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PART 1

INTRODUCTION.

CNC Machine Overview and Computer Numerical Control History

What is CNC?

CNC is the acronym for Computer Numerical Control. It is an outgrowth of the older term "NC", which stands for just "Numerical Control". It refers to the idea of controlling machine tools programmatically via computer. With the older "NC" term, a computer need not be involved. The machine might be controlled using, for example, punched tape. In the early 1970's computers were introduced to these controls, hence the name change. While people in most walks of life have never heard of this term, CNC has touched almost every form of manufacturing process in one way or another. If you'll be working in manufacturing, it's likely that you'll be dealing with CNC on a regular basis. Computer Numerical Control (CNC) machines are automated milling devices that make industrial components without direct human assistance. They use coded instructions that are sent to an internal computer, which allows factories to fabricate parts accurately and quickly. There are many different types of CNC machines, ranging from drills to plasma cutters, so they can be used to make a wide variety of parts. Though most are used industrially in manufacturing, there are also hobby versions of most of the machines that can be used in private homes. Before the advent of such automation, there was a lesser automation opportunity in the form of hydraulic tracer systems. Such systems used hydraulics to cause the cutting tools of a lathe or mill to follow a template. The taper attachments available for many manual lathes are not unlike the hydraulic tracer capability, it's just that the tracer is capable of more elaborate templates than simple tapers. But the advent of first NC and then later CNC radically increased the amount of automation that was possible.

A Short History of CNC

The first commercial NC machines were built in the 1950's, and ran from punched tape. While the concept immediately proved it could save costs, it was so different that it was very slow to catch on with manufacturers. In order to promote more rapid adoption, the US Army bought 120 NC machines and loaned them to various manufacturers so they could become more familiar with the idea. By the end of the 50's, NC was starting to catch on, though there were still a number of issues. For example, g-code, the nearly universal language of CNC we have today, did not exist. Each manufacturer was pushing its own language for defining part programs (the programs the machine tools would execute to create a part). While there are exceptions to this statement, CNC machines typically replace (or work in conjunction with) some existing manufacturing process/es. Take one of the simplest manufacturing processes, drilling holes, for example. A drill press can of course be used to machine holes. (It's likely that almost everyone has seen some form of drill press, even if you don't work in manufacturing.) A person can place a drill in the drill chuck that is secured in the spindle of the drill press. They can then (manually) select the desired speed for rotation (commonly by switching belt pulleys), and activate the spindle. Then they manually pull on the quill lever to drive the drill into the work-piece being machined. As you can easily see, there is a lot of manual intervention required to use a drill press to drill holes. A person is required to do something almost every step along the way! While this manual intervention may be acceptable for manufacturing companies if but a small number of holes or work-pieces must be machined, as quantities grow, so does the likelihood for fatigue due to the tediousness of the operation. And do note that we've used one of the simplest machining operations (drilling) for our example. There are more complicated machining operations that would require a much higher skill level (and increase the potential for mistakes resulting in scrap work-pieces) of the person running the conventional machine tool. (We commonly refer to the style of machine that CNC is replacing as the conventional machine.)By comparison, the CNC equivalent for a drill press (possibly a CNC machining center or CNC drilling & tapping center) can be *programmed* to perform this operation in a much more automatic fashion. Everything that the drill press operator was doing manually will now be done by the CNC machine, including: placing the drill in the spindle, activating the spindle, positioning the workpiece under the drill, machining the hole, and turning off the spindle.

Fig-1-1959 CNC Machine: Milwaukee-Matic-II was first machine with a tool changer.

A number of key developments brought CNC rapidly along during the 1960's:

- Standard G-Code Language for Part Programs: The origin of g-code dates back to MIT, around 1958, where it was a language used in the MIT Servomechanisms Laboratory. The Electronic Industry Alliance standardized g-code in the early 1960's.

- CAD came into its own and started rapidly replacing paper drawings and draftsmen during the 60's. By 1970, CAD was a decent sized industry with players like Intergraph and Computervision, both of whom I consulted for back in my college days.

- Minicomputers like the DEC PDP-8's and Data General Nova's became available in the 60's and made CNC machines both cheaper and more powerful.

Fig – 2.

Types of Machines

The most common CNC machines are milling machines, lathes, and grinders. Milling machines automatically cut materials, including metal, using a cutting spindle, which can move to different positions and depths as directed by the computer instructions. Lathes use automated tools that spin to shape material. They're commonly used to make very detailed cuts in symmetrical pieces, like cones and cylinders.

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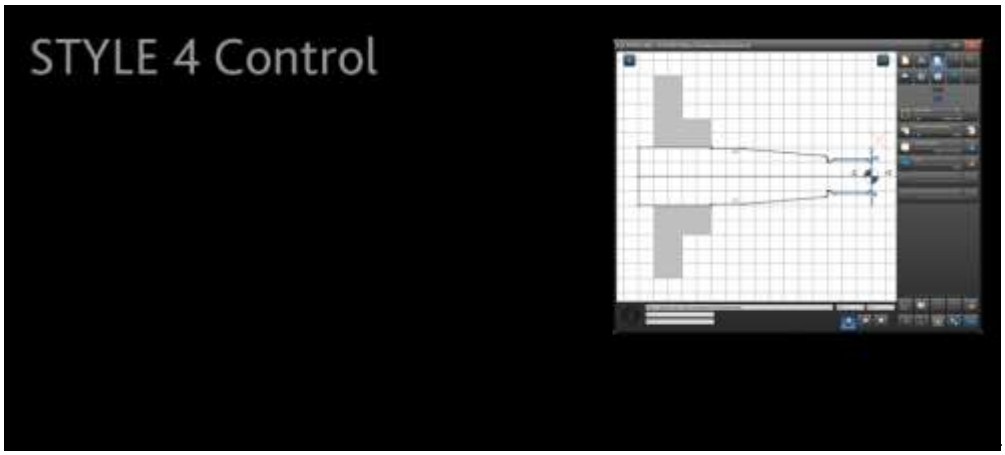

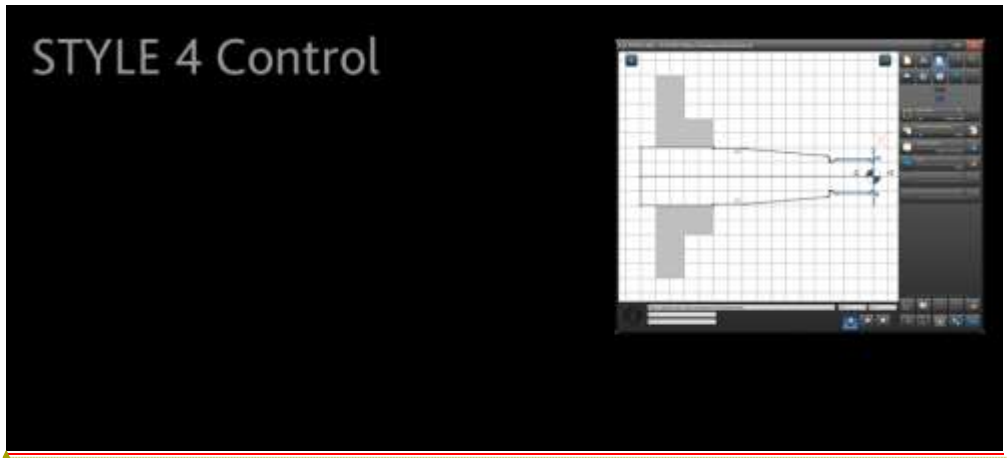

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Fig-6

Grinders use a spinningwheel to grind down materials, and mold metal or plastic into the desired shape. They're easy to program, so they're usually used for projects that do not require the same precision as mills or lathes. Besides these, there are also CNC routers, which are used to make cuts in a variety of materials; as well as computer programmable 3D printers; and turret punches, which are used to make holes in metal or plastic. This technology can also be used with different types of cutters, including those that work with water, lasers, and plasma.

Programming and Operation.

The code used to program CNC units is generally called G-Code. It contains information about where parts of the machine should be positioned, and tell the machine exactly where to place a tool. Other instructions tell the machine additional details, like the speed a part should run at; how deep it should cut, burn, or punch; and the angle of an automated tool. Must modern industrial CNC machines are tied into a network of computers, and received operating and tooling instructions via a software file.

Advantages and Disadvantages.

In an industrial setting, CNC machines can be combined into entire cells of tooling machines that can operate independently of each other. They are often driven by completely digital designs, which eliminates the need for design blueprints to be physically drawn up. Many are capable of running for several days without human intervention. In fact, some are so sophisticated that they can contact the operator’s cell phone and send an alert if a malfunction occurs. These automated features make it possible to produce thousands of parts with minimum supervision, and free the operator to perform other task. Beside this, a CNC machine can form parts with a level of precision that is nearly impossible using older tools. In a conventional factory, workers must control different tools by hand , and errors are common, but a machine can perform the same task without becoming tired, and can work non-stop. This saves allot of time, and the improved accuracy can help eliminate waste, since there are less faulty parts that has to be thrown away.

Despite their advantages, CNC machines are more expensive than older types of machines, which can made them unaffordable for smaller operations. They are also expensive to repair and maintained. Also, though they do limit the potential for errors, they don't eliminate it entirely, since operations can still program or operate the machine incorrectly. Additionally, these machines need to be operated by a skilled work-force with a specific type of trainings which may not be available in all areas.

Development.

CNC machines have evolved considerably since their initial introduction into the manufacturing industry. The earliest ones received code instructions through hard-wired controllers, which meant that the programming format could not be altered. Later models were programmed via mainframe cables and floppy disks, which permitted variations in programming. Modern ones can be operated by software files found on CDs, USB drives, or sent over a network.

What Kinds of CNC Machines Exist?

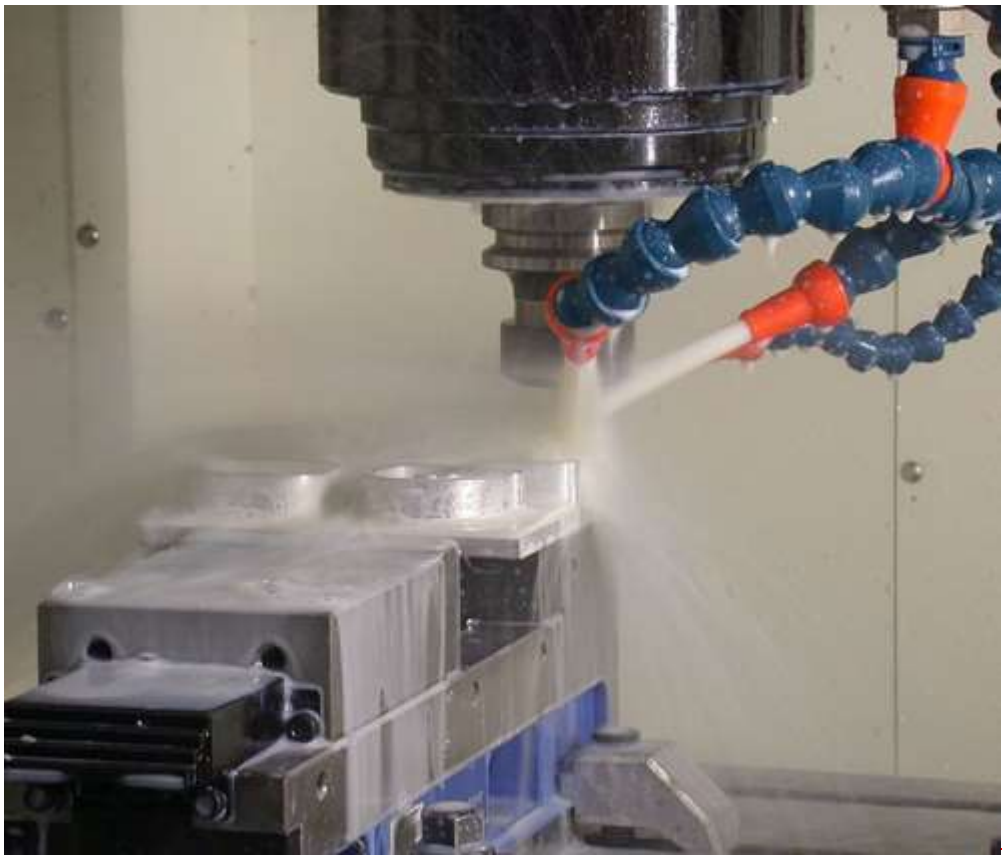
The short answer is more than we could possibly go into here, but let's try to cover some of the major categories of CNC, which are the most common.

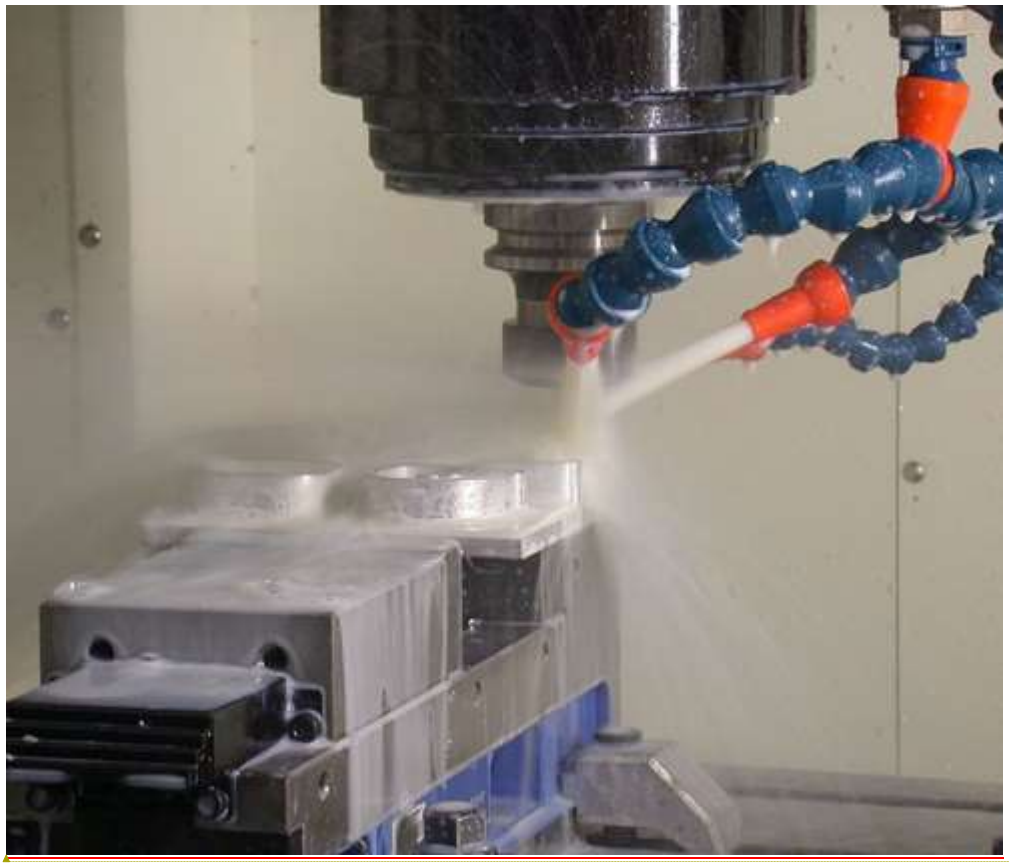
CNC Machine Lathes

Some view Lathes as the only universal machine tool because a lathe can make all of the parts needed for another lathe. A lathe spins the work-piece in a spindle while a fixed cutting tool approaches the work-piece to slice chips off of it. Because of this geometry, lathes are ideal for parts that have symmetry around some axis that could be chucked up in the spindle.CNC Lathes have at the very least the ability to drive the cutting tool under g-code control over 2 axes, referred to as X and Z. They may have a considerable amount of other functionality as well, and there are many variations on lathes such as Swiss Lathes. The act of cutting a work-piece on a lathe is called "Turning".

CNC Milling Machines

In a mill, the cutter is placed in the spindle where it rotates. The work-piece then moves past the cutter so that chips may be sliced off. The act of cutting a work-piece on a mill is called "Milling". CNC Mills have at the very least the ability to drive cut in 3 dimensions (some older machines may be limited to 2 or 2 1/2 if there are limitations on when that 3rd dimension may be used) which are referred to as the X, Y, and Z axes.





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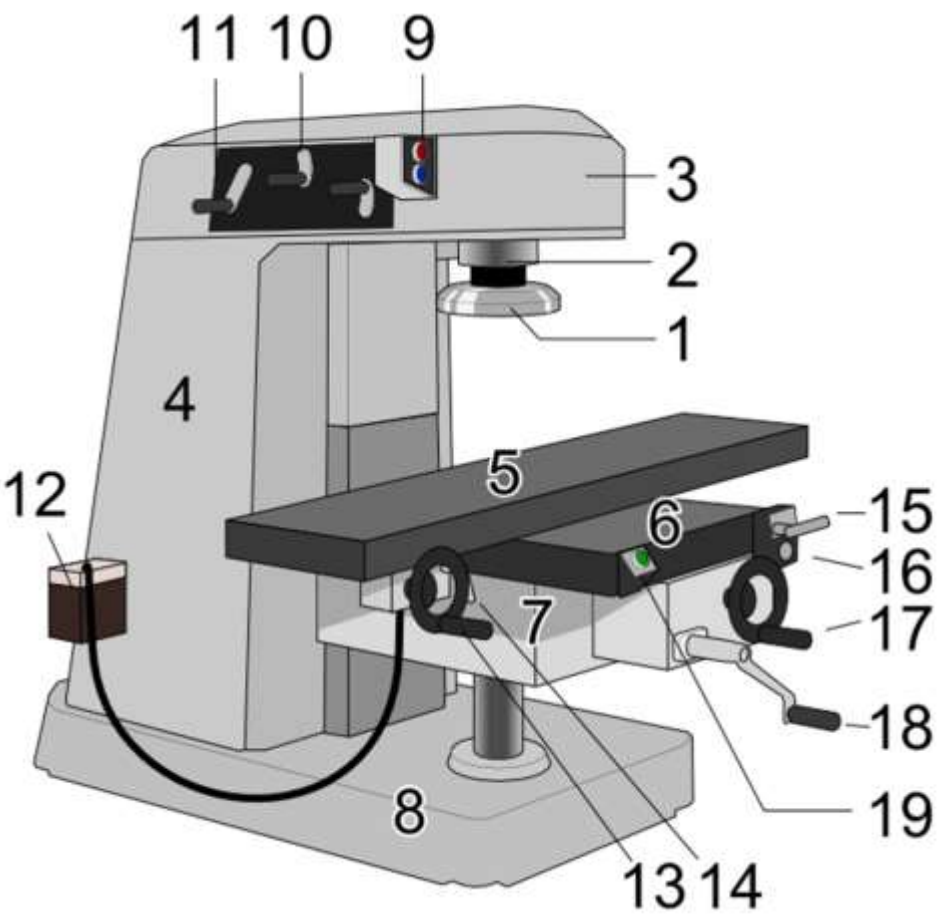
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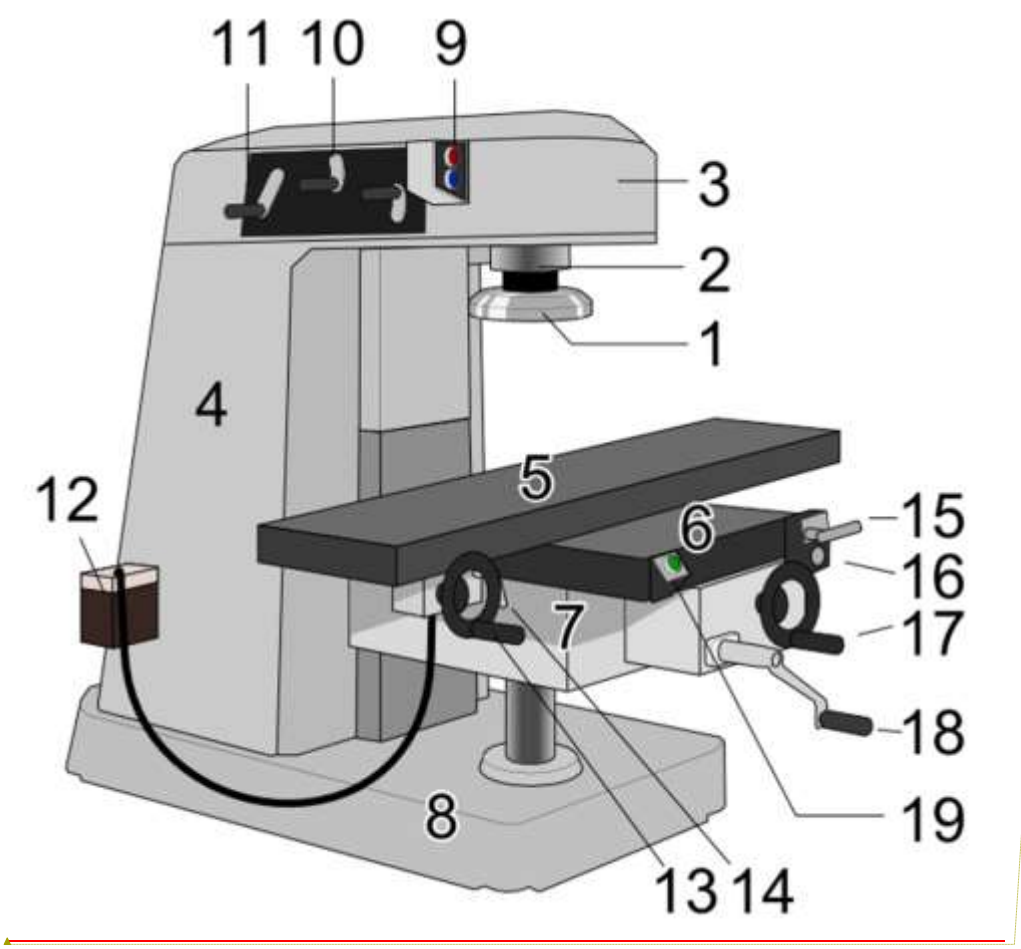

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Fig-9

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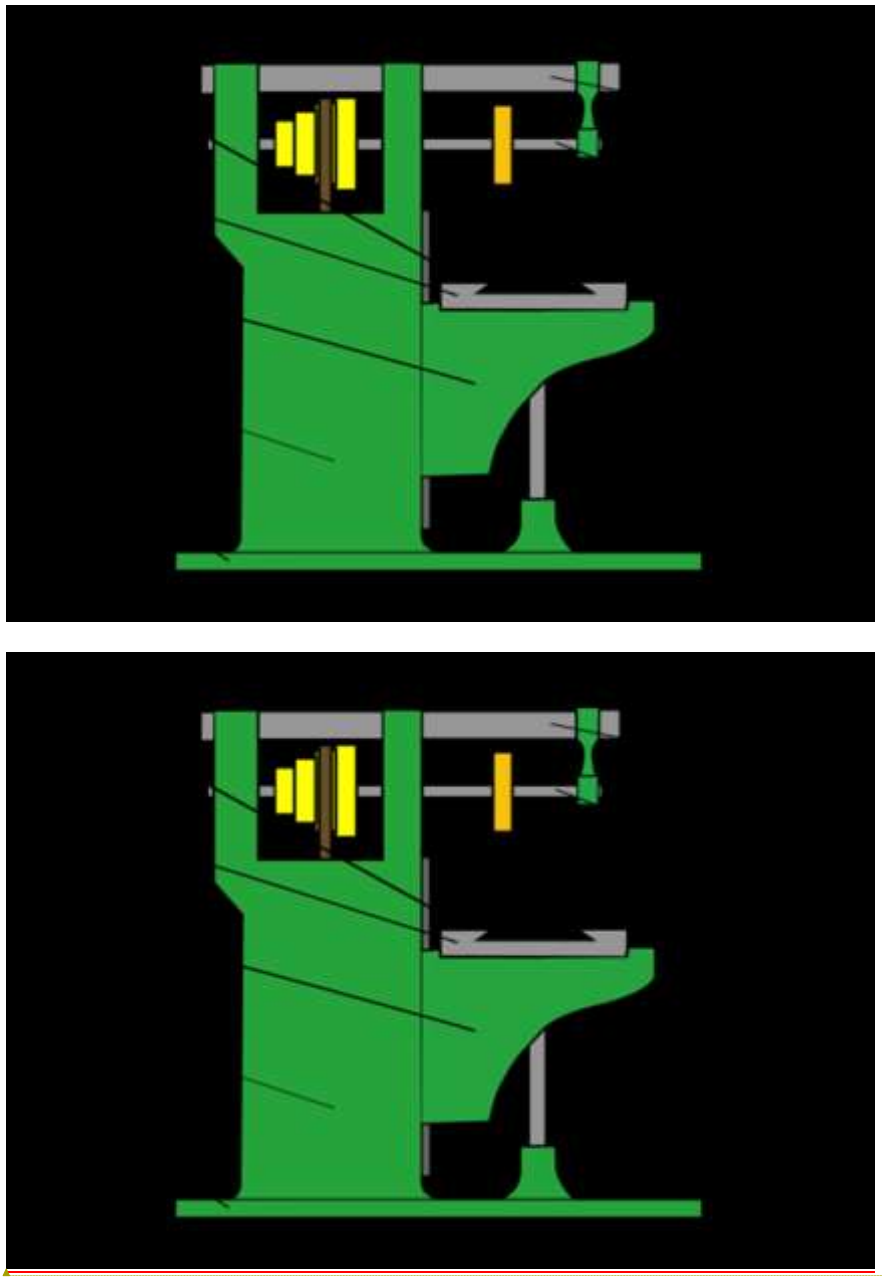

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Fig-11 STYLE BT 1500E (Mill)

CNC Routers

A CNC Router is actually a type of CNC Mill, typically one that uses what's called a "gantry" configuration. Typically they're called CNC Routers instead of CNC Gantry Mills when they're used to cut wood, but this need not exclusively be the case.Many think of CNC machines as being focused on cutting metal, but there is a huge market for CNC woodworking machines of which the CNC Router is the principle example. There are many more types of CNC machine than just these three most common types including CNC presses of various kinds and so on. New CNC technologies are appearing all the time. Who knows what the future will bring?

How CNC works

As you might already have guessed, everything that an operator would be required to do with conventional machine tools is programmable with CNC machines. Once the machine is setup and running, a CNC machine is quite simple to keeprunning. In fact CNC operators tend to get quite bored during lengthy production runs because there is so little to do. With some CNC machines, even the work-piece loading process has been automated. (We don't mean to over-simplify here. CNC operators are commonly required to do other things related to the CNC operation like measuring work-pieces and making adjustments to keep the CNC machine running good work-pieces.)Let's look at some of the specific programmable functions.

Motion control

All CNC machine types share this commonality: They all have two or more programmable directions of motion called *axes*. An axis of motion can be linear (along a straight line) or rotary (along a circular path). One of the first specifications that implies a CNC machine's complexity is how many axes it has. Generally speaking, the more axes, the more complex the machine.

The axes of any CNC machine are required for the purpose of causing the motions needed for the manufacturing process. In the drilling example, these (3) axis would position the tool over the hole to be machined (in two axes) and machine the hole (with the third axis). Axes are named with letters. Common linear axis names are X, Y, and Z. Common rotary axis names are A, B, and C.

Programmable accessories.

A CNC machine wouldn't be very helpful if all it could only move the work-piece in two or more axes. Almost all CNC machines are programmable in several other ways. The specific CNC machine type has a lot to do with its appropriate programmable accessories. Again, any required function will be programmable on full-blown CNC machine tools. Here are some examples for one machine type.

Machining centers

Automatic tool changer

Most machining centers can hold many tools in a tool magazine. When required, the required tool can be automatically placed in the spindle for machining.

Spindle speed and activation

The spindle speed (in revolutions per minute) can be easily specified and the spindle can be turned on in a forward or reverse direction. It can also, of course, be turned off.

Coolant

Many machining operations require coolant for lubrication and cooling purposes. Coolant can be turned on and off from within the machine cycle.

The CNC program

Think of giving any series of step-by-step instructions. A CNC program is nothing more than another kind of instruction set. It's written in sentence-like format and the control will execute it in sequential order, step by step.A special series of CNC *words* are used to communicate what the machine is intended to do. CNC words begin with letter addresses (like F for feed-rate, S for spindle speed, and X, Y & Z for axis motion). When placed together in a logical method, a group of CNC words make up a commandthat resemble a sentence. For any given CNC machine type, there will only be about 40-50 words used on a regular basis. So if you compare learning to write CNC programs to learning a foreign language having only 50 words, it shouldn't seem overly difficult to learn CNC programming.

The CNC control

The CNC control will interpret a CNC program and activate the series of commands in sequential order. As it reads the program, the CNC control will activate the appropriate machine functions, cause axis motion, and in general, follow the instructions given in the program. Along with interpreting the CNC program, the CNC control has several other purposes. All current model CNC controls allow programs to be modified (edited) if mistakes are found. The CNC control allows special verification functions (like dry run) to confirm the correctness of the CNC program. The CNC control allows certain important operator inputs to be specified separate from the program, like tool length values. In general, the CNC control allows all functions of the machine to be manipulated.

What is a CAM system?

For simple applications (like drilling holes), the CNC program can be developed manually. That is, a programmer will sit down to write the program armed only with pencil, paper, and calculator. Again, for simple applications, this may be the very best way to develop CNC programs. As applications get more complicated, and especially when new programs are required on a regular basis, writing programs manually becomes much more difficult. To simplify the programming process, a computer aided manufacturing (CAM) system can be used. A CAM system is a software program that runs on a computer (commonly a PC) that helps the CNC programmer with the programming process. Generally speaking, a CAM system will take the tediousness and drudgery out of programming. In many companies the CAM system will work with the computer aided design (CAD) drawing developed by the company's design engineering department. This eliminates the need for redefining the work-

piece configuration to the CAM system. The CNC programmer will simply specify the machining operations to be performed and the CAM system will create the CNC program (much like the manual programmer would have written) automatically.

What is a DNC system?

Once the program is developed (either manually or with a CAM system), it must be loaded into the CNC control. Though the setup person could type the program right into the control, this would be like using the CNC machine as a very expensive typewriter. If the CNC program is developed with the help of a CAM system, then it is already in the form of a text file. If the program is written manually, it can be typed into any computer using a common word processor (though most companies use a special CNC text editor for this purpose). Either way, the program is in the form of a text file that can be transferred right into the CNC machine. A distributive numerical control (DNC) system is used for this purpose. A DNC system is nothing more than a computer that is networked with one or more CNC machines. Until only recently, rather crude serial communications protocol (RS-232c) had to be used for transferring programs. Newer controls have more current communications capabilities and can be networked in more conventional ways (Ethernet, etc.). Regardless of methods, the CNC program must of course be loaded into the CNC machine before it can be run.

Types of CNC machines

As stated, CNC has touched almost every facet of manufacturing. Many machining processes have been improved and enhanced through the use of CNC. Let's look at some of the specific fields and place the emphasis on the manufacturing processes enhanced by CNC machine usage.

In the metal removal industry:

Machining processes that have traditionally been done on conventional machine tools that are possible (and in some cases improved) with CNCmachining centers include all kinds of milling (face milling, contour milling, slot milling, etc.), drilling, tapping, reaming, boring, and counter boring. In similar fashion, all kinds of turning operations like facing, boring, turning, grooving, knurling, and threading are done on CNC turning centers. There are all kinds of special "off-shoots" of these two machine types including CNC milling machines, CNC drill and tap centers, and CNC lathes.

Grinding operations of all kinds like outside diameter (OD) grinding and internal diameter (ID) grinding are also being done onCNC grinders. CNC has even opened up a new technology when it comes to grinding. Contour grinding (grinding a contour in a similar fashion to turning), which was previously infeasible due to technology constraints is now possible (almost commonplace) with CNC grinders.

In the metal fabrication industry:

In manufacturing terms, fabrication commonly refers to operations that are performed on relatively thin plates. Think of a metal filing cabinet. All of the primary components are made of steel sheets. These sheets are sheared to size, holes are punched in appropriate places, and the sheets are bent (formed) to their final shapes. Again, operations commonly described as

fabrication operations include shearing, flame or plasma cutting, punching, laser cutting, forming, and welding. Truly, CNC is heavily involved in almost every facet of fabrication.CNC back gages are commonly used with shearing machines to control the length of the plate being sheared. CNC lasers and CNC plasma cutters are also used to bring plates to their final shapes. CNC turret punch presses can hold a variety of punch-and-die combinations and punch holes in all shapes and sizes through plates. CNC press brakes are used to bend the plates into their final shapes.

In the electrical discharge machining industry:

Electrical discharge machining (EDM) is the process of removing metal through the use of electrical sparks which burn away the metal. CNC EDM comes in two forms, vertical EDM and Wire EDM. Vertical EDM requires the use of an electrode (commonly machined on a CNC machining center) that is of the shape of the cavity to be machined into the work-piece. Picture the shape of a plastic bottle that must be machined into a mould. Wire EDM is commonly used to make punch and die combinations for dies sets used in the fabrication industry. EDM is one of the lesser known CNC operations because it is so closely related to making tooling used with other manufacturing processes.

In the woodworking industry

As in the metal removal industry, CNC machines are heavily used in woodworking shops. Operations include routing (similar to milling) and drilling. Many woodworking machining centers are available that can hold several tools and perform several operations on the work-piece being machined.

Other types of CNC machines

Many forms of lettering and engraving systems use CNC technology. Waterjet machining uses a high pressure water jet stream to cut through plates of material. CNC is even used in the manufacturing of many electrical components. For example, there are CNC coil winders, and CNC terminal location and soldering machines.

Job opportunities related to CNC

There is quite a shortage of skilled people to utilize CNC machines. And the shortage is growing. Everywhere I go I hear manufacturing people claiming that they cannot find skilled people. Unfortunately, it has also been my experience that pay scales have not yet reflected this shortage. Even so, you can make a good wage and develop a rewarding career working with CNC machines. Here are some of the job titles of people working with CNC machine tools.