires a hardware lock, or dongle, which is available in either a parallel port version or a USB version. Though we had no problems with the dongle provided by General CADD, we've had difficulties with similar hardware protection features in the past. General CADD includes an illustrated HTML manual that you can print or use online. It's comprehensive and clearly written.

General CADD has successfully brought an older, popular DOS design application into the Windows age. From what we see in the beta releases of General CADD v3.1, it has refined and updated the product without losing of the character of the original version--no small feat.

PowerCAD Professional 6

GiveMePower

Price: $595

888.977.6937, 403.287.6001

www.givemepower.com

PowerCAD Professional 6 offers excellent compatibility with AutoCAD file formats. It supports the direct reading and writing of AutoCAD DWG and DXF files from AutoCAD Release 12 through 2005, with full round-trip retention of all objects.

This new release includes Spatial Technologies' ACIS viewing engine, which ensures accurate representation of 3D solids saved in this file format. Solids can be both rendered and output using PowerCAD's build-in rendering and plotting tools. PowerCAD Pro 6 also adds complex linetypes, leaders, tolerances, and many other time-saving objects not supported in previous releases.

At $595, PowerCAD Professional 6 is priced near the top of the range covered by this article, but it offers several sophisticated new features typically not found in low-cost design applications.

PowerCAD Pro 6 can export compact DWF (design web format) files for review by others and includes a stand-alone DWF viewer that is freely distributable for collaboration purposes, though some redistribution restrictions apply.

Yet another new feature is obvious right away--PowerCAD Pro 6's new Microsoft-standard interface with Object Linking and ActiveX Embedding, which supports in-place editing of files from applications such as Microsoft Word and Excel.

Other new features include VoiceNOTE, an audio note-keeping system, and XpressUpdate, a product update download system that lets users regularly check for new PowerCAD versions and any updates or enhancements that might be available online.

PowerCAD Pro 6 also includes support for mobile, as-built floor plan creation. Connect a Leica DISTO, Hilti PD 25/28 or Bosch DLE 150 portable laser measuring device to an XP tablet or laptop PC, and you have a mobile wireless design station that can produce laser-drafted, on-site drawings in record time, increasing productivity substantially over manual methods. It's surprising to find such support in such an economically priced application.

Among the features of PowerCAD Pro 6 are EnterPoint dialog-based data entry, redline and markup tools, object grouping and editing and an inspection list feature. Other useful tools include a Drawing Xplorer, Part Library Manager, a quick-render function and a raster image manager. System customization cababilities are strong with a second-genearation visual dialog, menu and toolbar editor, plus full LISP, C++ and Delphi programming support. All told, PowerCAD Pro 6 offers a substantial number of features for a very attractive price.

PowerCAD Pro 6 is available from GiveMePower Corp. and supports Windows 98/NT/2000/ME/XP, including XP Tablet. GiveMePower also offers several applications for the handheld PC.

PowerCAD SiteMaster, designed for XP tablet, laptop and Pocket PC, is an automated mobile/wireless building surveying solution that creates finished, AutoCAD-compatible drawings from input from a laser measuring device. Using a wireless portable laser, SiteMaster creates as-built floor plans and inspection drawing with intelligent walls, windows, doors, openings and areas. Digital photos, audio VoiceNOTES and 7,000 symbols proved on-site details.

DesignCAD 3d max v15

IMSI Software

Price: $89.95

800.833.8082

www.imsisoft.com

DesignCAD 3D MAX v15 is the only IMSI CAD product we're including in this roundup because we just reviewed IMSI TurboCAD Professional in the December 2004 issue.

At an estimated street price of $89.95, IMSI's DesignCAD 3D MAX v15 has the lowest price of any application included in this roundup of economical CAD applications. As with other budget CAD entries here, a low price does not indicate a lack of capabilities. There is, in fact, a wealth of new features in this release.

With DesignCAD 3D MAX v15, users can now set the base drawing units in the current drawing or can choose to draw in the classic unitless mode. Unit options include miles, feet, inches, millimeters, centimeters, meters and kilometers. In addition to setting units for the current drawing, users can specify default units for new drawings or for opening unitless drawings.

A new integrated raster-to-vector converter lets users scan paper drawings and convert them to editable CAD files, saving hours in design time. DesignCAD 3D MAX v15 also comes with a stand-alone utility called Instant Estimator that offers project cost-estimating capabilities.

Also new in this release is Hatch Pattern Position, which allows the user to change the seed location from which a hatch pattern is referenced, effectively panning the hatch pattern within its boundary. Users can now add words to hatch entities and double-line entities with hatch pattern fills.

With a toggle, users can hide or restore all toolbars to temporarily increase the drawing area--this is useful when working with complex drawings.

Running snap settings allow the user to turn running snaps on or off and toggle the use of individual running snap modes. Optional snap modes are GravitySnap, LineSnap, MidpointSnap and TangentSnap.

Dimension commands now let the user indicate a units multiplier, making it possible to dimension in some unit other than a drawing's base unit.

In addition to the application CD, DesignCAD 3D MAX v15 includes an installable Fundamental Training CD with tutorials that walk through various features and projects.

Fans of printed documentation will welcome the 262-page, well-indexed reference manual that covers the fundamental features of DesignCAD 3D MAX v15, including screenshots of various dialog boxes and operations. Though its price is low, DesignCAD 3D MAX v15 delivers a lot, particularly when you consider that this is an application that can operate simultaneously in 2D and true 3D.

For those concerned with compatibility, DesignCAD 3D MAX v15 supports the AutoCAD 2004 DWG file format. DWG, DXF, HPGL, IGES and other file formats can be both imported and exported.

The program comes with a good assortment of symbol libraries, as well as a coupon for 20% off all symbols from New World Graphics. DesignCAD 3D MAX also comes with a free CD of house plans from IMSI's Houseplans.com.

IntelliCAD 5 Standard

Various

Price: $249

503.293.7655

www.intellicad.org

The IntelliCAD Consortium recently released IntelliCAD 5. For this article we looked at the Standard version. IntelliCAD 5 supports DWG 2004 and 2005 while maintaining compatibility with previous versions of DWG back to v2.5. DWF import and export and SVG export are added to this release, along with numerous stability and performance enhancements.

Visually, new tabs located at the bottom of the drawing area allow users to switch how they want to view their drawing. The new Model tab can be used to create a drawing. When printing, users can use one or more Layout tabs to determine how the drawing will look when printed.

In IntelliCAD 5, the width of entities in a drawing can be controlled with the new lineweight feature. Users can assign lineweights to entities and layers and can also specify if they are to be displayed or printed. When multiple entities overlap, a user can change the order in which they are drawn and plotted. Draw order can be used to move entities to the front, back and on top of or below another entity.

IntelliCAD 5 also includes improved solid modeling, audit and recovery of damaged files, template files and improved printing support. Additional new features include support for i-drop, new system variables, improved documentation, a customizable status bar, new toolbars and improvements to the Trim, Extend and Offset commands.

If users have existing applications that were built using ADS or AutoLISP libraries, they can quickly use them in IntelliCAD, using the same languages and functions that they are accustomed to. IntelliCAD also includes a VBA object model.

The price for the base IntelliCAD 5 Standard edition is $249, but add-ons and options from members of the IntelliCAD Consortium can push the price upward substantially, depending on the options and features selected. A professional version of IntelliCAD 5 is available for $349. IntelliCAD differs from the other applications here in that it's developed and marketed by a consortium, an independent organization of commercial software developers that has been established specifically for the purpose of licensing and coordinating broad future development of CAD technology.

The ITC (IntelliCAD Technology Consortium) licenses the IntelliCAD technology to commercial members, who in return receive source code, documentation, installation software, developer support and such to develop the technology into commercial CAD products.

Commercial members can offer options such as VBA, rendering, ACIS solid modeling, raster image display and other features. They can also add their own improvements or applications. There is no one IntelliCAD product, but rather a variety of products based on IntelliCAD technology. A complete list of current commercial members authorized to provide stand-alone versions of IntelliCAD, and products that are powered by IntelliCAD technology, can be found at www.intellicad.org/members/memberlist.asp.

Cadopia (www.cadopia.com), for example, offers a collection of symbols for its versions of IntelliCAD. Autodsys (www.autodsys.com) adds capabilities such as bird's-eye view, a block manager and an Autolayer feature based on AIA or custom standards. Its version of IntelliCAD also comes with a bonus toolkit that contains 75 tools such as flatten, revision cloud, block count and curved text. BricsCAD (www.bricscad.com) offers an IntelliCAD version, BricsCAD v5, that supports the company's add-ons for architectural and structural design.

IntelliCAD is an alternative development platform for CAD application developers. It provides DWG file compatibility, as well as su port for industry standard commands, menu files, script files, shape files, text files, hatch patterns, linetypes, LISP commands, ADS/C++ programs and VBA.

VDRAFT AutoCAD Drafting System

SoftSource

Price: $250, $100 educational seat

(includes modeling program)

800.877.1875, 360.676.0999

www.softsource.com

Softsource's Vdraft (short for Virtual Drafter) is a highly customizable design application with a wealth of features and compatibility with a variety of AutoCAD DWG file formats. Its simplicity and direct approach makes Vdraft a good system to use for teaching CAD drafting, and it runs well on standard PCs with Windows 95/98/ME/NT/2000/XP. Priced at $250, Vdraft falls near the middle of this group of products.

Vdraft's improved hyperlinks are now compatible with AutoCAD hyperlinks. Simply hold the <Shift> key down and move the mouse over a drawing object to view the hyperlink information, then click to load the Web page.

A sketch mode, Sketch Freehand, is incorporated into Vdraft for making fast sketches of ideas before committing them to a drawing.

With Vdraft, users can view or edit multiple drawings simultaneously and easily cut or copy and paste elements between drawings. Included with Vdraft is a 226-page printed, spiral-bound manual that includes some very useful appendices. For example, an appendix, Type in this AutoCAD Command, shows the equivalent Vdraft pull-down menu for accessing the command and the command(s) that Vdraft executes. This is great for users familiar with AutoCAD commands to learn how Vdraft functions. Commands are broken down alphabetically and by groups, such as AutoCAD system variables and dimensioning commands, and there's a section on Vdraft-specific commands. The illustrated manual covers the basics of Vdraft--drawing setup, blocks, xrefs, attributes, dimensioning and working with drawing spaces and layouts, among other topics. Another useful section covers sharing data with other users and other programs, as well as a listing of Vdraft keyboard shortcuts. The documentation is extensive and very well done. Vdraft also continues to offer an excellent online AutoCAD Help system that provides quick reference to supported AutoCAD commands and where they are located in the menu structure. Many Vdraft commands use AutoCAD terminology, among them blocks, polylines, layers and attributes. For those interested in checking out Vdraft, a trial version is available from the company's Web site.

Vdraft Internet Tools provide instructors with a way to show real-world examples of on-line CAD drawings, such as the Army Corps of Engineers CADD standards library and NASA Langley facilities drawings. Students can be exposed to real-world drawings and use those drawings as part of their classroom CAD drafting projects. The Vdraft education license fee is $100.

Grants are available for educational use where Vdraft is integrated into existing CAD training programs.

In addition to its Vdraft design application, SoftSource also offers CADview for viewing and printing AutoCAD drawings. CADview has the ability to temporarily turn layers on and off and to measure. An AutoCAD/DXF plug-in gives users the power to view and print AutoCAD drawings in Netscape or Internet Explorer. Users can zoom in on drawing details, turn layers on and off and print the current view or entire drawing inside the Internet browser. Last but not least, SoftSource offers a SVF plug-in as a simple solution for access to SVF (simple vector format) drawings from a Web browser.

Table 1. Budget CAD FeaturesProduct AutoSketch 9Company AutodeskPhone 800.538.6401, 415.507.5000E-mail NoneWeb site www.autodesk.com/autosketchEstimated street price $129 (online)Operating systems supported Windows XP/2000 ProfessionalOperating system reviewed Windows XP Pro WorkstationOpens multiple drawings Yes simultaneouslySupports reference

drawings (xrefs) No, xrefs processed during DWG importWeb tools Yes (Publish to Web, hyperlinks)Intelligent objects (Visio, etc.) NoWorks in 2D/3D NoWorks in 2D/3D simultaneously NoConvert 2D to 3D/3D to 2D 3D to 2D during DWG/DXF importDrafting tools YesMetric option YesMaximum number of layers no limit (memory)Alphanumeric layer names supported YesUser-configurable layer system YesMaster layer controls YesAEC symbols library YesElectrical/HVAC symbols library YesFurniture symbols library YesGeneral business symbols library YesLandscape symbols library YesManufacturing symbols library Yes, someMechanical/plumbing symbols library YesSite symbols library Yes, someStandard process symbol library NoVehicles symbol library Yes, someWYSIWYG plotting view Yes (Print Preview)Plotting, color fills YesPlotting, batch mode NoPlotting, save configurations for multiple plotters NoOpenGL hardware acceleration No supportedPerspective view supported NoTexture mapping supported NoRay tracing supported NoTransparency/reflectance supported NoRefraction supported NoAntialiasing supported NoProcedural rendering supported NoRadiosity supported NoVBA supported NoAccess ActiveX object model interface supported NoOther customization tools NoFile formats supported for import SKF, SKD, QuickCAD, DWG (through AutoCAD 2000), Drafix 3.x/4.x, DXF, WMFFile formats supported for export SKF, QuickCAD, DWG (up to 2000), DXF (up to 2000), DWF, Drafix 3.x/4.x, WMF, BMP, DIB, JPEG, JPGWeb-based/print tutorials Yes (Getting Started tutorials)Multimedia tutorials NoProduct DataCAD LT 11Company

DATACAD LLCPhone 860.677.4004E-mail info@datacad.comWeb site www.datacad.comEstimated street

price $195Operating systems supported Windows 95/98/ME/NT/ 2000/XPOperating system reviewed Windows XP Pro

WorkstationOpens multiple drawings Yes, unlimited simultaneouslySupports reference drawings (xrefs) Yes, limited to view and print onlyWeb tools Yes, hyperlink to URLIntelligent objects (Visio, etc.) NoWorks in 2D/3D YesWorks in 2D/3D simultaneously

YesConvert 2D to 3D/3D to 2D YesDrafting tools YesMetric option YesMaximum number of layers 1000Alphanumeric layer names supported Yes, up to 255 charactersUser-configurable layer system YesMaster layer controls Yes, with Layer ManagerAEC symbols library

Yes, 1,700+Electrical/HVAC symbols library YesFurniture symbols library YesGeneral business symbols library NoLandscape symbols library YesManufacturing symbols library NoMechanical/plumbing symbols library YesSite symbols library YesStandard process symbol library NoVehicles symbol library YesWYSIWYG plotting view YesPlotting, color fills YesPlotting, batch mode NoPlotting, save configurations for multiple plotters YesOpenGL hardware acceleration No, but the o2c Viewer uses supported 3D hardware accelerationPerspective view supported YesTexture mapping supported YesRay tracing supported YesTransparency/reflectance supported YesRefraction supported YesAntialiasing supported

YesProcedural rendering supported NoRadiosity supported NoVBA supported NoAccess ActiveX object model interface supported

NoOther customization tools NoFile formats supported for import DXF, DWG, WMF, EMF, TXT, BMP, JPG, GIF, TIF, TGA, PNG,

PCX, PCDFile formats supported for export DXF, DWG, WMF, EMF, TXT, ACO, O2C, BMP, JPG, GIF, TIF,

TGA, PNG, PCX, PCDWeb-based/print tutorials YesMultimedia tutorials NoProduct General CADD Pro v3.1Company

General CADD ProductsPhone 607.264.8344E-mail support@generalcadd.comWeb site

www.generalcadd.comEstimated street price $599Operating systems supported Windows 95/98/98SE/ME/2000XPOperating system reviewed Windows XP Pro

WorkstationOpens multiple drawings No simultaneouslySupports reference drawings (xrefs) NoWeb tools Pop-up email addresses for support and bug reportingIntelligent objects (Visio, etc.) NoWorks in 2D/3D 2D onlyWorks in 2D/3D simultaneously NoConvert 2D to 3D/3D to 2D NoDrafting tools More than 400 2D drafting toolsMetric option YesMaximum number of layers 1024Alphanumeric layer names supported YesUser-configurable layer system YesMaster layer controls YesAEC symbols library No, conversion tool suppliedElectrical/HVAC symbols library No, conversion tool uppliedFurniture symbols library No, conversion tool suppliedGeneral business symbols library No, conversion tool suppliedLandscape symbols library No, conversion tool suppliedManufacturing symbols library No, conversion tool suppliedMechanical/plumbing symbols library No, conversion tool suppliedSite symbols library No, conversion tool suppliedStandard process symbol library No, conversion tool suppliedVehicles symbol library No, conversion tool suppliedWYSIWYG plotting view YesPlotting, color fills YesPlotting, batch mode Yes, via macroPlotting, save configurations for multiple plotters YesOpenGL hardware acceleration No supportedPerspective view supported NoTexture mapping supported NoRay tracing supported NoTransparency/reflectance supported NoRefraction supported NoAntialiasing supported

NoProcedural rendering supported NoRadiosity supported NoVBA supported No, internal macro languageAccess ActiveX object model interface supported

No, internal macro languageOther customization tools Internal macro languageFile formats supported for import GCD, CMP, MCR, MNU, HCH, PAT,

FNT, SHX, DXF, DWG (up to 2004)File formats supported for export DWG/DXF (up to 2004), JPG, TIF, PNG, BMP, WMF/EMFWeb-based/print tutorials HTML manual can be printedMultimedia tutorials NoProduct PowerCAD Professional 6Company

GiveMePower Corp.Phone 888.977.6937, 403.287.6001E-mail info@givemepower.comWeb site

www.givemepower.comEstimated street price $595Operating systems supported Windows 98/NT/2000/ME/XP/ XP

TabletOperating system reviewed Windows XP Pro WorkstationOpens multiple drawings Yes simultaneouslySupports reference drawings (xrefs) YesWeb tools

SomeIntelligent objects (Visio, etc.) NoWorks in 2D/3D YesWorks in 2D/3D simultaneously YesConvert 2D to 3D/3D to 2D

YesDrafting tools YesMetric option YesMaximum number of layers 4096Alphanumeric layer names supported YesUser-configurable layer system YesMaster layer controls YesAEC symbols library YesElectrical/HVAC symbols library YesFurniture symbols library YesGeneral business symbols library YesLandscape symbols library YesManufacturing symbols library YesMechanical/plumbing symbols library YesSite symbols library

YesStandard process symbol library YesVehicles symbol library YesWYSIWYG plotting view YesPlotting, color fills

YesPlotting, batch mode Yes, batch conversions as wellPlotting, save configurations for multiple plotters YesOpenGL hardware acceleration Yes supportedPerspective view supported YesTexture mapping supported FXRay

RayTrace/Rendering pluginRay tracing supported FXRay RayTrace/Rendering pluginTransparency/reflectance supported FXRay RayTrace/Rendering pluginRefraction supported FXRay RayTrace/Rendering pluginAntialiasing supported FXRay

RayTrace/Rendering pluginProcedural rendering supported FXRay RayTrace/Rendering pluginRadiosity supported NoVBA supported NoAccess

ActiveX object model interface supported YesOther customization tools Visual Desktop and Menu editor, LISP API, C++ API,

Delphi API, .NET extension wrapperFile formats supported for import DWG (R12-2004), DXF, FLX, TXT, JPG,

PNG, TIF, GeoTIFF, RLC, BMPFile formats supported for export DWG (up to 2004), DXF, DWF, FLX, WMF, BMPWeb-based/print tutorials

YesMultimedia tutorials Yes, online Help resourcesProduct DesignCAD 3D MAX v15Company IMSIPhone

800.833.8082E-mail support@designcad.comWeb site www.imsisoft.comEstimated street price

$90Operating systems supported Windows 98/2000/XPOperating system reviewed Windows XP Pro WorkstationOpens multiple drawings Yes simultaneouslySupports reference drawings (xrefs) Supports its own externally referenced files, not othersWeb tools

Yes, via Internet-compatible exports for drawing filesIntelligent objects (Visio, etc.) NoWorks in 2D/3D YesWorks in

2D/3D simultaneously YesConvert 2D to 3D/3D to 2D With a few easy steps.Drafting tools YesMetric option YesMaximum number of layers

000Alphanumeric layer names supported YesUser-configurable layer system YesMaster layer controls YesAEC symbols library

YesElectrical/HVAC symbols library YesFurniture symbols library YesGeneral business symbols library YesLandscape symbols library YesManufacturing symbols library Yes, available in Platinum editionMechanical/plumbing symbols library Yes, available in Platinum editionSite symbols library NoStandard process symbol library Yes, available in Platinum editionVehicles symbol library Yes, available in Platinum editionWYSIWYG plotting view YesPlotting, color fills YesPlotting, batch mode YesPlotting, save configurations for multiple plotters NoOpenGL hardware acceleration Yes supportedPerspective view supported YesTexture mapping supported YesRay tracing supported NoTransparency/reflectance supported Yes/NoRefraction supported NoAntialiasing supported YesProcedural rendering supported NoRadiosity supported NoVBA supported

YesAccess ActiveX object model interface supported NoOther customization tools YesFile formats supported for import DWG, DXF, HPGL, IGES, and moreFile formats supported for export DWG, DXF, HPGL, IGES, and moreWeb-based/print tutorials YesMultimedia tutorials YesProduct IntelliCAD

StandardCompany IntelliCAD Technology ConsortiumPhone 503.293.7655E-mail membership@intellicad.orgWeb site www.intellicad.orgEstimated street price $249Operating systems supported Windows 2000/XPOperating system reviewed Windows XP Pro WorkstationOpens multiple drawings Yes simultaneouslySupports reference drawings (xrefs) YesWeb tools

DWF Export, i-dropIntelligent objects (Visio, etc.) Via third-party applicationsWorks in 2D/3D YesWorks in 2D/3D simultaneously

YesConvert 2D to 3D/3D to 2D Via third-party applicationsDrafting tools YesMetric option YesMaximum number of layers

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TurboCAD Professional v10.2: all-purpose CAD program appeals to the cost-conscious

Joe Greco

TURBOCAD PROFESSIONAL IS ONE of many applications on the market that strive to be CAD Swiss Army knives. It handles both 2D and 3D as well as nongraphic tasks such as pricing and scheduling. It also provides application-specific tools for mechanical designers, architects, and other users. Its biggest competitors are products such as AutoCAD LT and VectorWorks. All members of this trio carry street prices in the $700-$800 range, so it's fair to compare them.

In April of 2004, I did a fairly in-depth review of TurboCAD 10.0 online for Cadalyst at http://manufacturing.cad alyst.com/turbocad. Rather than reiterate the findings in that article, here I'll focus primarily on the improved aspects of 10.2 and how they compare with the TurboCAD competitors mentioned above.

Interoperability Enhancements

IMSI claims improved STEP and IGES interoperability in v10.2, so I went ahead and tested a few files. A STEP file that gave v10.0 trouble came over much cleaner in this upgrade, but another, more complex file had some edges where tiny sliver surfaces were created. As for IGES files, even fairly simple models still imported with many of these slivers in between the faces. A very complex IGES that wouldn't import at all in v10.0 still looked pretty bad in v10.2, but at least there was something to work with. IMSI has not added options to control model tolerances, which usually help. By comparison, AutoCAD LT doesn't come with IGES or STEP translators. You have to purchase additional software, which I couldn't acquire in time to test. VectorWorks has no way to import STEP files, and models translated via IGES had most of the same problems as TurboCAD's.

3D Dynamic Editing

For quite some time, clicking on a 3D shape in TurboCAD has automatically exposed drag handles as well as the x, y, and z axes for that selected object. These handles allow the user to dynamically move, scale, and rotate the component without having to select a specific tool (this also works on 2D shapes). Though this dynamic editing is very interactive, visually dragging in this manner usually means a lack of precise control. However, in v10.2, when you click and drag on those aforementioned axis, the object's movement is constrained in that direction, making it easy to move shapes precisely (figure 1).

[FIGURE 1 OMITTED]

More control has also been added to the Deform to Point tool introduced in v10.0. The update adds a Move Along Normal option, which facilitates constraining the deformation perpendicular to the face being edited. In addition, there is now more control regarding which areas of the desired face get deformed (figure 2). Only VectorWorks has 3D reshaping tools similar to TurboCAD's, but they require a few more steps to activate.

[FIGURE 2 OMITTED]

Creating the underlying entities for building 3D components just got a little easier in TurboCAD v10.2. Clicking on the Point tool displays an option in the Inspection Bar that allows this point to be placed in 3D space. It's nice that the TurboCAD developers used the Inspection Bar rather than add another tool to the program's crowded user interface.

According to IMSI, by v11 TurboCAD should have a 3D curve command and the ability to turn a 2D curve into a 3D one by pulling its individual points off-plane. Even before that, v10.5 (which should be available by the time you read this) will add D-Cubed's Constraint Manager to provide 2D constraints.

Other new features planned for v10.5 include a perpendicular snap and an updated Lightworks rendering engine. Architectural design and dimensioning will also be improved.

Part Tree Improvements

TurboCAD also houses what IMSI calls a historical, editable Part Tree, something its competitors don't have. Under closer examination, it's not truly history based, because features such as 3D fillets and shells can't be reordered. However, it's improved in v10.2.

A good example is the case of an extruded circle. Now it's possible to click on the resulting 3D cylinder shape and select the circle in the Part Tree, which activates the Edit Tool. Then the diameter of the cylinder can be changed by pulling the drag handles that appear. In the case of a cylinder, another pair of handles turns a 360[degrees] circle into a wedge shape.

Doing this operation explodes the shape (figure 3, p. 34), but it's still considered a solid that can be Booleaned with another solid.

[FIGURE 3 OMITTED]

The Part Tree's editing process is still a little buggy. For instance, sometimes clicking on the Edit Tool does absolutely nothing, but the same click a few seconds later, with no other variables changed, correctly places you in editing mode. Also, when I changed something like the radius of a fillet, the procedure worked only every other time, even when the exact same steps were followed.

TurboCAD Professional v10.2 also houses a few miscellaneous enhancements in other areas. One that I like is the ability to assign priorities to the different snaps, helpful if you have several turned on. TurboCAD v10.2 also features rendering enhancements (figure 4, p. 35) and hatching improvements.

[FIGURE 4 OMITTED]

An Application for Professionals?

Let me start by saying that, for the price, TurboCAD does an amazing amount of stuff that will certainly satisfy the casual user. However, many casual users may find its user interface overwhelming, while many professional users will soon starting hitting a productivity wall.

For the casual user, TurboCAD's low price is certainly appealing. With that in mind, the program simply has too many tools that clutter the user interface. This wouldn't be so bad if they all did something useful, but parts of the user interface logic are fundamentally flawed.

For instance, four tools create lines tangent to arcs, but they are not necessary because TurboCAD's tangent snap can be evoked to do the same thing. (Technically, because of some limitations that aren't found in other programs, TurboCAD's tangent snap can't handle all of these conditions, but it should.) Three circle and three arc tools could also be eliminated by using the tangent snap. And there are many other examples.

TurboCAD Professional is still missing some basic functionality, even though it's a veteran application. Some may say I shouldn't be too harsh on a program that costs only $895, but an application that uses the word Professional in its name also chooses to be judged as a product that takes itself seriously.

Let's start with a quick example of a 2D limitation. Because it's impossible to run every command, I use a simple test to help determine how deep a 2D program's tools go. I draw two circles of different sizes and see how many fillets out of a possible eight can be created in between them (figure 5). While AutoCAD can at least produce two fillets, and VectorWorks four, TurboCAD does none. Also, TurboCAD is the only one that can't fillet between a line and circle.

[FIGURE 5 OMITTED]

This is, of course, not a tell-all test, but it gives an indication of potential issues professional users may face as they delve deeper into the software.

TURBOCAD PROFESSIONAL 10.2

2D/3D CAD Program star rating: 3.5 stars out of 5

pros: New 3D deformation and editing options; changes to Part Tree; new rendering capabilities; 3D point command proves handy.

cons: Cluttered and sometimes inconsistent user interface; operations don't always work the same; missing some basic filleting and other commands; interoperability tools still need work.

price: $895

IMSI Software

415.878.4000

www.imsisoft.com

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13 more express tools: handy tools ease layout, dimension, and selection tasks

Lynn Allen

This month, we continue down the yellow brick road to higher productivity with AutoCAD Express Tools. As a quick review, more than 100 Express Tools come with AutoCAD 2004. Those of you on AutoCAD 2001-2002 can purchase them at www.autodesk.com. We're picking up with the Layout Tools as they display in the Express Tools pull-down menu. See January's column at www.cadalyst.com/cad alyst/article/articleDetail.jsp?id=80705 for the previous batch.

Change Space (Chspace)

If you've ever wanted to push one or more objects from model space to paper space (or vice versa), you'll love the Chspace Express Tool. Perhaps your dimensions were made in model space, but you prefer them in paper space. Perhaps you created some text in paper space that's better suited to model space. Whatever the case may be, Chspace makes the switch for you while maintaining the object's original appearance.

Align Space (Alignspace)

A misplaced pan or zoom within a viewport can sometimes disrupt the alignment of objects in model space relative to paper space (dimensions come to mind). You can use Alignspace to reestablish the pan and zoom factor by matching up points in model space with points in paper space. Even the UCS is rotated where needed. You can select one or two points in model space, followed by one or two corresponding points in paper space.

Top-secret tip. To use only one reference point, press <Enter> when prompted for the second point--even though this doesn't display as an acceptable response.

Synchronize Viewports (Vpsync)

This Express Tool is somewhat outdated. You can use it to synchronize the scale factor of one or more viewports to the selected master viewport. In AutoCAD 2004, Matchprop permits the matching of viewports.

Viewport Scale Factor (Vpscale)

A quick command displays the scale factor for the selected viewport. The answer is displayed relative to your current units setting.

Merge Layout (Layoutmerge)

Saving a drawing back to AutoCAD Release 14 (before multiple layouts were a reality) saves only the current or most recently used viewport in the process. Layoutmerge merges all selected layouts into one and creates individual named views for each of the layouts. It even places a rectangle and a text identifier on the Defpoints layer to help you decipher the results! Try this great command when you work with clients who refuse to leave the Release 14 Stone Age.

Dimension Tools

Attach Leader to Annotation (Qlattach) This Express Tool combines an existing leader line and an existing mtext, tolerance, or block reference into one object. The leader line moves to meet the annotation. If the angle is appropriate, a hook line is also added. Both objects must be in the same plane.

Detach Leader from Annotation (Qldetachset)

Essentially the opposite of Qlattach, this command breaks up the leaders from the annotation object. The only visual change may be the deletion of the hook line.

Global Attach Leader to Annotation (Qlattachset)

Back in the AutoCAD Release 13 days (oh, the horror!), leader lines were not attached to the annotation. If you find yourself cleaning up an old Release 13 drawing, you might find this Express Tool handy. Simply window all the leaders and AutoCAD does its best to combine the leaders and annotations. A simple report is returned with the results.

Dimstyle Export (Dimex)

This is a quick way to export existing dimension styles to a file (figure 1) with the goal of importing them later on. AutoCAD 2000 brought Design Center into the picture, which also makes it easy to import existing dimension styles, so you may not find much value here. The advantage of Dimex and Dimim is speed--you don't have to leaf through folders and files to find the dimension styles. You also gain the option to export the dimension style name only (without settings).

[FIGURE 1 OMITTED]

Dimstyle Import (Dimim)

Use this Express Tool to import the dimension style file created with Dimex.

Reset Dim Text Value (Dimreassoc)

This all-time favorite is a definite crowd pleaser! Say that you're working with a client who hands you a drawing with dimensions on it. You foolishly believe that the dimension text is a reflection of the actual measurements on the drawing. It all looks fine. As you continue to work with the drawing, you find out that you were seriously mistaken--the operator overrode the dimension value to put in the correct one (meaning the drawing is inaccurate). You can't tell me that you can't relate to this scenario in one way or another! It's so frustrating to try and figure out any other measurements when you're not sure of the integrity of the drawing.

Enter Dimreassoc.

Dimreassoc is a great way to check a drawing for inaccuracies. You simply select the dimensions in question, and AutoCAD highlights the offenders! An additional <Enter> converts the overridden dimension values to their true values. Then you can have a little chat with the CAD operator. Dimreassoc is a priceless command that can save you from submitting incorrect information.

Selection Tools

Get Selection Set (Getsel)

A quick and easy alternative to grabbing objects, Getsel let's you visually select the layer(s) and the type of objects you want to include in the selection set. Let's take a detailed look:

Command: Getsel

Select an object on the Source layer <*>: Select object(s) on the desired layer(s)

Select an object of the Type you want <*>: Select the object type(s)

Collecting all Mtext objects on layer Furniture...

Two objects have been placed in the active selection set.

Start the editing command you need and use the Previous option to grab the selection set created by Getsel.

This is a clever Express Tool. You select one object, and Fastselect grabs all those objects that touch the selected object. You can even set it up to grab all the objects that touch the objects that touch the selected object (ouch!). Think of it as a chain. Fastselect works with a partner command called Fsmode. When Fsmode is off, only those immediate objects that touch the selected object are highlighted (figure 2). When Fsmode is on, it creates a chain of selected objects (figure 3). Key in FS to access this cool command.

[FIGURES 2-3 OMITTED]

Tools Make Us Happy

Hopefully you've found a nugget or two that will help you get your job done a little bit faster. I look forward to sharing more AutoCAD tips and tricks with you throughout the year! Until next month--Happy AutoCAD-ing! n

LEARN MORE ABOUT EXPRESS TOOLS

* "Express Yourself," February 2004, www.cadalyst.com/cadalyst/article/articleDetail.jsp?id=85228

* "Ten Express Tools Conquer Text," January 2004, p. 38, www.cadalyst.com/cadalyst/article/articleDetail.jsp?id= 80705

* "Digging Deep into the Express Tools," www.cadalyst.com/cadalyst/article/articleDetail.jsp?id=79229

* "The Return of The Express Tools," www.cadalyst.com/cadalyst/article/articleDetail.jsp?id=80457

Lynn Allen is the AutoCAD technical evangelist for Autodesk in San Rafael, California, and the author of AutoCAD 2002: Inside and Out from CMP books. E-mail her at lynn.allen@

autodesk.com.

How to configure sheet sets 1: AutoCAD 2005's new sheet set capabilities help enforce your CAD standards

Robert Green

NOW THAT AUTOCAD 2005 has been out for a little while, I bet most CAD managers have either seen or read about the new release. See our Cadalyst Labs review on p. 26 for more details. By far the biggest change in AutoCAD

2005 is the Sheet Set Manager, which lets you group layouts and drawings into cohesive sets that define an overall drawing package (figure 1). The sheet set's ease of use is clear for the normal CAD user--particularly those who aren't comfortable with navigating the operating system to find drawings. What isn't so obvious is how to configure sheet sets to make them behave the way you want them to. If you haven't experimented with sheet sets, view AutoCAD 2005's New Features Workshop demo.

[FIGURE 1 OMITTED]

This month, I'll begin a series on how to configure sheet sets to help you control your projects.

Sheet Set Mechanics

Right-click on the name of the sheet set to view the various properties that you can customize (figure 2). Understanding what each parameter controls is key in planning your sheet set implementation. Here's a description of what each configurable property does and why it matters:

[FIGURE 2 OMITTED]

Name. The title of the sheet set you see in the Sheet Set Manager dialog box.

Sheet set data fle. This is the full path and name of the DST file that stores all information about the sheet set. The DST file is new to AutoCAD 2005 and is not backward portable to earlier releases. The name of the DST file actually has no correlation to the Name parameter specified above, which is a bit counterintuitive.

Description. An optional field for text note entries. I use this parameter to keep notes about changes I've made to the sheet set data file, but you can use it however you like. Resource drawing location(s). A set of directories that contain model space drawings you can reference into new sheets in the set. Resource drawings are not mandatory. In fact, most new sheet sets won't have any resource directories set.

Label block for views. Many engineering drawings use a system that references a master layout of a project and then refers to details within the master as a view. These views typically must be numbered. Any change to the view numbering system within a large set of drawings plays havoc with the entire sheet set. In AutoCAD's Sheet Set Manager, this process is automated by using a label block for all view numbering. This setting simply lets you declare which label block you'd like to use by pointing to a template file that contains the block.

Callout blocks. In many engineering drawing environments, callouts link detail drawings back to the parent view and sheet number within the set of drawings. This callout system makes it possible to navigate a large set of drawings so long as the numbering in the callout blocks is correct. AutoCAD's Sheet Set Manager automates this callout functionality by using specially coded blocks, much as it does for views. This setting lets you declare which callout block(s) you'd like to use by pointing to a template file that contains them.

Page setup overrides file. One of the great benefits of working with sheet sets is that you can plot an entire set of files at one time, in correct order. Page setup overrides let you preconfigure page setups to use for the sheet set and place them in a single template file that controls the entire set of drawings as they plot. Because the page setups reside in the master template file, you never have to worry about what page setup is in the individual files in the set. Instead, you plot using the master set of page setups. This feature is outstanding for standardizing your plot setups and really sold me on using sheet sets. Sheet storage location. This directory specifies where any new drawings you create within a sheet set are filed. No more users placing drawings wherever they want. The Sheet Set Manager handles the filing. Sheet creation template. The master template file used when new drawings are created within the sheet set.

Prompt for template. When set to No, users must use your master template file as specified above whenever they create a new drawing. When set to Yes, users can override your master template file. Sheet custom properties. You can create a collection of database fields that have unique values for each drawing in the set. These fields are usually parameters you expect to see in a title block, such as drawn by, checked by, and drawn date.

Sheet set custom properties. A collection of database fields you can create that have a constant value for all drawings in the sheet set. Again, these fields are parameters you expect to see in a title block, such as project number and customer name.

Get Your Templates Ready

One immediate conclusion you can draw about sheet sets is that standardization of blocks and drawing creation is determined by the content of your template drawing (DWT) files. I can't stress enough that the more thought and standardization you put into your template files, the better off you'll be as you move forward with sheet sets. In addition to the view block, callout block, and page setup overrides, your template files should also contain all the layering, dimensioning, unit system, and title block standardization features you want.

In the case of multiple disciplines, where a single template file won't work for all drawings, the Sheet Set Manager provides for a targeted template file for each discipline, or subset in sheet set terminology (figure 3, p. 38). If you need to use multiple template files for drawing creation, be aware that the page setup overrides and view and callout block integration are still derived from the master template file.

Sheet Management

Sheet sets combine ease of use for the CAD user and enforcement of project standards for the CAD manager in a single easy-to-master interface. Taking advantage of the Sheet Set Manager requires some preparation and thought on your part, but when you consider the benefits you reap, the startup effort is minimal.

To prepare for the next installment of my CAD Manager column, collect all the information you need to create a master and discipline-specific template files so we can complete configurations using another cool AutoCAD 2005 feature: data fields.

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Buying CAM SOFTWARE

Waurzyniak, Patrick

What buyers need to consider when buying critical machining software

Today's CAM software offers manufacturers a wealth of new capabilities, but many CAM packages are often seen as expensive and difficult to use.

Some key software purchasing factors include not only thoroughly examining the CAM package's technical capabilities, but also weighing which program offers superior ease-of-use, support, or cost advantages. Manufacturing Engineering surveyed CAM software developers for their advice on what users should seek when buying CAM packages.

"With 20 years of experience delivering Mastercam software to shops worldwide, we've seen the CAM checklist change with the industry," notes Brian Summers, vice president of CNC Software Inc. (Tolland, CT), developer of Mastercam software. "However, there are a few constants that remain important in all CAM purchases and upgrades."

Test your own parts: Among Summers' recommendations, software should be checked by users with their own test parts; the software should be easily expandable; CAM packages should be open to all CAD packages; and CAM software should include superior support. To assist users evaluating new CAM systems, CNC Software has produced a booklet on the topic available at the company's Web site at www.mastercam.com.

"Test parts should be your parts and they should be made using your machining preferences," Summers says. "Make sure you see the software work with parts that are similar to your own, so you can get a feel for the capabilities and ease of the CAM software. Canned demos always look good. The real test is the important parts-your parts on your machines. That is the true test of how a product can add value to your shop.

"It's important that your software be able to grow and change with your shop," he adds. "If you add different or more complex types of machining, it's crucial that your software is ready to go."

CAM software also should be open to all CAD packages, Summers notes. "Your CAM package will need to accept native files from a wide variety of packages, in a wide variety of formats-solids, surfaces, wireframe, STL, and more. It's also a big help if your CAM software can model in these formats as well. "

Superior support also plays a key role. "An often overlooked element of CAD/CAM selection is your software dealer," says Summers. "Dealers are often the key to the most successful CAD/CAM setups. They can help you get up to speed quickly, and are there to help when you run into a problem. Ask around about your local CAM dealer's support-it can be one of the most important elements of your decision."

Technical capabilities are a basic consideration for CAM software buyers. Among Summers' suggestions, look for true support for today's top-of-the-line machines including: true high-speed machining; automated feedrate optimization to save money, cut time, and reduce tool wear; and new "smart" toolpaths that can evaluate a part and generate multiple-strategy approaches for a single pass.

"Other buying decisions can definitely include ease-of-use and cost," he says. "Ease-of-use can be essential, and as mentioned before, the best way to test a system's true ease-of-use is to see an example of work similar to your own. Although cost is clearly a consideration, value is perhaps a better consideration. What are you getting for the money? Will it fill your needs now and in the future? Does the maintenance program deliver value to your shop?"

Another element frequently considered is finding experienced programmers. "If a CAM system is widespread or used heavily in the educational system," Summers notes, "it can be much easier to find qualified programmers ready to start cutting chips."

Comparing CAM features is the wrong place for a CAM buyer to start, notes Bill Gibbs, president of Gibbs and Associates (Moorpark, CA). "They get us too focused on small specific things, and distract us from important issues," Gibbs says. "The important issues are big and easy to understand. I usually wrap them all into a single question: How well will my people be able

to program my parts on my machines? You just can't go wrong looking for the best solution in these three areas."?

Regarding 'my people,' Gibbs asks: "Who will be programming? Sometimes the programmer is a design engineer, a machinist, an operator, an experienced CNC programmer, an experienced CAM programmer, or a manufacturing engineer. What is their level of education and experience? What computer software are they already skilled at, if any? Who will be primary (full time) users and who will be secondary (infrequent) users? What is your turnover rate? All these factors should be part of your decision.

"A machinist will have a harder time learning an 'expert-friendly' CAM system intended for college graduate CAD computer geeks than he will a system intending machinists as its primary user," Gibbs notes. "You can always try a CAM system yourself, with assistance from the CAM salesman/demo jock. Program a simple part. Test drive it. See how it feels. Does it make sense? Are you lost in menus behind menus? Typing your fingers off? These last two are not good signs.

"It takes more than pretty screen graphics and Windows compatibility to make an easy-to-learn and easy-to-use CAM system," Gibbs states. "You can easily spend more money learning a CAM system than it costs. Remember your time has value. You can spend this much again on every employee you train, on every new hire, and hard-to-use CAM systems take longer to program parts, so you lose money on every job. In the first year these costs can be 10x the software purchase price. It's a very big issue. 'Expensive good' software can be cheaper than poor 'free' software."

Your mileage may vary. "Everybody doesn't make the same parts, and you don't make the same parts all the time," " Gibbs says. "You have parts that are typical of your bread-and-butter work. You have other parts that, while less frequent, are your hard parts to program. You need a CAM system that is absolutely the best at your daily type of parts, and very good on your

hard ones. I give the edge to your regular parts only because you will spend so much more time working on them. You can also give more value to a CAM system that is good at parts you think you'd like to do in the future. Be careful, as you aren't expert on these parts yet. You only need the CAM features you are going to use.

"Buying features for other classes of parts may be a waste. Any advertised feature may be valuable, or a total piece of junk. The best approach is to test a CAM system on your own parts.

When a CAM system has the features needed by your part, the programming time will be less, the program created will be more efficient. You know what a good part looks like and how long it should take to cut. Evaluating these issues makes sense to me-yes/no questions to buzzword features taught to you by CAM salesmen doesn't.

Regarding machines, Gibbs notes "your parts are probably parts that can be machined on your machines, otherwise you have problems more severe than CAM selection problems. Machine types are easy; three-five axis horizontal and vertical mills, two-to-four axis lathes and mill-turns, and multiaxis multitask machines (MTM) machines. CAM systems either will or won't support your machine types.

"Quality of postprocessors is an important issue," says Gibbs. "Are you buying a turnkey CAM solution, or are you planning to do your own posts? The latter choice is not a favorite of mine. I want to cut chips and make good parts, not learn how to customize postprocessors. I want the problems to be an expert's, not mine. Your posted output should look good, be compact and efficient, use your control's capabilities well, and should not require manual editing to run. You should not have to update your postprocessors when a new CAM version comes along.

"In addition to all of the above, look for a good company, with a good reputation, happy customers, good tech support, training services, and a program for future software updates."

Tailoring CAM to shop needs is a primary goal for anyone evaluating new systems. "In today's market, there are a myriad of options available to CAD/CAM users," says W. Thomas McCollough,

Jr., vice president of software development for Engineering Geometry Systems (EGS), developer of FeatureCAM software. "The most critical thing to keep in mind when shopping for a CAD/CAM system is to define your individual needs. There is no One-size-fits-all' package, but if you can identify your shop's specific requirements, selecting the best solution for you is much easier."

When determining a CAM system's capabilities, those that are originally developed under Windows can best provide critical ease-of-use functions, such as cut-and-paste, dragand-drop, right-click menus, icons, and wizards, McCollough notes. Other things to look for include flexible programming options, he says.

"Look for a CAD/CAM system that is easy to use for both beginners and experienced programmers," McCollough notes. "Programs should walk beginners through part creation and offer suggestions. The software should also allow experienced users to skip steps and program even quicker. It's also very valuable to have a program with a part library that remembers what you've done in the past. The current part then only needs to resemble a previous part and the program remembers the rest."

Postprocessing capabilities are a must, as CAD/CAM systems are useless if they can't post to the machines you are using, he adds. "Look for a system with postprocessors included with the software, and the ability to create new postprocessor and modify existing ones."

CAM systems also should allow users to customize the software to fit the types of parts they are designing and manufacturing. "Companies need to be able to define their own sets of features along with specialized machining processes so they can improve the productivity of their shop," McCollough notes. "CAM systems typically provide a selection of standard features, but many companies specialize in a specific product that has its own set of standard shapes. In those cases, it's easier for the company to create their own user-defined features and add them to the set of standard shapes already provided by the CAM system.

"User-defined features can be used to define virtually any 3-D shape, with the only limitation being your imagination. Unlike static shapes saved in a library, user-defined features are created dynamically by allowing the user to enter the dimensions they want to use to create a unique shape. It's up to the person defining the custom features to decide which dimensions are locked, and which dimensions can be input by the user."

Defining objectives before buying new software is key in evaluating CAM systems, says Chuck Mathews, vice president of DP Technology Corp. (Camarillo, CA). "We recommend that buyers start with a clear definition of the scope and objectives for their CAM purchase," says Mathews. "When they clarify what they are trying to accomplish, it becomes easier for manufacturers to evaluate their alternatives and ultimately measure their success.

"Measure individual CAM products for suitability and productivity," he adds. "Is the CAM system able to do the job out-of-the-box? What requirements are needed to attain this level of productivity, such as operator/programmer skill levels, training needs, etc.?"

Mathews sees four important feature sets for any CAM software. Among these, users need geometry to verify the part geometry in common usage that can be easily read/created in the CAM system. Another is machining processes, where users must know whether the toolpath patterns and axis control needs of the manufacturer or application are available within the system.

Regarding postprocessors, Mathews says users should know if the postprocessors available with the system can support the user's machine tools and required G-code formats. With regard to simulation and verification, he says the system needs to provide performance that accurately represents the configuration of machines to assure accurate computer-based dry-runs and program prove-outs.

"Avoid buyer's remorse by investing enough time to make an informed decision," Mathews suggests. "Limit the detailed evaluation to a maximum of three products; this is especially important for more-demanding applications. Fully evaluate the estimated return on the investment as you take into consideration how the CAM system can be the throttle body for the entire shop. Open your mind to change and avoid being average by choosing a product because it feels safe."

Patrick Waurzyniak

Senior Editor

The 2004 CAM software leaders

Alan Christman

In its annual NC software market update, CIMdata recently named UGS, IBM/Dassault Systems, CNC Software and SolidCAM as the 2004 worldwide CAM software market leaders. This is the same grouping of companies that were named for 2003, and they are also projected to be the leaders for 2005. Each was a leader in a different ranking used by the company to categorize NC software vendors.

UGS was identified as being the largest CAM software supplier on the basis of the dollar volume of NC software and services revenues received by a vendor. The company received an estimated $115 million in CAM-related revenues in 2004, which resulted in a 14.4 percent market share. This is relatively low for a market leader, as the CAM market is quite fragmented.

The remaining vendors (on the basis of dollar volume) were IBM/ Dassault, PTC, Hitachi Zosen Systems and Delcam. The total market share for the top five suppliers was 47.4 percent, which is again a low value for the top five companies in a market.

IBM/Dassault Systems is the largest vendor on the basis of end-user payments for NC software and services. This group includes the revenues received by the supplier and also the revenues retained by business partners or resellers that sell the products. The 2004 IBM/Dassault CAM-oriented, end-user payments for Catia manufacturing-related products are estimated to be $162 million. This generated a market share of 13.6 percent. The remaining top five vendors in this ranking were UGS, PTC, Hitachi Zosen Systems and Delcam. As such, the top five providers were the same in both of the revenue-oriented listings, with only UGS and IBM/Dassault Systems changing places.

SolidCAM was estimated to be the most rapidly growing worldwide CAM software vendor in 2004, with an estimated revenue growth of 51.1 percent over 2004. Other rapidly growing NC software providers in 2004 were Open Mind Technologies, with a 28.1 percent growth over 2003; Missler Software, with a 25.0 percent increase; Auton, with a 21.9 percent growth; and MachineWorks, which posted an increase of 21.4 percent. This is an international group: SolidCAM is an Israeli-based company; Open Mind Technologies is a German firm; Missler Software is based in France; Auton is headquartered in Italy; and MachineWorks is an English firm.

CIMdata also considers UGS to be the largest CAM software vendor on the basis of industrial seats shipped in 2004 because more seats of NX CAM and related products were shipped than that of any other product. The company shipped an estimated 4,830 NC seats, which is 7.2 percent of the estimated 67,110 total NC seats shipped in 2004. This was the first time since 1995, when CIMdata began ranking vendors on this basis, that CNC Software with Mastercam was not the leading vendor in terms of seats shipped. In 2002 and 2003, CNC Software barely edged out

UGS, but UGS overtook CNC Software in 2004. It is estimated that 4,544 seats of Mastercam were shipped in 2004. According to this criteria, the other top five vendors were PTC, Planit and

IBM/Dassault Systems.

However, CNC Software retained its position as the worldwide leading CAM software vendor on the basis of industrial seats installed. CIMdata estimates the company's installed seat count to be 48,152 (as of the end of 2004). It is followed in this ranking by PTC, UGS, Planit and IBM/Dassault Systems.

This information can be found in the 230-page Version 14 edition of the CIMdata NC Software and Services Market Assessment Report. In this report, NC software suppliers are ranked, and the CAM market and technology trends are identified and discussed.

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Evolution of CAM software - CAD/CAM Outlook

Alan Christman

In the 1960s and 1970s, CAM software was characterized by manual programming-oriented, APT-based systems. Although others such as Compact 2 were employed at that time, APT was the prevalent language being used. APT was typically run on IBM mainframes.

The 1980s saw the introduction of graphics-oriented software systems. Turnkey CAD/CAM systems were commonplace. In this scenario, the hardware and the software were sold as a package.

Digital models were employed, and interactive programming was introduced.

The 1990s became the PC era. Wintel-based PCs became the standard platform for both CAD and CAM software. The movement from 2D to 3D accelerated during this period, and 3D became common throughout the world. The use of solids became widespread, and CAM software accepted the use of this definition. Software for tool design, in contrast to product design, was first created during the 1990s.

On the CAM side, the 1990s saw the introduction of automatic re-machining software to cut material left behind from a prior operation without re-machining of the entire part. High speed machine tools that support spindle speeds of 20,000 rpm or more and NC programming software to support them were introduced. Considerable enhancements to the CAM software, such as the use of NURBS output and rounding of tool paths, were required to effectively support these tools.

CIMdata has referred to the 2000s as the era of the digital virtual enterprise. Most manufacturers are moving to a paperless factory environment, individual and complete operations are being modeled without prototyping, and tight interaction among contributors exists up and down the supply chain. The CAM environment in the 2000s is being further characterized by:

* A process-centric orientation throughout a factory.

* Interoperability and tight coupling among software products, permitting co-existence within an integrated solution.

* The use of highly visual graphics-oriented functionality as a core capability within all software applications.

* More application-specific software products that are targeted at the needs of particular types of users.

* The use of hybrid solid and surface models to take advantage of the strengths of both formats.

* Worldwide acceptance of 3D.

* The re-emergence of five-axis positioning and simultaneous five-axis milling as a cost-effective and productive technique.

* The introduction of adaptive and rule-oriented, knowledge-based software.

* The use of knowledge-embedded functionality within all application software.

* Continued evolution to full programming automation.

Although CAM software has been in productive and extensive use since the 1960s and is a relatively mature technology, its use and functionality has steadily evolved over time. This evolution will continue.

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CAM Software Eases Manufacturing Programming

SOFTWARE

Mark Summers is president of CNC Software Inc. (Tolland, CT), developer of Mastercam software.

Manufacturing Engineering: What are some of the major trends affecting CAM software users today?

Mark Summers: One of the major trends affecting software users today is simply to have higher expectations when developing NC programs or managing electronic files. Today's CAM users are sophisticated, knowledgeable, and know what's possible to achieve. More automated features that make programming easier allow a shorter learning curve and allow programmers to learn about the higher-level tools that they may not have had time to explore with yesterday's CAM system.

ME: How can good CAM software boost manufacturing productivity?

Summers: Quality CAM software simply works better and in more situations than software that may not have as much development time and maturity. CAM software that has more capabilities and more stability means the user doesn't have to struggle so much getting the job done and work simply flows much smoother. The end result can be that productivity increases.

ME: What are some features sought by most manufacturers?

Summers: Key features include easy interaction with a lot of CAD systems in the marketplace. Simple CAD file translation and recognition techniques are crucial. In many cases, the idea of a CAM system operating within the favored company CAD system is relatively common. Quality toolpaths and accurate G code of course are the lifeblood of a CAM system. When the cutter hits the metal, a CAM system must project a feeling of confidence to its user to eliminate the all-too-common fear of scrapping the part or driving the tool to an undesired destination. I'll go out on a limb by saying confident users indirectly keep the boss happier than people that are constantly frustrated with their programming tools and abilities.

ME: What does the redesigned Mastercam X CAM software offer customers?

Summers: Mastercam X CAM software, actually X2 is the latest, offers users more tools than previous versions including ways to perform tasks with fewer clicks of the mouse.

High-speed-machining improvements and more five-axis toolpaths seem to be most appreciated by users. Many incremental improvements create the feeling of a 'live product' with much thought and many development hours behind it.

ME: How difficult is it to undertake a major re-write of CAM software?

Summers: 'Difficult' equates to time, money, and stress. I think the answer is about an 8.

ME: What industries are making the most of CAM software to boost productivity?

Summers: Just about any industry that cuts metal, wood, or plastic takes advantage of CAM software. More complex metalcutting industries like the automotive, aircraft, and mold-making industries make the best use of CAM software, since the gain is much higher than in simpler applications where NC programmers might still use a pencil and a calculator to write an NC program.

ME: A key growth market cited today is the medical device/implant industry; how have medical manufacturers employed CAM as a productivity tool?

Summers: Medical parts designers are adopting more of a 'sky-is-the-limit' approach when thinking about what body parts and medical tools are really needed to keep our quality of life high when we have a serious illness or complication, or when we get old. Because quality CAM software can more easily develop complex machining programs, there are fewer design restrictions and more design successes.

ME: What is the current outlook for manufacturing?

Summers: I don't ever envision that manufacturing will dry up, since it's ingrained in us that we 'make things' to make our lives better. A perception might be that manufacturing may be slow or nonexistent when in reality there is simply a continuous shift with regard to where in the world manufacturing is being done. Economics is a powerful force, and low-cost labor is an attraction that many manufacturers cannot resist. Low-cost labor can create low-cost products for us, but the savings seem paltry when compared to trading high-paying manufacturing jobs for many lower-paying service jobs. As the saying goes, 'there is no free lunch,' and this one looks kind of expensive from where I sit. Back to the question, in general, manufacturing is getting easier because our machine tools and software tools are becoming more sophisticated and powerful. Knowledge about machine and software technology is more readily available, because the world communicates more easily these days, and there are fewer secrets in the manufacturing world. These elements force more companies to compete on a more level playing field, and all must work harder to set themselves apart from the pack. Aside from lowering prices, the idea of raising the quality standard is an obvious way for companies to keep their edge.

Technology trends in CAM software

Alan Christman

In the annual CIMdata survey, CAM software suppliers vendors arc asked to list the top three technology trends as they see them. The results are tabulated and punished in the annual CIMdata Market Assessment Report, a 225-page report that assesses the state of the industry. The findings of the most recent survey are shown below in order of frequency of mention, along with a few of my own comments. CIMdata concurs with this ranking by the vendors.

More multi-axis and multifunctional machining. There is a clear trend toward greater use of multi-configuration machine tools. Tools are becoming increasingly complex in terms of being multifunctional, multi-spindle with subspindles, multi-turret, and multi-axis. Lathes with 12 or so axes are being put into production, and the use of four-axis lathes and mill/turn machines is commonplace. The milling capability is comparable to that of some machining centers. Parts that previously required multiple turning and milling machines are now being produced on a single machine. This requires advanced software to effectively use the machines and may also require new postprocessors to drive the tools. However, the savings in setup time and the increase in production efficiency can be significant. Increased use of continuous five-axis machining. Continuous five-axis machines are machining centers in which three mutually perpendicular axes and two rotational axes move simultaneously. This type of machining has long been employed in aerospace operations, but it is now finding use in mold and die machining. Five-axis machines have the reputation of being expensive and difficult to program. However, with prices ranging from $100,000 to $200,000 and with software that is easier to learn and execute, their use is broadening.

High-speed cutting is becoming commonplace. Most mold and die shops now employ high-speed machining. The software to support this technology must provide for fast and efficient transfer of data; smooth tool movement that minimizes any sudden change in direction: a constant chip load to maximize the life of the cutter; and support of those machine tool features necessary to produce gouge-free, high surface finish parts. Surfaces must be tangent, without gaps or overlaps. Machining is sometimes done on the actual surfaces as opposed to tessellated surfaces to obtain a higher quality output. However, quality problems sometimes occur with high speed machining, as the material can overheat, cracks can develop and the material can move.

Nevertheless, the use of high speed cutting has become mandatory for toolmakers, and all CAM software vendors providing products to this industry segment must effectively support this technology.

Further automation and greater use of knowledge-based machining (KBM). Every aspect of CAM software is becoming more automated, making it easier to learn and use and more productive for the user. The utilization of KBM is the centerpiece technology for implementation of semi-automatic and automatic toolpath generation.

The two primary technologies for implementation of knowledge-based machining are adaptive and/or generative. In addition, a KBM process can be either feature-based or parts-based. When employing feature-based machining, automatic feature recognition software can be used to examine a model, determine which features exist and extract the features for subsequent processing.

More solid-base machining. Solids-based machining is increasing and is now commonplace. Seamless interoperability with solid models is occurring. Machining is often accomplished directly on a solid model. The three main elements of solid-based machining system are:

--A solid modeling system.

--The ability to import the data contained within the model into the CAM system without translation.

--A CAM system that uses the inherent intelligence and functionality with the solid model.

Most software vendors now support machining on a tessellated solid or surface model and solid and surface definitions can be intermixed with the same hybrid model.

Increased use of 3 + 2 machining. In five-axis positioning, also known as 3 + 2 machining, a two-axis tilting rotary figure is added to a three-axis machining center so that workpieces can be positioned at different angles. Once positioned, the workpieces are then cut in three-axis mode. This type of machining provides many of the benefits of full five-axis milling, and it can serve as an alternative approach to either three-axis or five-axis continuous machining.

This type of machining is particularly important for cutting deep cavities or deep standing cores in molds. Software is sometimes employed to optimize the tilt angle of the tool. The user defines the maximum tilt angle but does not need to define the specific tilt angles. The software finds the locations where tilt of the cutter is required and the calculates minimum tilt angle to avoid hitting the side. The software will maintain that angle until a collision is apparent. At that point, it will change the angle in order to avoid a collision. If an area is encountered that does not require a tilt, then the software reverts the tool to a position normal to surface or one with less tilt. All repositioning of the tool can be done automatically with a minimum amount of tilt. The tool path from this process will look like a continuous five-axis tool path. This technique is becoming increasingly common in mold machining.

Introduction of process-focused automation. Software is evolving from the use of basic instructions to full-process automation. A process-focused approach is better able to consider the full needs of a specific type of user. For instance, wizards can be used for processes such as electrode design or tooling assembly creation. A number of vendors have introduced application suites for design and cutting of progressive dies. Full five-axis processes including the machine tool, controller, toolpath generator and postprocessor, are available from some vendors for milling of intricate products such as impellers, blisks, turbine blades, tubes, pipes, tire molds, aerospace components, dies and deep cavities within molds. Software is usually customized to enhance a process.

Emergence of more realistic simulation. Significant improvement is being made in software for machine simulation, toolpath verification, and rendering. Realistic simulation of the entire machining process including the machine tool, holders, machine components, cutting tools and stock can be made. Simulation of the tool path is provided to verify its accuracy. Gouges, undercuts and any discrepancies between the target part and the machined part are shown. Users can compare the in-process model with the designed workpiece. Rendering software provides for photorealistic images of the machined part.

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CAM Software Speeds Manufacturing Productivity

SOFTWARE

Bill Gibbs is president and CEO of Gibbs and Associates (Moorpark, CA), developer ofGibbsCAM software.

Manufacturing Engineering: How can CAM developers help manufacturing customers boost their overall productivity?

Bill Gibbs: In so many ways. Productivity is ultimately about making parts with less labor, making parts with less machining time, making more parts. GibbsCAM's strategic focus is production machining. This is our number one priority, focusing on the needs of people who are involved in production manufacturing. We define production manufacturing as involving people who are concerned about the cost of a part, the run time, the machining time, the quality. There are areas of our industry that are not production machining, prototype shops and mold-and-die shops, and we like these people as customers, too, but that doesn't stop us from focusing on the needs of the production machinist as our first priority.

So how do we improve their productivity? Literally everything our product does is trying to answer that question and solve that problem. We start by having a product that we think takes less training to learn; a product that programs their parts in less time; one that produces programs that run without error, without flaws, because crashing the machine is certainly nonproductive; and we try to produce programs that have faster run-times. Because machine time has to be the single biggest cost, we want to be able to set up the part faster, because setup time is a key cost component. We want to be able to automatically produce setup and run-time documentation, so that our customers don't again waste hours and hours putting paper together for the machinist and the setup. All of these things become factors in how a machine shop is more productive with our software than without our software.

ME: How difficult is it to program CAM software?

Gibbs: At the high-end of production machining, we now have these multitasking [MTM] machines that are hot. Mazak picked GibbsCAM as the programming software to recommend for its Integrex machines, and we are a strategic partner of Mazak to supply their customers with high-end productivity software. Just recently, Mori Seiki approved us as a software supplier for their high-end machines. We had to jump through hoops to demonstrate to Mori Seiki that we had a quality product that supported their machines, and that their customers would be more productive programming their machines with our software. So, it's not any one feature of CAM software that's important-it's having the complete suite of capabilities in the product, as well as service, support, and training.

ME: What are some of the most important trends, such as high-speed machining, MTM, automatic feature recognition, and solids machining, in today's CAM software?

Gibbs: They're all important, and I don't think any one of them is necessarily more important than the others. In the CAM world, getting excited about any CAM system because it has one feature you like is about as myopic as you can get. A CAM system is not characterized by a single feature-it's not even well-characterized by a list of features. With a CAM system, again it comes back to how does it work with your people on your parts to run your machine? And the suite of capabilities required to be the best product for your people, your parts, and your machines, is going to cover all these bases. If you're doing high-speed machining, then you're going to be concerned about the highspeed machining capabilities. If you're doing three-axis surfacing, or five-axis rotary milling, you certainly need to be more concerned about those kinds of machining capabilities, but that doesn't mean you get to stop being concerned about all the other aspects of this rather complex decision.

ME: How are software developers making their CAM software easier to use?

Gibbs: I don't think most of them are. All of us have the same problem. What are we going to invest our $1 million or $2 million of development in next year? What are our computer programmers going to work on? And your sales department comes in and they give you the list of all the reasons their resellers say they lost sales. This is a vicious cycle. They go through this whole list of reasons that they felt they lost orders. 'If only we had these features, we would have gotten all those orders,' which isn't exactly true, but it's easy to get swept along by this feature madness. So with all this pressure to add new features, we strive to invest time in maintaining and improving the things that we feel make our software easy to use and high quality, even though they don't create new features.

ME: What are some of the key manufacturing markets, such as aerospace, automotive, medical, heavy equipment, that CAM serves, and how are those customers aided by CAM tools?

Gibbs: It's a difficult question to answer because we don't focus on manufacturing markets; I personally think that there isn't a whole lot of difference between medical parts and aerospace parts. There are more similarities than there are differences. Medical parts don't tend to be 60' long, and airplane parts don't tend to be made out of the same materials all the time. What CAM software cares about is what are we starting with? In both industries, what materials we're going to be cutting makes a little bit of difference. What tool strategies do we want to apply? What kind of machines are they going to be using? There's tremendous overlap. So it really doesn't matter a tremendous amount the difference between industries, if they're mainstream production machining industries. We work with the power industry, the oil industry in Texas, and we like medical. We have customers doing bone spurs and hip joints.

What's really neat about medical is that a lot of medical stuff is custom-tailored to a customer and low volume-and that means more programming. If a guy's going to run off three million bone screws, he's got a 15-minute program that he's going to run for a year and a half. If a guy's doing hip ball joints, then he's going to potentially make a different ball joint, or at least a range of sizes, for all the different customers. So again, there's more programming involved. It's fun working with the medical industry because a lot of times doctors are involved, and doctors are highly educated, technical people who are looking for technical solutions. These are interesting people to work with.

ME: Consolidation seems to be underway in the CAM market. What does this trend mean for the CAM market?

Gibbs: For the market as whole, we're following the paths of the business models of a mature market, meaning there are as many or more products on the market than there's market demand for. It means that most products have covered the basic capabilities to be good enough. It also means that we're all struggling to identify what makes us different. We're becoming a commodity. While I can point out all the differences that make us better, people who buy my competitors' products are not going to fail. They're not going to crash and burn. We have some reputable competition in this industry. What's going to happen is those of us who have achieved adequate success over the last 20 years, who have a large enough installed base over the last 20 years, who are still successful, profitable, can continue to grow our products, can continue to grow our business, we can still look forward to growing. Companies that are small and marginal cannot. They're going to get squeezed out, and this is what makes them attractive purchases to people who want to acquire them. We have looked at acquiring some of our competition over the past several years. It's a difficult business decision.

ME: Do you expect that consolidation in CAM will continue in a big way?

Gibbs: Sure, as the small companies struggle, they're going to be cheaper and cheaper to buy, and companies will be bought just for their installed base. At some price, it makes sense for me to buy a small company just to have access to their customers.

ME: How do you see the current-business outlook for CAM software, and for users of CAM software?

Gibbs: I think it looks strong, 2005 was a record year for Gibbs. We had very good sales, very good growth, and very good profitability. I would say that it was primarily economic conditions, and a good product. We've had some good partner-. ships established, including Methods Machine Tools picking us for Nakamura-Tome support, Mazak selecting us for Integrex support, and our collaboration with Mori Seiki, which is huge. It's a breakthrough for Mori to add other people to their approved list. To do this, we had to develop postprocessors for all their new NT Series machines, and Mori Seiki engineers had to approve all our postprocessors. Mazak had to approve our postprocessors for Mazak, and Methods had to approve our postprocessors for Nakamura-Tome. For all these high-end machines, we're offering factory-approved postprocessors that the customer can use. We have to match the parameters of the control, but other than that they're perfect.

ME: How key is it for CAM suppliers to guarantee that postprocessors will work 100% of the time?

Gibbs: We do strive to build perfect posts, and the majority of the postprocessors are factory-built by Gibbs. It's not a strange option we offer at incredible expense, it's the way we prefer to deliver postprocessors. We have about 10 people whose full-time job is postprocessors. They're experts at it. We check them against what the end user actually has, because as we say, every CNC machine is a snowflake-there are hundreds of parameters that could have been changed, there are dozens of options that might or might not be in the machine. Even though it's a machine that we have factory-approved, we don't know that the customer's machine is identical. We've done dozens and dozens of machines-all the same exact model number-that are all a little different in the way they program. They are snowflakes. They're all a little different, just a little, but if one thing is different and you don't get it, it crashes the machine.

So a post has to be 100% perfect, it has to pick up every detail, it has to match the snowflake. And if you get all that, then it's not the customer's problem. What we don't want is the customer to be saying 'geez, I've got to come in this weekend and work on fixing my post.' We want the customer to say 'we're cutting chips this weekend, untended, lights-out, 24/7, we got GibbsCAM.' That's what Haas does with us.

Solids CAD/CAM software

Life is getting easier for designers as new software takes on more and more of their work. It's now possible to make complex shapes, blend elements of several parts, and do some reverse engineering, all with one CAD/CAM package. One example is version 8.0 of Cimatron software that handles design through manufacturing, available from Cimatron Ltd. (Burlington, Ontario).

Cimatron is an integrated 3-D mechanical engineering CAD/CAM software package for both Windows and Unix. Application modules for conceptual design, engineering, rendering, and manufacturing all present the same interface to the user. The software is configured for advanced wire frame, surface, solid design, and two to five axis machining. Version 8.0 lets the designer integrate design software with manufacturing software to machine surface, solid, or hybrid models. All geometry can be used in one hybrid modeling environment for maximum design efficiency.

The design modules have two new functions for moldmakers: Split divides the part along any plane users select and automatically applies mold drafts, and the Reference Face option applies draft to faces abutting a curved surface. When constructing models in Solid Sketcher, users can modify geometrical dimensions and constraints dynamically. Smart shell generation automatically solves tight areas and rounded corners where shell walls overlap. Surface and spline tools now create nurbs entities. The fillet function benefits from nurbs modeling. For example, curve-to-surface fillets are now possible, and fillets may be keyed to control curves to define section orientation. It is easier to manage complex solid construction and assemblies. Flexible assembly management tools support top-down or bottom-up assembly, with exploded assembly views, sections, and detail views. New functions check interference for one or all components.

The improved NC machining module generates machine code directly from mixed solid, surface, and wire frame models. This frees engineers to use various modeling tools at will on complex partsand be assured of seamless NC toolpaths for the entire design. Because the integrated database structure unites design and machining data, NC-on-solid toolpaths change as the underlying parametric model is altered. The model can be analyzed to improve machining with tools such as WCUT. WCUT automatically adds additional layers between userdefined stepped planes in order to maintain the desired semifinish quality. Knowledge-based algorithms in the Core/pocket option optimize milling electrode geometries. The gouge checking feature has been improved to spot gouging caused by either conic tools or the toolholder. The new Up OnlyDown Only option is a shortcut that structures toolpaths containing only up or down motions. Tool parameters and cutting modes are stored as ASCII files, independent of part files, for application to other parts. Circle 201.

Keep CAM software quality in mind

Gibbs, Bill

QUALITY SCAN

The only acceptable level of bugs in software is no bugs

In today's CAM market, buyers are increasingly overwhelmed by lists of application features full of industry buzzwords, which for the most part can only be understood, differentiated or even appreciated by CAM experts. At the same time, competition, and a maturing technology, has turned these feature lists more into a "you say toe-MAY-toe, I say toe-MAH-toe" situation than ever before. To top it off, in an attempt to differentiate their product from the alternatives out there, CAM vendors stress some of these points as if one feature should have a tie-breaking bearing on the customers' purchase decision. For the most part, it just isn't so-at least not with the features that most vendors would offer up as definitive.

But one feature, I suggest, should be first and foremost in every CAM buyer's mind as they shortlist their choice of a system that will ultimately influence their company's manufacturing productivity and efficiency. It's actually a pretty universal aspect that you can, and should, measure before making that final commitment to a particular CAM system. What I'm referring to here is software quality.

There are many different aspects to software quality. Probably the most widely accepted measure of software quality is how bug-free the software is.

CAM vendors often claim that software quality is an ever-elusive characteristic of any software application. That if you write code, you can rest assured you're going to create bugs. That might be the case, but tell it to your boss when your job is late because of some bug in the software that naturally should be expected to exist, because after all, doesn't all software have bugs?

No, from a user's perspective the only acceptable level of bugs in software is no bugs. At the same time, creating bug-free software is not an easy thing to do. By its very nature, CAM software is (numerically) complex, which introduces lots of opportunities for software bugs to creep into the code. To create robust software, the software developer must be forever diligent in their efforts to detect, diagnose, and destroy-- the 3D's of software quality-flaws in their products. Continually striving for nothing less than bug-free code, rather than accepting bugs as a natural part of writing software, can make a difference.

But software quality doesn't stop with the system's basic functionality. How useable that functionality is represents an extremely important factor in software quality. You could have the most powerful CAM system in the world, but if you can't productively use that power, what do you have? Ease-of-use has become a very popular "check-the-box" claim with many vendors today, because they know it's a very important quality factor. But how many actually live up to those claims; how many do more than just adopt the term "ease-of-use," rather than designing their system to be easy to use? Spend the time to look at what it takes to use the system; how efficient is it, how intuitive or natural is its interface? Can the system adapt to the way you do things, or do you have to adapt to how it does things? Because you're going to be using your CAM system for a very long time, it's extremely important that you consider how easy it will be for your users to employ the software to do the type of work that your company does.

In a similar way, ease-of-learning, or how easy will it be for your users to learn how to effectively use your CAM system, is another important aspect of software quality. Again, you could have the most powerful CAM system in the world, but if you can't learn how to use it you'll never realize a fraction of what it's capable of accomplishing. And there's a big difference between a system that just makes a "check-the-box" claim versus one that has been designed to be intuitive and natural, and ultimately easy to learn by the user.

So, when it comes to comparing feature lists when buying CAM software, remember that differences in functionality are often fleeting-what one vendor offers today is often leapfrogged by what another vendor offers tomorrow. But a vendor's commitment and ability to deliver a CAM system with an excellent level of software quality is something that rises above the rest of the stuff on feature lists.

Bill Gibbs

Founder, President, and CEO Gibbs and Associates Moorpark, CA

CAD/CAM Software Advances

Waurzyniak, Patrick

Latest packages add more simulation, support for multitasking machines and high-speed machining Programming software for machine tools enables manufacturers to easily add new features for improving metalcutting efficiencies. With the latest updates to CAD/CAM and NC simulation/verification software, manufacturers can take advantage of an array of improvements including expanded support of multitasking machine tools, full-machine 3-D simulation capabilities, plus new toolpaths for multiaxis and high-speed machining.

With worldwide competitive pressures demanding the highest-quality finished parts, manufacturers increasingly require machine tool programmers to provide completed workpieces needing little to no rework. For five-axis machining, new capabilities in PowerMILL 7 from Delcam plc (Birmingham, UK) include a wider range of five-axis strategies for roughing and finishing, faster calculation times, improved point distribution, and easier data management. The five-axis roughing strategies now include machining to or from a point, orientation through a line or curve, and programming using a reference surface.

Among five-axis developments, some of them like point distribution on a toolpath are a little bit more subtle and difficult for users to immediately notice, says Craig Chester, Delcam's international sales support manager. "From a user point of view, they probably can't see any difference whatsoever. We've put in a lot of smoothing algorithms to smooth out the point distributions and make it a much more even point distribution, and subtle vectors moving as well," notes Chester. "The toolpaths may look the same to the naked eye in PowerMILL, but when you see them run on a machine tool, they're significantly different."

Higher-quality surface finishes allow manufacturers to avoid costly, time-consuming rework on parts, which is critical in today's ultra-competitive manufacturing environment. "A lot of surface problems in simultaneous five-axis are due to kinematics effects on the machine tool, so a toolpath may be mathematically correct and in theory give you a beautiful surface finish, but due to various kinematics effects, that's not necessarily the case," Chester notes.

"People are demanding that the part is finished and ready to be shipped as the part comes off the machine, whether in five-axis or threeaxis," he adds. "Certainly in the Western world where we're trying to compete with the low salaries of China, the only way we can compete is by being more efficient."

Multiaxis improvements from Pathtrace Systems Inc. (Southfield, MI, and Reading and Yorkshire, UK), which was acquired early this year by Planit Holdings plc (Ashford, Kent, UK), are included in the latest EdgeCAM 11. It adds new functionality to support four and five-axis simultaneous milling on the latest-generation mill-turn machines, as well as improved drilling routines for automatically finding and machining holes through cylindrical and conical faces.

"Advanced milling and mill/turn machines offer enormous productivity improvements, and EdgeCAM 11 enables businesses to maximize their investment by making the full range of four and five-axis cycles available," says Dave Boucher, Planit Holdings CAM product director. "The four and five-axis strategies in EdgeCAM have been designed with multitask machines in mind and offer unparalleled ease of use for this advanced technology."

Mold-and-die users are starting to use more five-axis machining, as costs fall on machines that until recently have been too pricey for smaller shops. "We're beginning to see five-axis coming to mold-and-die, and that's something people have been talking about for years but it's now beginning to happen," notes Vynce Paradise of CAM software developer UGS Corp. (Plano, TX). "The small tool companies are buying these smaller, cheaper five-axis machines, and they're looking for five-axis software to drive it."

At IMTS 2006, UGS demonstrated its NX CAM Express software, which is a full-function NC programming software package aimed at mid-sized companies with a lower pricing structure and more automated setup to make setups easier for novice users. "It has all the capability of NX because even small shops have complex machines," Paradise notes. "We haven't reduced the functionality. We've made it easier to use by putting in tutorials and pre-set environments. These pre-set environments will set the system parameters up so the programmer doesn't have to do that from scratch-you select your environment for prismatic machining, for turning or for five-axis, and then the system presets, and therefore, it can hide a lot of the system switches from the novice or new user."

Multiaxis additions from CNC Software Inc. (Tolland, CT) include new multiaxis functionality and toolpaths for HSM and hard milling to its latest Mastercam X Maintenance Release 2 software demonstrated at IMTS. The updated Mastercam software adds a new engine to the advanced multiaxis toolpaths, which provides a customized, streamlined interface that is fine-tuned to specific applications, such as impellers and turbine blades. Depending on what toolpath is being used, Mastercam's parameter pages display only parameters applicable to the specific toolpath type.

Advanced controls for gouge-checking allow full control of the tool motion in Mastercam, and users are not limited to retracting only along the tool axis. Full roughing capability is also available for all the advanced multiaxis machining strategies, including an option for plunge roughing. Advanced 3-D simulation capabilities were shown at IMTS by PartMaker (Fort Washington, PA), formerly IMCS Inc. prior to its acquisition in July by Delcam. In its preview of PartMaker 8, the company demonstrated its new full-machine simulation module which is said to offer photorealistic 3-D models of machine tools in action. The simulations, based on actual 3-D solid models, can help users pinpoint potential errors and collisions on the complex multitasking turn-mill and Swiss-type turning machines that PartMaker programs.

With PartMaker's new simulation module, the company is offering users improved error-checking and collision detection to users, by allowing them to perform an even more robust machining simulation than currently offered by the CAM supplier. With the new system, the machine model being simulated incorporates machine specific toolholders and attachments to ensure that any possible collisions that might occur on the machine will be detected off-line on the user's PC, resulting in CNC programmers and machinists spending less time setting up new jobs and performing dry runs to assure there are no collisions on the machine.

"Our specialty is multiaxis turning, programming turning machines with live tooling," says Lena Fishman, PartMaker founder, executive vice president and chief technical officer, noting PartMaker holds patents for programming multiaxis turning machines, both Swiss-type and turn-mills, and for synchronization. "We know that for multiaxis turning equipment to be effective, multiple tools cutting at the same time have to be properly synchronized to avoid collisions.

"We have a patent in this area that clearly is also very important for turn-mills, but far more important for Swiss machines," Fishman says. "Even before we had our 3-D simulation, we had our own 2-D simulations where it was specifically geared to the needs of Swiss machines, where we could show the moving parts, which is very difficult. Simulation is critical to our process."

After acquiring PartMaker, Delcam has no plans to make any changes to the PartMaker user interface, according to Delcam managing director Hugh Humphreys. "It's been developed for a specific customer so that will clearly stay," he says. "We will help them to grow their sales overseas, and that will generate more revenue and will go back into development, so it's good news for customers. The product improvement cycle will continue-if anything, it will be faster.

"PartMaker is an unusual CAM company, because there is a big difference between itself and the nearest competitor-nobody else really focused on SwissTurn, so it's their strength. Their software is available for milling and turning as well, but they've focused more and more on the more difficult area, and that proved to be of interest.

"The focus is very much on efficient machining, above all else, whereas a lot of products are maybe more focused on easy programming," Humphreys says of PartMaker. "That's not the case.

Swiss-CAM is focused on saving seconds of machine time."

Production machining updates previewed at IMTS by Gibbs and Associates (Moorpark, CA) included a suite of three-axis enhancements that extend GibbsCAM's existing machining capability and provide users with a complete range of milling functionality with support for high-speed machining.

With the new advanced three-axis functionality, GibbsCAM adds a variety of capabilities, such as 3-D rest milling, which focuses machining only on remaining material to be removed, minimizing air cutting, and significantly reducing cutting time. Multiple containment areas and avoidance areas allow precise control of toolpath to efficiently control the machining process, and users can also specify that the toolpath generated by the new three-axis functionality has no sharp corners, optimized for high-speed machining.

In addition, Gibbs also introduced its new GibbsCAM Machine Simulation option for multitasking (MTM), mill/turn, and turning machines at the show. The simulation option complements Gibbs' existing Cut Part Rendering process simulation capabilities, allowing an entire machine tool motion of a CNC program to be validated in an accurate simulation.

"As machine tools become more and more complex, the need for an accurate simulation of the machine tool motion becomes more and more critical," says Bill Gibbs, Gibbs and Associates president. "The latest class of multitasking machine tools represent just the beginning for machine tool complexity and configurability. We fully expect that multitasking machine tools will continue to evolve and place even more extreme requirements on programming systems."

Data interoperability issues are addressed with the latest Esprit 2007 CAM package from DP Technology Corp. (Camarillo, CA), which includes the company's new Esprit FX technology for CAD-to-CAM feature exchange. Demonstrated at IMTS, the Esprit FX technology is incorporated into DP Technology's milling and wire EDM software. The FX technology allows users to automatically capture design intent, defining what is being machined and allowing programming parts much quicker and easily.

The FX technology provides portions of the original CAD Feature Tree directly inside the Esprit CAM system's interface, including original design elements including features, tolerances, material properties, surface finishes, and administrative data. The system enables mapping the CAD features and their associated properties into machineable features providing a complete definition of what is being machined. These manufacturing features and their properties are then fed into Esprit's Knowledge-Base, aiding users in automatically selecting how to machine the part based upon existing best practices.

Known for its ease of use, the former SmartCAM software program was highly regarded years ago before the company folded. After its rights were acquired from UGS in 2003, the software was redeveloped by SmartCAMcnc

(Springfield, OR), which has released five major updates to its Windows-based SmartCAMcnc software package in just under three years, according to Hugh

Caldwell, SmartCAMcnc vice president.

At IMTS, SmartCAMcnc announced that SmartCAM V13.5 functionality provides all SmartCAM customers with its new Job Information Management enhancements for organizing and capturing of job and process data. The SmartCAMcnc line of stand-alone CAM software includes packages for milling, turning, fabrication, and wire EDM applications on a full range of parts, from two-axis work to complex three-axis molds, dies, and prototypes. SmartCAMcnc also provides maintenance contracts, updates, upgrades, and technical support for all SmartCAM users, regardless of version.

"The new enhancements allow a user to create a 'master job library' and to populate it by capturing and collecting the tooling, operation parameters, and speeds and feeds from their previous SmartCAM job files," notes Doug Oliver, SmartCAMcnc senior product manager. "Once the library is populated, the stored data can be easily inserted into the current job, which will greatly reduce the time required for defining tooling and job parameters, saving 50% or more of the time previously required to set up a new job. Because the new tools capture the existing tool and job data, users can now spend more time on their primary task: creating accurate and efficient toolpaths."

NC simulation and optimization in the Vericut NC software package from CGTech Corp. (Irvine, CA) have been enhanced with new capabilities to support more complex processes and machines, simulating multiple setups in a single simulation session. The updated Vericut 6.0 software offers new features designed to increase the ability of CNC programmers and manufacturing engineers to analyze and optimize the entire CNC machining process in order to increase manufacturing efficiency.

With Vericut, users can tie complex machining processes together with the ability to simulate multiple setups in a single simulation session. The updated software also includes enhanced collision-checking that monitors spindle states for milling and turning simulation, enabling users to catch common programming errors with spindle and cutting-tool usage.

The updated Vericut software includes significantly enhanced simulation of complex cutting-tool shapes commonly used in production processes and shows the NC programmer or manufacturing engineer exactly what will happen when using the tool. "The result of this work is a tightly unified environment for simulating complex mill/turn multi-function machining centers for production processes," notes Bill Hasenjaeger, CGTech product manager. "Vericut leverages the results of simulating complex processes with the ability to create inspection instructions, CNC inspection programs, and automated process documentation using the simulated workpiece. Because of Vericut's accurate, feature-rich inprocess model of the simulated workpiece, the inspection and process documents can accurately reflect the state of the workpiece at any stage of the process."

Patrick Waurzyniak

Senior Editor

Brief Update On CAM Software Automation

Alan Christman

A continuing objective for CAM software suppliers is to enhance the ease of use and level of automation, even as additional functionality is being introduced. As such, the evolutionary march toward further automation of the NC programming function continues. Many users state that they prefer total push-button automation, while others favor retaining control of the process and some degree of flexibility. In a recent study of worldwide moldmakers conducted by CIMdata, the extent of desired automation was ascertained. The results are shown in the following table:

Table 1Degree of automation preferredProvide guidance to a user/ 38.9%not full automationObtain maximum automation 37.0%Automation standard functions only 14.9%Retain maximum user flexibility/ 9.3%limited automation

It can be seen that more than 90 percent of the users prefer a significant level of automation. Further, the most frequent responses were from those who favor maximum automation and those who desire automation, but with guidance being left to the user. Maximum automation can currently be obtained by extensive software customization by users. Firms producing a parametric family of products, such as golf clubs, bottles or shoes, often employ this technique. In addition, research projects are underway, such as the one being conducted by STEP Tools, to directly cut a part from a CAD model without employing an NC programming process as an intermediary operation. When successful, this approach will provide a high degree of CAM programming automation.

Concurrently, to further software automation, a number of vendors have implemented or are implementing knowledge-based machining (KBM) software systems. Generally speaking, KBM systems are either adaptive or generative and are either feature-based orparts-based. In adaptive machining, traditional programming processes are captured by the software as programming occurs and are saved as process templates. In subsequent identical or similar situations, a template can be re-used directly or modified somewhat to adapt to a new situation. In generative machining, a predefined set of machining practices and/or rules are applied to a feature or a part. Given the part geometry, part material and tolerance, a machining process can automatically be created by the software.

In feature-based machining, a part is viewed as a group of interrelated manufacturing features such as pockets, holes or slots. Feature recognition is often used to automatically recognize the features. Specific machining strategies and parameters are then applied to each feature. This type of machining is usually employed for prismatically shaped parts.

In parts-based machining, a part is treated as a whole with methodologies that address an entire part and the resultant areas that require rework. This technique is most appropriate for complex-shaped parts such as molds and dies. The following table illustrates this KBM concept and lists some example vendors and products that employ the technique.

Over time there has been an evolution or cycling in the KBM technology being introduced by suppliers. The first products introduced in the late 1980s and early 1990s were generative-based products. These systems did not become commercially successful, primarily because of the level of effort required by users to embed their machining practices and rules in the process. In the mid to late 1990s, the adaptive approach became commonplace, as it requires a minimum front-end investment.

In comparing adaptive and generative KBM software, each approach has its advantages. The adaptive type is quicker to implement, does not require the creation of rules, involves lower development and maintenance costs, captures settings and does not base efficiency on the number of rules. The generative type is likely to be the ultimate solution, is more flexible to design changes and the range of parts, captures manufacturing rationale, has a process independent of templates and does not create a file management problem.

Table 2Knowledge-based machining grid Adaptive GenerativeFeature-based PTC/Expert Machinist EGS/FeatureCAMParts-based UGS/UG CAM

Delcam/PowerMILL

CAM Software helps mill-turn, solids machining

Richards, Paul

SOFTWARE

Manufacturing Engineering: What are some of the hottest trends currently in CAM software?

Ricard: The hottest trend in CAM software is full programming support for multifunction mill-turn machines. While the machine tool market as a whole is in a recession, the number of shops investing in single setup mill-- turn machines appears to have picked up rapidly in the last couple of years. Mill-turn machines combine the functionality of milling and turning machines and make them both fully available on one machine. These multifunction machines provide the ability to mill and turn both the front and back of a part, completing the required machining in one setup. What once involved two machines and four setups, now requires one machine and one setup.

Shops have been hesitant to invest in these machines because the programming task has been quite complex. Recently, an increasing number of CAM vendors are offering a user—friendly programming environment for mill-turn machines, enabling shops to achieve the dramatic productivity gains for which these machines are designed. CAM systems that provide one programming environment where users can do milling and turning operations in any combination on a single workpiece, while providing complete synchronization, optimization, and 3-D solid simulation are on the cutting edge of this trend.

ME: How has machining directly from 3-D models helped manufacturers?

Ricard: 3-D solid models minimize the need for the programmer to manually input part information, such as the height and depth of a feature, draft angles, hole characteristics, and feature type (slot, boss, or pocket). Using 3-D solid models, manufacturers significantly reduce the errors associated with manual input, as well as decrease the time it takes to program parts.

A 3-D solid model provides the additional information needed to increase automation, letting the software automatically recognize features and adapt machining processes to the new part geometry. For example, machining a hole versus a hole with a chamfer requires a process change to machine the new feature correctly.

ME: What impact has 3-D solids machining had on the 2-D market?

Ricard: In the 2-D market, the impact of 3-D solids machining is most significant because 3-D solid part representation offers a dramatic improvement over a 2-D drawing. When all machining is performed directly on the solid model, this assures that the on-screen "asmachined" part exactly matches the original "as-designed" version. 3-D solid modeling has contributed to the 80% reduction in programming time achieved by one of our customers supplying intricate parts for the medical industry, as well as enabling a leading pharmaceutical manufacturer to greatly increase the complexity of parts it produces internally.

ME: What can be done about moldmaking going overseas, with US moldmakers losing business to Asian competitors?

Ricard: US moldmakers need to narrow the cost-factor gap; production costs will have less of an effect if US manufacturers invest in state-ofthe-art equipment and software. There is a misconception that Asian manufacturers are not sophisticated-- in fact, Chinese manufacturers often hold advanced degrees in engineering and utilize top-notch machine tools and programming software in their shops. The United States needs to invest more in the training and emphasize higher education for future manufacturers. To ensure equipment and software is in tip-top shape, shops can hire consulting services and evaluate machining techniques to see if their programming methods can be further automated. For example, a CAM system that captures knowledge is able to adapt proven machining processes to future jobs and provide consistent quality for repetitive tasks, so the wheel doesn't have to be reinvented every time.

ME: How can CAM manufacturers protect their intellectual property rights in markets like China and India, where software suppliers have had problems?

Ricard: The best way to deter pirating is for CAM vendors to offer a quality software maintenance program that delivers regular and substantial improvements with each new version. In reality, the cost of software is insignificant compared to the cost of training and the productivity lost if users do not have the current version of the software. Piracy can be kept in check if companies educate the marketplace about the value of a software maintenance program, emphasizing the benefits of regular software upgrades at no additional cost, the included training and 24-hour support, and the productivity gains which compound year after year.

ME: What's the immediate impact of the STEP standard on CAM software, and how will STEP help manufacturers long-term?

Ricard: STEP is a data format-- just one of several available in use today. The immediate impact of STEP on CAM software is negligible. Where STEP differentiates itself is in the long-term; because STEP is neutral and modern, it has the most potential for survival over the long term. For CAM vendors, the job of maintaining the various proprietary file formats is expensive and time-consuming. Standardization on a single neutral file format, such as STEP, would benefit CAM developers and their customers, because the R&D investment currently utilized to support the numerous proprietary file formats could be redirected into features that have significantly more value and impact on productivity.

Paul Ricard is president and cofounder of DP Technology Corp. (Camarillo, CA), developers of Esprit CAM software.

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Plugging into STEP NC - Emphasis: CNC - CAM software firms offer programs for CNC machines

Mark Albert

CAM software companies are offering software programs that allow their users to read STEP-NC files info their existing CAM software to generate the tool path and output for specific CNC machines. These "plugins" make many of the benefits of STEP-NC available to the average machine shop today.

The concept behind STEP NC is simple. It enables a product model database to serve as direct input to a CNC machine tool. No separate files of tool paths. No G or M codes. No post processors.

This is a radically different approach to CNC programming. It has far-reaching implications for the emerging possibilities of "e-manufacturing." Recent developments, however, promise to make it easier for CNC machine shops to make the transition to this technology Without scrapping existing machine tool and CNC programming technology, shops now have a way to implement key aspects of STEP-NC.

Several leading CAM software companies have made it possible for STEP NC files to be used with their own software. This makes their users ready to participate in supply chains that are turning to global data exchange standards to streamline the flow of digital information over the Internet.

According to STEP Tools, Inc. (Troy, New York), a leading supplier of STEP software toolsets for application software developers, design firms and manufacturing companies, STEP NC offers significant savings to machine shops and their customers. The company estimates that, by fully implementing STEP NC, machine shops can reduce the time it takes to get jobs onto their machines by 35 percent if they can seamlessly read the 3D product geometry and manufacturing instructions of their customers. Likewise, original equipment manufacturers can reduce the time they spend preparing data for their suppliers by as much as 75 percent if they can seamlessly share the design and manufacturing data in their databases.

STEP Tools also estimates that STEP NC will reduce machining time for small- to mid-sized job lots by as much as 50 percent because STEP NC compliant CNC units will be capable of optimizing speeds and feeds with very little intervention from CNC programmers or machine operators. This factor could make it easier and safer to program high speed and five-axis machines, the company says, making it more likely that they will be used for small- to mid-sized job lots.

STEP NC In A Nutshell

STEP NC is an extension to STEP, the STandard for the Exchange of Product model data. STEP is the international standard that specifies a neutral data format for digital information about a product. STEP allows this data to be shared and exchanged among different and otherwise incompatible computer platforms. STEP NC standardizes how information about CNC machining can be added to parts represented in the STEP product model.

By using STEP NC to capture instructions on what steps to follow for machining the part, the "producability" of this part would not be affected by the availability a certain brand of control unit, programming system or post processor. Figure 1 compares the key features of STEP NC to current conventional approaches to creating CNC machine tool input.

If equipped with a STEP NC compliant CNC, any suitable machine tool could be designated to make the part. Because a product model database can be made accessible through the Internet, this designated machine tool could be linked to this global network virtually anywhere on earth. For manufacturing enterprises participating in a highly competitive global supply chain, this kind of flexibility is crucial. With the Internet acting as a global DNC system, the world becomes one big job shop.

Step Rather Than Leap

The availability of STEP NC software plug-ins for CAM software puts STEP NC within the reach of many shops. Currently, plug-ins are available for Gibbs CAM from Gibbs and Associates (Moorpark, California) and for Mastercam from CNC Software (Tolland, Connecticut). A plug-in for Esprit from DP Technology(Camarillo, California) will be completed soon. With these plugins (or "add-ins," as they are also called), a shop can take in a customer's STEP NC files and produce parts on existing CNC equipment.

A full implementation of STEP NC would involve equipping machine tools with CNCs customized with special software. This software enables the CNC to interpret the STEPNC data directly and use the information to machine the part without a conventional G-code program. This software is currently under development.

Machine tools with PC-based open architecture control systems may be able to install this software to upgrade to STEP NC compatibility rather effectively. The conventional input/output (I/O) structure and the servo system of the CNC machine do not need to be modified under STEP NC.

Of course, a great many perfectly serviceable CNC machines are not candidates for STEP NC operation. Likewise, legacy data in the form of existing G-code part programs must be preserved.

Shops are understandably reluctant to jeopardize these resources, even as they move toward STEP NC in future planning. The new plug-ins make it unnecessary to make a full leap to STEP NC.

Essentially, a STEP NC plug-in provides a bridge between conventional CNC programming and the product-model-as-input approach of STEP NC.

A STEP NC plug-in converts a STEP NC file into the data structures of an existing CAM system. Once converted, the data can be used to generate tool paths the way the CAM software would process part geometry derived from a CAD file or other source.

The resulting output would also need to be postprocessed to produce machine-specific CNC code.

One key advantage to this approach is that the shop can promote its capability to accept STEP NC files. Knowing that the supply chain is populated with these manufacturing resources will encourage OEMs and large prime contractors to implement STEP NC. Ready access to job shops with STEP NC adds to the' incentive for OEMs to adopt STEP NC as a means integrate machining instructions in the STEP product model database. As demand for STEP NC-enabled job shops grows, job shops will find it easier to justify the investment for full STEP NC implementation, which gains them all of the advantages of this streamlined approach to CNC operations.

The plug-in strategy reflects the wisdom of STEP NC developers and supporters. It tends to break the "you-first" syndrome that has stymied other standard-making initiatives. Creating momentum behind the implementation of STEP NC will speed the introduction of affordable STEP NC products to benefit both job shops and their customers.

Plug-In Demo

How a plug-in enables a conventional shop to use STEP NC files was demonstrated in February 2002, at the Industry Review Board meeting for the Model Driven Intelligent Control of Manufacturing (MDICM) project. The MDICM project, chartered to develop and deploy a digital input standard for CNC machines and awarded to STEP Tools, Inc. as the main contractor, is funded by the National Institute of Standards and Technology (NIST), an agency of the U.S. Commerce Department's Technology Administration. STEP NC is that digital exchange standard.

The Industrial Review Board--consisting of representatives from manufacturing companies, CAD/CAM software vendors, machine control builders, government and defense agencies and job shops (all stakeholders in the effort to streamline machining and manufacturing)--operates under the contract to help make sure the project truly meets its needs in a practical, realistic way.

The demonstration was held at Experimental Machine Tool & Plating Company in Troy, New York. This shop specializes in precision machining of complex workpieces in small lots, often on a prototype basis. With four CNC machining centers and four CNC lathes, it typifies the advanced job shop serving the aerospace and defense industry. The nearby Watervliet Arsenal is a frequent customer.

In the demonstration, the shop read a STEP NC-formatted file into its GibbsCAM programming system using the plug-in for this software. The plug-in converted the STEP NC information into GibbsCAM data structures and then used GibbsCAM to generate the necessary tool path and output machine specific code. The part, shown on page 80, was then machined in aluminum on the shop's Mon Seiki MV-65 machining center.

The demonstration also made use of GibbsCAM's Cut Part Rendering functionality to validate the machining process, and the Rep documentation. See Figure 2.

Because this is the final year of the 3-year ATP contract, demonstrations of STEP NC technology are vital to illustrate STEP NC's viability, raise general awareness of STEP NC and move

STEP NC "from science fiction to within the horizon of realization," to borrow words from STEP Tools.

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Clicking To STEP NC

A review of the online STEP NC resource can be seen at www.stepnc.com. STEPTools is offering a downloadable version of its plug-in technology for GibbsCAM and Mastercam. The plug-ins are not initially available for production use. However, interested manufacturers can view and test-drive the technology as it is continuously improved in the coming years. The technology will benefit greatly from Phase One implementers who will use it to begin the process of integrating STEP-NC into their manufacturing programs and supply chain. This core group of companies will be breaking new ground in machining, and ultimately these advancements will be felt throughout the NC community.

For more information about GibbsCAM from Gibbs and Associates, call (800) 654-9399, enter 37 at www.mmsinfo.com to visit Online Showroom, or write 37 on tire reader service card.

For more information about Mastercam from CNC Software, call (860) 875-5006, enter 38 at www.mmsinfo.com to visit Online Showroom, or write 38 on the reader service card.

For more information about Esprit from DP Technology, colt (805) 388-6000, enter 39 at www.mmsinfo.com to visit Online Showroom, or write 39 air tire reader service card.

To contact STEP Tools, Inc., call (518) 687-2848 or visit www.steptools.com.

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For the link to these articles, visit www.mmsonline.com/articles/070203.html

RELATED ARTICLE: Key Features Of STEP NC.

STEP NC describes "what" not "how"

* Make this geometry from this stock

* By removing these features

* In this order

* With this tolerance

* And with tools that meet these requirements

The old standard described "how"

* Move tool to this location

* Move tool to this location

* And so on for millions of commands

Data For Inside And Outside

"For the [manufacturing] enterprise, STEP NC allows the same data to be used by the external and internal supply chains," writes Martin Hardwick, president of STEP Tools, Inc., in a recent white paper on automatic programming of CNC machines.

Dr. Hardwick explains that, with STEP NC, all the data required to make apart is included in one AP-238 file. (Under the ISO STEP standard, STEP NC is designated as AP-238. It is an "application protocol," one of the sets of definitions for data related to a particular industry or type of product such as, in this case, machined parts.)

An AP-238 file contains the part geometry, geometric dimensions and tolerances of the finished part, along with the manufacturing features, the tooling and the material. Thus, Dr. Hardwick points out, STEP NC means that STEP now covers the capability of both IGES (CAD exchange files) and RS 274D (conventional G and M code CNC programs) in one specification. In the past, if a part were to be made in-house, a company sent an RS 274D program to its shop floor. If the part was to be farmed out to a job shop, the company sent out an IGES file. Whether the part is made inside or outside, STEP NC allows manufacturing to be driven from the same database.

It is simpler for a CAM system to produce AP-238 data than RS 274D data because AP238 data does not require the data to contain machine tool specific tool paths, Dr. Hardwiek notes. Any system that currently produces

RS 274D data can produce AP-238 data if it understands manufacturing features. He sites Unigraphics, CATIA and Pro/Engineer as examples of such systems and predicts that these systems will be enhancedsothatAP-238 data is available from them.

AP-238 datagives designers and engineers the assurance that the digital information about machining critical components remains in a viable database and will be available for manufacturing those components throughout the product's life cycle. This contrasts with the conventional approach wherein the digital information about machining a part is locked up in RS 274D data. This data may reside only with an external supplier such as the job shop contracted to machine the parts.

Likewise, this data may be valid only as long as that shop has the original or compatible resources used to generate it. Changes to these resources-the CAM software is no longer supported, the machine tool or its control unit are replaced, for example--are likely to occur before the product's life cycle expires, thereby jeopardizing the availability of machined parts critical to the product.

STEP NC protects machining data as a key manufacturing asset. As long as the company has its database of STEP NC files, the parts can be manufactured regardless of what happens to the external or internal supplier.

CAD/CAM, control systems, and software

Owen, Jean V

Buying new machines and tooling doesn't solve productivity profitability problems if they are underutilized. Today's sophisticated controls can constantly and automatically manage anything from a one-machine cell to multiple-machine/multiple-cell complexes and optimize resources. Cincinnati Milacron's (Cincinnati) Cincron controller, for example, offers a host of easy-to-use features: X-Windows; an Oracle relational database manager; material handling status reports; production expediting; workload, data, and physical resource management; process control; part serialization; machine status reports; work priority indicators; and an on-line route indicator. "Managing hardware and software resources automatically is crucial," says

Tim Chapman, manager, Milacron's Cells and Systems Group. "High machine utilization depends on work queued for immediate processing. Resource management is what improves productivity."

The Myth of Speed. Controls users can get caught up in vendor talk of 1-ms or even sub-ms block processing times (the time it takes a CNC to process a line of programming code). John Turner, product manager, GE Fanuc Automation North America (Charlottesville, VA), points out that most high-speed, high-precision r machining involves downloading long part programs from a CAD system, usually via a dripfeed from a PC. "If you have 1-ms BPT and update servos every 20 ms, you're not going to get the performance you expect, so you must consider more than BPT: servo performance and the time it takes to get a part program into the control are part of the equation."

Dave Platts, vice president of R&D, Hurco Companies Inc. (Indianapolis), hammers home the point: "Despite all the hype about high-speed machining, that's only one piece of the puzzle.

Whether you cut a part in five minutes or five hours, it may take days to create the part geometry, and days to create the toolpath. We don't want operators programming parts when the geometry is already established in the CAD system. It's up to CNC suppliers to get users from part geometry and toolpath to finished part with as little manual intervention as possible."

Enhancing CNC products on the factory floor are RISC (Reduced Instruction Set Computer) boards that allow CNCs to calculate motion profiles faster and more accurately.

Friendly Front End. Users want a good consumer-level multitasking operating system, says Turner. Adding Microsoft's Chicago, Windows, or Windows NT to a control can provide this user-friendliness. Windows helps by providing software packages for developing Windows look-alikes--drop-down selection boxes and menu bars. Moving files around is also easy.

If the goal is to provide an industrialized motion control surrounded by low-cost standard products like PCs and Ethernet networks, Turner says, "you link a PC to a CNC, with the PC doing the number-crunching, communications, and data handling, using off-the-shelf packages for solid modeling and path planning. After the PC generates programs and sends them to the CNC, the CNC runs profiles as defined by the computer. The operator sees one control system."

Multitasking. Windows doesn't solve the multitasking problem, though. The control builder still has to develop an operating system that keeps operations separate. Because PC environments require more memory than true multitasking operating systems like Unix, some control builders have adopted DOS in the last few years as a way to leverage existing technology and lower development costs and time to market. GE Fanuc's "man-machine controller" at the show is based on an "embedded workstation" in the backplane of the CNC that uses DOS and a standard ISA bus to integrate standard PC boards into the CNC. Some control builders work off a PC base with a dedicated motion board added. Watch for these open CNC-PC systems at the show.

PCs on the Shop Floor. Whatever the operating system, every control builder is on the CNC-PC bandwagon. "Acceptance of PC chip sets on the factory floor and affordable PC-based software have revolutionized the embedded industrial control market," says Platts. As new chip designs appear and volumes drive costs down, control builders can afford to incorporate them to add CNC power.

Small shops put special emphasis on user-friendly shop-floor programming, whether it's done off line via an integrated system tied into the CNC control or standing at the machine tool.

The ultimate in user-friendliness, of course, is the PC-based control. Hurco's control with conversational programming, says Platts, allows an operator in a mold shop who doesn't know G and M codes to do simple 2-D operations like basic facing and drilling on the control, while someone else does complex surfaces off line on a 3-D CAM system.

Anilam Electronics Corp.'s CNC Div. (Miami, FL) began the switch to PC-based controls about five years ago; now all its products are PC-based. David McCarthy, the company's CNC control manager, says users fear buying a product that will be outdated in a year. With PC-based controls, software updates can be provided on a floppy disk, and hardware can be updated with motherboard upgrades. Those who bought Anilam's original 386sx 16 could easily upgrade to the current standard, 486dx33.

Hurco will soon offer a PC motherboard as the main processing engine in the controls it provides to job shops, plugging in coprocessing subsystems, motion control, and I/O and display management. Its Ultramax control will quintuple processing capacity when it moves from 386sx to 486dx33, says Platts. "The 486 technology has the CPU power to crunch the data, and by

feeding the control much smaller bits of data, a shop can machine much finer. Customers want block processing times and accuracies twice what we deliver today, and this upgrade will give it to them."

Another user-friendly feature of the PC-based control is flexibility. McCarthy says a user can create a file in the control using flexible programming language, dump data into it, put it on a floppy, then go to an SPC unit or CMM and use the data. Operators can use calculators built into the CNC to find a tangency or solve geometric problems, then plug the solution into the appropriate program menu.

PC and Unix workstation manufacturers have increased performance while lowering costs and moving out of their traditional niches--high-end PCs are found in engineering/scientific applications, and lower priced workstations have moved into office automation. Software prices reflect the competitive pressure, says Richard M. Passek, vice president of technical services, Camax Systems Inc. (Minneapolis). Licensing a package for operation on a mainframe, which once cost many times that of a Unix workstation license, is now about double, and the differential between workstations and high-end PCs has dropped similarly.

How Open Is Open? Standard communication systems that everyone can hook up to may be open, but all devices on the syst connect on a system doesn't mean it can be tied together, and not all connections are identical. For example, says GE Fanuc's Turner, a control system running on Ethernet downloading a part program may accept data at 1000 characters/sec; with the same control, part program, and network, another user may accept data at 15,000 characters/sec. How so? One of these users may have software that allows a control to upload and download programs, access I/O status for data monitoring, or provide information on variables for production tracking or statistical process control; one may have a different effective communication rate.

Hurco calls its new Ultimax control an open-system CNC because, says Platts, it's based on off-the-shelf boards, an I/O system that uses a standard ISA bus, and software developed with third-party vendors.

How do control builders preserve their technology in this open environment? They keep the main motion controller-the core of the CNC--proprietary, says Turner, and around that core they wrap standards like human interface, I/O, and drives.

Digital for Diagnostics. Users want systems that are easy to operate, fix, and customize, and control builders are providing help screens to access built-in documentation diagnostics and maintenance functions. With digital servos, both position and velocity loops are closed in a CPU on the axes board, which controls four axes of motion and connects to the main CPU via a 32-bit system bus.

"When the interface between controls and drives is digital, along with the interface to the spindle and all I/O products," says Turner, "the control can act as a digital oscilloscope.

With the output and feedback signals it generates on screen, users can tune servos, examine servo or spindle performance, and compare ladder-sequence activities by histogram." These I/O signal sequences can be stored and compared over time--logs of the last 3000 alarms can be time-tagged and failures tracked back to pre-failure control states--all thanks to the lower cost of memory.

CAD/CAM AND SOFTWARE

While most industry shows get caught up in the "glitz and glamor" of CAD systems, IMTS is different, says John Callen, director, application/technology development, Point Control Co. (Eugene, OR). Because it focuses on manufacturing solutions, "CAM systems will be front and center at the show, as an equal partner in the CAD/CAM process; CAD is there to provide the finished part specs from which CAM systems operate." CAD and CAM vendors will showcase new partnerships to make CAD/CM easier to use.

The Big Buzzwords in CAM. "The biggest headache for both the users of CAM systems and the vendors who develop them is the link to the machine tool," says Paul Ricard, R&D manager, DP Technology Corp. (Camarillo, CA). Vendors are attacking the problem from two fronts: knowledge-based and feature-based CAM. DP Technology's Espirit knowledge-based machining software for wire EDM applications will be shown at IMTS, but feature-based systems will not.

Why all the interest? Ricard explains that "today, shop-floor programming is either done with a CAM system too complicated for shopfloor people to use or is done at the machine, where CAM isn't available. We need an easier way to customize and program on the shop floor, and knowledge-based CAM can make this passive product into an active partner in solving manufacturing problems."

Camax's Passek describes the obstacles that have held back these promising technologies: collecting and adding enough "knowledge" requires a staff of C++ programmers available only in giant companies; elaborate programming of the software must be done to accommodate features not previously "learned"; and management is reluctant to be first to make a large investment in unproved technology. "Lengthy beta tests in large production environments have built up knowledge bases and increased geometry recognition to the point where these systems are almost ready," says Passek.

Point Control's approach, says Callen, is to provide a system whose knowledge base is populated not only through use but also through existing process models developed from previous versions of the SmartCAM system. "By capturing the manufacturing knowledge encoded in existing process models," he says, "companies can preserve their investment in manufacturing data and end up with a knowledge base specific to their processes."

Passek sees the software as one of the hot IMTS technologies: "For machining simpler parts and family-of-parts programming, we now have software with some automation and sufficient knowledge base to recognize primary and sequential procedures to be performed on individual part features. We're beginning to apply knowledge-based systems to process planning."

How would this work? Ricard: "Once you have a size, depth, and material for a tapped hole, for instance, with most CAM systems you choose tools and perform all machining operations manually. With knowledge-based software, you specify size, depth, and material, and the software picks the tools and suggests depth of cut, drillpath, and other process values, which you can override if you choose." A wire EDM user plugs in the workpiece material (say, 2.5" [64 mm] aluminum), the wire specs (0.008" [0.20 mm] brass), the finish required, and the part accuracy. The software then calculates power settings, feed rates, wire offsets, electrical passes, and so on.

In a milling application that DP Technology will demonstrate at the show, the user who wants to mill or drill holes and pockets first customizes a general approach to doing pockets, drilling, and certain milling operations and builds a machine tool library. CAD software provides a solid model showing the material and specific hole and pocket locations, the user pushes a button, and knowledge-based software does the rest of the machining calculations.

Show visitors will find user-friendly software with solid modeling to handle more complex multisurfaced parts. CAM's unique functions and algorithms to handle these problems ran only on high-performance workstations until recently, says Point Control's Callen. Recent advances in PC technology and solid modeling are moving CAM into a new range of applications.

Better links between the two systems, integrated NC planning and process modeling, solids-based machining, and knowledge-based manufacturing engineering will be showcased. Software that runs under Windows and Windows NT will be conspicuous here too. Users will welcome vendors' move into MS Windows and MS Windows NT applications. Brian Summers of CNC Software Inc.

(Tolland, CT) says the Windows connection is one of the technical advances driving industry today. "It has hit software developers hardest because of the demand to run under Windows." He sees only expansion ahead. "New machine shops open every day, and some of those owners are looking for their first CAD/CAM system. They find that smaller, lower cost systems like MasterCAM are acting like high-end systems, with capabilities like multisurface machining. The gap is closing." He expects the trend to continue for the next few years.

Watch for machine tool simulation and NC program-verification software for milling, turning, millturn, laser, and wire EDM applications--all in a one-vendor package. Multiaxis Machining. Manufacturers who used the fourth or fifth axis on a five-axis machine only for positioning or tombstone machining are now using all five axes in simultaneous motion.

According to Passek, true five-axis NC programming software that can handle multiple machining styles and does gouge checking and collision detection is rare.

Watch for software packages with multiaxis graphic simulation and representation of machine tool motion and NC toolpaths, along with programming software for four-axis machining in simultaneous motion with interfaces for millturn equipment to make the programming and synchronization easier.

RETROFIT DRO

Microprocessor-based digital readouts work with linear encoders to monitor up to four axes. The units have flexible programming functions and retrofit on most machines. Also on display will be ERN 400 rotary encoders, LS 473 linear encoders, TNC numerical controls, and Metro and Certo digital length gages, with measuring accuracies of +/-0.5 and +/-0.1 mum. Heidenhain

Corp. Circle 444

CNC ALLOWS MANUAL & AUTOMATIC MACHINING

CNCplus mounts on a lathe and allows manual and automatic machining on one lathe. The software uses work plans, including coordinated sequencing of machine operations, tools, and technological data. The computer screen displays the production sequence so the operator can correct production-related faults. The machine has three modes of operation: conventional machining, where the operator uses handwheels to operate the lathe and the control remembers the movements; conventional plus, where software supports complex operations like radii; and CNCplus mode, for automatic contour generation with built-in CAD and a pictogram-oriented keyboard. Also on display will be the PCNC, a CNC and PC combination; Digital Integrated Servo

Control; and Profil 2-D contour programmer. Num Corp. Circle 449

SOFTWARE CREATES NC CODE

Ultrapath requires five definitions in programming a part and creates formatted NC code simultaneously as a contour is described. It supports four and five-axis lathes, four-axis wire-EDM, and machining on cylindrical surfaces, and includes routines for island pocketing, roughing and finishing, grooving and threading, and CAD/CAM data conversion. Also on display will be Ultracom communication and file management software. Leonard NC Systems Inc. Circle 447

SOFTWARE GENERATES TOOLSHEETS

CNCPro 4.0 uses Windows-type menu structures to generate tool sheets on its own, filling in pertinent fields and drawing information from other databases. It imports AutoCAD and CorelDraw drawings directly. Other features include bitmap manipulation to improve the quality of scanned bitmap images; Foxpro-compliant internal database; automatic page numbering; linking several drawings to one operation; optional plot viewer to view AutoCAD, Cadkey, DXF, and IGES files directly; basic DNC support of Mazak conversational language; tracking of all DNC transactions; automatic notification of changes via electronic mail; and a built-in tool presetter. A restructured tool crib pulls tool information from any X-base database and stores pictures, blueprints, and graphics. The operation manager may display either the Partview icon or the first photo in the MWI system. ShopTec Inc. Circle 516

PROGRAM, THEN VERIFY

Duct CAD/CAM software includes a roughing module and an NC verification package. DuctRough compares NC programs interactively to produce optimum machining times and leave minimum material for finishing. One command will generate a part program. Features include climb milling; automatic predrilling of blocks for plunge moves; use of user-defined drill points; and pocket milling. Ductviewmill NC verifier has a graphical user interface, extra simulation controls, and more color to simulate rough, semifinish, and finish machining. A block can have an arbitrary shape to allow premachining or to represent a forging or casting preform. Other enhancements to Duct include a constant Z-height function, spiral milling along a part, rest milling, flexible five-axis machining, and automatic gouge removal on five-axis finishing. Delcam International PLC Circle 505

VISUAL READOUTS

VROs have a 7" video screen that displays machine travel and position in up to four axes, gives approaching-zero warning, offers error compensation, and accommodates multistep programs and tool offsets. Millvision for mills has a preprogrammed subroutine to help calculate bolt-hole patterns and locate midpoints, has a 250-step memory, and stores up to 99 tool offsets.

Turnvision for lathes has built-in turning software to calculate vectors and tapers and can store eight part programs and 24 tool offsets. Both units have on-screen help and sealed-membrane keyboards. Also on display will be the Master series and the two-axis Mate series of DROs. Acu-Rite Inc. Circle 502

INSERT FAILURE ANALYSIS I

Software is the second module for the Valnet series of cutting-tool electronic aids. It allows users to compare failed inserts with digitized photos of typical failed inserts, list recommendations to solve metal-cutting problems, maximize metal-cutting through proper chipbreaker selection, compare insert grades, list feed and speed recommendations for 950 workpiece materials, and create a customized manufacturing database to track progress of a plant's machines. The software requires a 386DX or higher PC-compatible computer with 8-MB RAM, VGA monitor, mouse, Windows version 3.1 or higher, and 20-MB of free hard-disk space. Valenite Inc. Circle 453

DRO DISPLAY CABINET

Sapphire display cabinet comes in machine travel sizes of 12 x 30", 12 x 36", 16 x 30", and 16 x 36" (300 x 760 mm, 300 x 910 mm, 410 x 760 mm, and 410 x 910 mm). Features include switchable resolution between 0.2 and 0.5", customary-to-metric conversion, absolute or incremental operation, linear error compensation, preset capability, self-diagnostics, error alarm, center find, zero reset, security lockout, and datum point memory to monitor table movement after a power loss. Also on display will be the Spherosyn linear scale, which requires no regular maintenance or cleaning, and the DP7 series of display cabinets for milling, turning, and EDM. Newall Electronics Inc. Circle 448

FABRICATION SOFTWARE

Mastercam version 5 for Microsoft Windows and Windows NT is CAD/CAM software for two to five-axis mills, lathes, two and four-axis wire EDMs, sheetmetal punching and fabrication, plasma cutting, lasers, and 3-D design and drafting. Updates to version 5 include replacement of parameter screens with dialogue boxes, surface-shading utilities, advanced IGES and VDA entity translation, and enhancements to functions for pocketing, multisurface planar and surface roughing and finishing, creating and manipulating trimmed surfaces, and flowline machining. It also processes in the background, eliminating the need to switch from graphics to text mode. Also on display will be Mastercam Moldbase, a Mastercam Mill add-on. CNC Software Inc. Circle

503

INTEGRATED MACHINE CONTROL

Trans-04 reduces complex connections by integrating the functions of a CNC, programming terminal, programmable controller, and network interface into one panel-mounted control box. Each process, such as hydraulic, gaging, single-axis, or CNC, has the same look so the operator, electrician, and process engineer can communicate easily. Features include process diagram programming, ladder diagramming, and a flat-panel touch screen. Units may be networked together to control entire transfer lines. It supports a wide variety of I/O configurations from many vendors. For digital servo and vector drives, the unit provides real-time communication with the fiber-optic SERCOS standard. Indramat Div., Rexroth Corp. Circle 509

CAM FOR AUTOCAD

NC Works 5.0 is 2-1/2-5-axis NC programming software that runs with AutoCAD. It supports CNC punch presses, 2-4-axis turning, 2-4-axis wire EDM, and 21/z-5-axis milling. Other features include a fast graphical user interface, postprocessing, and the ability to use NURBS surfaces created from AutoSurf. Progressive Software Solutions Circle 513

ESTIMATING SOFTWARE

Machine Shop Estimating for Windows is an engineering-based estimating package for creating tailored estimates according to a user's estimating procedures and shop capabilities. It calculates process layouts and cycle times for each machine individually. Micro Estimating Systems Inc. Circle 512

SIMULATE MACHINING

Virtual Gibbs runs on DOS and Windows-based IBM PCs and compatibles, Macintosh, and Power Macintosh Power PC. The Lathe module shows a 3-D real-time color rendering of the cut part as it is programmed and displays the part at any angle, including solid sections of the part's ID and OD. The roughing cycles handle hills and valleys automatically. Multiple Process

Programming allows the user to rough, semirough, semifinish, and finish a section of the part in one action. Advanced Milling simplifies part programming using a four or five-axis rotary table on a vertical mill. It is for cutting several sides of a part and lets the user specify graphically how a rotary table is set up. The user can specify free-form workplanes anywhere

on the part and define 2-D geometry relative to the plane. The software automatically calculates A and B-axis rotation to bring the plane flat to the tool. Gibbs and Associates Circle 507

CNC ATTACHMENT

Attachment for Hardinge-style lathes uses G-code and standard Hardinge chucker tooling. Features include 0.00005" (0.0013-mm) resolution and repeatability, 10.5 x 5.5"(267 x 140-mm) travel, servo closed-loop axis drives, 300-ipm (7.6-m/min) rapid traverse, single-point threading 5 to 120 tpi, storage for 9000 programs, SPC capability, and unlimited tool offsets.

OmniTurn Circle 450

DIGITAL MACHINE CONTROL

A small four-axis NC is for compact machine tools. The digital numerical control for complex machining has modular components, positions axes with axis-specific feed, and does inclined-surface machining. It combines with a digital drive converter to form a complete digital system with high control quality, system resolution, and short sampling times. Siemens

Industrial Automation Inc. Circle 517

CREATE TOOLPATHS BY MENU

Quick'n'Easy CAM software has a menu-driven format, prints on most printers and plotters, and generates two and three-axis toolpaths for the user's machine control. The software has postprocessors and imports DXF or ASCII files. Contour mode drives the tool around the part outline and supports pick, chain, sketch, spiral, zig-zag, and surface of revolution contouring. Pocket mode clears out the interior of a closed shape, has unlimited island avoidance, and automatically roughs and finishes islands. Engrave runs the tool down the drawing's centerline by "color" or "window" methods, and Drill supports peck drilling, tapering peck drilling, subroutine calls, and chip break cycles. Servo Products Co. Circle 514

CAD/CAM FOR WINDOWS

Software uses the Windows interface and supports multisurface milling, lathe, laser, punch, plasma, and wire EDM machines. It has 2 and 3-D CAD capabilities and offers 3-D viewing, engineering, 3-D sculptured surfaces, and integrated DNC. TekSoft CAD/CAM Systems Circle 452

ELIMINATE PAPERWORK

Cimnet Folders collects part programs, part drawings, setup sheets, digital photographs, routing sheets, and tooling lists for a particular part into one electronic file, which is available over a user's network. The software runs on Windows, Sun Unix, and HP Unix systems and can display DXF, DWG, HPGL, TIFF, and other graphic formats. Other features include DNC

and SPC capabilities. JNL Industries Circle 445

GENERATE TOOLPATHS

WorkNC version 3.7 3-D programming software includes enhancements such as better roughing programs, spiral collapsing motion on each Z-level, less calculation time, automatic corner picking, ramped approaches added to several tool types, pencil tracing of fillet corners and valleys, and flowline machining to machine complex surface shapes while following user-defined flow lines. The software runs on DOS-based PCs and workstations from Silicon Graphics, Hewlett Packard, IBM RS6000, and SUN. It receives data via IGES or direct translators for Catia, Intergraph, and Unigraphics. Sescoi USA Inc. Circle 515

PAPERLESS SHOP CONTROL

Vista shop-control software for small to medium job shops of 5-30 employees runs on Windows and is written in Microsoft FoxPro. Another package called Vantage is for medium to large job shops, custom manufacturers, and mixed-mode manufacturers. Written in Progress 4GL/RDBMS, it provides an open system, client-server architecture and runs on PC networks, Unix-based systems, and IBM AS/400 computers. Both packages consist of integrated software modules, including those for estimating and quoting, order entry, job costing and tracking, shop-floor data collection, inventory and purchasing, bill of materials, job scheduling, ShopVision, and accounting. Other features include VistaTouch and VantagePoint touch-screen technology, Drag'n'Drop electronic scheduling board, multimedia tools, and VistaMail audio message system. DCD Corp. Circle 504

VERIFY SOLID MODES

N-See detects tool crashes, part gouges, and CNC program errors, checking 1000 blocks of CNC code per second on a 486-based PC. The software accepts G-code for almost any CNC and presents a realistic model of the part being machined, allowing real-time rotations to any view, cross-sections in any plane, and unlimited zooms. It reports accurate dimensional data and catches programming errors before machining. Microcompatibles Inc. Circle 511

LINEAR AMPLIFIER

Model SD.51-36 measures 2.4 x 3.65 x 0.75" (61 x 93 x 19 mm) and provides 1/2-amp continuous and 1-amp peak current, and +/ 36-Vdc output voltage. The unit has a back EMF option, which eliminates the need for an analog tachometer. Also on display will be the small SDFCC 1020-12 pulse-width-modulated amplifier with 10-amp continuous, 20-amp peak current at 120 V. Servo

Dynamics Circle 451

MODULAR PLANT PLANNING

Visibility software for order-driven enterprises contains 20 modules, including sales, engineering, project management, customer service, materials management, and finance. It helps users configure products, quote process and delivery dates, manage production and cash flow, and access all information quickly. The software is an open client-server system, which runs on Hewlett-Packard MPE/iX and HP-UX, Digital Equipment VAX/VMS and Alpha Open VMS, and IBM RS/6000 AIX with a relational database model. Visibility Inc. Circle 454

TAKE GUESSWORK OUT OF SHOP MANAGEMENT

EstiTrack Estimating for Windows has modules for estimating different aspects of shop management. Modules include those for bills of materials, speeds and feeds, automatic priority scheduling, bar coding, ET remote timecard and jobcard data collection, cost estimating, orders and releases, scheduling, production management, inventory, and shipping and receiving.

Henning Industrial Software Inc. Circle 508

SCHEDULING SOFTWARE

OnTime version 3.5 is a resource-based scheduler, which defines, prioritizes, and schedules the entire shop, including employees, machines, tooling, and molds. Each resource has a priority and a unique calendar to identify available shifts and downtimes so the software can reschedule if a problem or bottleneck occurs. The software helps identify idle or underused equipment, using colored icons to indicate the status of each job in the shop. The user can assign up to nine resources to each operation. Setup and runtime are treated as separate operations. The software works with the publisher's shop management tools, which include order entry, scheduling, tracking, invoicing, purchasing, inventory, payables, and complete financials. Smart Shop Software Inc. Circle 518

SIMULATE TOOLPATHS

Vericut version 2.0 NC-verification software interactively simulates, verifies, and displays the material removal process of an NC toolpath. The user detects and corrects inefficient motion or programming errors in two to five-axis milling, drilling, and turning operations without using the machine tool. The software runs on most workstations and PCs; complies with S3, VESA, Tseng 4000 XGA, and 8514/A graphic standards; and reads toolpaths from most CAD/CAM software. Features include X-Caliper, which obtains accurate measurements of simulated parts; OptiPath, to optimize toolpath feed rates automatically; Translucent mode, to observe operations concealed by the stock; and the photorealistic Zoom mode, to find toolpath errors. CGTech

Circle 443

MOTION CONTROLLERS

Power Mate controllers, including two multipath models, are for transfer lines, gantries, packaging and material handling equipment, and other applications requiring high-performance independent motion. A servo, based on variable reluctance technology, accepts motion-control commands from a host controller and performs all motion loop control functions. Also on display will be a high-performance I/O processor and additional axis-positioning module products that work with the Series 90-30 PLC. GE Fanuc Automation Circle 506

VARIATIONAL DESIGN AND MANUFACTURING

VDM module is for Synergy CAD/CAM software. It uses a database of associated design and manufacturing data, user variables, and process control intelligence. When a design or manufacturing specification changes, the software automatically generates new part programs for component parts and updates material requirement lists and manufacturing schedules. The user can mix and match dependent and free-form geometries on the fly. If the user enters impossible data, the software plots what it can and waits for new input. Weber Systems Inc. Circle

519

JOB CONTROL

JobBoss version 1.0 for Windows handles estimating, costing, tracking, scheduling, and integrated accounting. It imports data from other software, including Microsoft Word, Excel, and Lotus 123. Job Boss Software Inc. Circle 446

NONCONTACT LASER DIGITIZER

Optica connects mechanically to any CNC or CMM. It digitizes in 3-D at 14,000 points/sec with an accuracy of +/-0.0008" (0.020 mm). RI Scan software defines absolute and relative machine positioning, calibrates and sets system parameters, smooths digitized data, and outputs to any industrial CNC or to an IGES, ASCII, or DXF file. 3D Technology Inc. Circle 674

INTEGRATE SHEETMETAL SHOP AND OFFICE

Computer Integrated Manufacturing and Management System (CIMMS) is a group of software modules for connecting sheetmetal NC machine tools with other shop and office processes. For example, bar code terminals download NC programs and upload job locations. Other modules include estimating and quoting, automatic unfolding, CAD/CAM, nesting, SPC, vision inspection, purchasing, inventory control, scheduling, job costing, labor tracking, payroll, shipping and receiving, and accounting. Metalsoft Inc. Circle 510

SINGLE AND MULTIPIN MARKERS

TMP3000 single-pin marking unit marks up to five characters/sec. TMP6000 comes with rotary drives to mark circumferences or Z-axis control to handle irregular surfaces. TMM5000 multipin matrix marker, compact TM1000 for online marking, and PS-OCR for automated product marking will also be shown. Telesis Marking Systems Circle 697

Ken M. Gettelman

CAD/CAM Beats Cheap Labor

It's no secret that many mold and other tooling orders have left for the low-cost labor areas of Southest Asia.

How is the business won back by domestic shops where skilled mold makers and toolmakers earn ten times that of their Third World counterparts? The answer, as shown by Beach Mold & Tool of New Albany, Indiana, is not found in working harder by using traditional methods. It comes from completely changing the process by which such tooling is designed and made. The new processes instituted by Beach wring out direct labor hours and excessive lead times while adding new levels of quality assurance and product performance.

The key has been integrating computer-aided design (CAD), computer-aided manufacturing (CAM), and electrical discharge machining (EDM), both wire and ram, into a unified and disciplined production process.

The company was founded in 1972 by Bill Beach. It had three employees. Today, the organization has more than 250 people, in three functional groups, under one roof. The first group makes molds for plastic injection machines. The second operates a battery of 23 injection molding machines with capacities ranging from one to 165 ounces per shot. The third group coordinates an extensive assembly area where complex products, including complete sub-assemblies for the computer industry, are put together.

Contoured Surfaces

A pair of plastic speaker grilles for portable radios demonstrates the strategic value of Beach's integrated manufacturing capability. These grilles feature a curved surface that flows smoothly across the face of the radio and merges into its case. The clean, sweeping lines were an essential aesthetic element of this design.

Achieving the smooth surface contour and having it cleanly blend into the contour lines of the case were the prime challenges in designing and building the mold set. The finished grille, after shrinkage, had to have dimensional tolerances within a [+ or -]0.002-inch band around the entire curved periphery for easy assembly and an acceptable fit. Without CAD/CAM, these objectives could not be met (Figure 1).

Phil Kiesler, Chief Engineer, and Gary Wilson, CAD Manager, recall that the original drawing received in the request for a quote did not contain detailed dimensioning. Several points, radii, and matching curves were described and detailed, but smooth blending of surfaces was left to this mold shop.

The design work was done on a Calma CAD system by starting with the defined dimensional data and then using a series of splines and Bezier curves (curves drawn through points so no sharp junctures or cusps appear where they meet). One spline line must flow smoothly into the next. It turned out that this was no small task, because the rate of curvature slightly changes across the face of the grilles. In addition, blending had to be smooth in all directions. To make matters worse, the original specification called for hundreds of holes in each grille that had to be normal to the surface of the workpiece. The pattern easily could be defined, but some sophisticated math routines were needed to orient each one normal to the grille surface. This orientation would also greatly increase the mold cost. After a discussion, the customer agreed that the holes could be parallel. Again, the computer assisted in working out the various patterns for study and comparison.

Programming

The design database was generated in about four days, but it was only the beginning. The design showed the final shape of the workpiece and gave a thorough description of it in coordinate axes dimensions. But two mold halves also were needed, with the appropriate cavity, mounting surfaces, ejector pins, coolant connections, plastic flow channels, and all the other features inherent in the complete mold set.

One of the principal considerations in plastic mold design is allowing for shrinkage. Although some mathematical routines can be worked out, they are not infallible. There is no substitute for experience in this area.

Plastic shrinkage during cooling is not the only problem. A decision had to be made about machining the critical cavity areas. Mr. Wilson and Mr. Kiesler chose to machine all mold elements except for finishing the cavity, then use ram EDM to finish. The cavity, in 420 stainless steel, was roughed out to within 1/16 inch of its finish dimension, and then hardened.

It was then turned over to the ram EDM unit for the final finish cut. Individual NC part programs had to be generated to rough the mold cavity, machine the EDM electrode, and even machine a prototype part for visual inspection and checking.

Working from the basic design resident in the CAD computer, Mr. Wilson entered the desired machining sequence (the logical sequence of machining operations), the tooling that was to be used, and the offsets and shrinkage factors that were critically important. For example, EDM requires an offset to allow for the dielectric fluid and spark gap. It must be stated in the proper direction for either the male or female half of the mold. When using a ball nose milling cutter to rough out a cavity, the cusp height allowances must be stated to leave enough material for the finish cuts.

Single Data Source

Once this information is entered, the CAD system will generate the appropriate NC party programs for the mold components and the prototype part. One CAD file is the source for all of these programs, including those for programming a coordinate measuring machine (CMM) and analyzing the data from inspection routines.

The CAD database also is often used to generate NC programs for the wire EDM. Some mold features require more than one electrode to sink them. Wire EDM may be used to shape these electrodes in either graphite or copper. For the grille mold sections, one shaped electrode was used to generate the female mold surface. Another, with holes drilled in it, was used to plunge down over a solid steel section to form the die pins.

EDM is used to generate the finish cut in the mold cavity because of its ability to generate surface finishes some inch) or better. This gets close to a mirror finish and greatly reduces the final job of mold polishing.

Before any mold work was done, a prototype was machined from hard plastic on one of the CNC machining centers. After the roughing cuts were taken, a finish pass was made with a fine diamond cutter to get the curve and finish of the final contour. The machined model provided an excellent example of how the molded part would look and function. The model was taken to the customer for approval. Next, the mold manufacturing process needed to be determined. The process centered around the CNC machining centers and the CNC ram and wire EDM units.

The heart of the mold is the shaped cavity. But a mold also includes the base, top, fittings, flow channels, cooling passages, and so on (Figure 2). Standard fitting designs used by Beach have been entered into the CAD software. Calculations for coolant passages and plastic passages have also been made part of the software base. Thus, these do not have to be reprogrammed for each job. They can be called from the file and entered into the workpiece program.

For the grilles, several workpiece programs were generated. One program was used to rough out the mold cavity, and others were generated to machine the EDM electrodes that would finish the cavity. Another program was generated to compare CMM data against the finished part and the design data to assure conformance.

In each instance, the basic CAD part data served as the reference. Skilled mold makers determined the allowances for tool offset, electrode gap allowance, and shrink factors. These people also had to enter feeds and speeds, the desired sequence of machining operations, methods of fixturing and setup, and cutting tool or electrode selection that are vital components of any working part program. The computer made the thousands of calculations and specified coordinate points.

The final results were just what the customer wanted. The mold produced the parts to specification. Total time from design to machined prototype was four weeks. It could have been done in one week if serveral days had not been spent in conferring with the customer and presenting the prototype for his study and approval.

Data Exchange

Beach Mold & Tool, Inc., notes that many of its major customers are doing their design work on CAD systems. They are also using their CAD systems for engineering analysis, quality determination, geometric dimensioning and tolerancing, and group technology. It is essential to have expertise in these areas in order to secure work from such customers. Beach has had to wrestle with the process of translating data, whether received by wire or by tape, from the customer's CAD system to their own.

Beach has two basic approaches to this problem. One uses an IGES (Initial Graphics Exchange System) software package that is currently a standard and bridges the gap between different CAD software packages. However, software development is moving so fast that the IGES effort is hard-pressed to keep up. As a result, it will handle about 80 percent of the conversion on the average. The second approach consists of specific conversion software or direct translator packages. These direct t of the more complex geometry. Translator software packages are available from either the CAD vendors or independent software houses.

Not only does the CAD/CAM approach generate part programs, but it also enables Beach to develop detailed engineering drawings for the customer. These drawings can be used for manufacturing mating parts, assembly fixtures, and so on.

By constantly adding to the CAD/ CAM database, Beach is building its own expert systems software. The complete catalog of one of the major mold component suppliers has been entered. Thus, the specifications for standard bases, fittings, ejector pins, and so on quickly can be called up and entered into a specific mold design. Such components easily can be ordered by the computer. In 15 minutes, Mr. Wilson can design a mold base from standard components. This allows him to devote his creative efforts to designing the critical cavity for each job. In addition, tooling and fixture components for Beach's own CNC machine tools have been entered into their database. Feeds and speeds for machining various mold and die steels have also been included. Standard processing routines are being added as they are developed.

EDM

CAD/CAM is not an isolated entity, but a method of integrating all shop functions into a coordinated whole. Rich Shirley, Superintendent of the EDM department, has offered a lot of feedback to the design people to help them implement the particular processing for each individual job. Mr. Shirley has taken both ram and wire EDM to their limits with two Mitsubishi EDM units (one wire, one ram). He can use the wire to shape complex electrodes for the ram unit. With automatic electrode changing on the ram unit, he can use several different electrodes to sink complex geometric features (Figure 3).

Modern EDM has advanced to the point that the shop can hold tolerances to within a [+ or -]0.0005-inch band with wire in normal cuts and even to within [+ or -]0.0002-inch tolerance with successive skim wire cuts. The Mitsubishi wire machine has control over the U and V axes (secondary axes movements parallel to the primary X and Y), which are employed to generate tapers.

Although the machine builder rates the maximum taper capability at 20 degrees, Mr. Shirley has been able to achieve slopes as high as 26 degrees.

Many ram EDM electrodes, whether graphite or copper, are machined on one of the CNC machining centers. An Okamoto VMC 800 machine is equipped with an indexing head, for a fourth axis, and a powerful suction system that enables it to control the graphite dust (Figure 4).

Not A Cure-All

With the speed and versatility of CAD/CAM, the Beach organization pulls in a lot of prototype mold work. Appliance and other manufacturers often order molds made of aluminum or other lower cost alloys simply to build a prototype run. The important considerations are fast turnaround and design integrity. CAD/CAM provides them both.

CAD, CNC, and EDM are not remedies that will cure everything with the push of a button. The professionals at Beach have worked hard to master the benefits these individual technologies have to offer. All three technologies have gone through at least two generations of development. What Beach has done is integrate the people and the technology so that they can perfect a design and quickly develop it into a finished mold. The mold creates a precise image of the actual design.

Behind it all is the overall business strategy to which everyone is committed: Design it well in the shortest possible time and quickly translate that design into a working mold with an assurance of quality, integrity, and performance that wins business.

It is formula that defeats the low-cost labor challenge.

PHOTO : Fig. 1 - The design of this grille for a portable radio features clean sweeping lines. Beach Mold & Tool's CAD system allows them to view the contoured surfaces from any angle.

PHOTO : Fig. 2 - Mr. Kiesler with the female mold half and the part. CAD/CAM was the key to moving quickly from concept to finished design to NC programs that generated the mold.

PHOTO : Fig. 3 - A closeup of many standard mold cavity graphite electrodes used to sink standard cavity shapes on the ram-type EDM unit. Many of these electrodes were profiled with the wire EDM.

PHOTO : Fig. 4 - Some electrodes are produced on a CNC machining center equipped with a fourth axis. On this machine, an indexing unit mounted on the machine table provides that fourth axis. It is also equipped with a powerful suction system that controls the graphite dust.

CAD Manager survey 2004: is the 3D software revolution underway yet?

Robert Green

IN LAST MONTH'S EDITION OF CAD Manager (http://management.cadalyst.com/2004survey1/), I began to examine the CAD Manager 2004 survey by analyzing salary data, who's performing CAD management within the organization, machine and personnel support loads, and managerial parameters such as hiring and purchasing authority. This month, I'll wrap up the survey by examining trends in software and technology use.

CAD Software Overview

Because software trends shape CAD manager's careers so profoundly, I surveyed these trends again this year. I asked respondents to indicate both their primary and secondary (if applicable) CAD application. I asked about primary and secondary CAD systems because I've seen a growing trend toward multiple CAD packages being the norm in many offices. Most companies that use multiple CAD systems do so because both 2D and 3D designs are in use in different departments. This hybrid approach to CAD has increased support burdens on CAD managers as they struggle to support ever more complex software platforms.

As has been the case in all past surveys, AutoCAD (57%) shows up as the most frequently used CAD package, no change from last year's survey. Architectural and Land Desktop, at 15% and 9% respectively, round out the top three primary CAD systems reported. Table 1 shows where other systems rank. More companies are opting for industry-specific packages such as Autodesk's Desktop products, ArchiCAD, or mechanical CAD packages such as Inventor and SolidWorks for their primary CAD platform.

The only change in the survey results is the increasing presence of MicroStation respondents, who have risen to nearly 4% in the last two surveys. Bringing up the rear was a 5.7% block of CAD packages that garnered fewer than five responses each: Alibre, ArchiCAD, AutoCAD Map, AutoPLANT, Building Systems, CADENCE, CADKey, CADRA, CATIA, DataCAD, I-deas, and Revit.

The survey data leads me to draw a couple of conclusions about software use: * The trend toward replacing AutoCAD with more powerful industry-specific CAD platforms is more prominent in architecture and civil engineering than elsewhere.

* Mechanical CAD users continue to split their allegiance among a variety of software vendors. Autodesk has not displaced SolidWorks, but it has gained ground during the past year.

Upgrading Rather Than Replacing

Interestingly, as companies replace AutoCAD with more powerful application-specific software, they almost entirely do so with another Autodesk product. In fact, Autodesk's share of primary CAD systems is 86% in this year's data. As in past years, as users migrate from AutoCAD to more enhanced packages, they've largely chosen to stay with products based on the DWG format instead of going to proprietary formats such as Revit's. The sole exception to the DWG rule is the mechanical CAD market, where products such as Inventor, Pro/ENGINEER, and SolidWorks use nonDWG primary formats but have expanded their abilities to read and write DWG data.

Taken together, this trend toward upgrading to products that use the time-tested DWG file format (Land and Architectural Desktop) leads me to believe that AEC market customers are still hesitant to stray too far from the core

AutoCAD file format. Mechanical CAD users, on the other hand, now seem to be confident about storing their data in nonDWG based files.

What remains true is that DWG is still the dominant engineering data format, with 83% of survey respondents listing a DWG-based package as their primary CAD system.

The Hybrid Office

During the past year I've noticed more offices running a 2D primary system such as AutoCAD with a 3D-enabled secondary CAD system. This multi-system, or hybrid, office environment means that CAD managers must do double duty in terms of software support. I wanted to get a feeling for how this trend has evolved in the past year, so I asked about this topic again.

As you can see from figure 1, 57% of survey respondents (no change from last year) identify their company as totally or mainly 2D. Because AutoCAD was named as their primary CAD system by 54% of the respondents this year, I continue to conclude that a lot of people out there are running their businesses on AutoCAD, even 23 years after its beginning.

Though 5% (down from 7% last year) purport to be completely 3D, the number of firms evaluating 3D has remained constant at 26% of respondents. It's interesting that the use of 3D has remained static even though desktop 3D software has become more robust and cost effective. Trying to draw conclusions in this area is hard because the past two years of lowered economic performance in the industrial world may be the reason that 3D hasn't caught on more. On the other hand, the hidden costs of training and implementing 3D methodologies in general may be the root cause. No matter the reason, 2D still rules and totally 3D design-enabled businesses are in the distinct minority.

Technical Expertise

As you can see from figure 2, p. 46, CAD managers are technically astute, but the specifics of that technical expertise are changing. The percentage reporting some degree of familiarity with AutoLISP is 63% (down from 66% last year), and the percentage of those with some degree of familiarity with Visual BASIC is 33% (unchanged). Those who report being fluent in AutoLISP make up 27% (down from 34% last year), and in Visual BASIC, 14% (unchanged). Cross-correlating AutoLISP and Visual BASIC yields some interesting statistics: 26% of those who are familiar with Visual BASIC are also familiar with AutoLISP, but 46% of AutoLISP users are familiar with Visual BASIC. I have to conclude that new CAD managers are entering the field with Visual BASIC experience, but no AutoLISP experience. At the same time, it's evident that technical CAD managers who've learned AutoLISP are taking steps to learn Visual BASIC in greater numbers than in the past.

In this year's survey I asked CAD managers if they ran their CAD systems in a non-customized, out-of-the-box state or if they applied some sort of customization. Not surprisingly, 61% of the respondents reported customizing their software, a figure that correlates very well with the 66% AutoLISP literacy rate outlined above.

Some extended conclusions can be drawn from this data:

* No matter how feature-packed design software is, CAD managers aren't satisfied with out-of-the-box systems, so they learn how to extend and customize.

* AutoLISP is not dead by a long shot, but Visual BASIC is gaining ground. Serious AutoLISP users still outnumber serious Visual BASIC users by a 2-to-1 ratio.

As the number of full-time CAD managers has dropped, the technical expertise of the remaining CAD managers continues at very high levels. I think it's safe to assume that CAD management will still be a career where technical skills will be rewarded as CAD systems are tweaked and customized to fit a company's specific needs.

To Sum Up

Because of space restrictions, I've analyzed only a small portion of the data I collected in the CAD Manager's 2004 survey. The results here should help you gauge where your company fits into the software and technology spectrum and how your skill set compares with that of other CAD managers.

I invite you to stop by my Web site, www.greenconsulting.com/survey.htm, for a complete rundown of all the survey data. I'll also publish a detailed analysis of the survey in my CAD Manager's Newsletter.

TABLE 1: WHO'S USING WHAT?CAD Program Replies PercentAutoCAD 379 54.3%Architectural Desktop 104 14.9%Land Desktop 63

9.0%MicroStation 26 3.7%SolidWorks 25 3.6%Inventor 23 3.3%AutoCAD LT 20 2.9%Mechanical Desktop

11 1.6%Pro/ENGINEER 9 1.3%Unigraphics 6 0.9%40 others were named by 5 or fewer respondents, includingAlibre, ArchiCAD, AutoCAD Map,

AutoPLANT, Building Systems,CADENCE, CADKEY, CADRA, CATIA, DataCAD, I-deas, and REVIT.Figure 1. A majority of CAD managers oversee a hybrid CAD environment.2D vs. 3D Usage2D/3D hybrid mixture 38% (262)Mainly 2D, evaluating 3D 28% (186)Completely 2D 31% (217)Completely 3D 5% (34)Note: Table made from pie chart.Figure 2. Programming skills broken down to AutoLISP and VisualLISP knowledge. AutoLISP Visual BASICFamiliar 27% (186) 14% (95)Somewhat Familiar 36% (251) 19% (132)Not

Familiar 37% (261) 67% (471)Note: Table made from pie chart.

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Best practices for 3D file transfers: don't just send the file—plan ahead to minimize problems

Mike Hudspeth

WE'VE ALL BEEN THERE. You're modeling merrily along and the phone rings. "I have this file my vendor sent me that I can't open," the caller says, "Can you do anything with it?"

"Well," you stammer. "I, uh...."

Your e-mail bleeps that you have a message. "There's the file. Thanks!" you hear as your caller hangs up.

You look at the file. It's not a file extension that your software can open directly, but it is a format in your list of translators. You throw it through whatever programs you have and voila, you end up with something you can open. Unfortunately, that's when the real fun begins. After a very long time the file opens to reveal untrimmed surfaces that shoot off into space, large and small holes that shouldn't be there, wrinkly-looking surfaces that should be smooth--in short, a nightmare of digital proportions. Because you've been here before, you know what long, drawn-out steps you must go through to salvage what useful data has survived.

An ounce of prevention is worth a pound of cure. If designers followed a few simple steps when sending and receiving 3D data, the nightmare might just turn into a dream.

In the old days, transferring data was pretty easy: print and mail. That worked, but incorporating outside data was labor intensive--the receiver had to redraw everything. Computers then automated much of the process. When 3D modeling developed, users no longer had to redraw everything to make changes or additions. They merely changed the model and everything else took care of itself, more or less. Today, designers can bring data into designs from a bewildering number of sources via a simple cut and paste. But they must be careful what data they bring in and how they do so--they can't use just anything.

There are several ways to add outside data to designs. Most need at least a little preparation before being sent. Though some translators are fairly bulletproof, none brings along parametric information. Currently, three types of translators are available: 2D, 3D surfaces and 3D solids.

2D Geometry

Yes, many uses for 2D geometry remain even today: product manuals, instruction sheets, marketing materials and the like. Bit-map images are commonly used in presentations. Most 3D modeling programs provide some built-in way to save an image at high or low resolution, even if it's just a screen capture. Users can bring these images into almost any software. To go a little further, users can export vector-based geometry, such as CGM (computer graphics metafile), and bring it into a program such as Illustrator or CorelDRAW. These are wire frame images, but they can be edited easily by clicking and dragging. To use a vector-based format, users need to get what they want on the screen and export it. Vector formats present a few more choices than a bit-map. Usually text can be exported as text or lines--it depends on what the user wants to do with the data.

3D Surfaces

Designers need surface data for many reasons. The automotive industry, for example, is a big surface enthusiast. When dealing with surfaces, designers must look out for many more problems. Several different types of surface translations are possible. The most common are faceted, polygonal (very common in the gaming and entertainment worlds) and regular (such as bounded and NURBS). Faceted surfaces generally have a smaller file size and are less precise than regular surfaces. They are good for showing what a model looks like and can be manipulated faster and with less computing horsepower, but they don't carry as much technical information.

Faceted surfaces can also be used for other things besides visualization. Stereolithography files are basically faceted models. Designers can wrap image files around them and assign other properties. When brought into engineering software, they can't really be measured. Users can get an overall idea of how far apart things are supposed to be--just don't expect to make drawings from them.

Regular surfaces can be measured more exactly, but have their own issues. Many times surfaces are missing, so the data isn't usable as planned (figure 1). Users end up spending a lot of time going over the data, trying to find the problems and fix them (figure 2).

[FIGURES 1-2 OMITTED]

3D Solids

These are probably the easiest and hardest files to transfer. Easiest, because a solid transfers as a solid and is an exact representation of the part. Users can measure it accurately and create drawings and assemblies from it. It's the hardest because of the disparity among modeling kernels. One kernel isn't necessarily compatible with another. Keep in mind that one of the greatest advantages of parametric solid modeling--the parameters--won't survive the transfer. Another advantage of 3D solids is that users can also export them as 2D wire-frame data and 3D surfaces.

Send and Receive

That said, what should be the protocol for sending and receiving 3D models? Before sending models, ask recipients what program they intend to use the data in. Is a Unigraphics file moving into SolidWorks? Are Alias surfaces going into Pro/ENGINEER? Knowing that can save everyone a lot of trouble.

Some companies ask for IGES or DXF files without stopping to find out if the sender has the same software as they do. Also, translators may have been written specifically to take one software format into another. These are generally the best way to go because the work is done without reinventing the wheel. Always ask before sending anything. Next, find out the best file format to send. That decision depends on what the sender and the recipients want to do with the data. If the data will be used for visualizations only, there's probably no need for high accuracy. If the model will be used for general sizing, say for creating packaging, a faceted model should be enough (figure 3). If the data will be used to cut steel for molds, the receiver must have the most accurate model possible.

[FIGURE 3 OMITTED]

Most vendors have a list of acceptable formats they can handle. VRML and STL are faceted formats. Parasolid and ACIS are solid formats. DXF can handle just about anything, as can IGES, but be careful with these last two. Depending on the settings, they break a solid down into surfaces.

The Information Trade

It's interesting that recent studies show that most people use business software such as Microsoft Word and Excel to exchange information. Why? Because it's what they know. That's why Adobe is making such efforts to encourage 3D content within Acrobat 7. Adobe licensed Deep Exploration technology from Right Hemisphere. Right Hemisphere likes to say its product, also available as a stand-alone program, is intended to be "the Swiss Army knife of 3D file formats." It takes a file and converts it to the U3D format, a new polygon-based general format that's quickly gaining acceptance. It lets users rotate and zoom, view the model as wire frame or shaded and more. See the box at left for more on polygons.

Of course, many other techniques help ensure clean data transfer. Some are more effective than others. If you find a method that works, share it with your colleagues. You'll be very popular for it. Without distribution, 3D data is of limited use. To be able to send and receive 3D data is a must. To do it well greases the wheels of your corporate machine and makes it run smoothly, as it was meant to. n

POLYGON-BASED DATA MADE EASY

When using polygon-based data, keep the following in mind. First, the more polygons there are, the higher the resolution of the model. But there's a trade-off. The file size increases in direct proportion, and workstation performance will most likely slow.

Performance used to be tied to how much horsepower a computer had. Nowadays, most computers have what it takes to manipulate high-resolution models, so use the highest resolution possible. It's much easier to start out with a high-resolution image and change it to low resolution. You can try to bump up resolution from low to high, but it won't be accurate. You wouldn't want to send out an STL file that way.

To reduce the polygon count, do so in the application in which you plan to use the model. When bringing in faceted models, you may notice weird wavy surfaces. These are generally caused by conflicting face normals. Normals should face out, away from the center of the model (figure 3). Most modeling programs have tools to help with the problems encountered with polygon-based models. If not, third-party applications are available.

Find more mechanical CAD information in Cadalyst's MCAD Tech News e-mail newsletter. Subscribe at www.cadalyst.com/newsletters.

Mike Hudspeth, IDSA, is an industrial designer, artist and author based in St. Louis, Missouri.

Drawing Security: protect your data

Robert Green

IT SOUNDS SIMPLE ENOUGH: Secure your CAD data so your company won't lose valuable intellectual property. In recent years, collaborative software platforms running on wide-area networks and the Internet have conspired to make CAD security devilishly complicated. The fact is our work products are becoming more digital and there's increasing pressure to share data.

However, as data is exposed, we find ourselves one file copy away from losing control. How do we deal with these vexing problems? This month I'll pass along some useful ideas for protecting your data and working with your management to devise a comprehensive security strategy without breaking your budget.

Understand the Risk

Before CAD, the design process consisted of thought being captured on paper. These paper drawings contained the minimum information required to permit construction or fabrication of the design. Drawings were then released as print sets. The print sets we transmitted facilitated construction, yet divulged precious little about design decisions.

In today's digital domain, however, software is becoming much better at capturing the thought that goes into designs. We now have software that performs kinematics constraint modeling, tolerancing analysis, computations, visualization and more. The amount of information captured in digital design files is a treasure chest of analytical information that makes yesterday's prints seem primitive by comparison.

Though we've always faced the security risk of a paper drawing falling into a competitor's hands, the risk associated with losing a complete digital design database is chilling. If your management doesn't understand how much more information is at risk in electronic design environments, it's in need of a serious wake-up call, and you must deliver it.

Steps to Security

Despite the infinite number of scenarios your company could confront in terms of software, networks and collaborative partners, I've found that securing CAD data can always be described in a simple three-step process.

Use these as guiding principles to secure your data, and you'll make good decisions.

Step 1. Secure What You Have

Network. The first step to protecting your design data is starting safe network practices to make sure that only trusted staff members can access it in the first place. If you haven't already done so, ensure that all design files are in directories that can be viewed only by those who actually need to access the files. I've seen many firms place CAD files on public drives that are viewable by everyone, although only project team members can edit the files. Remember that any time a file is viewable, the file can be copied, e-mailed and otherwise compromised.

FTP. If you use FTP (file transfer protocol) servers to share files with outside customers, consultants and suppliers, make sure that you use the same network controls for any shared folders. Too often I see companies with good control over their central network allow their FTP servers to become a big jumbled mess of uncontrolled files. Also be sure to implement careful password control for anyone who uses your FTP site (don't allow anonymous logins) and require that users change their passwords regularly. FTP sites are a great low-cost way to move files back and forth as long as they are controlled.

EDM. If you use an EDM (electronic document management) system, examine it carefully to make sure users can't copy files out of the system. Most of the EDM systems I've worked with have some sort of back door to copy files out of the system and, shockingly, these back doors seem to be open by default. Just because you're using an EDM system, you can't assume that the system is secure. Take some time to audit your EDM software to be sure it doesn't harbor any unknown security breaches.

The reason I fixate on stopping unauthorized viewing of files from network and EDM/FTP servers is precisely because files can be illegally copied so easily. Unauthorized copying can, at best, result in parallel copies or loss of revision control. At worst, unauthorized copying permits outright theft of information. Users may whine about strict password controls or tighter restrictions, but you must stand your ground to protect company data. If all else fails, get your network support people involved and make sure that management understands how crucial it is to have a secure network environment. Make no mistake--if you allow people inside the company to make unauthorized copies, you'll never gain control.

Step 2. Limit What You Share

Now that you've tightened the screws on your network security, you must take steps to limit the amount of data that leaves your company when you transmit files to customers, vendors and suppliers. Find a way to provide customers and vendors with the data they need without giving away substantial amounts of intellectual property. One way to deal with this issue is to hop on the industry bandwagon of drawing publishing via use of an intermediate data format such as Autodesk's DWF, Adobe's PDF and SolidWorks' eDrawings. These formats convey the digital equivalent of a blueline drawing while removing the real design data. Each format has strengths and weaknesses. For more information, see this month's feature article, "Essential Guide to 2D CAD Publishing," Adobe PDF is almost universally recognized, and just about everyone has the free viewer. PDF is one of the most common file types, but has no more flexibility than a printed sheet. What you see is what you get with basic Acrobat ($299), and nothing more unless you upgrade to the Professional version that, at $495, may pose a substantial cost barrier. For details on the latest version of Adobe Acrobat 7 Professional, see Cadalyst's review in the March 2005 issue or online at http://management.cadalyst. com/0305acrobat/. This new version offers many more tools for designers. www.adobe.com

Autodesk DWF. This Autodesk-centric format is ubiquitous across Autodesk's product offerings and is key in Autodesk's strategy to give users secure publishing capability. DWF lets users toggle layers on and off, zoom and pan. It's also intelligent enough to comprehend AutoCAD features such as sheet sets, fonts and the like. DWF is much more functional for encoding AutoCAD files at a lower price point than PDF--the full-featured DWF Composer module costs $199. The only negative associated with DWF that it's not well known in the non-engineering world and government agencies. www.autodesk.com

SolidWorks eDrawing is similar to Autodesk's DWF but tailored to the SolidWorks CAD environment. In later releases, eDrawings also supports the DWG file format, which makes eDrawings a logical choice for mixed SolidWorks and AutoCAD environments. www.solidworks.com

All of these formats convey the visual information your customers and suppliers need, but don't divulge the complex data that facilitated the design. The publishing utility you choose depends on the software you use and on the willingness of your customers and vendors to collaborate. Unless you have a compelling reason to do otherwise, I highly recommend using one of these neutral publishing formats to limit your information liability. Do not send your full CAD data set unless it's absolutely necessary.

When transmitting information you can gain an additional layer of security by using ZIP files. I'd wager that 99% of you have created ZIP files, but are you aware that password security can be encoded into ZIPs? By encoding drawing submittals into a password-protected ZIP, you know that the recipient of your files (via e-mail or FTP site) must follow password protocols.

Step 3. Legal Contracts

Though contractual agreements with your customers and suppliers can't stop someone from illegally copying a file, they can give your company legal recourse to punish anyone who does so.

Good legal and contractual support signals everyone that you're serious about protecting your intellectual property. Consider how you'll exchange information during a project and convey that information to project management and legal team to confirm that contractual protection is in place.

A good contract requires the signer to agree to, at a minimum, the following components:

Nondisclosure. The recipient will not copy or disclose the information you send them.

Password security. The recipient will keep all passwords secure and follow all procedures regarding access to your FTP and EDM systems.

Disposal. The recipient will discard all digital information when it's no longer needed.

Copyrights. The recipient will not reuse any portions of your digital work product in any future projects without your express written consent.

You'll need to fill in the appropriate file types, password procedures, FTP/EDM parameters and the like to make sure the contract is specific enough to have teeth. If in doubt, hire a lawyer to help you refine your contract language. You don't need to become a lawyer, but you do need to pay attention to the details.

No Magic Bullet

There's no one way to protect your CAD information from digital plunder. However, companies who follow these basic steps reduce their risks substantially. CAD files, like accounting data, must be viewed as highly valued assets that must be protected. If you don't have security in place to protect your CAD data, talk to management now about implementing something before it's too late.

THREE STEPS TO DRAWING SECURITY

* Secure what you have.

* Limit what you share.

* Create and implement legal contracts.

Find more CAD manager-related information in Cadalyst's Cad Manager e-mail newsletter. Subscribe at www.cadalyst.com/newsletters.

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Model, mesh and analyze: harnessing analysis technology for CAD

Arnie Williams

Think back to the emergence of digital cameras, not so long ago, as the point-and-shoot choice of the everyday photographer. At first, professionals no doubt looked down their noses at these contraptions. All this trend will do, thought many of them, is make it easier for the untrained masses to take bad photographs. But as time has progressed, digital cameras have grown more sophisticated. And not only vacation-bound amateurs are toting digital cameras--professionals have embraced the technology.

An analogy between point-and-shoot photography and desktop design analysis isn't that far-fetched. Once the closely guarded province of highly educated and trained analysis specialists, desktop FEA (finite-element analysis) programs have enabled designers to minimize the probability of failure of their products by performing basic FEA and other analyses early in the design phase.

The math behind the analysis and the sophistication of the technology have advanced to the point where most designers can now take a model, mesh and design approach throughout early stages of product design.

Irreversible Trend

When software developers began placing basic analysis tools in the hands of designers a decade or so ago, many analysis specialists were mortified. They feared that too many untrained people would use technology meant for experts and end up manufacturing shoddy products. Some of the fear was cultural, no doubt, but there was also a legitimate concern that if designers were able to perform any kind of analysis early in the design phase, they might be tempted to skip the expert analysis that specialists bring to bear during the product-development cycle.

SolidWorks Corp. and the developers of COSMOSWorks (www.cosmosworks.com), its analysis wing, have kept the concerns analysis designers need to perform.

This approach to analysis exemplifies where the industry is headed today. The trend throughout the CAD industry, at this point irreversible, is to put enough analysis capability at the disposal of design teams so that basic behavior studies and failure studies can contribute to more efficient design (figure 1).

[FIGURE 1 OMITTED]

There doesn't have to be a war between analysis experts and product designers, notes Suchit Jain, vice-president of analysis software at SolidWorks. The invaluable training and knowledge of experts can be channeled into developing analysis templates that keep a designer from making mistakes. With these templates, much of the math and other highly complex calculations take place behind the scenes, giving the designer only what is needed in the results to make product design more efficient. COSMOSWorks was developed to work within SolidWorks, employing the same interface and behaving in the same way.

A designer can complete basic analysis in SolidWorks without learning a new software program devoted just to analytical elements. During the early product design stages, designers can perform model, mesh and analyze operations for a snapshot of the product's behavior under conditions that analysts typically examine.

From the early days of using FEA within CAD primarily to run failure analysis tests and so minimize the need to build expensive prototypes, COSMOSWorks, like other analysis products, has moved into producing advanced, color-contoured, animated results of part and assembly behavior, rather than just a set of numbers that must be interpreted (figure 2). This is fairly typical of design-level analysis.

[FIGURE 2 OMITTED]

The advantages of analysis in the early stages of a design are undeniable. Analysis leads to more efficient design, shorter cycle times and lower costs.

"Effective product design requires more than simply creating a geometric shape for a particular function," says Jain. "Designers have to balance a range of design variables and options, from the properties of available materials to size, weight and loading constraints. Quick and easy design analysis results, even if they show only the approximate deflection or stresses instead of the exact results demanded by analysts, can help designers make prudent decisions at the beginning of the design cycle that minimize problems, delays and costs later on."

Jain illustrates a number of trends that we can expect to see in FEA-type

programs for product designers. General-purpose stress and behavior analysis tools applicable to a broad range of uses will increasingly target specific physics functionality, such as drop test and bolt simulation.

"Just as customers are demanding customization in everything from automobiles to computers, engineers require analysis capabilities that address a narrow range of problems that are particular to their specific industry," he says. Basic capabilities in these areas of specialization will be addressed early on by designers with products such as COSMOSWorks (figure 3).

[FIGURE 3 OMITTED]

Making these more sophisticated and more specific early analyses will also get easier, says Jain, through the use of templates and a continual revamping of user interfaces. These capabilities will also lead to the spread of early analysis into areas not traditionally involved with FEA, he predicts--disciplines such as the medical products industry. This field is using nonlinear analysis to simulate the superelasticity of arterial stents, for example, which must expand and contract dramatically to clear arterial blockages.

Designer-Analysis Expert Partnerships

Jain emphasizes that the spread of FEA throughout the product design cycle and across diverse industries should not replace engineering judgment. There is still a valid concern, he says, that putting analysis technology in the hands of an untrained engineer who is working on mission-critical designs can be dangerous without appropriate guidance. That's why, notes Jain, many FEA training courses for designers now focus more on applying analysis and the engineering principles behind the technology rather than on how to use a particular software product's interface.

"Analysis packages have reached a level of ease of use at which anyone can use them," says Jain. "But applying FEA productively and effectively requires sound engineering judgment and best engineering practices."

The answer to the designer- engineering analyst stand-off is to transform it into a partnership. Jain notes that the early use of analysis in a product-design cycle can make an analyst's job easier later on. By relying on the best practices of analysts, many of which lie behind the templates developed for the software, the information the expert analysts need to run more sophisticated tests will already be incorporated in the CAD model. This will enable analysts to refine results, notes Jain, rather than spend the time to set up the information from scratch.

The role for the analysis expert in this approach to early product design is to establish best practices and to oversee the use of analysis by product designers. In this way, analysts can help product development organizations reduce cycle times and accelerate time to market.

Analysts also benefit from the embedded analytical data in CAD models as modeling technology grows in its ability to capture more and more sophisticated product data.

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Vault 3 locks up drawing management: free tool provides basic file controls

Bill Fane

Writing a review of Autodesk Vault 3 is an interesting challenge. This is not your usual software, because Autodesk gives it away "free" with every copy of Autodesk Inventor (those who use AutoCAD for mechanical design also get a copy, if they're on the subscription plan). Why would Autodesk do this? I'll come back to that later.

Let's begin with a quick tour of the Vault, and then look at some of its new features.

CAD systems have come a long way since I started using AutoCAD at version 2.17g in 1986, way back in the last millennium. In those days the big excitement was, "Gee whiz, look at all the cool things the sales rep is showing us it can do." It took a bit of struggle, but we managed to become fairly proficient at producing working drawings.

Before long, CAD reached the commodity phase. Employers now expect designers and drafters to be CAD-proficient as a matter of course, and thankfully most no longer advertise for CAD operators.

Whether they realize it or not, most companies have reached the stage where control and management of their files is of paramount importance. I find it interesting that in the good old days of paper and pencil, most successful companies developed good document control procedures. A document control manager kept the original vellums locked up and released them for revision only with the proper authorizations. Similarly, new or revised drawings could not be released to production, nor could they go back into storage, without being checked, approved and properly released using the correct engineering change orders or similar documents.

Surprisingly, many offices that converted to CAD did not immediately implement the same degree of control over their computer files. I worked as a doorknob designer for many years at Weiser Lock, where in the early days of AutoCAD we still looked on the plotted vellum as the original drawing, with AutoCAD being a mere tool like a pencil and eraser that was used to produce it.

The big difference, and big danger, is that there is only one original pencil-and-paper vellum, but it's all too easy to copy and to copy over computer files. Even with the best of intentions, things can rapidly get out of hand.

Fortunately we realized the implications before we had a real disaster and quickly implemented a file control procedure that involved network folder rights. It was crude by today's standards, but it worked. Recently, software developers have come to the same conclusion and are developing features to assist with document management. The new Sheet Manager in AutoCAD 2005 is an example of this.

Many EDM (electronic document management) and PLM (product life management) tools are available on the market. The problem is that they tend to be aimed at large corporate clients and may be overkill (and overly expensive) for an engineering department.

Autodesk's solution is the Vault (figure 1). This is Reader's Digest condensed document management, intended mainly for the mechanical design office. Earlier versions supported Inventor only, but that has expanded with the current version.

[FIGURE 1 OMITTED]

A Vault installation has two basic components. First, a server must be set up to hold the Vault (I named mine Pole). This contains users' files and the management tools.

Next, each user is set up as a Vault client. Different users can have their access limited to the vaults that are specific to their assignments.

The basic function of the Vault is enforcing sign-out and sign-in rights. No one else can edit a file or group of files while it's signed out to a user.

The Vault carries out a number of other useful functions. For example, version history archives are maintained. When a revised file is signed back into the Vault, the earlier version is also saved. You can go back later to see or access the earlier versions of a part (figure 2, p. 35) as well as the assembly version that contains the part (figure 3).

[FIGURES 2-3 OMITTED]

Another powerful capability of the Vault is that it can generate where-used data for a part. It's easy to delve into an other way. You may know that a certain part is used in an assembly, and you may know that you need to modify the part to make it work better in the assembly. It would be nice to know that your modification to the part won't mess up other assemblies that use it.

Vault v3 adds more useful functionality. For example, you can select one existing part or subassembly and move it to the Vault. All related files, both upstream and down, will be moved to the Vault as well. This includes component parts, subassemblies, and their components. Going the other way, Vault picks up higher-level assemblies and all the related 2D drawings of assemblies and components.

Vault also contains a facility that will search Inventor iProperties for specific values. Yes, Windows Explorer can do that too, but Explorer won't search for specific block attributes in an AutoCAD drawing file.

Vault now includes more support for other Autodesk products. It manages AutoCAD, AutoCAD Mechanical and Mechanical Desktop files from within those applications. AutoCAD Electrical files can be managed through the Vault Explorer. DWF files can be set up to update automatically and can live outside the vault so those who don't use CAD can access them.

There are three kinds of Vault users in the world. Version 3 now allows Administrators with full control over the server; Editors, who can access their particular vault folders to sign out and sign in files; and now Guests, who can look but not touch.

Vault control now extends beyond Autodesk files. For example, a user can sign out an Inventor assembly and its associated files along with relevant Word and Excel files. While the files are signed out, no one else can edit them.

So why is Autodesk giving away Vault? Simple. It wants you to buy Productstream.

The basic Vault is a very useful tool, but there are a few things it won't do. Autodesk has developed its Productstream application to supply these advanced features, but for it to work, users need to be comfortable with creating and using the basic Vault database. Vault uses standard SQL database technology, so it will be easy for Autodesk to develop advanced products that access the Vault data.

For example, Vault administers versioned archives. As Robert Green pointed out in the October 2004 issue of Cadalyst, there is a difference between "version" and "revision." You may go through several versions of a product design or change before you are ready to release the next revision.

Once users have the Vault database established, Productstream will be able to handle things like bills of material, revision releases, routing, and workflow support.

The bit of time and effort it takes to set up and learn Vault is well worth it, even if you don't move on to Productstream. Autodesk, of course, hopes that eventually you will.

People Unclear On The Concept. I recently came across a pirate Web page that offered to sell me a copy of Autodesk Vault 3 for only US$28. Hey, people, it comes free with Autodesk's mechanical products! And only works with them! n

VAULT 3

FILE CONTROL

OVERALL PRODUCT: A

This version: A

Ease of Use: A

Feature: B+

Installation: B+

Customization: Unknown

Interoperability: AThird-

party add-ons: N/A

Help: A

Innovation: A++

Value: A+

Pros: Can't beat the price tag; handles basic document management tasks.

Cons: Works only with Autodesk products, however it can manage any file.

Price: Free

Autodesk

800.538.6401

www.autodesk.com

Bill Fane is a Cadalyst contributing editor and a professor at the British Columbia Institute of Technology.

AutoCAD Electrical 2005: autodesk brings parametric design to the electrical engineer's desktop

Bill Fane

All reviews, articles, and press releases about AutoCAD Electrical seem to start in the same way, saying something like, "If you design electrical control systems, you need AutoCAD

Electrical." Well, they're correct.

AutoCAD Electrical is intended for electrical control systems designers, but it does much more than just offer some 2D customizing tools. This is a fully parametric product, similar to 3D parametric design programs such as Inventor, Mechanical Desktop, SolidWorks, and the like.

For example, the symbols in the library are intelligent. As you design a control circuit, you specify a relay by brand and model. AutoCAD Electrical knows how many contacts the specified relay contains and won't let you connect too many circuits to it.

In a similar fashion, you can automatically assign wire and connection numbers and component tags, and everything automatically updates when you make changes--including information within the schematic diagram and the related control panel layout drawing.

Drawings are created in the familiar 2D ladder logic format. A couple of quick examples show how AutoCAD Electrical simplifies and automates this process.

Figure 1 shows a portion of a ladder diagram to which we want to add a new rung.

[FIGURE 1 OMITTED]

After a simple menu or toolbar pick, AutoCAD Electrical invites us to pick a location. When we do, it adds a new rung (figure 2). Note that it took only a single location pick, as shown by the cursor in figure 2. The process didn't use object snaps, and ortho and polar mode weren't turned on. AutoCAD Electrical automatically found the two bus lines and determined the correct rung spacing.

[FIGURE 2 OMITTED]

So far, so good. Now we need to add some components to this rung. Select Components | Insert Component from the menu and proceed through a series of dialog boxes to reach a specific model number from an individual manufacturer (figure 3, p. 40).

[FIGURE 3 OMITTED]

AutoCAD Electrical inserts the desired component into the selected rung of the ladder (figure 4, p. 40). It cuts the rung and automatically generates and inserts all the annotation tags.

[FIGURE 4 OMITTED]

And, so it goes. We can insert pushbuttons, limit switches, pilot lights, PLCs (programmable logic controllers), and pretty much anything else from a standard catalog. Parent/child relationships are established between a relay coil and its matching contacts, and between the poles of a multipole switch. AutoCAD Electrical automatically reviews these relationships so that we can't assign too many circuits to a relay or a switch. They're taking all the fun out of engineering! AutoCAD Electrical also automatically generates wire numbers and component tags and updates them accordingly. All tags and numbers are unique, so you never need to worry about duplicate assignments again. When placing ID tags, AutoCAD Electrical automatically searches for a clear space in the drawing.

Report generation is also highly automated in AutoCAD Electrical. You can create a variety of reports, including bills of materials, terminal numbers, PLC I/O addresses, and From and To listings. In fact, the Schematic Reports dialog box lists 16 different reports.

One export file format is particularly interesting--you can export an AutoCAD Electrical wire list in a format Autodesk Inventor 9 Professional can read so 3D wiring harness models can be generated from it.

AutoCAD Electrical also works the other way. You can use an Excel spreadsheet to create a PLC I/O assignment file. When you import the spreadsheet, AutoCAD Electrical generates virtually the complete 2D ladder diagram drawing in a few seconds. Figure 5 shows a portion of such a spreadsheet, and figure 6 shows the resulting AutoCAD Electrical drawing.

[FIGURES 5-6 OMITTED]

AutoCAD Electrical is helpful for creating 2D drawings for control panels. Figure 7 shows part of a control panel layout with many of the controls already placed. It also shows the dialog box used to select the next control to place. The dialog box contains a complete list of all components required in this panel, automatically derived from the ladder diagram. When you select an item, AutoCAD Electrical checks out the manufacturer and model specifications and then inserts an anatomically correct 2D picture of the component. It also generates and adds the required tags and labels.

[FIGURE 7 OMITTED]

Of course, all of this is parametric so that if you change the specification of a component in the ladder diagram, its representation changes in the panel layout drawing. The schematic and the panel always match. They're taking even more fun out of engineering!

AutoCAD Electrical also works with three-phase buses and can mix and match single-phase and three-phase within the same drawing.

As automatic as AutoCAD Electrical is, it still permits a great deal of versatility in defining drawing layouts. For example, you can define and create templates for drawings that specify your desired rung spacing, numbering formats, and so on.

You can create your own layers for wires, and AutoCAD Electrical recognizes objects on them as wires. You can thus have separate layers for all the different colors of wires so that the schematic colors match the real-world wire colors. Separate layers can also be defined to separate control vs. power wiring, wires by voltages, or by whatever you want. If the supplied catalog of stock components doesn't completely meet your needs, you can easily add your own definitions on the fly.

All AutoCAD

AutoCAD Electrical 2005 is built on the AutoCAD platform and is a flavor of AutoCAD, just like Mechanical Desktop and Architectural Desktop.

AutoCAD Electrical maintains all of its unique information within the drawing file in the form of attributes and extended entity data. Once created, the files don't require access to any other unique support files. The files aren't damaged in any way by a roundtrip through any other flavor of AutoCAD, including standard AutoCAD, LT, and Mechanical Desktop.

New Features

For starters, the catalog is expanded--it now includes more than 43,000 stock components from many major manufacturers.

New PLC modules are released frequently. You don't need to wait for the next release of AutoCAD Electrical to access them. AutoCAD Electrical 2005 includes a new module builder that lets you add modules to the catalog as soon as they are available.

To further enhance customizability, you can merge a newer catalog database with the existing customized one on your system. All your customizations carry forward.

A new terminal strip editor makes it easy to create and manage all the terminal strips for an entire project. As usual, they're turn, they're taking more fun out of engineering! AutoCAD Electrical offers multiple report options and now can generate multiple types of reports from within one session of the report generator.

AutoCAD Electrical now supports drawing standards as published by JIC, IEC, JIS, and GB. Inventor support now includes cables as well as individual wires. Autodesk Vault functionality makes it easier to manage and control documentation.

Bottom Line

The bottom line is that AutoCAD Electrical eliminates boring, repetitive, error-prone chores. It lets you concentrate on the design, not the documentation. I can't resist--I have to close with an electrical joke. Two atoms are having a conversation.

"How did you like the party last night?"

"It was great, but I lost an electron."

"Are you sure?"

"I'm positive."

Highly Recommended. n

REVIEW SUMMARY

If you design electrical control circuits, you need AutoCAD Electrical. It's a powerful, versatile, parametric tool that takes the drudgery out of circuit documentation so you can focus on your design.

AUTOCAD ELECTRICAL 2005

Parametric Electrical Design

star rating: 5 stars out of 5

pros: A powerful parametric tool; built on the AutoCAD platform.

cons: None significant.

price: $5,295

Autodesk

800.538.6401 or 415.507.5000

www.autodesk.com/autocadelectrical

Bill Fane is a Cadalyst contributing editor and a professor at the British Columbia Institute of Technology.

Mechanical CAD today: software innovations accelerate the mechanical design process

Don LaCourse

When I was asked to write about the state of the mechanical CAD industry, I was more than a little reluctant to parade the usual charts and graphs that show statistics and market growth for the well-known CAD developers. Such reporting is better left to industry analysts such as Daratech (www.daratech.com), who do it so well and so often. However, I did check in with many mechanical CAD developers, and all report double-digit percentage increases in sales from this time last year. There is a clear consensus that the economy has completed its rebound and is on the rise.

If you follow my columns, you know that I write from the perspective of those using and managing the mechanical CAD application. Don't get me wrong--charts and graphs serve a very important purpose, but you don't need them to know that mechanical CAD is alive, well, and better than ever. Just look at the applications today and remember what it was like even a few short years ago. Here are some things that clearly make mechanical CAD what it is today--I bet you're already taking them for granted.

[FIGURES 1-2 OMITTED]

Object-based Context Sensitivity

Not too long ago, you wasted a lot of time locating commands buried deep within the menu hierarchy. You needed to know and understand what menu selection to make to perform a given task, such as applying draft to a face. Today, object editing removes the guesswork by displaying only the applicable commands when you select or highlight an object such as Offset, Draft, and Extend when you select a face.

This object-based context sensitivity is now widely used in mouse-driven pop-up menus, pull-down menus, and all dialog boxes. Today's mechanical CAD applications understand what you need at any given time and even try to anticipate what you will or may need soon.

In many instances, you can bypass the menu structure, saving precious design time.

Integrated Design Environments

Mechanical CAD is defined today by its ability to deliver integrated and highly specialized design environments that were once the sole domain of third-party applications (figure 3, p. 52). Designers are fortunate to have the most common tasks almost completely automated. For mold designers, defining complex parting lines, separations for core and cavity regions, and slide, insert, and cooling designs take a fraction of the time previously required. That's not to mention complete mold base assemblies that you can create on-the-fly from built-in parametric libraries.

[FIGURE 3 OMITTED]

For sheet-metal designers, today's mechanical CAD applications save enormous amounts of time by providing a command for virtually every common sheet-metal feature, including flanges, dimples, louvers, and corners. What previously took ten commands and 45 minutes to model now takes one command and five minutes (figure 4). Productivity is increased tenfold. Such super features aren't exclusive to sheet-metal design. You can also find them for injection-molded part design.

[FIGURE 4 OMITTED]

Other sheet-metal tasks are also automated or integrated, such as folding and unfolding for flat-pattern creation and K-factor compensation (figure 5). K-factor is a ratio based on the expansion and compression properties for a given material. It's used to define the location of the neutral axis within the thickness of the sheet metal for bending.

[FIGURE 5 OMITTED]

Self-Analysis and Topology Healing

I've written extensively on the subject of data exchange and how data loss and topology errors are commonly introduced during data translation. This thorn in the side of 3D CAD has caused the loss of immeasurable amounts of time and money. Today, mechanical CAD is further defined by its ability to meet this problem head on and in many cases overcome it.

Mechanical CAD applications provide the tools needed to analyze and heal the most common topology problems that can stop design and development in its tracks. I'm talking about missing surfaces, edge mismatches, cracks, and gaps--just to name a few. Many applications even perform topology healing automatically during imports.

The State of the Union

The next time you wonder about the state of mechanical CAD, remember how far the technology has come. The economy and mechanical CAD sales may rise and fall, but the heart and soul of mechanical CAD, the applications themselves, only get better.

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Cookeville, Tennessee. eDocHelp is a Gold Star sponsor of www.3DCADTips.com.

VX CAD/CAM v10: all-in-one CAD/CAM package

Don LaCourse

VX CAD/CAM is known for its ability to import and heal advanced surface data from other 3D CAD applications, a fact that has helped it find a niche in industrial design, mold making, and CAM applications in particular. Version 10 builds on this foundation with new global shape deformation (morphing) tools, new point cloud tools, standard parts and mold base libraries, and many enhancements to the VX CAM application.

VX CAD/CAM is a hybrid mechanical CAD application built on the proprietary VX modeling kernel. Hybrid means the product supports integrated advanced surface and solid modeling tools, and has done so since it was first introduced in 1999. VX CAD/CAM is the flagship product from VX Corp., a developer of 3D MCAD tools since 1985.

New Modeling Tools

Version 10 includes some interesting new modeling (figure 1) and editing tools. The most exciting is a series of Morph Shape (global shape deformation) commands that let you deform any shape (open or closed) by controlled warping of face geometry (figure 2).

[FIGURES 1-2 OMITTED]

The commands let you grab a point, edge, or curve on any face and move (or drag) it to deform the original shape (figures 3a-3e, p. 30). This change is an historical operation, meaning you can parametrically edit it later in the design. The deformation spans seams of multiple surfaces.

[FIGURE 3 OMITTED]

Like many VX commands, this one provides a number of ways to control how a deformation proceeds (such as along direction, along path, to point, and about axis), what surfaces are locked, which ones can move, and other things that affect the shape of the deformation. The range of deformations possible with these tools is quite impressive. Another area where VX CAD/CAM excels is reverse engineering using scan data from 3D scanning and CMM (coordinate measuring machines) devices such as Romer CimCore (www.romer.com) and MicroScribe (www.immersion.com).

Version 10's ScanShape tools are significantly expanded (figure 4). With them you can section scan data to fit surfaces through smaller subsections. VX reports significant speed enhancements to the overall process and the ability to handle 360[degrees] scan data.

[FIGURE 4 OMITTED]

Many modeling commands are enhanced. The Bi-rail Loft now supports rails from a cylinder or cone, and the FEM Patch lets you orient surface direction (figure 5). It recreates fillets after draft is applied and automatically identifies all holes associated with an imported face.

[FIGURE 5 OMITTED]

The Morph Shape commands are not unique in the industry. They're similar to the Global Shape and Zone Modeling commands in think3's thinkdesign and the Blue Dot/Blue Surf commands in Solid Edge. They are however, very easy to use considering the number of options available.

VX CAD/CAM's ScanShape commands are unique to the suite of midrange mechanical applications available today. To date, I haven't reviewed any other product with similar tools or the ability to achieve what VX CAD/CAM can do with these commands. It's very impressive.

New Part Library Tools

A continuing trend in today's mechanical CAD applications is the integration of tools that were once third-party applications. VX CAD/CAM v10 now ships with built-in parametric libraries for mold and die designers that include complete mold base assemblies and standard components (figure 6, p. 32).

[FIGURE 6 OMITTED]

These are welcome tools. The mold base library comes with everything you need, but the selection is limited to DME Series A and B mold bases. The company indicates that it will add HASCO mold bases to the library soon.

2D Layout and Drafting

VX CAD/CAM contains a complete drafting environment that you can use to create detailed layouts of your 3D models. A bonus is the ability to detail both open surface and closed solid models in a similar manner, without limitations.

Version 10 adds some new 2D functionalities worth mentioning. Hidden-line creation is faster--the company notes a 10X improvement in creating complex hidden-line views. Also new are an option for creating Bent Section views (figure 7), a Do Not Section attribute, a weld symbol generator, and controls that synchronize layer use between the model and the drawing.

[FIGURE 7 OMITTED]

Machining with VX CAM

Earlier in my career I spent two years as mold designer--a stark contrast to my previous ten years as a product designer. The hours were long. I had to work with 3D part data from many different CAD systems, pump out multiple mold designs at the same time, and send that data directly to the CAM operators on the shop floor.

You're going to be hard-pressed to find a good midrange mechanical CAD application with integrated CAM capability. VX CAM, with 2.5- to 5-axis tool path capabilities should contain everything you need to satisfy folks on the shop floor (figure 8, p. 34).

[FIGURE 8 OMITTED]

Version 10 extends the CAM module further with a new 5-axis side cut operation, multiface chamfering, toolpath transformations (arrays), CAM sketching, boosted performance during solid verification, and a native VX postprocessor.

The major improvements to VX CAM actually began in a prior release, when the user interface was completely revamped. Because of this, v10 makes it very easy for beginners to create and visualize toolpaths.

System Requirements

For best results, VX Corp. recommends that you run VX CAD/CAM v10 on an Intel or AMD 1GHz or greater workstation with 1GB PC 133MHz SDRAM, 200MB of empty hard disk space, 1GB or more swap space, a three-button mouse, and an NVIDIA chipset video card capable of 1280X1024 16-bit resolution. At a minimum, you need an Intel or AMD 700MHz workstation with 512MB PC 133 SDRAM, 512MB swap space, and any Microsoft-supported video card capable of 1024X768 16-bit resolution. VX CAD/CAM v10 supports Windows 2000/XP.

Bottom Line

I last reviewed VX v6.5 in the August 2002 issue of Cadalyst. Version 10 is yet another step in the right direction for VX's flagship product line.

You may wonder if there's anything I don't like about this product. There is, but it's mostly cosmetic. The user interface was redesigned in v6.5. It improved the flow of user input considerably, but the command input dialog boxes can still get quite long and, when displayed with others, can block a significant amount of the display from view. This is still the case in v10. I recommend moving the dialog boxes to a left vertical panel like the history, assembly, and CAM manager dialog boxes.

Other complaints that I had in my previous review have been addressed. The history manager now shows an industry-standard icon-based, expandable tree structure. We've come to expect this structure, and it makes the history easier to understand. The bottom line is that VX CAD/CAM v10 is well worth a good strong look. If you work with a lot of imported data from different systems, as in the tool and die industry, VX is a perfect fit. If you're an industrial designer looking for shape deformation tools that can be applied to both surfaces and solids, VX

CAD/CAM is now a serious contender. If you just want a basic modeling tool with drafting, there is a scaled-down version available for $995. Highly Recommended.

VX CAD/CAM V10

CAD/CAM Software star rating: 5 stars out of 5 pros: New shape deformation tools for industrial designers; new mold component libraries for tool and die designers; new user-friendly postprocessor for VX CAM.

cons: Command dialog boxes should be moved to a side panel; need more mold bases in the library.

price: $3,995-$11,495 (VX Basic $995)

VX Corp.

800.683.9222

sales@vx.com

www.vx.com

For AutoCAD Users

AutoCAD users looking to upgrade to 3D should take a look at VX. The depth of v10 is greater than that of many other midrange mechanical applications. You can convert AutoCAD DWG and DXF multiview drawings on-the-fly so you can perform complex assembly, mold design, and manufacturing tasks.

Once you import your DWG file into VX, you can add additional parametric features such as fillets, chamfers, holes, ribs, and lip. You can unfold sheet-metal parts, taking into account material thickness, bends, and stretching to determine exact stamping requirements. Furthermore, VX offers integrated reverse engineering and healing to assist with rapid prototyping applications such as stereolithography.

Don LaCourse (don.lacourse@ cadalyst.com) has spent the last 25 years working with and writing about CAD/ CAM operations. He is a Cadalyst contributing editor and principal partner of eDocHelp (www.edochelp.com), an edocumentation, online help, and technical writing services firm in

Cookeville, Tennessee. eDocHelp is a Gold Star sponsor of www.3DCADTips.com.

Are you up to standards? Homegrown standards vs. the U.S. national CAD standard

H. Edward Goldberg

One of the best ways to ensure that your CAD department is productive is to create and work according to a set of CAD standards. Doing so helps new employees learn their jobs quickly, speeds projects to completion with greater accuracy, and facilitates more effective data exchange with clients and collaborating firms. Because the AEC industry is now dependent on CAD data and because project collaboration is so common, the absence of CAD standards can cause expensive problems that are frustrating to design firms and their clients. In the absence of universal standards, many design firms have developed their own standards or implemented the United States National CAD Standard.

Proprietary Office Standards

Many firms create their own proprietary CAD and operational standards that are often quite viable. Proprietary standards should guide an operator through the process of opening and plotting existing drawings. They should also include enough information about office equipment to get a new CAD operator up and running on the first day at the job. Beyond this, operators need to know the office standards for numbering, editing, and annotating drawings. The CAD standards should also explain your company's layering (or levels) system.

Well thought-out CAD standards must include information on how to set up new projects and drawings and provide guidelines for exchanging CAD data with clients and other companies. A FAQ (frequently asked questions) section can help users troubleshoot on their own. Appendices impart additional information in a way that doesn't detract from the overall focus. If an office intranet is available, all office standards can be organized there in an easy-to-access format.

Your CAD software likely provides tools such as drawing templates, libraries, and so forth to help enforce your chosen standards. In addition, third-party applications may be available.

ProSoft's NETSpex for AutoCAD and MicroStation, for example, creates a central database to store components and layer definitions. Softco's S-Man is a set of utilities for managing AutoCAD standards.

The United States National CAD Standard

Although proprietary CAD standards work well in small, isolated firms, offices that work on larger projects or need to collaborate with other disciplines should consider adopting the U.S.

NCS (National CAD Standard) for architecture, engineering, and construction.

The latest version of the NCS, v3.0, was published in June 2004. The NCS codifies information for the building design and construction industry by consistently classifying electronic building design data to help streamline communication between owners and design and construction project teams. According to the publishers, NIBS (National Institute of Building Sciences), using these standards reduces costs associated with developing and maintaining individual office standards and transferring building data from CAD applications to facility management applications. NIBS also claims that the National CAD Standard offers greater efficiency during the design and construction process.

The National CAD Standard is a compilation and modification of three existing standards documents published by members of the FIC (Facility Information Council): the CAD Layer Guidelines by the AIA (American Institute of Architects), the Uniform Drawing System Modules 1-8 by the Construction Specification Institute, and Plotting Guidelines by the U.S. Coast Guard. The FIC, a council of the NIBS, formed the National CAD Standards Project Committee to develop the standard. The committee reviewed and commented on the documents and produced a report that describes the relationships of the documents, one to another, resolves discrepancies among them, and ensures the full integration of all previously independent parts.

Implementation of the NCS, in whole or in part, is voluntary. Individual firms retain the right to determine their degree of conformity with the NCS. The agreement between owner and design professional or between design professional and consultant may specify the degree of conformity required for a project. Projects that claim substantial or partial conformity with the NCS include an NCS Statement of Substantial Conformance.

Advantages of the NCS

Using the NCS helps consistently classify data for all projects, regardless of the project type or client, and it he design team members. It also reduces preparation time for translation of electronic data files between different proprietary software file formats, giving predictable file translation results. Use of NCS also greatly reduces staff training time compared with teaching proprietary office standards. If your CAD software supports the standards, time needed for setup and data file formatting is reduced.

NIBS anticipates that not all project documents will fully conform to the NCS in every respect and detail and that most projects will include several minor variations. Provided these minor variations are listed as part of the Statement of Substantial Conformance, the project is still considered to be in substantial conformance.

NIBS' ultimate goal is voluntary adoption of the National CAD Standard by the building design and construction industry to streamline and simplify the exchange of 2D design and construction data in the project development phase and throughout the lifecycle of a facility.

Standards for 3D computer models--those produced by object-oriented programs--are not currently part of the NCS, although the council is considering their inclusion in a future release of the standard.

Any software vendor, manufacturer, material supplier, or other organization, commercial or nonprofit, may apply to the NIBS and register as a publisher of electronic data. On acceptance of registration application, agreement with the terms and conditions, and payment of the yearly registration fee, the organization can advertise its products as fully or partially in conformance with the NCS.

You can buy a copy of the United States National CAD Standard from NIBS at www.nationalcadstandard.org. Members pay $400, nonmembers pay $540, and those in education pay $267. n H. Edward Goldberg, AIA, is a practicing licensed architect, industrial designer, AEC industry analyst, and author of Autodesk Architectural Desktop 2004: A Comprehensive Tutorial

(Prentice Hall, 2003; www.prenhall.com) and Autodesk Architectural Desktop 2005: A Comprehensive Tutorial (available this fall). You can reach him ed.goldberg@cadalyst.com or via his Web

site at www.hegra.org.

Resources

* AIA www.aia.org

* CADD/GIS Technology Center https://tsc.wes.army.mil

* Construction Specification Institute www.csinet.org/

* ProSoft www.prosoftnet.com

* Softco www.softcosys.com/

* "Build your CAD standards," Cadalyst, April 2000, by Mark Middlebrook www.cadalyst.com/cadalyst/article/ articleDetail.jsp?id=89439

* "Set the Standard," Cadalyst, May 2002, by Bill Fane www.cadalyst.com/cadalyst/article/articleDetail.jsp?id=94427

* "Trying to Follow those Standards," Cadalyst, September 2003, by Lynn Allen www.cadalyst.com/cadalyst/article/ articleDetail.jsp?id=80458

Know your business: employers say they have trouble finding CAD operators who know their software and their particular industry

Sara Ferris

LEARN THE BUSINESS AS well as the software. That's the overriding kernel of advice from those of you who sent in comments on last month's Editor's Window about the demise of the drafter.

Jimmy Moore, president of VisionREZ, a 3D modeling application built on Architectural Desktop, notes that such applications demand greater knowledge of how a structure is actually built:

"You can no longer fake the closure of a roof with a few well-placed 2D lines. You must know what is required to make the roof close." On the flip side, he predicts that companies will have to pay better wages to attract CAD operators who have the required expertise in construction.

Educate yourself about construction if you're an architectural drafter, or manufacturing if you do mechanical drawings. Also look for opportunities to specialize. David Busarello, who runs his own structural steel and miscellanous metals business, notes that many fields such as his still have need for drafters. These include sheet metal/ductwork, rebar, precast concrete, plumbing/mechanical, and commercial electrical. Likewise, we heard from an HVAC firm that looks for, and has great difficulty finding, people with three years' experience in HVAC design.

David also recommends getting as much hands-on experience as possible in your chosen field, ideally with your intended customer: "You will learn from those who must read and work with your drawings." Also spend some time learning basic business skills such as writing, communication, and project management. Robert Green's column this month (p. 38) provides more details on the qualities and skills that a CAD manager should value.

Though CAD programs themselves grow more and more specialized, the technology itself is used in a broad range of businesses. For several years now, Cadalyst has faced the challenge of remaining relevant to readers across an ever-expanding spectrum of businesses. In our monthly allotment of pages, we have to cover mechanical design and AEC and mapping/GIS and civil and plant design and facilities management and, oh yeah, HVAC and structural steel.

This month we're shaking things up a bit. The Web site is now home to all product-specific articles and tutorials. That means Lynn Allen's "Lines and Circles" and Mike Tuersley's "CAD Clinic" will now appear only at www.cadalyst.com. We also have a new installment of Tony Hotchkiss' AutoLISP Solutions, again only at www.cadalyst.com. The expanded table of contents on p. 6 lists all the new Web articles this month. Down the road we hope to add additional columns, so feel free to let us know what other CAD applications you'd like to see covered. E-mail editors@cadalyst.com.

One more note on the Web site. We're planning to launch a new look on the 20th of September. We'll have four separate sites: AEC, manufacturing, GIS/mapping, and CAD management. The goal is to make it easier to find the material that relates directly to your line of work.

Next month we'll follow up on an interesting theme common to many replies: the quality of drawing these days is on the decline. Is this because the drafter has indeed disappeared, replaced by engineers or architects-in-training who have little interest in or knowledge of production drawings? Does CAD software encourage more attention to appearance than content?

Or is this simply unfounded hand-wringing, and drawings today are more accurate and precise than ever?

SARA FERRIS

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Where have all the CAD jobs gone? Today's job market demands diverse set of skills

Sara Ferris

I HEAR THS QUESTION OFTEN these days from readers and Web site visitors, ranging from students considering a drafting career to 20-year AutoCAD veterans to CATIA users with automotive experience. Positions such as drafter and CAD operater are tough to find. Overseas outsourcing, and general economic sluggishness, may account for a certain number of disappearing jobs, but other factors appear to be at work, too. Drafting in many cases is no longer done by a specialist--it's been absorbed into the duties of engineers, designers, architects, and others.

One of the big selling points of 3D modeling software is that it generates the 2D drawings automatically as a byproduct of the 3D model.

Michael Dakan, in a recent edition of the AEC Tech News e-mail newsletter (www.cadalyst.com/cadalyst/article/articleDetail.jsp?id=103066), points out that drafting tasks in AEC firms are frequently done by architectural interns, who must work under the supervision of a licensed architect before they can apply for licensure.

Indeed, it's nothing new to speculate that drafting is dead. Back in 1994, and then again in 2001, this space urged students to focus not only on drafting skills, but also on the processes and materials used in manufacturing and building. The traditional associate's degree is not sufficient anymore. Companies are looking for at least a bachelor's in engineering or architecture for entry-level positions. Those starting out should view CAD skills as only one element that future employers will require.

Certainly, there are and will continue to be job openings for CAD drafters, but they'll become harder and harder to find. The Department of Labor predicts slower-than-average growth for drafting positions, which totaled about 216,000 in 2002. Future growth for engineering jobs is also predicted to be below average, but the total job pool--around 1.5 million across all disciplines--is larger. The Labor Department does anticipate greater-than-average growth in surveying and mapping work.

Those drafting positions that are advertised, by both architectural and mechanical firms, most often require a certain amount of actual work experience with a particular software package.

So even if you do expand your software repertoire through continuing education, that may not be enough for prospective employers. A better path may be to invest in architectural or engineering classes. (Even those lucky enough to have stable jobs should study up on new skills, especially when you can get your company to pay for it.)

Also tailor your resume to emphasize not only your technical skills, but how those skills benefited your previous employers. Think in terms of results: You didn't just design new housings, you designed new housings that reduced bearing wear and cut maintenance downtime by 30%. Also be sure to note nontechnical experience and skills that employees value: working as a team member, supervisory experience, presentation skills, proven ability to learn new skills, and so forth.

Perhaps those of you now working and hiring can pass along additional tips for those struggling to find work, whether it's classes to take, fields to focus on, or skills to highlight in resumes. E-mail your ideas to editors@cadalyst.com.

SARA FERRIS

Editor-In-Chief

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Barriers to model exchange: why is it so difficult to send data from one CAD system to another?

Don LaCourse

Wouldn't it be nice if we all used the same MCAD application--and that it had all of the bells and whistles found in each application available today?

Everyone could send each other 3D models without worrying about losing data. Everyone could collaborate using the original master model. Everyone could benefit from each other's design intent. Wouldn't that be nice?

Ok, you can wake up now! If you're one of those rare individuals who exchanges 3D data only with partners that have your same system, you can go back to sleep. For the rest of us, this month's topic, model exchange, is one I enjoy talking about because it causes so much aggravation for MCAD operators and administrators. I don't like to see us aggravated, but I do like to take every opportunity to point out the problem and dig for solutions.

This year, I've focused on topics using one mechanical CAD program as an example and asking the developer to respond to various questions. This month, we ask Bob Fischer, vice president of sales and marketing at VX Corp. (www.vx.com), the tough questions. This should be interesting.

Q: Why has there been such a problem moving 3D CAD data from one system to another?

A: I think it's a question of differing objectives on the part of the people who create and use 3D data. For example, industrial designers are typically consumed with issues such as design aesthetics or ergonomics and have little or no concern for production and part manufacturability. Industrial designers are artists intent on creating beautiful, marketable products, and as artists don't want to be concerned with issues such as tolerances.

The downstream moldmaker faces different challenges. Moldmakers must take a 3D part and create a whole new set of 3D models. Their core objectives revolve around creating efficient molds that produce thousands of parts that are in tolerance.

While the moldmaker worries about draft, core and cavity separation, and parting lines, a CNC programmer is more worried about being able to manufacture the resulting 3D parts. Often, manufacturing models lack suitable features for automatic tool selection, or 3D models don't meet tolerance standards.

Q: What are some of the difficulties that developers have overcome (or addressed) in recent years?

A: To meet the needs of end-to-end customers (designers, moldmakers, and CNC programmers alike), application developers have taken a proactive stance by developing extensive suites of healing tools for working with 3D models. This enables all users to work with and heal imprecise data.

The hybrid-modeling environment is one way that users can overcome some of the difficulties in model exchange. Typically, solid modelers require a closed solid to perform most 3D functions such as moldmaking and manufacturing. Hybrid modelers let you work with open solids, thereby dramatically increasing their flexibility and efficiency.

Another important translation development is ongoing improvements in data recognition and fault tolerance. Although geometry can be automatically healed as it is read in, that occurs only after the data format is repaired.

Q: What are current model translation trends from the perspective of CAD software developers?

A: There seems to be a movement to direct translation. Customers are shackled to a CAD system if they can't convert their part libraries to another system with a high degree of accuracy.

This conversion involves geometric accuracy. Users want full feature transfers, undo and redo, history, annotations, and so on. With a direct translator, the customer has the best chance of converting data.

Q: What are the challenges yet to be overcome?

A: The industry needs better tools to translate features, design history, and intent. A few developers are attempting to fill the gap, but there's still a long way to go.

Q: What nontraditional methods are being used to exchange 3D modeling data?

A: There seems to be an active resurgence and interest in reverse engineering. We've experienced growing interest in our ScanShape tools, especially from companies that want to recreate 3D digital models from parts that weren't designed using CAD technology. An additional reverse-engineering trend is the high-tech world of 3D printing using yet another neutral file format, STL.

Tips for translation

Yes, it would be nice if we all lived in that perfect world where model exchange hassles were a thing of the past. However, this problem has been with us for at least 20 years, and I expect it to continue. If you're having model exchange problems, look for a good direct translator between you and your exchange partners. If you use one of the neutral formats, such as IGES or STEP, perform extensive testing between the CAD systems. If you are one of those rare individuals who only exchanges 3D data with partners that have your same system, wake up now and go back to work. The rest of us will keep on dreaming!

A special thanks to Bob Fisher of VX Corp. for sharing his expertise with us this month. Don LaCourse (don.lacourse@cadalyst.com) has spent the last 25 years in CAD/CAM operations and e-documentation. He is a Cadalyst contributing editor and principal partner of eDocHelp

(www.edochelp.com), an e-documentation and on-line Help services firm in Cookeville, Tennessee.

Roots of the Problem

Why has there been such a problem moving 3D CAD data from one system to another? The translation experts at VX listed these additional reasons:

* The IGES standard is a couple of hundred pages long and has existed under strict scrutiny for more than three decades. VDA-FS weighs in at a dozen or so pages. STEP documentation is huge--as in a truckload. These standards are open to interpretation, and developers interpret them differently. And there is always the opportunity for programming errors--dare I say bugs!

* The purpose of a translation standard is to provide a pipeline by which competing products can communicate without giving away trade secrets. This is very effective because it minimizes the translation burden. Instead of an n-by-n translator, one for each pair of applications, the pipeline is composed of a handful of accepted translation types.

* VX is making it easier to export in STEP by providing free-use STEP tools at www.vx.com/step/ that repair the documentation and make it easier to implement. The documents are hyperlinked with encoding generators and inheritance mappers to ease the implementation burden.

* This brings us to flavored outputs that target individual CAD systems, part of the movement back to direct translation between systems. This movement is driven by the desire to transfer more complex information, such as part history regeneration, between systems.

* With these elements muddying the waters, we get to the fundamental problems of data transfer: customers want to make a roundtrip translation without losing any of the benefits of the native system, such as undo, redo, and feature recognition.

* The root of all translation evil is tolerance. Tolerance defines when two different points are considered close enough to define the same point. Complication is magnified by magnitudes when curve tolerance and surface tolerance are thrown into the mix.

Reverse Engineering and CAD Translators

Figures 1-5 illustrate reverse engineering, a nontraditional method of model exchange. If you are interested in reverse engineering, these vendors offer additional options:

* INUS Technology www.rapidform.com

* Paraform www.paraform.com

* Raindrop Geomagic www.geomagic.com

* UGS PLM Solutions www.eds.com/products/plm/imageware/

In addition, the following are some of the companies that develop CAD translators:

* Compass Technologies www.compasstech.com

* Delcam www.delcam.com/exchange/exchange.htm

* Elysium www.elysiuminc.com

* Sescoi USA www.worknc.com

* TransMagic www.transmagic.com

* Transcendata www.transcendata.com

* TTI www.translationtech.com (online service)

Articles & Online Resources

* "Lost in Translation: Understanding data loss and how to avoid it," December, 2003, p. 28
www.cadalyst.com/cadalyst/article/articleDetail.jsp?id=79667

* Get free modeling tips and a CAD glossary at www.edochelp.com

* Find more information on data translation at www.cadalyst.com

[FIGURES 1-5 OMITTED]

Ten-step process to make sheets work for you

Heidi Hewett

At first glance, the new Sheet Set Manager may seem overwhelming. You don't have to learn and implement all of its functionality at once. Start using it immediately to access, manage, and share current drawing projects, and as you get comfortable navigating with the Sheet Set Manager, customize your existing templates and blocks to include fields. Use this ten-step process to go from the simplest to the most complex capabilities with minimal disruption to your current workflow.

STEP 1. Create a new sheet set from existing drawing layouts. First, import your existing drawing layouts into a new sheet set. Using the Create Sheet Set wizard, you can emulate your project's folder structure and automatically organize your sheets into subsets. The Sheet List tab displays sheets and subsets, and a right-click menu provides access to most of the functionality needed to manage and share your sheets.

STEP 2. Organize sheets and subsets. Sheets in the sheet list are pointers to layouts in drawing files. Subsets let you organize those sheets into visual clusters. You can create any number of subsets or nested subsets and then drag and drop the sheets to organize them. When you select a sheet or subset in the sheet list, you can view detailed information or display a preview image. You can remove sheets from the sheet set without moving or deleting the source files. To track the contents of your sheet set, you can insert a sheet index into your title sheet. As you make changes to the sheet list, the sheet index automatically updates.

STEP 3. Open drawings. From the Sheet Set Manager you can double-click on any sheet to quickly open the associated drawing. You don't need to know the name of the drawing file or where it's located in your directory.

STEP 4. Add sheets to a sheet set. Add sheets to an existing sheet set by importing layouts from existing drawings or by creating new sheets from scratch. Because sheets are pointers to layouts in drawings, you can import existing layouts as sheets by navigating to the drawing and selecting the appropriate layout. If you want to create a new sheet from scratch, AutoCAD automatically creates the new drawing file and layout based on the sheet creation properties associated with the sheet set. You can assign your typical drawing standards or template file as a sheet creation template, and you can specify where to store the new drawing file. You can also assign different sheet creation properties for subsets.

STEP 5. Plot using default page setups. Use the Sheet Set Manager to batch plot sheets using their respective page setup information. You can plot any combination of sheets or the entire set, and you can plot them in the background while you continue to work on your designs.

STEP 6. Publish to DWF. Regardless of the current page setup information associated with each sheet, you can publish any combination of sheets or the entire set to a DWF file. You can specify properties such as output location, password protection, and single sheet vs. multisheet DWF.

STEP 7. Create electronic transmittal or archive sets. Publishing your sheet sets to paper or to DWF files lets you share your designs with no worry that they may be modified. To share data with design partners or consultants who require access to the drawings, you can create an electronic transmittal set. Enhanced eTransmit functionality, available from the Sheet Set Manager, lets you create a ZIP file, self-extracting executable, or folder with any combination of sheets or the entire set and all of the associated drawings. Similar to eTransmit, the new Archive functionality lets you create a snapshot of your project data at key points throughout a project.

STEP 8. Plot using any page setup. When you need to plot a set of sheets, you can create a new page setup on the fly and plot any combination of sheets or the entire set using the specified page setup properties, regardless of the page setup information currently stored in each drawing layout.

STEP 9. Automate plot stamp and title block data. Use fields to create plot stamps that are flexible in appearance and location. You can add fields to existing title blocks so that changes to title block data, such as the sheet number and sheet name, automatically update.

STEP 10. Automate callout and view label data. Improve productivity and drawing accuracy by updating your existing callout and view label blocks to include fields. With field-enabled callouts and view labels, not only is the textual data updated as changes occur, hyperlinks provide easy navigation between callouts and views. You can click on a callout to open the sheet and zoom to the appropriate view.

Heidi Hewett is a technical marketing manager at Autodesk. An AutoCAD user for 17 years, she first was a lighting designer for a small electrical engineering firm.

Training tips and strategies: tailor training to solve your biggest problems

Robert Green

Frustrated CAD managers often ask me how to handle user-training programs. Questions range from how to identify materials to the best time to train to how to justify training to dubious upper management staff.

Invariably, answering any question about training involves building a justification for training that management agrees with and will fund. In my experience, it doesn't matter how well you can train from a technical standpoint if management doesn't see a business advantage to doing so.

Clarify Your Needs

Assuming that you have a certain amount of time and funds to execute a training program, what should you concentrate on to get the biggest bang for your buck? If you start to build a training program using this simple questioning metric, you'll stay on task and deliver training content that addresses key company needs. Ask yourself the following questions and write down your gut responses so you can analyze them in a few moments:

* What questions do users ask me over and over?

* What mistakes that cost time and money do we seem to repeat?

* What new methodologies could we use in our CAD software to save us time day-to-day?

* What problems are we having with standards enforcement?

I've found that almost all CAD managers, regardless of design discipline, can answer these questions quickly. If you know where your problems are, you have a solid idea of what your training program should address.

Quit Wasting Time

When I go through the above question-and-answer session with a CAD manager, I always point out that the answers to the questions not only show where you should be training, but also where you're already working too hard. What I mean is that if you're answering questions again and again, or fixing the same problem repeatedly, you're wasting time. In fact, you're not only wasting your own time by fixing the same problem over and over, you're wasting staff time as well because your staff isn't working as efficiently as it could.

By cataloging your company's needs, you build a list of action items. Your challenge now is to prioritize the list of action items in order of importance so you can address them in the most efficacious order.

Get Management on Board

Now that you have a prioritized list of training topics that address key needs within your company, it's time to convince management of the following:

* You've analyzed your company's needs carefully and know exactly what topics to cover.

* You've prioritized your training program to give the greatest degree of payback for the company.

* You understand that CAD (and CAD training by extension) can play a pivotal role in improving the company's business processes.

I've found that senior management is very impressed when a CAD manager presents a well-justified training plan based on business metrics. Management teams can change their outlook on CAD training completely when they're confronted with the problems and inefficiencies that cost them money.

Bottom line: If you can frame your CAD training program within the parameters of fixing problems and saving the company money, management will get on board. Getting Started

Now that you've created a prioritized list of training topics and brought management on board, it's time to turn your list into deliverable training classes. I like to tackle training development in the following order:

1. Identify and create training materials.

2. Benchmark your materials on a test group.

3. Prepare a training environment.

4. Deliver training and insist on trainee attendance and accountability.

Training Materials

Training materials are the key element to success in training. After the training is over, written materials become the only backup resource for users who didn't take good notes. I'd go so far as to say that you shouldn't bother with training if you don't have written training materials.

You can buy training materials or generate Word documents with screen captures that reflect your specific company environment. Either way, use just enough materials to make your point without being too wordy. If you plan on using Internet-based or multimedia training materials, have a written handout for after-training reinforcement.

Before you roll your training program out to the masses, rehearse with a small group of users and gather their feedback. This sort of informal benchmarking exposes weaknesses in your training plans, such as typos and missed topics, and helps you become comfortable with the material.

Training Environment

To deliver your training, you'll need an environment that provides noise control, room to spread out materials, and, at minimum, a computer and data projector so you can present a visually stimulating training session. Ideally, users should have computers with them in the training so they can apply the knowledge they gain.

Be warned that poor training environments typically yield poor training results!

I've also found it beneficial to record training presentations for future use in new employee orientations or in case a participant has to miss a training session. I highly recommend TechSmith's Camtasia software (www.camtasia.com) to record audio and video training sessions to disk-based files that you can replay via your corporate network.

Trainee Accountability

As you wrap up your preparation and charge ahead into delivering training sessions, insist that your trainees are on time, on task, and ready to learn. After all, you've persuaded your management to fund a training program to increase productivity, and they expect results. How can you deliver solid training results unless your users take the training seriously?

I've found that maintaining a sign-in sheet along with notes on who was absent or late motivates attendance. If those attending the training report directly to you, make training attendance records part of their personnel files and let them know you're doing so. If you set the tone that training is important and required, users are more likely to attend and master the training content.

Make the Grade

Conceptualizing and executing a custom CAD training program for your company is no small task. However, the only alternative to a targeted, needs-based training is answering the same questions over and over. If you don't train users in the most efficient or standardized methods for completing day-to-day tasks, you'll be destined to fight fires and fix the same problems again and again.

Take some time to think through your company's needs, design a training program to meet those needs, and then implement the program with zeal. You'll be amazed at the results.

Online Resources

Cadalyst's Web site lists training materials and providers for a number of different applications: www.cadalyst.com/training/

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10 express tools conquer text: express tool exploration continues - Circles And Lines

Lynn Allen

I've been besieged with e-mails requesting that I finish what I began a few months ago when I started to cover the ever-popular Express Tools. Worry not! I interrupted the series with my introductory article for Cadalyst, but this month I intend to pick up where I left off.

For those of you just tuning in, AutoCAD 2004 includes more than 100 Express Tools that make your everyday drawing life just a little bit easier. If you have yet to convince your boss to upgrade to AutoCAD 2004, you can buy the Express tools from the Autodesk estore at www.autodesk.com/estore. The Express Tools are worth their weight in gold--have a bake sale or a car wash to raise the funds if you must! Bad news for LT users: because most of the Express Tools are AutoLISP routines, they work only with full-blown packages of AutoCAD.

Most of the Express Tools appear in the Express Tools pull-down menu, though a few remain destined for Command line use only. To add this priceless menu to your existing AutoCAD menu, type in Expressmenu. If you prefer, toolbars are also available. This month, we pick up with the Text commands, an area where we all love to save some time.

Remote Text (Rtext)

Imagine a text file that acts like an external reference. You reference this external text file into the designated drawings, and any time you update the text file, it automatically updates in the associated drawing files. Think of the time you could save here! If you have lengthy assembly instructions or specifications in multiple instances, you can surely see some advantages. You can use the Rtext command to select the external text string, as well as the height, text style, and rotation angle. If you are enough of a guru to know DIESEL code, you can include that as well. For example, you can set the DIESEL string up to access the drawing name automatically (for a title block) with $(getvar, "dwgname"). Wouldn't it be nice to have a title block that partially answers its own questions?

Note: If you send your file to someone who doesn't have Express Tools, the text is converted to a bounding box. No worries--just explode the text to convert the text to mtext.

Also, if you forget the name of the associated text file, use the List command to provide a friendly reminder.

Textfit

This Express Tool comes in handy if you have difficulty getting your text strings to fit into a designated area. Simply pick a new end point (the justification is used as the start point) to squeeze that text into the proper space. You can also select a new start point if needed. Textfit manipulates the text width behind the scenes.

Textmask

You must be able to read valuable text strings, but this can be difficult when they are placed over busy drawing files. Textmask puts a masking rectangle around your text strings so you can read them easily. If you need to move the text string, the mask moves with it--they're grouped together. If you need to remove the mask, use the Textunmask command. You can control the size of the masking rectangle as well as the type of object used to mask--use the default value of Wipeout. You'll have difficulty using Textmask in paper space to cover model space objects unless you select the option Plot Paper Space Last in your Page Setup. This keeps your text masks on top of the model objects. If you want to see the bounding rectangle from Wipeout, use the Tframes command.

Text Explode (Txtexp)

AutoCAD 3D users who want to assign an elevation and thickness to text will love Text Explode. This command explodes your text objects, including mtext, into individual lines and arcs. A word of caution--it also enjoys moving your text objects around randomly! It also tends to drop the first letter ... okay, so it's a little buggy.

Convert Text to Mtext (Txt2mtxt)

Now that mtext is so awesome, why not change those vintage text objects from single lines to paragraphs? This command makes it easy to change the paragraph width, add additional words, control word wrap, and more.

Arc Aligned Text (Arctext)

AutoCAD is great at writing text along a line, but what if you need a curve? Arctext to the rescue! Simply create the arc you want your text to follow, and this Express Tool does the rest. You can place the text above the arc or below, as well as control all those things you'd expect with text (figure 1). The four justification options--Fit, Left, Right, and Center--are also helpful in getting just the desired results. If you don't like the results, you can use Arctext again and again on the same text string until you do (oh, for a Preview option!).

[FIGURE 1 OMITTED]

Justify Text (Tjust)

AutoCAD 2002 added the Justifytext command for those cases where you'd like to change the justification of text without changing its position, so this command is now redundant. Note: Neither command plays well with mtext--the end result usually involves the text moving.

Rotate Text (Torient)

When you rotate text objects, some text strings usually end up unreadable. Torient fixes this by orienting the strings so they're right-read, similar to dimension text (figure 2). You can also specify an absolute angle.

[FIGURE 2 OMITTED]

Enclose Text with Object (Tcircle)

Great for callouts and balloons, this command encloses the selected text or mtext object with a circle, rectangle, or slot. You decide whether you'd like the object to be a constant size or relative to the text string.

Automatic Text Numbering (Tcount)

Tired of numbering items in your drawing files? Let Tcount do the work for you. Tcount sequentially numbers text objects, with the number as a prefix, a suffix, or a replacement for the existing text object. You control the start number and the increment, as well as the sorting order. This lets you place bogus text in balloons, knowing that you plan on replacing it later. It also makes it easy to renumber down the road as needed. You can control the sorting order by the x (left to right) or the y (top to bottom), or by manually selecting the order.

You then indicate the start order and the increment (separated by a comma as indicated). The four replacement options are:

Overwrite: Replaces the existing text with a number.

Prefix: Puts the number before the existing text.

Suffix: Puts the number after the existing text. Find and Replace: Replaces a specific text string with a number.

Until Next Time

So many Express Tools, so little time. I hope you've found some helpful text tips that will whisk you through the laborious process of annotating your drawing files! Until next month--Happy AutoCAD-ing!

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Did ya know? 30 quick tips and tricks you can digest in 15 minutes or less - Circles and lines: all things AutoCAD - Column

Lynn Allen

I just finished a Webcast designed to help AutoCAD 2000 users catch up to AutoCAD 2004. In doing so, I was reminded of a number of cool tips and tricks that somehow fell by the wayside during the past few years.

That said, I thought I'd use my first column in Cadalyst as a quick brain dump of short AutoCAD nuggets that will help your everyday drawing life go just a little bit easier. These tips are easy to digest and implement, yet powerful time savers.

No doubt some of you already know quite a few of them, but I'll cross my fingers that you come across at least one that improves your work day tomorrow!

1. Use <Ctrl><Tab> to toggle between open drawings. I'm much too lazy to use the Windows pull-down menu to switch from drawing to drawing.

2. Use the close all command to close all your open drawings at once. If you use AutoCAD 2004, this feature works even if you're in the middle of a command in any of the sessions.

3. You can use the new Styles Toolbar in AutoCAD 2004 to quickly switch between one text and dimension style to another. Be sure to add this toolbar to your desktop to save time (figure

1).

[FIGURE 1 OMITTED]

4. If you're tired of that annoying prompt in the Pedit command that reads: Object selected is not a polyline. Do you want to turn it into one? <Y>, turn that evil prompt off by setting the PEDITACCEPT system variable to 1.

5. Do you want to customize the sample text string that displays when you first enter AutoCAD 2004's updated Mtext command? You can set the MTJIGSTRING system variable to display your favorite football team, pet, whatever! Timesaver, no, but good fun nevertheless!

6. Use the Layerp command to undo the last settings made in the Layer dialog box without undoing anything else. It's super simple to snap the Layer

Previous toolbar button, as shown in figure 2--it sits right next to the layer drop-down list.

[FIGURE 2 OMITTED]

7. I often use the Files pull-down menu to pull up a recently used drawing file. Be sure to change the default number of recently used files to list from 4 to 9 in the Options dialog box Open and Save tab so you have more to choose from.

8. Tired of hitting Grid by mistake on the Status bar? In AutoCAD 2004, right-clicking on the Status Bar lets you remove any of the existing buttons. If you don't use it, get rid of it!

9. Do you want your dimensions to have a slightly higher IQ? From the Options dialog box User Preferences tab, turn on Associative Dimensioning. This even makes your paper space dimensions smart!

10. Do you find yourself wading through directories searching for drawings? Be sure to include your most frequently used folders in the Open dialog box. Right-click on the far left of the dialog box to add and remove directories.

11. Don't forget you can now easily move between Trim and Extend. Press <Shift> while in Trim to switch to Extend, and vice versa.

12. Wish you could use the right-mouse button to execute <Enter> and still get those nifty shortcut menus? A new setting in the Options dialog box User Preferences tab under Right Click

Customization gives you the best of both worlds. A quick pick acts like <Enter>, and holding down the mouse button yields the appropriate shortcut menu. Very cool!

13. The new Qnew command starts a new drawing--no questions asked! As long as you have a default template file set (Options dialog | Files tab), you'll find yourself with one less question to answer in life. When you select the New icon on the Standard toolbar in AutoCAD 2004, the Qnew command executes by default.

14. Try the new Revcloud command to highlight changes quickly and easily.

15. Need to open and edit an attached xref? Try the new Xopen command. It works much better then Refedit. You can also find this command in the shortcut menu that appears when you highlight an xref.

16. Say you've been asked to e-mail someone a drawing file that has many attached xrefs and images. Do yourself a favor and use the Etransmit command. This lets you strip out those pesky hard-coded directory paths so the recipient won't have any problems opening the file--and you won't get any mean phone calls. Etransmit is also smart enough to save your files back to a previous format should your client not be on the same AutoCAD release.

17. Are you constantly switching between various layer set-tings? Save some time by setting up layer states in the Layer command.

18. Don't forget the powerful Matchprop command for quick editing. Here you can match up hatch patterns, text styles, polyline widths, viewport scale factors, and more. Why do more work than you have to?

19. The quickest way to change existing text height is through the Textscale command. You don't even have to know the desired height if you can find another text object to match it with.

20. The quickest way to change the current text justification is with the Justifytext command.

21. Need to zap out a bunch of dimensions in a hurry? Try one of my personal favorites, the Qdim command. You won't believe how much time you save.

22. Are you a keyboard junkie? Did you know you can jump between layouts by pressing <Ctrl> and the page-up and page-down keys?

23. Isn't it frustrating when a viewport is embedded within another viewport and you can't figure out how to get inside? Use <Ctrl>--R to toggle among all your viewports.

24. Switch to a new current layer at super speed by using the Make Object's Layer Current button on the Layer toolbar (figure 3).

[FIGURE 3 OMITTED]

25. Use the Saveas command to password-protect your drawing file. Select Tools | Security options. Be sure to write that password down because there's no way to retrieve it if you forget it!

26. Multiple Redo arrived with AutoCAD 2004, but did you notice the drop-down list added to both Redo and Undo in the menu bar? This makes it very clear which commands you want to undo and redo--thus avoiding accidents!

27. Try the Refedit command when you need to edit an existing block definition. It's the easiest method out there for editing existing blocks, and it removes much of the tedium for you. Incidentally, double-clicking on any block definition automatically takes you into Refedit.

28. Want to make a JPEG of your drawing file in a hurry? Try the new Jpgout command. There's also a Pngout and a Tifout command!

29. Tired of trying to hit that itty-bitty X in the upper right corner of the Properties and Design Center commands? Instead, use <Ctrl>--1 and <Ctrl>--2 to toggle those two frequently used commands on and off.

30. And my most important tip by far--get those magnificent Express Tools at any cost. Have a bake sale if you must. When you upgrade to AutoCAD 2004, you get all 100+ Express Tools for free. If you can't convince the powers that be to upgrade, scrape your pennies together and get them for yourself at the Autodesk e-store.

[FIGURE 4 OMITTED]

OVERDOSE?

Well, that was a huge dose of tips in a very short time. I hope you found a few gems to incorporate into your routine. As many of you know, my column is generally a more detailed explanation about one solid topic. Don't panic! You'll still get those difficult topics explained in plain English here in Cadalyst. This was just a kickoff Tips and Tricks party to celebrate my move! I look forward to getting to know some of you new readers, and as always I welcome your feedback. Until next month, happy AutoCAD-ing!

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What's next for MCAD? The quest for intuitive software

Mark Huxley

Much confusion is circulating in the MCAD marketplace about PLM (product lifecycle management). What does it mean, and how is it changing product development? Though CAD remains a keystone of PLM, both are changing rapidly. Our design processes evolve continually, and challenges to "the way things have always been done" abound. They range from wholesale changes in overall business strategies to critical thinking about reducing the number of mouse clicks needed to accomplish specific tasks.

Innovation and development follow several patterns of varying complexity, regardless of what industry you look at. Incremental advances take place, following Moore's Law, and those are interspersed with major jumps in technology (that is, totally new ways of achieving similar goals). If you believe that few to no truly significant developments have taken place recently, you are not alone. It's been fifteen years since solid modeling made its commercial debut, and more than six years since virtual reality caught our eye. Though many great improvements have taken place in that time, engineers and designers still incessantly click, drag, and bang out products on our keyboards. Meanwhile, we continue to wait for "the next big thing."

Vendor Perspective

Of course, we are all to blame for the apparent lack of radically new technology. Any of us could dream up a viable permutation at any moment. Rest assured that many vendors are working toward that goal. Marcelo Lemos of Dassault Systemes notes that, "For the first time last year, the market did not grow globally." He believes that customers still are not aware of all the benefits PLM can offer. Among other things, PLM has the potential to "minimize new product development cycles, reduce time to market, and lower development costs. The market will soon understand the feasibility and return on investment of knowledge-based PLM," he says.

David Primrose from EDS PLM Solutions points out that, through the use of KBE (knowledge-based engineering), models are becoming smarter. Rather than simply claiming space and defining what the geometry looks like, they interact with other components and assemblies to help define why they look that way. Increasingly impressive implementations of KBE are continually coming to fruition.

Unfortunately, KBE tools are available only to a relatively small niche of users, and they ultimately fulfill the needs of an even smaller group. Part of the reason for this is that most users aren't granted the time in their schedules to exploit KBE.

Dave Primrose says that EDS PLM Solutions is working to expand model intelligence by providing "support for design, development, analysis, and manufacture of electromechanical products."

In addition to 3D topology, the model file "needs to contain additional knowledge about its functional requirements, mechanical behavior, manufacturing considerations, and, increasingly, the software needed to control it," he says.

By incorporating all of this data, you can achieve full product lifecycle support from concept to obsolescence. Interest in KBE should grow as more examples and metrics become available (figures 1-3).

[FIGURES 1-3 OMITTED]

Joe Gavaghan from PTC says, "Product designers and engineers need to focus on delivering great products without having to stop and learn software." Once users adapt to Pro/ENGINEER

Wildfire's new interface, "the distinction between CAD, collaboration, and data management is so blurred that one moment, an engineer may be in the midst of a design task, the next, he's using the Pro/E Wildfire embedded browser to access PDM vaults and project workspaces located across the ocean."

Development of "The Next Big Thing"

MCAD development has been sluggish over the past year. Certainly, the major software releases from each vendor have substantial merit, but nothing screams, "You must buy this now!"

Several major vendors recently made substantial investments in revamping their user interfaces to make them more intuitive, less obtrusive, and easier to learn. Taking this as a cue, perhaps the next quantum leap in our technology will be a somewhat revolutionary interface. The medical industry, and we as its end customers, are already reaping many benefits that MCAD vendors are still striving for (figure 4, p. 14).

[FIGURE 4 OMITTED]

More than seven years ago, I witnessed an extremely effective VRML demonstration created using SmartScene software from Multigen (now Multigen-Paradigm; www.multi gen.com). The presenter, tasked with landscaping a front yard, dropped a picket fence into place (I didn't say high-quality landscaping). The fence was simply stretched to length and snapped in place to match the edge of the lawn. With two flicks of his hand, the presenter, like a maestro, made the entire "assembly" appear and grow, with the number of pickets adjusting accordingly.

Certainly if any of the MCAD vendors make it that simple, many customers will be calling on them instead of vice versa.

Automation reminiscent of this exists today in MCAD through KBE, but even the current improved interfaces make it challenging to readily accomplish even this simple example.

Industrial design applications such as Maya and Studio Tools from Alias (formerly Alias|Wavefront) have far more accommodating user interfaces for manipulating points, curves, and surfaces than do MCAD applications (figure 5). Though control of all six degrees of freedom is not readily natural to a new user, the controls are always within easy reach. Still, users struggle until they master idiosyncrasies such as using the keyboard and mouse combinations.

[FIGURE 5 OMITTED]

Virtual environments are today's version of virtual reality. Using relatively low-precision sensors, a computer can detect your body's movements. Tracking these movements in combination with a Cyberglove (a sophisticated glove capable of translating about 90% of sign language) or simple switches to change tools, you can perform actions in mid-air. Stereoscopes can then project what you've done in 3D, and magically your work is alive in front of you, ready to be modified.

Computer science doctoral student Steven Schkolne and Dr. Peter Schroder from the California Institute of Technology conducted a study comparing Maya and a CAVE (Cave Automatic Virtual Environment; figure 6). The subjects assembled and manipulated 3D mannequin models.

[FIGURE 6 OMITTED]

One user commented that the CAVE "was much more user friendly. I instantaneously had infinite directions of movement and infinite rotational axes, and it was all done with simple motions of my hands. It was very intuitive how to use the program because it was almost exactly like putting together tangible objects. Visual determinations were a breeze because I could change the angle just by moving my head, and at the same time I could manipulate a shape." Do any MCAD companies you know of get reviews like this from first-time users?

What does the future hold?

Discussing attempts by vendors to create a single interface that is capable of performing a wide range of tasks (sketching, building, assembling, measuring, etc.), Mike Evans, an IT columnist, said, "Can the interface adapt to the task? Or, heretical thinking, do we need different tools?" Applying this train of thought to CAVEs, what if many 3D tools could be displayed in your hand (pencils, tape measures, hammers, and sandpaper would likely be popular requests)? Combining a virtual "dream toolbox" with CAD accuracy and a Cyberglove to create a system that at the same time guides and accomplishes what you are attempting to do could provide an even more immersive experience without prohibitive extra costs. Incorporating haptic feedback could make the process almost realistic.

Schkolne has discovered better code is needed for interacting with virtual models, not necessarily more accurate sensors. In his talks with several larger companies, he finds that they "tend to move more incrementally" rather than by leaps and bounds. He believes that "a killer application needs to appear, and then larger businesses will take hold of it."

Surely KBE will continue to proliferate, and its tighter integration into our CAD programs will foster more automated geometry creation. Perhaps we will eventually be able to create knurl patterns, involute gears, and Class A surfaces with ease and without large file size penalties.

We appreciate today's technologies, but yearn for the next big development that will be as profound an improvement as solid modeling was to t-squares and slide rules. If we are allowed to focus on creativity and problem solving instead of wrestling with our software, perhaps the field of engineering could entice a wider group of prospective students.

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Additional reading ...

For more information on research mentioned in this feature:
www.cs.brown.edu/research/graphics/research/
www.cs.caltech.edu/csresearch/groups.html

In this article ...

Alias (Maya, StudioTools) www.alias.com

Dassault Systemes (CATIA) www.3ds.com

EDS PLM Solutions (Unigraphics NX) www.eds.com

Immersion Corp. (Cyberglove) www.immersion.com

PTC (Pro/ENGINEER Wildfire) www.ptc.com

Helping or Hurting? Top cad Interface Annoyance

Certainly layers, windows, and the like help us stay organized and manage data, but on the whole, reacting with them slows the creative process. Among the top user interface concerns with today's MCAD applications are:

* Assigning items to layer(s) with repeated duplicate clicks.

* Manually creating FEA or assembly animations frame by frame instead of simply exporting what is shown on the screen to an animated GIF file.

* Correcting flaws in imported geometry.

* Sketching tangent entities only to have them assume another, improper solution.

* Toying with blends and rounds that are not quite what you envisioned. Ninety percent or more of the feature is acceptable, but that last portion is a definite deal-breaker.

* Cursing when recording macros with all-or-nothing key sequences. Perhaps MCAD vendors could offer better graphical macro creation and editing tools (as in Photoshop) with plain English error messages complete with Continue and Stop options instead of "crashes."

* Resizing windows that pop up at sizes reminiscent of postage stamps. If you have a 190 LCD running at 128031024, why would a file navigation window default to 4903274? Is anyone really running an MCAD/PLM application at 6403480 screen resolution? How many versions of the software need to be built before it actually remembers window sizes, locations, last-used directories, and so forth. At the very least, you should

have the option to save the current state so you don't have to change it every time you restart the application.

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Productivity Soars With CNC Machines

By Guy J Morris

CNC machines can be a lifesaver in an industry setting. They speed up work in those tedious jobs that seem to never end. Although they can be a bit pricey new for solo use, you can put one to work on your wood working room for around half the price if you buy used.

About CNC Machines - How Do They Work?

CNC machines, aka Computer Numerated Control machines, are mechanical drillers, in a nutshell. When they are programmed properly, the CNC equipment can produced drilled holes in record time. This technology first hit industry in the 1970s and turned manual labor on its head. Production times were reduced significantly by this milling machine.

The reason CNC machines were so revolutionary is because they could complete the work of many human drillers in record time, and the work they were produced all but eliminated human error. Many industrial industries rely upon CNC equipment every day.

CNC Machine Types

If woodcutting is your thing, a CNC lathe is the way to go. This machine can cut your wood in any width and shape you want with minimal error and incredible speed.

For a milling machine, a Bridgeport machine is the best choice. Although these machines are extremely pricey, they can also make milling significantly more productive.

CNC machines can also be used for engraving. They can engrave on nearly any surface, and with the right programming, they can engrave a huge variety of different fonts, letters, and designs.

CNC Machines on a Budget

These machines might be ultra productive, but most individuals could never make enough use out of them to justify their hefty price tag. However, if you have a small but growing business, a CNC machine could take you to the next level. Buy used, save big time, and watch your profits grow.

Refurbished CNC machines are even cheaper than ones that are merely used but have never had any problems. A refurbished machine is one that has been repaired by a professional, and the extent of the repairs will impact the price you can get on one. You don't have to fear these refurbished machines because they have had a few problems in the past. In almost every case, a refurbished machine will come with a warranty that will give you peace of mind about your investment. Shy away from those "buyer beware," no warranty type of packages. A good refurbisher won't mind backing up their own work.

Article Source: http://EzineArticles.com/?expert=Guy_J_Morris
http://EzineArticles.com/?Productivity-Soars-With-CNC-Machines&id=904733

CNC Machines Being Used In Industrial Settings

By Greg K. Hansward

In various industrial settings and woodworking shops CNC machines are used. For personal use nearly all are out of the price range. But it can be purchased second-hand for about half the cost. When doing large jobs or repetitive tasks these machines are just perfect in case of speed and accuracy.

Usability

In various industrial settings, manufacturing processes and woodworking shops CNC equipment is used. To drill holes CNC routers are used. A number of machines have the capacity of holding several apparatus. Thus at a time they make more than one function and save time and offer accurateness.

Computer Numerated Control is the full name of CNC. In the 1970s this technology was introduced. Before operation the machines require to be programmed and arranged appropriately. When the primary set up is finished, they are quite easy to activate and go on operation.

CNC routers can be arranged to drill holes in an automatic manner. In comparison to manual drilling this is faster and more perfect over a number of pieces and the outcome is more consistent. For larger jobs this technique is very helpful where a lot of drilling is required. Physical drilling can become exhausting and when the machinist becomes tired, the outcome can become conflicting.

Various types

For cutting wood a CNC lathe is an excellent piece of apparatus. Different ranges from 15 to 40 horsepower of different models can be found in the market. You will use the amount of power according to the amount of wood you will be using with the lathe machine. Top quality models operate in several different modes, from entirely manual to all CNC lathe and lets you tailor the machine's operations for every function.

In milling technology a Bridgeport mill is the top. In many industries both large and small shops, mills are used. These are proficient and dependable. They are built to last a life span though they are very costly. It is so out of range that most people cannot afford a milling machine.

In milling technology the CNC mill is a specialty piece of apparatus. To provide accurate function it uses computer programming and robotics and the results are more perfect than any individual could ever do. Thus, Bridgeport mills are often used in the airline engineering. Once you enter the specs, it's up to the CNC to decide the particular tools that will be needed and it will also change the tools automatically when needed.

If you want a better option, you should look for renovated apparatus. Machines that are inspected at the factory, replaced if any part is broken. The machine is also painted and new decals are even applied in many cases. Thus you can get a new machine in a much low-cost. Also you may get a one year warranty with repaired apparatus which will make you sure that it is functioning accurately and if not, you will have it fixed at no cost.

Greg Hansward's long articles are published on a variety of websites related to woodworking tools and cnc machinery. His writings on cnc machines and tools are found on http://www.insidewoodworking.com

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CNC Machining

By Ross Bainbridge

CNC machining in the industrial the context refers to Computer Numerical Control. Computers are used to control machine tools for the purpose of manufacturing complex and intricate parts of metal and other material. More over the cutting process is enabled, using a program written in a notation confirming to EIA-274-D standard, which is often referred as G-code. The computer numerical controls were developed in late 1940's and 1950's, but were briefly preceded due to less advanced numerically controlled machines. However the CNC technology has developed greatly, with advances in mechanics and the computer sector. The developed CNC machines have drastically changed the face of the manufacturing industry.

More over the CNC structure has dramatically reduced human intervention in machining. It is easy to cut curves or straight lines, and structuring intricate 3-D parts has become relatively easy.

However CNC machines have helped to increase automation of the manufacturing sector, and have enabled improvements in consistent and quality production. The machininig technology has even helped significantly in reducing the frequency of errors and has provided the CNC operators with time to perform additional tasks. CNC automation also gives higher flexibility to the way tools are gripped in the manufacturing process, and the time required to produce different products.

Often for producing parts requiring several operations, a series of CNC machines are combined into one station, commonly referred to as a cell. However CNC structures today are controlled directly, with help of the files created by CAM software packages. Wherein the assembly can go directly from design to manufacturing, eliminating the need of producing a paper draft of the manufactured component.

Moreover CNC technology has enabled convenient and automated handling, of various machine tools such as drills, edm, lathes, milling machines, wood routers, sheet metal works, and hot-wire foam cutters. CNC technologies represent a special segment of industrial robot systems, as they are flexible and programmable to undertake any machine operation task.

Machining provides detailed information on Machining, CNC Machining, Casting Molding Machining, Precision Machining and more. Machining is affiliated with Automotive Machine Shop Services.

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CNC Machines

By Linden K. Walhard

A CNC machine is used in woodworking shops and some other industrial settings. They are very expensive, so most individuals do not buy them, although used ones can be obtained more cheaply. They are important for speed and accuracy in large, repetitive tasks.

There are many uses in industry for CNC machines. Routers drill holes, for example. Many CNC machines can perform a number of tasks at once, improving efficiency in the manufacturing process.

The technology behind these machines is Computer Numerated Control. This technology was developed in the seventies and it allows for a machine to be programmed in advance so the operations are set up to work almost automatically. The initial setup is a little complicated, but once that is done the machine is easy to operate.

A CNC router would be programmed to drill a hole repeatedly at certain intervals. This is much more efficient than manual calculation and drilling and eliminates inconsistency due to human error or fatigue.

A CNC lathe would be used to cut pieces of wood of uniform size and shape. Lathes can have horsepower ranging from 15 to 40 HP, and how much power is needed depends upon the job being done. A good CNC lathe will allow you to work at various levels of automation, so that you can work all manual, or all automated, or any combination in between.

The best mill available is the Bridgeport mill. Mills are designed to be used in both large industries and small milling shops, and the Bridgeport mill is built to last in any situation.

The price is prohibitive, however, for individual use.

A CNC mill is considered specialty equipment. The concept is to use computer programming and robotic operation for speed and accuracy. This kind of speed and accuracy would be impossible to achieve for an individual. The airline industry frequently uses the CNC technology of Bridgetown mills; specifications are entered, and the mill automatically determines which functions to perform and how.

Engravers can also be CNC machines. Engraving can be done on many materials, including wood or wood composite, metal, stone or glass. These machines can do very exact engraving on materials from the smallest to the largest, and have the same result over and over.

Since CNC machines are so expensive most individuals cannot afford them, there may be individuals who do a lot of repetitive machine work and would like to obtain one. An option in this case is a used CNC machine, which can be as low as half the price of a new one. It is important to make sure the used machine is in good condition, so you may be better off looking for a rebuilt machine. This is one that has had the major components replaced so it is almost a new machine. Frequently, rebuilt machines have a warranty of at least one year, so that you can be assured that it will be working, or you can get it repaired if it does not.

Linden Walhard pens mainly for http://www.insidewoodworking.com, an online publication covering information on woodworking tools, cnc machinery and other areas. His work on cnc machinery and cnc machines and tools are found on his web publications .

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http://EzineArticles.com/?CNC-Machines&id=444211

Tool Presetters - What to Look for

By John Regulski

When most companies with CNC machines look to become efficient, few look at the processes that precede the CNC manufacturing process. Offline presetting is that process which can help companies become most efficient.

As a shop floor manager, foreman etc a question needs to be answered. "What should I be looking for?"

Before getting that question answered you need to arrive at a budget. This is very important as there are so many different units on the market and this plays an important part. So after the budget what's next? As a company, you are looking to fulfill a need which allows you to reduce as much of the overall operating costs as possible. What are those operating costs?

1. Material

2. Labor

3. Setup

4. Machine

5. Tooling

Most presetters on the market today will allow you to achieve a reduction in cost as mentioned, what sets one apart from the other, is the presetter makeup itself. Here are some of the questions you should be asking your presetter company.

Where is it made? How is it constructed? Are the components tier 1 quality or below. Can I use it on the shop floor? Does it need to be in a controlled environment? What options do I absolutely need? What options are available? How will the options work to my companies advantage? How reliable is the presetter? How long has the company been in business? Is their service reliable? If I have computer issues whom do I call, third party or the company itself? Will my operators need extensive training or is it simple execution?

These are the questions that need to be asked and answered by the company you are prospecting. In order to achieve your desired success get the answers, do your homework and above all, work as a team in making your decision.

John Regulski - Product Manager EZset LLC.

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http://EzineArticles.com/?Tool-Presetters---What-to-Look-for&id=778129

Lathe Chuck

By Usharani Vairam

The lathe chuck has been an important tool more or less as the antique Egyptians used a simple man-powered lathe to cut designs and forms into wood. Working with the ancient lathes requires two-man task. One person has been engaged in cutting tools to carve or shape the revolving piece of wood. The second person twisted the wood by using a bow and piece of cord or rope to work. Lathe chuck parts have become very dedicated to a variety of wood spinning and also metal functioning tasks and stock. At present, lathes are computer proscribed exactitude machines with limited similarity to most of its early forerunner.

The wood revolving lathe is the spirit of most DIY and profitable woodworking workshops. Lathe machines are accessible in a multiplicity of sizes, from small pen lathes that have a greatest capability of 2" stock to much better lathes than can spin stock as large as 10" or 12". The massive lathes are used to turn items such as bowls and vases. Wood lathe hurls are obtainable throughout a number of woodworking tool outlets, as well as a great number of online distributors. They offer discounted pricing and speed delivery service for wood lathe chucks. Lathe has been utilized as a woodworking tool almost as long as the knife and the sledge hammer. People have an attraction with wood and the products than can be fashioned with a lathe.

Machining centers get the splendor in most shops. They make the complicated cuts whereas CNC lathes frequently do little more than OD clean-up and facing. It makes the lathe more proficient than the machining core for many difficult jobs. Automotive contractor Hillsdale Tool demonstrates an illustration. Its plant is now using a CNC lathe to machine an element that once obligatory a machining center and a chopper. Generally the manufacturing time are saved to about 30 percent.

The part is lodging for a transaxle oil force gathering. Its most important characteristic is an amalgamation of non-concentric ring-shaped surfaces making up the hollow space of the part. If these surfaces were concentric, they would create a spherical ring between them.Lathe chuck is considered for perpendicular whirling centers in which contaminants hamper procedure dependability. The lathe chuck proffers high securing forces and long jaw stoke up, in a small-summary chuck body. Clamping forces ranges from 95 kN to 330 kN, with jaw strokes ranging from 9 mm to 15 mm per jaw.

Sizes ranging from 165 mm to 500 mm are available.It is highly necessary to protect eye and ear when working in a wood working shop. For the requirement of the parts of wood lathe such as a wood lathe chuck, it is best to contact the manufacturer for the specific brand of wood lathe and find out where the parts are available. Especially while replacing the wood lathe chuck it is needed to ensure the part fits perfectly.

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Home Machine Shops

By Kevin Stith

A profession or hobby that uses a power-driven machine tool such as a lathe or drill to shape metal, is known as machining. The person specializing in its use is called a machinist. A machine shop that is run from home is called a home machine shop.

Most machining operations are those that remove metal from an item or those that add metals. There are typical tools that are used in home machining. A lathe is a machine tool that creates sections in circles by rotating a metal work piece. A drill or punch press is used to remove metal in the form of a hole. Some other tools that are used in machining are saws, grinding tools and milling machines.

Advanced machining operations make use of electrical discharge, electro-chemical erosion and laser cutting to shape metal work pieces. Many car restorers have good home workshops and a wide array of tools. There are also individuals who build up a home workshop with the scheme of building some project in the long run. They eventually get sidetracked into building the machine tools and their accessories themselves.

There are magazines that provide advice on ways of solving problems being faced in the home shop. It is also possible to get information about a used lathe and other machine tools, in

case the owner's manual is missing. These magazines and sites have a list of operating instructions on the various tools used. They also give detailed information about various manufacturers and their details.

Information about various new technologies that are being used, are also discussed. New techniques such as computer aided manufacturing processes, which have brought about a revolution in the machine shops, are also discussed. Home shop machinists can use this type of technological software to get the desired product results.

Machine Shops provides detailed information on Machine Shops, Automotive Machine Shop Repairs, Automotive Machine Shop Services, Automotive Machine Shops and more. Machine Shops is affiliated with Casting Molding Machining.

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http://EzineArticles.com/?Home-Machine-Shops&id=407748

Useful Information About Machining

By Ross Bainbridge

Machining in the industrial context refers to the use of power driven machine tools to shape metal. Metals are cut using various advanced machines and hence the process is often referred to as metal cutting.

Machining has various categories such as grinding, milling, turning, and drilling. In addition advanced technology has been developed to cut away material using electricity, chemicals, lasers, and water.

For grinding, a grinding belt or wheel is used, which is chafed against the work piece to remove material, for which water is used to avert the grinding wheel from getting hot and creating sparks. Grinding is often used for cutting metal pieces that are too hard to be machined.

However for cutting work pieces into asymmetric shapes, a manual machine would be an ideal aid. The process of manual machining is called as milling, and is good for general machining.

However the milling process is less accurate, and not preferred as much as the turning or grinding machining process. The milling machine resembles a drill press, and the cutter looks like a drill bit that goes downwards in the piece to be cut. There are various different kinds of milling machines, and all serve in setting the depth of the cut.

Turning is another machine cutting process. However, the turning machining has a very unusual process of cutting, which is done on a lathe. Wherein the lathe turns the piece around, as a blade cuts away the required portion of the material.

Similarly drilling is a very common process of machining, which is used for cutting. The drilling process involves use of a drill or a drill press that has a drill bit on it, to cut away the work piece. Drill bits are available in many sizes and shapes, which help in cutting intricate shapes.

Nontraditional methods are also used for machine cutting such as a water jet technique, which is mainly used to cut softer materials, or materials that have cracks. Similarly the electrochemical machining technique is used for precise cutting. More over the advances in the machining process has been very crucial in the growth and development of the manufacturing sector.

Machining provides detailed information on Machining, CNC Machining, Casting Molding Machining, Precision Machining and more. Machining is affiliated with Automotive Machine Shop Services.

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http://EzineArticles.com/?Useful-Information-About-Machining&id=277149

CNC Milling

By George Ure

Computer Numerical Control (CNC) machines perform functions of drilling, milling, turning, etc. CNC Mills are usually defined in terms of the number of axes they handle. Axes are generally labeled as x and y for horizontal movement and z for vertical movement. The number of axes of a milling machine is significant. A standard manual industrial mill typically has four axes: * Table x. * Table y. * Table z. * Milling Head z. A five-axis CNC milling machine has an extra axis. This axis is the basis of a horizontal pivot for the milling head. This allows a greater flexibility for machining with the end mill at an angle with respect to the table. A six-axis CNC milli ng machine has another horizontal pivot for the milling head, perpendicular to the fifth axis.

Material is usually removed by both the end and the side of the cutting tool. In CNC milling the cutting tool usually rotates about an axis that is perpendicular to the table, which holds the material to be cut. Cutting tools of various profile shapes include: square, rounded, and angled. A wide variety of part shapes and geometries are possible by a CNC machine.

Interestingly, CNC machines come in various models, which range from small desk-top lathes and milling machines to larger full-sized machining centers.

CNC machines used by www.eMachineShop.com are traditionally programmed using a set of commands known as G-codes. G-codes represent specific CNC functions in alpha-numeric format. CNC milling machines carry out the cutting process in which materials are removed from a block by a rotating tool. In CNC milling, the cutting tool is moved in all three dimensions to achieve the desired cut shape.

Online CNC machining ensures optimal work-related selection of manufacturing systems and the configuration to satisfy the range of parts to be processed.

A key advantage of CNC machining is the wide variety of work piece features that it can produce. Part features such as walls, pockets of different depths, tapped holes, bolt-hole circle patterns and others commonly found on prototypes can be precisely produced on a CNC machine. One other advantage of CNC machines is their ability to produce metal molds which can then be used for injection molding operations.

About the Author

George is a well-known author who writes on topics related to cnc machine shop, waterjet cutting, for the site http://www.emachineshop.com/

Full CNC Multispindle

The Model MS22C from Index Corp, introduced at IMTS 2006 in September, is the latest addition to the company's line of CNC multispindle machines. A fully CNC multispindle for turning and milling small workpieces from bar as large as 22-mm diam, the machine has six fully independent CNC spindles, each capable of speeds to 10,000 rpm.

Developed for the medium-complex workpiece market, which Index says has until now been dominated by cam-controlled multispindle automatics and simple sliding and fixed-headstock automatics, the machine is designed for production of precision parts with different features in one single-step operation.

Supplied as a modular system, the machine can be equipped with up to 62 axes, 12 CNC compound slides, and Y axes, plus an optional two synchronous spindles and six tools for backworking, four of which may be live tools. In every spindle position, a C, X, and Z axis is available. Backworking can also be done using three fixed tools.

Its open-front work area allows more than one tool on each of the CNC compound (X, Y, Z) slides to be engaged at once, and also provides a freely accessible work area and unrestricted chip flow.

The V-shaped arrangement of the tool carrier in every spindle position means that only the toolholder determines the type of machining, so external and internal machining can be done with fixed or driven tools at every station. Furthermore, the machine can also be configured as a double three-spindle machine. The C axis, available in all spindle positions, allows the complete machining of complex workpieces in short cycles. With the available Y axis, eccentric machining can also be performed.

The modular design permits building the machine with options that fit a wide range of requirements including polygon turning/milling/drilling/gear hobbing. A bar loader or stock reel can be used with the unit.

The machine employs the same multispindle technology seen on the rest of the Index machine range. The multispindle's centerpiece is the spindle drum, with six spindles driven by individual air-cooled AC motors. A three-ring face-tooth coupling mechanism locks the spindle drum into the headstock.

All six backworking tools, located between the cut-off position and the exit conveyor, can either be fixed or live (driven). The kinematic motion drive for the spindle automatically includes the Y axis, so that off-center features can be machined on the cutoff side of the workpiece in conjunction with the C axis on the pickup spindle. This new design allows very quick cycle times-around 2 sec, depending on the workpiece.

Olaf Tessarzyk, president and CEO of Index Corp., says the MS22C allows machine shops to transition into the company's MS CNC technology at a cost typical of a cam machine with CNC slides.

The MS22C is part of a full line of CNC multispindle machines, all based on the same design concept. The other models include the counter-spindle versions MS32P and MS42, which allow machining of longer and more complex parts, and the MS32G and MS52G with six additional opposed spindles for the most complex parts, which require extensive backworking.

According to Index, the MS22C can pay for itself with lot sizes from 5000 parts for repeat orders. Circle 180

CNC Machine Tool

Douglas Betts

Background

CNC or "computer numerical controlled" machines are sophisticated metalworking tools that can create complicated parts required by modern technology. Growing rapidly with the advances in computers, CNCs can be found performing work as lathes, milling machines, laser cutters, abrasive jet cutters, punch presses, press brakes, and other industrial tools. The CNC term refers to a large group of these machines that utilize computer logic to control movements and perform the metalworking. This article will discuss the most common types: lathes and milling machines.

History

Although wood-working lathes have been in use since Biblical times, the first practical metalworking lathe was invented in 1800 by Henry Maudslay. It was simply a machine tool that held the piece of material being worked, or workpiece, in a clamp, or spindle, and rotated it so a cutting tool could machine the surface to the desired contour. The cutting tool was manipulated by the operator through the use of cranks and handwheels. Dimensional accuracy was controlled by the operator who observed the graduated dials on the handwheels and moved the cutting tool the appropriate amount. Each part that was produced required the operator to repeat the movements in the same sequence and to the same dimensions.

The first milling machine was operated in much the same manner, except the cutting tool was placed in the rotating spindle. The workpiece was mounted to the machine bed or worktable and was moved about under the cutting tool, again through the use of handwheels, to machine the workpiece contour. This early milling machine was invented by Eli Whitney in 1818.

The motions that are used in machine tools are called "axis," and are referred to as "X" (usually left to right), "Y" (usually front to back), and "Z" (up and down). The work-table may also be rotated in the horizontal or vertical plane, creating a fourth axis of motion. Some machines have a fifth axis, which allows the spindle to pivot at an angle.

One of the problems with these early machines was that they required the operator to manipulate the handwheels to make each part. Besides being monotonous and physically exhausting work, the ability of the operator to make identical parts was limited. Slight differences in operation resulted in variation of the axis dimensions, which, in turn, created poorly fitting or unusable parts. Scrap levels for the operations were high, wasting raw materials and labor time. As production quantities increased, the number of usable parts produced per operator per day were no longer economical. What was needed was a means to operate the motions of the machine automatically. Early attempts to "automate" these operations used a series of cams that moved the tools or worktable through linkages. As the cam rotated, a link followed the surface of the cam face, moving the cutting tool or the workpiece through a series of motions. The cam face was shaped to control the amount of linkage movement, and the rate at which the cam turned controlled the feedrate of the tool. These early machines were difficult to set correctly, but once set, they offered excellent repeatability for their day. Some have survived to this day and are called "Swiss" machines, a name synonymous with precision machining.

Early Design to Present Day Operation

The modern CNC machine design grew out of the work of John T. Parsons during the late 1940s and early 1950s. After World War II, Parsons was involved in the manufacture of helicopter rotor blades, which required precise machining of complex shapes. Parsons soon found that by using an early IBM computer, he was able to make much more accurate contour guides than were possible using manual calculations and layouts. Based on this experience, he won an Air Force contract to develop an "automatic contour cutting machine" to produce large wing section pieces for aircraft. Utilizing a computer card reader and precise servomotor controls, the resulting machine was huge, complicated, and expensive. It worked automatically, though, and produced pieces with the high degree of accuracy required by the aircraft industry.

By the 1960s, the price and complexity of automated machines had been reduced to the point where they found applications in other industries. These machines used direct current electric drive motors to manipulate the handwheels and operate the tools. The motors took electrical instructions from a tape reader, which read a paper tape approximately 1 in (2.5 cm) in width that was punched with a select series of holes. The position and sequence of the holes allowed the reader to produce the necessary electrical impulses to turn the motors at just the precise time and rate, which in effect operated the machine just like the human operator. The impulses were managed by a simple computer that had no "memory" capability at the time. These were often called "NC," or Numerical Controlled machines. A programmer produced the tape on a typewriter-like machine, much like the old "punch cards" used in early computers, which served as the "program." The size of the program was determined by the feet of tape needed to be read to produce a specific part.

CNC TECHNOLOGY For Mold Applications - Computer Numerical Control

Bill Griffith

CNC technology is changing rapidly, and the changes are helping to improve the productivity of machine tools used in the mold industry. Faster central processing units (CPUs) are at the heart of many CNC changes. However, the improvements go beyond just faster processing, and the speed itself touches on many different CNC advances. With so much that has changed in recent years, it's worthwhile to present a summary of the state of mold-making CNC technology today.

BPT And Beyond

As CPU speeds have increased and CNC manufacturers have incorporated this speed into highly integrated CNC systems, there have been phenomenal changes that increase CNC performance. The faster, more responsive systems do more than just process program blocks faster. In fact, a CNC system that can process part program blocks at a very high rate may perform as well as a system that processes data at a slower rate, because there are other potential bottlenecks downstream that the overall feature content of the CNC system also has to address.

Most mold shops today intuitively understand that high speed machining requires more than just block processing time (BPT). In many ways, the analogy of a race car illustrates why this is so. Should the fastest car win the race? Even a casual observer of racing knows there is more to it than this.

First, the driver's knowledge of the race track is important. He has to know a sharp curve is coming so he can slow down just enough to take the curve safely and efficiently. CNC look-ahead performs a similar role in high-feedrate mold machining, giving the CNC advanced knowledge of the sharp curves coming up.

Similarly, how quickly the driver reacts to what other drivers do, and other unpredictable effects, can be compared to the CNC's servo loop times--including position loop, velocity loop and current loop.

Consider also the smoothness of the driver's execution as he goes around the track. Skillful braking and accelerating have a significant impact on performance. Bell-type accident in the CNC system gives similar smoothness to machine tool acceleration. Look-ahead helps here as well, because it allows many small acc/dec adjustments to replace an abrupt acc/dec change.

The analogy also applies in other ways. The power of the engine can be compared to the drives and motors. The weight of the car can be compared to the mass of the moving elements of the machine tool. The strength and rigidity of the car can be compared to the strength and rigidity of the machine. And the CNC's ability to maintain a specified path error can be related to how well the driver keeps the car on the track.

One other way the analogy relates to the state of CNC today is this: A ear that isn't one of the very fastest may not need the most skilled driver. In the past, it was only high-end CNCs that could maintain high accuracy at high speeds. Today, mid-level and low-end CNCs are so powerful that they may also do an acceptable job. The high-end CNC still offers the best

available performance, but perhaps for the machine you have, the lower-level CNC will permit the same performance as a CNC at the top of the line. It used to be that the CNC was the limiting factor determining the maximum feed rate in mold machining, but today the limiting factor is the mechanics of the machine. A better CNC won't deliver more performance if the machine itself is already operating at its performance limit.

Features Inherent To The CNC System

Here are some of the CNC features fundamental to many mold machining processes today:

* NURBS Interpolation. This technology for interpolating along curves instead of dividing curves into short, straight line segments is still gaining in popularity. Most of the CAM packages for die/mold applications today now have an option for outputting NURBS-formatted part programs. At the same time, more powerful CNCs have allowed CNC manufacturers to add five-axis NURBS capability, as well as NURBS-related features that deliver improved surface finish, smoother motor performance, faster cutting rates and smaller part program size.

* Finer command unit. Most CNC systems issue motion and positioning commands to machine axes using a command unit of 1 micron or coarser. Taking advantage of the increase in processing power, some CNCs today offer a command unit of 1 nanometer (0.00000l mm). This control increment is 1,000 times finer, providing for improved accuracy. It also provides for smoother motor performance, which can allow some machines to accelerate faster without increasing the shock to the machine.

* Bell-shaped acc/dec. Also called "jerk control" or "S-curve acc/dec," bell-shaped acc/dec allows a machine tool to accelerate faster than linear acc/dec. It also provides less position error than various acc/dec types including linear and exponential.

* Look-ahead. This is a widely used term, with many performance differences separating the way the feature works on low-end versus high-end controls. In general, look-ahead lets the CNC pre-process the program

to ensure superior ace/dec control. The number of look-ahead blocks can range from two blocks to hundreds of blocks depending on the CNC. The number of blocks required depends on factors such as the minimum part program execution time and the acc/dec time constant, but 15 blocks of look ahead is probably the minimum acceptable value.

* Digital servo control. Digital servo technology has improved significantly, and most CNC manufacturers can now offer a digital servo solution. Advances include faster communications, serial connections between the drive and CNC, and faster and more numerous digital signal processors. These advances have combined to allow CNCs to control the servo loops more tightly and thus control the machine better.

The technology helps in many ways:

1. Increasing the sample speed of the current loop, combined with better current control, results in the motor heating up less. This not only extends motor life, it also means there is less heat transfer to the ballscrew and therefore improved accuracy. Increased sampling speed can also make possible a higher velocity loop gain, helping to increase the overall performance of the machine.

2. Because many newer CNCs offer a high-speed serial connection to the servo system, the CNC can now get a lot more information about motor and drive operation through this communication link. This has resulted in improved maintenance features.

3. Serial position feedback permits higher accuracy at high feed rates. As CNCs got faster, the position feedback rate became a bottleneck in determining how fast a machine could move. Conventional feedback is carried by a signal type that limits speed according to the sample rate of the CNC and the electronics of the external encoder. Serial feedback eliminates

this bottleneck, allowing fine position feedback resolution even at high speeds.

* Linear motors. This technology has improved significantly in recent years in both performance and acceptance. Every IMTS sees more machining centers offered with linear motors, and to date, Fanuc has shipped more than 1,000 units. Some of GE Fanuc's advances have resulted in machine tool linear motors with a maximum force of 15,500 newtons and a maximum acceleration of 30 G. Other advances have led to smaller size, lighter weight and more efficient cooling. All of these changes serve to enhance the benefits linear motors offer over rotary motors--benefits that include higher acc/dec rates; superior position control and higher stiffness; improved reliability; and inherent dynamic braking.

Features Added From Outside: Open-System CNC

Open-system CNC products have changed rapidly. The higher speed communications choices available today have led to many different types of open architecture. Most of these open-system CNCs integrate the "openness" of a standard PC with conventional CNC functions. The key advantage of specifying an open-system CNC is that it can allow the CNC features to remain current with the state of technology and the needs of the process even while the machine hardware ages. Among the capabilities that can be added to an open-system CNC via third-party software, some are more relevant and some are less relevant where mold machining is concerned. But across all shops using open-system CNCs, some of the most common choices include:

* Low-cost network communications

* Ethernet

* Adaptive control

* Interfaces to bar code readers, tool ID readers and/or pallet ID systems

* Mass part-program storage and editing

* SPC data collection

* Documentation control

* CAD/CAM integration or shopfloor programming

* Common operator interfaces

The last item is particularly significant. A growing requirement in the mold industry is for the CNC to be easy to use. An important component of this ease of use is commonality of operation from CNC to CNC. Typically, operators must be trained separately for separate machines because the CNC interface differs between machine types and between machine tool builders.

Open-system CNCs provide new opportunities for working toward a control interface that's common throughout the shop.

Now, machine tool owners can design their own interfaces for CNC operation--and they don't have to be C programmers to do so. In addition, open-system controls can permit individual log-on so personnel performing various functions--operator, programmer, maintenance and so on--see only the screens they need. Eliminating unnecessary screens makes CNC operation even more straightforward.

Five-Axis Machining

Five-axis machining is increasingly being applied to complex mold work. The technology can reduce the number of setups and/or machine tools required to produce a part, thereby minimizing work-in-process inventory and reducing total manufacturing time.

As CNCs have become more powerful, CNC manufacturers have been able to add more five-axis features. Capabilities once found only in high-end controls are now available in mid-range products. Most of these features have to do with making five-axis machining easier to use for shops that have little five-axis experience. Today, accessible CNC technology can deliver all of these benefits to the five-axis machining process:

* Eliminate the need for qualified tooling

* Allow tool offsets to be set after the part program has been posted

* Support "machine anywhere" programming, so that posted programs are interchangeable from machine to machine

* Improve surface finish

* Support various machine configurations, so the program no longer has to account for whether the spindle pivots or the workpiece pivots. This is now accounted for by parameters at the CNC.

One example of a five-axis machining feature specifically suited to mold machining is ball-nose end mill compensation. In order to properly compensate for a ball-nose end mill as the part or the tool pivots, the CNC must be able to dynamically adjust the cutter compensation vector in X, Y and Z. (See illustration above.) Better finish is one benefit of keeping the tool's contact point constant.

Other five-axis CNC functionality can be separated into the features related to pivoting the tool; features related to pivoting the part; and features that allow the operator to manually move the tool to a new vector.

When rotary axes pivot the tool, the tool length offset that normally affects only the Z axis now has components in X, Y and Z. In addition, tool diameter offsets that normally affect only the X and Y axes also have X, Y and Z components. And because the tool may be feeding in the rotary axes while it's cutting, all of these offsets have to be updated dynamically to account for continuous changes in the tool's orientation.

A CNG feature called "tool center point programming" can take of this. The feature lets the programmer define the path and speed of the center point of the tool, while leaving it to the CNC to take care of the commands in the rotary and linear axes to ensure that the tool follows this programming. This feature makes the tool center point independent of the specific tool loaded into the machine, meaning (A) tool offsets can be input at the machine tool just as in three-axis programming, and (B) programs don't have to be re-posted to account for tool length changes. The feature simplifies programming and posting for machines that achieve rotary-axis motion by pivoting the spindle.

Machines achieving rotary motion by pivoting the workpicce use similar functionality. Newer CNCs can compensate for this movement by dynamically adjusting fixture offsets and rotating coordinate axes to match the part's rotary motion.

The CNC can also have an important role when the operator is jogging the machine manually. Newer CNCs allow the axis to be jogged in the direction of the tool vector ... and allow the tool vector to be changed without the location of the tool tip changing. (See illustrations above.)

These features make a five-axis machine easier to use for 3+2 programming--the most common use of five-axis machines in mold making today. However, as new five-axis CNC features continue to evolve and gain acceptance, true five-axis mold machining is likely to become more common.

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Stan Dornfeld

A Philosophy For Purchasing A CNC Milling Machine

Among other common considerations, a strong thought must be given to the table travel area. This factor has the most impact on ROI (return on investment). Since the table travel area is the only place where work can be done, lets study it in detail.

Past technology (hand crank mills) required the machinist to "dial in" and "weld" the setup to limit the number of human errors. These setups were designed around holding usually only one part at a time to do only one operation at a time. The natural concept which developed was to use the smaller machines for the smaller parts and the larger machines were reserved to accommodate the "big stuff". This idea was great when the fear factor was the almighty human element.

The human element, during machine operation, has diminished considerably thanks to "computer control". The computer allows the human to be more creative in tooling design while it does the tiresome repetitive work of machining close tolerance parts.

The new technology has a few unique advantages: * The computer does not "whine" if it is instructed to crank all the way across the table at 400-inches a minute to drill a hole. Try that with your hand crank mill! * The computer can also position the table anywhere within the table travel to an accuracy of 0.00005 inch or better. It does this feat while traveling at "warp" speed.

These two factors alone allow us to program and use the entire table travel area--safely, confidently, and profitably. Imagine, take that little part and toss it on the table anywhere, hold it and machine it right where it is.

Think about it...ANYWHERE!

Remember the old geezer that would tell us to put the vise on the other end of the table for a while to even out the table wear? Now, by mounting parts all over the table, we can even out the table wear and at the same time, be far more productive. And we can do all this while we are out having lunch, because a table full of parts can run a long time.

While holding this thought, an interesting idea comes to mind. Divide the total table travel area into the machine's price and we establish a cost per-square-inch of table travel. Now we have one valid "yardstick" to use.

Comparisons between machines will generally yield a lesser cost per-square-inch for the larger bed-type mills.

Two examples will show how:

A Fadel VMC 40 machining center with a table travel of 20" x 16" has an approximate CPSI (cost per-square-inch) of $205.00, while the Fadel VMC

6030 with a table travel of 60" x 30" has a CPSI of around $62.00. The CPSI on the big machine is 30 percent of the VMC 40.

A Hurco KM3 knee mill with a table travel of 24" x 14" has an approximate CPSI of $117.00, while the Hurco BMC 40 with a 30" x 40" table travel, has a CPSI of around $93.00. And they throw in a tool changer! For just about 80 percent of the price and you can do the bigger parts too.

Using all the available area requires imagination, but the rewards are many. If the work is long run and steady, then large fixtures can be built to hold large numbers of parts. If, however, the work is short run and varied, then perhaps the table can be divided into sections. One section might have two vises set up. Another section could have an indexing head. In the rear section, a subplate used to mount various fixtures could make this machine quite versatile.

The main thrust, of course, is to limit the downtime needed to setup tooling.

In any case, remember, anywhere within the confines of the table travel is fair game to machine a part. Use it advantageously.

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Lorincz, Jim

Tapping and thread milling head the list

Technological advancements in thread mills, taps and tapholders, and CNC machine tools are enabling manufacturers to meet many of their production objectives for quality threading. These include reducing cycle time, increasing production, and eliminating costly scrap and associated downtime that result from broken tools.

Modern CNC machine tools feature synchronous rigid tapping and helical interpolation capabilities that are needed to control processes, which by their very nature are regarded as more complicated than traditional milling and drilling.

The most dog-eared pages in your shop copy of Machinery's Handbook (Industrial Press, New York) are likely to be those dealing with the complexity of threading, including such technical aspects as ANSI and ISO standards, types and sizes of thread forms, and how and to what purpose threads are produced.

"Tapping is a process that goes back a long way, but the reality today is that it is much faster than ever before," says Alan Shepherd, technical director, Emuge Corp. (West Boylston, MA). "CNCs that have synchronous tapping cycles, coolant through, and high-pressure coolant capability have provided significant advantages to the cutting process," he adds.

"The basic perishable tool, the tap itself, has been developed to a point where tapping can be done at speeds formerly not practical, in large measure due to improvements in CNC controllers and machine tools, as well as new coatings, like our GLT-1, which enables us to run 20-30% faster in stainless and alloyed steels.

"What is high speed? If you were tapping cast iron at 70-80 fpm, or even 100 fpm, we can now bring that up to 200-250 fpm. We can double speed and sometimes quadruple it. Stainless steel that would normally be run at 15-20 fpm can be run at 60-90 fpm," says Shepherd.

When tapping, the productivity of the operation is governed by the cutting speed (sfm) and feed per revolution is fixed to the pitch (thread per inch) of the thread being produced. Unlike drilling and milling tools, tapping feed rates cannot be increased unless the rpm is increased accordingly, to match the required thread pitch.

For high-speed tapping, Shepherd recommends quality tool holders and application-specific coated tools. "Years ago, when I conducted training seminars on tapping, the first thing I talked about was tap breakage. It always topped my list. Today it's on the bottom of my list of topics. At the top is cutting oversized threads because modern taps have high rates of relief and require rigid collet-type holders to be able to run at high speeds," he says.

The ability of the tap to follow the same cutting path as closely as possible is essential to extending tool life by minimizing tool wear. Coatings on taps and coolant-through capabilities are important to reduce the heat-generating friction that limits tap life. Tap holding and machine feed control are critical to minimize the effects of backlash and thrust that all modern machine tools will have to some degree, says Shepherd.

Emuge, which is a manufacturer of both taps and thread mills, as well as end mills, thrillers, and holders, recently moved into a new HQ and technology center in West Boylston, MA, where its customers can see machining demonstrations, receive training, and benefit from applications engineering.

At IMTS, Tapmatic Corp. (Post Falls, ID) demonstrated on a Haas VFl machining center how its selfreversing RDT and RCT tapping attachments produced a steady rpm, compared with fluctuating rpms when running a rigid tap driver. Tapmatic has designed its tapping attachments to compensate both axially and radially for the unavoidable discrepancies between the machine's programmed rpm, feed, and traverse to produce exact thread pitch and precise hole locations.

In the demonstration, a machine load monitor showed spiking during machine reversal for rigid tapping. However, there was very little loadabout one-fourth as much-when the Tapmatic self-reversing tapping attachment was used. Less load translates into reduced machine wear and energy costs. In addition to CNC machining centers, Tapmatic self-reversing tapping attachments are also available for conventional drill presses and milling machines, manual or automated equipment, as well as for CNC machining centers or CNC lathes with nonsynchronous tap cycles.

An increasingly popular alternative to tapping is thread milling, which traces its use back to aerospace applications in the Gemini Space Program. The drawback at the time was that engineers had to write programming manually, in the absence of helical interpolation routines now commonly available on CNC machining centers.

The basic distinction between tapping and thread milling suggests applications where each is likely to be preferred. As holes get larger and deeper, tapping takes more spindle power.

There is always the danger of broken taps that lead to scrapped workpieces, downtime to remove broken taps from high value workpieces, and the recutting of chips.

Thread mills can be of a singlepoint (tooth) design or a multi-point design. Thread mills generate the thread profile by helical interpolation. To generate the thread, a single-point cutter requires the same number of interpolations as there are pitches, i.e. an 8-pitch thread, 1" (25.4-mm) long would require eight circular interpolations around the workpiece threaded diam. A multipoint cutter, which is essentially a series of single cutters on one body/flute, can normally complete a screw thread in one revolution of the work.

Advent Tool and Mfg (Lake Bluff, IL), a supplier of thread and form milling products in solid carbide, carbide-tipped, and indexable tools, describes helical interpolation: "Thread milling requires the use of a machining center capable of helical interpolation. This means that the machine must be capable of three-axis simultaneous movement. Two of the axes perform a circular movement around the center of a plane while the third axis moves perpendicular (axially) to the circle's plane the equivalent of one pitch in a 360Â° circle. For the most part this is achieved by using standard G-code commands."

"When asked what we do," says Advent's Ross Wegryn-Jones, "my standard answer-my 'pitch,' if you will-is that at root we are a formmilling company that specializes in thread forms. Thread forms are predefined ANSI and ISO standards. We duplicate that form and put it on the shelf, ready to go. If someone orders a 3-mm pitch thread mill, we have it. We have a good milling platform that is a very good ground tool body and insert-locking and locating system."

Thread mills are selected based on the application, considering the number of parts or holes that are being produced. In the case of larger lot sizes, cycle time may be an issue along ith tooling cost. This is where a single or multiple-flute replaceable insert thread mill would be the best choice.

The main advantage of an indexable thread mill is the ability to change out inserts quickly and inexpensively while utilizing the benefits of increased wear resistance and tool life inherent in carbide. In the case of smaller holes, where replaceable indexable tooling is not available, solid carbide or carbidetipped tooling should be considered.

For selecting the right thread mill, Advent advises having ready access to the following application parameters:

* Major and minor diam of the thread to be milled

* Length of the thread form

* Pitch (number of threads per mm or inch)

* Material to be thread milled and its inherent machining properties

* Relative quality of fixturing and rigidity of machining center

* Amount of tool extension; the shorter, the better

"Due to the cutting action of a thread mill, the forces acting on the tool and the workpiece differ greatly from those that occur with traditional tapping. The more rigidly the part is fastened to the fixture, the faster you can thread mill. The speeds and feeds are maximized when vibration of the part and fixtures is minimized," says Wegryn-Jones.

"There's a lot of interest in thread milling among customers and engineers as well as a lot of intimidation about it, but once they have seen it in action and try it, they love it," says

Don Halas of seco Tools Inc. (Warren, MI). "Thread milling works in many key areas, especially in hightemperature alloys like Inconel, Waspaloy, stainless steel, and titanium, where taps are more likely to break. Another common application is tapered NPT threads for pipe where you eliminate the need for taper reaming prior to tapping, getting rid of an entire step."

Halas points to the quality of thread produced by thread milling. "Thread milling produces a superior thread because thread milling is free cutting. Chips are very small and recutting chips as in tapping is not a problem. Thread milling can be done with the lightest duty machine in the shop, as long as it has helical interpolation," he adds.

"A rule of thumb for cycle times in typical material is that in 1/2'' [12.7-mm] diam holes and smaller, tapping is quicker. In larger diam holes, thread milling is quicker," says Halas.

"Although you also need to consider that if a tap breaks and you scrap the part, this can still blow your cycle time."

The consequences of breaking a tap when threading a small hole in high-temperature alloys, however, is far more serious. "In this instance, it'll take time to get that broken tap out, because these are intrinsically expensive parts that cannot be readily scrapped," says Halas. "So, with high-temp alloys, you should really look at thread milling as a first machining choice."

Halas says: "One of the primary applications for thread milling is aerospace, but we are starting to see it across the board, including big-valve manufacturing where you have 3 or 4" (76 or 102-mm) type pipe or couplings. It's both more cost-effective and easier to thread mill in these types of operations. You can rely upon one thread mill with different thread pitches to handle the various applications. Another common area for thread milling is on automotive engine blocks-both in cast iron and aluminum-where they are getting away from tapping on transfer lines and moving toward machining centers to thread mill," says Halas.

Software has taken a lot of the mystery out of the thread-milling process and made it more user friendly. seco Tools has developed its Thread Milling

Wizard software to simplify programming for users of its indexable thread mills and solid carbide thread mills.

The Thread Milling Wizard requires only that the operator enter the type of thread, diam, depth, and material group. The software generates the machine code, reducing setup time and creating the required thread from the first cut. The correct cutter body is chosen and all cutting data are downloadable to the CMC.

Jim Lorincz

Senior Editor

Drill and bore with a face mill

Chris Koepfer

Making holes in metal is probably the most common operation in any machine shop. Specialized drilling and boring tools do a fine job making accurate holes.

Increasingly though, shops are successfully using interpolated milling cutters to drill and bore blind and through-holes. Usually this operation is performed with end mills.

Because of the improvements in machine tool design, CNC and servo response, and especially in the design and manufacture of freer-cutting tool geometries, some face mills are now capable of pulling double-duty. They can handle linear milling of planar surfaces and helical milling of holes.

To find out when and why a shop might consider interpolation of a face milling cutter over traditional end mills, drills and boring tools to cut holes, we talked to Jeff Fox, training and applications manager for Widia North America, a cutting tool maker; and Jim Turner, senior application engineer at Widia's parent, Cincinnati Milacron. They are using circular and helical interpolation of face milling cutters to produce holes that are close to boring bar quality in roundness, size and finish.

What Is Interpolation?

Interpolation of machine tools, which is the movement of multiple axes at the same time, has been around for a while. On most CNC machine tools, interpolation is transparent to the machine operator and programmer.

An interpolator - actually a small computer within the CNC - does the complex mathematical calculations based on a few descriptive inputs. Once the interpolator knows how big and how deep to make a circle, the operator doesn't have to think about it.

Circular interpolation involves simultaneous motion of two of the three axes on a standard three-axis machining center. The cutting tool is fed to a programmed depth of cut, often by plunging. Interpolation is then performed by combination moves in the X and Y axes.

Helical interpolation employs all three axes simultaneously. As the X and Y axes interpolate a circle, the Z axis is fed down in a spiral motion until it reaches the programmed depth.

Why Not Drill, Bore And Ream?

In general, there are two methods of generating a hole: milling and drilling. To clarify our terms, let's agree that milling a circle involves a cutter rotating on its own axis in conjunction with an orbiting workpiece motion.

Drilling uses a fixed diameter tool, rotating on its own axis, and plunging uni-directionally (Z-axis feed) into a stationary workpiece. Making a very accurate hole - meaning good size, roundness, depth and finish - has traditionally been at least a two-step process and sometimes has required several more steps.

First, the hole is drilled. Sometimes, when drilling from a solid, a pilot drill is used to make a place for the drill to start. As a drill advances through a workpiece, it encounters vagaries in the material. These can be material inconsistencies such as inclusions or hard spots. The drill will tend to deflect or wander off course slightly when encountering one of these "bumps in the road." In some applications, "a drill can wander as much as 0.008 to 0.015 inch," says Mr. Fox.

To straighten the wandering drill path, a boring bar is used. It can be set to the exact diameter initially or gradually brought to size with incremental passes. After employing a boring bar, hole size should be at spec. To meet very tight surface finish specs, a reaming tool is used to smooth the bore and bring size to finish diameter.

Proponents of interpolation use the process to eliminate some of the steps in hole drilling. For shops faced with increasingly demanding production and shipping schedules, knocking off a few steps in the production process, especially in a pervasive operation such as drilling, can have significant impact on throughput and profitability.

"Trying to simplify the manufacturing process is a key driver behind using interpolation of a face milling cutter," says Mr. Fox. "If you can eliminate a pilot drilling sequence, or a boring sequence, or drill several different size holes with one cutter, you've saved cutting time. That's good. Moreover though, you've eliminated the attendant non-cutting time [such as tool change, tool setting and balance, loading and transport] for those other tools."

What Does It Take?

"The key to using interpolation is smooth transition around the workpiece without having to do position updates every half-degree and leave marks on the work," says Mr. Fox. "Today, much of that is done in software. Most newer CNC machine tools are capable of running an interpolation macro. Differences between controls generally play out in how fast the X and Y axes can create an orbit."

One software technique used to perform circular interpolation is called looping. Basically a software macro does the math that results in a tool orbit of a programmed diameter.

Feed in the Z axis is set incrementally. In each orbit, the tool notches down in the Z axis by a prescribed amount. The interpolation, or combination X-axis and Y-axis moves, is "looped."

"We run the same circle over and over and move down in Z axis one increment for each orbit, until the milling cutter reaches programmed depth," says Mr. Fox. "This gives us the smooth orbit, without pause, needed to drill and bore using a face milling cutter."

Using this incremental Z-axis feed significantly reduces the amount of data blocks needed to execute a programmed interpolation. According to Mr. Turner, "if I have a counterbore that is to be two inches deep, I start at one point and tell the control to make a circle and return to my start point. I then tell the control to move two inches in the Z axis from where I'm starting. However, if my insert is capable of a quarter-inch depth of cut, I need to tell the control for each circular revolution or orbit to change my depth of cut by a quarter inch.

Eight revolutions are needed to make the hole, but those eight revolutions are made from a single block of code."

The calculations needed to divide the two-inch depth of cut command to accommodate the quarter-inch feed requirement are in the interpolation macro. The macro "does the math" needed to get the cutter to the programmed depth - using a single go-to command.

"It used to be that if you had a machine capable of helical interpolation, you had to program eight orbits of the cutter with a quarter-inch depth of cut change for each pass," says Mr. Turner. "That was eight blocks of code in order to make one circle. It's much easier to program milled holes today with the interpolation macros built into the CNC. The same hole that used to need eight blocks of code now needs only one."

In addition to software, good hardware is needed for interpolating holes. A machine tool with a very true spindle and a good set of ballscrews is also important for interpolation because of axis reversals that occur in the X and Z axes when a circle is generated.

Face Mill And Drill

Metalcutting shops are continuously searching for ways to consolidate operations. Five-sided fixturing, gang tooling, turn-mill and mill-turn, are examples of ways to reduce multiple handling of workpieces.

Shops are also demanding that cutting tool makers try to find ways that allow more operations to be performed by a given cutter. Widia and several other cutting tool manufacturers have developed single cutting tools, with insert geometry and chip breakers, that can perform with one tool what once took multiple tools.

"Until recently," says Mr. Turner, "there simply wasn't a single tool available with the chipbreaker geometry that could effectively pull double-duty performing both face mill and end mill work. These new cutters enable us to use one tool for plunging and the same tool for sidecutting." Depending on the insert shape, chamfering can also be done with the same insert.

The advantage of one tool doing the work of three is obvious for shops strapped for tool pockets in their machining centers. It's also advantageous to use one tool for a range of hole sizes. Milacron has successfully processed workpieces requiring face milling, chamfering, the rough and finish boring of six- and eight-inch holes, all with just one cutter.

What's Happening In The Cut?

Once the rpm is established in the conventional drilling operation, the Z-axis feed rate is the primary variable that needs to be considered. Interpolation on the other hand is a more complex set of variables.

There are, for example, two feed rates that need to be understood. "Feed rate one," says Mr. Fox, "is how deep, in Z-axis, the tool is fed per revolution or orbit of the hole. Feed rate two is how fast the cutter is moving through the material in the X/Y plane."

What's making it possible to use a face mill for plunge and side cutting is insert geometry that is designed as positive axially and positive radially. What's not obvious to the observer of an interpolated milling cut hole is that most of the cutting is done on the face. Chip loads on the side are relatively low.

Mr. Turner says he could use an end mill, drop down to a Z value, run around the circle and repeat that until he gets to depth, which is the conventional hole milling technique. Using the face mill, the depth of feed cannot exceed the height of the insert, and therefore, most of the cutting is done on the face of the cutter. Moreover, metal removal is higher because of the size of the cutter and the number of teeth.

The size of a face mill is also an advantage. Using a cutter close to the size of the hole diameter reduces the size of orbit needed to get around the hole circumference, which also reduces side loading.

"Instead of using a two-inch end mill to go in and cut a six-and-a-half-inch diameter hole such as in a pocketing routine," says Mr. Turner, "we can plunge in with a six-inch cutter. We made a six-and-a-half-inch hole but side cut only a half-inch circle.

"You wouldn't do that cut with a six-inch end mill," Mr. Turner continues. "We're trying to use tools that would be in the chain for other operations and extend their usefulness to drilling, which is why the face mill works."

Cored Holes And Solids

Ideally, milling interpolation for drilling and boring holes is best applied in holes above six inches. "It's still more economical to cut with a drill and boring bar below that," says Mr. Fox.

When interpolating a face milling cutter for large holes cut from solid, it may be advantageous to use a drill as a pilot hole. "Chip evacuation is the main reason for drilling a pilot," says Mr. Turner. "These milling cutters don't have flutes to help auger the chips out of the cut. A drilled hole, using the biggest standard drill in the shop will provide sufficient room for chip relief." It's in cored holes that interpolation with a milling cutter is very efficient. With blind or through-holes, the milling cutter needs only to be a minimum of half the hole diameter to effectively interpolate a hole. At less than half the hole diameter, the orbiting cutter would leave material in the center of the hole.

On the other end of the scale, orbiting a six-inch cutter to make a six-and-a-half-inch hole can be done. That same six-inch mill can then cut an eight-, ten- or twelve-inch hole if needed.

On blind holes, Mr. Turner cautions that chip evacuation can be a concern with a milling cutter that is very close to the hole diameter. High pressure coolant is helpful in evacuating chips as is a horizontal spindle orientation on the machining center. Vertical machining centers benefit from interpolating a face mill for hole making if the hole depth is not too excessive for chip clearance.

How Good Is It?

Drilling and boring with a face mill really extends the usefulness of a single tool. In many operations, milling a surface and then cutting out a large cored bore is ideally suited to interpolation with a face mill.

"In applying this technique," says Mr. Turner, "we were hoping to eliminate rough boring bars. It's still a milling operation, so there will be some milling pattern marks in the bore. If feeds are slowed, a reasonable semi-finish cut quality can be produced with this technique. However, we've found that for tolerances tighter than 0.002 inches and surface finish specs better than about 125 Ra, you'll probably still need to use a finish boring bar for good results."

A bored finish is created by cutting a continuous spiral chip. Many shops require production of this kind of surface to satisfy a boring tolerance spec. Milling makes very small chips and the surface is serrated or cross-hatched. "To get the boring bar look, you need to use a boring bar," says Mr. Turner.

Consider Milling Holes

Few metalworking processes can be eliminated completely. There is always a need to drill and bore holes. What Widia and Milacron are trying to accomplish by using interpolation to drill with a face milling cutter is to reduce some of a shop's tool inventory and its associated costs for purchase and setup.

"In cellular manufacturing, a shop will often try to use redundant tooling to keep running," says Mr. Turner. "Tool pockets can be a premium especially if every workpiece hole needs multiple tools to rough out the bore. One cutter that can do the rough boring work of several tools and face mill is very helpful here."

For high mix, low volume operations, interpolation can save a shop significant direct and indirect machining time. Throughput calls the tune for these businesses. Reducing the need for setting rough boring bars can enable a shop to really shave precious time off increasingly shorter lead times.

"Using milling cutters for drilling and boring means a shop doesn't need to stock a large selection of boring bars," says Mr. Turner. "A job shop can carry a four-, six-and eight-inch face milling cutter that can be used on any job. For a workpiece that has a four-and-a-half-inch bore and another part with a five-inch bore, one boring bar might not have the range for both jobs, while a four-inch face mill could do them both."

Manufacturing today is about choices. Shops have many tools at their disposal to get the job done. Applying a face mill to drilling and boring operations is another opportunity to incrementally increase the efficiency and profitability of machining appropriate workpieces.

For more information about Widia's line of drilling, boring and face milling tools, call them at (888) 872-9434 or fax them at (513) 841-8329.

End mill designed for ramping

Peter Zelinski

In milling, ramping has gradually grown more significant. The speed and precise interpolation of modern CNC machines make it possible for a small tool to mill out a much larger hole or pocket in a relatively short time. Ramping is an important element of doing this. Either the tool ramps from one level of passes to the next within the feature, or else it follows a helical path at a continuous angle all the way down to the feature's depth.

Limitations on the ability to ramp generally result from the tool. Many end mills that are able to ramp were not necessarily designed to emphasize this type of cutting. When the tool is designed with ramping in mind, various features change.

Brian Hoefler, milling product manager with Kennametal (Latrobe, Pennsylvania), offers some elaboration on this. His company's "Mill 1" end mill is an example of a tool designed for ramping and other aspects of milling within r holes and pockets.

The most fundamental design consideration is greater clearance beneath the insert, he says. The clearance lets the tool ramp in at a steeper angle and reach the bottom of the feature sooner, potentially reducing machining time.

Other considerations relate to quality. As the tool removes material from the hole or pocket, it also leaves behind an inner wall. If the tool can leave this wall surface smooth enough, then an extra boring or finish milling operation might be avoided.

The squareness of the insert helps determine the tool's ability to generate this smooth wall. If the insert has a straight side edge, it has to be set in the tool body so that the edge is precisely square with the work. If not, then this cocked insert will leave a line between passes at successive depths.

On the Mill 1 tool, two features address this problem. One is an insert clamping screw oriented at an angle. The screw pulls the insert into the pocket to lock it in place more precisely.

The other feature is a wiper face on the side of the insert that, instead of being straight, is crowned by a slight arc. With this form, the insert doesn't have to be perfectly square in its seating. The crown leaves small scallops between passes that can't be seen, says Mr. Hoefler, and effectively can't be measured.

The angled screw also offers one additional benefit that gets back to cutting time. This screw lets the tool run faster. Because of the angle, part of the centrifugal force resulting from the tool's rotation is directed not against the screw's shear strength, but instead against its tensile strength. The tensile strength is stronger. As a result, the tool can be spun at a faster rpm safely. Its top speed is 30 percent faster than what the tool would permit if the same screw were oriented in the traditional way, says Mr. Hoefler.

Turning two! - twin spindle lathes

Not double plays--double turning capacity from twin-spindles. It's a most efficient way to produce parts of rotation in high volumes and batch quantities, according to the distributor for Hwacheon (pronounced wha-cheon) twin-spindle turning centers--Machinery Techniques (Santa Fe Springs, California).

So what's the deal with two spindles? Well, as shops continuously look for ways to get more production from fewer machines, twin-spindle lathes--especially those with fully independent operation of each spindle--begin to make some sense.

Machines like the Hwacheon are essentially two turning centers that share a common base. The spindle arrangement for the Hwacheon puts the spindles in the back of the machine, side-by-side facing the operator. The tool turrets (one per spindle) are on either side of the spindles and move independently. Each turret has capacity for eight ID and eight OD tools.

An ergonomic advantage of this arrangement is that an operator can tend both spindles from one spot. If two machines are located opposite each other, four spindles are within easy reach of a single operator. It is not necessary to run up-and-down a line from machine-to-machine. Everything is right there--accessible.

Sharing a base makes owning twin-spindles economical because the cost for one of these machines is less than the cost of two single-spindle machines yet, you get virtually the same turning capacity. The twin-spindle configuration from Hwacheon uses significantly less floor space than one, not to mention, two conventional single-spindle machines. A twin-spindle arrangement gives shops production flexibility. While it is true these machines can be set up to run high volumes, and often are, they are also flexible enough to turn smaller batches efficiently. Some variations include, turning two identical workpieces at the same time, which effectively doubles production rates. Or, first and second operations can be run simultaneously, making runs of smaller quantities more efficient. Another way to use the machine's capacity is running two different parts at once, increasing throughput.

Hwacheon makes this machine in 6-, 8-, 10-, and 12-inch chuck capacities. Turning speed is 5,000 rpm and power is from a 30 hp drive motor. Depending on the application, the headstock can be arranged with direct drive for high-speed in aluminum or a geared headstock for higher torque operations in harder materials.

One key to the efficient operation of this machine are two Fanuc OT CNCs, standard on the machine. Housed in a single pendant mounted box they are literally two CNCs in one. Each of the machine's spindles, slides and turrets is independently controlled by a dedicated CNC. Duplicate operator controls are mounted on the front of the machine opposite each spindle.

One drawback to dual-spindle lathes has been their all-or-nothing downtime. If one of the spindles broke down, the whole machine was off-line. Builders like Hwacheon have managed to allay that concern with independent spindle operation. Now, if one spindle goes down, the other can keep producing.

Turning two. One of the most efficient plays in baseball--and, a pretty efficient way to turn workpieces too.

A lathe that doesn't turn the workpiece

Mark Albert

The essence of turning on a lathe is to rotate the workpiece as a rigidly held cutting tool is brought to bear along the length or across the face of the workpiece. One class of lathes, however, holds the workpiece steady as the toolhead rotates around it. Cams or CNC servo units within the head move two or more cutting tools to perform a variety of lathe-type operations. This configuration allows such a machine to produce "turned" parts that would be difficult, more costly or slower to produce any other way.

The concept of holding the stock steady while rotating a toolhead around it was developed more than 50 years ago by a parts maker in Switzerland. Esco, the Swiss company formed to build machines embodying this concept, continues to design and manufacture these unusual lathes as part of its Escomatic line. Although all of these machines follow the Esco turning concept, the line includes standard and customized versions, several of which incorporate units for machining the front end and/or the back end of the part to produce it complete on one machine.

In North America, Tornos Technologies (Brookfield, Connecticut) is now responsible for service, sales and application support of new and existing Escomatic lathes.

One of the most important benefits of rotating the toolhead around the stationary workpiece stock is that it can be fed as bars or coils from 0.02 mm to 12 mm in diameter. Round or profiled material can be used. Large coils of material allow continuous machining for extended periods without downtime. The stock is held in place by feed rollers and a set of guide bushings as material is removed by cutting tools in the rotating wheelhead.

For coiled stock up to 6 mm in diameter, a straightening unit must be used to straighten the incoming material before it is fed into the rollers and guide bushings. A rotating straightener is standard on the Esco machine line. It revolves around the stock, straightening it with a combination of moves as the stock passes through five bushings. The center bushing is adjustable; it cambers the stock as the unit rotates. For material from 6 mm to 9 mm in diameter, a roller straightener is available.

After passing through the straightener, the material is clamped between a set of grooved rollers, which rotate to feed the material into the cutting zone. The grooves can be round for wire or contoured to match profiled stock. By locating the rollers close to the guide bushing, small diameter wire can be machined without bending or whipping.

Depending on the model, the toolhead rotates between 8,000 to 12,000 rpm. The toolholders pivot into the workpiece stock rather than entering directly along the radial axis. The resulting tool stroke follows an arc, helping to compensate for the outward thrust of centrifugal force. The tool stroke is very short, minimizing cycle time. After the machining cycle is complete, a counter collet supports the workpiece for cutoff. Supporting the part produces a flat, clean end with no nib at the center.

Workpieces that lend themselves to production on these machines include automotive parts, connectors, components for watch making, jewelry, parts for lock manufacturing, medical and dental components.

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Henry Stier

Automatic Measuring During Or After Finish Turning On A CNC Lathe

With fully automatic machining, especially in small or medium lots, close part tolerances pose a technical measuring problem. Without an operator it is often desirable to measure the part while it is still in the machine. This process has been done for a long time during grinding operations. Turning poses greater problems. No chips or cutting tools can be in the path of the measuring stylus. The surfaces to be measured have to be totally free of coolant and small particles. This can be achieved by an air blast clearing the location to be measured. The gaging can be executed by one or a multiple of styli in the tool turret. The machine's CNC has to be able to position the measuring stylus, make the measurement and then correct any deviation from the required part dimension with tool compensation. Despite temperature variation and tool wear, the system is adequate in most cases where tolerances of [+ or -] 0.002 inch are allowed.

The system can be used to measure outer diameters and bores as well as groove width, depth and distances between two faces. No gaging fixtures or masters are necessary for this system. It is mostly applied for the production of bigger parts in small quantities. Since the parts stay chucked during the gaging, corrections on oversized portions of the part can be made. A disadvantage is the increase in production time, since the cleaning and measuring adds to the actual cycle time. In-process gaging is valid mainly on bigger parts with higher material costs and longer cycle times.

Post-process gaging is better applied on high-production runs of smaller parts. The gaging station has to be adopted to hold the part. Several dimensions are measured at once. Are the dimensions within the given tolerance zone? If so, no correction is signaled to the CNC system. Is the measured value above the warning zone? A correction is then made through the CNC to the next part. All measured dimensions can be statistically held for an evaluation of the process capability of the machine. With this system a high quality standard of the output can be achieved. With post-process gaging a higher productivity is achieved since the gaging is not part of the machining cycle.

The average extra cost for automatic quality surveillance is approximately ten percent of the total production cost. A reduction in defects, rework and less customer complaints more than makes up for this added cost. In the future both in-process and post-process gaging will become necessary to stay competitive in the marketplace to satisfy the quality requirement of customers who expect more from their suppliers.

Henry Stier

Considerations For Unattended Turning

There is a trend toward unattended machining, and turning presents its own special situations that should be accounted for in the early planning stage.

In any turning operation, one of the main problems is chip formation. If not broken up, long stringy chips can damage either the part or machine. Thus, some method of assuring proper chip formation is essential. Proved chipbreaker inserts or high pressure fluid methods are two chip control techniques currently employed.

Another problem is the possibility of a tool breaking and going undetected to damage either the workpiece and/or the machine. For this reason, a broken tool detector or limiting tool life to a satisfactory risk level and incorporating backup tooling should be considered at the planning stage. When switching tools, it is necessary to either have preset tooling within acceptable tolerance levels or a method of automatically picking up the appropriate tool offset so the machine control unit can make the proper compensation. Another possibility is having an automatic gaging cycle of the first part after tool change and a compensating feedback to the machine control. If this is done, some provision must be made for setting aside the out-of-tolerance part.

Most turned parts have a relatively short machining cycle. If this is the case, an unmanned operation during lunch breaks or other extended times requires a sufficient holding capacity for both blanks and finished parts. When changing from one part to another, even within a family, there is often a need for considerable flexibility in both the chucking and handling system. Thus handling, gaging, transport, and storage facilities become important considerations when planning a successful unattended turning operation. Attempting to rig satisfactory solutions after installation can lead to both frustration and a poor performance level.

Several options are available for automatic loading and unloading turning equipment. Stand-alone robots are one, but usually the fastest and most satisfactory approach is a dedicated robot arm as part of the machine itself. Depending on part size and weight, loading and unloading times of four to twelve seconds are quite common with this latter approach.

The particular storage racks or magazines for blanks and finished parts will determine the size and form of workpieces that can be handled by a particular CNC unattended lathe operation.

Usually two completely different systems are necessary for chucking and shaft work. The capacity of such a storage and handling system must be relatively large for long periods of unattended operation. A universal arrangement to cover a greater range of part sizes and shapes will usually require more floor space.

The 100 percent quality level of parts produced without operator standby usually can be assured only by automatic 100 percent gaging of the parts. If coupled with a printout, it can be a powerful productivity and quality assurance tool for increasing all aspects of your production operations.

There definitely is a trend toward more automatic and unattended machining. But turning presents its own set of unique situations that are usually quite different from those of machining centers. Thus, they should be approached individually to arrive at productive installations.

Turning Turned

Leo Rakowski

Imagine taking a CNC horizontal chucker lathe and standing it on end, spindle end up. Several lathe builders have done essentially that. They call the configuration an inverted vertical turning machine or an inverted-spindle vertical lathe, and they expect it to challenge the horizontal chucker in a substantial number of small-, medium- and large-batch automation applications.

The drawing shows most of the features of an inverted-spindle lathe. First, there's the inverted spindle, which moves in both the X and Z axes. The lathe is equipped with a multiple-part conveyor system outside the machining area that delivers discrete blanks or near-net-shape parts to a pick-up station. And here's the revolutionary feature: the lathe spindle travels in X from the machining area to the pick-up station, picks up the blank, takes it back to the machining area and presents it to a fixed tool turret for machining.

When the machining is completed, the spindle returns the finished part to the pick-up station, the conveyor advances to move the next blank to the pick-up station, and the cycle repeats.

The process continues until all of the blanks on the conveyor have been machined.

The operator's role is reduced to loading blanks on the conveyor and removing finished parts. Movement of the parts in and out of the machining area, and of course the machining, occur behind closed doors. In fact, the only time the doors to the machining area need to be opened is during setup changes.

The genius of the inverted spindle lathe is that the spindle doubles as the workpiece loader/unloader. With its parts conveyor, the inverted spindle lathe functions as a largely unmanned turning cell, without the need for the robot or gantry loader essential to the horizontal chucker turning cell. The user avoids not only the cost of a separate loader but also the space requirement; three or four inverted spindle lathes can be accommodated in the space typically required for two conventional turning cells.

Compact machine design makes for short travel distances, which make for fast cycle times. One builder boasts a part-to-part time (from end of machining on one part to start of machining on the next part) of 4.5 to 6.5 seconds. During that interval, the machine spindle comes to a stop after machining the first part and returns the machined part to the pick-up station, the conveyor indexes to the next blank, the spindle picks up the blank and takes it to the machining area, and machining resumes.

A Machine For Every Need

Whether you're a small job shop or a large manufacturer, there's an inverted spindle lathe ideally suited to your needs. The Hardinge-Emag VL3 inverted-spindle vertical CNC lathe is built in Germany by Hardinge-Emag GmbH, a joint venture between Emag Maschinenfabrik and Hardinge Inc. (Elmira, New York). The VL has a 21-hp spindle drive that delivers spindle speeds up to 7,500 rpm. It has a 12-station VDI 40 turret with bi-directional indexing. Live tooling at all stations is optional. Traverse rates are 2,362 ipm and 1,181 ipm in X and Z respectively.

The VL's integral, circular, parts conveyor can accommodate 20 parts up to 3.1 inches in diameter or 14 parts up to 5.1 inches. Blanks are placed in positioning guides on the conveyor (and machined parts are removed) at the front of the machine. The operator punches the diameter of the parts being run into the control, and the control automatically advances or retards the positions of the guides on the conveyor to center the parts at the precise position for capture by the spindle at the pick-up station.

Parts travel on the conveyor to the pick-up station located behind the machining area. The pick-up station has a floating base that can tilt in any direction; if the part arrives at the station slightly skewed, the floating base tilts in response, to the downward pressure of the chuck jaws so that the part squares up. (See drawing.) If for some reason--a wrong part, an inverted part and so on--the part fails to load properly, the base tilts the part away from the chuck to avoid a crash. The spindle retracts to a position predetermined by the program, and the conveyor advances to the next station, continuing the cycle.

The S-series of inverted vertical turning cells offered by Hitachi Seiki U.S.A., Inc. (Itasca, Illinois) gives the buyer a large selection of lathe sizes. Models range from the CS15, a two-axis machine with a 10-hp, 6,000-rpm spindle, a 12-station turret (live tooling optional) and an integral, rotary part-indexing table that can accommodate eight parts up to 4 inches in diameter, to the CS40, a two-axis machine with a 50-hp, 2,000-rpm spindle, a 12-station tool turret (live tooling optional) and a variety of part conveyor packages that will handle parts up to 24.4 inches in diameter.

The line's CS20Y model offers Y- and C-axis motions in addition to X and Z. Its 12-station VDI turret provides ample rotating-tool power (5 hp) and speed (3,000 rpm), making the machine useful for turned parts requiring extensive milling and drilling operations.

The CS20Y is available with several parts feeder options. They range from a small-batch, economy-type, integral, indexing turntable capable of holding eight parts up to 6 inches in diameter, to an in-line conveyor with 14, 20 or 26 stations capable of holding parts up to 8 inches in diameter by 6 inches long and weighing 44 pounds. The parts feeder is enclosed in a housing at the side of the machine. The spindle zips to the right to pick up a blank from the conveyor's loading station and then zips back to present the blank to the tool turret.

Although we've looked at one-machine/one-feeder combinations thus far, it should be obvious that the spindle-loading feature of the inverted-spindle vertical CNC lathe readily accommodates multiple-machine installations for high-volume production. The fast-cycle-time machines can be joined with simple part conveyors to create flexible transfer lines that can be easily relocated or reconfigured depending on production requirements.

One of the most impressive features of the inverted-spindle vertical CNC lathe is its adaptability to most machining requirements. For example, if you are more interested in machining the part complete on one machine rather than moving the part from machine to machine, you'll appreciateHitachiSeiki's CS25W twin-inverted-spindle turning cell. The machineincorporates two inverted spindles on a common frame. The first spindle removes a blank from the pick-up station of the parts feeder and presents it to its 12-station tool turret for machining of one side. The blank is then turned over within the machine, and the second spindle and turret handle machine the reverse side. Finally, the second spindle places the completely machined part on the exit conveyor, ready for downstream processing.

Need Tooling? No Problem

Flexibility of the inverted-spindle vertical CNC lathe extends to tooling as well. Index Corp. (Shelton, Connecticut) provides a comprehensive offering of standard and optional tooling on its VerticalLine inverted-spindle vertical turning machines intended for demanding turning/milling applications. In addition to the fixed turret standard on most inverted-spindle lathes,

Index offers some interesting options. A tool table mounted behind the spindle provides up to six stations for stationary or live tools. The table also provides a convenient place for mounting equipment for special operations, such as laser welding, heat treating and the like, that may not be mountable on the turret.

The tool table can be installed instead of the machine's standard 14-station turret and equipped with gang-style tooling for turning, boring, reaming and threading operations. It will even accommodate long boring bars, milling spindles ... even multispindle drill heads. Large special attachments such as high-frequency spindles or polygon-generating units can also be installed.

Need still more tools? You can add a second turret to augment the first turret and tool table. Index explains that requirements for specialty tools for producing a fine finish, engraving, knurling and so forth can quickly exceed the number of tooling stations available. The second turret provides the capacity needed for the most tool-demanding parts. There's another benefit: the spindle can present the workpiece to one turret while the other turret is indexing for additional cycle time reduction.

Adding Up The Advantages

Mark Leeser, vice president-general manager for Hitachi Seiki, explains why he thinks the inverted-spindle vertical CNC lathe will eventually capture a significant share of the CNC chucker market: "The inverted-spindle machine has a very small footprint for its chuck size and work envelope," he begins. "As a result, three or four machines will fit in space required for two horizontal chuckers equipped with robots or gantry loaders. That's important for firms that need to increase capacity within existing plant space. It's a more-parts-per-square-foot consideration.

"The inverted-spindle machine makes it easier for a shop to install an automated turning cell by eliminating the need for a robot or a gantry loader," he continues. "Not only does the shop save the initial cost of the robot, but it also avoids having to program the robot, design and make grippers for the robot, and so forth. And once the automated cell is in place, it will deliver a significant increase in productivity. The operator of a horizontal CNC chucker takes a break, goes to lunch, gets tired, comes in late, doesn't come in at all ... parts don't get made and jobs fall behind schedule. By contrast, the inverted-spindle lathe is completely automated. As long as the feeder is stocked with blanks, the cell will turn out finished parts during breaks, during lunch hours, overnight, during holidays ... the productivity gains can be dramatic.

"Taking everything into consideration, the inverted-spindle machine costs about 30 percent less than a horizontal CNC chucker with a robot, so the shop owner is saving money and floor space and getting that dramatic boost in productivity," Mr. Leeser continues. "We expect that a number of firms are going to discover the advantages of these inverted-spindle machines and that, down the road, they will account for about 20 percent of the market." Mr. Leeser adds that the machines have been in use in Europe for several years, and that approximately 80 percent of the machines are used by larger firms such as first- and second-tier suppliers to the automotive industry, and the rest are used by smaller job shops. He expects to see the same usage pattern in the United States. He stresses that the inverted-spindle CNC chucker can be used advantageously to produce part quantities ranging from 50 to 10,000 pieces.

"Labor savings is another important advantage," adds Brian Ferguson, product manager for Hardinge's VL inverted-spindle vertical lathes. "One operator can easily tend to two or three machines and still have time to perform other tasks. Then, too, finding skilled shop people isn't getting any easier, and machines like our VLs enable the shop owner to make better use of his or her best people."

Is inverted turning a brand new development? "Since the early '90s, inverted-spindle configurations have been used in high-volume, dedicated applications, for example, a transfer line for an automotive part," Mr. Ferguson notes. The real significance of the inverted-spindle machines currently being introduced is that they are standard configurations, and their automation advantages are available today on a machine that anyone can buy."

Precision turning

Aronson, Robert B

You can buy lathes with guaranteed accuracies ranging from a few tenths to a few microns. Some years ago precision depended chiefly on the operator's ability. An experienced man who "knew his machine" could do wonders with a good lathe. Today, accuracy is more dependent on the quality of the precision. The methods of turning a part precisely are well known. The problem is in deciding how much precision you want to pay for.

Conventional lathes have an advantage over milling machines in that only two axes need to be controlled in the cutting operation: Carriage motion (Z axis) and cross feed (X axis). Conventional lathes routinely offer accuracies of a tenth or a tenth and a half--0.0001-0.00015" (0.003-0.004 mm) at stable temperature conditions.

Horizontal and vertical lathes have about the same accuracy, as long as the parts are about the same length. Horizontals begin to lose accuracy on long shafts due to droop.

Higher precision lathes operated to different standards. Dan Luttrell, technical director for Precitech (Keene, NH), a manufacturer of precision lathes suggests that lathes that can achieve tolerances less than 0.00004" (0.001 mm) be consider precision machines while those that achieve tolerances less than 0.000004" (0.0001 mm) should be considered ultra-precise machines.

WHAT'S ACCURACY?

Machine accuracy involves how well the tool point is positioned anywhere in the envelope, and there are three types to consider. The most common is positioning accuracy which is how precisely the carriage and cross slide put the tool tip where you want it. For about 80% of all turning jobs, an accuracy of 0.0005" (0.013 mm) is acceptable and most machines currently offered can easily achieve this.

Dimensional, or part accuracy, concerns how one dimension relates to another and is a second "accuracy." For example, are two diameters on a shaft concentric? The third accuracy consideration is finish.

While accuracy is the ability to position a tool, repeatability is the ability to positoin that tool consistantl over a given time. One lathe manufacturer cautions that sometimes a repeatability figures doesn't give an accurate picture if they involve only part of the motion envelope. For example, if someone turns 100 parts on a 5" (130-mm) diam shaft to an accuracy of 0.0005" (.013 mm) they are talking repeatability, not accuracy. Resolution refers to the smallest distinguishable dimension the machine's sensing systems can detect and is usually four or more times greater than what the machine can deliver.

While accuracy and repeatability specifications give some idea of what a lathe can do, many buyers want to know what a machine can do with a specific part. According to Monarch Machine Tool Co. (Sidney, OH) president, Bob Siewert, "Machine accuracy specifications are not that relevant. Buyers want a guarantee that our machine can give them six-sigma quality with their parts. Often we are required to do one set of parts here at the plant and a second set after the machine is installed."

WHERE ARE THE ERRORS?

There are four major error sources. Displacement caused by thermal expansion is by far the greatest source, sometimes as high as 70% of the total error. According to an old saying, "On a machine tool, everything is a thermometer." Mechanical deviation is around 20%--the errors introduced by wear and tolerances of the various machine components. Forces acting on the part, and tool error and wear, combine to make up the rest.

Designers attack thermal errors in two ways: prevention and compensation. The simplest way to eliminate heat is to apply excess coolant or to have chillers in the coolant circulation system maintain temperature. Next are machine enclosures that are temperature-controlled or entire rooms with temperature conditioning.

In a system developed by Dr. Alex Slocum of MIT, channels made of a special damping material are built into the machine's base and cooling fluid flows through them. The system both damps machine motion and carries off heat.

TECHNOLOGY TRANSFER

A number of government research efforts dedicated to improving turning precision has produced ideas that work under laboratory conditions. The next phase is to find out how "machine specific" these solutions are. Can they be incorporated into a general category of machine tools, and will they produce the same results on the shop floor?

The National Institute for Standards and Technology (NIST) has been working on machine-tool accuracy for some time. In one of their more recent programs, their researchers took a commercial piston turning machine and developed a control program that compensated for thermal and mechanical errors. They have given it back to the manufacturer for "real world" trials.

During the tests, the manufacturer will determine the economic feasibility of the design and which features, if any, are transferrable to a commercial product. One of the problems with this project was the length of time taken to develop error compensation models. An effort is now underway to speed up the characterization of a machine tool to develop the computer models. "Currently complete data acquisition and analysis takes at least several days for each error component," says Alkan Donmez, leader in the sensor systems group of NIST's automated manufacturing engineering lab. "This will have to be reduced to a half day or less to be commercially practical."

In a similar NIST-sponsored project conducted at Saginaw Machine Systems, Inc. (Troy, MI) the goal was to find ways of reducing error on a conventional vertical turning center. In carrying out the program, the first step was to characterize the machine's geometry. Then they measured the effect of thermal changes on the mechanical characteristics over an extended period. Jules Myers, R&D manager, explains, "We found that a large part of the thermal error came from the spindle and ballscrews. The two sets of spindle bearings sometimes heat at different rates causing a skewing effect while the ballscrews and spindles all grow in length with temperature rise." The machine analysis ultimately led to a math model which gives compensation values that can be plugged into the X and Z-axis controls for real-time corrections. Explains Myers, "The program is resident in a separate PC which we interface with the CNC because we can't get into the controller's architecture. Our system interrupts the feedback and 'plugs in' the correction signals on the fly. The separate PC takes the sensor input, compares it with its own program positions, and adds or subtracts data to the control's feedback command. In this way we can use any control and not worry about the need for open architecture. With this system, we are able to get close to 25 millionths (0.0006 mm) axis resolution available."

"Our research efforts are already moving on to the next phase by applying what we learned with the first machine to an ARPA-sponsored program with a major automaker," continues Myers. "We currently can take care of 80% of the thermal and geometric error with this system. Later we will look at fixturing and tool loads. For example, we can measure the stiffness of the fixturing systems and workpiece and make that part of the equation. This will only work, however, if the machine is very stiff and exhibits good repeatability."

NIST is also looking at the influence of fixturing and loads. First, researchers will evaluate process-related errors such as those due to tool load and correlate them with the machine's geometric errors. They then check parts turned on the machine to determine the influence of the tool on the dimensions and surface finish. Both these error sources will then be incorporated into a compensation program.

In another NIST project, a charged-couple device (CCD) checks the tool face during cutting and initiates real-time compensation based on face changes.

An outside company is now working to perfect this idea as a marketable instrument.

ULTRA-ACCURATE

The nation's national laboratories, particularly Lawrence Livermore, Los Alamos, and Oak Ridge, have specialized in high-precision turning machines for some time. The work began years ago with attempts to develop high-precision metrology. That technology was later applied to precision turning, particularly turning of material that would be the backing for defense-related systems.

One of the Livermore lathe designs, designated the DTM 3, has a 2-m swing capacity and uses a single-point diamond to create optical components. The second, a vertical axis diamond turning machine with capacity of 1.5 m, built at a cost of $13 million, is billed as the world's most accurate machine tool. It has a volumetric accuracy of 30 nm rms and has turned surfaces with roughness of about 3 nm rms.

There are 14 feedback loops on the machine's two axes with motion measured by laser interferometer operating in a vacuum. Temperature is maintained to a millidegree Fahrenheit. "A major issue is a high-capacity controller with great enough capacity to handle all the inputs and enough bandwidth to work quickly," says Dan Thompson, program leader at the Livermore Lab. Although the applications suitable for these ultraprecise lathes are limited, the technology they utilize may have wide appeal. "With the high-precision machines made by Livermore and the other laboratories, the rational was, 'We need a precise part, so build a machine that will make it possible,'" says Dr. Ken Blaedel, a member of Livermore's machine tool development group. "On the other hand, industry says, 'We are making a line of machines, what level of accuracy do we have to have to sell these machines?' Now the labs with expertise on precision systems are 'backing off' the technology to see what can be practically applied to an industrial situation."

OVER-THE-COUNTER PRECISION

One of the several techniques applied to economically achieve precision by Precitech is the use of glass linear scales to control motion. The scales are holographically generated with a pitch of 20 microinches (0.0005 mm). Signals from these sensors are interpolated electronically so that the resolution is just under 10 nanometeres or half a microinch. In addition, slides run on fluid-film bearings, both air and oil hydrostatic. "The external pressurization gives us good slide geometry plus smooth motion," says technical director Dan Luttrell. "We use air-bearing spindles which have radial and axial errors of two microinches or less. As we move into hard turning, we may be looking at oil hydrostatic rotary bearings."

Many of the company's lathes are used to make optial elements, lens molds, and small mechanical components. Materials typically turned include nonferrous metals, electroless nickel plating, infrarred crystals, and polymers.

"The tools include single crystal diamond and CNB as well as more conventional materials" says Luttrell. "We prefer to have our machines operate in rooms with central air conditioning controlled to 23degC, +/-2deg. The machines can also be provided with a continuous shower of air controlled to 0.1degC."

Bearings, of course, are a major concern in precision turning. Rank Pneumo, (Keene, NH) another builder of ultra-precision machine tools, also uses air or oil bearing spindles and slides for smooth, accurate motion. "The type and design of bearings selected for each machining system we build relates directly to the stiffness requirements for the applications," says Allen Lake, company sales engineer.

System resolution is also important. The company's Nanoform 600 two-axis CNC lathe utilizes a 1.25 nm (0.00000005") resolution, closed-loop laser feedback system on both slides. A thermal compensation system detects and compensates for thermal drift.

Hardinge Brothers Inc. (Elmira, NY) makes two lines of lathes: "precision" and "Super-Precision." With the precision version the spindle has a runout of 30 millionths (0.00076 mm) TIR.

For the Super-Precision version, it's 15 millionths (0.00038).

"We do not make laboratory lathes. They are 10 to 35 hp (7.5-26.1 kW) machines that operate every day and can routinely hold an 8 micron finish," says Robert Agan, company president and CEO, "We make most of the major parts ourselves including the base and spindle. Although we analyze new technologies available to increase accuracy, we don't touch them unless they are cost effective."

The machines have Harcrete polymer composite bases. This is an artificial granite that has a very low coefficient of expansion and low conductivity. In their most precise designs, they offer a surface finish of 8-10 microns using conventional tools. With a single-crystal diamond tool, the finish is 2-3 microns along with a continuous machining accuracy of 0.0002" (0.005 mm) on roundness.

Their designs both isolate heat sources and provide thermal compensation. A mechanical system on the Super-Precision machines measures the thermal migration of the headstock relative to the turret. The operator then introduces an "M" code which causes a positioning compensation. To prevent the compensation motion from disturbing the finish, the command is usually given just before the finishing cut.

Traub-Hermle (Menomonee Falls, WI) also has a temperature compensation system, "We can meet six-sigma specifications with our machines. Our thermal compensation system checks temperatures in the area of the spindle and compensates with offsets. We also use linear guideways which give us much better accuracy than box or dovetail designs," says company president, Harold Welge.

In reviewing the elements that determine accuracy of their lathes, according to Monarch's operations director, Kass Reda, "We use rolling element guideways to eliminate stick slip, as well as cut the need for drive power. The bed is cast iron because welded sections sometimes creep. To monitor slide motion we use optical glass scales with a one micron resolution.

Ballscrew accuracy is not a major issue. Many of those available are of high quality, so they are not a major source of error, plus encoders take the ballscrews out of the loop. Our spindle bearings are ball in front and roller in the rear to take the load of the drive chain.

CUTTING TOOLS

Tool technology continues to lead that of machine tools in some applications. New variations of tool material, size, and geometry are being introduced at regular intervals. One example is the Jet Cut insert from Iscar Metals, Inc. (Mansfield, TX) which allows coolant flow though the insert at the cutting face for improved accuracy. The system can tap into the machine tool's coolant system and provide flow at 30 psi (0.2 MPa) or have a separate high-pressure supply at 1500 psi (10.2 MPA) or more. With this type of lubrication, fluid is between the cutting face and part. It penetrates the heat barrier and gets to the workpiece where it will do the most good. According to Ken Johnson, product manager for Iscar, "Through-tool-cooling increases tool life at least twice. The cooling helps maintain the cutting edge and because there is a more uniform face, the cut is more accurate. Repeatability is also improved with more parts per offset. Because heat is generated in a smaller area, the metal breaks with fewer curls and chips are more manageable."

Most machine tool manufacturers are looking at high-pressure coolant. Some systems report operating pressures of 55,000 psi. At these pressures, containment is a consideration. In addition, the fluid must be carefully filtered so sludge does not block the insert hole.

According to John Israelsson, product manager for turning, Sandvik Coromant Co. (Fairlawn, NJ), modular turning is another way to reduce tool-induced errors. "It offers more precision because you set the tool against a reference before you put it in the lathe. This presetting offers repeatability of 80 millionths (0.002 mm) and precision to one tenth, while a conventional insert will give you a few thousandths," he explains.

Matching the tool to the material is also as major factor in controlling accuracy. "For example carbides work at 45 R sup c , and for them you need CBN and ceramic tools, " says Israelsson.

ULTIMATE CUTTER

In ultraprecise turning, the single-crystal diamond is the optimum cutting tool for high-precision turning of nonferrous material. It's hard and has a smooth face that introduces no scratches to the surface being cut. The tool is made from a natural diamond that is precisely shaped so that the diamond presents the best cutting surface. Some of the natural diamond's market has been taken by lower cost polycrystalline diamonds, but these materials are bonded, with a lot of small stones held together with a binder, so the tool face is not as smooth as a real diamond's.

It's a paradox that most of the pioneering work on diamond turning was done in our national laboratories for various defense programs. Now, a major commercial use of diamond a turning is heads for VCRs, which is done almost exclusively by the Japanese.

PRECISION BEHIND THE PRECISION

Accuracy of any machine tool depends on the attention given the manufacture of individual components. When Russell T. Gilman decided to make a major commitment to high-quality spindles, they built a 13,500 ft sup 2 temperature-controlled addition. Spindle components are manufactured in this area which has a cleanliness equivalent to a class 100,000 clean room. Within this area is a separate certified class 10,000 clean room where spindle assembly takes place. Temperature is controlled to +/-2degF (1.1degC). Equipment includes precision turning, grinding, and boring equipment. A key machine is the Swiss-made SIP AFZ (Elmsford, NY) precision vertical coordinate boring and milling machine which has a spindle that can develop 10-15 hp (7.5-11 kW) and speeds to 6000 rpm. Axis speed ranges from 0.004 to 400 ipm (0.1-10,000 mm/min). Resolution of the measuring system is 0.00001" (0.00025 mm) and positioning accuracy over the entire travel of the three axes is 0.00006".

As a result, according to Lothar Kinscher vice president of manufacturing, "Our spindles, which were formerly offered with a runout of 0.0002 to 0.0003" [0.005-0.008 mm], are now routinely made to a runout of 0.0001" [0.003 mm]. Where customer specifications require, we can also produce a surface finish of 25 microinches."

INFORMATION SOURCES

SME has many opportunities to broaden your understanding of turning. The most basic resource is the Tool and Manufacturing Engineers Handbook series, particularly vol. I, Machining.

Consider also a new video course, "Turning Center Programming and Operations" which is concerned with CNC turning centers. Call Customer Service at 1-800-733-4SME, 8 am-8 pm Eastern time, Monday through Friday.

Talking turning technology

Chalmers, Raymond E

Customers demand reliability, productivity, and value. Here's how companies are responding.

Aside from the hammer and anvil, probably the most fundamental metalworking tool is the turning lathe. Turning machines are among the earliest known metalworking technologies, (the patent for the Wilkinson screw-cutting lathe with slide rest was issued in 1798). Turning and the products it produces shaped the infancy and growth of entire manufacturing industries, including automotive and aerospace.

The reason the lathe survives and thrives is that it's also among the most versatile of machine tools. Add machine rigidity, precision accuracy via computer-- numerical control (CNC), and 21st Century tooling advances, and

CNC turning shapes the outer and inner diameters of countless products with precision, as well as providing such additional operations as threading, profiling, boring, honing, and polishing, to name but a few.

It's important to recognize there's a range of turning users as well. At one end are companies requiring high-volume, high-precision, high-speed automated turning centers, often incorporating multiple operations governed by leading-edge software and control technology, for dedicated, high-output operation. Making up most of the field, though, are smaller manufacturing operations of less than 500 employees producing on a make-to-order basis.

"Traditionally, we've been involved with the job shop/contract manufacturer customer of all sizes," says Dave Hayes, product manager/CNC turning for Haas Automation (Oxnard, CA). "The major concerns are reliability, service, maximizing productivity, and reducing setup times."

"We run the gamut of manufacturing companies we supply," says Dan Soroka, vice president of engineering at Hardinge Inc. (Elmira, NY). "We manufacture high-precision machines, conventional turning machines, complex multi-axis machines, Swiss-type lathes, and manual equipment. The areas of interest we hear about most from customers are speed (spindle, live tooling, and turret indexing), accuracy, and untended operation."

Haas is a relatively young company among machine tool manufacturers, incorporated in 1983 and supplying CNC lathes since 1994. In 1983, Haas entered the machine tool industry with the SC collet indexer, the first-ever, fully automatic, programmable collet indexer, a device used to position parts for machining with very high accuracy. Today, Haas manufactures four major product lines: vertical machining centers (VMCs), horizontal machining centers (HMCs), CNC lathes, and rotary tables, as well as a number of large five-axis and specialty machines.

Hardinge, on the other hand, was founded over 100 years ago, and is also a leading machine tool manufacturer. The company designs, manufactures and sells CNC metalcutting lathes, machining centers, and related tooling, as well as a wide range of collets, chucks, and other workholding products.

Productivity issues such as high-speed turning differ among various manufacturing customers. "We've had 7000-rpm capabilities for a few years now, and have sold maybe a dozen," says Hayes. "Total speed is not as important as time to maximum speed. We resolve this issue with horsepower rather than using integrated motor spindles as some manufacturers do. Although such integrated motor spindles provide a speed gain, they're fairly exotic and can cause significant downtime if there are any problems. Providing more horsepower as we do on a 5000-rpm option with 30 hp gets users to maximum speed faster."

Hardinge, for its part, sees a direct relationship between advancing spindle speed and improving machine throughput. "In the next five to 10 years, we can see supplying spindle speeds three times faster than today on conventional products, and maybe five times faster on niche machines," says Soroka.

Advancing speeds usually means thoughts of automating the turning process, whether by automatic loading and unloading or by integrating multiple operations in a single setup. "We surveyed our customers, asking them if they want to drop a part complete out of a machine or use secondary operations," Soroka explains. "It depends on the philosophy of the shop owner. Automation or combination machines can be a heavy investment, and it's not a generic solution. There is room for growth for highly automated combo machines, but that growth will be limited due to cost and cycle-time issues. So much depends on the nature of the application. And as tolerances get more restrictive, parts are subject to damage in handling," he adds. "Resolving this problem requires more than the conventional part--catching basket."

Scott Easley, project manager at South Bend Lathe Corp. (South Bend, IN) brings up another issue: safety. "In our view, automatically loading parts or removing them from a machine is most favorable for high-speed operations, but this is motivated more by safety concerns, with the efficiency being an added benefit," he asserts. "When things are happening very fast, it is important to keep the operator out of the way. This factor will be even more important in years to come as things go faster."

On the controls side, Haas develops its own CNC system inhouse, everything from building its own servo amplifiers and servo drives to writing control software. "It's an advantage," Hayes says, "because setup can be simpler, we can provide custom displays, the control system is the same among our milling and turning equipment, and the learning curve is shorter."

Other suppliers embrace the non-proprietary type of machine controls, most often based on the personal computer (PC) platform. "We foresee a greater role for open machine control architecture in the design of turning machines," says Scott Easley. "The need to fine-tune the process, even in a standard machine tool like ours, facilitates using these types of controls. Furthermore, the need to accommodate a workforce that is not as traditionally trained in programming skills means the controls of the future will have to do more."

More sophisticated controls also will include more sophisticated process monitoring, where the machine monitors tooling and workpiece conditions online, and communicates that information constantly to the machine, he adds. Hard guarding and other safety systems will be integrated with electronic monitoring as well.

For example, the PC-based programming system on South Bend Lathe's Magneturn 1220 slant-bed CNC lathe can switch between conventional EIA/ISO G-- codes and conversational, menudriven formats. In setup mode, the operator enters safe zones and test modes to ensure machine/part protection.

"Manufacturing is getting more specialized, not less, and customers want a control that fits exactly with what they are doing," Easley says. "The PC platform lets you tailor things more easily, adding a robot for example. Extracting part information and generating resource reports is easier, too."

But the question of what constitues an open architecture depends as much on how a shop operates as on what machine builders or software companies supply. As with personal computer users, there are customers who want to plug in a machine and get to work, and there are others who want to customize their equipment with special cards and the like. As mentioned, Haas supplies its own servos, amplifiers, and control software in-house. "We've debated this for a couple of years and have come back to why supplying our own control is a highlight for us," says Dave Hayes. "Sure there are standards for PCs, but the last thing you want to do with a machine tool control is get in there and tear it up, adding or pulling out boards. There's nothing really forcing us to open-architecture controls, in fact it's quite the opposite. We hear of crashes and such from customers, and whenever that happens, the solution that gets them back up and running fastest is best."

"With the use of PC front-end controls, remote diagnostics is what people want," adds John Boulas, manager of the controls and software group at Hardinge. "They want to use a PC-based Ethernet network for uploading and downloading parts programs as well as monitoring machines."

Eliminating proprietary backplanes or motion-control cards is likely as open as a machine control gets, where everything is controlled by software alone and runs on off-the-shelf PCs. This is the environment championed by Manufacturing Data Systems Inc. (MDSI, Ann Arbor, MI), and admittedly one met with initial disbelief by manufacturers. "A software CNC with no motion control cards or proprietary hardware? I didn't believe it, not for a second," says Kevin Smith, process engineering manager at Dana Clark-Hurth's Spicer Off-Highway Products Division plant in Statesville, NC.

The software was given a try, though, for retrofitting a 20-year-old J&L two-axis lathe at a nearby Dana plant in Morganton, NC. According to Sammy Nguyen, manufacturing manager at Morganton, the original control was obsolete and unreliable. After retrofitting the lathe with OpenCNC, Nguyen reports improved machine capability according to QS9000 reporting requirements. "Uploading and downloading part programs is easier, and the software is easier to edit," he says. "I can go in and upgrade when I want, and change what I need to." "We can literally look into the software and see what the spindles are doing, how fast it's turning, or what the encoders are doing," Smith adds. "There's all kind of things we can tap into."

Want More Information?

New this year, "Turning & Lathe Basics," part of SME's Fundamental Manufacturing Processes series, is now available on an interactive CD-ROM. Users can click on the lessons they want, and receive video clips and narration on their selected subject. A glossary and interactive refresher quiz also are included. For more information, contact Customer Service at 1-800-733-4SME, 8 am-5 pm, Eastern Time, Monday through Friday.

For more on turning-related technology and equipment from the following companies, circle the following numbers on the reader service card.

Gotta love a lathe

Mark Albert

As a metalworking operation, turning is surely one of the most fascinating. The basic concept is so simple: a workpiece is made to rotate as a rigid tool is brought to bear along its length or across its face. The resulting form will be symmetrically shaped about its centerline. It will be wonderfully round.

Some of the oldest machine tools known to historians and archeologists are lathes. For power, many ancient designs used a treadle and bent pole or bow to pull a cord wrapped tightly around the spindle. Early metal cutting lathes produced elaborate bowls, tankards and candlesticks. Lathes were the instruments of craftsmen, their use strictly guarded by guilds.

The development of mechanical devices to hold and move the cutting tool, which occurred only a few hundred years ago, was one of the breakthroughs that ushered in the industrial revolution. Being able to control the longitudinal feed of the tool relative to workpiece rotation allowed lathes to do precise screw cutting. Precisely made screws, in turn, furthered advances in machine tool design and the creation of micrometers and other measuring devices. The lathe was coming into its own as a tool of industry and science.

Yet lathes and turning equipment have always been fun to watch. Perhaps it's the elemental appeal of rotating objects, the spinning motion that children find so engaging in tops and yo-yos. The object rotates yet its apparent shape always looks the same.

Workpieces on a lathe have this paradoxical appearance, too. When a cutting tool moves against this seemingly static workpiece, chips flow out almost magically, as if unwinding a strand of silver or unreeling a deep blue ribbon. The initial pass across a rough casting or piece of bar stock is especially remarkable. The dull surface that precedes the path of the tool gives way to a freshly turned profile so shiny and clean. No other machine tool works a transformation so dramatic and entertaining.

Even today's high-speed, high-powered CNC turning centers, which usually hide this vision behind Lexan dripping with coolant spray, notify us of their power with the machine gun sound of chips ricocheting against the sheet metal guarding.

No matter how you cut it, a lathe cuts with a unique style and grace. It should be everybody's favorite machine tool. Long live the lathe!

Center-Drive Offers A Turning Alternative

Chris Koepfer

All interesting aspect of the metalworking industry is that for a given application there is often more than one way to process the workpiece. We've seen in recent years, for example, the growth of multi-processing machine tools that combine one or more operations on a single machine platform. In many cases, these machines allow a shop to fixture a workpiece blank and perform all of the operations necessary to complete it.

In turning, the imagination has been stretched with the advent of turn/mill, turn/grind, turn/laser and other process combinations. Moreover, the traditional configuration of the VTL (vertical turning lathe) has literally been turned upside down with the popularity of inverted spindle lathes. These innovative machine tools use a carrier-mounted chuck as a combination workholder and part handler.

There is another wrinkle in multi-processing turning center design that hasn't seen much exposure. It is the center-drive lathe concept. Shops with an application for them find the design ideal. But much of the general metalworking industry has not been exposed to the concept.

What differentiates the center-drive lathe configuration from other horizontal turning centers is the placement of the machine's headstock unit in the middle of the turning center bed.

Slides operate on either side of the headstock and carry the X, Z and sometimes Y axes motions. These machines are built with a minimum of one tool carrier on either side of the headstock. For this reason, they are a least a four-axis turning center. However, there are configurations available that can put four tools on a workpiece simultaneously. These machines use up to eight linear axes of linear motion.

Center-drive lathes are specifically designed to process cylindrical workpieces for automotive, truck, marine and related industries. Because the workpiece is gripped in the middle, both ends can be machined simultaneously. This setup promotes production of close tolerance workpieces owning to a single chucking of the blank. With reduced handling, concentricity and geometric relationships between part features are preserved.

For production applications, the ability to bring two, three or four cutting tools to bear simultaneously on the workpiece keeps cycle times to a minimum. Integrated loading and unloading devices are available to automate the machine for higher volume and lightly attended production.

A newly developed line of center-drive lathes was introduced in the United States at IMTS 2000 by German manufacturer WMS Sinsheim. These lathes are imported by Sytec Corporation (Essex, Connecticut). The design of these center-drive lathes accommodates live tooling and up to two programmable tailstocks for outboard support of long workpieces. Called the C-series, these machines have a 20 kW main spindle drive with 6,000 rpm speed capacity.

The machines are modularly designed and can be equipped with two, three or four tool turrets all programmable from the machine's CNC. Two headstocks are available, and capacity is 15.75 inches in diameter with a standard part length of 10 feet and an optional length of 23 feet.

As shops continue to seek ways to reduce or eliminate multiple workpiece handling, the multi-processing capability of the center-drive concept may be worth a look. It's a proven concept, and maybe it's an answer for your shaft work.

Hardly turning it all - hard turning process

Tom Beard

Hard turning may sound like something best left to the specialists. But with a decent lathe and sound methods, many more shops con use this efficient process to bypass that final grinding operation.

Hard turning can't be called a new process, but it is still largely unknown outside the auto industry where it has been well accepted for years. Thus, it is a process ripe for broader application in a host of industries who seek a viable alternative to post-heat-treat grinding. Hard turning offers all the flexibility of conventional CNC turning - quick setup and tool change as well as the capability to generate complex or contoured surfaces. Though hard turning will not easily yield precision grinding tolerances, a good lathe can consistently hold five tenths either side of nominal and deliver a surface finish in the 10 to 15 microinch rms range.

No one suggests that hard turning is a replacement for grinding on all round parts. But turning is proving the more viable process for an increasingly large number of applications, for a number of different reasons. Contrary to what you might expect, hard turning is not necessarily faster than grinding, though that is often the case. But hard turning can be executed on a conventional CNC lathe, which is generally more accessible technology to the average shop as well as being less expensive than the grinder that would be required for comparable work. It also generates less heat than grinding does, which proponents claim makes the hard turning process considerably less inclined to thermally damage the workpiece surface. It doesn't even require coolant.

But hard turning does present its own set of technical challenges. Perhaps most important of these is the proper selection of tooling. Carbide won't last very long up against steel hardened to Rockwell C 50 or above. That forces a switch either to CBN inserts. or to the more commonly applied ceramic materials. For that reason, we spoke to Kyocera Engineered Ceramics, Inc. (Mountain Home, North Carolina) - an experienced developer of tooling for hard turning applications - to get some practical advice on how to go about mastering the process.

And for a user's perspective, we toured the shop of L.T.C. Roll & Engineering (Mt. Clemens, Michigan) who has been hard turning their parts for over twenty years.

A Pressure Situation

By Kyocera's definition, hard turning is the machining of materials hardened to the range of 52 to 65 Rc. With such a hard workpiece material, the most obvious process requirement is to find an insert formulated to resist rapid edge deterioration, and that is indeed a prime consideration. But there is an even more significant aspect of hard turning to bear in mind because it quite literally impacts every physical component of the process. Cutting forces are generally 30 to 80 percent greater in hard turning than in conventional "soft" machining processes. It is, in a sense, the proverbial case of the irresistible force meeting the immovable object, which will exploit to the fullest extent any lack of rigidity in the machine tool, toolholder or chuck.

So good advice is to keep the cut light, and the setup tight. Specially designed machine tools are not required, but the lathe should be very rigid from top to bottom, and spindle runout and feed drive play should be tightly controlled. High-precision, balanced chucks are recommended as well.

Likewise, lightly designed tooling systems will have too much give to produce acceptable results. Kyocera recommends selecting toolholders with a 1 1/4 inch square shank or larger, and to keep tool overhang to a minimum. Use standard tools wherever possible, but should special tools be required, be sure they are designed to take advantage of the best insert applicable to the specific job requirements.

As with any turning, the ideal insert geometry is highly dependent on the part to be machined, but generally speaking, always select the strongest insert available for the job. Round or square inserts are recommended for roughing; so save the diamond inserts for a light finishing touch. And in all cases, use negative rake geometry.

While tool material selection is always a tradeoff between toughness and wear resistance, it is most acute here. For hard turning to be economically viable, you can't have the operator constantly stopping the process to change tools, so wear resistance comes to the fore as the leading requirement. Carbide simply will not deliver acceptable service life for the majority of applications. Thus, there are basically two options for ferrous workpieces: CBN or ceramics. The tougher CBN makes sense in high-impact work, such as when cutting through heavy scale or in interrupted cuts. But, asserts Kyocera, for general continuous cutting of hard materials, hot-pressed ceramic will achieve longer tool life, higher part quality and better surface finish.

Still, insert toughness is an issue with ceramics, so it must be kept in mind in managing other process variables. For one, selection of the proper edge preparation is very important to minimize chipping and to deliver a suitable surface finish. A typical edge prep might be a straight chamfer (specified by width and angle), a honed radius,or a combination of both. The ideal edge prep may vary for different materials, hardness levels, and even machine tools. A tooling manufacturer can usually offer some rule-of thumb guidance on edge-prep selection, but optimization will likely be a matter of trial and error on your own shop floor.

Establishing the best combination of cutting parameters will take some experimentation as well, but the general rule is that they all must be adjusted downward as hardness of the part increases. As for speed, it is usually best to cut as fast as possible with ceramics, but the rpm must come down substantially as parts get harder. Kyocera's recommended speed range (see chart) goes as high as 1300 sfpm for 36 Rc steel, and down as low as 100 sfpm for steel hardened to 64 Rc. Similarly, recommended maximum feed rates run from 0.014 to 0.004 inch. over the same 36 to 64 Rc hardness range, and depth of cut runs from 0.200 to 0.040 inch. Coolant is not required, or even recommended, but some practitioners do contend that it helps extend tool life.

[TABULAR DATA OMITTED]

In Action

At least, that's what a supplier says. But what does someone who makes his living making parts say about hard turning? Partners Ned Cavallaro and Andy Ligda have been applying the process for the last twenty years in their business, L.T.C. Roll & Engineering. The company manufactures roll form tooling, and does roll form production, primarily for the automotive and building products industries. Their tooling typically produces such parts as formed molding strips or structural members for auto door frames.

They also do a lot of retrimming, where worn rolls are returned to the factory, and recut to the original form specification. Rolls can be "resharpened" in this manner as many as ten times over their life. Whether the rolls are new or refurbished, the final cutting is done with hard turning. Here's how it plays out in the plant.

The business places a premium on flexibility. A complete set of roll form tooling may cover anywhere from four to sixty stations, each of which consists of a top and bottom roll. A small, simple roll may be a single piece, but a more complex form may have as many as eight pieces which are bolted together to make the complete roll. And every single piece is different.

Exacting precision is a requirement on the multipiece rolls, as the fit of one piece to another is critical. And in all cases, accurate machining is essential. L.T.C. Roll & Engineering does nothing but quantity-of-one machining, and botching the final hard turning process creates a very expensive piece of scrap.

Traditionally, form rolls were soft turned hardened and then ground. But some years ago, L.T.C. Roll & Engineering began hard turning, the rolls on manual machines using carbide tooling.

The process wasn't as accurate as one might hope, forced frequent tool changes, and required highly skilled operators, but Mr. Cavallaro still felt it was more efficient than grinding for their application. The move to CNC came about eight years ago, and along with it came a significant boost in quality and a dramatic reduction in labor.

The process begins with a blank, a sawed-off piece of round stock. Most of the steel is D-2, and they occasionally use some oil-hardened grades as well. A center hole is drilled, and the blank is pressed on to an arbor so the piece can be turned between centers. This workholding arrangement is important initially because it allows the lathe to get at the OD and both sides of the soft workpiece in a single setup. Later, it will provide the firm support necessary to stand up to the heavy cutting forces of hard turning. The art is soft turned on a Mazak Quick Turn 20 CNC lathe. Next it is removed from the arbor, ID stamped, and then sent to heat treat where it will be through hardened to 60 to 62 Rc.

The hard part is remounted on an arbor and turned between centers on a Mazak Quick Turn 28. On roughing cuts, they will generally take a depth of cut between 10 and 20 thousandths of an inch, says operator Tony Harlukowicz. Cuts have gone as deep as 75 thousandths, but with extremely reduced speeds and feeds. For a 0.010-inch cut, they will generally set speed in the neighborhood of 450 surface feet per minute, and feed at a rate of 0.008 inches per revolution. A finish pass may be as light as two thousandths, with speed of 450 surface feet per minute, and feed of 0.008 ipr.

The results? According to Mr. Cavallaro, jobs frequently must beheld to [+ or -] 0.0005, and they have no problem meeting the tolerance. He believes that the surface finish is generally in the 16 rms range. though they do not formally track that attribute since the rolls will be polished anyway. Mr. Harlukowicz adds, however, that surface finish is extremely consistent, unless there has been a problem with heat treat. The only other significant detriment to surface finish is flank wear on the insert, but that also provides a sensitive process indicator as to when tool changes are warranted. Changes are not necessary as often as one might think. On average, he estimates they get roughly 25 minutes in the cut per edge.

As mentioned earlier, conventional wisdom says run the speeds up as high as possible with ceramic tooling, and forego the coolant. However, Mr. Cavallaro has found that slower speeds and a flood coolant both contribute to longer tool life, so they almost always cut conservative and wet.

Moreover, they often will tend both lathes with a single operator, so a somewhat longer cycle time is a highly acceptable tradeoff.

All final profiles are generated through hard turning, though the center-bore is still ground. And finally, they are polished to generate a near mirror finish. The tools are then tried out on one of the shop's own roll forming machines to ensure they produce an acceptable part. Occasionally, some modifications are required, which means some rolls will go back to the lathe for a recut.

An interesting sidelight to the shop's roll-making operation is how they go about part programming - it's all done on the shop floor. Both Mazak lathes have CNCs designed for shopfloor programming, meaning they have CAMlike software that assists the operator in the preparation of a part program. Moreover, they have "background programming" capability, which means one part can be programmed while another is being machined, without compromising the CNC's performance in either function. Once a part is set up, and running, they will go ahead and program the next component part. The program is graphically simulated on the CNC, which helps the operators spot any errors before the tool hits real metal.

Also, rather than generating a new part program for hard turning, they simply import the program that was generated for the soft turning operation via floppy disk. This way, they simply pick up the tool path for the final soft cut, offset it to the proper depth for the hard cut, and then edit the feeds and speeds. The technique makes for very efficient overall programming, and essentially provides a "try out" for the hard turning routine in the form of the soft turned part.

Bottom line-what hard turning does for L.T.C. Roll & Engineering is enhance their competitiveness in the markets they serve throughout the Midwest. They are not a price shop. Rather, they stake their reputation on quality and service, and a quick and consistent manufacturing process goes a long way to enhance their reputation.

Aronson, Robert B

Turning machines are doing much more

No machine-tool type has reached beyond its initial simple purpose like the lathe. With the addition of extra turning spindles, and live spindles for drilling, milling, and even grinding, turning machines have become turning centers. At the same time, chucks, robots, and internal handling systems have made the lathe a system that's able to feed itself and provide complex internal part handling.

At the leading edge, the need for greater speed and precision, with reduced part handling, is driving designs. At the same time, there is a significant group that is doing well with a "just enough technology to get by" attitude.

Mighty Multitasking. "There has been an evolution of the multitasking market,"says Chuck Birle, Marketing Vice President of Mazak's Performance Division (Florence KY).

"Machines such as our Integrexes combine turning, and milling/ drilling/tapping and probing. The benefits of multitasking turning include: reduced workpiece setups, reduced tooling and fixturing, increased workpiece accuracy and, probably most important, it offers users an even throughput. Parts, or sets of parts can ship as they come off the machine."

"In the evolution of turning machines, we had turning centers with single-point turning, then automated loading and unloading. Next came the idea of a turning center that could do the same work as a machining center. A lot of builders moved into multitasking by making modifications to existing two-axis lathe designs, such as adding live milling heads. This approach had limitations: tooling interference, programming difficulties with the additional machine axis, and most important, severe limitations to the machining abilities. With our Integrex design, we took a "white paper" approach. As a result, almost anything you can do on a machining center, you can do on an Integrex.

"Initially, with our Integrexes we saw turning operations as the dominant process, now things are shifting away from turning-dominated operations. One company that bought an Integrex hardly does any turning at all. Milling dominates the machine's operation. This operator takes advantage of the fixturing reduction the Integrex provides. Instead of elaborate, inflexible, and expensive machining center fixtures, fixtures are now just chuck jaws. Instead of turning and machining-center tooling being scattered around the shop, tooling is resident in the ATC behind the Integrex.

"By moving the machine's cutting operations around the workpiece, rather than moving the workpiece around the shop to various machines for different operations, crucial workpiece datum's are not lost, they stay digitally contained within the machine's axis envelope. With larger workpieces weighing hundreds of pounds, safety is a big factor since the workpiece can be automatically loaded and unloaded. In high tech applications, such as medical, semiconductor, or aerospace, reduced handling also means reduced workpiece marring.

"Once companies realize the value of multitasking, they want to put more and more part numbers on the machine, making it easier to justify than they originally anticipated. Now, with Integrexes having Y and B axis capabilities, shops are able to machine the entire part complete in one handling."

"In addition," notes Dick Lewis of Hardinge (Elmira, NY), "there is more demand for working with near-net-shape parts, and this requires minimal setup to be profitable."

"We're doing a lot of multitasking and can mill, drill, and turn in one machine. This allows us to make complex parts with fewer setups," says Bob Lewis, senior manager of applications for Okuma America Corp. (Charlotte, NC). "If you are going to do four operations, you have to queue them up waiting for machine time. So queue time is often longer than operating time. We want to avoid `sleeping inventory' that is, parts sitting around waiting for the next step in the process. With a multitask machine, you put in raw stock and take it out a complete part.

There is no queue time. We are not doing any grinding because we are not comfortable with the effects of grinding dust on the machine."

"Naturally, one machine's design can't do it all," says Mazak's Birle. "Workpiece flow is king. In some very high volume applications, you may want to isolate individual machining processes and pass the part from machine to machine.

Multitasking fits well in lower to medium-volume part runs. But this is changing since the newer, smaller Integrexes with fast machining and chip-to-chip tool-change times make sense for even some higher volume applications. With multitasking, there are so many machine axes to keep track of (C, X, Z, Y and now B) that a strong conversational control is needed to reduce programming times."

General wants. "The early CNC multispeed machines were slow and cumbersome," says Mark Smith, vice president, Schutte MSA (Jackson, MD.

"But modern CNC, such as Schutle's virtual CAM control used in the S-32PC machine, provides the speed and control to handle the larger number of axes. Designs now range from commodity single-spindle lathes to multispindle machines.

"Our market is at the high-precision end making high-volume products. We have traditional camoperated machines for long runs and multispindle automatics for lower-volume production of precision components."

The newest Schutte machines are CNC units with as many as 30 programmable axes on six spindles that can mill, drill, and do ec cent ric work. The S32PS Camless Electronic Control system collects data from typical multispindle layouts with parallel processing software and prompt screens. The control then calculates and coordinates the stroke and synchronization of a maximum of 30 axes. Little, if any, programming is needed, so the system can be readily integrated into conventional multispindle shops.

"The mill-turn machine is drawing a lot of interest, especially on larger machines where pallet shuttles and other material-handling systems are not cost effective or there are space problems," comments Ken Campshure, Giddings & Lewis (Fond du Lac, WI). "We make parts more than 84" [2.1 m] long, so you want to leave the workpiece in the machine for as many operations as possible. Another trend is to get more Y-axis motion. Some have that motion built into the machine, and others have an attachment on the ram.

"There is some interest in machines with grinding capability, particularly in the aerospace market, but that's limited. Normally, in a machine tool, the bearing spindle and table are not of the same quality as that needed for a grinding machine."

Simplicity is important. "At Bridgeport we see strong sales in the low end of the market," says Steve Miller, lathe product manager for Bridgeport Machines, Inc. (Bridgeport, CT). These buyers come from three areas.

People just getting into turning who want a machine that is easy to use, but one that has the potential to carry high-tech options.

Those with a severe shortage of trained turning operators who can't afford to risk a high-cost machine.

Those with a highly variable production volume who will buy three or more smaller machines instead of one massive high-production unit. That way, during low- volume demand, one machine runs and two are idle, but all three run when demand is higher.

"We offer machines that can be manual or automatic," says Miller. "For example, our EZPath III operates manually, as a semiautomatic, or a full automatic. As users want more sophistication, they can add accessories such as bolt-on CNC turrets or power chucks.

"Our designs have to take into account that there are fewer and fewer operators familiar with conventional flat-bed turning."

Manual/automatic combination lathes are popular for most conventional production. The next level employs automated accessories such as bolt-on CNC turrets, power chucks, and workholders with either air or manual control.

Heavy gripping. "We are looking at higher chuck speeds, more than 1.5 mile/min [2.4 km/min] at the chuck OD. You have to worry about centrifugal force on the chuck and you usually need a counter-centrifugal chuck, which is kind of expensive," explains G & L's Campshure.

Clever machine design does no good if the part is not securely held. "In our design, we counterbalance on the face of the three-jaw chuck," says Steve Ennis, sales engineer for Goss and DeLeeuw Machine Co. (Kensington, CT).

"We counterweight on the chuck face, not internally," explains Ennis. "With the internal design you are limited in the amount of counter mass you can fit in. Room is limited. We mount two sets of jaws: regular top jaws and low-profile, pie-shaped jaws, which we call balance jaws. With this arrangement, each top jaw has a balance jaw 180 away. The two are connected within the chuck. As the chuck spins, the top jaw tries to pull away from part while the balance jaw pulls in the opposite direction, negating the effects of centrifugal force. When you change jaw mass or design you can accommodate the increased forces by moving the balance jaw."

The Goss and DeLeeuw chuck reportedly doesn't lose any holding force at speed. For example, a standard 8' (200 mm), chuck works well at 5000 rpm and the high-production version can run at 9000 rpm. Actuation is by air or hydraulics. The completely sealed chuck is maintenance free with the lube sealed in. Jaws are easily changed and give highly repeatability.

Too many chips. Chip handling continues to grow as a problem. "It's bigger than we initially expected," says Okuma's Lewis, "because faster speeds mean more chips. In addition, there is more fluid to filter, and we need to find a way to get the chips out. Conveyors now have to have filtering capabilities, you can't just let the coolant run off. People are going to high-pressure coolant systems to move the chips." According to Yusuf Venjara, engineering manager for Hitachi Seiki (Congers, NY), "Pressures up to 1000 psi [6.9 MPa] are often needed because faster speed means more chips, and it's important to keep the cutting surface clean. With highpressure coolant, part making that formerly required four minutes can now be done in

40 sec. In addition, filtration is important."

"Customers don't want chip conveyers in the floor," explains G&L's Campshure, "because they want to be able to move the machine. We are responding by putting chip conveyors on the front of our machines when practical. In addition, we need to keep chips where they belong, so we give extra attention to enclosures."

Speed penalties. High speed is not the answer to everything. It depends on the application. "When you increase speed you sometimes sacrifice horsepower and torque. You can't always have it both ways," says Dick Lewis of Hardinge.

Campshure of G&L agrees, "Although high spindle speed gives you higher throughput, you have to pay for it in more expensive equipment. But customers are asking for higher traverse rates, faster tool change, and increased swing capacity for a given table size. For example, with a 36' (914-mm) diam table, the user wants a swing of 54 or 60" (1.4-1.5 m). They are not so much concerned about weight capacity, but size."

Big job spread "At the low end of the line, we have the simple, two-axis machine," explains Venjara of Hitachi Seiki "If you go to three or four axes, the tool has to be modified to machine with a fourth axis subspindle and toolchanger. The next step up is a move to a more complex machine like our Hicell.

"Our control system answers the need for the supervisor who wants more information and does not want to go to the floor and find out what's going on. We want to connect with the Ethernet and PCs. The next frontier coming is the phasing out of RS 232 and the introduction of the Ethernet and other proprietary systems like Mazak's fusion control system.

"You can't buy a low-cost machine and expect to get the work done, you still have to consider setup. We are working to see how we can use our Flex Link design to further reduce setup time.

"More integration is the next step in turning centers. Expect faster tool changes and a triple-station turret that provides turning, milling, and a station for specials. With this configuration, the part passes from station to station. The turning center is approaching the capability of a machining center," concludes Venjara.

"A trend that started several years ago is to first buy equipment for the simplest work, then move up as needed," says Lewis of Hardinge. "At Hardinge, we recognize the need for multiple product levels in our turning machines to address the entire market. We start with our economical Cobra lathes and move up to our newest machine, the Conquest TwinTurn 65, which is a fullfunctional twin-spindle, twin-turret turning center. In between, we offer gang-tool machines, Swiss machines, vertical turning lathes, and the flagship of our turning line, the Conquest T-series machines. We also recently introduced the GT Autoload, which features an automation system integrated with our GT gang-tool machine."

Another example of ever-expanding lathe offerings in the industry are the Hawk CNC turning centers from Cincinati Machine (Cincinnati). The company now offers the 6" (152-mm) TC-150, 8" (203 mm) TC-200 and 10" (254 mm) TC-250. They are all controlled by the PC-based Acramatic 2100 CNC.

On the other hand, it's possible to modify existing designs to meet fresh requirements. For example Haas (Oxnard, CA) took their proven SL30 lathe with programmable tailstock and added the spindle and gearbox from the larger SL-40. The result was the SL 30BB midsize CNC lathe with larger capacity.

This unit has a maximum cutting diameter of 14.5" (370 mm) and 30" (760 mm) swing.

Haas offers three basic models in their SL series to meet customer demand. The SL 20, SL 30 and SL 40 with 20, 30 and 40" (0.5, 0.8, and 1-m) swings respectively. Cutting capacities range from 10 X 20" (254 X 508 mm) to 25 X 44" (254 x 510 mm).

Watch out for the heat. "One way we improve accuracy is by doing a better job of thermal compensation," says Lewis of Okuma. "We monitor the heat better and know what to do with it. The improved accuracy means we are taking over more grinding jobs. Five years ago, one in 20 jobs was hard turning. Now it's five of 20, especially among auto products."

Saginaw Machine Systems, Inc. (Troy, MI) has been looking into ways of improving machine tool performance, particularly in the area of thermal compensation. According to Gerald Romito, vice president of technology, "The project is doing well and we currently have eight vertical lathes from our Crusader line in the field." To set up the system, they use probes positioned at key locations on the machine to develop a thermal map. Then they use this information to introduce compensating factors into the lathe's control.

"The key to making it work is the location of six thermal sensors that look at spindle growth, and X and Y-axis growth. We have held eight microns over 24 hours though a varying cycle that included cold start, cutting, rest, then cutting." Other trends include: No more holes. Okumas's Lewis notes that installation is also changing. "No one wants to dig a hole in the shop floor any more. They want to have movable machines so they can reconfigure in a short time. We avoid the problem by making the entire floor 24" (610 mm) thick so we can put machines anywhere we want them."

Internal hands. A lot of the part handling goes on inside the enclosure after the part making starts. Lathes use a variety of robotic systems. Some have gantry robots to move parts, while others have stand-alone or built-in robots.

"We use robots in about 20% of our machines for automated loading, either gantry or stand alone," says Lewis.

Tighter specs. "The area in which we are seeing the most change is accuracy," Lewis states. "We now offer a total tolerance of 25 microns."

Then there is a push for hardturning applications, because people want to eliminate grinding.

Loading is important. "For parts from 6 to 8 lb [2.7-3.6 kg], automatic loading is usually practical," explains Vanjara of Hitachi Seiki. "Over that weight, the cost of the loader relative to the turning machine increases substantially. When part weight gets into the 20-30 lb (9-13.6 kg) range, loaders cost more than the machine."

Waurzyniak, Patrick

Faster lathes, turning machines mandate speedier, more efficient chucks

Talk to just about any machine tool operator about chucks and they'll tell you they want faster, stronger chucks. With improved turning machines capable of faster spindle speeds coming on the market, high-speed chucks are becoming more common for many applications. But as much as machinists need speed, factors such as machine tool accuracy, quick-change capabilities, and quality, all remain important.

In workholding equipment, technical developments sometimes lag improvements in the industry's latest machine tool turning centers, lathes, and machining centers. But higher spindle speeds are forcing machine shops to reconsider their chuck requirements.

"There's an old saying that on the workholding side, nothing new has been invented in 150 years-it's actually reapplication of old technology, which is partially true," notes Spencer Hastert, vice president, Kitagawa Division/Sumikin Bussan International Corp. (Schaumburg, IL). "The trends tend to follow lathe technology and cutting tool technology, where I think speed is becoming more and more a factor with higher rpm spindles."

Some extremely fast chucks sporting speeds above 10,000 rpm have debuted in North America, notably the high-speed chuck introduced by The Goss & DeLeuww Machine Co. (Kensington, CD at IMTS last year, but relatively few applications require speeds exceeding the 6000-7000rpm levels typically found in Europe and Asia.

"We're working with [machine tool] builders in Japan, to develop the technology for power chucks with high-speed applications to 10,000 rpm," says Hastert of the jaw chucks which Kitagawa hopes to bring to North America in the future.

High-Speed Hazards. Most applications simply don't require running machines at more than about 6000 rpm, notes Sidney Roth, president of SMW Autoblok Corp. (Wheeling, IL). And going too fast with an unsafe chuck could be very hazardous to shop personnel.

"You run the danger of ripping the bolts right out," says Roth. He recalls an instance where an automotive shop running a machine at 4000 rpm had a small brass part that flew off a chuck and embedded into a nearby steel structure. "Can you imagine something like a workpiece coming out of the machine? None of the machines are built with enough protection for the workers-and here in the US, if someone's injured, the lawyers are going to line up.

"Safety must be a primary concern," adds Roth, noting that not all chuck manufacturers use the same ratings when publishing data on chucks' grip-force curves. Roth says that while SMW Autoblok measures its chucks' maximum rpm ratings at 50% loss of grip force, another competitor's specs assume a 66% loss of grip force, and safety levels differ.

"High speed doesn't have to mean high rpm," Roth states. "I've never sold one for running at 8000 rpm, and we probably sell more 10" [254-mm] high-speed chucks running at 5000 rpm than any other."

Litigation worries may even have prompted some overseas manufacturers to delay marketing their fastest chucks here in the North American market, preferring instead to sell those models in Europe or Asia until the highest speed chuck technologies are proven in the field. Until then, the fastest chucks most likely are available only from Goss & DeLeuww, which has tested its new counterbalanced chucks at speeds well above what is considered the top-end norm for turning speeds. "We went way past 10,000 rpm, but there's no sense in shouting about that because nobody's got a lathe that could go anywhere near that fast," says Richard Hippner, Goss & DeLeuww's CEO.

Most lathes today run between 5000-7000 rpm, notes Hippner, with some shops turning parts at up to 8000 rpm. "There are a couple of smaller lathes spinning at 10,000, Wasino's got one," he says. "Spinner is developing one. Allied Signal was trying to machine at 8000 and had a terrible time hanging onto the parts, so they asked us if we could provide a solution, which we did, and it's in production testing now."

Faster chuck speeds are becoming more common, but in some instances, high-speed applications may be better suited to collets than the traditional power chuck, notes Hardinge Inc.'s

(Elmira, NY) Workholding Engineering Manager Neal Des Ruisseaux. "High speed is definitely a trend," agrees Des Ruisseaux. "There are [highspeed] chucks available that are, even at this moment, ahead of the machines. There is the tendency for machine tools to move to higher spindle-speed capability, and in order to improve productivity, there's probably some market for that high-speed chuck. Whether it dominates or not, that's quite another question."

Accuracy's Critical. Today's shop floor demands not just improvements in a chuck's speed rating, but also in product quality achieved by improved accuracy. "People want to run it faster, but they also want higher and higher quality output," says Brian Lane, vice president and general manager of Logansport Matsumoto Co. (Logansport, IN). "I've been in this business many, many years, and I've seen requirements in turning operations go from maybe 0.002" [0.05 mm] accuracy on dimensions to where these new lathes will hold 0.0005" [0.013 mm].

"That's rather precise, and so this workholding has to improve," says Lane, whose company manufactures chucks, hydraulic cylinders, Neidlein face drivers and rotary tables. "It has to be capable of performing in that same environment, which it will, and so people are working hard, eliminating grind operations in some cases, because the turning centers can do the job. I've seen our workholding have to go in that direction to stand up in the turning environment. You have catalog chucks that'll run 7000 rpm, and they're just standard three-jaw chucks."

Lane sees an emphasis on end-user product quality, plus the elimination of downstream operations like grinding, as keys for the market. "If that customer can accomplish the end result that he needs on the lathe, then he stays away from grinding operations."

Some machining operations simply can't be accomplished at the higher spindle speeds used with the latest chucks. "There will always going to be some exceptions, but I think the more that machine developments move toward higher speed, the shop floor will demand more accuracy," Hardinge's Des Ruisseaux points out.

Given the choice of smaller parts run in short cycles, using a collet might be a superior choice over the traditional power chuck, he adds. "There's the issue of the type of part that you're holding-parts that chucks are typically used on tend to be bigger. It may be a first-operation situation where the part is pretty rough, it may be from bar, it may be a casting.

"You may not need the accuracy right away, and you may not be able to run it at the highest speeds," says Des Ruisseaux, "compared to the situation that exists when some of the operations have been done and you've got a part that's more inherently in balance which can be run at higher speeds."

Maintenance-Free Chuck. Another problem machinists constantly face is keeping chucks free of chips and other debris during machining operations, notes Autoblok's Roth. Since high-pressure coolant at up to 1000 psi often washes away most chuck lubrication during machining operations, and also forces chips and dirt down into the moving parts of a chuck, Autoblok has developed a new completely sealed chuck. The company recently demonstrated the unit at the EMO show in Paris.

Autoblok's new sealed chuck series features sliding jaws and requires no daily maintenance, says Roth. The chucks are completely sealed to resist penetration by fluids, dirt, and swarf, allowing the chucks to maintain lubrication even when used with high-pressure coolants. "The number one effect of highpressure coolant is that within a very short period of time, it blasts away all the chuck's lubricity," says Roth. "Any kind of chuck grease is going to be blown away. Another impact of high-pressure coolant is that it forces chips and swarf into the jaw slides."

Loss of lubrication can quickly lead to high chuck wear or even failure, he says. Likewise, if a chuck's moving parts are contaminated by chips or dirt, the chuck will bind and eventually lose gripping force. Autoblok's new 8.8, 10.6 and 13" (225, 270 and 330 mm) sealed chucks are available in threejaw versions with metric serrated master jaws, and inch serration will be made available in the future.

QuickCaange Chucks. Along with increasing speed, workholding manufacturers constantly strive to reduce customers' cycle times in setups and fixturing. Toward that goal, many chuck manufacturers now tout quickchange jaws on chucks that aim to cut down setup times and boost overall manufacturing productivity.

"Quick change is becoming more and more popular," notes Kitagawa's Hastert. "In the past, quickchange workholding typically has had a couple of problems. It tends to be a little more expensive than the standard workholding, and with any quick-change system, contamination with chips is a big issue.

"With any quick-change system, when you take something off and put it back on, there's always a potential to introduce some sort of contamination that will either affect your accuracy or affect the functionality of the chuck," he adds.

Some observers caution that many workholding users still haven't found the quick-change chuck jaws to be truly effective in boosting overall machining productivity. Hardinge's Des Ruisseaux estimates that from figures he's seen, roughly about 5% of chuck buyers opt for the relatively new quick-change systems, which he says could save some users about one-fifth of the setup time required for changing jaws.

"It does not seem that a high percentage of chuck users want to convert to quick-change usage," says Des Ruisseaux, "and I think that's because the labor savings or setup time reduction isn't great enough relative to the total job that they're doing. They don't deem the economics or the added cost to be particularly worth it."

Using quick-change jaws can be more accurate, however, since the systems include fixed positions for operators to return to, as opposed to conventional jaws, he says. "It's a little bit easier to make a mistake with the conventional jaws," says Des Ruisseaux. "You can miss the serration, and then the part's running out.

"The time-savings benefit may be small potatoes compared to total changeover time, because you've not only got to change over jaws on a chuck, but you're also probably retooling the machine," he adds. "You're setting up the machine, putting all new tools on, loading a new program, so it may be that the savings in changeover time is a small percentage."

Custom Workholding. Along with quick-change workholding, custom workholding solutions have become much more important to customers, and custom workholding is an area where Kitagawa has put particular emphasis, according to Hastert. Pressured by the waves of corporate downsizing over the past two decades, many manufacturing operations that might have employed a full-time workholding expert simply don't have that expertise in-house today, he notes.

"Historically companies would take just the standard chuck that came with the lathe and make it work-they'd do their own workholding," says Hastert. "There's a trend now for companies to realize there may be a better way, by taking advantage of custom workholding. They may contact a workholding house and ask: 'Here's my part; I run 100,000 of these a month. I'm just using a standard three-jaw chuck right now; is this the best way, or is there a better method?'

"With corporate downsizing and a lot of outsourcing, when you go into mom-and-pop shops, a lot of workholding knowledge has been lost," he adds. In one recent case, trailer-hitch manufacturer Holland Hitch Co. (Holland, MI) kept trying to turn out a 3" (76.2 mm) pin, called a kingpin, that locks into a semi-tractor's hitch to connect its trailer. In order to improve the manufacturing process, Holland switched from its previous lever-style chuck to a Kitagawa wedge-style chuck.

"That's an example of where they used a standard chuck, but the application was so aggressive that they're just beating the workholding to death, they're literally killing it," notes Hastert. Holland decided to employ Kitagawa's N Series Closed Center Power Chucks designed for high-speed, accurate, repetitive chucking.

"Kitagawa's N15 chuck uses a lot less hydraulic input to grip the same part as our previous workholding equipment," says Bill Bushee, Holland Hitch manufacturing engineer. "There's much less wear and tear on a chuck when you compare 8000 lb [35.6 kN] of gripping force to 18,000 lb [80.1 kN] of force."

A major manufacturer of heavy-duty trucking couplings, Holland Hitch annually produces around 200,000 kingpins for trailer manufacturers like Utility and Great Dane. The kingpins generally last for about 500,000 miles before needing to be replaced.

Holland Hitch chose Kitagawa for its combination of quality, price, and delivery, says Bushee. "We expect Kitagawa's N15 to perform for the life of a machine," he says, "but if it lasts only as long as our former chuck, replacement costs would be far less."

Turn up productivity with turn/mill machines

Destefani, Jim

Multifunction tools may be an idea whose time has come

This article was supposed to be about all the things you wouldn't want to do on a turn/mill machine. A prime example: you wouldn't want to try to produce a part with minimal turning content on one of the hybrid machines.

That may have been true in the early days of the technology. "The rule of thumb for years was that milling and drilling should be no more than about 15*20% of total cycle time," says Tim Thiessen, lathe product manager, Okuma America (Charlotte, NC).

But, he notes, that rule applied (and still does) for lathes with live tooling capability, not the current crop of turn/mill machines that feature multiple spindles, multiple turrets, and milling capability comparable to that of some machining centers. Some machines with high-speed spindles are used for grinding; others incorporate operations as unusual as laser welding.

All the machine builders contacted for this article told stories of users who make parts with essentially no turning content.

Typical is one from Yusuf Venjara, general manager, engineering, Hitachi Seiki USA (Con gers, NY). He tells of a customer machining small, disposable medical parts from forgings on a VMC with a pallet changer. The operation was switched to a turn/mill machine with a magazine-style bar feeder, and now runs 6-7 hours at a clip untended. "The turning component of cycle time on this part is really limited to feeding the bar," Venjara says. "Everything else is machining center-- type work. They even use a slitting saw for cut off."

Given this blurring of the distinctions between conventional turning and milling machines, Venjara now employs a purely functional definition to answer the question of whether a particular unit is a turning machine or a milling machine. "I base it on how the machine is being used. When the spindle is turning, it's a turning machine. But, when the spindle is stopped, it becomes a fourth axis. So it's all relative."

What's driving machine builders to develop more capable and more complex multitasking machines is the desire of many users to produce on a single machine parts that might previously have required both turning and milling operations.

"The big attraction of these machines is, customers can feed raw material in one end of the machine, and take finished parts out the other end," says Brian Ferguson, lathe product manager, Hardinge Inc. (Elmira, NY). "With the right workholding and handling systems, customers can pick parts out of the machine and place them on conveyors. With a magazine barfeeder, these machines can run untended for hours at a time."

And, making parts complete is naturally more accurate than moving parts from machine to machine or from fixture to fixture. "You have built-in accuracy," says Chuck Birkle, VP, Cybertech Div., Mazak Corp. (Florence, KY). "Whenever you can move the machine around a fixed workpiece, you're on one common datum for turning, milling, drilling and other operations."

Klaus Voos, VP, Index Corp. (Shelton, CT) says the all-in-one machining ability of turn/mill machines can provide a major advantage in an era of small lot sizes and just-in-time delivery schedules. "You can go from raw material to a finished part in a relatively short time compared to multistep processes," he says. "When you have to go through several machines, it can take days to add another operation on the part."

Amplifying this point is Birkle, who urges manufacturers to rethink their definition of cycle time. "Many people believe the primary measure of machining productivity is measured by the time between start and stop on the machine," he says. "But if you take a step back and look at the bigger picture, cycle time is not just the time between the green button and the red button; it's the time between when raw materials are ordered to the time that material is converted into a product for the customer."

According to Birkle, turn/mill machines can help streamline production by promoting a more even flow of components through a shop. "Is machining cycle time lower than it would be on a machining center? Maybe not, but the fact that I can get these parts complete, in ship sets, and I can ship in smaller quantities, is a real key point. It gives many smaller shops better cash flow, and it allows them to fulfill just-in-time deliveries with smaller lot sizes."

But Voos points out that operating such sophisticated machines places a premium on both process development and having the right manufacturing infrastructure in place. "In terms of process development, it's important to find the right sequence of operations, the right tools, speeds and feeds, chip control-all these things are important, and it's more challenging than a conventional process, because you're looking at a lot more tools," he says.

"Operating one of these machines is a bigger challenge for an operator than running a small machine that's just part of a sequence of operations," he continues. "The programmer has more demands placed on him, and procedures for tool preparation, material flow, and other support issues need to be solid."

Programming also remains an issue for turn/mill machines. In fact, as the machines become more complex, programming becomes an even bigger key to productivity, according to Hanan Fishman, vice president, IMCS Inc. (Fort Washington, PA). He claims the company's PartMaker software was the first CAM system developed "from the ground up" for programming turn/mill applications.

"Other CAM systems focus largely on two-axis turning and milling," Fishman says. "But turn plus mill does not equal turn/mill. A turn/mill machine has a number of different coordinate systems at work for performing different types of milling operations. Users of turn/mill machines know which coordinate system they want to use, but they need an intuitive means of handling them."

IMCS's patented Visual Programming capability "lets users literally `divide and conquer' a part," Fishman says. "On these kinds of parts, you may have some turning work, some drilling of off-center holes, some polar interpolation [rotational indexing of the spindle], and milling on the part OD. When you program a part in PartMaker, you break down the part into its most basic elements. In one window, you perform all turning operations, in another window, you program all polar interpolation in another window, you program all your OD work, and so on."

The software then lets users resequence operations using what the company calls a Process Table, which shows all operations and lets users point and click to reshuffle them to get the optimal cutting sequence. The table tracks both the time needed for each operation and total machining time, giving users a reliable picture of cycle time before they cut the first part.

Another difficulty when programming the increasingly common twin-spindle and/or twin-turret machines is synchronizing the simultaneous operations, according to Fishman. "These machines can essentially do the work of two machine tools, but it's not as if you have two separate machines," he says. "The programs need to be linked through synchronization ["sync"] codes. Our software uses Visual Synchronization, which lets users click on a picture to choose the kind of synchronization they want to perform. The most common type of synchronization is where one turret is cutting on the main spindle and one is cutting on the subspindle."

One user getting a lot of mileage out of PartMaker software is Slabe Machine Products (Willoughby, OH). The 100-person shop has invested in turn/mill technology for some time with the goal of machining parts complete in a single setup. Slabe's lineup currently includes twin-turret, twin-spindle machines from Hardinge and Nakamura-Tome.

With the complexity of its machines on the rise, Slabe realized it had to address programming, according to VP Brendan Slabe. "As more and more jobs go to the turn/mills, PartMaker greatly simplifies programming so we really can 'drop them complete.'"

The software's visual approach lets Slabe programmers handle the live-tooling capabilities of the turn/mill machines, and supports simultaneous machining capability by giving them the ability to perform process synchronization in an intuitive manner. The program automatically inserts "Wait" or "Sync" codes into the NC code it generates.

PartMaker may be the first software developed specifically for CAM on turn/mill machines, but the field is becoming more crowded. Just introduced at last month's Detroit Advanced

Productivity Exposition-an SME-- sponsored trade show-is the latest version of GibbsCAM. Developed by Gibbs and Associates (Moorpark, CA), the package provides all-new support of mill/turn programming. But development of the new capability wasn't easy, according to company founder and CEO Bill Gibbs.

"The minute you step across the turn/mill line, you kind of go through the looking glass," he says. "Before, everything was either a mill or a lathe; everyone understood what they were and what they did. But when you cross that turn/mill line, suddenly no two manufacturers build the same thing. Each builder has a spin on what's more effective and more marketable. And while there are some general groupings of popular features, it's dangerous to get hung up on a rigid machine definition."

Gibbs overcame this problem by developing a piece of software that lets the person setting it up define the machine in terms of the number of turrets, slides, and spindles it has, where these components are all located in space, and a variety of parameters such as rapid traverse rates and feeds. This machine definition document (MDD) is the first thing users select, so the software knows up-front which machine is being programmed.

Machines with subspindles and multiple turrets also create what Gibbs calls "significant process management issues." To address these concerns, the company developed what it calls utility operations. "Normally, we define an operation as a tool cutting something," Gibbs says. "But a utility operation doesn't cut; instead, it allows the programmer to take discrete control graphically over things in his machine that don't cut metal-for example, a tailstock or a subspindle, or a barfeed, or part loading/unloading. The programmer needs to have discrete ways to represent these things in the program flow as he generates the program.

Finally, GibbsCAM addresses the issue of synchronizing simultaneous operations using a drag-anddrop interface called a Sync Dialog, which gives programmers the ability to see the program with every operation represented in real time. Users click on the items they want to start and end at the same time, then resequence operations to optimize the job.

"Our typical user sits down and draws some shapes, places them on the screen where his spindles would be, and creates some milling and turning operations as he would on a simple machine,"

Gibbs says. "Then, as a final step, when he has the components of his program, he can optimize the job in terms of time and flow, and see a full graphic visualization of what the machine is doing."

Users of NC verification also now have new capabilities for turn/mill simulation and visualization. VeriCut 5.1 software from CGTech (Irvine, CA) can simulate and verify turn/mill machines, including simultaneous display of the entire machine tool and cut stocks. The package supports multiaxis, synchronized machining with multiple tools, according to the company's Bill Hasenjaeger.

In the new release, all machine components attached to the machine spindle automatically spin during turning operations. Thus, when the spindle is turned on, nonsymmetric components such as three-jaw chucks, fixtures, and nonsymmetric stocks become realistic "spun" models. During mill/turn machining, the turning operations dynamically update the milled stock, and milling operations update the "spinning" stock used in turning operations to provide what Hasenjaeger says is the most accurate turning and mill/turn production machine simulation available.

Look at Machine Capability Before Buying

Ervin, J Patrick

When selecting a machine tool, some companies want machines that minimize part cycle time, generally to the detriment of changeover time. Other companies want to purchase machines with a wide range of functionality-such as lathes with two spindles, multiple turrets or tool slides, live tooling, C axis, Y axis, and B axis. Generally these companies want to combine multiple machining operations on one machine to reduce the waste involved in handling parts between operations, while minimizing operator intervention and manufacturing throughput time. Other manufacturers want to purchase machines with limited functionality in terms of combining manufacturing operations, and elect to turn on a lathe, mill on a machining center, and grind on a grinding machine.

There is a wide array of improvement programs aimed at increasing the productivity of manufacturing operations. Lean techniques coupled with Six Sigma initiatives have proven their ability to increase productivity in company after company by focusing on and eliminating waste. But regardless of the manufacturing philosophy of your company, one thing often overlooked in the purchase decision is how machine capability, not functionality, affects waste on the shop floor. Functionality is simple. Once a decision has been made as to what level of functionality (combination of features) is desired by the company, elaborate spreadsheets are assembled comparing the features of brand "A" vs. brand "B," to determine which product is the best buy. Unfortunately, what generally occurs is that products are grouped by like features-factors like spindle horsepower, axis travels, and spindle speed.

All machines are not created equal.

This analysis is flawed. What isn't generally considered is a comparison of machine capabilities. Attempts are made to address the capability question by including terms on the spreadsheet such as axis repeatability and positioning error, turret-index repeatability, programming resolution, and spindle runout. These are all valid considerations, but to me capability is a machine's ability to produce a part to tolerance on an ongoing basis without significant operator intervention. Key differences exist between machine tools that may look similar on spreadsheets.

All machines are not created equal. We offer products for customers for whom price matters most, and we offer products for applications where performance matters most. Why don't two machines with similar functionality perform alike? The answer is not easily placed on a spreadsheet. Thermal effects can determine whether the first parts made in the morning are produced to tolerance or are scrap. Also, what occurs when the machine is stopped for a period of time during a shift? The difficulty of keeping a machine producing parts in-tolerance despite thermally induced changes in the machine structure is a factor not often considered.

What does a machine's capability mean to the level of waste generated on the shop floor? Obvious waste is the level of scrap or rework that must be performed. Another waste is the waste of an operator's time because he or she must tend to the machine and tweak the process to keep parts in an acceptable tolerance band. Waste can also be the waste of having to perform subsequent machining operations because the machine can't maintain the desired tolerance or surface finish.

These factors should be considered by manufacturing engineers when selecting a machine tool, but far too often the purchase decision is driven by price alone. Generally the cost of waste generated by an inferior machine tool over the machine's life will far outweigh its lower purchase price.

I don't mean that companies should over-spec their machines, but you must understand that all machines are not the same, even when similar specifications are listed on a spreadsheet. We offer machines with similar functionality that can differ in price by 20-80%. This price difference is based on changes in the machine structure that improve the machine's capability. The next time you contemplate a machine tool purchase, realize that the up-front price difference between two machines may be a minor point when compared to the impact on waste at the shop-floor level.

J. Patrick Ervin

PRESIDENT AND CEO

HARDINGE INC.

ELMIRA, NY

Using a turn-mill machine - includes related article

Chris Koepfer

It seems every machine tool builder with a lathe in its bag of products offers models with turn-mill capability. This article looks at some of the considerations one shop uses to determine when turn-mill is appropriate for its production mix.

Adding rotary tool capability to a turning center significantly increases the manufacturing capability of the machine tool. Applications that previously required turning and, subsequently, milling, and drilling, can be processed in one setup on the turn-mill machine. However, not every application is a candidate for one-stop processing. Some applications lend themselves well to turn-mill, some do not. Key to successful implementation of a turn-mill machine is recognizing what will work on the machine and what will not. It's not always obvious.

To get some insight into that decision-making process, we visited Task Force Tips (TFT) Inc. (Valparaiso, Indiana)--a manufacturer of fire suppression equipment and Production Dynamic chucks for metalworking applications. Much of the company's product mix is comprised of parts of rotation. Finding better ways to make those parts led the shop to turn-mill machines.

Currently, 60 percent of the company's turning equipment has milling capability. They produce over 1500 different parts for their product lines and use turn-mill whenever possible.

Turn-Mill Basics

Fundamental to successful application of turn-mill processing is understanding that it is not the sum of separate turning and milling processes. It is a different way of approaching the manufacture of a workpiece.

For example, using a conventional method of manufacture (a lathe operation followed by a machining center operation) part processing is sequential. First, all the turning operations are performed on the workpiece. On a two-axis machine, rough turn is followed by finish turn of the OD and ID. After step one, the part is either flipped or moved to a second turning machine for step-two processing.

After the part comes off the turning center, it is usually checked by the operator against a tolerance on the part print. If the part is OK, it moves on to the next station.

With the turning complete, the workpiece is moved to a machining center for any milling and drilling operations. Flats are cut, followed by any other milling work. Then holes are drilled, followed by tapping, if specified. Again, when the part comes off the machining center, it is inspected. Depending on the operations performed, deburring may be required, making an additional processing step.

Practitioners of turn-mill processing, like TFT, approach the workpiece more holistically. Rather than plan operations sequentially around two machines, they can program the machine to cut in an operation order that allows optimum manufacturability. Essentially, they can turn some, mill some, turn some more, mill some more, instead of having to turn all, then mill them all. An often overlooked area of savings is in quality assurance. By processing the part complete, only one inspection is necessary for the whole part.

An example of how this processing freedom helped TFT is found in a collar they make for their nozzles. Before it was put on the Mazak Super Quick Turn 18M turn-mill machine, the workpiece required four handlings and had a total cycle time over seven minutes. Not factored into the cycle time was a deburring operation needed after the part came off the machining center because the milling operation damaged the OD threads that were already cut on the turning center.

With turn-mill, the same part is now machined complete in one handling, and takes just three minutes to complete. Because the sequence of operations can be intermixed, the milling of the flats on the OD now comes before the threading operation so the thread deburring step is eliminated.

Consider Complexity

There are many factors that impact the decision to turn-mill a part rather than process it across distinct machine tools. One of those factors is part complexity. But complexity is kind of misleading as a factor because, as Figure 2 shows, complexity sometimes lends itself better to the turn-mill machine.

On the other hand, some simple looking parts just don't work well on a turn-mill machine. One example of a part that looks like a candidate is a simple two-inch-diameter by 3/4-inch-thick convex disk, in aluminum, with two drilled and tapped through-holes on the face. Using a bar feeder and cutoff tool, these seem like they should crank through like salami on a turn-mill machine. In prototype testing for the part, however, it was discovered that the drill going into barstock caused problems making the next part. The drill had to go into the bar far enough for the tap to bottom out. Getting the spindle back to position for the holes to align for the next part was too problematic. So the disk is turned and the holes are done as a second operation. In some situations, additional stock could be faced off the bar to give a fresh start for the holes. The cost of material would be the deciding factor.

Consider Geometric Relationships

Geometric relationships are a better gage of turn-mill processing potential than geometric features. Holding dimensions relative to each other is where a turn-mill machine can really earn its pay.

According to Stewart McMillan, president of TFT, "Often a part print has handling allowances built into the part tolerance. For example, a 0.001-inch tolerance may be indicated as an allowance for fixturing a workpiece into a machining center after a turning operation. And those tolerances grow as secondary and tertiary operations are needed. It's a compounding effect. With turn-mill machines, that handling allowance is unnecessary since the part is not moved from the original fixture (chuck). Our engineers can design closer tolerances, where warranted, and forego refixturing allowances altogether."

Sometimes the engineers at TFT are able to design parts for turn-mill processing that would not be practical or economical to produce any other way. An example is a proportioning valve, shown in Figure 3. It is machined complete on a turn-mill machine, and would be very complex to make with a machining center. One feature, a semicircular groove on the back side of the major diameter, is readily accomplished with a straight milling tool and C-axis interpolation. "This used to take eight hours to set up and run on a machining center. On the turn-mill machine, it took two hours to program, and runs in minutes," says Mr. McMillan.

Consider Throughput

Any manufacturer, whether making a product of its own or vending for another company, is aware of the need for good throughput in the shop. TFT is no different. According to Mr. McMillan, "We probably run larger batches than we would like, but that tune is called by the finisher who anodizes our aluminum parts. Since most of our products are exposed to water, we anodize all the parts to prevent corrosion. The finisher runs batch quantities that are most economical for him. Generally, those quantities are not ideal for us. But, we accommodate the finisher to keep our costs down."

Another throughput consideration for turn-milling is the relative speed of the turning and milling processes. Generally, turning is about twice the speed of milling or drilling. Depending on the ratio of turning to milling/drilling, it may be better to gang parts on a fixture and machine a bunch at one time, than to do one at a time on a turn-mill machine. "That decision often has to do with part tolerance," says Mr. McMillan. "If the accuracy requirements are less stringent, we'll look to optimize throughput with a second operation."

According to Jim Walker, who operates the prototyping test area for TFT, "Generally speaking, you don't want to do heavy milling with large amounts of metal removal on a turn-mill machine. Separate operations are better suited for that." While geometric complexity is often easier to deal with on a turn-mill machine than on a separate machining center, throughput is a consideration if tolerances for the part are wide enough to allow efficient production off the turn-mill machine. A shop has to weigh the relative gains of single-setup processing against the throughput gains of multiple part setup and machining. In other words, sometimes it's better to make them one at time complete, and other times it's better to turn a batch on the lathe and then second-op them in a multiple-part fixture on a machining center.

Other Considerations

Since implementing turn-mill, TFT has made a concerted effort to look at how each part is processed to see if it can be done complete on one machine. So far there have been many successful transfers. As the capability of turn-mill technology expands, for example, machines with subspindles and dual-turret configurations, the re-evaluation starts over. It's an ongoing process.

"That's how we've done business from the beginning," says Mr. McMillan. "When we started TFT in our basement, we used engine lathes and bench mills. Our first CNC four-axis lathe was purchased in 1980, and within six months, it was doing the work of all of the manual machines. Soon, we bought a second CNC and the growth has continued. Now most of the four-axis lathes have been replaced by turn-mill machines."

Key to successful implementation of turn-mill in the shop was a go-slow attitude, at first. Early turn-mill machines required excessive amounts of time for the main spindle to convert from turning to milling mode and back. As much as 20 seconds might be added to a single cycle. "We would still be in a go-slow mode if this key factor had not changed," says Mr. McMillan.

Recent innovations, including integral spindle headstocks, now allow near instantaneous change-over from turning to milling and back. This has changed the equation used to measure times between milling machines and turning machines.

In 1989, TFT bought a used CNC turning center with live tools. Mr. Walker recalls that programming a simple hex on barstock took three hours using the point-to-point method of programming. "Even with that, I could see how this technology could help increase production," says Mr. Walker. "At first, I was not enthusiastic about turn-mill technology. After working with it, the benefits became obvious."

Dedicated Turn-Mill

The system used at TFT to determine what goes across the shop's production turn-mill machines is an off-line turn-mill machine dedicated to production testing and prototype work. Mr. Walker runs the machine. "Not many shops would dedicate a piece of equipment like this to non-production work," says Mr. Walker.

"It serves a couple of purposes for us," says Mr. McMillan. "First, it allows us to prove out a turn-mill candidate without interrupting production. It also allows our engineers to test more than one concept at a time. Prototype turnaround is now a matter of hours instead of days or weeks. The advantages to the company of having a dedicated machine more than justify the costs."

Results from the dedicated turn-mill cell have been impressive. Last year, product development was able to introduce new products at a rate ten times more than the previous average. And the trend is up, reports Mr. McMillan.

"A big advantage of this CNC machine for R&D purposes is that when an engineer is developing a product and needs prototypes to test, the turn-mill machine can crank out twenty of the same part or twenty slightly different versions of the same part for testing. Our conventional toolroom simply can't produce the quantity and variety that this machine tool can. Plus, the part program serves as a record of what changes were made and what works best. When the design is approved, we can transfer the program directly to a production machine and be assured the production pieces will match the prototypes," says Mr. McMillan.

Programming Turn-Mill

Programming a turn-mill machine is conceptually different than a conventional lathe, but may or may not be more difficult, depending on the capability of the machine's CNC. "We know how to program lathes from our experience with four-axis. That can get fairly complicated and some of the processing techniques, such as simultaneous cuts and operation sequencing, aren't that different from turn-mill," says Mr. Walker. Turn-mill programming is done on the machine. The CNC for these turn-mill machines is powerful, fast and has macros that make the programming job very easy. "The milling portion is as simple as programming a knee-mill, except you're using a high-powered computer to move it around," says Mr. Walker.

"The maximum time for programming a part on one of these machines is approximately two hours," explains Mr. Walker. The part shown in Figure 4 was programmed in one hour and took only about four minutes to cut.

At the prototype machine, Mr. Walker programs and test-cuts potential production parts to prove them out for turn-mill processing. When the program is written and proven, it is duplicated and sent to the machine that will run it. TFT uses DNC to save all programs on a UNIX-based host computer.

Looking Down The Road

TFT firmly believes in turn-mill technology as a viable manufacturing process for many of their workpieces. Where does TFT see itself going in the future? "That's easy," says Mr. McMillan. "More automation and increased capability of the turn-mill concept."

As an example of that future, Mr. McMillan points out a Mazak Super Quick Turn 15MS with a gantry loader. The machine can produce up to 128 parts untended. In operation, the machine is tended about two hours a day, one each on the first two shifts, for part loading. Shift three runs untended until all the blanks are machined.

The machine has a subspindle that picks off the workpiece from the main spindle for back turning operations. Live tooling is available to machine on either spindle. "That's where the technology is going next," says Mr. McMillan. "And as for price, this cell cost only slightly more than our first four-axis turning center back in 1980--actually it cost less in constant dollars."

Is It For You?

Some people argue that adding milling capability on a turning machine is a division of efficiency. Combining distinct metalworking operations on one machine creates a compromise between the operations. One machine can't do two different operations, optimally.

On the other hand, if a workpiece needs turning and milling operations performed, it makes sense to set the part up once and do all operations then and there. This is the rationale for the turn-mill machine. Efficiencies are gained by less workpiece handling, relative tolerances can be more accurately controlled and throughput is faster.

Both of these positions are valid. Turn-mill capability is not applicable across the metalworking universe. However, when it can be applied, results are often dramatic. The technology has advanced to a point where it is a viable machine tool for any shop. With increased pressure on delivery schedules and quality, turn-mill should be added to the must-see equipment shopping list.

A Need And A Napkin

The idea that launched Task Force Tips was sketched out, literally, on the back of a napkin by Mr. Clyde McMillan, the company founder. Mr. McMillan was a volunteer firefighter and an engineer. The original idea was to manufacture a nozzle that automatically controlled the pressure of the water coming out so firemen could always have the correct water pressure to fight a fire.

With automatic pressure control available at the nozzle, it allows the fireman to operate the valve on the nozzle like a throttle. As the valve is opened and closed, the discharge nozzle automatically sizes itself to deliver water in a controlled manner. For the first time, a nozzleman, deep inside a burning building, could control the amount of water delivered on the fire from a dribble to a 250-gallon-per-minute deluge, without having to send a runner out to the pump operator to make a change in pump pressure.

Product innovation continues to come from the company. But those innovative products are possible, in large part, to innovative manufacturing and the use of appropriate technology, regardless of convention.

For more information on turn-mill technology from Mazak, circle 36 on the Postpaid Card.

Machine tool axis drift (and what to do about it)

Gluzman, Dave

Machine tools equipped with rotary encoders can experience position drifting when they reverse their axial direction of movement. Precision milling operations require a linear accuracy of 0.0003" (0.0076 mm) over 15" (380 mm) of axial travel, and drift can make attainment of that accuracy impossible.

Machines that exhibit this phenomenon are normally equipped with a rotary encoder, a ballscrew with a ballnut-leadscrew coupling, a pair of matched thrust bearings that support the screw, and a CNC control that can compensate for backlash and pitch error.

During tests conducted to find out why axial drift occurs, each axis traveled a certain number of steps in each direction. At every stop point, a laser interferometry data acquisition/analysis system automatically measured the difference between the actual position and the target position. That difference equals the axis error. To detect backlash, after the last stop the axis did an overrun (a short "forward-reverse" motion), and the system read data again. On some machines we tested, the error curve shifted with each run and never settled down. We call this phenomenon axis drifting.

Drift severity varied from one machine to another, ranging from barely measurable to 0.0001" (0.0025 mm) per run. Machines went through a warm-up period before the tests to eliminate any temperature-- induced effects.

Normally, with the axis reversing direction at each end of the travel, any noncompensated backlash should appear on an error plot as a shift in the curves for forward and reverse moves for one run. A difference in backlash at the ends of travel, though, results not only in shifted forward-- reverse curves, but in drifting as well. Putting it another way, axis drift occurs because backlash at the right-hand reversing point differs from backlash at the left-hand reversing point.

With unequal backlashes, compensating backlash at one end leaves the other end not completely compensated. If both end backlashes were absolutely equal, a change in the direction of movement would not cause drift, even without backlash compensation.

It's well known that backlash occurs because of loose or worn ballnut-leadscrew couplings; loose, worn or non-- similar axis thrust bearings; improper bearing preload; or improperly adjusted gibs. Experience suggests thrust bearings are the major contributors to drift. Thrust bearing replacement and proper pre-load minimize drift. Because some machines we tested were nearly drift-free, we believe that proper installation and adjustment procedures, and replacement of faulty components, could cut drifting to a negligible level.

Keep in mind that mills equipped with linear scales, as opposed to rotary encoders, don't experience this drift. Even if a mechanical backlash occurs, the linear scale eliminates its effect. It's also important to differentiate between drift caused by warming and that resulting from backlash.

Dave Gluzman

Equipment Reliability Engineer Sulzer Carbomedics, Inc. Austin, TX

Looking For Laser Engraving Information?

By Helen Hecker

Laser engraving history: It was in the early sixties that scientists first discovered they could create a light source, focus its energy and have a tool powerful enough to affect a wide range of materials. You can think of a laser as a light source that's similar to a light bulb. A light bulb will emit energy all around it.

The favored marking method is by laser when permanency or aesthetics are called for. And with advanced software today you can laser engrave practically anything including Bar Codes, 2D codes, photographs and company logos.

Unlike the conventional engravers some use an intense beam of light instead of a rotating or vibrating tool. This beam can either vaporize a small area of the surface called laser engraving or cause a change in surface color of the material called laser marking. The beam is controlled by a computer at high speeds and accuracy to give exceptional quality at a very cost-effective price. Sometimes marking is referred to as laser etching. Unlike conventional etching, needs no masks or chemicals.

Like many inventions in our recent times, lasers were first conceived in the laboratory. There are many advantages to using a laser over other methods of engraving. Because the tool is a beam of light, there's no contact with product, which means less chance of having product damage or deformation.

The metal cutting option can easily be added to some of the laser cutting machines. Engraving metal uses the most power especially if it is the harder type.

Laser etching can take place on many materials including slate, granite, stainless steel, leather, arborite, glass, mirrors, premium hardwoods and on graphite it's a clean operation.

Laser cutting adds high precision, less contamination or warping and quality finishing to industrial cutting applications. The ability to cut complex profiles can totally eliminate the need for added operations, making it highly economical.

A few of the items that CO2 laser systems can be used for regarding marking and etching glass or quartz are float glass plants, manufacturing of glass doors and windows. There is also permanent serial numbering, ANSI safety information, customer logos, decorative or specialty glass manufacturing, manufacturing data related to plant, production date and line, and/or part numbers. You can easily mark in batches of from 1 to 10,000. Marking of glass by CO2 lasers while moving can be an excellent add-on for many industrial environments and applications.

Laser marking is a process in which the material is indelibly marked at fast speeds (milliseconds per character). It's also favored when the part to be marked is too small or has too complex of a shape to be marked with anything except laser etching. Industries that use it include the promotional, engineering and medical industries.

Amid the many items being engraved today, iPods and laptops rank among the highest in the marketplace. Some of the products include wedding giveaways, nametags, table nameplates, trophy and wood engraving.

Laser engraving can be used for the kind of jobs carried out by conventional industrial engravers. Engraving machines are common today. And services are available in specialty stores because it's the most common type of engraving today.

For more information on laser engraving and laser engraving machines, laser marking, laser etching and laser cutting go to http://www.EngravingLaser.net for tips, help, facts, free

resources, including information on all types of laser engraving

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The Different Types Of Model Prototyping

By Low Jeremy

Rapid prototyping is an intensive process of collecting information on requirements and on the adequacy and functionality of fairly new product designs. Model prototyping is an important data resource during the different stages of product development. Model prototyping makes use of various kinds of rapid prototyping techniques to provide the right model types used for different testing procedures. Such techniques may require the use of requirements animation, incremental, and evolutionary prototyping.

1. Requirements Animation- is the method used mainly to demonstrate functionality in test cases that can be easily assessed by users. Software

tools are used to produce representational prototype models that are built using animation packages as well as screen painters.

2. Incremental prototyping- enables the development of large prototype system models installed in phases in order to avoid delays between product specification and its final delivery into the consumer market. Once the customer and supplier have agreed on certain core features, the installation of a skeleton system is applied as soon as possible. Important requirements can be checked out as the model is being used, enabling changes to core features while in operation with extra and optional features can be added later.

3. Evolutionary prototyping- considered as the most integral form of prototyping. It acts as a compromise between production methods and with that of model prototyping. Employing this technique, a model prototype is initially constructed that is then evaluated as it evolves continually and becomes a highly improved end product. Many designers believe that more acceptable systems would result if evolutionary prototyping were interconnected with periods of requirements animation or rapid prototyping. Here the tools are the actual facilities resources where the final system will be implemented.

The use of different model prototyping techniques can help do away with the uncertainties about how well a final design may be able to fit into the end user's needs. The different model prototyping techniques help product designers make the necessary decisions by obtaining information from initial test users about the effective functionality of a certain product prototype.

Model prototyping can also be an effective aid in determining how effective and ideal the features and the overall design can be for proposed users. Model prototyping and the subsequent testing procedures can provide useful representation information that can reveal possible design flaws, effective features as well as useless functions that can either be corrected, enhanced or done away with on the next stages of product development.

Low Jeremy maintains http://prototyping.articlesforreprint.com

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The Benefits Of Rapid Prototyping

By Low Jeremy

Rapid prototyping objects have been one of the many contributions of modern technology. Rapid prototyping makes it possible to make out and construct physical objects by using solid free form fabrication methods. Different industries make use of rapid prototyping techniques to produce evaluation models and prototype parts of new products before they can ever be put into final production.

Having an evaluation model can help product developers look for certain design errors or further improve a new product before manufacturing them for the consumer market. This will ensure consumers of better quality products with little or no defects. All can be made possible through the use of rapid prototyping processes.

Rapid prototyping techniques can help reduce the many uncertainties about how well a new product design will fit the user's needs. Rapid prototyping helps designers to assess and make better informed decisions by obtaining data from the initial prototype users about the functionality and features of a new product. Rapid prototyping techniques can provide additional information to designers that enable them to improve and correct possible defects on a new product before it can ever be put out into the market.

Rapid prototyping techniques can help product designers and developers come out with better quality products. Here are just some of the benefits of rapid prototyping:

1. Prototyping is very important at different stages of design. From conceptualization at the task level and determining the feature aspects of a new product, rapid prototyping techniques can help provide designers with a better visual as well as physical understanding of the product and see for themselves how their product will eventually fare out in the market.

2. Prototyping can be used to gain a better understanding of the kind of product required in the early stages of development. It can help designers keep track of the design improvements and possibly test out its effectivity with a control group.

3. Rapid prototyping techniques help product developers become more flexible as well as more creative in coming out with new products. It helps widen the room for improvement in terms of product design. Most people may tend to believe that once a good version of an product design is made, they can get easily carried away by thinking that this must be the only or the best possible design solution. By having prototypes made, designers may be able to think of other design approaches that they think will be better for a certain product concept.

Low Jeremy maintains http://prototyping.articlesforreprint.com

Rapid Prototyping Building Materials

By Low Jeremy

Rapid prototyping is the process used to generate three-dimensional models that do not require any machining or tooling. Instead, rapid prototyping makes use of cutting edge technology that allows a physical object to be formed by adding a material layer by layer until the desired shape is achieved. This additive process is being used instead of building prototypes by cutting away material through machining which is subtractive.

Rapid prototyping allows more flexibility than machining because the even complex model designs does not suffer any limitations during its production. Rapid prototyping enables engineers and product designers to generate three dimensional models quickly and accurately.

Different rapid prototyping systems make use of a variety of materials to create different three dimensional objects. A comm. on material used is prototyping wax. This material is usually ideal when engineers and designers require small quantities of casting parts to create intricate patterns without the use of tooling.

Prototyping wax can also be used together with other types of prototyping materials in order to make the resulting prototype work better with different casting methods that make use of metals as well as non-metals. Combining prototyping wax with other materials to create the models will also be ideal for low-temperature furnaces and vacuum plaster casting methods.

A rapid prototyping modeling process utilizing prototyping wax to create a wax pattern can be advantageous in some ways. Forming and de-waxing a shell mold made from prototyping wax can be done quite rapidly using normal casting procedures. Using this type material simplifies in a way the model-making process that helps you to get your products to be developed and be released in the market faster.

Aside from prototyping waxes, there are also other materials being used for a number of rapid prototyping processes. One such material is thermoplastics. If product engineers are looking forward in creating durable prototype parts that might require aggressive functional testing, thermoplastics can be the ideal material to use for rapid prototyping. Thermoplastic materials have effective heat and chemical resisting properties that make them the best choice for models that undergo aggressive product testing procedures.

Not only that, thermoplastics also provide excellent surface finish to prototype models. They are also machinable and weldable when required. Thermoplastics can also be joined mechanically or with the use of special adhesives. Other prototyping material choices available include powdered metals for injection molding, and for directly creating metal prototype parts, Polycarbonate and polyphenylsulfone materials for forming durable, high-strength, and functional prototypes that are to be used for testing and final design verification.

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Benefits of Rapid Prototyping

By Low Jeremy

The basic principle in rapid prototyping is done in broad applications on wide range concept designs. The range covers no bound, but commonly applied to medical, engineering, and industrial discipline. It involves the digital capabilities of computers to accomplish its complex processes. To make it easier to understand, the essence of rapid prototyping starts from the word simulation.

Rapid prototyping starts from drawing boards or papers, whether graphically drawn or written, the concept takes off and digitally represented. An example of this is when sensitive surgical operations involve wasting away one life to execute, the studies are accomplished not just by diagnosing but the whole process has to be simulated with computers.

Say, a cranium (of the skull) can be remodeled artificially from 3D generated prototyped models in its actual form for planned strategies before the execution takes place. Pre-operations with the use of this system will lessen the risk of failure than the traditional way of imagination only.

Today, in the advent of vectors, or mathematically computed imagery manipulated by computers, designs can be simulated to scales with very minimal error or difference of about less than 1 millimeter. Applied to engineering tasks, mechanical and any other tangible items are pre-designed via rapid prototyping.

Clients are able to see realistic images of simulations, can scrap everything or do changes without wasting insurmountable funds for actual samples, except for the design payment of the particular stage.

Models are machine prototyped for better visibility and appreciation. Achieved as 3d designs, it is easy to manipulate physical property changes with computers while it makes the whole method fast, reliable and rewarding.

It takes teamwork to achieve rapid prototyping and the application of its principles in a particular field. Basically, most of the tasks are done during the design schematic process. It is now a part of any sensitive productions to do rapid prototyping before deciding on how the project or product will make or break it own future in the market. Or in case of surgical applications, it aids in the crucial steps the specialists will take part in a life-threatening solution rapid prototyping can offer.

As advancements go further, rapid prototyping will gear to better improvements. It will always involve additional cost to a company or organizations, but the benefit is something the world cannot let go as a simple life-saving advantage. It is one of the great accomplishments of the digital age.

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What You Need to Know About Rapid Prototyping Systems

By Low Jeremy

Rapid prototyping is the method of constructing physical objects using solid freeform fabrication. The use of rapid prototyping techniques had its start during the 1980's where it was used to build product models. Its current applications have been put into use in a wider range of objectives.

The technique can even be used in order to manufacture quality useable parts in small numbers. Rapid prototyping has even found some applications in the art scene where sculptors use the technology to create intricate shapes that become art pieces.

An improved digital rapid prototyping system makes use of computers in order to create highly accurate design pieces. A digital rapid prototyping system makes use of virtual designs usually created with the help of computer aided design or animation modeling software programs.

The system then transforms the design into virtual cross sections which a special machine uses to recreate the exact design cross sections in physical space until a physical model is finished. The highly technical process enables virtual designs to take physical shape in very exact and accurate manner.

In rapid prototyping, there are usually two basic approaches to design systems being used. The approach chosen can either be formative or summative. The formative approach is being used for situations wherein the prototype is first built based on the current stage of the design. It is then tested on a control group with the results being used to integrate into the next stage of development in order to further enhance and improve on the usefulness of the current design.

The summative approach on the other hand takes a different course in developing product design. A single test exercise is performed at the end of the overall design enhancing process. At most times the approach is a two step stage. Following the summative approach can sometimes make it too costly to make design changes as the end stage nears.

But this approach is less time consuming and can be more cost effective initially if the projected design is seen to require little refinements when a prototype is done. But in the long run, using the formative approach will definitely be more beneficial. The main reason for this is because when a system is tested as a whole only once at the end of the design period, it may be very difficult to pin point the various flaws that may exist within the design.

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Rapid Technology Prototyping

By Lisa Parmley

Rapid technology prototyping, alternately referred to as rapid prototyping (RP), is currently the most advanced method for quickly creating a prototype.

This technology is accomplished by using a rapid prototyping machine. Rapid prototype machines can produce prototypes in mere hours. Depending on the complexity of the prototype, it may take anywhere from just a few hours to a few days for its completion.

Rapid technology prototyping is also commonly called solid free-form fabrication, layered manufacturing, or computer automated manufacturing.

The benefits of using rapid technology prototyping are…

»Any object of any complexity can be formed fairly easily and quickly without the need for machine setup or assembly.

»Objects are made from multiple materials or as composites.

»Since usually only a single unit is produced, the costs can be kept down to a bare minimum.

Here's a brief explanation of how it works…

Basically, rapid technology prototyping takes traditional 2 dimensional printing and adds a third dimension to it. Therefore, rapid prototyping machines are fondly called 3 dimensional printers. Rapid technology prototyping takes a Computer-Aided Design (CAD) model and using a laser, creates a physical model out of a variety of media. The media types include paper, ceramic material, wax, or even plastic.

In contrast with most machining processes, rapid technology prototyping is an "additive" technique. This means layers of media (whether paper, ceramic, wax or plastic) are combined to create a 3-D solid object. Most machining processes, such as drilling and grinding, are "subtractive" techniques, where material is removed from a solid block.

The process of rapid technology prototyping is listed out below …

»First, you need a CAD model of your invention.

»Next, the CAD model must be converted to STL (stereolithography) format. This file represents your invention as a series of triangles like that of a cut diamond. STL does not represent curved surfaces, only cut surfaces. However, you can create what appear to be curved surfaces by increasing the number of triangles.

»The STL file will need to be sliced into layers from 0.01 mm to 0.07 mm thick, depending on the build technique you choose.

»Construction of the object takes place layer by layer. The rapid technology prototyping machine builds the layers from the selected media.

»The final step is to clean and finish the prototype. In many instances, it will be sanded, polished or painted.

What is it used for?

Rapid technology prototyping is commonly used by inventors to help communicate their invention to a patent attorney or a trade representative. It may also be used for gaining manufacturing quotes, trying to sway investors and in marketing focus groups. As you can imagine, it is much easier to communicate an invention using a 3-D prototype than with a 2-D drawing or blueprint.

What does it cost?

Of course, costs range due to the complexity and size of your invention. They can also increase if you need additional design work such as painting done. Smaller prototypes can be made using rapid technology prototyping for about $250. You can gain an estimate by calling several companies.

There are limitations to rapid technology prototyping, but it truly is revolutionary. In the past, inventors had to wait weeks, sometimes up to months and pay much higher fees to have a single prototype made.

It is also possible to use rapid technology prototyping for making tools. This technique is known as rapid tooling. In addition, it can even be used for the production of parts and manufactures, known as rapid manufacturing.

Please visit www.PatentYourInventions.com to learn more about patenting, prototyping and marketing your invention.

Lisa A. Parmley - Registered Patent Agent

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The Fabber - Real World 3D And Rapid Prototyping For The Hobbyist And Home User

By Tim Morrison

Solid Freeform Fabrication or Rapid Prototyping has been around for quite a long time now. Many commercial companies offer various type of machines that can manufacture high precision parts out of both plastic or metal to exating tolerances. The downside, they cost anywhere between $15,000 and upwards of $90,000. Some machines can even run up to $500,000.

The Fabber is a joint project started in the Computational Synthesis Lab at Cornell by Dr. Hod Lipson. He initially visualized the Fabber as a tool to reproduce lost Lego pieces. It is a low cost reasonable detail sold freeform modelling or fabrication tool with a build volume of about 512 cubic inches. or an 8" cube.

What the Fabber really represents is a grass-roots approach to what has been a niche product for more than 20 years. As they explain, they are comparing the Fabber to the Altair 8000, one of the first microcomputers and one of the things that triggered the home computer boom back in the mid 1970's. The Fabber even costs about the same with inflation, at about $2300 for parts, whereas the old Altair would have cost about $2000 in today's dollars.

What the Fabber is specifically, is a Solid Free Form Fabrication tool. It uses a lifting table combined with a XY axis stepper motor that guides a print head or engine that contains a number of syringes. Each syringe can hold a different fluid material, and depending on the size of the nozzle, you can potentially use the Fabber to build very small and detailed objects.

The real beauty of the tool is that it is all made from off-the-shelf components. For a little over $2,000 you can buy the complete kit and put it together, or buy a fully assembled unit from a company called Koba Industries, which has partnered with Fab @ Home to build and sell the product at only a little bit above assembly prices.

The Fabber will take a standard STL file format used by any of the 3D design applications and produce an actual model based on that file. They have used the Fabber to produce a watch with embedded electronics, a working flashlight with circuitry injected, as well as some other really cool things.

This is a brand new technology and certainly not as refined as the high end production machines that can be bought for multi-thousands of dollars. But as a concept, it's something that can be developed and evolved. All it takes is ingenuity and a desire to see how far you can go.

For details on this exciting new hobby tool go to http://www.fabathome.org

Tim Morrison is a founding member of Morristreet.com, a technology company developed to bridge the gap between virtual and real worlds in the realm of 3d. Our goal is to be able to produce a 3d image on the computer and then produce it as a physical object - no matter what the complexity or detail involved. In this vein, we keep track of anything in relation to 3D imagery that can bring our goals closer, be it gaming consoles that can do more than play games, hardware imaging solutions, or software that can make our lives easier. Real World 3D is coming, Morristreet is in the lead!

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Rapid Prototyping by Annette Kalbhenn

Rapid Prototyping (RP) is currently the most advanced method for quickly creating a prototype. This is achieved by using a Rapid Prototyping machine. Rapid Prototyping machines can produce prototypes in a very short time. Depending on the complexity of the prototype, it may take anywhere from a matter of hours to a few days for its completion. Rapid prototyping is also commonly called solid free-form fabrication, layered manufacturing, or computer automated manufacturing.

Rapid Prototyping helps in the following areas:

* Help to visualize models better and thereby increase communication * Help you to test and verify your design for fit & function * Decrease development time and hence time to market *

Help avoid costly manufacturing mistakes

In addition to parts for testing and verifying, Rapid Prototyping can be used for the production of 'short run' parts where multiples are produced without traditional tooling and molds being required. This is also known as Rapid Manufacturing.

Rapid Prototyping grows a part using a Computer-Aided Design (CAD) model and a Rapid Prototyping machine to create a physical model using an additive method, layer by layer. A variety of materials are available depending on the specific method of Rapid Prototyping equipment used. These materials can include plastic, resin, metal and wax. Machining processes, such as CNC milling use a subtractive technique, where the material is removed from a solid block to create the part.

Here's a brief explanation of how Rapid Prototyping works:

Step 1: A computer-aided (CAD) model is constructed and then converted to STL (Standard Tessellation Language which is native to CAD software) file format. The STL file is the standard interface between the CAD software and the Rapid Prototyping machine.

Step 2: The Rapid Prototyping machine reads the STL file and creates cross-section layers of the model.

Step 3: The first layer of the model is created. The next layer is added at the thickness determined by the Rapid Prototyping machine and the process is iterated until the complete model is built.

Step 4: Selected users from the stakeholder groups participate in a brainstorming session to test the prototype.

Step 5: User observations are summarized and evaluated.

Step 6: The prototype is refined where necessary and the above processes are repeated. If necessary.

What is it used for?

Inventors and product development teams easily use rapid prototypes to help communicate their invention to customers, supervisors, manufacturers without communication barriers that can sometimes occur with 2D drawings and words. Prototypes are now an integral part of the design-to-market process as they help ensure projects run as quickly and cost efficiently as possible.

Rapid Prototypes may also be used for communicating with manufacturers (especially over seas), to attract investors, customers and in consumer marketing focus groups. As you can imagine, it is much easier to communicate an invention or design using a 3-D prototype than with a drawing or blueprint.

What does it cost?

Costs vary widely based on the complexity and size of the invention, the type of process used and quantities required. You can gain a quote by contacting companies who offer Rapid Prototyping services or requesting a quote on-line.

About the Author

Annette Kalbhenn is Business Development Manager at a Rapid Prototyping service bureau. For more info on how you can benefit from Rapid Prototyping check out http://www.3dprototype.com/

Rapid Prototyping Improves Your Business Result

by Gordon Styles

Making errors in manufacturing process can be a disaster to a factory. Substantial re-work will increase the cost and that can kill your factory, especially for small factory. To avoid making fatal errors, manufacturers should construct a conceptual design. The most effective way to construct a conceptual design is rapid prototyping (RP). This method allows you to build a prototype with minimal cost in a short time period. Unluckily, there is only 10% small companies have adopted rapid prototyping (RP). The following presents advantages of adoption of RP in depth.

What is RP?

RP makes virtual designs from CAD software, processes them by transforming them into cross sections, still virtual, and then forms or manufactures each cross section in physical space, one after the next until the model is finished. The appearance of prototypes is almost identical to the actual product.

Stereolithography is one of the more commonly used RP technologies. It is considered to provide high accuracy and good surface finish. It involves building plastic parts a layer at a time by tracing a laser beam on the surface of a vat of liquid photo-polymer. The photopolymer is solidified by the laser light. Once one layer is completely traced, it is lowered a small distance into the liquid and a subsequent layer is traced, adhering to the previous layer.

Benefits of RP

1. Time Reduction

In most cases, firms using RP technologies have gained time reductions in the production of prototype tooling and parts.

The figures for time reductions on prototyping vary greatly, ranging from 60 to 90%. On the whole this range is likely to be realistic given that the estimation of time savings, when compared to the conventional methods of prototyping, is a fairly straightforward matter.

2. Cost Reduction RP allows firms to identify mistakes before commitments are made to expensive tooling, machines, and large scale manufacturing process. It is widely known that correcting errors at initial stage is much cost effective than correcting errors at later stages.

3. Innovation For the reasons of short production cycle and relatively low cost, some firms are using RP in more innovative ways. Some examples include:

- Development of new analysis and testing procedures - Manufacturing conceptual design of production tooling - Improving communications across product divisions - Supporting customized manufacturing

Conclusion: RP provides designers, model makers, manufacturers and others with highly accurate prototype parts. Rapid prototype turnaround time is a proven way to reduce time to market.

It can even reduce direct development costs.

The only drawback is the initial high capital investment for RP machines. One of the ways to eliminate this disadvantage is to employ a RP manufacturing service provider.

About the Author

Star Prototype China Limited, a rapid prototyping manufacturer offers high quality but low cost rapid prototype production. It provides a SLA prototyping and CNC prototyping

A Quick Look at Rapid Prototyping. solid model - The technology for creating a physical model directly from a computer-aided design CAD

Lawrence S. Gould

Nowadays you have a slew of machines to choose from for making physical reality out of virtual solid models.

Rapid prototyping (RP)--the technology for creating a physical model directly from a computer-aided design (CAD) solid model--has grown quite a bit since its introduction in the early 199Os. For starters, there are a lot of RP technologies. Second, there are a lot of vendors making RP machines. Third, these machines are getting smaller, while the models they can create are getting larger and more accurate.

All the RP technologies have some things in common. All are additive processes (machining is subtractive). All the RP machines "grow" models one, thin, two-dimensional layer at a time--from the bottom up. Models are grown on an elevator-Like platform, which is lowered one layer-height once that layer is completed. Each layer is a cross section of a solid model created in CAD. The thinner the layer, the smoother the finish on the completed model; however, once the model is complete (after curing and support structures removed, if required), most of them, depending on material, may be sanded, plated, painted, or finished in some way.

There are differences. RP technologies are mostly either "dry" or "wet" processes. Most of the RP machines solidify some sort of loose powder, liquid, or semi-liquid. One RP machine cuts through adhesive-coated sheets of material. RP powdered materials are either some sort of polymer, powdered metal, or wax. One company uses starch. Some of the powders require a binder.

The liquid materials are photosensitive polymers that solidify when exposed to either laser or ultraviolet (UV) light. Wet RP processes generally require a curing phase.

Here's a rundown of several RP technologies.

Dry: Direct Metal Deposition (DMD)

DMD, commercialized by Precision Optical Manufacturing (Plymouth, Ml), uses a computer numerically controlled (CNC) laser to fuse layer-upon-layer of metal powder. The resulting prototypes--made from H13 tool steel, aluminum, and other metals--are finished injection and die casting molds meant to be used in production.

While the layering process is slow--for steel, the deposition rate is approximately 1-in. 3/hr--DMD has one big advantage over other RP methods: the metallic composition of the finished parts can be altered "onthe-fly" by Adding different types of metal powders to the mix (e.g., adding copper for heat sinks in tool stell molds).

Dry: Fused Deposition Modeling (FDM)

FDM from Stratasys Inc. Eden Prairie, MN) acts like a finely controlled hotmelt glue gun. But instead of glue, FDM gingerly extrudes an ultrathin layer of thermoplastic filament from a spool. Actually, two filaments are extruded: one for the model and the other for the undercut/overhang support. FDM modeling materials include ABS investment casting wax, elastomer, polycarbonate, polyphenylsulfone, and durable polyester. Stratasys makes RP machines ranging from small, networkable "office modeling systems" to large standalone machines. The office systems can make parts as large as 12 x 8 x 8 in. at a rate of 4 in./sec. accuracy is [+ or -]0.013 in. The standalone machines can build models measuring 23.6 x 19.7 x 23.6 in. The accuracy of these models, when larger than 5 in., is [+ or -]0.0015 in./in.

Dry: Laminated Object Manufacturing (LOM)

The LOM process from Cubic Technologies, Inc. (Carson, CA), which acquired LOM from Helisys, builds wood-like parts using a laser to cut layers of thin paper coated with heat-activated adhesive. This paper is individually cut and bonded together until the model is finished. Along the way, crosshatches are cut into the excess paper. The finished part out of the LOM system is inside a solid block of material as big as the work envelope. This excess material, along with other unwanted material within the part, is removed manually. LOM models are accurate to 0.002 in. along the Z-axis and 0.005 in. overall. Large parts-up to 22 x 32 x 20 in.-can be made at a rate of 3 to 7 hours per vertical inch. Thick- walled parts are made just as fast as thin-walled ones.

Dry: Selective Laser Sintering (SLS)

DTM Corp. (Austin, TX) uses a CNC laser to draw cross-sections in a bed of fine, heat-fusible powder. The laser raises the temperature of the powder particles momentarily to where they sinter. Hence the name SIS. ("Suntering." just as a refresher, means welding without melting.) SLS works with a broad range of materials, including rigid thermoplastics, thermoplastic elastomers, polystyrene, stainless steel powder, investment casting wax, and ceramic powder. DTM's latest SLS RP machine can create complex parts with features as thin as 0.020 to 0.025 in. in a work envelope measuring 15 x 13 x 18 in.

Wet: Stereolithography Apparatus (SLA)

The SL series of machines from 3D Systems (Valencia, CA) creates models as large as 20 x 20 x 23.75 in. having a laser "draw" cross sections of the model in a vat of liquid pho boundaries of the cross as its internal structure, are draw and cured-- by laser under separate intense UV fies the model's internal structure.

Three-Dimensional Printing (3DP)

Imagine an ink-jet printer. Now think of it producing 3D prototypes instead of printed pages. That's the 3DP technology invented at Massachusetts Institute of Technology (Cambridge, MA).

A variety of RP vendors have licensed that technology to make relatively small and inexpensive RP machines that can make a quick, on-demand concept model, as well as more durable prototypes for production (as in for making dies).

3DP: Direct Shell Production Casting (DSPC) Soligen Technologies Inc. (Northridge, CA) is a rapid-castings company. Its DSPC process produces ceramic casting molds for metal casting using a layer-by-layer printing process. The process involves a multijet print head depositing liquid binder onto a layer of ceramic powder. After a mold is "printed," it is fired to create a rigid ceramic mold. You can pour any molten metal into these molds, thereby eliminating several steps required in investment casting. Plus, these molds are more accurate than those from standard sand casting. Tolerances for lengths smaller than 1 in. are [+ or -]0.021 in.; for lengths greater than 6 in., accuracy is [+ or -]0.031 plus 0.003 in./in. over 6 in.

3DP: Photopolymer

The Objet Quadra printer from Objet Geometries (Mountainside, NJ) should be commercially available about now. The printer has 1,536 ink-jet nozzles that spit out a proprietary photopolymer that is cured under UV lamps located on the ink-jet head assembly. For models with undercuts and overhangs, the Quadra deposits support material made of a photopolymer designed for easy removal. The Quadra printer has a print resolution of 600 dpi x 300 dpi x 1270 dpi (X, Y, Z); the prototypes it creates can measure 10.6 x 11.8 x 7.8 in.

3DP: Powdered metals

The ProMetal Div. of Extrude Hone (Irwin, PA) uses an electrostatic ink-jet printing head to deposit a liquid binder material onto powder metals. The resulting metal part is then sintered in a furnace and infiltrated with secondary metal. These printers can make steel molds and parts up to 40 x 20 x 10 in. at over 250 [in.sup.3]/hr.

3DP: Starch

Z Corp. (Burlington, MA) uses a conventional print head from an ink-jet printer to produce full-color (24-bit, six million colors) models using a special--and inexpensive--starch powder for the model and binder as "ink." (You can just about eat your design failures.) Models can be as large as 8 x 10 x 8 in., with a model accuracy of [+ or -]0.005 in. in the X- and Y-axes, and [+ or -]0.010 in. in the Z-axis. Finished parts can be dipped in wax; sanded, finished, and painted; or infiltrated with another material, such as an elastomer, urethane, cyanoacrylate, or wax. Z Corp. also offers a plaster-based powder for greater part strength (10 MPa versus 4 MPa), which is particularly suited for delicate or thin-walled parts.

3DP: Thermoplastic

RP printers from Solidscape Inc. (Merrimack, NH) are best for making high-precision tooling and casting patterns, and for making tiny, intricate parts. Solidscape's RP machines have two ink-jet heads that spew out 6,000 to 12,000 droplets per second. One head deposits a non-toxic thermoplastic material similar to an investment casting wax. The other deposits a red wax that serves as a sacrificial support.

Solidscape's RP machines have a 34 x 26-in. footprint and can make models measuring 12 x 6 x 8.5 in., with accuracy [+ or -]0.001 in./in., surface finish between 32 to 63 micro-inches (RMS), and a minimum feature size of 0.010 in. (3D Systems offers a similar printer that makes models as large as 10 x 7.5 x 8 in.)

Principal Rapid Prototyping TechnologiesTechnology * CompanyDirect Metal Deposition POM (Precision Optical(DMD) Manufacturing) GroupDirect Shell

Production Soligen Technologies Inc.Casting (DSPC)Fused Deposition Modeling Stratasys Inc.(FDM)Ink-jet printing Extrude Hone Corp.Ink-jet printing Objet Geometries Ltd.Ink-jet printing Solidscape, Inc.Ink-jet printing (Multi 3D Systems Inc.-Jet Modeling, MJM)Ink-jet printing Z Corp.Laminated object Cubic

Technologies, Inc.manufacturing (LOM)Selective Laser DTM Corp.sintering (SLS)Solid Ground Objet Geometries Ltd.Curing (SGC)Stereolithography 3D Systems Inc.Apparatus (SLA)Technology * RP processDirect Metal

Deposition Laser beam bonds(DMD) powdered metalsDirect Shell Production Multijet print head depositsCasting (DSPC) liquid binder onto powder layer to produce ceramic casting moldsFused Deposition Modeling Melted resin from a spool(FDM) extruded directly into partsInk-jet printing Electrostatic ink-jet printer deposits liquid binder material onto powdersInk-jet printing Ink-jet printer sprays layers of droplets of photopolymer cured by UV lightInk-jet printing Ink-jet printer sprays layers of droplets of thermoplasticInk-jet printing (Multi Ink-jet printer sprays layers-Jet Modeling, MJM) of droplets of thermoplasticInk-jet printing Ink-jet printing using starch- or plaster-based powders, plus a binderLaminated object Laser cuts sheets of adhesive-coatedmanufacturing (LOM) paper laminated into a single modelSelective Laser Laser melts and fusessintering (SLS) powdered materialsSolid Ground UV light through a mask solidifiesCuring (SGC) photo-sensitive liquid resinStereolithography Laser solidifies photo-sensitiveApparatus (SLA) liquid resin(*)(trademarked name, if applicable)

Material Issues

Just as there are various machines, there is an array of materials to select from, depending on both the machine's capability and the model's application. Thermoplastics: For durable plastic parts and patterns or test parts for aggressive functional testing. Resists heat and chemicals, provides an excellent surface finish, is machinable and weldable, and can be joined mechanically or with adhesives.

Elastomers:

For flexible, rubber-like prototypes and parts. Features high elongation, water impermeability, and heat, abrasion, and chemical resistance. Photopolymeric and polypropylene-like resins: For near end-use plastic prototypes right out of the RP device. Offer various characteristics including durability for fine features and thin walls snap-back memory, translucency, good thermal performance, and humidity resistance.

Foundry wax:

For small quantities of investment casting parts or for creating complex patterns without tooling. Foundry waxes can be infiltrated with other materials to make the resulting RP models work well with cast ferrous and non-ferrous metals, as well as autoclaves, low-temperature furnaces, and vacuum plaster casting methods. Powered metals (infiltrated or not):

For complex metal tooling and durable metal molds for injection molding and for directly creating metals parts. Has high thermal conductivity and can be plated, textured, machined, or worked with electrical discharge machining equipment.

Polycarbonate, ABS, and polyphenylsulfone:

For durable, high-strength, functional prototypes for testing and final design verification, as well as for producing tooling patterns and masters for casting and spray-metal tooling applications. Feature high impact resistance, toughness, heat stability, rigidity, and chemical resistance to corrosive agents such as oil, gasoline, and acids. Prototypes can be machined, drilled, tapped painted, glued, and sanded.

Rapid Planning for CNC Milling-A New Approach for Rapid Prototyping

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Abstract

This paper presents a description of how CNC milling can be used to rapidly machine a variety of parts with minimal human intervention for process planning. The methodology presented uses a layer-based approach (like traditional rapid prototyping) for the rapid, semi-automatic machining of common manufactured part geometries in a variety of materials. Parts are machined using a plurality of 2 Â½-D toolpaths from orientations about a rotary axis. Process parameters such as the number of orientations, tool containment boundaries, and tool geometry are derived from CAD slice data. In addition, automated fixturing is accomplished through the use of sacrificial support structures added to the CAD geometry. The paper begins by describing the machining methodology and then presents a number of critical issues needed to make the process automatic and efficient. Example parts machined using this methodology are then presented and discussed.

Keywords: CNC Machining, Rapid Manufacturing, Rapid Prototyping, Process Planning, Computer-Aided Manufacturing

Introduction

The cost of producing small numbers of parts has been driven by the cost required to process-engineer the part(s). Traditional computer-aided process planning (CAPP) systems have reduced the time required to plan machined parts, but the cost for one or two-of-a-kind machined parts is still dominated by the cost of planning the part. The current use of CNC machining for these small quantities of parts is further limited by special tooling costs and machine setup.

The typical approach to planning parts for CNC machining has been to define the "features" of the part and match these features and tolerances to a set of processes that can create the required geometry to the specified accuracy. This approach has worked reasonably well for medium to high-volume parts, but it has had marginal success for the production of very small quantities of parts. In most cases, the time required to plan the part, kit the required tooling, and set up the machine (both fixture and tooling) has limited the use of CNC for these applications. The result is that rapid deployment of CNC machining has been relegated to a simple set of part geometries. The promise of minimal process engineering is a major factor that has driven the use of freeform rapid prototyping (RP) techniques. Unfortunately, many of these processes have been restricted to a small variety of materials with limited geometric accuracy.

In the literature, process planning is often approached with a set of goals driven by high production levels of parts-that is, a set of plans that strives for cost effectiveness through maximizing feeds and speeds and creating repeatable setups that can be paid for through economies of scale. Process planning for CNC machining includes tasks such as fixture planning, toolpath planning, and tool selection. There is a considerable amount of work in the literature pertaining to these three areas (Maropoulos 1995; Chen, Lee, and Fang 1998; Joneja and Chang 1999). The concept of flexible fixturing has been the topic of much research, though a completely autonomous fixture design system has yet to be developed (Bi and Zhang 2001).

Some exploration into the use of CNC machines for rapid prototyping has been published. Chen and Song (2001) describe layer-based robot machining for rapid prototyping using machined layers that are laminated during the process. The process is demonstrated using laminated slabs of plastic, machined as individual layers upon gluing to previous layers.

A hybrid approach using both deposition and machining called shape deposition manufacturing (SDM) continues to be developed (Merz et al. 1994). For each layer, both support and build material is deposited and machined in a combined additive and subtractive process. Sarma and Wright (1997) presented Reference Free Part Encapsulation (RFPE) as a new approach to using phase-change fixturing for machining. The approach was discussed recently in conjunction with high-speed machining (HisRP) (Shin et al. 2002). RFPE, in combination with feature-based CAD/CAM was proposed as an RP system (Choi et al. 2001).

Another approach is to use CNC machining for prototyping dies, an area called rapid tooling (Radstok 1999). One approach to rapid tooling uses machined metal laminates stacked to form dies (Vouzelaud, Bagchi, and Sferro 1992; Walczyk and Hardt 1998).

Many of these methods utilize CNC machining but do not address the fundamental problems of automating a fully subtractive rapid machining approach. This paper presents a method for "feature-free" CNC machining that requires little or no human-provided process engineering. The methodology described in this paper is a purely subtractive process that can be applied to

any material that can be machined. The method described herein was developed in response to the challenge of automating as much of the process engineering as possible. The ultimate goal is to generate both the NC code and an automatically executed fixturing system by the touch of a button, using only a CAD model and material data as input. The process is perfectly suited for prototypes as well as parts that are to be produced in small quantities (~1 to 10).

Before beginning a discussion on the methodology, it is necessary to elucidate the set of constraints, both known problems in CNC machining and some self-imposed by the authors. For one, there will be a general assumption about the user-in particular that the human planner has no experience in machining. This is justified in light of the fact that one use of this methodology is for prototyping. During the early stages of design, one cannot assume that an experienced machinist is available. The system may need to be usable by a designer or engineer inexperienced in machining. The existing RP processes allow users to download CAD files and simply push a button to initiate the part building process. The same will need to be true for a rapid machining process. What does this mean in terms of the typical steps for process planning? The implication is that even moderately skilled tasks, including setting fixture and tool offsets, must be eliminated. More importantly, fixture design and implementation must be at least semi-automated. Overall, it is expected that the user will only be responsible for loading a piece of stock in a workholding device that is straightforward to use (e.g., a simple vise, chuck, collet, etc.).

Another assumption is that feature information will not be available as data input. In some cases of simple prismatic parts, feature extraction may not be a problem; however, for the general free-form part shape, it cannot be assumed that accurate and complete feature information is known. An example would be a CAD model generated by laser scanning of biological objects such as bones. This assumption suggests that toolpath plans must be generated without knowing what type of surface geometries are to be machined. This includes choosing the tool diameter and length, depth of cut, feeds, and speeds. Specifically, this assumption implies that the process planning method is not intended for populating features on a piece of stock material; rather, the entire surface of the CAD model must be cut from the stock material. In other words, process planning does not have to be done for each feature individually and then each feature milled in a sequence of operations. Although the difference may appear subtle, this assumption will be shown to have a significant impact on the framework of this methodology and will be explored in further detail in the proceeding sections of this paper. Lastly, it will be assumed that this process will be executed in a lights-out operation; given that, any catastrophic failure such as crashing the tool, holder, or spindle with any part of the machine tool or fixture must be prevented.

Overview of the Methodology

Methods have been developed to cover all aspects of process planning for rapid machining, including toolpath planning, choosing tool geometries, calculating setup orientations, and a concept for a universal approach to fixturing.

With regard to toolpath planning, the presented method borrows from layer-based RP methods. The general idea is to machine the visible surfaces of the part from each of a plurality of orientations. From each orientation, some but not all of the part surfaces will be visible. Only parts whose entire external surface is visible can be completely machined with this methodology. In some ways, this limits what can be done when comparing the methodology described herein to traditional RP techniques, but in no way reduces the flexibility when compared to traditional CNC machining. The goal is to machine the part from enough orientations such that, after all toolpaths are complete, all surfaces have been fully machined from at least one orientation. For each orientation, there is not a particular plan for a set of feature machining operations; rather, each orientation is machined using simple 2 Â½a-D layer-based toolpaths. This is very similar to the existing rapid prototyping systems; however, in this case, one is limited to removing only visible layers from each orientation instead of creating and stacking all of the true cross sections of the part from just one orientation.

Unlike existing rapid prototyping methods, CNC machining is a subtractive process; therefore, one can only remove the material around the periphery of a part (visible cross section of the part). To simplify the problem from both a process and fixtureplanning standpoint, only rotations about one axis for orientations of the stock material during processing are used. This not only reduces the problems associated with process planning, but it will be shown how this supports the collision-free nature of the approach.

The method can be executed on a three-axis CNC milling machine with a fourth-axis indexer. Round stock material is fixed between two opposing chucks and rotated between operations using the indexer. For each orientation, all visible surfaces are machined using simple layer-based toolpath planning. The feature-free nature of this method suggests that it is unnecessary to have any surface be completely machined in any particular orientation. The goal is to simply machine ALL surfaces after ALL orientations have been completed. This process is illustrated in Figure 1.

In the first operation (Figure 1a), much of this surface is visible from the first orientation; however, the dark areas under the overhanging surface are not visible. In the second operation, the originally "shadowed" region of the same surface is now visible (Figure 1b). This approach avoids the problem of feature recognition and feature-based process planning. At least two, but more likely numerous, orientations will be required to machine all the surfaces of a part about one axis of rotation. Even a simple part like a sphere will require two orientations.

Because it is assumed that no feature information is available, then a general method for tool selection is required. At each orientation, a tool is required that can reach to the last layer for machining without colliding with any previously machined surface or the stock material. This requires that the shank diameter be less than or equal to the flute diameter.

Because simple 2 Â½-D toolpaths are being used, then a flat-end tool is an appropriate choice. One will note that planning, only in this case the layer depth is set shallow enough (typically, maximum of 0.005 in./125 microns) that one can expect near finish machining results. Lastly, the diameter of the tool is simply the smallest diameter available in the given length. Because it is assumed that no feature information is available, then the only general approach is to use a small-diameter tool such that the most general shapes can be accessed. Unfortunately, there can be trade-offs with using the smallest diameter tool. For one, a small-diameter tool does not remove as much material at a given feed rate as a tool of larger diameter. The other problem is that small-diameter long tools can be deflected more easily under cutting forces. Tool deflection and chatter can be a problem. These problems make it necessary to maintain feed rates and depths of cut such that the tool does not bend or break. As such, the method is not very efficient. However, it is not as critically important to find an efficient solution for rapid manufacturing and prototyping, or at least not with respect to the actual material processing. The more important goal is to reduce or eliminate the preprocess engineering. Therefore, it is reasonable to trade off time spent planning the process for actual processing time.

Using this method, part surface contours are created with the same "staircase" effect seen in other RP methods. However, because machining is able to make very shallow depths of cut, rapid machining can produce very thin layer thicknesses. Although machining time increases with reduction in layer thickness, it does not necessarily do so proportionally because shallower depths of cut enable higher feed rates. Rapid machining can achieve layer thicknesses easily down to 0.001 in. (25 microns) or less.

One would note that if all the visible surfaces of a part from numerous orientations about a single axis of rotation were machined completely, then at some point the part would simply fall from the stock material. However, this method employs a fixturing approach that is similar in concept to the "sacrificial supports" used in many existing additive rapid prototyping processes. In this case, the supports are not added to the physical model; rather, they must be generated as added surfaces prior to toolpath planning. The sacrificial supports are currently implemented as small-diameter cylinders added to the solid model geometry parallel to the axis of rotation. During processing, the supports are created incrementally, along with the rest of the part surfaces. Upon completion, the finished part is left secured to the round stock material by these cylinders. The setup and process steps for creating a part using the current method are shown in Figure 2. An example of a toy jack is shown to illustrate the method for a typically complex and challenging part to machine-but straightforward using the current approach.

Toolpath Planning Method

The challenges in creating layer-based toolpaths is not in the actual cutter location data generation. A commercial CAM software package can easily generate 2V2-D roughing toolpaths. It is as simple as setting the maximum step down parameter to the desired layer depth. The critical steps in the toolpath planning method are to determine: (1) How many orientations about the axis are needed to machine the part? and (2) Where are they? The problem is two-fold: (1) determine whether all surfaces of the model are machinable with rotations about the selected axis, and if so, (2) calculate the minimum number of orientations (index rotations) required to machine the entire surface. A necessary condition for a surface to be machinable is that it must at least be visible. Other sufficiency conditions exist, including tool reach and proper cutter contact for complex surfaces. For example, a ball-end mill will need to have sufficient length to reach a surface and be able to contact the surface with some point on the hemispherical end of the tool.

This research has addressed the necessary condition of visibility using a simplified approach that does not require feature recognition. Because tool access is restricted to directions orthogonal to the rotation axis, 2-D visibility maps for a set of cross sections of the surface of the model are used for finding the set of orientations for machining. This procedure approximates visibility to the entire surface of the model. For example, consider the part illustrated in Figure 3a.

The entire presentation of the visibility algorithms will not be covered in this paper; however, a descriptive summary of the approach to visibility is provided in this section. A complete description of the visibility algorithms has been previously described in (Frank 2003) and is the subject of a future publication. For the method developed in this research, visibility for each polygonal chain is determined by calculating the polar angle range where each segment of the chain can be seen (Figure 4a). Because there can be multiple chains on each slice, one must consider the visibility blocked by all other chains. Therefore, the visibility data for each segment can be a set of ranges (Figure 4b).

If a visible range exists for every segment on each chain, for all slices in the set, then the remaining problem is to determine the minimum set of polar directions such that every segment is visible in at least one direction.

The problem of finding the minimum set of rotations sufficient to see every surface of the model can be formulated as a minimum set cover problem. The reader will note that the minimum set cover problem is NP-hard. Because large instances of NP-hard problems do not have known solutions that can be solved consistently or efficiently (Tovey 2002), an approximate solution is found using a greedy approach (Chvatal 1979), employed after the visibility mapping is complete.

The solution of the set cover provides the minimum set of angles from the set [0Â°, 360Â°] such that, for every segment, at least one angle is contained in one of its visibility ranges.

However, other criteria will need to be considered to determine a minimum, yet sufficient, number of 2 Â½-D toolpaths necessary to machine all surfaces of the part. Tool diameter and length, and the processing sequence for the indexing operations, need to be considered. Furthermore, one needs to determine the axis or axes of rotations necessary to machine all the surfaces.

In the current approach, it is only important that all surfaces of the part geometry are visible in some direction. Because this methodology uses segments of polygons, this implies that each segment must be visible from some polar direction, regardless of any other segments around the one being investigated.

Given each orientation, there remains a set of parameters that will need to be given to the CAM system to generate the layer-based toolpaths. Layerbased machining has been illustrated as a featurefree approach to rough machining (Balasubramaniam 1999). Balasubramaniam describes the method of "clipping" layers to the vertical shadows cast by all layers above it (higher in the z-direction). He describes the visible cross section at a given z-layer as the union of its cross section with the cross section of the layer immediately above it (Figure 5). In the current approach, finish machining is accomplished in a similar manner, using significantly thin layers.

For all l[l â^^ L|set of all cross sections]lv^sub i^ = l^sub i^ â^ªl^sub i-1^

where lv^sub i^ = visible cross section at layer i

Because this is a feature-free approach, the selection of surfaces for each machining operation is straightforward; all surfaces of the part are used for toolpath planning for every orientation of the solution set. For each orientation, the containment boundary for creating layer-based toolpaths must be defined. Assuming the tool is oriented in the z-direction, the containment boundary above the part is specified by a rectangle (x-y). The other information required is the depth of the maximum and minimum z-level layers (see Figure 6).

The length of the boundary (x) must be greater than the part length along the axis of rotation, while the width of the boundary (y) must be greater than the maximum part diameter.

Specifically, the containment boundary must be greater in both length and width of the part by at least the diameter of the tool (on all four sides). This is necessary because the tool requires a path around the part equal to its diameter in order to machine around the visible boundaries of the part. Given this boundary, layerbased toolpaths can be generated with layer thickness set by the maximum stepdown parameter in 2 Â½-D machining. The toolpath layers must begin at or just above the stock surface and proceed through the distance (z) to the furthest visible surface from the current orientation.

Recall that the information from the visibility map provides the set of segments visible from a given orientation. From this, one can calculate the maximum distance to all segment endpoints visible from each orientation in the solution set. This distance is the maximum z-depth for layer-based toolpaths in an orientation of the solution set (see Figure 7).

The data from the visibility method provide the set of segments visible from each orientation in the solution set. Each segment is defined by its endpoints (P^sub i^, P^sub i+1^) where each endpoint has coordinates in the y-z plane (y^sub i^, z^sub i^). The perpendicular distance from each point to the tangent line at the solution orientation is calculated. The maximum distance to all points visible from each orientation is used as the location of the maximum layer depth for that orientation.

Although the STL representation is used for visibility mapping, if a solid model exists then it can be used for toolpath planning in CAM. The model is simply rotated in the CAM environment to each of the orientations from the visibility algorithm, and the toolpaths are created using the other setup parameters from the slice file information.

Tool Selection

Proper tool selection must ensure collision-free machining for any model complexity. One condition to ensure collision-free toolpaths is that the tool length must be greater than or equal to the distance to the furthest visible surface with respect to current orientation. In this manner, one is assured that even on the deepest layer, the toolholdcr will not collide with the stock (see Figure 8).

To ensure that no portion of the tool will collide with any previously machined layers, the tool shank diameter must be less than or equal to the flute diameter. This criterion unfortunately makes a tool more susceptible to deflection and breakage. Typically, long tools are designed with large shank diameters and only have the length of the cutting surface (flutes) at the prescribed diameter. Figure 9 illustrates a tool with the proposed characteristics reaching to a z-depth without tool collision.

A desired goal is to choose tools that will be capable of machining a variety of complex surfaces at the required accuracy. The current approach is to select the smallest tool diameter available in the necessary length that is specified.

Because only 2 Â½-D layers are to be machined, a flat-end tool is most appropriate. Whereas a ball-end (spherical) tool is able to machine smaller radii surfaces in some cases, the diminishing diameter of the cutter contact patch is a problem because very shallow depths of cut are used each layer (see Figure 10).

As noted, one of the goals in tool selection for rapid CNC is to minimize the cutter diameter. This is directly opposite of the goals of a typical manufacturing process plan. However, based on the assumption that feature information is not known, one must use the smallest diameter tool available in a given length. From a purely geometric standpoint, this increases the likelihood that the smallest features of the part can be machined. Tool selection is both related to, and impacts, other process planning parameters. For example, the diameter of the tool defines the extent of the toolpaths along the rotation axis direction. This affects the length of the sacrificial support cylinders because they need to protrude from the ends of the part.

Fixturing Challenges for Rapid Machining

Designing a fixture scheme for CNC machining is a difficult task that requires a significant amount of work from a highly skilled technician. In general, fixturing or workholding serves three primary functions: location, clamping, and support (Chang, Wysk, and Wang 1998). This section presents these functional requirements in the context of rapid CNC machining.

Just as the approach to developing toolpaths of this research differs from traditional machining, the fixturing requirements for rapid machining are significantly different. Typically, a human operator orients the stock material between setups. Fixtures, in combination with hard stops and/or probes, are used to establish reference locations on the stock material. If a part is to be machined in multiple setups, it is critical that the fixture scheme facilitates repositioning of the stock such that dimensional constraints can be satisfied.

Once the stock is located in the fixture, sufficient clamping force is needed to withstand the machining forces. In addition, the fixture must provide support for overhanging or slender features so that the stock material will not deflect too much under the machining forces.

The goals of rapid machining make the fixturing problem both more and less difficult. In rapid machining, accessibility to the surfaces of the part is of paramount importance. When using traditional vises, for example, much of the part surfaces are in contact with either the jaws or the bottom of the vise. This is not always a problem in traditional CNC machining, where a piece of stock (usually prismatic in shape) is populated with features. For example, in one setup the process plans for a part may include a pocketing operation, then a slotting operation in the bottom of the pocket. The face of the stock where these features are being created may be cut during the machining operation, or created in a preprocessing step, or it may simply be the result of the original stock production. In the current method, one does not assume that any shaping operations have occurred, nor is the original stock shape considered viable for a finished feature. The current methodology suggests a feature-free manufacturing approach whereby all surfaces of the part are candidate "features" to be machined from an orientation.

Consider a comparison between a typical machining approach and the current methodology, as illustrated with a simple part, shown in Figure 11a. In Figure 11b, the pocket and slot are machined on the face of a block, with the sides of the block clamped by the jaws of a vise. Because these are the only two features to be machined in this setup, then the vise fixture is appropriate. This is the case where the stock material is being populated with two features, namely the pocket and slot. In Figure 11c, the same part is being machined out of a larger piece of stock material. In this case, the top, front, back, and sides of the block must be machined (to some depth) in addition to the pocket and slot on the top.

Recall that for each setup orientation all surfaces are used in process planning. The intent is that all visible surfaces from any orientation may be machined in that orientation. The feature-free nature of this method demands that the fixture solution provide as much access to the part as possible.

Each rotation places the stock material in a new setup orientation; however, the work offset must be retained for each orientation without having the user re-establish it. Therefore, the fixture solution for rapid machining must allow rotations of the part without the need to relocate reference points. The current fixturing method takes advantage of the fact that reorientation of the stock is only executed about one axis, which makes it easier to develop an automated method.

Typical cutting forces during machining can cause the stock material to slide or shift, and some elements of the part can deflect under load. A characteristic of the method of rapid machining is that cutting forces are significantly lower in magnitude and less variable because the depth of cut is very shallow and is the same for all operations. This results in a significant decrease in the amount of clamping and support that the fixture needs to provide. Although cutting depths in traditional machining vary, if one considers the fact that a constant 0.005 in. (125 microns) or less depth of cut is used in this method, the cutting forces will be orders of magnitude less than those of a typical machining process plan.

A significant challenge for developing a fixturing scheme for rapid machining is that the fixtures must be generated automatically. Existing rapid prototyping techniques are usable by unskilled people in a turnkey application. One cannot assume that a user will be available to design and create a custom fixture for each part, nor will he/she be available to rotate/flip the stock between each new setup orientation.

Fixturing Approach

The approach to fixturing for CNC RP borrows from the general idea of sacrificial supports, which are used in existing RP systems. In this work, the general intention is retained, however, the requirements for the support structures are different. The goal is to have a fixture solution that is created inprocess and is customized for each part. Specific to this work, the fixture supports need to allow the part to be rotated about the axis while providing access to as much of the part surface as possible. Conventional fixturing methods for CNC often utilize vises, clamps, vacuum surfaces, and so on. These approaches occlude visibility to a significant amount of the part or make it difficult to reorient the part for multiple setups. The following paragraphs describe an approach to fixturing using sacrificial supports in CNC machining.

In this method, the sacrificial supports are added to the ends of the model (in CAD) such that the model remains attached to the round stock material throughout the set of machining operations. In the current implementation of the method, small diameter cylinders are manually added to the CAD model at its ends prior to creating the process plans, so that toolpaths are created to machine the cylinders in the same layer-based fashion that the model is processed.

At least one sacrificial support is necessary, but numerous ones may be required to fixture the part during machining operations. This concept is illustrated in Figure 72, where a finished part is fixed within a cylindrical piece of stock material, which in turn is fixed between the jaws of two opposing chucks. For every orientation about the axis, the relative tool (z = 0) offset location is constant at the center of rotation. Similarly, the part coordinates (Coords^sub ART^) remain at a consistent location with respect to the stock material clamped in the indexer (Coords^sub INDEX^) and located on the table (Coords^sub TABLE^) for every rotated orientation.

A practical advantage of using sacrificial support fixturing is that, for a given setup orientation, the amount of visible surfaces can be increased compared to traditional fixtures. If a traditional vise were used and features needed to be machined on numerous surfaces, the part will need to be undamped, reoriented, and then reclamped for each orientation. It is difficult to reorient and reclamp a part without introducing error during location. Utilizing sacrificial supports, the stock is reoriented without changing the relative location of the part with respect to the machine table.

When the complete set of rotated toolpaths has been executed, the cylinders are cut by the user, which releases the part from the round stock material. This of course adds a post-processing step, where the surfaces of the model at the contact point of the cylinders must be sanded, ground, and so on. A proposed improvement is to generate a separate set of machining operations that focus on reducing the diameters of the cylinders for easy removal.

Using a sacrificial support, a minimal amount of the surface (the support contact "patch") will be left inaccessible. Another drawback is the rigidity of sacrificial supports, depending on the size and number of supports used. There is a trade-off between minimizing the size of the support for accessibility while maximizing the overall rigidity of the fixture.

In addition to the technical advantages of using sacrificial supports, there are practical advantages with respect to making this rapid machining method straightforward to implement. To set up the workpiece for the current method, the user clamps a piece of round stock between two chucks. The diameter of the stock is simply as large as the diameter of the part about the rotation axis, and its length can be calculated in a straightforward manner (see Figure 73). The collision offset, b, ensures that a part program can be run with no risk of collision between the toolholder and either of the chucks. It is assumed that the rest of the spindle will not collide, given a proper choice of toolholder length. A significant advantage of this fixturing methodology is that work and tool offsets do not need to be set before running a part program. The collision offset, h, can be used to translate the part coordinates such that tool collision cannot occur, given a toolholder and maximum tool diameter. This makes setting the work offsets for each new part unnecessary. The work offset coordinates [x(Q), XO)] will always be aligned with the axis and located at the face of the stationary (along jt-axis) chuck on the indexer. Similarly, the tool off-set is set to the z-height corresponding to the axis of rotation, as mentioned previously. If a proper length and diameter stock is clamped between the chucks, a part program can be executed collision-free with no need for the user to set offsets; a time-consuming and often error-prone task in CNC machining.

Example Parts Using the Rapid Machining Methods

The visibility algorithms were implemented in C and tested on a Pentium 4 2.0 Ghz PC running Windows XP. The software accepts slice files as input and returns several critical process parameters: (1) the minimum number of orientations, (2) the minimum stock diameter, and (3) the distance to the minimum and maximum layer depth for each orientation.

Using the set of orientations, max/min depths of cut, and stock diameter, toolpath plans can be generated using CAM software. Several metal prototypes have been machined in the laboratory. Although the intent is to integrate the visibility software with CAM and automate process planning tasks, at present the steps of toolpath processing are done manually. The steps that were executed are as follows:

1. Visibility software executed.

2. CAD model rotated through each of the orientations of the visibility solution.

3. Toolpath containment boundary created using stock and tool diameter and length of part.

4. For each orientation, rough surface pocket toolpaths (MasterCAM) generated. Minimum depth set at stock radius and max depth set to parameters given by visibility software.

5. NC code for each orientation combined manually into file with fourth-axis rotation commands.

Time required for step 1 is on the order of seconds, and less than half a minute for most parts. Steps 2-5 require 5 to 15 minutes depending on the number of rotations and the processor speed of the computer. The following are example prototypes machined in the laboratory.

The first prototype is the toy jack. The jack was machined on a Haas VF-O three-axis machining center. The number of orientations provided by the visibility method was five. The part was created in approximately three hours. Figure 14a shows the prototype of the jack in between machining operations, while 14b shows the jack after being cut from the stock at the sacrificial supports once all orientations were machined.

The next model is of a human leg bone, the femur. The model was machined from Delrin plastic. Figure 15a presents a view of the femur prototype during processing. As can be seen, the bone model is secured to the remaining stock via three sacrificial supports. The stock material is clamped on both ends in three-jaw chucks, one on a tailstock and one on the face of a rotary indexer. Figure 15b shows the finished prototype after machining from three orientations. The three orientations for machining are illustrated by the arrows in Figure 16, as viewed from the distal end of the femur (left end in

Figures 15a and 15b). The total machining time was approximately 12 hours.

The final prototype example is a simple prismatic part, a block with three through-holes. Although this is a considerably simple part to machine using traditional methods, it can easily be measured on a coordinate measuring machine (CMM) to evaluate the accuracy of the current process (Figure 17). Again, the part was made without the use of a tailstock. A grossly oversized sacrificial support was used on one end to ensure stiffness for this test.

The prismatic block was measured on a Zeiss Vista CNC CMM. A runout error of 0.002 in. (50 microns) was detected in the fixtured stock prior to machining and is presumed to be the source of much of the measured error, in particular the undersizing of the width of the part. Overall the largest deviation in dimensions was on the order of 0.005 in. (125 microns), but it is expected that machine accuracy can be achieved with a fully implemented fixture scheme. In particular, runout with respect to the axis of rotation should be eliminated using the proposed fixturing method using opposing three-jaw chucks.

The same prismatic part was also created using a stereolithography (SLA) machine (see Figure 18). The processing time on the SLA machine was estimated using a software build time estimator (Georgia Tech-BTE 2002) at 2 hours and 56 minutes; however, the laser on the machine was old (laser power reduced from 35 mW to 19 mW) and the part required additional time

(total of 4 hours and 46 minutes).

For the SLA part, the larger deviations in dimensions were the diameter of the holes (0.004-0.005 in./100-125 microns) and the largest was in the height of the part (~ 0.02 in./500 microns). The total time to create the SLA part was ~7 hours. This included 4 hours and 46 minutes to build it on the machine, 15 minutes to clean it and remove the supports, and finally, 2 hours in the post-curing oven.

Although the CNC machined prismatic block was not built with two appropriate sacrificial supports, it is estimated that removal of the supports would have required -15 minutes, as was true with the jack and the bone. A comparison of the actual, or estimated (Georgia Tech-BTE 2002; Stratasys), build times for creating the three parts using rapid machining (CNC RP), fused deposition modeling (FDM), and SLA are shown in Table 1.

For the three examples listed in Table I, rapid prototyping using CNC machining is shown to be the fastest of the three rapid methods in all but one case (SLA of bone). There is also the added benefit of having a part made of better materials (aluminum and Delrin plastic) rather than ABS plastic or photosensitive resin.

Conclusions and Future Work

This paper presented a new methodology for rapid planning in CNC milling. The method makes it possible to rapidly plan and create machined parts and prototypes with little or no human intervention. The method presented involves milling parts using a plurality of 2 Â½-D toolpaths oriented about an axis of rotation. Because the method strictly adheres to feature-free solutions, the complexities of most models do not affect system performance. Visibility approaches using 2-D slice geometry have made it simple to extract critical process planning information. The research has also further developed the concept of sacrificial supports for use in a subtractive process.

The method can be used for moderately complex part geometries. That is, parts with complex geometries that are accessible by rotations about one axis are possible; however, even simple geometries that are not visible about the axis of rotation are not machinable. Parts with severely undercut features can also be a problem, and hollow parts are, of course, impossible. In addition, small inside-corner radii are difficult or impossible to machine, depending on tool geometry. Not all parts will have a feasible axis of rotation such that all surfaces can be machined using the proposed method. An example of a prismatic part that would not have a feasible axis of rotation is shown in Figure 19a. This prismatic block has three pockets located on mutually orthogonal faces. As such, at most two pockets could be machined from one axis of rotation. The next example is a spherical-shaped part with several slots about its surface

(Figure 19b). If an axis is chosen such that all slots can be machined (A1 in Figure 19b), then a significant amount of the interior will not be accessible. If an axis is chosen such that the entire interior can be milled (A2 in the figure), then only as many as two of the slots can be completely machined.

The visibility algorithms answer the question of whether an axis of rotation is feasible, but they currently do not search for a better solution. In its current implementation, the visibility method accepts a model oriented by the user and generates visibility information based on that axis of rotation. The next development will be in a method for evaluating multiple orientations and guiding the user at least semi-automatically to a "better" axis of rotation sacrificial support fixturing for CNC machining. Sacrificial supports will greatly reduce the cost in both prototyping using CNC machining, and in many cases, in short production runs or batch processing of parts.

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Simple motion control

Tryling, David P

In positioning applications that are repetitive and non-complex, PLC-supplied motion control hardware might be the answer SOME READERS MIGHT view this article's title and say, "There is no such thing." And they may be right. But there are possibilities in motion control that tend to be overlooked. These could be added to your toolkit of ideas for solving motion and positioning applications.

There are numerous industrial applications that require the positioning of a part, the rotation of a tool, or the travel distance of a component. This is at the heart of what motion control is all about. In the simplest form, mechanical cylinders or actuators can perform any of the operations just described. However, when you add the complexity of making the distances, rotations, or other motions variable, it's fairly inevitable that an electronic device will be applied.

The rub, as they say, is always in the cost of the application. This is usually because the application of motion control is expensive in terms of hardware and complex in terms of effort.

However, there are simpler ways of getting position control for these general applications.

Consider the application of programmable logic controllers, or PLC's, using pulse output capabilities. This is alternately referred to as Pulse Trained Output, or PTO. Many smaller and medium-sized PLC's are equipped with this capability, and they are easier to use than you would think.

Pulse output capability is the hardware and programming process where a chain of pulses is sent to a drive or power amplifier that moves a motor in a particular direction and for a specific amount. For example, if the PLC sends 10,000 pulses to a servo amplifier, the rotary action of the motor will move a specific number of rotations in relation to those 10,000 pulses.

There are two basic formats in which pulse output capabilities are available. First is the integrated output. This is most commonly found on smaller PLC's ("brick" type) where one particular output will be pulse-output-capable. When the pulse output is integrated to the PLC chassis, there is additional hardware related to that particular output. While in most cases the output can perform in a standard way, it also would be capable of providing a series of pulses related to an internal set of hardware. This hardware allows the output to operate independently of the PLC logic execution. Therefore, when a command is issued to send pulses to the output and then on to the power device, the PLC logic's scan time continues on while the pulse output processing hardware performs the pulse generation necessary as configured.

Obviously, there is a difference between PLC manufacturers when it comes to how these basic functions are programmed and executed. These will depend on the basic programming structure of the languages from the PLC manufacturer. Some manufacturers work with configured parameters, others may use block instructions that send data to the pulse output logic area and perform the configuration requirements. Regardless of the programming method, the manufacturers have similar capabilities. Listed in Table I are some of the parameters that are generally sent to the pulse output electronics.

PLC's are also able to perform some of the more common motion controller functions such as "jog" or "home" or "move to." These may be done using specific inputs that are tied to the pulse output hardware or by program parameters/bits.

The second type of hardware used for pulse output motion control would be a plug-in card. This is obviously used in PLC types that have racks for plug-in modules. Plug-in-type cards may have additional features that are not available from the manufacturer in their brick-type PLC's. These might include additional high-speed input lines for positioning and home sensing, overtravel, and other higher-speed functions called interrupts.

There are some important functions that the motion control hardware provides. Some bit functions that are usually available are shown in Figure 1. These can be used subsequently in ladder logic programming to control the flow of information to the motion hardware and for the balance of the program to know the status of the motion functions.

Just as in any other positioning system, accel and decel are important when thinking about and creating a positioning move. The pulse output hardware can provide accel and decel by changing the width of the pulses. It will be important, however, that the drive or power amplifier be capable of responding correctly to this. Through the use of accel and decel, a true motion profile can be created. (See Figure 2.)

One of the important planning details that will need to be established is calibration. As with any device or sensor, the motion will need to be calibrated. This is done by establishing the engineering units with which the machine will be operating and then determining the number of counts or pulses that equal the smallest increment of those engineering units, as shown in the equations at left.

A couple of things to keep in mind. First, while it is true that these motion control capabilities are extensive, there are things that this type of simpler motion control cannot perform. If motion needs to be coordinated between two devices or axes, if complex motion moves need to be performed, then this is not the hardware for your application. However, if your application requires configurable general motion, then this is a good fit.

Secondly, these motion devices operate in open loop format. What this means is that the control hardware in the PLC does not actually receive a position feedback signal from the power amplifier. The PLC hardware is sending a series of pulses to the power system, which interprets that and performs a movement. The PLC hardware assumes that this movement is completed, either from a signal back from the power amplifier or in some sort of timer. If the application has a high potential for slip or other position errors, you will need to look to different controller hardware.

By David P. Tryling, EA Electronics Editor

Manufacturing & motion control

The motion control industry is changing. Current trends include direct drive motors, a move to electrical solutions, open architecture, and standard communications and interfaces," said Philip Hollingsworth, director of engineering at California Linear Devices. These trends are bound to persist over the next decade and more.

To respond to ever-increasing competition, motion control system designers will continue to seek ways to reduce system costs by eliminating or consolidating the number of system components. Frank P. Monteleone, senior director of worldwide sales for Thomson Airpax Mechatronics, cites an instance of trend. "An example is the increased use of sensor technology for simplified position feedback. Reducing the number of system components also decreases the assembly time, and improves reliability. Since there are fewer components, there will be less system maintenance and increased mean time between failure (MTBF) ratings for the customer's product."

Prominent among trends in the coming years will be the growth of the use of microelectromechanical (MEMS) devices in motion control instrumentation. Marketing firm Frost & Sullivan estimates that the total MEMS market, now at $1.4 billion, will increase at a compound annual growth rate of 17 percent through the year 2004, when the market is expected to exceed $3 billion. Automotive applications such as airbag inflation sensors currently make up one third of the total market, followed by the medical market, which uses MEMS in products like disposable blood pressure sensors.

But there are numerous applications that are certain to reach the market in the coming decades. These could include smart munitions that can alter their paths after firing, metering nozzles for inkjet printers, drug delivery systems, accelerometers used in antilock braking systems, and sensors for measurfing fuel level, tire inflation, and oil pressure. Applications in the photonics industry abound, including reliable telecommunications switching devices.

MEMS-based designs can produce systems on a chip in which a transceiver, batteries, sensors, and microprocessors are all on a single component not much larger than a postage stamp. They are rugged - many will be made of silicon, which is many times stronger than steel - and can operate for long periods with little power. The challenge for the years ahead is to create components able to endure internal heat buildup and withstand excessive structural loads, ambient temperature swings, and severe shock and vibration. But few doubt that these devices have a bright future.

The near future will see changes in encoders as well. Already in evidence are optical encoders that use fewer components, yet provide better reliability and performance at lower cost.

According to Edward Burk, technical sales manager at Renco Encoders, "Component reduction is being done by incorporating the optical sensors and conditioning circuitry into a single, application-specific integrated circuit (ASIC). By reducing component count on the encoder, you open up valuable printed circuit board space, allowing additional capabilities to be integrated with the encoder. Future developments will add memory to contain encoder data, user data, or both, and a communication bus to transfer this data to external devices."

Thomson's Monteleone sees a similar push toward integration in the world of motors and controllers. He notes a trend away from high-torque, closedloop multiple device systems with separate motor, control electronics, power supply, and feedback devices, toward "having everything necessary to perform all of the functions required in one package." He added that "surfacemount, field-effect transistors are a driver of this trend. Power needs can be scaled down to a lower level. The older servo systems were very expensive."

Nick Johantgen, manager of engineering at Oriental Motor USA Corp., said his company will continue to migrate toward all-inclusive solutions. "The customer will simply input a description of the mechanical system and motion profile he would like to achieve. The solution would then provide the proper motor, driver, and/or controller, and cause these components to execute the motion upon command. This technology will be applied to both rotary or linear motion products with minimal effort required by the user."

In the world of machine vision, George Blackwell, senior manager of marketing at Cognex Corp., expects the drive toward networked machine vision to accelerate. "To catch defects earlier in the manufacturing process and improve process control, companies will distribute vision systems at even more points along the production line. Ethernet will likely continue to serve as the basis for networking the sensors, together with an emergence of new types of industrial networking protocols."

Dimitri Dimitri, president of Delta Tau Data Systems, sums up the changes coming in motion control. "During the next decade, the number of motion control solutions will continue to grow.

We'll see a continuation of distributed and centralized architecture, and while old technology solutions are not disappearing, the real growth will be in new technology, resulting in much higher resolutions that increase accuracy.

Single-chip solutions will be available for volume applications," he said. "The biggest issues for customers," predicted Dimitri, "will continue to be price performance, simple wiring, and easy setup without sacrificing performance and flexibility. As a result, more commodity-type motion control solutions will be available."

The major trend that affects manufacturing in general - the actual production of parts - is rapid prototyping. Being able to produce prototypes of parts before they are put into production reduces product development costs, time to market, and the chance of producing defective products.

Although still a rather young technology, rapid prototyping has developed quickly in the past decade. 3D Systems introduced the first commercially available rapid prototyping machine in 1987, with a limited choice of materials. The first systems were used primarily in the automotive and aerospace industries, but over the past 15 years, it has become more of a staple in the manufacture of all types of products, from cell phones and medical devices, to computers and consumer products.

Today's rapid prototyping systems incorporate CAU/LAD/UAM software with many types of materials such as plastics and resins to construct, layer by layer, a working prototype of a product or part. Using techniques such as injection molding, stereolithography, and high-speed machining, rapid prototyping machines are available from many manufacturers, including DTM, Stratasys, and 3D Systems. Desktop-sized machines, called 3D "printers," also are becoming more commonplace in today's manufacturing environments. As prices for this equipment come down, the use of rapid prototyping could continue to replace conventional methods such as hand carving in many industries.

Philip Hollingsworth of California Linear Devices: End users are getting the best state-of-the-art equipment as it's developed.

George Blackwell of Cognex expects the drive toward networked machine vision to accelerate.

Delta Tau Data Systems' Dimitri Dimitri: More commodity-type motion control solutions will be available.

Photodiodes: A smart motion control solution

Koren, Brock

The automotive industry is increasingly using photodiodes to provide greater levels of automation and product sophistication.

Mechanical and piezoelectric motion control has already reached nanometer-level precision and repeatability. While some further improvement in these areas can still be expected, a more commercially significant trend is towards "smart" systems, where feedback signals control motion using microprocessors and DSP-based controllers. The feedback signal is often derived from some type of optical sensor, frequently utilizing a photodiode.

This article briefly reviews the technology and advantages of photodiodes, and then examines some emerging applications in the automotive industry, which is one of the fastest-growing markets for smart motion control systems.

A photodiode is a special type of semiconductor diode that converts incident light into a useful electronic signal. The majority of photodiodes are silicon-based and respond to light in the 350- to 1000-nm range, i.e., the near-UV through near-IR. Like other solid-state components, photodiodes are small, simple, rugged, and reliable. Moreover, advances in wafer fabrication technology means they can be manufactured in high volume for relatively low unit costs. Obviously, all these advantages are direct benefits in a motion control system.

Just as important for OEMs, photodiode functionality and performance are highly customizable. For example, by fabricating small, low-capacitance devices, the response can be as short as 300 ps. On the other hand, other devices can offer over 10 decades of linear response. Also, photodiodes can be fabricated as single elements or multielement arrays, as well as position-sensing detectors, where a duplex electrical signal indicates the x-y centroid position of an incoming light beam.

Photodiode manufacturers have also supported the development of sophisticated "smart" applications by offering custom assemblies that incorporate optics and/or amplifier and signal-processing electronics. Indeed, many OEM customers have found it more cost-effective to incorporate a photodetector subassembly, in which the individual components are all

preassembled, aligned, and fully tested. Modern packaging techniques, such as plastic encapsulation and surface-mount interconnects, enable this integration to be provided in an economical manner.

Two recent advances, the large-area avalanche photodiode (LAAPD) and the Filtrode(R), both patented by Advanced Photonix, offer specialized performance benefits for motion control applications. The LAAPD uses internal amplification to generate multiple charge carriers from a single incoming photon, yielding high sensitivity and low-light performance characteristics formerly only found in bulky, fragile vacuum-tube-based detectors. The Filtrode(R) is a photodiode in which a thin-film optical coating is deposited directly onto the detector's surface, enabling it to reject or accept specific wavelengths (Figure 1).

Automotive Applications

Automotive applications place unique demands on photonic devices. Simple economics dictates that these components must provide high reliability, meaning years of service, at a low cost.

But at the same time they must withstand constant vibration over a range of frequencies. Also, devices outside the passenger compartment must endure extreme changes in temperature and humidity, as well as exposure to grit, oil, and dirt. Obviously this necessitates excellent bonding and packaging techniques. In fact, to supply devices to the automotive market, component manufacturers must meet a very strict set of qualifications referred to as QS 9000. These are similar in philosophy to the widely used ISO 9000, but even more stringent.

An interesting smart motion control problem in the automotive industry involves power windows. At present, power windows offer automatic travel only in the opening direction: this feature allows a window to be fully opened without the switch having to be continuously held down. This "hands-free" operation is obviously an advantage at toll booths, drive-through services, etc. Clearly, it would be just as advantageous to have hands-free closing as well. At present, this feature is not offered because of the danger of causing trauma to an object-e.g., a child's finger-accidentally placed in the window's opening; the switch must therefore be actively held down throughout the entire range of travel.

Unfortunately, a simple mechanical interrupt based on resistance pressure is not a viable solution to this problem. In order to force a good wind-rain seal, the closing window is typically accelerated over the last inch or two of travel. Consequently, the reaction time of a resistive-force-based loop would not be fast enough to completely eliminate the potential damage to a small finger. Engineers are therefore developing potential optical solutions.

One approach that has been investigated uses a near-infrared light-emitting diode (LED) located in the corner of the window. A low-cost cylinder lens is used to fan the LED's output to produce a flat sheet of light that is parallel to the window and close to its inner surface (see Figure 2). A photodiode-based sensor is located in the same module, with wide-field optics to gather light from the entire window area. The system is set up so that any sudden change-increase or decrease -in the photodiode signal will momentarily disable the automatic window-closing system.

Eliminating False Positives

A significant limitation of this approach is the number of false positives: the system can be fooled by sudden changes in the ambient light level, such as would occur when passing through the shadow of a building or a large tree. The goal of system designers is to reduce background effects while still delivering one hundred percent response to the industry-standard test: a 4-mm-diameter opaque tube placed in the furthest corner of the window.

A possible solution that is currently being investigated relies on wavelength discrimination. Advanced Photonix's Filtrode(R) technology offers an economical route to this goal. The light source is an LED that emits over a narrow wavelength band, and the Filtrode(R) coating is designed to transmit only this same wavelength band. This approach not only improves discrimination by orders of magnitude, but preserves the key goals of simplicity and low cost.

Fully automated window operation will also allow for smarter climate control. For example, the windows could be programmed to close automatically in response to rain falling on the car.

Also, when the temperature of a parked car reaches a certain level, the windows would open and close to regulate the interior temperature. Photodiodes would also be used to determine the temperature by measuring the ambient near-infrared intensity at two different wavelengths.

Photodiodes and Cruise Control

As cars become smarter, photodiode-- based systems may also play an increasing role in controlling the motion of the car itself. An early example of this is the smart cruise control, already available on some German luxury models. Here a photodiode is mounted on the front of the car, together with an LED sending unit. The photodiode detects light that is reflected from objects in front of the car, allowing continuous ranging by measuring time or phase delay.

In practice, the cruise control is set at the desired speed. When an object enters the lane in front of the car, the cruise speed is lowered as necessary to maintain a minimum distance.

When the vehicle in front accelerates or exits the lane, the original cruise speed is restored. In contrast to the automated window problem, this collision avoidance application utilizes basic highspeed photodiodes, where rugged packaging and low cost are the most important design parameters.

Finally, looking even further into the future, automotive engineers are exploring the concept of "drive by wire" and "drive by fiber." Analogous to the systems used in some airplanes, the controls would no longer be mechanically linked to the wheels and transmission, etc. Photodiodes are expected to play a key role, not only in transmitting information, but also as optical sensors to monitor the steering and transmission functions.

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Toolmaking through rapid prototyping

Aronson, Robert B

A "sometimes" answer

Rapid prototyping (RP) is evolving from just a means of making prototypes to a technique for making production tooling, chiefly dies for plastic parts.

Initially the prototypes were quite fragile and the various techniques produced products that could only show form. As materials improved and prototypes became stronger, the products could be tried for fit and measured. Today some systems can produce parts strong enough to run briefly in a machine and do low-volume production of parts.

It didn't take RP manufacturers long to realize there's more profit in making a usable mold than making one prototype, so many system makers are concentrating on making molds for injection-molding operations.

This industry moves cautiously. The good news is that there are a wide variety of rapid tooling (RT) systems; the bad news is no black and white answers exist on how to match a project with a system. And a few companies in the mix just might overstate their capabilities.

A number of techniques still in the laboratory stage still need debugging. A lot of work is needed to convert them into practical systems that are able to operate at a competitive cost.

Milling May Be Better. The initial "rapid prototyping" system was-and still is for the most partthe conventional machine tool. In many cases users find it simpler to dash off a part the usual way. However RP systems do not require any elaborate front-end processing or software. Once you have created a solid model and output an STL file, you're ready to begin the build.

Rapid tooling has an edge when you need many parts and, in particular, when that part is very complex. Cost, speed, and precision govern the decision on whether to use rapid prototyping or conventional machining.

"It's taking the developers of RT technology longer to commercialize and make a business out of what they have to offer," according to Terry Wohlers, Wohlers Associates, Inc. (Fort Collins, CO). "They're finding it is difficult to match the precision, flatness, and surface finish offered by CNC machining."

Three Ways to Go. There are three levels of rapid tooling. Some users need only a few prototypes. Called soft tooling, these parts can usually be made from room temperature vulcanizing (RTV) materials. The next, "bridge tooling," includes those production situations that require up to several hundred items to cover the time between early prototype and full production.

The third type, hard tooling, employs tools for actual production.

Most of the examples following are used for bridge or hard tooling.

Government Job. A group working specifically on the Rapid Solidification Process and consisting of a consortium of 10 major industries, has been organized through the National Center for Manufacturing Sciences (Ann Arbor, MI). The process reportedly produces steel molds and dies.

Detail transfer between the mold and inserts is described as exceptional, with an EDM-like finish. The process completes projects that normally take a week in a day. This spray-forming process uses hot inert gas to atomize molten metal alloy. Currently it can produce 3" (76 mm) parts, but the goal is 12" (300 mm).

Extrude Hone (Irwin, PA). This company uses an MIT-developed system based on an ink-jet printer. It deposits liquid-binder material. Sintered and then infiltrated with a second metal, the resulting form is +/- 0.125 mm plus +/- 0.05 mm per 25 mm. The process can use almost any metal powders or mix of metals and powders but stainless steel is usually preferred.

3D Systems (Valencia, CA). Company uses the Direct AIM process for bridge-type production, this system is based on a stereolithography machine. First an insert is made using a CAD design, then the core and cavity are formed by stereolithography. The process is used for rather small parts.

3D Keltool is the company's process for volume production and typically starts with a CAD design. Then the operator forms a core and cavity using stereolithography. Next, cast silicon rubber creates a mold into which a mixture of metal power (tool steel and tungsten carbide) and binder is poured. Sintering burns away the binder and fuses the metal. Finally copper infiltration gives the material the properties of tool steel. Typical 3D Keltool accuracies range from 0.1% to 0.2%.

Epoxy SteeL Dynamic Tooling (Fresno, CA) starts with an RP pattern then forms the tool with a blend of 90% steel and 10% epoxy. The process can produce molds suitable for glass-filled nylon, ABS, and wax. It is possible to produce more than a thousand parts with an accuracy of +/- 0.025 mm without secondary machining. The molds are 400% stronger than aluminum and kirksite (a zinc-based alloy) and shrinkage is said to be negligible, with dimensional repeatability of +/- 0.013 mm.

In a rather surprising turn, GM is favoring this newcomer to the industry. The company has built three molds for working parts that measure about 1 ft^sup 2^ (930 cm^sup 2^). In one case, 18,000 parts were reportedly made from a single mold. They are working with the manufacturer to produce a 2 f^sup 2^ (1858 cm^sup 2^) part.

GM likes the process because the molds produced provide good wear characteristics, can mold abrasive material, and endure high pressure and temperature.

A GM spokesman points out that it is not always high accuracy or ability to work with exotic materials that gets the nod, but features important to a specific industry or process, such as speed and cost/part.

Electroforming Process. The operation of this technique from Express Tool (Warwick, RI) begins with a CNC-machined mandrel which is coated with a 1-2 mmthick layer of nickel that has a hardness of Rc 20-40. Cooling lines are then formed with a 2-4 mm layer of copper that reduces hot spots and cuts cycle time. Then the form is backed with a composite-filled material and the mandrel removed. Production versions have reportedly lasted for 200,000 shots.

DTM Corp. (Austin, TX). The selective sintering process (SLS) is another fabrication technique for tool making. The user first creates digital models of the core and cavity, as in similar techniques. The CAD system is then used to form a tool in a powder consisting of stainless steel with a polymer coating.

In the SLS process, a CO^sub 2^, laser fuses the powdered steel together in the shape described by the digital drawing. After processing, the core and cavity are placed in a reducing atmosphere furnace to burn out the polymer and partially sinter the steel. After another trip to the furnace, the part is infiltrated with bronze to form a steel/bronze tool. The tools are fitted with ejector pins before being use in a molding machine.

Another system, using a copperpolyamide casting material, is intended for short-run tooling applications. The material is a metal-plastic composite and with SLS processing a tool can be turned around in a day. The mold must be finished and fitted into a mold base. Copper polyamide has been used to mold plastics such as polyethylene, propylene, ABS, and nylon. Because of

its heat resistance and thermal conductivity, the system can mold parts with a very short cycle time, like cycle times achieved on parts made using conventional tools.

Metal-Matrix Composites Co. (Chesterfield Twp., MI) This group works with a metal-filled vinyl ester compound called Vestalloy. It's claimed to exhibit high heat properties and better heat conduction. Reportedly, the material works well in some reaction-injection molding and thermoforming operations in the 500 deg F (260 deg C) plus range. According to the manufacturer, the material has 20% greater wear resistance (and double the heat conductivity) of conventional epoxies

Rapid Prototyping on the Rise

Paced by unprecedented sales of low-end machines, the worldwide rapid prototyping industry reversed its downward trend as sales grew by $45 million in 2003.

Robust sales of low-end systems including 3-D printers have helped the rapid prototyping industry return to revenue levels of the past, according to the latest research from the Wohlers Report 2004 released at the recent SME Rapid Prototyping & Manufacturing 2004 Conference and Exposition held in Dearborn, MI.

"Low-end machine sales soared to unprecedented heights, with 3-D printers becoming the crown jewel of the RP industry," says Terry Wohlers, president of Wohlers Associates (Fort Collins, CO) and principal author of the 270-page report. "With the increase in the number of machines sold and installed, the total number of models being produced annually also grew.

Consequently, material sales were strong."

Rapid prototyping supplier Stratasys Inc. (Eden Prairie, MN) said that it attained market leadership at 37% of units shipped during 2003, up from 31% of industry sales in 2002, according to the report. Citing the Wohlers report, Stratasys said that the RP industry grew to $529 million in 2003, up from $484 million in 2002, while also noting that the report projects the industry will grow to $586 million in 2004 and $655 million in 2005. Stratasys also said that its sales accounted for 48% of all RP units shipped by US manufacturers in 2003, and that Stratasys now has the highest global installed base of RP systems, surpassing its competitors for the first time.

Justifying rapid prototyping

Sorovetz, Thomas

Rapid prototyping allows both designers and manufacturing engineers to see and hold physical models of part designs on demand--often in under a day after the prototyping process begins.

Models can be used to visualize designs; verify engineering changes; check for form, fit, and function; and verify part producibility. Sometimes, they can be used in test applications.

Resulting cost savings over conventional methods can be significant.

Justifying the necessary equipment can be difficult, though. One reason is that key benefits of rapid prototyping aren't always easy to quantify. For instance, how do you quantify the benefits of increased communication between design and manufacturing engineers] Another is that the financial staff may not understand the need for a new technology that can radically change the way a company produces prototypes. Here's how I prepared a successful acquisition proposal.

Demand Rise

Several rapid prototyping technologies are available today. The method chosen depends on the application. For example, the stereolithography apparatus (SLA) from 3-D Systems (Valencia, CA) excels at building plastic models with thin walls and intricate internal structures. Another method may be more efficient at large, thick-walled structures.

SLA is a layer manufacturing process. Users must develop a CAD solid model or fully closed 3-D surface model of both the part geometry and support structures required to produce the prototype and convert these to an STL file format. A "slice" computer automatically divides the STL file into cross sections. These slice programs drive a laser across a bath of photopolymer (liquid plastic), successively solidifying each layer to produce the model. After postcuring the plastic model can be finished by sanding, sandblasting, painting, or dyeing and used for various applications, including conceptual design, prototype parts, and patterns for metal castings.

Chrysler Corp. began using rapid prototyping (RP) in 1990 when Jeep/Truck Engineering acquired two new SLA machines and support equipment. Our goal at the Rapid Prototyping Lab was to provide RP services at no cost to all engineering groups within Chrysler to help reduce tooling costs and rime to market.

By 1992, the SLA equipment was in almost continuous use seven days a week, supporting T300 and PL vehicle programs. Maximum capacity was about 550 geometries (models) and 1300 parts/yr.

Fed by model data designed with Chrysler's Catia CAD/CAM systems, it produced a typical prototype part in about 13 hr.

Results after two years of rapid prototyping were promising. The average plastic model saved about 320 man-hours and $10,500 in out-of-pocket costs compared to traditional methods.

Although difficult to extrapolate, in-house SLA savings were probably in the range of $5-$10 million. The RP Lab also was operating at maximum capacity.

It was time to ask management for new equipment. Justification would be based on the need to support new vehicle programs and the need to benefit from software advances that would increase the number and types of parts that could be prototyped on an SLA. We expected the capital acquisition process to flow a little smoother than the first time, since management was now familiar with rapid prototyping and Chrysler had documented several success stories. Still, the proposal had to avoid supplying reams of data without sufficient explanation. It also had to be in a clear, concise format that both financial staff and engineering management would understand.

Basics of the Capital Proposal

A well-written capital equipment acquisition proposal has several key ingredients, including the following-:

*The Executive Summary. This should be no more than 1/2 to one page in length and describe an operation's current status and why the new equipment is needed. It also can be beneficial to include a productivity improvement factor for the proposed acquisition. This is equal to the total savings from the acquisition over a five-year period divided by the cost of the acquisition and support expenses throughout five years of use. We've found that a successful capital project usually has a productivity improvement factor no less than four and no greater than 10. With this RP equipment acquisition, for instance, we anticipated a fourfold increase in savings by year end 1993.

*The wish list. Ours included two SLA-250 machines, two Silicon Graphics Iris "slice" computers, postcuring apparatus, and two laser units. This equipment, along with upgrades to existing equipment requested in a separate proposal, would double our RP capability. We evaluated both new and used equipment and provided a total cost for each option, including costs for equipment transportation and installation, installation support, and systems integration support.

During our initial foray into rapid prototyping, we bought new equipment from the vendor for several reasons. The first was knowing that the equipment would be supported by that vendor.

In addition, training would be included in the acquisition package, and maintenance provided for the first year. With used equipment, you have no idea where that machine's been or how it's been maintained. Moreover, you may need to replace elements, such as the laser and power supply. You also have to pay a fee to have the technology certified for maintenance by the original vendor. Nevertheless, once you have some experience with the technology and know what to look for in used equipment, there are some good deals out there. This is why this proposal was essentially a request to buy used equipment.

*Alternatives. A well-written capital project also details the alternatives to the acquisition and their possible downsides. For example, one alternative in this RP project was simply to upgrade existing equipment by buying a new computer workstation (already part of another proposal). The problem was that this alternative would increase productivity 25-30, but would be insufficient to address the fourfold increase expected in demand for services.

Another option was to use an outside service bureau. For small companies, this may be the best route when exploring use of rapid prototyping. One year, Chrysler averaged more than $300,000 in service bureau business. Cost of this proposed RP equipment acquisition was a little over $200,000, so it made more sense to have the equipment in-house. Moreover, with service bureaus, RP equipment use was subject to limited availability, and the bureaus we examined couldn't always meet required turnaround times.

*Case histories. In any capital acquisition request, you should do your homework. Find out how your competitors are using the technology, and document their published results. Examine the technology's impact on production flexibility, responsiveness to market changes, quality and reliability improvements, human resources, inventory levels, even customer satisfaction.

For our first RP proposal, we faced the problem that our people didn't understand the technology. We solved that by including a videotape of rapid prototyping along with documented case histories from competitors. For our second proposal, we had several proven Chrysler applications of rapid prototyping, including the following:

1. Experimentation on an intake manifold SLA model allowed us to determine that the flow test of the SLA model was equal to that with the conventional prototype. We saved three iterations of prototypes by testing and revising the stereolithography models of the intake manifold.

2. An "A" pillar blocker couldn't be tooled in time to support the F1 prototype build. Using stereolithography, we created a model from surface data and made a tool off of that to create a mold. This saved some $30,000 in design and CAD time, iteration of the A" pillar blocker design, and production of a hand mold.

3. A model for a cylinder head flow box typically takes 320 hr (2 months) to fabricate at a cost of $10,000. Rapid prototyping produced the model in two weeks (80 hr). Early in Chrysler's rapid prototyping history, we faced another problem that many new users will experience, that of convincing the design people that they now had to start designing in

solid models or "volumes" so we could create the STL file to drive the system. This brings home a key issue in any acquisition project for rapid prototyping. You may start out focusing on the technology's immediate impact in your area, but don't be surprised if there is a ripple effect--the technology has potential to improve efficiency of both upstream and downstream applications.

Rapid Prototyping: A True Tool for Change

Grimm, Todd

GUEST EDITORIAL

It wasn't so long ago, actually back in 1987, that an industry was born. That year, 3D Systems unveiled the world's very first rapid prototyping device. This technology ushered in an age of direct, digital technologies for the rapid production of models, prototypes, and patterns. Since its introduction, rapid prototyping has changed design, engineering, and manufacturing processes within the consumer products, aerospace, medical devices, and automotive industries. There is no question in my mind that rapid prototyping is amazing, powerful, and revolutionary. Since the delivery of the first rapid prototyping system, the applications and breadth of uses have grown beyond belief. Rapid prototyping users have been on a sharp increase due to a new class of machines available for less than $30,000. Virtually every industry that designs and manufactures mechanical components has used rapid prototyping. The technology is so pervasive that most people will use at least one product a day to which rapid prototyping has been applied.

What exactly is rapid prototyping? The most universal definition is "a collection of technologies that are driven by CAD data to produce physical models and parts through an additive process." Simply put, rapid prototyping is a digital tool that grows parts on a layer-by-layer basis without machining, molding, or casting. Rapid prototyping can reproduce (quickly and accurately) designs that are impractical or impossible to create by any other method.

Rapid prototyping, according to the "Wohlers Report," is nearly a billion-dollar-a-year industry with more than 30 system vendors. Wohlers Associates, Inc. also reports that in 2002, 22.4% of rapid prototype models were used for functional models, 19.2% as patterns for prototype tooling, 15.3% for visual aids for engineering, and 15% for fit/assembly. Another 28% of rapid prototype models were utilized for patterns for cast metal, tooling components, and direct manufacturing-to name just a few. You also might find it very interesting and surprising that rapid prototyping has already been used to generate time and cost savings in fighter aircraft and the Space Shuttle.

Innovation is another reality of rapid prototyping. The reproduction of ancient statues, creation of art, and the modeling of anatomical structures are a few of the innovative applications. For instance, rapid prototyping was used in 2001 to help surgeons separate two Egyptian twins who were born conjoined at the head. Through rapid prototyping, models were created to help surgeons visualize the Ibrahim twins' shared anatomy, and plan for their separation surgery in 2003. Happily, the twins were successfully separated late last year after more than a year of planning and a 34-hour-long operation.

On the racing scene, rapid prototyping develops metal and plastic components for NASCAR and Formula 1 cars. In an environment where weight reduction is critical, race teams have found that rapid prototyping allows them to produce parts that improve performance.

So what will the future of rapid prototyping look like? As with many new technologies, research and development in this area is at a significant level. New methods, new applications, and new materials are continuously being tested in labs around the world. What this means to the users of rapid prototyping is that the future is likely to reveal not only many incremental advances, but also a handful of technologies that will change the process and the business of design and manufacturing. Over the next five, ten, or twenty years, rapid prototyping will have a broader application, wider acceptance, and a greater impact on many industries.

Although it may appear contradictory, at the same time that R&D increases, the rapid prototyping industry will also move toward standardization. As we progress into the future, consumers will set the tone by selecting standards based on what is most beneficial and desirable for their needs. In the coming years, standards for the process and deliverables will ensue, yielding clear classifications of rapid prototyping technologies.

Rapid prototyping's impact reaches far and wide. There is diversity in the application of rapid prototyping in terms of the disciplines that use it, the processes that benefit from it, the industries that employ it, and the products that are better because of it. The common element of all of its applications is that rapid prototyping is a tool that speeds up processes, improves product quality, lowers costs, and sparks innovation. The possibilities for rapid prototyping are endless, and I firmly believe that this technology can help designers, engineers, and executive management alike make better business decisions.

If you are interested in rapid prototyping and want to learn more about it, you should attend the Rapid Prototyping & Manufacturing 2004 Conference & Exposition. The event will be held in Dearborn, MI, May 10-13. Hear from Todd Grimm as he discusses the relative strengths and weaknesses of different rapid prototyping methods, and be the first to purchase his new book, "User's Guide to Rapid Prototyping." Grimm will be available to sign books on Tuesday, May 11, at a special networking reception. If you are not already a member of SME and you join at the conference, you will receive the book for free. What's more, you can hear from Terry Wohlers of Wohlers Associates, Inc. regarding the most significant trends in rapid prototyping during his "State of the Industry Executive Summary." For information and registration, visit www.sme.org/ rapid or call (800) 733-4763.

Todd Grimm

Founder and President

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Rapid Prototyping Makes Technologies Affordable by Enabling Mass Customization

PALO ALTO, Calif. -- The growing trends toward mass customization and demand for the quick turnaround of parts have boosted the importance of rapid prototyping (RP) as a manufacturing process. By quickly creating prototypes, RP enables faster time to market. In some cases, it can also reduce manufacturing costs by fabricating end-user parts without the need for hard tooling or molds.

Rapid prototyping technologies are exceptionally useful for short runs of specifically tailored parts or products. With RP, manufacturers can produce parts in hours and customization becomes as easy as changing a data file. RP can also aid engineering companies by enabling them to make prototypes quickly within the office environment itself.

In addition, RP helps designers and engineers design parts without having to adapt the design to the constraints of traditional manufacturing. It makes it easier to add customized features and complex designs.

Of the four main RP processes -- fused deposition modeling, selective laser sintering, stereolithography (SLA), and 3D printing -- some consider SLA to be the most suited to customize parts because of its ability to produce fine feature details. SLA is used in the dental, hearing aid, jewelry, and motor sport markets. RP technologies have gained a place in the toolbox of a number of manufacturers such as automotive, toys, golf equipment, medical devices, shoes, and NASA.

Despite SLA's popularity, many companies are looking to 3D printing as one of the most promising technologies in the RP field.

"3D printing allows prototypes or models to be made in an office setting, quickly and efficiently," says Technical Insights Research Analyst Shirley Savage. "3D printing is the breakout technology that will make RP a common engineering and manufacturing tool."

Already having netted 40 percent of the RP market, 3D printing is set to be the 'killer application' that will popularize RP technology. These expectations are based on its versatility, accommodation of a wide range of materials, and its easy use in an office environment.

The fact that 3D does not have any geometric limitations and hence, engineers can design just about any part using this process also attributes to its printing's potential.

"Manufacturers have shown interest in 3D printing as it can help produce prototypes as well as parts for end use directly from a computer-aided design model," notes Savage.

"Among its many firsts, 3D printing has the distinction of pioneering fabrication of ceramic parts," comments Savage. "Developers of 3D printing process are currently focusing on speeding up the process and looking for new ways to use materials other than plastics to broaden the range of applications."

Rapid Prototyping Technology, part of the Industrial Manufacturing Vertical Subscription Service, analyzes its uses in various applications, and examines the techniques involved. The research also looks at the future of this technology and explains the importance of advanced manufacturing. The RP processes included in this study are fused deposition modeling, selective laser sintering, stereolithography (SLA), 3D printing, combination RP techniques, and Internet-based RP and RP software. Executive summaries and interviews are available to the press.

If you are interested in an analysis overview which provide manufacturers, end-users and other industry participants an overview, summary, challenges and latest coverage of Rapid Prototyping Technology -- then send an email to Julia Paulson -- North American Corporate Communications at jpaulson@frost.com with the following information: Full name, Company Name, Title, Contact Tel Number, Contact Fax Number, Email. Upon receipt of the above information, an overview will be emailed to you.

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Rapid Prototyping Technology

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Rapid prototyping: bigger & stronger

Once it was all about small, fragile parts. But now, models made with rapid prototyping equipment are not only sizable, but durable

Lawrence S. Gould

A mere 17 years ago this month, stereolithography debuted at the Autofact show in Detroit. This ushered in rapid prototyping (RP), the process of creating physical models out of plastic directly from computer-aided design (CAD) geometry files. Gone would be the clay, wooden, and metal models that took lots of time and more money to produce. Back then, trade show attendees all stood in awe as cute, little gears and propellers and chess pieces and dinosaurs and so many more things essentially grew in the RP machines--right before our eyes. Better than pens, rulers, and other trinkets handed out at trade shows, attendees coveted these semitransparent or opaque prototypes out of plastic resin.

A lot has changed since then. The number of RP vendors has expanded and then consolidated. The number of RP materials has grown to satisfy all sorts of applications. More impressive, RP is no longer just for small parts, and RP parts are even being used in final assemblies. (Although those clay, wood and metal models have yet to disappear.)

FIT TO BE TRIED

Hyundai Mobis (Seoul, Korea) got around the limits of RP size when it needed to check for mechanical interferences and evaluate the airflow in a dashboard it was designing for a Kia being introduced in North America at the end of this year. Needless to say, car dashboards are larger than your average chess piece. Much larger. The new Kia dashboard measures 20 in. X 18 in. X 54 in.

Mobis has been using RP for about three years now on such projects as modeling ABS and airbag cases. These prototypes help Mobis verify part designs, mold patterns, and the master model of a mold, according to Tae Sun Byun, principal research engineer at the Autotech Div. of Hyundai Mobis. In the past, Mobis would have milled a prototype of the dashboard in plastic.

While effective, producing an accurate prototype for testing would have taken more than 20 days. Much of that time would have been spent cutting out the complex backside surface of the dashboard. Explains Byun, some of the walls in the dashboard measure only 1-mm or 2-mm thick, and some of the cavities in the dashboard are deep and difficult for a cutting tool to reach.

So, Mobis deployed an FDM Maxum, an RP machine from Stratasys Inc. (Minneapolis, MN; www.stratasys.com), to make the dashboard out of ABS plastic. This material, says Byun, "gives us the durable parts we need for assembly and functional testing." The designers had a prototype dashboard ready for testing in less than a week. It was an assembly of four pieces glued together. The dashboard model was mounted on a fixture and inspected with a coordinate measuring machine. The greatest deviation in the RP model was just 0.030 in. over its entire length of 54 in. In the next phase of part verification, the dashboard was mounted in a Kia cockpit mock-up. This revealed a few mating problems between the initial dashboard design and the ventilation ducting and related subassemblies. Sensors in front of the exhaust ports in the dashboard confirmed the effectiveness of the ventilation system.

All this checking identified 80 design problems--before the dashboard's release to tooling production. The designers went back to the CAD system to make the appropriate changes. Byun estimates the company saved more than $70,000 through RP. "If we did not make the RP dashboard," he says, "we would have had to pay that money to fix the finished injection molding tool used for the dashboard."

PARTS ON DEMAND

S & S Cycle, Inc. (Viola, WI) is an OEM and aftermarket supplier to motorcycle enthusiasts. About five years ago, it decided to take its RP work in-house by buying a Vanguard Selective

Laser Sintering system from 3D Systems (Valencia, CA; www.3dsystems.com). (3D Systems was the company that debuted RP at Autofact in 1987.) Since then, S & S has been using its RP machine to make prototypes, to help in making molds, and to make one-offs for actual races.

[ILLUSTRATION OMITTED]

For example, using OneSpace Designer Modeling, a 3D solids modeling system from CoCreate Software, Inc. (Fort Collins, CO; www.cocreate.com), S & S engineers and designers applied a shrink factor to a 3D model of a new crankcase. This model was then used to produce a RP master that perfectly replicated the aluminum engine part as it would have come out of the mold. S & S's casting vendor then rammed loose sand around the RP plastic model, removed the model, poured in aluminum, and made engine parts they can test before actually committing to tooling.

These are mostly destructive tests. S & S puts the parts in motorcycles and engine dynamometers and runs "the absolute hell out of them," says Eric Wangen, Concept Designer for S & S. But in the process, he continues, "we have simultaneous engineering and testing going on, rather than test at the end design cycle and hold up the sale of our product."

This is how S & S learns about its newly designed parts--before tooling is ever made. Wangen admits that without RP, he doesn't know how S & S would shorten product development from concept to production. He doesn't relish going back to the "old way": six months design, six months testing, and another six months or so to make tooling. And when all is done, S & S may still need to make modifications to that tooling.

Sometimes RP is used directly to make tooling. For a new cylinder head, S & S used RP to make a head for a sand cast mold that was used in production until a low-pressure permanent mold in steel was ready 26 weeks later. This provided two broad benefits. First, S & S was able to work out any glitches in the mold design before committing half a million dollars to the final mold for high-volume production. RP is "smart money," says Wangen; "all the changes to the mold design were done before we started making tooling." Second, S & S could produce 1,000 or so aluminum engine parts from the sand-cast mold, using it as a bridge between low-volume and high-volume manufacturing. This "bridge tooling" let S & S ship product six months earlier than expected.

But here's a big win for RP: Producing finished parts. The gearheads that race bikes are constantly changing something, tweaking a little here or there, looking to get more power out of their bikes. Last year, at the Mopar Parts Mile-High Nationals in Denver, the team behind rider Dave Feazell changed the location of the port where it comes out of the cylinder head. They sent the head to S & S, which designed a new manifold in 48 hours. Another day or so was spent using RP to make the new port out of 3D Systems' DuraForm glass-filled material. This material is resilient enough to withstand the violent vibrations that are the norm in bike racing. Because the intake system of the manifold was running cool air, all Feazell's team had to worry about was the resident heat after the engine was shut off. For that, S & S applied silicone around the manifold ends to insulate the part and keep it from melting.

Feazell's team got the part on his bike in time for the qualifying rounds. The RP part held its own; Feazell shaved over 0.003 seconds off his race time.

By Lawrence S. Gould, Contributing Editor

Engravings bring stone to life

Michael Hooper

By Michael Hooper

THE CAPITAL-JOURNAL

An interest in engraving images on marble and granite has turned into a business for Kent and Terry McPherson of rural Topeka. "We weren't looking for a business," Kent McPherson said. "But we just couldn't pass it up. It is such a neat product."

The McPhersons, owners of Laser Art Creations, use a special machine to engrave images on marble, granite, acrylic, wood and leather. They discovered laser engraving in Las Vegas during a trade show Jan. 15, 2006, on Kent's 50th birthday. While there, they saw a laser engraver that put images on stone.

In January 2006, they ordered a VyTek Laser Engraver. They went to a Boston suburb for training in March and started their business, Laser Art

Creations. Terry McPherson had previously done freehand diamond-tipped etching.

"We thought it would be a good retirement business, something to keep us occupied," Kent McPherson said. "We like to do it."

She works full-time for AT&T, and he works for McPherson Wrecking. They aren't planning on giving up their day jobs yet, but they have been getting busy. They received about 40 orders for Christmas.

"We started getting orders after the Buy Kansas Expo in May," she said. "We've been really busy for Christmas."

Their most popular product so far is a slab of heart-shaped marble with a picture in the middle. A photo supplied by a customer can be duplicated on stone.

One young boy put together several images for an acrylic plaque to honor his mother for Christmas.

The couple has made plaques and headstones for people who want to honor loved ones. They also have made a few headstones for pets. Customers may put images of their pets on the stones.

Some customers put engraved stones in their gardens.

McPhersons can engrave images on marble slabs ranging in size from 23/4 inches by 43/4 inches up to 18 inches by 24 inches. The 18- by-24-inch marble piece is $325.

The couple had a display during Cider Days this fall and sold about 20 pieces, many of them with pictures of children.

They also sell keepsake boxes, jewelry and leather pieces.

Orders have been pouring in, and the McPherson garage northeast of Topeka is filling up with product.

"We've come a long way since March," Terry McPherson said.

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Examine the Coating, Engraving, Heat Treating, and Allied Activities Industry in the U.S

DUBLIN, Ireland -- Research and Markets (http://www.researchandmarkets.com/reports/c75166) has announced the addition of "Coating, Engraving, Heat Treating, and Allied Activities Industry in the U.S. and its Foreign Trade (1997-2009)" to their offering.

This industry report includes 168 pages of the latest market research information. In addition to the detailed explanations of the provided statistical data, there are 112 charts, 18 tables, and 2 maps to effectively illustrate the content. Use this report as an in-depth analysis of the industry, an industry reference guide, an aid for benchmarking and forecasting, and as a tool for uncovering new business opportunities. The report is considered the most comprehensive research in the market.

Our clients include Fortune 500 companies, domestic and global manufacturers, major retailers and wholesalers, professional trade associations, financial corporations, universities, governmental entities, start-ups and individuals.

This industry report packs 10 years of data from hundreds of reliable government and private statistical resources. The data have been compared and verified to assure the highest research

quality. We frequently contacted these agencies and private companies to acquire the latest information, most of which is unavailable to the general public. It is estimated that to gather and organize the same information into an easy-to-read format in each report, an individual researcher would spend at least a year's worth of effort. The challenge is, by the time this is accomplished, some data most likely becomes obsolete. Our business is dedicated to the research of U.S. industries and their associated foreign trades. We can meet that challenge easily as our databases are directly linked to these resources.

Want to find out the industry's supply, demand, capacity, market size, and import and export? What about the industry's products and materials? Need benchmark information on the industry's cost structure and profitability? Need data to analyze labor force and its productivity? Who are the major players in the industry? What are the latest trends? What about green manufacturing, sustainability and compliance?

The industry's revenue for the year 2006 was approximately $23,780,000,000. The total import export value for the year 2006 was $77,542,712,000. There were 218 countries that conducted foreign trade with the U.S. in 2006, 1 more than year 2005. The top trading countries were: Canada, $15,998,607,000 (20.63%); China, $13,768,683,000 (17.76%); Mexico, $11,168,844,000 (14.40%); Japan, $5,115,771,000

(6.60%); and Taiwan, $4,281,039,000 (5.52%). Their combined total represents approximately 65% of all imports and exports.

There are no import/export data for this industry. For reference, we are using the Fabricated Metal Product Manufacturing industry (NAICS - 332). The total import value for the year 2006 was $45,962,879,000. This represents a 11.9% increase from year 2005. The top importing countries were: China, $11,811,657,000 (25.70%); Canada, $6,359,319,000 (13.84%); Mexico, $5,258,586,000 (11.44%); Taiwan, $3,633,174,000 (7.90%); and Japan, $3,583,829,000 (7.80%). Their combined total represents approximately 67% of import from all countries.

There are no import/export data for this industry. For reference, we are using the Fabricated Metal Product Manufacturing industry (NAICS - 332). The total export value for the year 2006 was $29,438,779,000. This represents a 16.4% increase from year 2005. The top exporting countries were: Canada, $9,547,752,000 (32.43%); Mexico, $5,864,942,000 (19.92%); Japan, $1,382,716,000 (4.70%); United Kingdom, $1,342,538,000 (4.56%); and China, $980,584,000 (3.33%). Their combined total represents approximately 65% of export to all countries.

This industry report packs 10 years of data from hundreds of reliable government and private statistical resources. The data have been compared and verified to assure the highest research quality. Supplier Relations US, LLC. frequently contacted these agencies and private companies to acquire the latest information, most of which is unavailable to the general public. It is estimated that to gather and organize the same information into an easy-to-read format in each report, an individual researcher would spend at least a year's worth of effort. The challenge is, by the time this is accomplished, some data is most likely obsolete. Our business is dedicated to the research of U.S. industries and their associated foreign trades. We can meet that challenge easily as our databases are directly linked to these resources.

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Will we use welding technology to make RPs?

Processes under development at Southern Methodist Univercity's RCAM (Research Center for Advanced Manufacturing) in Dallas employ a high-power laser and/or different welding processes

(gas metal arc welding [GMAW], gas tungsten arc welding [GTAW], and variable polarity gas tungsten arc welding) for rapid manufacturing or solid freeform fabrication of metallic components.

Led by Radovan Kovacevic, FSME, the RCAM research team is developing a solid free-form fabrication system that consists of a Nd:YAG laser, multiple-powder delivery unit, coaxial nozzle, three-axis CNC positioning system, and sensing units to monitor temperature, metal powder flow rate, and geometry of the clad bead. When perfected, this system will be used to make metal parts, to repair worn parts, dies and tools, and to build parts with functionally graded materials.

RCAM's effort may represent the first attempt to control rapid prototyping welding processes for depth of penetration and heat buildup into the layer. Researchers say that part accuracy and surface finish must be improved, and the weld bead's microstructure, residual stresses, and geometry must be controlled.

Existing methods for metal transfer control in GMAW have two major flaws: uncertain detachment time and inconsistent droplet size. To avoid these flaws, a new sensing and control method for metal transfer in GMAW uses a high-frame-rate digital camera assisted by a He-Ne laser and a real-time image-processing algorithm to monitor droplet formation. A PCI frame grabber and a Pentium III PC provide realtime droplet monitoring and control. This method of controlling the GMAW process reportedly is the first that can accurately control the height to width ratio of the bead layer generated by GMAW. To decrease the cost of sensing and metal transfer control in GMAW, researchers recently eliminated the high-frame rate camera and replaced it with a simpler device that consists of a controller and a sensor based on a photo diode and a laser diode for backlighting.

Researchers also use gas tungsten arc welding (GTAW) instead of GMAW for deposition by welding. In GTAW, the wire-feeding rate does not depend on the welding current as it does with GMAW.

It's possible to completely stop the metal deposition process with the arc on. Also, GTAW wire can be fed directly into the molten pool. Surface tension spreads the liquid metal evenly and thus avoids possible irregularities inherent to the droplet-based metal transfer. The weld bead in GTAW can be placed next to the previously deposited bead. In GMAW, however, the previously deposited bead will affect arc stability, and an additional mechanism is necessary to ensure that the wire is always fed in front of the moving arc. In GTAW, to achieve a uniform cooling rate or uniform mechanical properties of the welded substrate, the molten pool volume is kept constant by adjusting heat input. Controlling the welding deposition process for GTAW requires controlling the shape and size of the molten pool.

A machine vision system supplied by Weldware Inc. (Columbus, OH) co-axially installed with the torch acquires information on the size of the molten pool. A closed-loop control system now under development controls pool size by changing the heat input by altering the welding current in real time. Another new deposition process uses aluminum alloys. To remove oxides from the top surface of the aluminum substrate through so-called cathodic cleaning action, variable-polarity gastungsten arc welding is used. Switching between positive and negative polarity causes the periods of electrode positive to remove the oxide and clean the surface. The experimental setup consists of a four-axis CNC positioning system, a variable-polarity welding power source, an arc-length sensor based on machine vision, an image processing system, a GTAW torch with a wire feeder, an infrared pyrometer, and a PC-based control system.

One workpiece made by this system, a cylinder 120-mm high and 100-mm in diam, was built by layering 300 weld beads, each 4mm wide and 0.4-mm high. Another, a cone, consists of two segments: the first is 76 mm in diam and was built of 60 layers, 5mm wide and 0.4-mm high. The second has a starting diameter of 76 mm and an ending diameter of 46 mm, and consists of 100 layers with the same dimensions as the layers from the first segment.

Surface quality of both samples is reportedly comparable to that obtained in precision investment casting. However, to directly fabricate metal parts and tools that are dense, metallurgically bonded, geometrically accurate, and exhibit good surface appearance, the researchers built a hybrid rapid prototyping machine that incorporates deposition by welding with 2 1/2-axis CNC milling. This hybrid machine allows the production of metallic parts and tools with high dimensional accuracy and with complex external and internal geometrical features.

The 21/2-axis positioning system only permits fabrication of parts with vertical walls. Kovacevic says the future hybrid rapid prototyping machine will consist of a six-axis robot, a five-axis CNC milling machine, a six-torch automatic changer, and six torches with corresponding wire feeders providing the ability to use different wire diameters and metals. It will have two welding power sources for different welding processes (GMAW, GTAW), with internal control and pulsing capabilities, and a number of sensors and controllers.