

## Training Objectives

After watching the video and reviewing this printed material, the viewer will gain knowledge and understanding of basic milling theories and procedures. In addition, the viewer will become aware of the use of NC technology and the features and functions of the CNC machining center.

- the basic vertical knee mill machine is examined
- the parameters for successful metal removal are defined
- the application of CNC technology to milling is explained
- modern machining center features and functions are featured
- various cutting tools, workholding, and workchanging devices are detailed

## The Milling Process

Milling is the most versatile of machining processes. Metal removal is accomplished through the relative motions of a rotating, multi-edge cutter and multi-axis movement of the workpiece. Milling is a form of interrupted cutting where repeated cycles of entry and exit motions of the cutting tool accomplish the actual metal removal and discontinuous chip generation. Milling has more variations in machine types, tooling, and workpiece movement than any other machining method.

All milling machines, from compact tabletop models to the standard vertical knee mill and the massive CNC machining centers, operate on the same principles and operating parameters. The most important of these operating parameters are:

- cutting speed, which is the speed at which the tool engages the work
- feed rate, which is the distance the tool edge travels in one cutter revolution
- the axial depth of cut, which is the distance the tool is set below an unmachined surface
- the radial depth of cut, which is the amount of work surface engaged by the tool

The capabilities of the milling machine are measured by motor horsepower which determines maximum spindle speeds and spindle taper size.

## Milling Machine Types

The most basic milling machine is the vertical spindle, ram-type "knee" mill. Though not well adapted to production milling, it is ideal for toolmaking and prototype modeling. Knee mills are primarily used for manual operations, but their capabilities can be expanded.

The knee travels vertically, up and down the column and supports the saddle and table. The saddle moves in and out from the column, while the table moves side to side of the column. Additionally, the ram, at the top of the column, supports the milling head containing the motor, toolhead, speed and feed controls, quill and spindle. The non-rotating quill holds the rotating spindle. The ram can be moved both in and out from the column and can be tilted for angular milling and drilling.

Cutting tools are secured in collets or drill chucks held in the spindle. Work is usually secured to the table using bolts and clamps, or by using vises or fixtures bolted to the table. The work table contains longitudinal "T" slots to facilitate the attachment of these devices.

The knee mill's capabilities are expanded by the use of digital readout displays and CNC technology. This CNC technology provides three-axis capability to the mill. Manual mills require that the operator/machinist set all the required parameters, change tools, and manually direct all table movement. However, with CNC capability, work is performed three to four times faster, with exceptional repeatability. In addition, CNC computer programs can be verified and completed graphically before an actual metal cutting begins.

A machining center is a machine for both milling and holemaking on a variety of non-round or prismatic shapes. The unique feature of the machining center is the toolchanger. The toolchanger system moves tools from storage to spindle and back again in rapid sequence. While most machining centers will store and handle 20 to 40 individual tools, some will have inventories of over 200.

Machining centers may either be vertical or horizontal. There is also a universal type capable of both orientations. The vertical type is often preferred when work is done on a single face. With the use of rotary tables, more than one side of a workpiece, or several workpieces, can be machined without operator intervention. Vertical machining centers using a rotary table have four axes of motion. Three are lineal motions of the table while the fourth is the table's rotary axis.

Horizontal centers with their horizontal spindles are better suited to larger, boxy workpieces. With a horizontal spindle, a wider variety of workpiece shapes are easier to mount and chips fall out of the way better. Like vertical machining centers, horizontal centers have multiple-axis table movements. Typically, the horizontal center's table rotates to present all four sides of a workpiece to the tooling.

The principle of the universal machining center is that the workpieces on the table may be addressed by a vertically-oriented or a horizontally-oriented spindle. Further, the combination of tilts and swivels available in the spindles and tables allow the workpieces to be addressed at a variety of compound angles.

The heart of the milling operation is the milling cutter. These are rotary tools with one or more cutting edges, each of which remove just a small amount of material as it enters and exits the workpiece. The variety of cutter types is almost limitless. One of the more basic is the face mill cutter used for milling flat surfaces. Used at high speeds, they range from three inches to up to two feet in diameter. Some face mills will simultaneously mill a shoulder that is square to the surface.

Work that requires edge preparation, shoulders, and grooves, is accomplished with other cutting mills. An end mill cutters is a tool with cutting edges on its end as well as on its periphery. End mills are used for short, shallow slots and some edge finishing. Circular grooving or slotting cutters are more adapted to the making of longer and deeper slots. This is because end mills are more easily deflected during heavier cuts. Chamfers and contour milling are performed with specially shaped end mills.

## Milling and Machining Center Basics



In all kinds of milling a critical component is the workholding device and the ability to be changed over quickly to present new work or work surfaces to the tooling. Machining centers can utilize long machine beds, pallet changers and multi-storied "tombstone" part holders to enable new work to be set up and positioned while previously setup workpieces are being milled.

Machining centers can also incorporate two very useful accessories. One is the touch-trigger probe which, with its computer software, will dimensionally check workpiece measurements before removal from the machining center. The probe is stored with other tooling for quick application. The second accessory is the tool presetting machine, which allows the technician to assemble the tooling according to the programmed part requirements before placing tools in the machining center tool storage.

## Review Questions

1. In milling, stock removal is accomplished by:
  - a. repeated cycles of cutting tool engagement with the work
  - b. continuous chip generation
  - c. the combination of speed and tool contact pressure
  - d. continuous cutting tool contact with the work
2. Feed rate is described as:
  - a. down pressure by the spindle
  - b. travel speed of the work past the cutter
  - c. distance covered by the tool cutting edge during one revolution
  - d. spindle and cutting tool rotational speed
3. The vertical spindle ram type knee mill is usually:
  - a. manually operated
  - b. capable of horizontal conversion
  - c. CNC controlled
  - d. used for high production
4. The singularly unique feature found on a machining center is the:
  - a. spindle arrangement
  - b. digital readout
  - c. number of possible axes
  - d. the toolchanger
5. Horizontal machining centers are useful for work that is:
  - a. small and round
  - b. long and thin
  - c. short and thick
  - d. large and boxy
6. Face mill cutting tools can have diameters ranging from:
  - a. two to four inches
  - b. two to four feet
  - c. one to three inches
  - d. three inches to two feet
7. End mills do not produce accurate slots that are long and deep due to:
  - a. problems in lubrication
  - b. vibration
  - c. deflection
  - d. chattering
8. A machining center accessory used for checking part dimensions is called:
  - a. a tool set
  - b. a digital readout
  - c. a trigger probe
  - d. a dial indicator

# Milling and Machining Center Basics



## Answer Key

1. a
2. c
3. a
4. d
5. d
6. d
7. c
8. c