

Creating forest sector solutions

Understanding CNC Routers



FPInnovations™ brings together Feric, Forintek, Paprican and the Canadian Wood Fibre Centre of Natural Resources Canada, to form the world's largest private, not-for-profit forest research institute. FPInnovations™ works towards optimizing the forest sector value chain. It capitalizes on Canada's fibre attributes and develops new products and market opportunities within a framework of environmental sustainability. The goal is leadership through innovation and a strengthening of the Canadian forest sector's global competitiveness through research, knowledge transfer and implementation.

The Forintek Division provides the industry with innovative solutions, sound scientific advice, direct technical support, and relevant market and economic studies. It creates solutions for wood – from forest to market.

Understanding CNC Routers

First Edition

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About This Book

- ▶ **Why Create a Book on CNC Routers?**
- ▶ **Who Needs a CNC Machine?**
- ▶ **What is a CNC Router?**

Why Create a Book on CNC Routers?

There is a lot of anecdotal information on CNC (Computer Numerical Control) technology and machine vendors are often quick to highlight certain features of their products while minimizing other very important characteristics.

The truth is that in every case the purchaser must make compromises to come up with the solution that best fits their needs. Not one application is exactly the same and not one machine will be the perfect fit in every shop.

This book was created to give potential consumers of CNC routers a basic understanding of the inner workings of the technology. A better informed consumer can then make better purchasing decisions and increase the chance of successful integration of the technology in his or her shop.

Who Needs a CNC Machine?



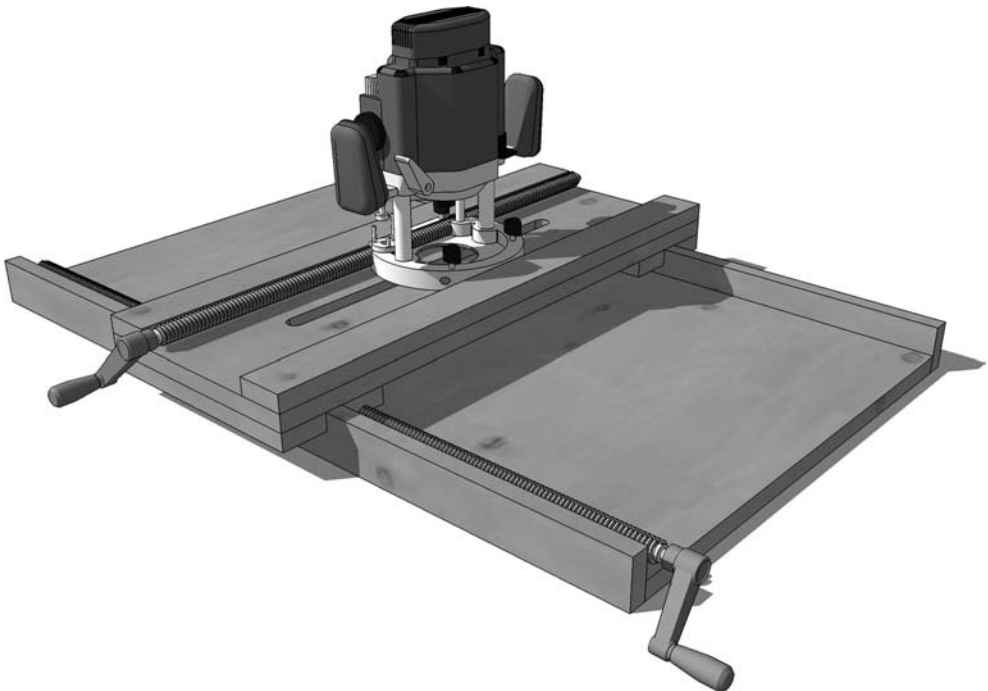
What does a CNC do? Will it replace workers? Is my job in jeopardy? These are some of the questions you will face from your employees when you are thinking of buying a CNC machine.

While it will probably replace tedious repetitive jobs with higher skilled ones, most companies who purchase this technology end up growing and hiring more employees.

The work that happens downstream from the CNC machine will also be impacted. The parts are likely to be more accurate and in the case of nested based systems, they will remain grouped together, simplifying subsequent processes.

What is a CNC Router?

In short, CNC technology is not very complicated. It is a tool controlled by a computer. It only becomes more sophisticated when considering how the computer controls the tool. The illustration below shows what a bare bones CNC machine might look like minus the controller.



The History of CNC

- ▶ **Definition**
- ▶ **History**

Definition

CNC = **C**omputer **N**umerical **C**ontrol. A computer “controller” reads G-code or machine language instructions and drives a tool.

The NC (Numerical control) program is a detailed set of step by step instructions that tell the machine which path to follow and which operations to perform.

History

NC or simply **N**umerical **C**ontrol was developed in the late 1940s and early 1950s by John T. Parsons in collaboration with MIT (Massachusetts Institute of Technology). It was developed to help in the post war manufacturing effort. Aircraft parts were becoming more complex and required a level of precision that human operators could not achieve.



Complex machined parts could no longer be made by skilled operator alone

Photo courtesy of CNC Software – Mastercam

At first machines were hardwired, and then instructions were given via punched tape starting in 1952. Five years later, NC machines were being installed in metal working production environments all over the United States. By the mid 1960s, NC technology was playing a dominant role in the industry.

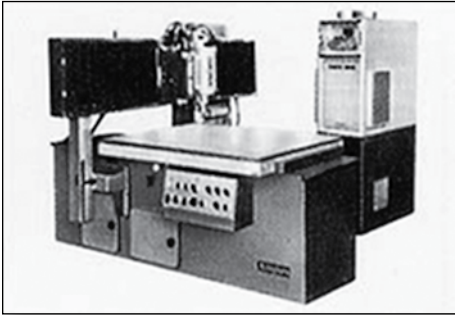
Most machine programs were recorded on a punched paper or aluminium tape until about 1980. In the 1970s and 80s, the growth of microprocessor technology made it possible for computers to be connected directly to NC machines using cables, hence the term CNC.

Fundamentally, numerical control is a technique for controlling machinery rather than a specific type of machine. CNC machines were originally built for machining metal. They were subsequently adapted for other industries such as wood, fabric, foam, and plastics to name just a few. All these machines have some features in common which are:

- a program (instructions)
- a controller
- a machine tool.

Wood routers differ from their metalworking cousins in that they are not subjected to the same forces of load and vibration. They spin faster, up to 24000 rpm and have larger work tables; up to 5'x20'. They use smaller tools and tool holders and work at faster machining speeds; up to 1200 inches per minute or 30 m/min. Another difference is that they don't require the same level of accuracy. Metalworking applications usually require much greater precision and tighter tolerances than for machining wood.

Mr. Isao Shoda claims to have made the first NC Router in the world and he exhibited it at the International Osaka Fair in 1968. (Model: NC-111A)



1968 – Shoda exhibited the first ever NC wood router (NC-111A) at the International Osaka Fair

Photo courtesy of Shoda Iron Works Co. Ltd.

Early in the 1970s the advent of the first CNC appeared in the aerospace industry (controlled by a Mainframe Computer).

In the late 70s NC drilling machines were the first to appear in the wood industry. They were called point-to-point machines because they moved a drill from one point to another and drilled a hole. The term point-to-point was coined from an electronics circuit assembly method from pre-1950 which required professional electronic assemblers to operate from books of photographs, and follow an exact assembly sequence to ensure that they did not miss any components.:

Other events that impacted CNC technology were:

- Mid-1970: first microprocessor (Intel 8080)
- End of the 1970s: First 5 axis CNC in woodworking.

CNC routers were first used by the aerospace industry to cut complex patterns out of sheets of aluminium. Bolting the aluminium sheet to the table surface was a lengthy process. In the early 80s, the

engineers at Thermwood came up with the idea to draw air through huge butcher blocks made of Balsa wood. Since Balsa wood lets air pass freely through the end grain, they added a high flow vacuum to hold the aluminium sheets down without the use of mechanical fasteners. They later realized that particleboard had similar porous properties and universal vacuum tables were born.

By the early 1980s, CNC technology was used in many types of machinery in the secondary woodworking industry. Some examples follow:

Point-to-point systems such as **boring machines** have been used since the beginning of the NC era. Since there was no contact between the part and the tool until a pneumatic drill was activated, it mattered little which path the spindle took to reach its final destination, hence the term point-to-point. These machines were later adapted to the newer CNC technology and although they incorporated more options than just drilling, the name persisted.

Straight cutting systems such as NC **panel saws** confine the control to only one single axis of motion. The saw blade then travels independently from the control across the length of the beam to perform a straight cut.

Contour cutting such as that seen in **CNC work centers** allows for the simultaneous motion control of 3 or more axes while performing machining operations. In other words, the computer controls the cutter in space along the x, y and z axes while performing the cut.

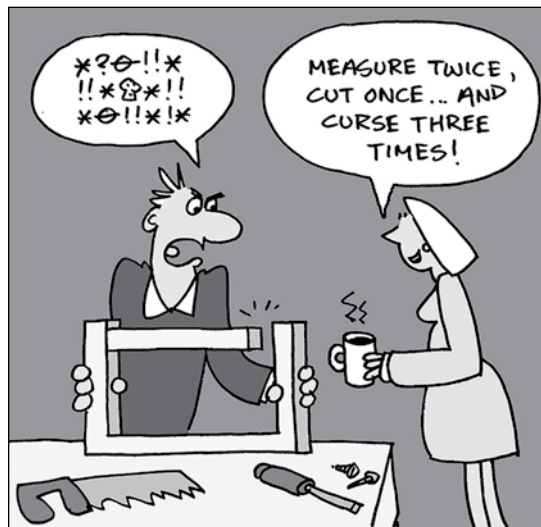
Today CNC machines are a ubiquitous part of the manufacturing process. New functionality and improved performance is being developed every day which will give CNC an ever increasing role in the success of our industry.

Benefits of CNC machines

- ▶ **The Appeal of CNC**
- ▶ **Cut Quality**
- ▶ **Accuracy**
- ▶ **Maximizing Performance**
- ▶ **CNC in the Media**

The Appeal of CNC

While the specific applications of CNC vary greatly from one machine to the next, all these sophisticated machines have become widely used in a variety of industries. A few of the major benefits offered by CNC technology are described below.



CartoonStock

Automation

The first benefit offered by all forms of CNC machine tools is improved automation. The skill level of the operator in producing the work can be reduced or eliminated. Many CNC machines can run unattended during their entire machining cycle, freeing the operator to do other tasks. This gives the CNC user several side benefits including reduced operator fatigue, fewer mistakes caused by human error, and consistent and predictable machining time for each work piece.

Precision

The second major benefit of CNC technology is consistent and accurate work pieces. Today's CNC machines feature a typical accuracy rate in the range of 2 to 4 thousandths of an inch or 0.05 to 0.10 mm and repeatability near or better than 8 ten-thousandths of an inch or 0.02 mm. This means that once a program is verified, two, ten, or one thousand identical work pieces can be easily produced with the same precision and consistency.

Flexibility

A third benefit offered by most forms of CNC machine tools is flexibility. Since these machines are run from computer programs, running a different work piece is as easy as loading a different program.

This leads to yet another benefit, quick changeover. Since these machines are very easy to set up and run, and given the ease with which programs can be loaded, they allow for a very short set up time. This is critical with today's Just-In-Time production environments.

The resulting reduction in the number of machines needed in a wood manufacturing shop is yet another benefit worthy of noting. In the past, a great number of dedicated machines were needed to produce furniture or cabinets. With the advent of CNC technology, this reality has changed drastically.

Less time spent between work centers means faster production time. Less Work-in-Progress (WIP) also translates into lower inventory and less investment in non value-added resources.

As a result, machinery requirements decrease, employee workloads are simplified, and waste is minimized while production is maximized.



Less inventory and Work-in-Progress (WIP) results in shorter lead times

The CNC machine takes no breaks and although the human operator does, he can prepare work for the machine to perform on its own while he is undertaking other work.

For example, a company could run a carving program whenever the machine is not scheduled to be used. This carving program runs for many hours while the operator performs other work, providing extra revenue for the business.

Limitations

Machines are made to optimally perform a set of functions and they don't inherently have the same mobility and versatility as humans. Newer machines have evolved to become multitasking and more versatile and although there are still some limitations with CNC software technology, manufacturers are constantly improving their machines and creative users are finding new ways of using them beyond their limitations.

Embedded skill

Since the machine will be running under program control, the skill level required of the CNC operator is also reduced as compared to a worker producing work pieces with conventional machine tools. Of course this is offset by the skill needed in the office to draw and program the parts for the machine.

Cut Quality

CNC machines allow for precise control of all the variables that affect how the tool performs its cut into the material being machined. This translates into consistent high quality, smooth, even cuts.

Frame rigidity

It is generally believed that better cut quality is achieved by using a more rigid and accurate machine. While rigidity of the frame and accuracy have major roles to play, other factors are very important in affecting cut quality, such as control features, acceleration and deceleration, tool holding, and part holding.

Mass alone will tend to compound machining errors since a heavy moving part carries more momentum and is harder to start and stop. Conversely, too light a frame will allow for more vibrations and limit the loads that can be applied.

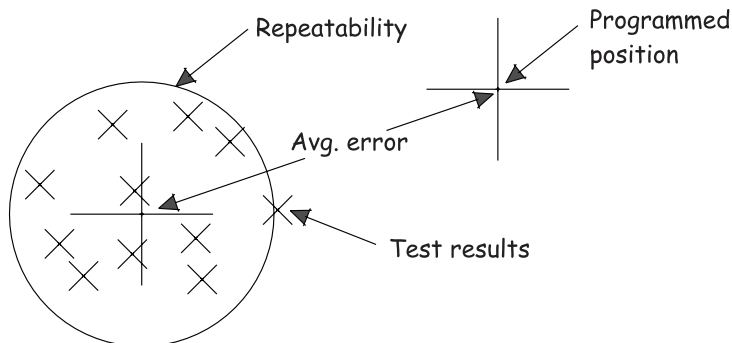
Bear in mind that not one single feature of the machine will determine its quality but a combination of all of these features.

Accuracy

Accuracy is a simple machine characteristic to measure although simply comparing cut length with programmed length alone is not a good evaluation of accuracy.

Positioning accuracy

Absolute positioning accuracy means the ability to reach a point in space within a certain tolerance. This measure can change greatly whether it is measured on a single or on multiple axes, or on whether or not there is a load applied to the cutter head. This measurement is also dependent on the position of the piece on the work table. Different numbers can be obtained in different areas as ball screw compensation tables can be off or missing altogether.



Spatial accuracy is mostly dependent on encoder resolution. A high quality, properly adjusted servo system can normally position within plus or minus ten times the encoder resolution. Therefore, a system with 0.0005" resolution can only be expected to achieve plus or minus 0.005" or 0.1 mm positioning accuracy.

Repeatability

Repeatability is the ability to return to a point in space each time a program is executed. Just like absolute accuracy, repeatability can either be measured on a single axis or on multiple axes. On most systems, repeatability always outshines absolute positioning accuracy.

Predictability

This is important in the business of cutting parts using computer controlled equipment. You want the control portion of the machine to work the same way every time no matter what program is running. A good controller will calculate the tool path many steps ahead and alert you or decide on a different course of action when it finds problems.

In the early days of Point-to-Point machines, the computer told the head to move to a certain position in X-Y. The drives executed this operation without consideration for the path that the tool would take.

On newer CNC machines, the movement of the axes are coordinated with each other to obey a set of given rules. This gives them the ability to circle around fixtures and to ease the cutter in and out of a part for example. This is known as an interpolated path.

Maximizing Performance

In today's competitive manufacturing environment, it is imperative for companies to maximize their production performance.

As can be seen in the table below, the average North American furniture plant still lags behind its international counterpart regarding performance.

Performance of Furniture Manufacturers

The average U.S. furniture plant is performing well below the benchmarks established by their "world class" competitors...

| Performance Measure | Typical Plant | World Class |
|----------------------------|---------------|-------------|
| Output per Ft ² | \$75 | \$125 |
| Travel Distance | 5,200 ft | 300 ft |
| Inventory Turnover | 4 turns | 18 turns |
| Time Adding Value | 3% | 25% |
| Set-Up Time | 180 min | 10 min |
| Output per Worker | \$75,000 | \$200,000 |
| Cycle Time | 3 weeks | 3 days |
| On-Time Delivery | 80% | 95%+ |

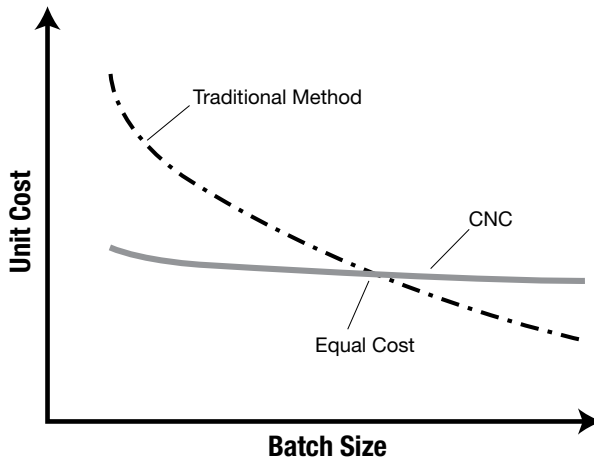
For a typical furniture company with \$25 million in sales:

- An inventory reduction of 1 day is worth \$60,000
- The cost of one hour of production is \$4,500
- A 5% reduction in cost is worth \$937,500 in additional gross margin

Table courtesy of A.G. Raymond & Company

As Lean Manufacturing principles are becoming more popular in the wood manufacturing sector, manufacturing practices such as "one piece flow" and "mass customization" are being implemented. These practices can be accomplished through using the full potential of CNC automation.

As seen in the next table, a batch size of one can be made for a much lower unit cost using CNC technology compared to traditional methods.



CNC in the Media

There is no doubt that as CNC technology gets more established in the woodworking market, it should also get more coverage in the media. The fact is that this technology is changing so rapidly that it provides an endless supply of material that deserves to be put in print.



Photos courtesy of FDM and CabinetMaker magazines

Things To Consider

When thinking of buying a CNC router, there are many things to take into consideration. One of the first things to do is take a hard look at what the machine will be expected to do. Too often woodworkers are lured by the technology and buy unnecessary options.

Although most router vendors will promote the speed of their machines, overall speed will have nearly nothing to do with whether or not automation will be successful in a particular shop. Quality and ease of use will be much more important factors.

Is the entire infrastructure available that will be needed to comply with this new technology? Are computers available in the office for CAD or CAM? What about suppliers for tooling? There are many things to think about when buying a CNC machine for the first time. Often these seemingly trivial details can balloon into nightmares. Better to deal with them early in the process.

Space

Space is the one commodity that is often lacking (along with time). These machines not only take up a large footprint but one has to take into consideration other space uses such as raw material, finished parts, jigs and fixtures, and tooling. It is always a good idea to do a plant layout when introducing new technology into the manufacturing line. This exercise will help maximize the performance of the new equipment and the flow of the manufacturing process.

As some of these machines weigh upwards of a few tons and are sensitive to vibration and movement, it will be imperative to check the load bearing capacity of the shop floor. It would not be recommended to install a heavy gauge steel framed, high performance router on the second floor of an old wooden building for example. On the other hand, a light gauge sheet metal low end machine would work perfectly well in this environment.

Electrical requirements

Electrical power is always an afterthought and it can be a costly one if overlooked. Check with an electrician to see if power requirements can be accommodated. Machines come in different voltages: 110, 220, 440, 600 volts and it's useful to check the required amperage as well. It is always a good idea to have an electrician run the wires and the junction boxes before the machine is delivered so that the installation can be completed faster.

Pneumatics

Compressed air capacity measured in cubic feet per minute (CFM) or metres cube per minute (m^3/min) and pressure given in pounds per square inch (PSI) or kilopascals (kPa) are parameters that are readily stipulated by the machine manufacturers. It is important to check whether there is enough capacity in the plant's system to accommodate the needs of this new equipment. Typically when a CNC machine runs out of air, it triggers a hard stop which results in lost time and perhaps damage to the part that it was cutting. It is not enough to have the capacity, but a good source of dry air will also ensure that the sensitive pneumatic and electronic equipment doesn't corrode.

Vacuum

Is the vacuum system supplied and installed by the CNC vendor or is it the purchasers responsibility? Make sure that it will be designed to meet the company's applications requirements and that it is compatible with the equipment.

Plant layout

Rethinking plant layout might be a good idea at this point since the introduction of automation will surely affect the fundamental operational flow. Equipment may have to be moved just to get the CNC machine to its final spot. Air ducts and dust collector pipes might also have to be re-routed. Check to make sure the machine will fit through the door or up the freight elevator. Making holes in exterior walls is always an expensive proposition but not unheard of.

Workflow

Plant workflow will invariably change when a CNC machine is purchased. Not only will it affect the current plant layout and the routings of operations but Bill of Materials and any scheduling software may have to be modified to allow for the changes to workflow.

Inventory

The inventory needed to operate the new CNC machine and the parts it will produce will be something to think about before the machine arrives. MDF spoilboards, cutting tools, maintenance parts and consumables are just a few of them. The cost of this extra inventory is something that is often overlooked in the equipment purchase decision process.

Tools

Talk to the tool supplier and if necessary, research other local suppliers. Also look at supplies of cutting equipment online as the savings on the price of the tool could offset the transportation costs. However, it is still wise to retain the services of a good local tool vendor who can sharpen tools and quickly procure some in emergencies.

Programming

The programming will preferably need to be done somewhere other than at the console of the machine. While some production shops can only afford to hire programmers part time or on contract, most will need an employee on site who can deal with last minute changes and custom programs.

Computer network

Extra computer equipment will be required to do the drawing and the programming of parts. They will probably need to be networked and have access to the web. In smaller shops a diskette or a USB flash drive can be run between the office computer and the CNC machine but it is worth the cost of running a network cable. This will prevent the programmer from having to run back and forth to tweak programs or to make changes.

Skills

When moving to CNC technology, a shop will shift skills and become less reliant on skilled labour to machine parts as the skill of the person designing products and programming machines will become the key to success.

Training

Training will become very important. Not only should the designer and programmer be up to date with the latest technology available but assemblers and other plant personnel must be trained to handle the increased output as efficiently as possible.

Outsourcing

Can some of the work requiring a CNC machine be outsourced now? Or perhaps, once a machine is purchased, it might be used to perform some work for other shops in the area. It is a good idea to research this option because it could have an impact on the timing of the purchase of new equipment.

Dust collection

Most shops run low in dust collection capacity. CNC machines require a great deal of dust suction. As dust will affect the operation of this sensitive equipment, the quality of the work will suffer even more from a lack of dust collection. Consider purchasing a stand alone dust collector rated for the requirements of the machine if it is suspected the existing equipment will not suffice.

Operator

Who will operate this new piece of machinery? Although workers probably operate all the machinery in the shop when they need it, it's probably not a good idea to leave the CNC open to universal abuse.

In most shops there will be a dedicated operator for this machine. While it can be the owner of a small shop or the designer/programmer in a mid-size shop who operates the machine, it's a good idea to have one person responsible. Consider creating a protocol for the operator that includes maintenance, training, operation and safety.

Scheduling

There are many possible strategies for lining up work at this new work center. Chances are there is already a system in place for scheduling work in the shop. Spend some time to incorporate all the implications of this new technology into the organization.

Maintenance

If there is concern about quality and efficiency, then maintenance is the single most important item to consider doing properly in the future. There is no question that a well kept machine will give years and years of good service while a neglected one will cause headaches very quickly. The best example of this is to look at the cars we drive. A brand new car that is never serviced would not run smoothly for very long. Why should a different outcome be expected from equipment?

The Components of a CNC Router

- ▶ **Controller**
- ▶ **Work Tables**
- ▶ **Motion**
- ▶ **Drive System**
- ▶ **Spindles**
- ▶ **Tool Changers**
- ▶ **Tooling**
- ▶ **Cutting Parameters**
- ▶ **Work Holding**
- ▶ **Vacuum Pumps**
- ▶ **Material Handling**

Controller

The controller is the brain of the CNC machine. The term controller usually refers not only to the computer but also to all the electronic and electrical devices that give motion to the machine.

There are two types of controllers available on machines today. Proprietary controllers and open-architecture, personal computer (PC) based controllers.

Some manufacturers claim that the required safety and reliability of CNC machines can be assured only through proven but proprietary controller technology. On the other hand the high speed processors of today's PCs allow more complex motion calculations in real time, resulting in smoother machine motions and faster speeds. The individual features of each system have to be compared and weighed against the desired outcome on a case-by-case basis.

Some of the important features to look for in a CNC controller follow.

Full colour display

With the price and availability of full size, full colour flat panel displays today, having one makes information easier to read and understand. It allows for the display of more information, including graphics and pictures and generally makes the control simpler and easier to use. You should have serious questions about a manufacturer who only offers a small monochromatic display.

Program storage

As with the display, an 80 Gigabyte hard disk drive or bigger is a must, allowing for the storage of hundreds or even thousands of machining programs. It is especially useful for very large programs such as those used for carving.

Hand-held programmer

A hand-held programming device is an option that can be used to move the machine around. It is used to quickly and easily create programs without having to deal with CNC code. This is a great tool for those not familiar with CNC or those who deal with existing parts that have to be reproduced.



Note that some optional hand-held devices do not allow for programming at the machine. In many cases this could be problematic or ineffective when the programs are created in a space far from the machine.

A hand-held programmer can add versatility in programming parts

Photo courtesy of Thermwood Corporation

Sealed air-conditioned cabinet

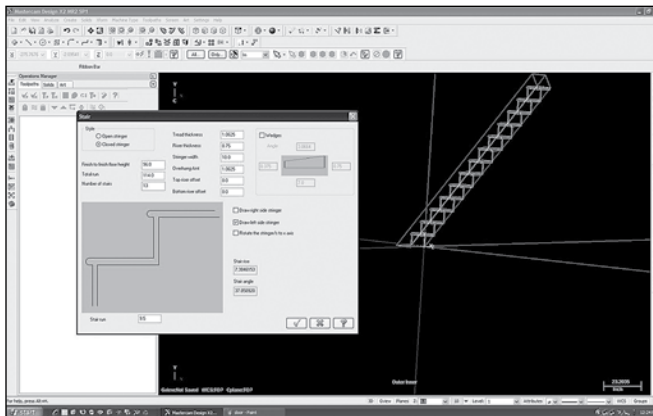
Most PCs are not made to operate in the dusty environment of a wood manufacturing plant and their operating life can be quite short. It is therefore important that the electronic components, including power supplies and servo drives, be enclosed in a sealed, air-conditioned cabinet keeping them cool and free from contamination.

Three-dimensional axis compensation

Some controls provide for lead screw compensation, that is, they use a table of measured positions along the axes as a reference to compensate for any positional inaccuracy that might be present. The computer constantly compares the position of the axis with the values in the compensation table and makes fine adjustments ensuring better accuracy. Newer controls compensate for all three axes at every position within the three-dimensional working envelope. Every inaccuracy or misalignment, regardless of its source, is automatically corrected by the controller.

Parametric design functions

This refers to the ability to design parts by defining pre-set parameters rather than drawing the parts from scratch. Some controllers are designed with the ability to create parts using simple user inputs such as width and depth. These functions can be seen in specialized machines such as the ones made for the window and door industries or for cutting glass or fabric. Other machines provide the ability to create MDF doors, or 5 piece doors, or dovetailed drawers directly from the controller's screen just by changing size parameters.



Parametric design automates customizable programming features

Photo courtesy of
CNC Software - Mastercam

Raw design files

Some controllers today have the ability to accept raw design files (data that has not been altered, compressed, or manipulated in any way by the computer) such as DXF files directly, without additional processing. It automatically performs any program preparation necessary to machine the part. These controllers can combine files from multiple software sources into a nest, which is a cutting layout that maximizes the use of the raw material.

Older controllers were primarily playback devices — like a record player. They required that the programmer not only design the part but also perform a series of additional functions prior to creating the program that the controller could then execute. Newer machines incorporate much more intelligence into the machining process, making the job of programming parts easier, more intuitive, and automated.

Panel saw programs or Microsoft Excel files

Newer controllers can run Microsoft Excel or CPOUT files commonly used to send size information to a panel saw optimizer. They can interpret the files, nest the panels and cut them. Since panels do not need to be lined up along common cut lines as they do when using a panel saw, they can be true shape nested (nesting of interlocking parts), often resulting in a better yield. Simple cuts such as rectangles and squares can usually be programmed at the control panel and the program will nest and cut them automatically.

Profiles without custom tooling

In the case of a design with a profiled edge and where there is no custom tool to machine that profile, some controls will automatically cut it in multiple passes using existing tools.

Reacting to problems at the machine

Some controllers are designed to react to specific situations. For instance, if a program has to be stopped because of a tool breakage or if a part has to be made again because of some type of failure, the machine will provide appropriate options to follow.

Error reporting

When an error occurs, the control displays a message and can also show an illustration of the machine, pointing out possible causes for the error and suggested solutions.

Automatic tool management system

With the advent of automatic tool changers and complex use of tools, this function makes managing tools easier and tracks their use, informing the operator when tool life has expired for a particular tool. It can even automatically switch to a back-up tool when a tool expires.

Newer tool holders incorporate a radio frequency identification or RFID tag that can be programmed with the parameters of the tool. This means that the machine will get information directly from the tool instead of relying on operator input. This is especially useful when using the same tools on different machines.

Preventative maintenance scheduling

Some controllers can track routine maintenance schedules, alerting the operator when maintenance such as lubrication or filter cleaning is required.

Direct networked link to technical assistance

With the advent of the internet and virtual communications, some controllers can quickly connect to the manufacturer's technical service through a network cable. With a webcam and a microphone, the machine operator and the technician can see and hear each other. The link also provides in-depth data sharing, allowing for complex diagnostics. Using this virtual service communication link lets the technician evaluate machine performance remotely, then adjust and reconfigure the machine as required.



Instant access to a factory technician can drastically shorten downtime

Photo courtesy of Thermwood Corporation

Switch between code and plain English

On some controllers, plain English language descriptions can be substituted for the cryptic NC programming languages “M” and “G” code. This greatly simplifies operation and training for people not yet fully familiar with CNC programming.

Depth oscillation

Certain materials such as high pressure laminates and certain types of plywood with abrasive adhesive between layers will quickly dull tooling at the point where the tool contacts the abrasive layer. Some controllers have a feature which oscillates the tool up and down as it cuts to move this abrasive contact point over a larger area of the tool, thus dramatically increasing tool life. Care must be taken with this option as plunging into a spoilboard with a straight bit can cause it to break or to overheat.

Proper manuals and component labelling

A good manufacturer uses professional wiring procedures and affixes labels and color codes on all wires and major components inside the control cabinet. A good practice is to supply complete blueprints or manuals of wiring and other components inside the control. This makes it much easier to replace parts or do simple maintenance in-house (changing a fuse for example) rather than having to call in a technician.

Watch for labels written in Italian, German, Russian or Chinese. This can be a problem because a North American technician might not be able to read these languages.

Easy to update and upgrade

New features are always being created by CNC manufacturers. When they can be easily added to an existing machine, benefits will follow from the latest advances in control technology and the productivity improvements.

Some proprietary controls that are not PC based don't allow for downloading new upgrades without extensive hardware changes. This limits the owner to the technology available at the time the machine was built.

Work Tables

Many types of tables are available today and these vary depending on the type of work being done and the work holding methods that are being used.

Flat tables

This is the most basic table offered with a CNC router. It consists of a flat surface made of laminate, aluminium or MDF. To hold down parts onto these tables, glue, double sided tape, clamps or vacuum pods connected to a small rotary vane pump are used. These types of tables are usually associated with entry level machines.

T-slot tables

T-slot tables are a by-product of the metal working industry. The only difference is that for the wood working machine, they are usually made of aluminium extrusion. These tables permit the use of inexpensive bolt-on clamps to hold down parts. They are mostly found in the sign making industry and on economical tables.

Pod and rail

This work-holding approach is considered by many to be the staple for the point-to-point machine (P2P). Although very few true P2P machines still exist, these tables are good for machining single flat parts where access to the edge is important. Even if no spoilboard is necessary, they can be time consuming to adjust between operations. Vertical accuracy is poor and replacing parts if the tool strikes the pod is usually expensive.

There are many variants of the pod and rail system. On some machines, the pods and rails are controlled by the program and move themselves to the setup location. Another variation uses pneumatic clamps instead of vacuum pods.

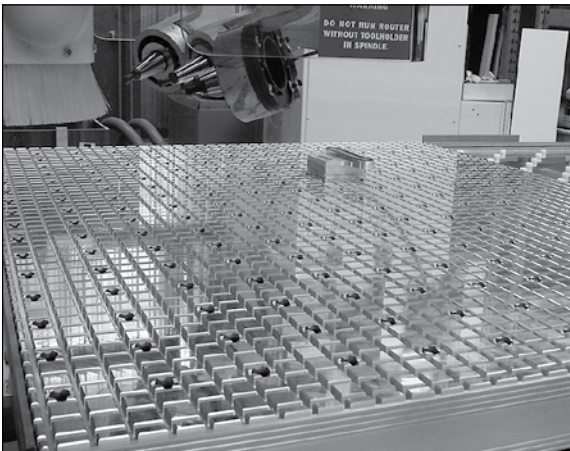
This type of work-holding approach is being used more in specialized fields like the window frame and door industries.

Universal vacuum

Otherwise known as nested tables, this method is used when machining parts out of full sheets of materials. Little or no access is afforded to the edge of the material but vertical accuracy is very good. Machining glued-up solid wood panels works well when the panel is flat. Fixturing is often needed when machining small parts, rough or warped solid wood parts.

Matrix tables

Matrix tables are a variation on the themes of pods and universal vacuum tables. A matrix of grooves is machined into the surface of a phenolic or aluminium table. Port holes are then distributed evenly across the surface of the table. A gasketing material can be inserted into the grooves and port holes opened for holding individual parts or for the use of a spoilboard. Special vacuum cups that fit into the matrix can also be used to hold small parts and simulate a pod and rail system.



Matrix tables offer the versatility of universal vacuum and the convenience of pods

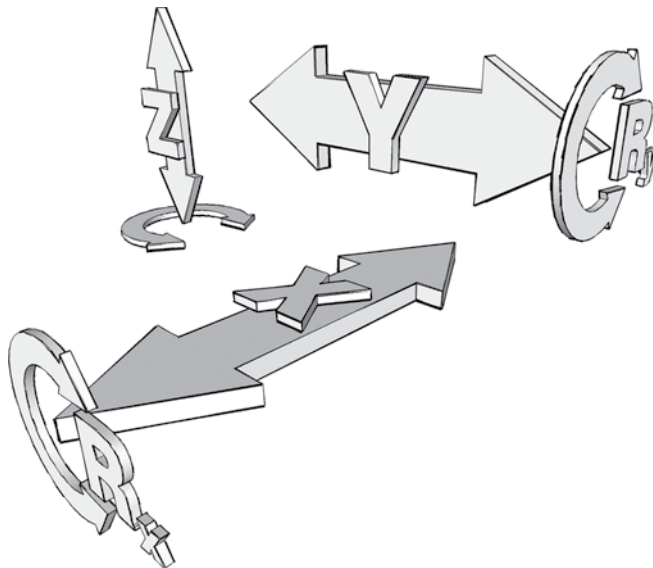
Photo courtesy of
Northern Engineering & Mfg. Inc. - NEMI

Motion

Motion is defined as a continuous change in the position of a body (the cutting tool) relative to a reference point (the part), as measured by an observer (the operator) in a particular frame of reference. A frame of reference is the perspective from which space is observed. Specifically, in physics, it refers to a provided set of axes from which an observer can measure the position and motion of all points in a system, as well as the orientation of objects in it. This is important for the CNC machine because every movement it makes has to be measured and calculated.

The Cartesian coordinate system

Also known as the rectangular coordinate system it is used to define each point in space through three numbers, usually called the x, the y and the z coordinate of the point.



Linear and rotational motion

There are two kinds of motion, linear and rotational. Linear movements are produced by the different axes moving along their rails. Diagonal lines, and arcs and circles, are the result of two or more axes moving at the same time in a synchronized manner. Rotational movements are the result of the part or the head rotating around an axis.

3 & 5 axis

3-axis machines move in a Cartesian manner along x, y and z. A fourth axis often takes the form of a rotating device for the part being cut, similar to a lathe or an indexing head along the spindle that permits the controlled rotation of an aggregate tool.

5-axis machines have a much greater range of motion and can move in a manner similar to the human hand. These machines often have a deep z stroke to be able to work in a large three dimensional area. There are 6 possible axes of motion, 3 linear and 3 rotational, one of which is considered to be the cutter spinning in the spindle.

The CNC machine must calculate the direction, speed and acceleration on each of the axes in order to cause the proper movement to be made. This is done with the help of complex mathematical formulas called algorithms.

Rapid vs. cutting motion

There are other terms that machine manufacturers refer to when talking about motion. Rapid motion refers to a motion that the machine makes when travelling only and not cutting. This is used when going from one point to another away from the material being cut. There is no need to limit the speed because it won't affect the

quality of the cut. Vendors often erroneously refer to this as being the top speed of the machine. The theoretical top speed of cut will be set by the cutter used and the material being cut, as well as by the length of the cut, more so than by the speed of the machine unless quality and precision of cut are not important.

When making a short cut, the cutter almost never has enough time to accelerate to its top speed before having to decelerate ahead of coming to a full stop.

Absolute vs. incremental motion

Absolute motion and incremental motion are the terms used to describe the point of reference used by the machine to follow a specific path. Absolute motion is measured from the base reference point specified earlier in the program. This may or may not be the zero of the machine. Incremental motion, on the other hand, is measured using the last known point as the reference. In other words, measurements are made from the previous instructions. Care must be taken when working in incremental mode not to skip over any point because every subsequent measurement will be affected.

Drive System

The drives are the devices that cause the machine to move. Three different drive motors have been used to power CNC routers: stepping motors, DC servo drives and AC servo drives.

A stepper motor does what the name suggests – it takes steps and keeps track of these steps to always know where it is on the machine. Stepper motors work in an open loop setting where they don't receive feedback when the work is done. This can negatively impact the accuracy of the parts. It's also difficult to find stepper motors that offer both high speeds and torque. One typically has to be selected in favour of the other.

A servo motor works in a closed loop and is paired with an encoder which provides an amplified feedback to the motor thus constantly correcting its position on the machine. While more precise, more powerful and less noisy than stepper motors, servo motors are more expensive.

Stepper motors

A stepper motor uses a permanent magnet rotor and wire wound stator. The stator is wound so that the motor has a large number of poles, typically 200.

These poles are generally arranged in groups of four. When one pole is energized, the rotor will align with that pole and lock in place. The force that it exerts holding that position is essentially the amount of torque available from the motor.

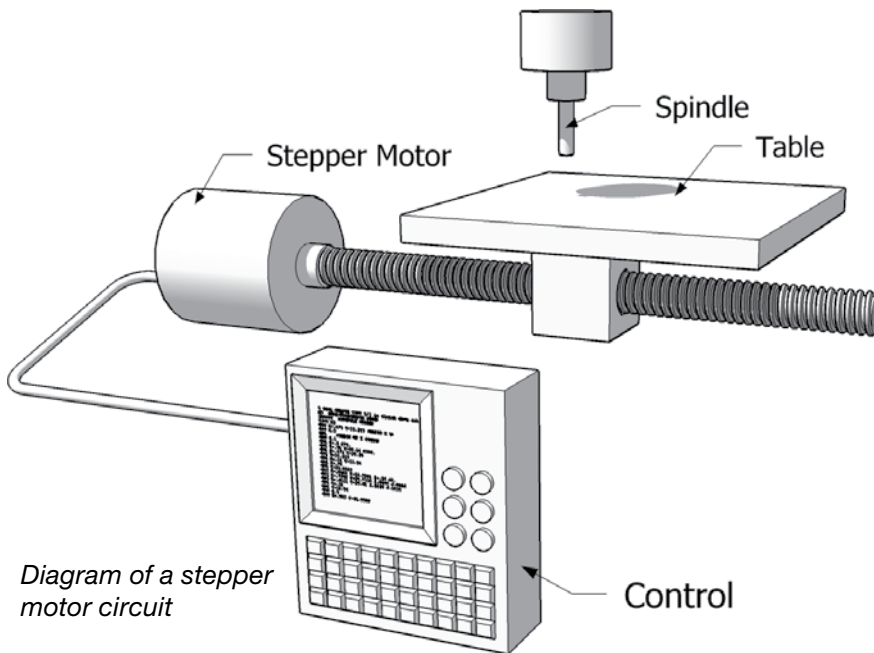


Diagram of a stepper motor circuit

When an adjacent pole is energized and the current pole turned off, the rotor “steps” over to the new position. This stepping motion between poles is the origin of the name.

An axis controlled by a stepper motor is positioned by feeding the proper number of steps to the stepper motor drive. The motor then steps to the correct position. This is known as an open loop system.

Acceleration and deceleration in a stepper motor system must be limited to make certain that the holding torque of the motor is never exceeded. A safety factor must be given to factor in the weight of the material being machined as it can affect the momentum of the motion.

Another method of controlling stepper motors is called microstepping. Instead of simply energizing each pole one at a time, the microstepper systematically balances forces between two adjacent poles to carefully rotate the field and thus the rotor. This system works well to eliminate oscillation but because for much of the time the rotor is being acted on by two opposing poles, overall torque may be reduced.

DC servo motors

As the cost of DC servo motors and AC servo motors came down, stepping motors lost favour. The greatest advantage of steppers — cost — was no longer significant. In addition the technical effort required to properly install them has surpassed that of servo drives.

A DC servo motor is configured with a permanent magnet stator and a wound wire rotor. The permanent magnets making up the stator are attached to the outer case of the motor. A set of carbon brushes transfer power through an armature to the wound stator. A position feedback sensor or encoder is attached to the rotor so that as it rotates, a signal is sent to the drive indicating the position of the rotor.

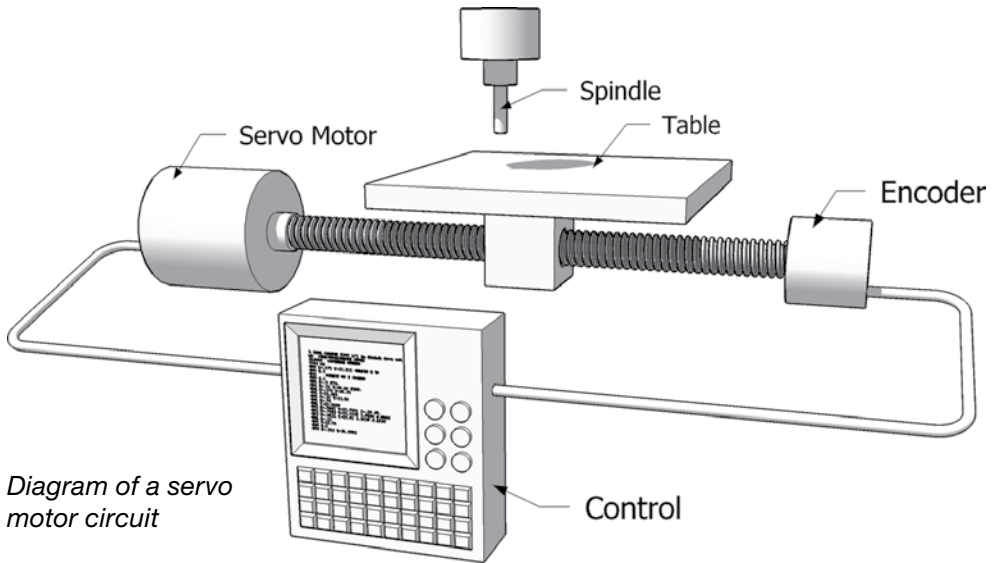


Diagram of a servo motor circuit

When the system is first energized, the axis moves until a switch or other signal determines a reference machine axis position. Once the reference point is achieved, the control keeps track of the rotation of the servo motor through the encoder.

Unlike the stepping motor, this is a closed loop system. Not only does the control dictate the position, but it also checks through the encoder to determine whether or not its control signals have been executed properly.

When the control wants the motor to move, it knows where the motor is currently positioned and where it should be positioned. The difference between these two positions is called an error signal. This error signal is fed to the servo drive, amplified and fed to the servo motor to cause it to turn in the direction needed to eliminate the error signal. As the error signal becomes smaller, the voltage fed to the drive also becomes smaller and motor rotation slows until there is no error signal and the drive is stopped. Although there is no force on the motor in the stopped position, as soon as the operator tries

to rotate the rotor, an error signal is developed, amplified and fed to the servo motor to resist the motion. It is as if the motor is locked in position.

The greatest advantage that the DC servo system has over the stepper motor is that there is no danger of losing steps. The closed loop nature of the design means that the current position is always known.

DC servo motors do, however, have problems of their own. The first centers on the fact that an error signal must be present for the system to work. This means that the machine is never at the position it is supposed to be at, it always lags behind the proper position. The distance that it lags behind is called a "lag error". The faster an axis tries to move the greater the lag error.

AC servo motor

To address these problems, a new type of servo motor has become popular today. This motor is commonly called an AC servo. It is also called a brushless DC servo by some companies. This motor is constructed differently from the DC servo motor. In an AC servo motor, the rotor is a permanent magnet and the stator is wire wound. Because there are no wires in the rotor, there is no need for brushes. Commutation is performed electronically by the servo drive rather than being performed by the brushes and commutator.

First, because there are no brushes to arc, the maximum limit of the power that can be fed to the motor is the power required to melt the wires in the stator. This is substantially greater than the power that can be fed through rotating brushes. The average power at which a motor can operate is also higher.

In the same frame size, an AC servo motor will provide more power. It can also generate bursts of power well beyond normal as long as the average power is below the design limit. The permanent magnet rotor

generally has less mass than a wire wound rotor, making acceleration and deceleration faster.

Higher end AC servo motors use rare earth magnets that have less mass and can contain higher magnetic fields than iron cores. These provide even higher acceleration/deceleration performance.

Spindles

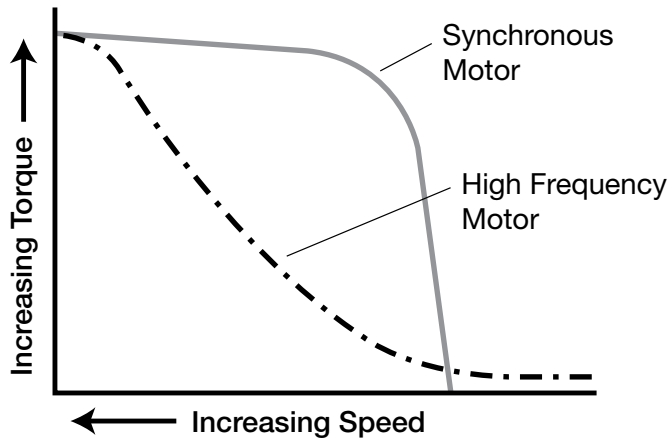
Essentially there are two different types of spindles in use today, the belt driven, stand-alone spindle and the high frequency motor spindle.

The earliest spindles used for routing were belt driven spindles. They were primarily used on fixed routers, such as pin routers. To obtain high router speeds, the synchronous electric drive motor was equipped with a large diameter pulley and the spindle shaft was equipped with a smaller diameter pulley.

High frequency motor spindles

As CNC routers became more popular, demand developed for a router spindle that was smaller and lighter than the belt driven spindles of the day. Someone discovered that a synchronous motor wound to rotate at 3,600 RPM on a 60 cycle electric current would turn at 18,000 RPM if operated on a 300 cycle current.

Although both motor types have the same horsepower rating, when cutting less horsepower is available from a high-frequency motor than from a synchronous motor. It is common to see 10 or 15 horsepower in a high frequency spindle when a 5 horsepower manual router operated by a synchronous motor has more than enough power for most applications.



Torque versus Speed curves

In addition to the motor loads, the bearings on these motors now need to handle not only the motor loads but also the cutting forces generated by the routing process. Heat generated by the routing process is being introduced directly to the motor shaft, exposing the bearings to the heat.

With higher loads, faster speeds and higher heat, bearing life has been drastically reduced. Some manufacturers have simply added a second bearing on the bottom of a spindle motor and some others have designed a separate spindle with its own bearings coupled in-line with the motor.

In general, for speeds up to about 30,000 RPM, standard steel ball bearings provide the best combination of capacity, life and resilience. For speeds above 30,000 RPM, ceramic bearings will be required, but these bearings are less tolerant to misuse and poorly balanced tooling.

Keep in mind that bearing lubrication is the most important part of a spindle's life. Too much lubrication as well as too little will drastically reduce the life of the bearings.

Many manufacturers offer auto lube options on their machines. These not only lubricate the spindle bearings but also the linear bearings along the axes.

One method of lubricating the bearings is to send a pressurised shot of grease to the bearings at predetermined intervals. This is an older method adapted from the metalworking industry and tends to drip clumps of used grease on parts every now and then.

The best method is to send a constant mist of oil mixed with compressed air to the bearings. This option has the added benefits of cooling down the bearings and creating a positive pressure in the bearing housing which keeps the fine dust out.

Tool Changers

Manual

A manual tool change is done with the spindle turned off. The nut on the collet is loosened and the bit is changed. In some cases the tool change is commanded by the program which resumes once the change is done. Most often though, a separate program needs to be run for each tool change.

Multiple head

Some machines simply resort to multiple heads in order to accommodate different tools. Some machines, also known as “workcenters” have multiple heads mounted on one axis that are activated pneumatically by the program. A new tool can be lowered in seconds and start cutting much faster than initiating a tool change. The consequence of having all these separate moving parts can be lower accuracy.

Tool holders

There are many variations of tool holders. The two most prominent kinds in the CNC router market are ISO-30 and HSK63F.



ISO-30 tool holder

Photo courtesy of
ROYCE//AYR Cutting Tools

Although the HSK63F is more stable and can handle a larger tool, it is more costly and more prone to dust contamination than the ISO-30 tool changer.

The cutting tools are set into the tool holder by various means. The most common is a tapered collet that is tightened by a nut. Other methods use hydraulic pressure or heat shrinking.

Hydraulic locking tool holders and heat shrink tool holders are more expensive and require special equipment but they hold the tool much better which results in a more balanced tool, less vibration and a better cut finish.

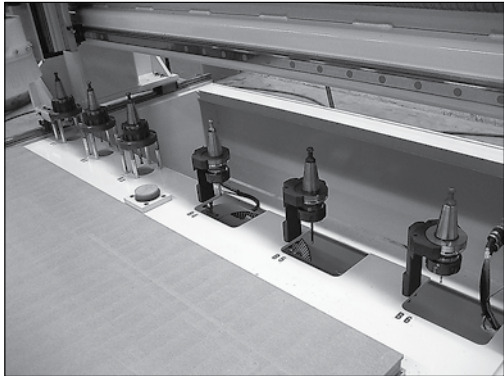
Cutter sharpening centers can offer heat shrink services. Some manufacturers may use heat shrink tool holders for their main tool and send the whole tool holder assembly out for sharpening. The tools will then last much longer and give a much improved cut.

Automatic tool changers

Automatic tool changers are actually a specially designed spindle. This spindle uses a drawbar to pull a tapered tool holder into a tapered receptacle at the bottom of the spindle. This drawbar has several fingers that grip a knob screwed into the end of the tool holder. When the drawbar retracts, it pulls the tool holder tightly into the spindle taper.

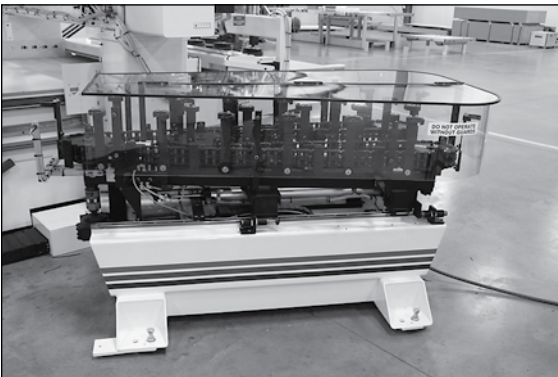
An automatic tool holder can be manually changed by pressing a button that releases the tool holder. A new tool holder can then be inserted by hand into the spindle.

The simplest form of automatic tool changer is called the bar style tool changer. It is usually located at one end of the machine and consists of a series of receptacles. To change tools, the head moves to an empty receptacle and deposits the current tool. It then moves to the location of the next tool and retrieves it.



Bar style tool holder positioned at the back of the machine

Photo courtesy of Thermwood Corporation



Bulk tool changer

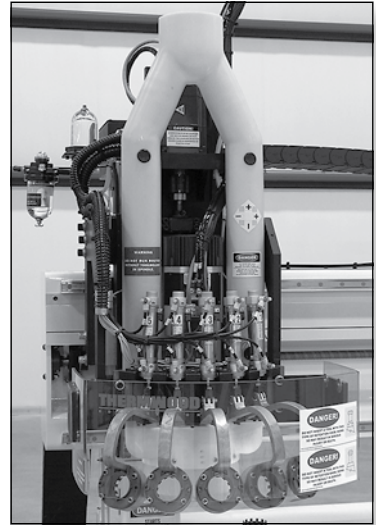
Photo courtesy of Thermwood Corporation

Magazine or bulk tool changers are designed to hold a lot of tools. They can be on a chain or arranged in a series of circular carousels each holding a number of tool holders. To change tools using a bulk tool changer, the head moves to the load/unload position and deposits the existing tool. The chain or magazine then rapidly positions the next tool, which is retrieved by the head. The bulk tool changer can normally hold upwards of fifty tools.

Typewriter style tool changers were introduced just a few years ago. The objective of this type of tool changer is to have it ride along with the main spindle and be ready to change a tool on the fly. This is done without having to move the gantry, the table or the head all the way to the edge of the machine. In the last couple of years, many companies have followed this lead and created variations on the same theme. The main advantage of these systems are fast tool changes. The drawback is that they are limited to smaller and lighter tools.

Turret spindles were first introduced in the metalworking industry. The idea is that the z axis supports an octagonal structure that can turn to expose one of its 8 sides. On each side a separate spindle or pneumatic drill which can hold one tool is mounted. As a different tool is needed, the whole head rotates to the appropriate position and is ready for use. This system produced very rapid tool changes but fell out of favour because they were heavy and their many complex parts were prone to failing.

Aggregate tools are used widely for special applications. They come in many configurations and can be ordered custom built. The most common are drill banks, horizontal routing or boring, saw and v-grooving. Some aggregates can simulate 5 axis movements on a 3-axis machine.



Typewriter tool changer mounted on the head

Photo courtesy of Thermwood Corporation

Tooling

Tooling, surprisingly enough, is often the least understood aspect of CNC equipment. Given that it is the one element that will most affect the quality of cut and the cutting speed, operators should spend more time exploring this subject.

Cutting tools usually come in three different materials; high speed steel, carbide and diamond.

High speed steel (HSS)

HSS is the sharpest of the three materials and the least expensive, however, it wears the fastest and should only be used on non-abrasive materials. It requires frequent changes and sharpening and for that reason it is used mostly in cases where the operator will need to cut a custom profile in-house for a special job.

Solid carbide

Carbide tools come in different forms: carbide tipped, carbide inserts and solid carbide tools. Bear in mind that not all carbide is the same as the crystalline structure varies greatly between makers of these tools. As a result, these tools react differently to heat, vibration, impact and cut loads. Generally, low cost generic carbide tools will wear and chip more rapidly than higher priced name brands.

Silicon carbide crystals are embedded in a cobalt binder to form the tool. When the tool is heated, the cobalt binder loses its ability to hold on to the carbide crystals and it becomes dull. At the same time the hollow space left by the missing carbide fills up with contaminants from the material being cut, amplifying the dulling process.



Solid carbide (left) and diamond (right) tooling

Photos courtesy of ROYCE//AYR Cutting Tools

Diamond tooling

This category of tooling has come down in price in the last couple of years. Its remarkable abrasion resistance makes it ideal for cutting materials such as high pressure laminates or MDF. Some claim that it will outlast carbide by up to 100 times. Diamond tipped tools are prone to chip or crack if they hit an embedded nail or a hard knot. Some manufacturers use diamond tools for rough cutting abrasive materials and then switch to carbide or insert tooling for the finishing work.

Tool geometry

Shank

The shank is the part of the tool that is held by the tool holder. It is the part of the tool that has no evidence of machining. The shank must be kept free of contamination, oxidation and scratching.

Cut diameter

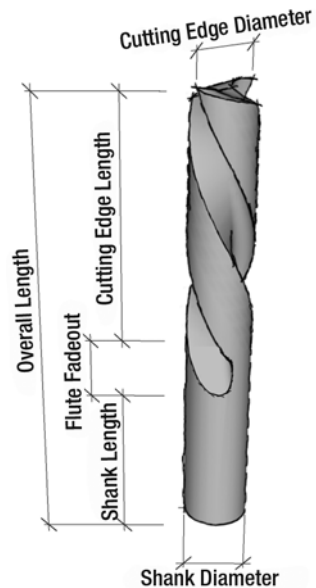
This is the diameter or the width of the cut that the tool will produce.

Length of cut

This is the effective cutting depth of the tool or how deep the tool can cut into the material.

Flutes

This is the part of the tool that augers out the cut material. The number of flutes on a cutter is important in determining the chip load.



Tool geometry

Tool profile

There are many profiles of tools in this category. The main ones to consider are upcut and downcut spirals, compression spirals, rougher, finisher, low helix and straight cut tools. All of these come in a combination of one to four flutes.

The upcut spiral will cause the chips to fly upward out of the cut. This is good when doing a blind cut or when drilling straight down. This geometry of tool however promotes lifting and tends to tear out the top edge of the material being cut.

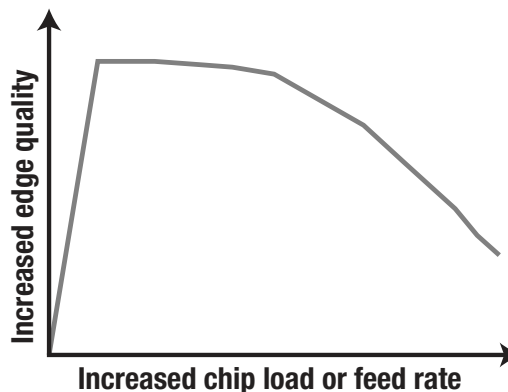
Downcut spiral tools will push the chips downward into the cut which tends to improve part holding but can cause clogging and overheating in certain situations. This tool will also tend to tear out the bottom edge of the material being cut.

Both the upcut and downcut spiral tools come with a roughing, chip breaker or a finishing edge.

Compression spirals are a combination of upcut and downcut flutes. Compression tools push the chips away from the edges towards the center of the material and are used when cutting double sided laminates or when tear out of the edges is a problem.

Low helix or high helix spiral bits are used when cutting softer materials such as plastic and foam, when welding and chip evacuation are critical.

Chip load



The most important factor for increasing tool life is to dissipate the heat that is absorbed by the tool. The fastest way to do this is by cutting more material rather than by going slower. Chips extract more heat away from the tool than dust does. As well, rubbing the tool against the material will cause friction which translates into heat.

Another factor to consider in the quest to increase tool life is to keep the tool, the collet and the tool holder clean, free of deposits or corrosion thus reducing vibrations caused by unbalanced tools.

The thickness of material being removed by each tooth of the tool is called the Chip Load.

The formula for calculating chip load is as follows:

$$\text{Chip Load} = \text{Feed Rate} / \text{RPM} / \# \text{ Flutes}$$

When the chip load is increased, tool life is increased, while decreasing the cycle time. Furthermore, a broad range of chip loads will achieve a good edge finish. It is best to refer to the tool manufacturer's chip load chart to find the best number to use. Recommended chip loads usually range between 0.003" and 0.03" or 0.07 mm to 0.7 mm.

Cutting Parameters

Having an intimate knowledge of the characteristics and limitations of a machine will have a huge impact on the quality of the parts that can be produced on it.

When programming a part to be cut, bored, shaped, etc, having a good handle on the cutting parameters will be crucial to the quality of the end result. Sometimes these parameters will change as a result of extensive trial and error. Here are a few of the main ones:

Feed speed

This is by far the most fundamental to consider and often the most misused. In theory, the fastest feed speed possible that will produce an acceptable cut finish should be programmed. There are many factors that affect this parameter, such as RPM, material density, machine rigidity, tool geometry and many more.

The best starting point for calculating feed speed is to refer to the tooling manufacturer's chip load chart. Keep the tools running as fast as possible without compromising edge quality and without breaking the tool. Remember that running a tool too slowly in a cut can also lead to breakage because of the excessive heating that occurs.

Always remember to cut as fast as possible while still maintaining an acceptable edge quality. This will increase tool life and increase the machine's output.

Climb and conventional cutting

Conventional cutting or chip cutting is the term used when the tool rotates against the direction of the material being fed. Climb cutting refers to the material being fed in the same direction as the rotation of the cutter. When using a hand-held router it is quite dangerous to climb cut because the router or the part would be pulled away from the operator which can result in serious injury. In the case of a CNC router however, the spindle and the material are held rigidly in place and both directions of cut are possible.

A climb cut can be very useful when cutting material that has a tendency to splinter but it also tends to create more fuzz in fibrous material. Again, some experimenting will be necessary to determine the best parameter to choose in specific situations.

Rough cutting and finish cutting

In some situations, it is a good idea to do one pass with a rough mill to quickly remove most material without consideration for edge quality and then come back in with a finish cutter to smooth off the edges. Remember that depending on the cutting tool being used, the same finish can probably be achieved in one pass instead of two.

On less rigid machines or when cutting hard material, it might be a good idea to use a two pass combination to offset the accuracy issues that might result from flexing on the axes.

Ramping and offset

These parameters are used at the start and at the end of a cut. Dwelling and plunge entry can create burn marks causing quality issues. As well, when using a non-plunging tool, a long ramp can alleviate some of the pressure and excess heat that would be produced on the end of the tool.

Tab and skin

Tab and skin parameters are used when trying to cut small parts that are hard to hold down. The tabs or the skin left on the bottom of the piece can then be cut in a second pass or by other means.

Work Holding

In order to machine a part on a CNC router the part must be held securely in place. This seems obvious, however, this is the one area that often causes major headaches.

Another term used for part holding is fixturing. The hold-down system has a significant impact on part accuracy, quality of finish and on feed speeds and tooling life.

Keep in mind that holding the part securely is important and there is no one system that will properly hold all parts.

There are two fundamentally different types of parts that must be held in place. The first is a flat part or a sheet of material and the second is a three-dimensional object. The fixturing systems for each are similar, however, the three-dimensional part normally requires somewhat more complex arrangements.

Some materials require higher cutting forces than others and these materials will require a more rigid hold-down system. Some materials will vibrate or chatter when cut.

Manual

The most cost effective way to hold down parts to a table is to screw, nail or to bolt the part to the work table. Other good methods of manually holding parts down are to glue the part down with regular or thermo fusible glue or with double sided tape. In the case where a prototype or a single piece will be cut, it might not be cost effective to build a holding fixture.

For short production runs or for fixturing prototypes, another useful method is to use a toggle clamp. These come in many different configurations and sizes and are easy to adjust and to setup on a jig.

One must be careful not to crash the tool or the spindle into the clamp when using this kind of device. It is always a good idea to test the program in a dry run at low speeds before putting such a fixture into production.

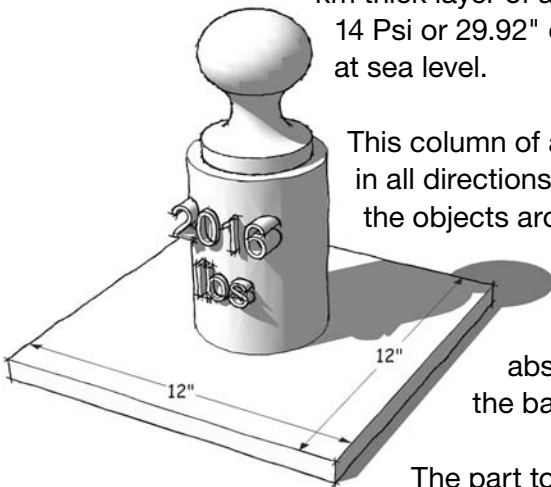


Toggle clamp

Photo courtesy of DE-STA-CO

Vacuum

The most common system for holding down parts on the CNC router is conventional vacuum. Vacuum is simply the absence of air. The 45 km thick layer of air surrounding the Earth weighs about 14 Psi or 29.92" of mercury (Hg) or 100 kilopascals (kPa) at sea level.



This column of air pushes down equally on everything in all directions so that no resultant force is felt on the objects around us. When the air is removed from one side of an object, the air on the other side now pushes against the object with a force proportional to the absence of air on the opposite side. This is the basis of vacuum hold-down.

The part to be machined is sealed against the tabletop or a fixture and then the air inside the seal is removed using a vacuum pump. The air on the outside then pushes the part against the fixture.

The vacuum pressure is not the only thing holding the part against the table. Since lateral pressure is exerted by the cutter when it is machining the part, the coefficient of friction between the part and the fixture plays an important part as well.

A perfect vacuum is not possible with current technology, no matter which kind of vacuum pump is used.

Capacity

The capacity for vacuum pumps is specified in a couple of different ways, depending on the type of vacuum pump and the manufacturer. It is important to know the ACFM rating of the pump. It expresses the “actual cubic feet per minute” inlet capacity at a specific vacuum level. Capacities expressed in CFM or SCFM (standard cubic feet per minute) can be very misleading because one has to take into consideration the volumetric efficiency of the pump at a specific vacuum level. Rotary vane pumps are generally rated in CFM of free air displacement, which is the theoretical displacement at 0" Hg vacuum.

The requirements in vacuum flow or the capacity of the pump will be different whether vacuum cups, clamps or high flow universal vacuum tables are being used.

A vacuum hold-down where the part rests on rubber seals may allow the part to move or wiggle slightly on the soft seals. This can easily result in excessive tooling marks, chatter and a poor quality edge. It is also possible that under the pressure of cutting, the part may move slightly resulting in a loss of accuracy.

Conventional vacuum fixturing

This method is mostly used in 5-axis production when trimming moulded parts. Since these parts are almost never flat, special vacuum fixtures are made using plaster to conform to the part and a rubber seal is used around the vacuum ports.

Pod and rail

This vacuum cup type of hold-down is a widespread method of holding parts on a CNC machine. This is well indicated when one part at a time needs to be machined.

There are many different configurations of pods for different applications and as it takes time to adjust the pods to different configurations and part sizes, this can be an inefficient way to work. Pod systems are not the universal solution that some manufacturers advertise.

Combination pod/flat table

On lower-priced or older systems, a combination of pods on a flat table using conventional vacuum is often found.

Rotary vane vacuum pumps are relatively inexpensive as they are small and are not required to pull a great volume of air. This system works well when there is a good seal with the part.

High flow vacuum

This method is often associated with nested based systems. A sacrificial board otherwise known as a spoilboard made of MDF or particleboard sits atop a vacuum plenum on the worktable. Flow is

so high through the MDF that a low-pressure area is created on the surface. A flat part that is laid on this table will be held in place in this low-pressure area without the need for fixtures or seals.

The amount of force generated on the part is much less than with conventional vacuum. The best systems today generate a force between 4 and 6 pounds per square inch. This means that a 12"x12" piece of melamine will be held to the surface with a force of 576 to 864 pounds. This is more than enough to do the job in most cases.

Remember to take into consideration the permeability of the material that is being worked when purchasing a vacuum pump. Low density fiberboard is very porous and will let a good quantity of air seep right through the material while Plexiglas is completely impermeable and once a good seal is achieved, it takes very little work to maintain it.

Roller hold-down

Other methods of material holding have surfaced in response to specific industry needs. Roller hold-down systems are often seen in upholstery shops. This method is used to hold rough and often warped plywood that could not otherwise be held in place by a high flow vacuum.

Some advantages of this method include achieving faster accelerations and that more than one sheet



Roller hold-down fitted with an automatic sheet loader

Photo courtesy of Thermwood Corporation

at a time can be held down. The outcome is a lower quality edge but this is not often an issue with upholstered furniture. Also, small parts will be difficult to cut if they are not pressed by the two rollers at all times.

Vacuum Pumps

Machine vendors will present a variety of choices regarding the type of vacuum pumps that they offer. These vary widely in specification and in price range.

The main features to look for when specifying a pump for a particular application are:

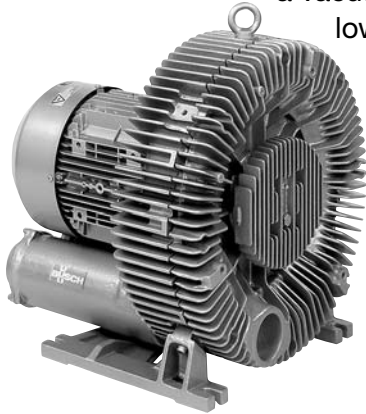
- vacuum level (in Hg or kPa)
- vacuum flow (CFM or m³/min)
- operation noise level (db)
- price (\$).

The best pump for any particular application will be a compromise arrived at after a thorough analysis of cost and performance of the different components available at the time.

All vacuum pump manufacturers publish performance curves. As part hold-down efficiency will be a very important factor in the success of any CNC application, proper selection is vital.

Regenerative vacuum blowers

These are the lowest in cost and consist of a motor connected to an impeller. As the impeller pushes air through the exhaust, it creates a vacuum. These types of pumps typically generate low vacuum pressure but a great volume of air.



They are noisy, operating at approximately 90 decibels. These pumps are best suited for holding less dense material such as foam and fabric.

Vacuum blower

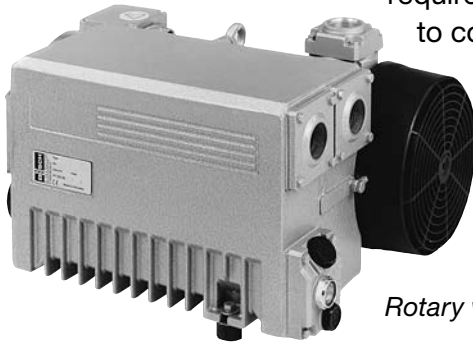
Photo courtesy of Busch Vacuum Technics Inc.

Dry running rotary vane vacuum pumps

Widely used in the woodworking industry they use self-lubricating phenolic vanes that rub against the pump housing as they turn. They run moderately quietly at approximately 80 decibels. Although they require more maintenance and are less efficient than their oil recirculating cousins, they are inexpensive. They are best used to hold down non-porous materials when a good seal is achievable, such as with suction cups.

Oil recirculating rotary vane vacuum pumps

These pumps reach a very high vacuum although at relatively low volumes. Because the vanes slide continuously on an oil film they offer a practically wear free operation. On the other hand, they require an oil separator which is prone to contamination and the oil filters have to be replaced often. These pumps are widely used in the woodworking industry in veneer presses and in some clamping operations.



Rotary vane pump

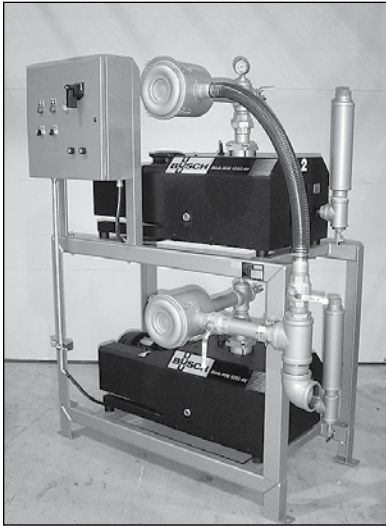
Photo courtesy of Busch Vacuum Technics Inc.

Positive displacement rotary blowers

These types of pumps use either one rotor or two rotors that turn in opposite directions to one another compressing the air as it is exhausted. These blowers are very noisy, approximately 100 decibels and should be kept in a separate enclosed area. These blowers are used mainly in material handling applications as they are not suited for clamping purposes.

Rotary claw vacuum pumps

Also called Roots pumps, these dry running pumps are relatively new and rapidly gaining acceptance in the woodworking industry.



Since no parts are in contact with each other or with the housing, these pumps require less maintenance than other models. They are relatively noisy and generate an average level of vacuum but a very good displacement of volume. As such they are very well suited in all kinds of high volume applications.

Two rotary claw pumps mounted in parallel

Photo courtesy of Busch Vacuum Technics Inc.

Rotary screw vacuum pumps

These are the most costly and the noisiest of the lot. As well, they need the most maintenance with regular oil changes and upkeep to sensitive electronic controls. On the other hand, they achieve the best vacuum/flow ratio of all the different pump types.

Liquid sealed pumps

These are also called liquid ring pumps because oil or water is used as a seal between the vanes and the pump housing. As no parts are in contact with each other, they achieve very high vacuum levels while producing very little noise, approximately 70 decibels. They need regular maintenance as their efficiency is greatly reduced

when the water or oil temperature increases. These units are fairly expensive and should be used where high vacuum pressure and moderate volumes of air are needed.

Material Handling

Manual material handling is often the norm in furniture and cabinet shops. This oversight is often at the expense of the manufacturer since the time spent loading and unloading machines often makes up most of the wasted time in a day.

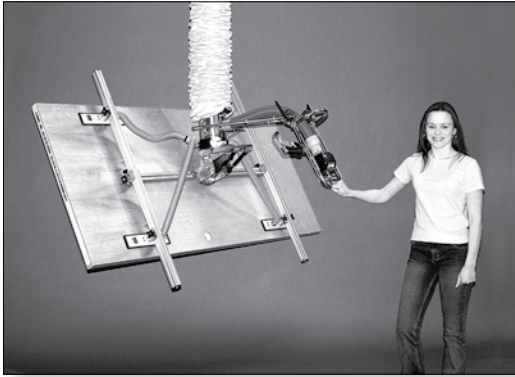
Often, CNC owners will try to trim seconds off a program or even try to run parts at much faster speeds. This will result in marginal savings in time and most often result in poor cut quality. Often they overlook parts and machine idleness and unnecessary material handling in their time analysis.

Most of the efficiencies that can be gained at a CNC work station are in handling material. Whether talking about the methods used to handle material or the strategies used to deal with material handling, large quantities of inventory or work in progress can usually be found all around the shop. Ensuring that raw material gets to the shipping door as a finished product in the best possible time will always have the greatest impact on a manufacturer's bottom line.

Scissor lifts

A simple scissor lift at the end of the worktable is often enough when mostly the same material is being processed all day. When more than one material is used, manufacturers often pre-stage lifts with the right combination of material so the operator can slide the right sheet onto the worktable. Care must always be taken when dragging sheets across each other as this can ruin the surface of the sheet below.

Vacuum lifts



Vacuum lift with tilt option

Photo courtesy of Anver Corp.

Vacuum lifts are a little more expensive than a scissor lift but are also more versatile. They can pick up sheets from different piles around the CNC and give the added ability of removing larger parts from the work table once the machining is done. They are usually mounted on a crane bolted to the floor or wall. Some use high flow vacuum for both the holding and the lifting, while others use an electric winch for lifting and an Air-Vac on a suction cup for holding.

Automated material handling

Automated material handling equipment is mostly found in very large production plants. Automation can vary from a mechanized conveyor system to robotic arms doing most of the loading and unloading of the work.

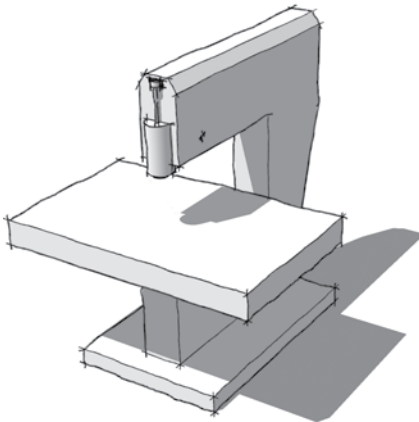
Router Configurations

- ▶ **X-Y Tables**
- ▶ **Cantilevered**
- ▶ **Moving Table**
- ▶ **Moving Gantry**
- ▶ **Pendulum**
- ▶ **5-Axis**
- ▶ **Industrial Robot**
- ▶ **Other Categories of CNC Equipment**

X-Y Tables

This is a machine style that is seldom used anymore. They can usually be found on smaller machines or in special applications such as for chair legs or for making templates.

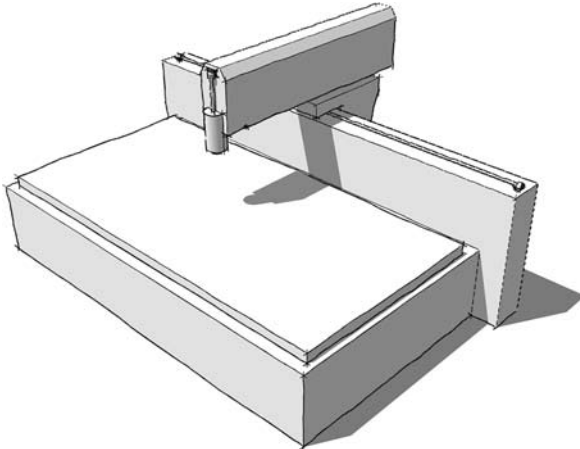
In this configuration, a table that moves both right to left and front to back is mounted under a spindle that moves up and down. The first of these machines was actually a pin router with an X-Y table mounted to it.



It is quite easy to get a very rigid machine in this manner. However, from a practical standpoint it is limited to rather small table sizes. The spindle must be attached to the machine base by an upright column. The distance from the column to the spindle defines the maximum table width and this distance cannot be too large without making the overall machine structure impractical.

X-Y tables have evolved from pin routers

Cantilevered



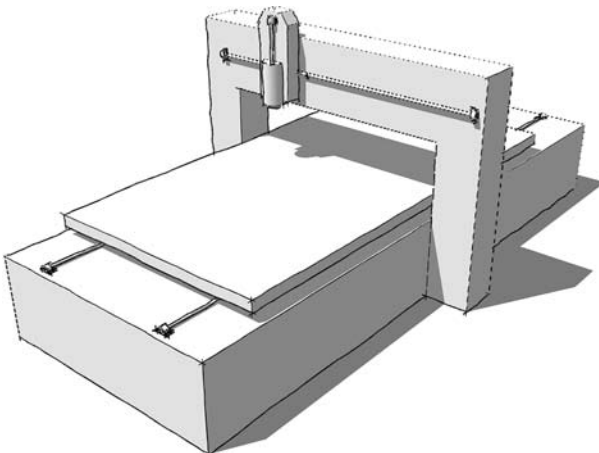
Cantilevered Arm Router

These are usually referred to in the industry as point-to-point machines although only very old machines actually qualify as such anymore.

This configuration has one major advantage. It is easy to load and unload. The table is suspended in front of the operator and all of the operating mechanism is located behind the table. Every part of the table can be easily reached.

Since the arm structure is suspended from only one side, developing a structure that remains rigid becomes quite difficult.

Moving Table



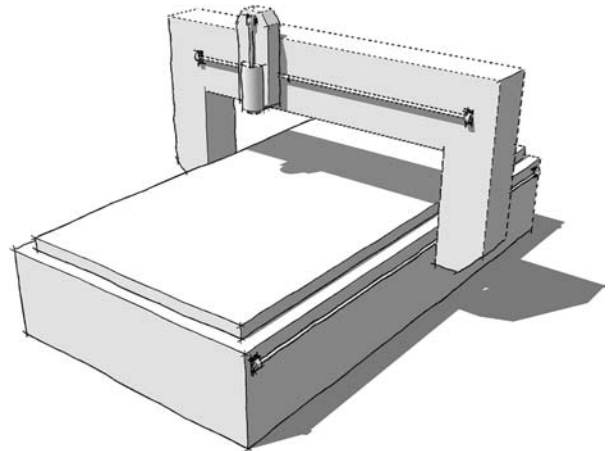
Moving Table Router

The moving table and the moving gantry designs are the most common in industry today.

The moving table machine is more popular than the moving gantry machine, not because it is inherently more stable but because of a control system limitation. A moving table machine has a single lead screw moving the head back and forth on the gantry and a single screw moving the table front to back.

Moving Gantry

A moving gantry machine has the gantry mounted to a rail located on either side of the table. One lead screw moves the head back and forth on the gantry, but two lead screws are required to move the gantry. As a result, the moving gantry machine requires one extra servo motor and drive making it more expensive. Each screw must also have its own independent compensation table which makes it more demanding on the controller.



Moving Gantry Router

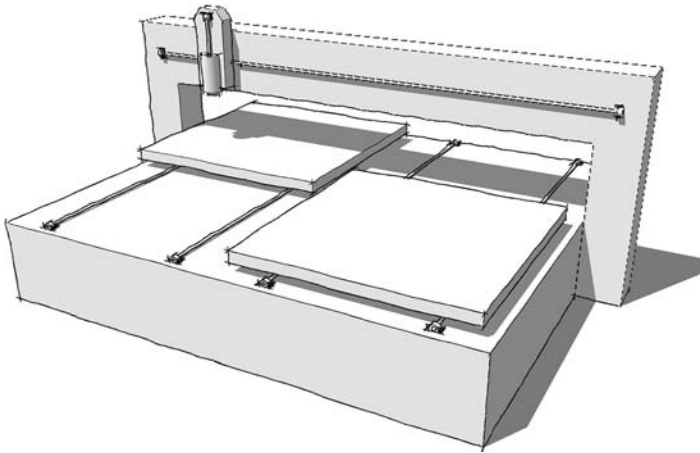
The biggest practical difference between the moving gantry and the moving table construction is that for equal table size, the moving gantry design requires about half the floor space.

A moving gantry machine can generally carry heavier parts than a moving table machine.

This is mostly true when working with stone or metals. When the fixture and work piece weighs thousands of pounds, this can become a problem. In these circumstances it is better to place the fixture and work piece on a fixed table braced to the floor and move the gantry over the work.

Pendulum

Pendulum, or dual table routers are usually seen in high volume applications where maximizing cutting time is key. One table works at a time allowing for setup and parts removal from the other table. In certain cases, both tables can work in tandem allowing for the machining of larger parts.



Pendulum or Double Table Router

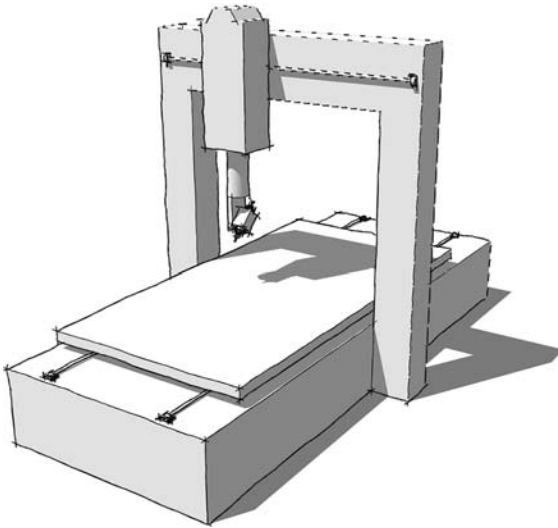
These machines were popular in the early days of CNC routers since price was not an issue. They fell out of favour when manufacturers started making lower cost machines, but are coming back in style now that maximum efficiency is of the essence.

These machines are often seen in a multiple spindle configuration.

5-Axis

5-axis machines were first used in the aerospace industry and used to cost millions of dollars. They soon became sought after by other industries because of their potential for machining large three-dimensional objects.

Both moving table and moving gantry 5-axis CNC designs are commercially available. The vast majority of machines are of the fixed gantry, moving table design.



5-Axis CNC Router

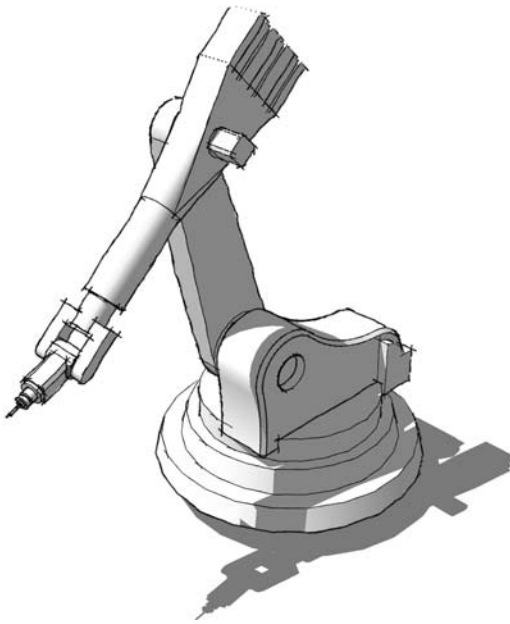
There are several major differences between the 3-axis CNC routers and the 5-axis machines. The biggest difference is that 5-axis machines are generally designed to work on large three-dimensional parts where the 3-axis machines are intended to process primarily flat parts. The gantry, whether it is fixed or moving, must be taller and the z-axis, will have much more stroke than the 3-axis machines, sometimes up to 60 inches (1500 mm) or more.

This greater height does offer larger part processing capability but at a significant cost. As the gantry gets taller and the z-axis gets longer, both accuracy and stability are diminished. This situation can be improved by reducing the acceleration and deceleration of the various axes that affect the gantry, although this will significantly slow the machine down. For this reason alone it is best to try to keep the z-axis and gantry height as low as possible for every application.

Industrial Robot

Industrial robots, once relegated to material handling applications have come a long way. Because of better software applications and their widespread use in many industries, their price is significantly lower.

They are well suited to replace 5-axis CNC routers in trimming operations on large parts such as boats and hot-tubs. They can

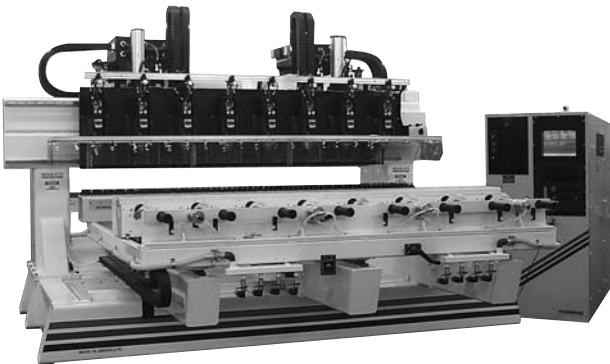


6-Axis robot fitted with a router spindle

also be very useful in finishing applications as a robot can be made to sand the part, apply the finish and then move it along to the next operation.

These machines cost about \$50,000 for the basic machine, plus tooling and integration costs. New applications are being worked on by independent companies as each one is likely to be customized to the customer's particular needs. Expect to see more of these machines in the wood industry in the near future.

Other Categories of CNC Equipment



8-head CNC carving machine

Photo courtesy of Thermwood Corporation

Aside from the omnipresent CNC router, there are many other applications that use CNC technology. Amongst these are CNC edgebanders, CNC lathes, CNC bandsaws, CNC sanders etc. All these machines use computer controlled motion hence the label CNC.

Software

- ▶ **CAD**
- ▶ **CAM**
- ▶ **Parametric Design**
- ▶ **Nesting Software**
- ▶ **Post Processors**
- ▶ **G-Code**

Software is at the heart of any NC machine. Even the most advanced piece of machinery cannot perform to its full potential without the proper software to make it happen. It is also the area that will require the highest skill set on the path toward CNC success.

There are many levels of software needed to run a CNC router: from the technical drawings to the sales requirements and scheduling, to the actual NC code that makes the axes move. All have a specific role to play in the overall solution.

A new concept is evolving in automated manufacturing circles. It is called “Human Machine Interface” or HMI. This is the means by which the operator (the user) interacts with a particular machine (the system). This concept aims to improve the interactions of the operator with the machine. An example of this is when the operator can visualize the machining operation on the screen and they can change or adjust cutting parameters on the fly in the middle of the operation.

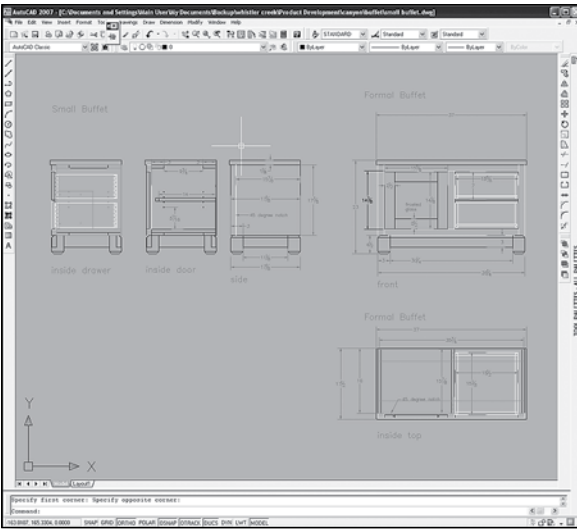
Great progress has been seen in the past decade, and even greater advances can be expected in the years to come. Software and CNC technology are proving to be a fundamental tool in the continued survival of the North American wood products industry.

CAD

The acronym for Computer Aided Design (CAD) originally meant Computer Aided Drafting because of its use as a replacement for traditional drafting.

CAD is used to design, develop and optimize products which include goods used by end consumers or intermediate goods used in other products.

CAD enables designers to lay out and develop work on screen, print it and save it for future editing, saving time on their drawings.



2D CAD program showing line drawing

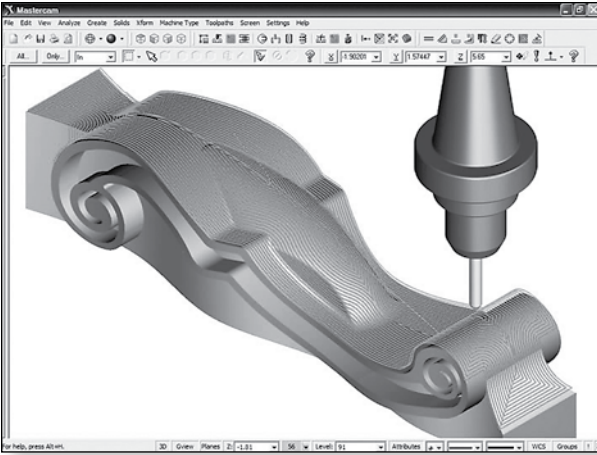
Many different CAD software packages exist, some drawing in 2D, some in 3D, some cater to architects, some to engineers and some are made for the layman. Some are very complex and require a long learning curve, while others are unsophisticated and very intuitive to use. Still others are made with specific products in mind such as kitchen cabinets or doors and windows.

Care must be taken in choosing CAD software so that it corresponds well to needs. It's very easy to waste a lot of time on unnecessary functions in day to day operations. An example of this is if parts are drawn in 3D when only shop drawings are needed. On the other hand, the 3D drawings can be very useful in product marketing.

CAM

Computer Aided Manufacturing (CAM) takes the CAD drawings and helps translate them into manufactured parts by adding tool sequences, machining parameters, cutting speeds, etc.

CAM refers to a wide range of computer-based software tools that assist engineers, tool and die makers and CNC machinists in the manufacture or prototyping of product components.



CAM software simulating machining of complex 3D part

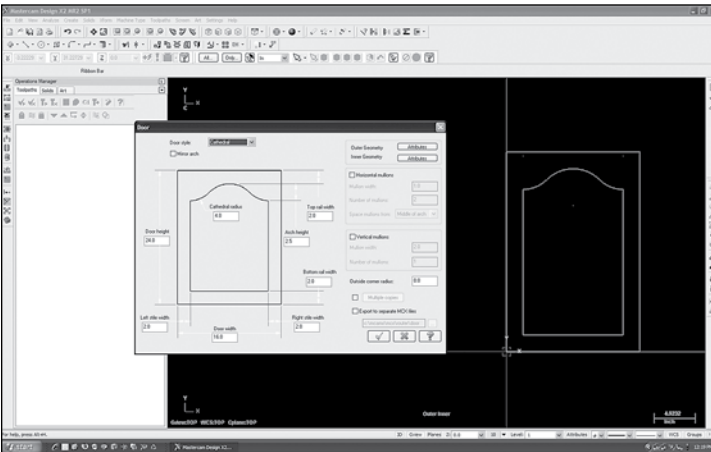
Photo courtesy of CNC Software - Mastercam

Traditionally, CAM has been exclusively considered as an NC programming tool. Although this is most often the case, CAM functions have expanded to integrate more fully with different engineering functions.

The days of programming parts in cryptic G-code on a small monochromatic display at the control are long gone and today's CAM software can offer much more versatility and efficiency.

Parametric Design

Parametric design software has often been associated with very specialized industries but it is becoming more and more widespread.



Parametric software automates the design process

Photo courtesy of CNC Software - Mastercam

An example of this is its use in CNC work centers dedicated to making window frames. In this application, the operator inputs the style and required size of the window and the machine calculates all the parameters needed to produce the parts. The same is true for other types of components, including

drawer boxes, kitchen cabinet doors and cardboard boxes to name a few.

This software is often associated with a dedicated machine and will not work for producing out of the ordinary parts, however they are most often very productive and outperform some of the more universal programs.

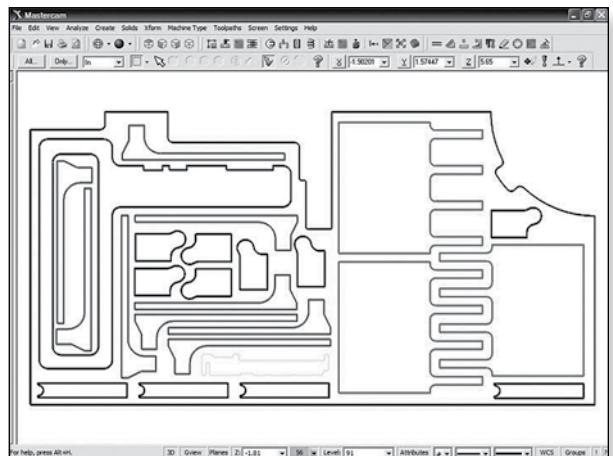
Nesting Software

Nesting or optimizing refers to the process of efficiently manufacturing parts from sheet goods to minimize waste.

Although most nesting is done through the CAM software, there still exist stand alone nesting programs. Some will import part descriptions from other CAD or CAM software and others will also permit the user to import cut sizes directly from sales or spreadsheet software.

Nesting uses various powerful and intelligent nesting algorithms that rotate and translate part geometries into the most efficient use of the panel surface.

There are two major nesting models. Rectangular or block nesting bounds the shape by a rectangular border and moves the rectangle around the panel. True shape or geometric nesting takes into



Nested parts maximize the use of available material

Photo courtesy of CNC Software - Mastercam

consideration the real shape of the part, including holes and protrusions, to find the best arrangement for maximizing raw material usage.

Post Processors

A post processor is a program that translates the centreline data it receives from the CAM software into the NC code that the machine will use to machine the part.

There must be a post processor for each CAM software program and for each CNC machine. Even similar machines of the same make and model require subtle tool shift data that is unique to each machine.

G-Code

G-Code is the language that the CNC understands in order to move its axes and perform operations. Also known as RS-274D, it is the standard for numerically controlled machines and was developed by the Electronic Industry Association in the early 1960's.

G-Code was developed and first used with the original punched paper tape. The basic unit of the program is called a 'block', which is seen in printed form as a 'line' of text. Each block can contain one or more 'words', which consist of a letter, describing a setting to be made, or a function to be performed, followed by a numeric field, supplying a value to that function. Various words can be combined to specify multi-axis moves, or perform special functions.

Descriptors preceded by the percent sign (%) or bound by parentheses are text or comments that are ignored by the machine. Their sole purpose is to add comments and clarity to the code.

G-Code can be entered manually using a text editor but these days it is usually produced by a post processor directly from the CAM software.

```
% TOOL CHANGE T309 1/2 in fin/dwn/cut POCKET iOP: 3
M5 (PRE-TOOLCHANGE STOP)
S18000 (SPINDLE SPEED)
T309 M3
G00 X-.475 Y-33.215 (RAPID X Y)
G00 Z.5
M31 (CHECK UP 2 SPEED)
G00 Z.1
G01 Z-.5 F75.
G01 X-.51 Y-30.14 F380.
G01 X-.475 Y-30.34
G01 Y-33.215
G01 X-.21 Y-33.54
G01 X-.74
G01 Y-29.9389
G03 X-.8162 Y-29.7551 I-.26 J0.
G02 X-.7949 Y-29.7338 I.0106 J.0106
G03 X-.6111 Y-29.81 I.1838 J.1838
G01 X-.21
G01 Y-33.54
G00 Z.5
G00 X-.983 Y-31.9989
```

Sample block of G-code

Accessories

Label printing

This is an option that is becoming more and more popular in the industry especially since CNC machines are becoming more integrated into the whole business formula. The controller can be connected to the sales or scheduling software and part labels are printed once the part is machined. Some vendors use labels to identify left over material for easy retrieval in the future.

Optical readers



Otherwise known as bar code wands, they can be integrated into the controller so that a program can be called by scanning a barcode on the work schedule. This option saves valuable time by automating the program loading process.

Bar code reader facilitates program automation

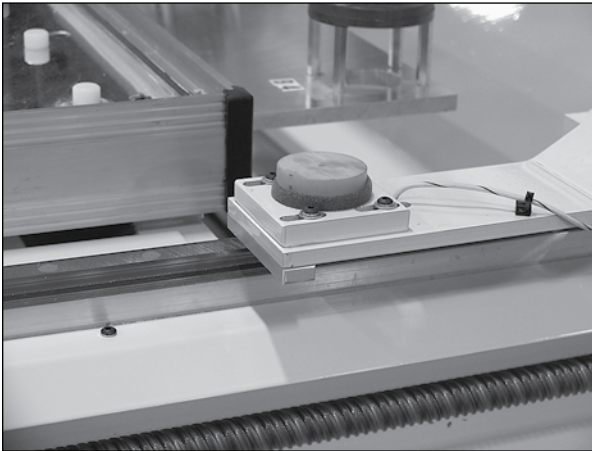
Photo courtesy of Thermwood Corporation

Probes

These measuring devices come in a variety of forms and perform many different functions. Some probes merely measure the surface height to ensure proper alignment in height sensitive applications. Other probes can automatically scan the surface of a three-dimensional object for later reproduction.

Tool length sensor

A tool length sensor acts like a probe that measures the daylight or the distance between the end of the cutter and the surface of the workspace and enters this number in the control's tool parameters.



This little addition will save the operator from the lengthy process required each time he changes a tool.

A tool length sensor quickly measures tool daylight

Photo courtesy of Thermwood Corporation

Laser projectors

These devices were first seen in the furniture industry in CNC leather cutters. A laser projector mounted above the CNC work table projects an image of the part about to be cut. This greatly simplifies positioning the blank on the table to avoid defects and other issues.

Vinyl cutter

A vinyl knife attachment is often seen in the sign industry. This is a cutter that can be attached to the main spindle or on the side with a free turning knife whose pressure can be adjusted by a knob. This attachment permits the user to turn his CNC router into a plotter to make vinyl masks for sandblasting or vinyl letters and logos for trucks and signs.

Coolant dispenser

Cool air guns or cutting fluid misters are used with a wood router to cut aluminium or other non-ferrous metals. These attachments blast a jet of cold air or a mist of cutting fluid near the cutting tool to ensure that it remains cool while working.

Engraver

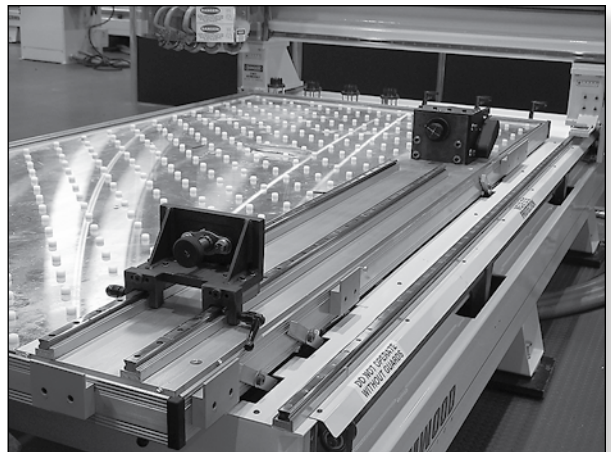
Engravers are mounted to the main spindle and consist of a floating head holding a small diameter engraving knife that turns between 20,000 and 40,000 RPM. The floating head ensures that the engraving depth will be constant even if the material thickness changes. This option is most often found in the sign making industry although trophy makers, luthiers and millwork shops use it for marquetry.

Rotating axis

A rotating axis set along the x or the y axis can turn the router into a CNC lathe. Some of these rotating axes are simply a rotating spindle while others are indexable which means they can be used for carving intricate parts.

Turn a CNC router into a lathe with a rotating axis

Photo courtesy of Thermwood Corporation



Floating cutter head

Floating cutter heads will keep the cutter at a specific height from the top surface of the material being cut. This is important when cutting features onto the top surface of a part that might not present an even surface. An example of this is cutting a v-groove on the top of a dining room table.

Plasma cutter

Plasma cutters are an add-on to some machines and allow the user to cut sheet metal parts of varying thicknesses.

Aggregate tools

Aggregate tools can be used for many operations that a straight cutter cannot perform.



Aggregate tools can perform functions that straight cutters cannot

Photo courtesy of Benz Inc.

Justifying the Cost of CNC

The cost of a CNC machine might make most manufacturers nervous but the benefits of owning a CNC router will most likely justify the cost in very little time.

The first cost to take into consideration is the machine cost. Some vendors offer bundled deals that include installation, software training and shipping charges. But in most cases, everything is sold separately to allow for customization of the CNC router.

Light duty

Low-end machines cost from \$10,000 to \$30,000. They are usually bolt-it yourself kits made of bent sheet metal and use stepper motors. They come with a training video and an instruction manual. These machines are meant for do-it-yourself use, for the signage industry and other very light duty operations. They will usually come with an adapter for a conventional plunge router. Accessories such as a spindle and vacuum work holding are options.



These machines can be very successfully integrated into a high production environment as a dedicated process or as part of a manufacturing cell. For instance, one of these CNC's can be programmed to drill hardware holes on drawer fronts before assembly.

A process dedicated CNC can be a valuable component of a manufacturing cell

Photo courtesy of ShopBot Tools Inc.

Medium duty

Mid-range CNC machines will cost between \$30,000 and \$120,000. These machines are built of heavier gauge steel or aluminium. They might use stepper motors and sometimes servos; and use rack and pinion drives or belt drives. They will have a separate controller and offer a good range of options such as automatic tool changers and vacuum plenum tables. These machines are meant for heavier duty use in the signage industry and for light panel processing applications.

These are a good option for start-ups with limited resources or manpower. They can perform most operations needed in cabinet making although not with the same degree of sophistication or with the same efficiency.

Industrial strength

High-end routers cost upward of \$120,000. This includes a whole range of machines with 3 to 5 axes suited for a broad range of applications. These machines will be built out of heavy gauge welded steel and come fully loaded with automatic tool changer, vacuum table and other accessories depending on the application. These machines are usually installed by the manufacturer and training is often included.



A broad range of machines fit this category

Photo courtesy of Thermwood Corporation

Shipping

Transporting a CNC router carries a considerable cost. With routers weighing anywhere from a few hundred pounds to several tons, freight costs can range from \$350 to \$3,000 or more, depending on location. Remember that unless the machine was built nearby, the hidden cost of moving it from Europe or Asia to the dealer's showroom is likely included. Additional costs may also be incurred just to get the machine inside once it is delivered as it is always a good idea to use professional riggers to deal with this kind of operation.

Installation and training

CNC vendors typically charge from \$500 to \$1,000 per day for installation costs. It can take anywhere from a half day to a full week to install and test the router; this cost could be included in the price of buying the machine. Some vendors will provide free training on how to use the hardware and software, usually on-site, while others will charge \$500 to \$1,000 per day for this service.

The Formula

In the book "Furniture Manufacturing in the New Millennium" by K.J. Susnjara, the author describes how he would justify the cost of buying a CNC machine for a woodworking operation. The formula that he puts forward can be used to compare present processing costs with future costs using a CNC machine.

Processing Cost = Machine Cost + Labour & Overhead + Tooling Cost + Handling Cost

Using this formula and also referring to many websites and magazine articles, it can be concluded that any company of 2 or more workers cutting 15 to 80 sheets a week and selling around \$300,000 per year or more should seriously consider purchasing a CNC router.

An example

While it is always hard to justify this kind of capital cost using proven arguments and quantifiable facts, consider the following:

A machine that is fully loaded with a vacuum table, pump, attached computer terminal, automatic tool changer, and additional accessories can cost upwards of \$200,000. A lease over 60 months on a \$200,000 machine with 10% down and a buy back option of 10% will cost approximately \$3,500 per month. All told, that is roughly the same amount of money as a \$20 per hour worker.

The Future

- ▶ **The New Factory**
- ▶ **New Techniques**
- ▶ **New Materials**

The New Factory

Wood products' manufacturing, like any other discipline, is in a state of constant evolution. While there is certainly a great deal of turmoil in the industry in North America today, it would be foolish to predict its demise. Those companies that make good use of available technologies such as CNC will have a better chance of survival.

For the last fifty years and maybe more, the industry has remained the same. The methods and the tools in use today have been refined and modernized over time but the industry is essentially the same as it was after the Second World War.

The wood manufacturing industry is steeped in tradition and the old formulas simply don't compute anymore. Competition is no longer in a local marketplace with just one or two shops that make similar products.

The economy and markets are now worldwide. Factories half-way around the world can ship their wares to our client's stores. They benefit from very cheap labour and heavily subsidised raw materials. Even when one factors in shipping costs, their product is less expensive than anything similar that can be made in North America.

Another factor to consider is that the consumer's tastes and habits are evolving very rapidly. They have access to a world of choice through the internet and they can research anything from wood species to styles in an instant. Consumers today are configuring and customizing their purchases online and they expect to receive their orders in very short order.

Can the same stale products of yesteryear continue to be delivered with a long turnaround time of 6 to 8 weeks or more?

The North American secondary wood manufacturing company of the future may look somewhat like this:

It will be a modern manufacturing plant with the latest automated equipment.

This company will be lean. No inventories and the production flow will be fine-tuned so that once an order is started, it doesn't stop until it's in the customer's hands, along with the invoice. The production cycle will be measured in days, not weeks.

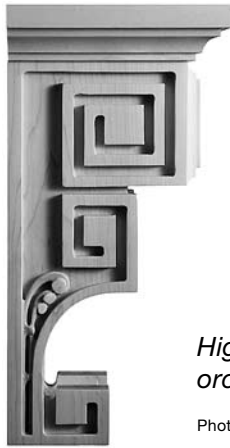
The product offering will be fully customizable. New product introductions will utilize the principles of mass customization. The manufacturer will stay away from commodity products and his offering will be much differentiated and most likely cater to a niche high-end market.

The manufacturer will sell directly to the end customer and will take advantage of a complete online presence.

New Techniques

As CNC technology becomes more sophisticated, so do the techniques. Three-dimensional machining is becoming commonplace. Combined with portable laser scanning technology and powerful CAM software, intricately detailed carvings and turnings are not only possible but easy to do.

Other simpler procedures are making the life of the modern manufacturer much easier than that of his ancestors. Blind dado joinery, nested dovetail drawer boxes and countless other techniques are making the integration of mass customization into today's factories possible.



High end carvings made to order using CNC technology

Photo courtesy of Art for Everyday Inc.



All these innovations are blurring the line between specializations as well. Indeed, a kitchen cabinet manufacturer today can make children's furniture and office furniture as well as kitchen cabinets and closet organizers.

New Materials

There is an amazing array of new materials available to manufacturers today. The days of knotty pine and red oak as the only two choices are long gone. Lightweight panels, reconstituted veneers, sustainable and low VOC particleboard are only a few of the items that are readily available today. One can buy metal laminates and reconstituted stone that can be cut with a CNC router. The combinations are limitless and are bound only by the limits of the imagination.

Conclusion

To quote a well respected CNC manufacturer:

“CNC machine engineering is a highly complex science. It involves physics, electronics, pneumatics, mathematics and a bunch of other disciplines. There is no scientifically proven best way to design a CNC machine. Every decision, every component is a compromise. In no area of machine design can you gain something without giving up something else.”

Remember this when looking to purchase a machine.



Scalloped solid wood cabinet

Photo courtesy of Pacific Woodworking

The only really accurate way to judge a machine is to judge the results.

- How well does the machine actually perform its tasks?
- How good is the quality of the machining it produces?
- How easy is it to use?
- How well does it hold up in production?
- How reliable is it?
- How long will it last?
- How easy is it to upgrade or change?
- What does it cost?
- How much can you rely on the vendor for after sales service?

While it is true that much of the North American wood products manufacturing capacity has now moved to developing countries, the new market opportunities that are now open have never been more plentiful. Find a niche and make it happen.

CNC technology should help a business become more successful and improve the bottom line. The one common fact that has been experienced by countless manufacturers of wood products around the world is that a taste of CNC technology will change a business forever.

Terminology

Absolute zero

This refers to the position of all the axes when they are located at the point where the sensors can physically detect them. An absolute zero position is normally arrived at after a home command is performed.

Axis

A fixed reference line about which an object translates or rotates.

Ball screw

A ball screw is a mechanical device for translating rotational motion to linear motion. It consists of a re-circulating ball bearing nut that races in a precision threaded screw.

CAD

Computer-aided design (CAD) is the use of a wide range of computer-based tools that assist engineers, architects and other design professionals in their design activities.

CAM

Computer-aided manufacturing (CAM) is the use of a wide range of computer-based software tools that assist engineers and CNC machinists in the manufacture or prototyping of product components.

CNC

The abbreviation CNC stands for computer numerical control, and refers specifically to a computer “controller” that reads G-code instructions and drives the machine tool.

Controller

A control system is a device or set of devices that manage, command, direct or regulate the behaviour of other devices or systems.

Daylight

This is the distance between the lowest part of the tool and the machine table surface. Maximum daylight refers to the distance from the table to the highest point that a tool can reach.

Drill banks

Otherwise known as multi-drills, these are sets of drills usually spaced in 32 mm increments.

Feed speed

Or cutting speed is the speed difference between the cutting tool and the surface of the part it is operating on.

Fixture offset

This is a value that represents the reference zero of a given fixture. It corresponds to the distance in all axes between the absolute zero and the fixture zero.

G-code

G-code is a common name for the programming language that controls NC and CNC machine tools.

Home

This is the programmed reference point also known as 0,0,0 represented either as the absolute machine zero or a fixture offset zero.

Linear and circular interpolation

Is a method of constructing new data points from a discrete set of known data points. In other words, this is the way the program will calculate the cutting path of a full circle while knowing only the center point and the radius.

Machine home

This is the default position of all the axes on the machine. When executing a homing command, all the drives move toward their default positions until they reach a switch or a sensor that tells them to stop.

Nesting

Refers to the process of efficiently manufacturing parts from sheets. Using complex algorithms, nesting software determines how to lay out the parts in such a way as to maximize the use of available stock.

Offset

Refers to the distance away from the centerline measurement that comes from the CAM software.

Piggyback tools

This is the term used to refer to air activated tools that are mounted beside the main spindle.

Post processor

Software that provides some final processing to data, such as formatting it for display, printing or machining.

Program zero

This is the reference point 0,0 specified in the program. In most cases it is different than the machine zero.

Rack and pinion

A rack and pinion is a pair of gears which convert rotational motion into linear motion.

Spindle

A spindle is a high frequency motor fitted with a tool holding apparatus.

Spoilboard

Also known as the sacrificial board, it is the material used as a base for the material being cut. It can be made of many different materials, of which MDF and particleboard are most common.

Tool loading

This refers to the pressure exerted onto a tool while it is cutting through material.

Tool speed

Also called the spindle speed, this is the rotational frequency of the spindle of the machine, measured in revolutions per minute (RPM).

Tool diameter offset

This is the measured diameter of the tool. It will be used to determine the distance between the centerline of the edge of the part and the edge of the tool.

Tool length offset

This is the measurement that gives the machine the real distance between the end of the tool and the material to be cut.

Wear compensation offset

In certain cases when the diameter of the tool is bound to change while machining a part, parameters for compensation are given.

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Alain Albert is an Industry Advisor to the wood manufacturing sector for FPIInnovations – Forintek Division.

Alain started his career studying architecture at the University of Waterloo in Ontario when he developed a passion for furniture. Alain went on to start his own industrial design company where he helped countless furniture manufacturers in Quebec with their new product developments.

As an industrial designer, Alain earned many prestigious design awards and his work was published in countless design magazines. He was accepted as a Chartered Professional Member of ACID (Association of Canadian Industrial Designers), ADIQ the Quebec chapter and BCID the British Columbia Industrial Design Association.

Alain started his own furniture manufacturing plant in Montreal in 1995 and purchased his first CNC machine. After he sold his company in 1999, Alain moved on to work as a designer and a production manager for many furniture related manufacturers across the country where he was exposed to many brands and models of CNC machines.

Cover photo courtesy of Thermwood Corporation



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