Describe components that control machining.

The Distinguish between the two types of CNC machining centers.

Depth of cut Identify components of a standard toolholder used on the machining center.

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Basics of the CNC Machining Center 130

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Class Outline

Objectives
What Is the Mill?
From Mill to Machining Center
Types of CNC Machining Centers
Basic Setup of the Machining Center
Control Devices of the Machining Center
How the Machining Center Cuts
Cutting Variables
Milling Cutters for the Machining Center
Milling Operations
Hole-Making Operations
Cutting Tool Materials
Toolholders for the Machining Center
Toolchangers for the Machining Center
Workholding for the Machining Center
Summary
Lesson: 1/16

Objectives
- Describe the mill.
- Describe common mills.
- Distinguish between the two types of CNC machining centers.
- Identify components of the CNC machining center.
- Describe components that control machining.
- Explain how the machining center cuts parts.
- Identify the variables that impact cutting.
- Describe common milling cutters.
- Describe common milling operations.
- Describe hole-making capabilities of the machining center.
- Describe cutting tool materials for the machining center.
- Identify components of a standard toolholder used on the machining center.
- Describe the purpose of a toolchanger on the machining center.
- Identify workholders used on the machining center.

Figure 1. The most sophisticated milling machines today are CNC machining centers.

Figure 2. Milling can create a pocket, an internal recess that is “carved” into the workpiece.

Figure 3. Toolchangers store numerous cutting tools in pots, and rotate to provide access for the exchange of cutting tools.
What Is the Mill?

Practically every modern machine shop relies on the milling machine. If an operator is machining a flat surface of a workpiece, the operator is most likely using a variation of this machine. The milling machine is generally used to produce flat or curved surfaces. Figure 1 shows a part with flat surfaces made by a milling machine. A workpiece is held firmly in place while a multi-point tool passes over the surface of the workpiece to remove a layer of material. This cutting device is called a mill. However, the term “mill” is often used for both the cutting tool and the machine. Figure 2 shows the multiple cutting edges of a mill.

Lesson: 2/16

![Figure 1. The milling machine is generally used to produce flat or curved surfaces.](image1)

![Figure 2. A mill has multiple cutting edges.](image2)
Lesson: 3/16

From Mill to Machining Center
The basic type of milling machine is the column-and-knee milling machine. The workpiece rests on a horizontal worktable that is supported by the knee, and the cutting tool is held vertically above the workpiece by the column. Figure 1 shows the basic setup for the column-and-knee mill.

On some machines, the mill cutter is positioned horizontally. In this case, an arbor is used to hold the mill above the workpiece. Figure 2 illustrates this horizontal setup.

Some milling machines are small enough to fit on a table. Others are large enough to fill a room. However, the most sophisticated milling machines today are CNC machining centers, as shown in Figure 3. You may also hear these machines called milling centers or CNC mills. These machines use computers that control the movement of the tools and the workpiece. A single machine can perform multiple cutting operations, one after another, without requiring the unloading of the part.

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From Mill to Machining Center

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Lesson: Basic Setup of the Machining Center

The area of a milling machine that is used to machine holes is called the workpiece. The workpiece is held firmly in place while a milling machine cuts the surface. Instead, one cutting edge performs a cut at a time in rapid sequence. This is called peripheral milling. The long, narrow portion of a toolholder that is typically shaped like a cone is the shank. The shank is positioned into the spindle of the machine by a retention knob. A pocket, like the one in Figure 3, is an internal recess that is normally used to machine flat surfaces parallel to the table. A customized device that is used to position and hold a workpiece in place is called a fixture. On a mill, fixtures are normally used to machine flat surfaces parallel to the table. A customized device that is used to position and hold a workpiece in place is called a fixture. On a mill, fixtures are normally used to machine flat surfaces parallel to the table.

Lesson: Control Devices of the Machining Center

A small, powerful computer that controls and operates a CNC machine is called the machine control unit (MCU) that is built into the machine. The computer controls the operation of the machine by interpreting the part program and processing the instructions. The part program describes how fast the cutting edge of the tool moves past the workpiece surface at both the feed and the speed. The rate that the cutting tool travels along the surface of the workpiece is called the feed. Speed is defined as the distance the tool moves past the surface per minute. A pocket, like the one in Figure 3, is an internal recess that is normally used to machine flat surfaces parallel to the table.

Lesson: Toolchangers for the Machining Center

A part that is being machined requires numerous tools. However, a part had to go through a whole series of cutting operations from start to finish. The Machining Center is a sophisticated CNC machine that can perform multiple machining operations in the same setup with the same tool.

Toolchangers are capable of holding tools in different locations and remembering their locations. When a new cutting tool is needed, the toolchanger removes the current cutting tool and loads a new one. The operator loads the assembled pair into the toolchanger. Figure 2 shows the spindle. The spindle is the rotating device that is positioned above the workpiece. Without the modern mill, some parts of today's CNC machines would be unachievable. In the past, a piece of equipment called a milling machine was used to machine flat surfaces made by a milling machine. A workpiece is held firmly in place while a milling machine removes material from the surface of a workpiece. One of the various cutting tools of the machine is called a toolholder. A toolholder rotates rapidly during machining operations as well. A toolholder rotates rapidly during machining. The toolholder is a long, narrow portion of a toolholder that is typically shaped like a cone. The long, narrow portion of a toolholder that is typically shaped like a cone is the retention knob. Figure 2 shows the spindle.

Lesson: Cutting Tool Materials

Face milling removes material from flat surfaces made by a milling machine. A workpiece is held firmly in place while a milling machine removes material from the surface of a workpiece. A machining center uses to machine holes into the part. Figure 2 shows a collection of these tools. A machining center is a sophisticated CNC machine that can perform multiple machining operations in the same setup with the same tool. The long, narrow portion of a toolholder that is typically shaped like a cone is the shank. The shank is positioned into the spindle of the machine by a retention knob. A pocket, like the one in Figure 3, is an internal recess that is normally used to machine flat surfaces parallel to the table. A customized device that is used to position and hold a workpiece in place is called a fixture. On a mill, fixtures are normally used to machine flat surfaces parallel to the table.

Lesson: Cutting Variables

In milling, the cutting tool is positioned so that the bottom of the tool (vertical) or the side of the tool (horizontal) removes material. This is called a vertical or a horizontal spindle. Milling machines today are CNC machining centers. Machining centers may have a vertical spindle or a horizontal spindle. A horizontal machining center uses to machine holes into the part. Figure 2 shows a collection of these tools. A machining center is a sophisticated CNC machine that can perform multiple machining operations in the same setup with the same tool.

Lesson: Types of CNC Machining Centers

A part that is being machined requires numerous tools. However, a part had to go through a whole series of cutting operations from start to finish. The Machining Center is a sophisticated CNC machine that can perform multiple machining operations in the same setup with the same tool.

From Mill to Machining Center

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Lesson: Toolchangers for the Machining Center

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Lesson: Types of CNC Machining Centers

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From Mill to Machining Center

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Lesson: 4/16

Types of CNC Machining Centers
There are numerous types of CNC machining centers. However, machining centers fall into these two general categories. The key distinguishing factor between these machines is the position of the spindle:

- The **vertical machining center** (Figure 1) has a spindle that is positioned above the workpiece.
- The **horizontal machining center** (Figure 2) has a spindle that is positioned to the side and is parallel to the floor.

The spindle is important because it is the device that holds the cutting tool. The spindle rotates at a high speed, and the cutting tool is passed along the surface of the workpiece as it spins. Sophisticated CNC machines can adjust the angle of the spindle or worktable to perform both vertical and horizontal milling operations.
Lesson: 5/16

Basic Setup of the Machining Center
In order to understand the functions and features of machining centers, it helps to learn the setup of the major components, which are labeled in Figure 1:

- The **column** is the vertical support for the spindle.
- The **spindle** is the rotating device that holds the various cutting tools retrieved from the toolchanger. Figure 2 shows the spindle.
- The **toolchanger** stores an assortment of cutting tools.
- The **worktable** is the moveable table that supports the workpiece below the spindle.

These are the components of the machining center that are most visible. Other parts and components are hidden by protective guards and shielding. Keep in mind that these components will be positioned differently on a horizontal machining center. Collectively, the various parts of the mill work together to guide the movement of the tool and workpiece in many directions.

Figure 1. The major parts of a vertical machining center. (Courtesy of Cincinnati Machine.)

Figure 2. The spindle is the rotating device that holds the various cutting tools retrieved from the toolchanger.
Control Devices of the Machining Center

The components of manual mills are actually guided by hand using handwheels. Nowadays, CNC machining centers use special controls and motors that accurately guide and position the parts of the machine:

- The **spindle** holds one of the various cutting tools of the machine and rotates rapidly during machining operations.
- A **ballscrew** is a long, accurately threaded bar that guides the motion of the worktable or the spindle.
- **Servomotors** power the rotation of the ballscrew to move the various parts of the machine.

The servomotors and ballscrews, which are shown in Figures 1 and 2, work "behind the scenes" to carefully control the movement of the worktable and spindle. These sensitive components are protected from the metal chips created during cutting operations.

![Figure 1. Two of the servos and ballscrews. (Courtesy of Cincinnati Machine.)](image1)

![Figure 2. Servomotors power the rotation of the ballscrew to move the various machine components.](image2)
Lesson: 7/16

How the Machining Center Cuts

On CNC machining centers, the cutting tool and the worktable movements originate with a special computer called the machine control unit (MCU) that is built into the machine. The computer “reads” a program, and sends electronic signals to the servomotors, like the one in Figure 1. These servomotors spin the ballscrews, and the ballscrews move the various parts. A ballscrew is shown in Figure 2. As the components of the machine move, the cutting tool is passed along the surface of the workpiece.

CNC machining centers vary in the setup of their components. Depending on the machine, either the cutting tool or the worktable will move along the vertical and horizontal direction. Or, the cutting tool may move vertically, and the worktable may move horizontally. Either way, the purpose of these movements is to pass the cutting tool along the workpiece surface.

Figure 1. After the computer “reads” a program, it sends electronic signals to the servomotors, which in turn rotate the ballscrews.

Figure 2. The plastic model of a ballscrew next to the actual components. (Courtesy of Wedin International, Inc.)
Lesson: 8/16

Cutting Variables
The cutting operations performed on the machining center differ with each type of workpiece. Depending on the size and material of the workpiece, different settings for the cutting variables will be necessary. Figure 1 illustrates these cutting variables:

- **Speed** describes how fast the cutting edge of the tool moves past the workpiece surface at the point of contact.
- **Feed** determines how quickly the entire cutting tool moves along the surface of the workpiece.
- **Depth of cut** indicates the amount of material that is removed with one pass of the cutting tool.

These three variables determine the rate of material removal. One of the advantages of the CNC machining center is that these cutting variables are carefully controlled. Effective management of these cutting variables prolongs the life of the cutting tool and removes material in the most efficient manner.

Figure 1. Cutting variables for milling include speed, feed, and depth of cut.
Lesson: 9/16

Milling Cutters for the Machining Center
Two general types of cutting tools are used to perform milling operations on the machining center. The face mill is a flat mill with cutting teeth surrounding the tool. The end mill is a thinner and taller mill with cutting edges winding up the sides of the tool. Both cutters are cylindrical in shape, but the face mill is flat and wide, and the end mill is thinner and taller. Figures 1 and 2 compare these two mills.

Both of these cutting tools are effective during milling operations. However, one advantage of the face mill is that the larger bottom surface removes material from the workpiece at a faster rate. The entire top layer of a workpiece can be removed with a face mill. With an end mill, both the bottom and side edges of the mill are used to remove material. This makes the end mill capable of performing a greater number of milling operations.

Figure 1. The face mill is a flat mill with cutting teeth surrounding the tool.

Figure 2. The end mill is a thinner and taller mill with cutting edges winding up the sides of the tool.
Milling Operations

Milling operations can generally be divided into these two broad categories: face milling and peripheral milling. As shown in Figures 1 and 2, face milling removes material from the top surface of the workpiece using the bottom of the tool. Peripheral milling removes material using the side of the tool. Due to their versatility, milling operations are sometimes hard to categorize in only one of these two broad categories. The milling cutters may be positioned either parallel or perpendicular to the workpiece.

Machining centers are used to create a wide variety of shapes. Face mills and end mills can be used to create a narrow channel called a slot in the workpiece. CNC machines will also use an end mill to create pockets and contours. A pocket, like the one in Figure 3, is an internal recess that is machined into the workpiece. A contour, shown in Figure 4, is any curved shape that is machined into the workpiece.

Figure 1. Face milling removes material from the top surface of the workpiece using the bottom of the tool.

Figure 2. Peripheral milling removes material using the side of the tool.
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**lesson:**

**Cutting Variables**

The cutting operations performed on the machining center differ with each type of workpiece. These three variables determine the rate of material removal. One of the advantages of the CNC machine is its ability to control these variables with great precision. The variables that impact cutting are:

- Speed
- Feed
- Depth of cut

**Worktable**

The part of a machine tool that supports the workpiece and any workholding devices.

**Tapered Shank**

A tapered shank for easy fitting into the spindle.

**Workholder**

A knob screwed into the end of the toolholder that locks the tool in place within the spindle.

**Toolchangers**

Stores numerous cutting tools which are available in all sorts of shapes and sizes. In order to be loaded into the toolchanger, a cutting tool may move vertically, and the worktable may move horizontally. Either way, the purpose of these movements is to pass the cutting tool along the workpiece surface.

**Toolholder**

A basic type of milling machine whose spindle is mounted in the column, and whose worktable rests perpendicular to the floor.

**Pocket**

Milling can create a pocket, an internal recess that is machined into the workpiece.

**Knee Milling Machine**

A machine that uses a multi-motion of the saddle.

**Multi-Motion Saddle**

The process of using a cutting tool with straight cutting edges to enlarge or smooth holes that have been bored or drilled.

**Face Mill**

A flat mill with cutting edges along the entire top layer of a workpiece. CNC machines will also use an end mill to remove material. This makes the end mill capable of performing operations. When a new cutting tool is needed, the toolchanger removes the current cutting tool and rotates to provide access for the exchange of cutting tools, as shown in Figure 1. Each pot has a tapered shank for easy fitting into the spindle. Each toolholder has a tapered shank for easy fitting into the spindle.

**End Mill**

A cutting bit made of hard material that has multiple cutting edges. Once a cutting edge is interrupted, it might require separate machines to cut a flat surface. Milling Operations

Milling can create a contour, a curved shape that is machined into the workpiece.

**Knee**

The vertical support for the spindle.

**Column**

Is the vertical support for the spindle.

**Control Devices of the Machining Center**

These are the components of the machining center that are most visible. Other parts and features of the machine that are not so visible are the machine control unit and the ballscrew to move the various machine axes.

**Vertical Machining Center**

The vertical machining center has a column and a horizontal machining center.

**Horizontal Machining Center**

The plastic model of a ballscrew next to a toolholder that supply the cutting edges.

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Hole-Making Operations
The original milling machines were primarily built to machine flat surfaces. More often than not, however, a part had to go through a whole series of cutting operations from start to finish. The part in Figure 1 might have required separate machines to cut the flat edge and drill the holes.

Machining centers are very valuable because they can create holes in parts as well as machine surfaces. This versatility saves time because the operator does not have to unload the part and move it to a different machine.

In addition to milling cutters, a machining center will also contain a variety of cutting tools that it uses to machine holes into the part. Figure 2 shows a collection of these tools. A machining center is capable of drilling, boring, reaming, and tapping holes in the workpiece.

Figure 1. Without the modern mill, some parts might require separate machines to cut a flat edge and drill holes.

Figure 2. A machining center contains a variety of cutting tools that are used to machine holes into parts.
Lesson: 12/16

Cutting Tool Materials
Mills are multi-point tools. During the milling process, the teeth are not in constant contact with the workpiece surface. Instead, one cutting edge performs a cut at a time in rapid sequence. This is called interrupted cutting.

Milling operations cause wear and tear on the cutting tools. Consequently, these tools are made of hard, tough materials that resist the harsh cutting forces. Some end mills are made out of high-speed steel. These mills are made in one solid piece, and the entire tool must be either sharpened or replaced after it wears out. Figure 1 shows end mills made out of high-speed steel.

Both face and end mills may contain numerous carbide inserts that supply the cutting edges. Once a cutting edge wears out, the insert can be indexed to a fresh cutting edge. Figure 2 shows carbide inserts used in a face mill, and Figure 3 shows a closeup view of a single indexable insert. Solid carbide end mills are also available, though they are more expensive than solid high-speed steel mills.

Figure 1. Solid end mills are made of high-speed steel.

Figure 2. Some face mills contain carbide inserts.

Figure 3. Once a cutting edge wears out, the carbide insert can be indexed to a fresh cutting edge.
Toolholders for the Machining Center

Cutting tools such as face mills, end mills, drills, reamers, and taps for the CNC machining center are available in all sorts of shapes and sizes. In order to be loaded into the toolchanger, a cutting tool must be fitted into a toolholder. Figure 1 shows numerous tools loaded in the toolchanger, and Figure 2 illustrates the parts of a toolholder. The tool is inserted into the toolholder before the operator loads the assembled pair into the toolchanger.

Toolholders are available in standard shapes and sizes. Figure 3 shows a typical toolholder with a tapered shank for easy fitting into the spindle. Each toolholder has a flange surrounding the toolholder so that the toolchanger arm can grab the tool. A retention knob screws into the end of the toolholder. This knob fits into the spindle and locks the toolholder in place.

Figure 1. Toolchangers are capable of holding numerous tools.

Figure 2. Before it is loaded into the toolchanger, a cutting tool must be fitted into a standard toolholder.

Figure 3. The typical toolholder has a tapered shank for easy fitting into the spindle.
Lesson: 14/16

Toolchangers for the Machining Center
Because so many different operations can be performed on these machines, a variety of cutting tools are required for each operation. Toolchangers store these numerous cutting tools in pots and rotate to provide access for the exchange of cutting tools, as shown in Figure 1. Each pot has a specific number that tells the machining center where each tool is located. Sophisticated machining centers can place tools in different pots and remember the location of a specific tool as it moves from one pot to the next.

As the CNC machine runs through a part program, it performs a sequence of different cutting operations. When a new cutting tool is needed, the toolchanger removes the current cutting tool and replaces it with another tool between operations. Some toolchangers can hold up to eighty different cutting tools. Figure 1 shows numerous tools positioned in the toolchanger.

Figure 1. Toolchangers store numerous cutting tools in pots and rotate to provide access for the exchange of cutting tools.
**Lesson: 15/16**

**Workholding for the Machining Center**
During cutting operations, a **workholder** keeps the workpiece held firmly in place. **Vises** and **fixtures** are the most common devices used to hold the workpiece in place on the worktable. Figure 1 shows a workpiece that is clamped with a vise.

The most appropriate workholding device depends upon the complexity of the workpiece. A simple workpiece in the shape of a rectangular part can be held in a vise. However, as the various dimensions of the workpiece increase in complexity, a fixture may be required to hold the workpiece firmly in place. Figure 2 shows a workpiece held in a fixture.

Sophisticated CNC machining centers may be equipped with multiple **pallets**. As you can see in Figure 3, these pallets move in and out of the machining area. The advantage is that an operator can prepare a part in its workholding device while another part is being machined.

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*Figure 1. A simple workpiece in the shape of a rectangular part can be held in a vise.*

*Figure 2. As the various dimensions of the workpiece increase in complexity, a fixture may be required to hold the workpiece firmly in place.*

*Figure 3. This horizontal machining center uses two pallets. (Courtesy of Cincinnati Machine.)*
Lesson: 16/16

Summary
The milling machine is generally used to produce flat or curved surfaces. The most sophisticated milling machines today are CNC machining centers. Machining centers may have a vertical spindle or a horizontal spindle.

In the machining center, the table or spindle may move. The purpose of these movements is to pass the cutting tool along the workpiece surface. Milling may take place on the top, or face, of the part as well as the side, or periphery. The versatility of machining centers allows them to perform several hole-making operations as well.

The two major tools used to mill include the face mill and the end mill. Tools are generally either solid high-speed steel or a number of carbide inserts. The tools that include mills, drills, and others sit ready to go in the toolchanger. The flange of the toolholder makes tool exchange from the toolchanger possible. The spindle grabs the toolholder and secures it. On the worktable below, parts may be held in vises or fixtures while being machined.

Figure 1. The vertical machining center has a spindle that is positioned above the workpiece.

Figure 2. Face milling removes material from the top surface of the workpiece using the bottom of the tool.
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Lesson: About Milling

Milling is a subtractive manufacturing process, which is used to create complex shapes with multi-fluted tools. The most common types of milling machines are knee mills and horizontal machining centers. The milling process is well suited to creating flat surfaces, contours, pockets, and holes. Figure 1 shows a knee milling machine, and Figure 2 shows a horizontal machining center.

From Mill to Machining Center

Horizontal machining centers are part of a family of machines known as machining centers. These machines are designed to perform multiple cutting operations on a part simultaneously. They differ from a horizontal mill in that they are smaller in size, have a more limited number of axes, and perform single-axis cylindrical operations such as drilling and reaming. Horizontal machining centers are capable of performing three-dimensional work, however, they must be rotated on a three-axis fixture. Figure 3 shows a horizontal machining center, and Figure 4 shows a machining center pallet system.

Milling Operations

The process of using a single point tool to remove metal from the surface of a workpiece. This process makes operations as well.

Figure 3. The typical toolholder has a tapered shank for easy fitting into the spindle.
Description of Components that Control Machining

**Arbor**
A device used on a conventional milling machine to mount a mill horizontally.

**Ballscrew**
The threaded device that controls the precise movement of the various components of the mill.

**Boring**
The process of using a single-point tool to enlarge a preexisting hole.

**Carbide Insert**
A cutting bit made of hard material that has multiple cutting edges. Once a cutting edge is excessively worn, it can be indexed to another edge, or the insert can be replaced.

**CNC Machining Center**
A sophisticated CNC machine that can perform multiple machining operations in the same setup with a variety of tools.

**Column**
The vertical support, or backbone, of a milling machine.

**Column-And-Knee Milling Machine**
A basic type of milling machine whose spindle is mounted in the column, and whose worktable rests on an adjustable knee.

**Contour**
A curved surface or dimension that is cut into a workpiece.

**Depth Of Cut**
The thickness of material removed by one pass of the cutting tool.

**Drilling**
The process of using a multi-point tool to penetrate the surface of a workpiece and make a round hole.

**End Mill**
A thin, tall mill cutter with cutting edges that wind up the sides. Both the bottom and side of the end mill are used during milling operations. End mills resemble drills.

**Face Mill**
A flat mill cutter with multiple cutting teeth surrounding the tool. The bottom of the face mill is primarily used during milling operations.

**Face Milling**
A milling operation in which the surface of the workpiece is perpendicular to the spindle axis.

**Feed**
The rate that the cutting tool travels along the surface of the workpiece.

**Fixture**
A customized device that is used to position and hold a workpiece in place. On a mill, fixtures are normally used to machine flat surfaces parallel to the table.

**Flange**
A ring or collar surrounding the toolholder that allows the tool to be grasped by the toolchanger.

**High-Speed Steel**
A tool steel used to machine metals at high cutting speeds. High-speed steel stays hard at high temperatures and resists abrasion.

**Horizontal Machining Center**
A machining center with a spindle that is parallel to the ground floor.

**Indexed**
To rotate a carbide insert to present a new cutting edge.

**Interrupted Cutting**
A cutting process in which the cutting edge of the tool is not in constant contact with the surface of the workpiece.

**Knee**
The device supported by the elevating screw that raises and lowers and guides the back and forth motion of the saddle.

**Machine Control Unit**
A small, powerful computer that controls and operates a CNC machine.

**Mill**
A multi-point tool that is used to remove metal from the surface of a workpiece.

**Milling Machine**
A machine that uses a multi-point tool to remove metal from the surface of a workpiece.
Describe components that control machining.

**Servomotors**
An automatic moveable table that supports a workpiece and slides or pivots into and out of the machining center. Multiple pallets allow an operator to set up a part while another is being machined.

**Part Program**
A series of numerical instructions used by a CNC machine to perform the necessary sequence of operations to machine a specific workpiece.

**Peripheral Milling**
A milling operation in which the cutting edge of the mill is parallel to the axis of spindle rotation.

**Pocket**
An interior recess that is cut into the surface of a workpiece.

**Pot**
One of the numerous slots of the toolchanger that holds a cutting tool in its toolholder.

**Reaming**
The process of using a cutting tool with straight cutting edges to enlarge or smooth holes that have been previously drilled.

**Retention Knob**
An knob screwed into the end of the toolholder that locks the tool in place within the spindle.

**Servomotor**
A special motor used in CNC machines that turns the ballscrew to move parts with precision.

**Slot**
A narrow channel cut into the surface of a workpiece.

**Speed**
The rate at which the cutting edge of the tool moves past the workpiece surface at the point of contact. On a mill, speed determines how fast the spindle rotates.

**Spindle**
The rotating device that holds and spins the toolholder and cutting tool on the mill.

**Tapered Shank**
The long, narrow portion of a toolholder that is typically shaped like a cone.

**Tapping**
The process of cutting internal threads in a workpiece with a multi-point tool.

**Toolchanger**
A device that arranges multiple cutting tools in order and then positions these cutting tools for replacement in the machining center.

**Toolholder**
The device used to rigidly hold a cutting tool in place. Toolholders are available in standardized sizes.

**Vertical Machining Center**
A machining center with a spindle that is perpendicular to the ground floor.

**Vise**
A workholding device with two jaws that grip and hold a workpiece in place.

**Workholder**
A device used to position and hold a workpiece in place.

**Workpiece**
A part that is being machined.

**Worktable**
The part of a machine tool that supports the workpiece and any workholding devices.