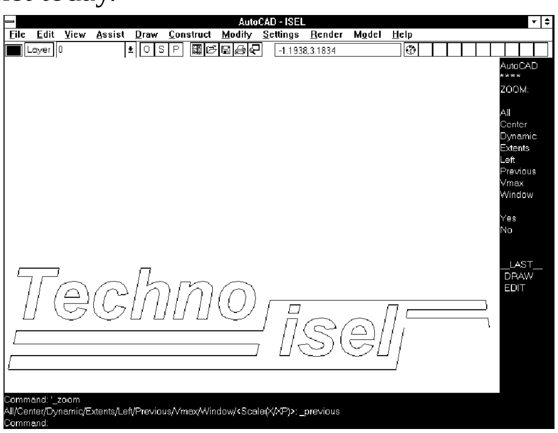
1. CAD, CAM and "Alphabet Soup"

Introduction

The CAD/CAM industry has developed a diverse set of jargon (mostly "alphabet soup") to describe its various parts. Normally, this condition would not present a major problem except that the CAD/CAM industry affects so many other industries, such as woodworking, sign-making, plastics fabricators, etc. In this brief overview we will attempt to organize and clarify the "alphabet soup", by looking at CAD, Illustrator and CAM programs.

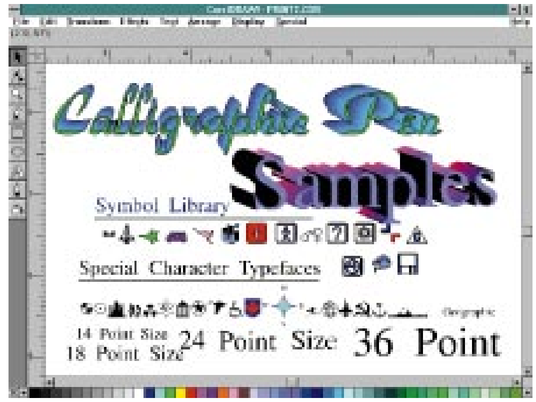
CAD

CAD stands for Computer Aided Design and, as the name implies, its programs are meant primarily for engineering drawings and drafting. These programs typically provide dimensioning information and the ability to draw geometric shapes, and produce drawings based mostly on lines, arcs, spline curves and, more recently, 3-D surfaces. Packages such as AutoCAD, CADkey and ProEngineer are some of the more commonly used CAD programs on the market today.



Illustrator Programs

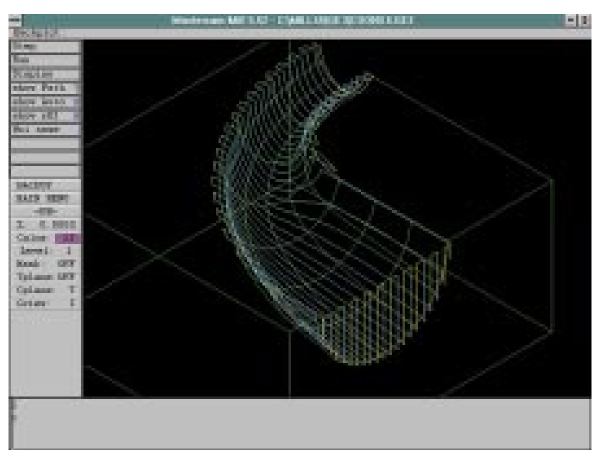
Illustrator or drawing programs are similar to CAD programs, but are more artistically oriented. These programs are used to develop illustrations, graphics, fonts, etc. They typically are based on lines, arcs and Bezier curves. Bezier curves are special shapes that produce very smooth curves. These illustration or drawing programs can only produce 2-D drawings with optional 3-D effects such as extrusions and perspectives. Note that these are strictly effects, and that the drawing remains 2-dimensional. Examples of illustrator programs include Adobe Illustrator, and Corel Draw.



CAM

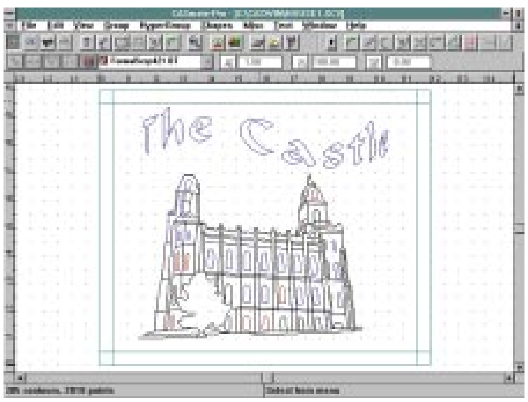
CAM programs (Computer-Aided Manufacturing) take the drawing to the final stage to produce machining instructions or toolpath instructions to make the part on a router, milling machine, lathe or any CNC (Computer Numerically Controlled) machine.

These programs have limited provisions for drawing compared to CAD programs, but this capability is improving as the three families of programs start to converge. The primary capability of CAM programs is the generation of toolpaths to produce parts, taking into account tool shape and diameter. Various applications require large diameter tools for the roughing work and small diameter tools for the detail work. Other applications might require tools with flat bottoms, round bottoms, angled cutters or even specially-shaped tools (e.g., to cut decorations in cabinet doors). Among the top choices for CAM packages are MasterCAM, SurfCAM and Enroute.



Sign-Making Software

There is yet another class of software that is a hybrid between illustration software and CAM software: Sign-Making Software. There are a number of excellent packages (CASmate-Pro being our preferred selection) that provide the drawing capabilities, fonts and special effects usually found in illustration programs, as well as toolpath and routing capabilities usually found only in CAM programs. The specialized tools developed to perform these functions are usually much more efficient than trying to combine existing packages together to perform similar functions. Specifically, our experience is that one could, for example, use a combination of Corel Draw and MasterCAM to make virtually any sign desired, but the CASmate-Pro package can accomplish the same task in far less time, with far less effort, by using tools that are better designed for these specific applications.



2. Producing the Drawings

The first step in any type of CAD/CAM application is to generate a computer model of the part that you wish to develop. There are many different methods and software packages that can be used to accomplish this task. The following is a listing and description of some of the more commonly used approaches.

Drawing

Drawing, of course, is the old-fashioned way. Adapted to working with a CAD program and a mouse, this process is the electronic age equivalent of pen + paper + ruler. The designer, using a drawing as a reference, creates a CAD file. Different programs offer different approaches to user interfaces and drawing features. This method of redrawing is extremely accurate but can be time consuming. When high accuracy is not an important consideration, redrawing is not an efficient use of time.

Tracing

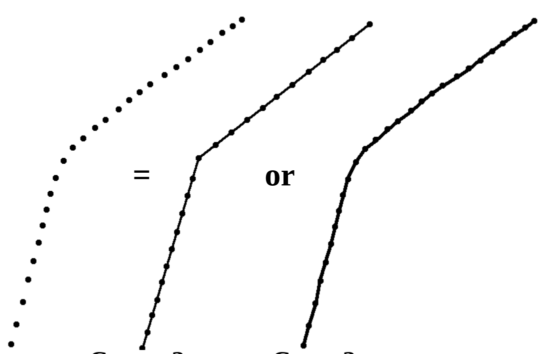
This process involves tracing a piece of artwork with a stylus or cross-hair-based digitizing tablet. The artwork is taped to the surface of the tablet and the user can “click” on key points such as corners or points along curves to “enter” the coordinates into the CAD program. Note that the program can be in a mode where it is accepting a line, an arc or a series of points along a spline curve.

2-D Scanning

There are now a number of low cost (under $1,000.00) scanners capable of accepting original artwork and scanning it to produce a computer model. This process, actually, consists of 3 steps: scanning, vectorizing and, usually, editing. It is only after these steps that the part is ready for the CAM operation.

There are several types of scanners available. Hand scanners tend to be extremely inexpensive, but their drawback is that it is very difficult to drag a scanner in a straight line at a constant speed. Variations in speed or straightness result in a distorted image output. Another type is the rolling scanner or sheet-feed, in which rollers move the artwork across the scanning elements. These usually produce better results than hand scanners, and are quite acceptable. Flat bed scanners generally produce the finest quality images. The operating mechanism is a scanning head that moves under (or over) the stationary artwork. In any case, the output from any of the scanners is a bit-map, or “sea of points.” In the case of a "line art" type scan, the data points are a series of 1's and 0's that indicate a "dot" is or is not present. A "gray scale" type scan is usually used for photos and each dot has an intensity, typically ranging from 0 to 255, to represent how dark the dot is.

The bit map must be vectorized, namely, converted into a collection of lines and arcs since CAD/CAM programs do not work on the bits produced by scanners. There are two distinct approaches to this process, depending on whether the original art was line art or filled art. The easier of the two processes involves finding the boundary of filled areas, or blobs. The conversion of line art involves converting a collection of bits into lines and arcs. This process tends to be a little more difficult since the software has to filter the information and make decisions about the nature of lines. Some packages will perform only one of these processes while others will perform either, or a combination of the two. Regardless of which software package is used to create the artwork, the bit-map is usually vectorized with a single command. A good software package will automatically vectorize the image so that the resulting lines and arcs are fairly smooth and continuous, which saves endless hours of editing time.



Example of filtering-type decisions faced by vectorizing programs

Once the image has been vectorized, a critical and necessary step is editing, or cleanup. This step involves straightening crooked lines, fixing corners, getting rid of noise, etc. Our experience is that this step is the most critical step, in that the most time can be lost here depending on the efficiency of the editing tools. Any evaluations of this type of software should concentrate on the editing process, with special attention paid to ease of use and available features. Critical features include smoothing, squaring off corners, making lines horizontal or vertical, adjusting curves, etc. This process, however, is largely a matter of personal preferences rather than objective evaluation and should be thoroughly examined by the end user.

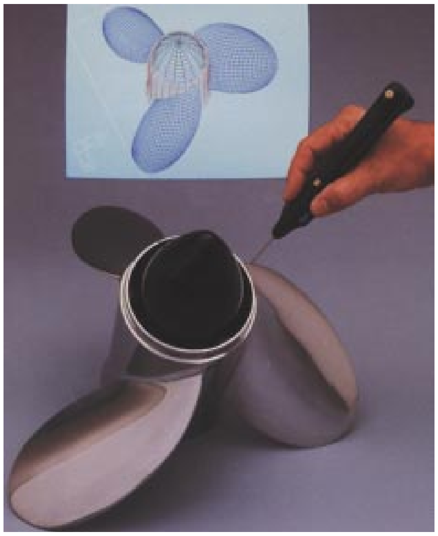
The final step in the design process involves placing and adjusting the image. Often, this means importing the image and resizing, or introducing special effects such as mirroring, rotating, shadowing, etc.

3-D Scanning

It is now within the realm of the practical budget, under $10,000, to actually scan 3-dimensional models and produce a CAM or CAD drawing. This process generally has two distinct approaches: probe type scanners, and hand-held pendant type scanners. In both cases, a series of (X,Y,Z) coordinates are collected from the object and are then brought into a CAD or CAM package. Once in the software package, the user will generally filter the points or create special features such as circles, lines or edges based on the shape of the "sea of points." Some effort is required to accomplish this task, but far less than alternatives to reverse engineering a complex shape.

The family of Probe Type Scanners includes touch probes, ultrasonic displacement measurement devices and laser type displacement devices. Each of these devices are typically mounted onto a CNC machine or a Techno type positioning table. The device is then moved over the part along a grid of X-Y locations, and the "height" of the object (actually, the distance from the object to the probe) is recorded. In effect, a "sea of (X,Y,Z) coordinates" is collected. The denser the grid, the finer the detail that can be measured. This approach is ideal for reverse engineering a smooth, varying surface that does not have any (or at least many) hard edges. The probes can collect a great deal of accurate points on the surface, but unless the grid is extremely fine, edges and crisp lines will not be easily or accurately determined.

The family of Hand-Held Pendant Scanners are like 3-D versions of digitizing tablets. A pen or stylus is positioned by the user at various locations on the part and the (X,Y,Z) coordinates of the pen tip are recorded on a PC. Because this is a manual process, it is difficult to collect large quantities of data over uniform grids, but these devices do have an advantage in that special features such as edges, boundaries and crisp lines can be directly measured and recorded because of the direct interaction of the person.



Hand held 3-D scanner

3. “Conquering the Tower of Babel”

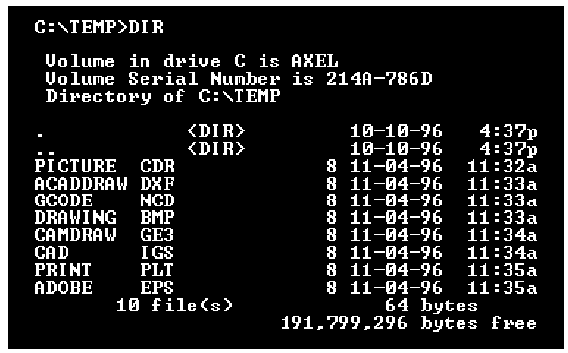
Each of the various types of software packages has its own unique internal representation of a drawing. These packages can also “import” or read in various formats of drawings and they can also “export” or output various formats of a drawing. There are a large variety of import and export formats and each has its own characteristics. The following section will describe the various advantages and disadvantages of each of these formats.

Introduction

One of the most formidable tasks involves making a number of different programs work together; i.e.:

- ☞ CAD programs with CAM programs
- ☞ illustrator programs with CAD and CAM programs
- ☞ sign programs with CAM programs
- ☞ other combinations that can get kinky.

Each software package has a number of ways in which the drawings may be described and stored. These varieties are called either format types or file types. The name of the drawing is usually specified by up to 8 characters, followed by an extension which can use up to 3 characters; e.g., “FILENAME.EXT.” The nature and flexibility of these data formats becomes critical when sending information back and forth between different software packages, as not every file format can be understood by every package. Different formats representing a drawing are like different languages (French, English, Japanese, etc.) representing an idea.



Universal Formats

There are a number of universally accepted formats or industry standard file types for CAD, Illustrator and CAM packages, such as .DXF, .AI and .NC, respectively. A brief description and background for each is given below:

Extension: **DXF**

AutoCAD, the originator of this format, has changed the definitions slightly, creating some confusion. This format is still the most universally used, but is limited with respect to 3-D drawings. Also, it is virtually impossible to transfer font information via .DXF, since only the font name is provided, not the font geometry.

Another serious drawback of this format is that drawing programs tend to linearize curves when using this format to export drawings. That is, a Bezier curve is usually converted to hundreds and thousands of line segments. This process results in simple drawing files producing huge .DXF files with thousands of entities. A .DXF file with thousands of entities usually slows down the target software (CAD or CAM) and can result in a shoddy finished product if the .DXF file is machined or routed. Curiously, a .DXF file produced by a CAD program can be read by most drawing programs without losing the arcs from the .DXF file.

Extension: **IGS**

The IGES format is generally used almost exclusively by CAD programs. This format is the most universally accepted and consistent. Similar to .DXF, it is limited in its font information since only the font name is provided and not the details about the font geometry. IGES is the best for transferring information about 3-D surfaces because of the large variety of surface types that can be described.

Extension: **AI, EPS**

Adobe Illustrator and Encapsulated Post Script are general graphics languages developed by Adobe which are used to generate printing instructions for Post Script type printers. Output is in the forms of text characters, lines and Bezier curves. These two formats are virtually identical and are excellent for transferring information between drawing programs and sign software. Very few CAD programs use this format (although Auto CAD and a few others have begun to do so) and virtually no CAM programs use this format.

Extension: **PLT**

This format is usually used for plot files, and can be considered a "back door" approach to transferring drawing information. Since a plotter is a "natural" output medium, virtually every package outputs to the industry standard HP plotter. The language for this is HPGL, which stands for Hewlett Packard Graphics Language. Most drawing programs also have the capability to import this format, so it is a convenient way of getting information into drawing programs and sign-making packages. The major drawback with this format is that curves are usually converted to a large number of short line segments, slowing down the software and producing curves that might not appear smooth.

Extension: **NC, NCD**

This extension usually, but not universally, refers to standard G-code programs using EIA-274 standard CNC commands. Most CAM type programs can import or "reverse post" this format to create a drawing from a toolpath.

Proprietary Formats

In addition to the universally accepted file types, each software company has its own proprietary formats to describe and store the drawing information. These formats are generally used internal to the software of origin. A few of the more common types are listed below.

Extension: **DWG**

Internal AutoCAD format for drawings.

Extension: **CDR**

Corel Draw internal format for drawings.

Extension: **CDL**

CADkey internal format for drawings.

Extension: **GE3**

MasterCAM internal format for geometry.

Extension: **NCI**

Neutral Cutter Information describing toolpath in a generic format. Internal to MasterCAM.

Extension: **BMP, MSP, PCX, TIF**

Various formats all of which refer to bit mapped images produced from scans or "paint" type programs. TIF is the most universal format, found in both PC and MAC systems.

The Exchange of Information and Its Limitations

It is sometimes desirable to use several different software packages in combination to achieve a desired result. For example, you may wish to begin by scanning a drawing into Adobe Streamline; then use AutoCAD for its drafting capabilities; then use CASmate-Pro for its powerful editing features and toolpath generation capabilities. At first, this process seems like quite a task; but, with some practice, it becomes a common and easy thing to do, even for beginners.

Each of these software packages, has the ability to import files from or export files to other packages, which is also known as the "reading and writing" of files. This exchange usually involves a translation of formats, but nearly all software packages will allow the user to initiate simple menu-driven commands to perform the task. The exchange of information consists of two parts. First, the proprietary format (all images are displayed and manipulated in the packages' proprietary format) must be converted into a universal format and exported into a common directory, which is performed from within the first package. Once the second software package has been accessed, the universal format from the common directory can be imported. The importing software package actually converts the file into its own proprietary format and then displays the image. The drawing is now ready for manipulation in the second package.

This compatibility allows most all packages to be used in combination with each other, although limitations do exist. Some formats lend themselves well to specific types of information, while others do not. Here are a few examples of some of the limitations one can encounter, although hands-on experience with file and drawing manipulations will prove to be the best teacher.

.PLT: This approach is limited in that the curves and arcs are usually converted to a series of line segments, resulting in very large files. This method should be considered a last resort when transferring font geometry from one program to another.

.DXF output from illustration programs: This format usually results in curves being broken into thousands of lines, slowing down programs and producing a jagged output.

.AI, .EPS formats usually cannot be imported into CAD programs.

Internal fonts and clipart

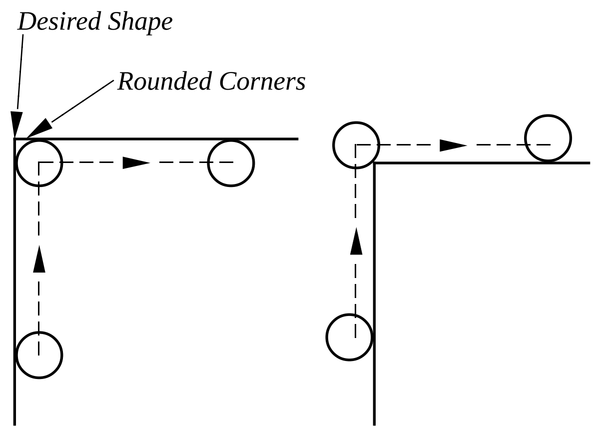
Often, these are only specified by name, rather than by description of shape. Thus, fonts often cannot be transferred between programs. The desire/need for fonts and clipart has produced a tremendous migration of software to the Windows environment. The fonts and clipart are readily available and there is far less difficulty sharing them between applications. Windows provides the "clipboard" as universal language translator to transfer text, fonts, drawings, etc. between packages.

4. Toolpath Generation

Once the part to be machined is represented by a computer model, a set of machining instructions must be produced. These instructions are needed to guide the path of the cutter over the raw material. The toolpath is always created with a CAM software package. This type of software allows the user to input parameters such as cutter size, finish quality, and number of passes over the material. Based on the specified parameters, the CAM program then calculates the toolpath.

Inlays

Inlay work requires special consideration of corners prior to the toolpath generation. When a round tool is used to cut an inside corner, the corner will have a radius equal to at least that of the cutter. The corresponding corner on the mating part is an outside corner and must match the radius of the inside corner to fit properly.



Female Cavity
All internal corners are rounded to the shape of the cutter

Male Inlay
Sharp outside corners can be cut but will not fit into female cavity

The user must go through the drawing and fillet or round all corners to ensure a proper fit.

Working with Scanned Images

Drawing and CAM programs often have the ability to vectorize scanned images. When it is necessary to include a logo or some unique artwork in a machined part, a scanner is extremely useful. There are any number and type of scanners available.

There are several factors to consider when working with scanned images. The resolution, or amount of detail in the scan, is determined by the quality of the device used. Low end scanners typically have resolutions of 300x300 dots or pixels/inch. Higher quality models usually have 600x1200 pixels/inch, while professional quality scanners have pixel densities of 2400x2400 or better.

Another scanner feature to consider is color resolution. Scanners are available in both monochromatic and color versions. Color scanners are equipped with an additional parameter which indicates the number of available colors which can be scanned. Lower end color scanners have either 8 or 16 bit color resolution, resulting in either 256 or 65,536 different colors that can be resolved, respectively. Newer models now feature 24 and even 32 bit color resolution, meaning that either 16 million or 4 billion colors can be scanned. High color resolution is critical for capturing subtleties of shading, such as skin tones. Monochromatic scanners usually feature 8 bit resolution, or 256 levels of grey shading which can be scanned. Higher end monochromatic scanners will often have 16 bit shading, meaning 65,536 degrees of grey.

The type and quality of scanner selected depends largely upon the applications and frequency of use. Line art tends to need higher resolution to prevent "jaggies," or jagged lines, from appearing. On the other hand, filled art (artwork made up of black and white or colored regions as opposed to lines) can often be scanned and worked with moderate resolutions. One important consideration is that the size of the scanned file grows enormously as the pixel and color resolution increases.

e.g., image - 4" x 4"
at 300 x 300 dpi = 1,440,000 bytes
at 600 x 600 dpi = 5,760,000 bytes

Thus, doubling the resolution increases the file size by a factor of 4.

Note that these figures are for 8 bit grey scale images. If the images are stored as pixels, both file sizes reduce by a factor of 8. Also, scanned images are usually stored in a compact format that takes into account large blocks of blank area or large blocks of black area. Thus, the actual file sizes would usually be smaller but the geometric increase in file size still remains.

Machine Code and Post-Processing

CAM programs store toolpath information, in a separate file, as a set of executable motion instructions. The format of these commands can be unique to a particular program or a universally accepted standard. The most common standard format is the G-code machine tool command language. G-Code is a universal standard set of motion commands used by CNC machine tools. This set of commands is sometimes called APT, but in either case it is a standard way of specifying linear and circular motions. Once the toolpath is written to a G-code file, the user can exit the CAM program to begin machining.

The toolpath created in the CAM software package is most often translated into G-Code with the use of a post-processor. Post-processing software accepts the toolpath information and allows the user to customize the toolpath commands for a particular CNC controller or machine. This post-processing allows for machine specific instructions such as tool changers, canned cycles or special format requirements.

5. Fixturing & Dust Collection

Several different methods exist for securing the raw material to the work surface of a gantry table. Vacuum tables allow for quick and easy fixturing of materials. This type of table is extremely useful in production operations where speed and ease of operation is required. The surfaces of nonvacuum tables are usually slotted to allow for the mechanical fixturing of workpieces. The T-slots on the table accept T-nuts which the operator can use to secure clamps and bars. Vacuum cups can also be secured to a T-slotted surface to create a vacuum table.

Machines, as well as their operators can be adversely affected by the waste products the machining process generates. Dust reduces the effectiveness of lubrication which shortens the life of a machine. Also, particles in the air generated by some materials can be harmful when breathed into the lungs. In order to keep the work environment free of damaging dust and debris, a collection system is required. Most often this type of system consists of two parts, a vacuum and a vacuum shroud. The vacuum shroud is fitted over the cutting head to collect the dust during the cutting process. A hose is attached to an intake on the side of the shroud and a vacuum is applied, collecting the dust. AC motor type dust collectors are recommended because of their increased air flow and because the motors are much more silent than conventional shop-vac type systems.

6. Tool Selection

Once a part has been programmed and the raw material fixed to the table surface, the operator must select the cutting tool. Cutters are available in a great variety of shapes, sizes and materials. Several factors must be taken into account when choosing the type of cutting tool to utilize. The type of material to be cut, the finish quality required, and the shape of the desired cut are some of the factors which must be considered.

The material to be cut directly affects the shape of the cutting flute selected. Standard helical flutes work best with metal, while straight flutes are used for optimal performance in wood cutting operations. The straight flute provides for high chip clearance which improves the surface finish. O-flute cutters provide space for waste chips, reducing the amount of material which is remachined and consequently remelted on the surface. Evacuation of waste chips and their effects on the material surface is an important concern when choosing the spiral direction of a cutting tool. Spiral up tools are ideal for plastics, solid woods, and metals because they provide fast, efficient evacuation of material. Cutting of laminated materials is best achieved by spiral down tools because the downward pressure of the spiral keeps the laminate from separating and producing a jagged edge. This effect is especially important on laminations and in surface cuts on MDF, particle board, and plywood. "Through cuts" on MDF and plywood require a hybrid up/down spiral cutter. This compression type cutter produces downward pressure on the top surface and upward pressure on the bottom surface, thereby cutting both edges cleanly. V-shaped cutters (v-cutters), available in a wide range of angles, are useful when engraving wood and plastic. V-cutters, when used in 3D engraving, produce a "hand carved" look with square corners. When used for shallow engraving, V-cutters are available in both a "half round" and "quarter round" configurations. The half round cutter, a full round blank split in half, is excellent for engraving plastics and other soft materials. This type of tool allows for high cutting speeds and high material removal rates which produce clean finished engravings. Engraving metals such as stainless steel and titanium calls for a quarter round shaped cutting tool. The quarter round shape allows for even more chips to be evacuated from the cutting area, producing the best possible finish.

The material of the cutter is also directly affected by the material which is to be cut. Carbide is a common tool material which is used on most woods and plastics. Carbide tends to hold an edge longer, especially with abrasive materials, such as woods. High speed steel is utilized when cutting metal, especially aluminum. There are any number of coatings applied to cutters to enhance performance and tool life, including cobalt and TiN (or titanium nitride). The scope of these coatings goes beyond this introduction to tooling.

7. Lubrication and Cooling

Finally, we cannot have a discussion on tooling without discussing lubrication and cooling; some materials require a great deal of both, while others can be cut without any cooling or lubrication. Woods in particular do not require either. When plastics are cut they generally can be cut dry, but the harder plastics such as Lexan, Delrin and ABS fare much better with mist or flood type coolants. We have found in particular that a major consideration is the removal of heat and the chips which helps prevent remelt on the cut surface. We have used inexpensive mist coolers with a very high air to liquid ratios to produce very nice cuts in plastics.

Metals tend to vary much more greatly in their cutting properties. Even among aluminum alloys, one can see large variations in the metals cutting properties. With most metals, we have found that at least a mist coolant is required. The lubricant/cutting fluid also can greatly affect the quality of the cut. There are any number of specified fluids for different metals including steel, aluminum, magnesium and titanium among others. Each of these metals and their alloys require special cutting fluids.

We have successfully used dishwashing liquid containing lanolin (such as Palmolive) for light cuts in stainless steel and aluminum. We have also found that nothing short of a flood coolant with a high flow rate would work for titanium. This metal in particular seems to heat up and we have even seen chips ignite when the pieces did not have flood cooling.

The only specific recommendation that could be made is that a great deal of investigation might be necessary to find the best cutting fluid for a specific metal. One of our customers, cutting gold, searched for weeks until he came on the right combination of tooling and cutting fluid. In the end, the result was sensitive to the point where supposedly equivalent competitive brands of cutting fluid did not produce the same results.

Finally, we must mention that, in cases where fluids are not an option, air cooling often works well. As was mentioned earlier, removing the chips and the heat are the main concerns and although flooding is often the most effective, high air flow rates will often work as well. There is in fact an air chiller available for this purpose. This device utilizes the principle that expanding air absorbs heat. This type of cooling jet can produce temperature drops of 50 to 100° F and blow the chips away at the same time.

Finally, we must emphasize that caution be used with any cutting process. Besides the obvious physical dangers, many metals become highly reactive and, in fact, explosive when heated and cut into small parts. Titanium, mentioned earlier, and magnesium are two of just many reactive metals that should be dealt with great care. Even woods have to be handled with care, as the dust produced by many exotic woods is extremely toxic.

8. Tool Changing Systems

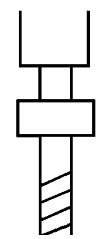
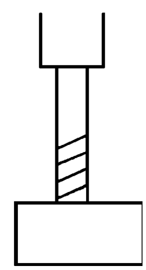
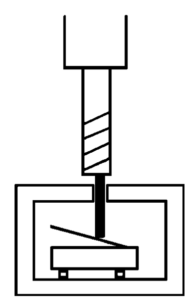
Tool changing systems, generally, fall into 3 categories:

A. Manual
B. Manual quick change
C. Automatic

The 3 systems become progressively more complicated and consequently more expensive.

A. Manual Tool Changer

This is the simplest, least expensive and requires the most attention and care when tool changes are required on a single workpiece. The major difficulty in manual tool changing is inserting the cutters to a uniform depth. The difficulty stems from the fact that most collet systems tend to "pull" the tool slightly when the tool is tightened. Some common approaches to consistent tool length adjustment are as follows:

- **Tool Shank Collars**
  
  A collar, usually made from a hard plastic, is press fit onto the tool shank, a precise distance from the tool tip. This provides an automatic height gauge as well as a block to prevent the tool from being pulled in too far as the collet is tightened.
- **Gauge Block**
  
  This approach involves using a hard surface as a height reference. The tool is inserted into the collet and then the tool is allowed to slide down till the tip hits a gauge block. Assuming the spindle is at a standard height, this assures that the tool length remains constant. Care must still be taken to make sure the tool is not pulled up as the collet is tightened.
- **Tool Touch-Off Sensor**
  
  This method requires a sensor system to actually locate the tool tip. Thus, even if the tool is not inserted to a consistent length, the tool tip is located precisely by the sensor. This method is, of course, the simplest to use, but is technically more complex and expensive than the previous 2 methods.

B. Manual Quick Change

This method provides a very quick and reliable system for changing tools and assuring consistent tool lengths, quick-change tooling usually involves a special tool holder. This system, generally, has the parts as shown in the diagram below.

A "holder" is inserted in the spindle to adapt the spindle to the quick-change mechanism. The collet chuck or taper is designed to be quickly inserted and removed from the holder. The collet chuck holds some standard collet (e.g., ER16) which grips the cutting tool. The collet nut is used to retain and tighten the collet. The benefit of this system is that tools can be preadjusted in the collet chuck to precise lengths. The preadjusted tools can then be quickly inserted and removed from the holder either manually or with some simple tool. Note that the collet chuck fits into the tool holder in a precise and consistent way. Two of many suppliers of such systems are Universal for low rpm (typically, less than 10000 rpm) applications and Leuco, for high rpm applications (typically, up to 30000).

C. Automatic Tool Change

This type of system is similar to the quick-change system but usually has a pneumatically controlled system for securing and releasing the taper or collet chuck. For safety reasons, these system are generally designed to be fail-safe so that, in case of loss of air pressure, the tool is not accidentally released. Generally, a wave washer spring system is used to grab the taper and a pneumatic cylinder is used to compress the spring and thus release the taper. The tapers are available in a number of "standard" configurations. We, at Techno, use the ISO standard tapers with industry standard ER collets. Just as in the quick-change system, the advantage of this system is that tools can be preset in the tapers to precise lengths.

Furthermore, an important benefit of the automatic tool change system is that long programs can be run with minimal attendance by operators, unlike the manual methods.

Finally, an alternative tool change system must be mentioned for completeness. This automatic tool change system has a pneumatic collet for automatic release and capture, but it uses the plastic collars rather than a taper system for holding the tools. This dramatically reduces the cost of the mechanisms and the overall system. Its primary limitation is that this system was designed for the electronic circuit board industry and is consequently limited to tools of 1/4" shank, typically. We, at Techno, offer such a system (see pages 98 and 99) and it is very useful for fine applications requiring less than 1 HP and tools up to 1/4" shank, such as engraving, circuit board applications, small molds and patterns.

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10 Tips To Know Before Investing In A CNC Router

Increasingly, manufacturers are turning to automation in order to meet their profitability goals, and their success rate is amazing. Right now, you may be sitting there, thinking: "I'd love to automate – but I can't afford it". Considering what CNC (Computer Numerically Controlled) routers have already done for so many industries around the world, you can't afford not to automate.

What Does a CNC Router System Consist Of?

Most CNC router systems available today consist of a motorized XYZ router table, a control unit, computer, and programming software.

Here's How a CNC Router Works:

A CNC router enables you to design a part on your PC, and then make it in minutes. There are three basic steps:

1). Generate a computer image of the part, by drawing or scanning.

2). Create a tool path using simple menu-driven commands.

3). Run the program on the router and make the part.

This Is What a CNC Router Can Do:

In most cases, a CNC router system needs to be extremely versatile in order to be a true asset! A good system will be able to easily handle different applications such as contouring, drilling, milling, routing, inlays and cutouts, and even engraving with little or no system configuration changes. On the other hand, a cheap CNC routing system that does not easily lend itself to the everchanging and increasing needs of today's businesses and customers is of little value.

Remember, you get what you pay for!

How a CNC Router Can Make You More Money:

A CNC Router can produce parts much faster and more accurately than doing it by hand. This type of automation has a high repeatability, and thus greatly increases a manufacturer's yield and consistency. There is a minimal number of steps involved, again improving the manufacturing process.

The precision, accuracy and flexibility of a CNC router allow you to take on projects that might not have been considered either feasible or economical using manual techniques.

The fact is, the initial cost isn't nearly so imposing when you begin to realize how a CNC router can revolutionize the way you manufacture, and how CNC can open up new possibilities for your business. In fact, we have had many customers tell us that one job paid for the CNC router itself. Just as the manual router improved upon earlier manual techniques, a CNC router takes things a giant step further. Think of a CNC router as a tool in your shop, albeit one that outstrips all the other tools. A CNC router turns a good craftsman into a great one by bringing precise artisan skills to any operator.

Craftsmen know that their work will only be as good as the tools used in the product's design and manufacturing. Likewise, any professional knows that the quality of the product is what makes or breaks a reputation. It doesn't take much to realize that if you are working with shoddy or inadequate tools, your product and your profits are going to suffer. In short, an economy style or bargain brand routing system may cost less initially, but sacrificed quality and problematic production runs will expose the true cost of the cheap solution to be enormous. When shopping around for the right CNC router, there are many things to consider before making a decision. In order to help make this search easier, Techno has come up with the following guide.

1) Do You Have the Right Tool for the Right Application?

Does the router's software suit the requirements of the application? Different applications require different tools, and no single tool can serve all applications efficiently. There is an old adage which says: "When the only tool you have is a hammer, everything looks like a nail." This lack of flexibility does not make for efficient or productive manufacturing. Different applications require different software. For example, programming and carving intricate 3D surfaces such as violins, is a complex geometric surfacing problem. On the other hand, making signs requires the ability to create a wide variety of fonts, as well as logos and artwork. Techno offers three different types of software to meet these diverse needs. Routing applications that are geometric in design, in either 2D or 3D, can be done using MasterCAM™ software. For those applications which are more artistically oriented, such as lettering, sign making, engraving or routing of logos or artwork, we offer CASmate-Pro™ software. Our newest software package, ArtCAM®, offers tremendous 3D carving capabilities. There is no comparable package on the market in terms of capability or ease of use. With ArtCAM®, a simple 2D piece of artwork can be scanned and converted into a true 3D relief in minutes. And like all our other software packages, it is extremely user friendly.

2) Is It Accurate Enough to Make Circles and Inlays?

Not all CNC routers are created equal. Many routers, especially ones that use acme screws, or racks or belts, have backlash. Backlash is the hesitation in the motion of the machine when the motor changes direction due to loose or imprecise mechanisms that connect the motor to the machine. If a motor has backlash, circles will not close accurately, arcs will have "steps", and inlays will not fit. Make sure that the CNC router you choose delivers the precision and quality that your business demands. Techno routers all have anti-backlash ball screws for play-free motion that will remain play-free. With these anti-backlash ball screws, Techno routers can produce circles that are accurate to the resolution of the machine, .0005". You can also make inlays with as small a clearance as you want, down to the machine resolution, .0005".

3) Is the Router Durable?

The accuracy and reliability of a CNC routing system begins with the individual components used to build the system, and how they are integrated together. The use of acme lead screws is generally a warning sign of a poorly designed system. The friction from sliding contact between the screw and nut creates constant wear which causes inaccuracies and the need for replacement parts. It also offers very poor power transmission, which results in overloading of the motors. Other components that hint towards a poorly designed table are rack and pinion drives, belts and pulleys, and V-grooved guide wheels. All of these drives contribute to system backlash and the

inaccurate reproduction of parts. The Techno CNC routing systems are built for longevity, precision and efficiency. Each axis is driven by precision ball screws, which have excellent power transmission due to the rolling ball contact between the nut and screws. This type of contact also ensures low friction, low wear and long life. The screw is driven by the motor shaft through an anti-backlash coupling. As a result, the Techno tables are more accurate, more heavy-duty and durable, and less problematic, which translates into a greater value. Over 7000 units are being used worldwide, and of course, Techno is always there to provide free telephone support, if needed.

4) Is It Open Architecture?

Open architecture is a term used to describe the control unit's ability to accept different types of software output formats. If a controller can only accept G-codes, for example, the user will be limited to use only those packages that produce G-codes, which can be quite inconvenient. The Techno controller is open architecture, which allows the user to interface with most of the industry standard output formats. Via software interface, the Techno controller can accept FANUC, Excellon, G-code, DXF and HPGL commands, as well as others. The versatile nature of the controller makes it a perfect hub for a CNC Routing center.

5) How Good Is the Software?

The heart and soul of any CNC router is software. Software is indeed critical, since the usefulness of the router is limited by the software's capabilities. When examining software, keep these questions in mind: Is it easy to use? Does it have bugs? Is it slow? How many units have been sold? Can it be used with other packages? What kind of support can I expect? How easy is it to upgrade it? We, here at Techno, try each type of software before we sell it. We look for ease of use, ease of learning, bugs, etc. We support all software we sell so we have to make sure it can get the job done, and done well. MasterCAM™ has sold thousands of copies worldwide, in machine shops and woodworking shops, and CASmate-Pro™ is being used by thousands of sign-making shops worldwide. MasterCAM™ is the software available for most well-known routers. Techno has sold hundreds of copies of MasterCAM™ and provides free phone support for all our customers. MasterCAM™ can import and export files with DXF, IGES, ASCII, CADL, and ANVIL formats, and can handle just about all of the industry CAD/CAM files available. It can take 3D digitized files and read them in as either points or 3D surfaces. CASmate-Pro™ also has very powerful import and export features, with the additional capability of converting postscript .EPS files from Illustrator packages. CASmate-Pro™ takes full advantage of Windows clipboard, and can use any font available through Windows applications. Both MasterCAM™ and CASmate-Pro™ are highly refined programs which allow rapid drawing, editing and routing of work pieces. These packages increase overall efficiency, and allow for easy and efficient trials.

Our experience with ArtCAM is equally pleasing. It is an easy to use, “clear” software package that provides unmatched capabilities. This software easily and quickly makes true 3D relief carvings and signs from scanned 2D artwork. It is unique in its capabilities for producing jewelry, molds, wood carvings and engravings on molds.

6) Is It Easy to Install?

The sooner you can install a CNC router, the sooner it can begin paying for itself. If the router cannot be installed easily, this will impact on productivity and waste valuable time. When you unpack a Techno CNC router from its box, simply plug it in and load the software onto your PC. It's that easy. No need for alignment of machine parts, building machine frames, or even assembly of bits and pieces. The machine is ready for immediate use, with no additional assembly other than the installation of your tooling.

7) How Long Does It Take to Learn?

It doesn't matter how many complicated functions a CNC router can perform if nobody can figure out how to use it. Don't just look at the machine when shopping around. If the software is cumbersome, we guarantee that you won't get very far. MasterCAM™, ArtCAM® or CASmate-Pro™ software can be learned in just a few days, even if you are starting out with no computer experience whatsoever. In conjunction with MasterCAM™, CASmate-Pro™ and ArtCAM® Techno provides "Application Manuals" with the software. The MasterCAM™ book of exercises was developed by a university as part of a class, teaching the students the use of MasterCAM™. The CASmate-Pro™ and ArtCAM® manuals include training sessions and a series of tutorial exercises. Each exercise shows you step-by-step and screen-by-screen how to draw and machine the indicated sample. Our experience has been that you learn by doing, and that our customers go through 2 or 3 exercises, at which point they start making their own parts.

8) How Long Does It Take to Program?

Chances are that if your business is making an investment in a CNC router, you plan to use it heavily. If the software requires you to go through too many steps, or is awkward, it will directly affect the speed at which you work.

One of the key benefits of a CNC router and software is the ability to quickly try "what if"'s and just as quickly fix problems and make last minute changes. This, of course, requires a powerful "edit" capability. All of our software packages provide quick and easy "edit" capabilities, in addition to simple and clear program and toolpath generation capabilities.

9) How Fast Can It Cut?

The average machine will perform millions of cycles in its lifetime. If it takes too much time to run each program, the cumulative loss in terms of time wasted will be staggering. If you plan on using your machine a lot, it had better do the job fast enough for you each and every time out. With a Techno CNC router, you can rapid move and cut at 200 ipm on our stepper machines. You can even cut circles at 120 ipm. Our servo machines will rapid move at up to 700 ipm on the 5' x 8' and cut up to 400 ipm. Note that we have noticed rampant "spec inflation", (competitive machines suddenly becoming faster and stronger).

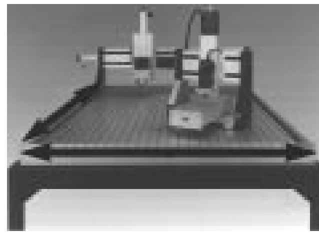
10) What Is the Actual Cost, in Terms of Production Capabilities?

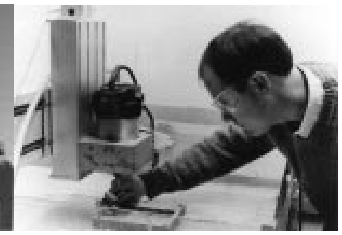
This final point is really just the sum of the first nine. In the final analysis, you have to ask yourself which machine will be the most profitable, according to your needs. Initial machine cost is only a small part of the daily operating cost. Reliability and production time ultimately become at least as important in determining what a machine really costs. You need to find a machine which will perform all the necessary functions you desire, at a level which meets your high standards. The machine should be user-friendly, reliable, fast and affordable.

We, at Techno, believe that our CNC routers, in conjunction with MasterCAM™, CASmate-Pro™, or ArtCAM® software packages provide the best value of any comparable routers available, in terms of price, performance and versatility. Give our Application Engineers a call, at (516) 328-3970 and we will be glad to discuss the Techno routing system in more detail, analyze your application and cut you a sample piece.

Culin/Collela *designs and produces custom furniture using a Techno routing system. See the feature story at page 23.*

Choosing Between Stepper and Servo Motors





Cost Comparison

In general, **stepper motor systems** tend to be less expensive than servomotor systems. Stepper and servo systems often become comparable in price when the stepper system uses motors larger than NEMA 23 or when micro-stepping is used. **Servomotors** in the NEMA 23 frame size tend to be 10% to 30% more expensive than similar stepper systems. Brushless servomotor systems tend to be 50% to 100% more.

Stepper Technology

Reliability and Maintenance

Stepper motors are brushless. They experience little or no wear, and are virtually maintenance-free.

Resolution and Accuracy

For a given screw pitch, typical four phase **stepper motors** can produce 200 full steps, 400 half steps, and up to 25,000 micro steps per revolution. It is significant to note that since the stepper motor is open loop, it does not necessarily achieve the desired location, especially under load. Particularly poor positional accuracy can result when using microstepping, which is primarily useful for smoothness of motion.

Speed and Power

Steppers have very poor torque characteristics at higher speeds. This condition is improved somewhat by microstepping. However, unless the stepper is used in a closed loop mode, it does not usually perform as well as a servo.

Closed Loop Vs. Open Loop

Stepper motors are almost always used in an open loop configuration. If used in a closed loop, they typically become as, if not more, expensive than servomotor systems. The open loop nature of stepper motors is their principal drawback. Commands are issued to move prescribed amounts, and barring unforeseen circumstances, the motor moves the amounts prescribed. In rare cases, resonances or unexpected forces can cause a stepper motor to lose steps or stall out. Although rare, this is an ever present possibility.

Servo Technology

Brush-type **servomotors** require a change of brushes, typically, every 5,000 hours. Like steppers, brushless servomotors have virtually no servicing requirements.

Servomotor resolution depends upon the encoder used. Typical encoders produce 2,000 to 4,000 pulses per revolution, and encoders with up to 10,000 pulses per revolution are available. Since servos, which are closed loop, can and do achieve the available resolution, they are able to maintain positional accuracy.

Servos can produce speeds and powers two to four times that of similarily sized steppers. This improvement is a direct result of the closed loop (i.e., constant position feedback), which allows for higher speed and greater reliability. The closed loop nature of the servo also allows such a system to better utilize peak torque capabilities.

By nature, **servomotors** have constant positional feedback. The positional feedback is used to correct any discrepancy between a desired and an actual position. This constant corrective action results in faster speeds (up to three times the throughput), and increased power (up to three times the torque) at high speeds. The closed loop nature of the servo also ensures that stalling cannot occur unless there is an immovable object in the path.

Choosing a system

In general, we recommend **stepper systems** for cost sensitive applications requiring low-to-moderate volume production capabilities. Servo systems are recommended for high speed, high volume, high reliability applications. A typical **Techno servo gantry** system sells for about $2,700 more than a stepper system. Servos can perform high speed continuous motion reliably, making them particularly superior in three-dimensional contouring applications. We have found time reductions of up to 80% on some applications. The continuous motion also results in better finish quality without the fine faceting that is found with stepper systems. In addition, the servo's reliable high speed continuous motion can reduce the possibility of scorching and melting when working with woods and plastics.