CUTTING TOOLS

Objectives

- Name two types of material of which end mills are made and state their application
- Describe the purpose of two-flute and multiple-flute end mills
- Know the purpose of climb and conventional milling

End Mills

- Greatly improved since days of carbon-steel cutting tools
- High-speed steel (HSS) cutting tools maintain very important place in metal-cutting industry
- Variables influencing cutter decision
  - Part shape, work material, wear resistance of tool, red hardness, machine condition

High-Speed End Mills

- Relatively inexpensive, easy to get and do jobs quite well
- Capable of machining with close tolerances
- Single most versatile rotary tools used on conventional and CNC machines
- If need harder tool, frequent solution is cobalt end mill
  - Less expensive than carbide, long tool life

Coated End Mills

- Greatly improved performance of cutting tools by using hard, wear resistant coatings of
  - Carbides
  - Nitrides
  - Oxides
- These coatings
  - Increase tool life
  - Increase manufacturing productivity
  - Reduce machining costs

Coated End Mills (Continued)

- Combinations of two or three materials coating the end mill can provide qualities such as
  - Strong wear-resistance
  - Toughness
  - Shock resistance
  - Chemical stability at high temperatures
- Polycrystalline is another coating that can be used in the machining of abrasive, non-metallic, non-ferrous materials

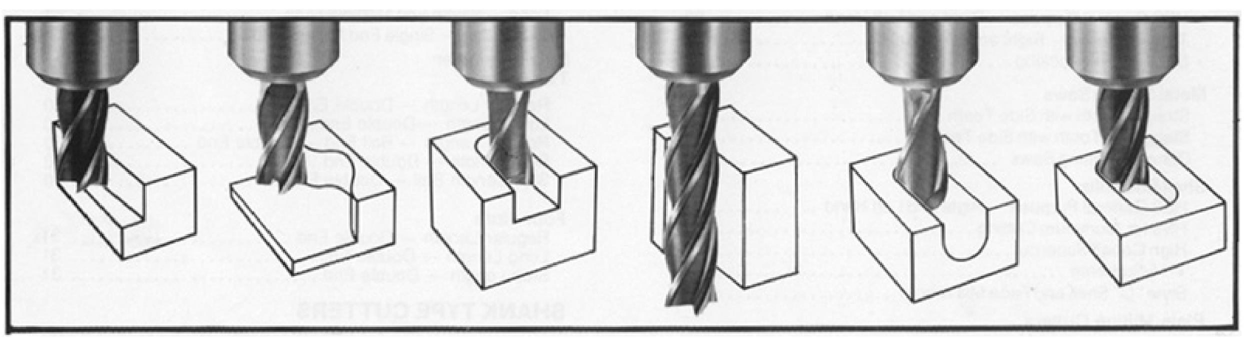
Carbide End Mills

- Carbide properties vs. HSS tool materials
  - Higher hardness
  - Greater rigidity
  - Can withstand higher cutting temperatures
- Can run at higher speeds and feeds
  - Increasing production rates
  - Providing long tool life
- High-performance tool material

Common Machining Operations

Performed with HSS, cobalt, solid carbide, or indexable insert type end mill

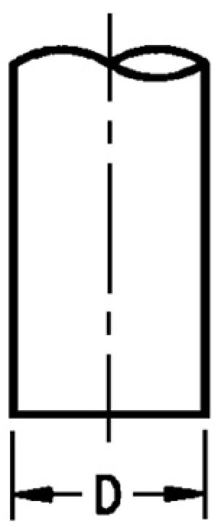
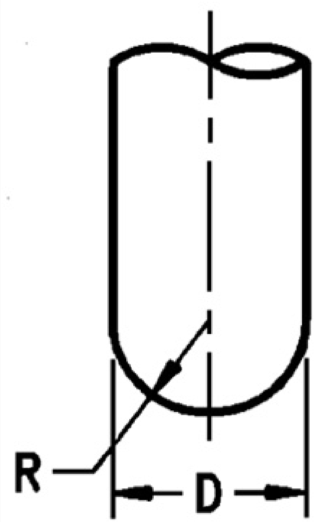
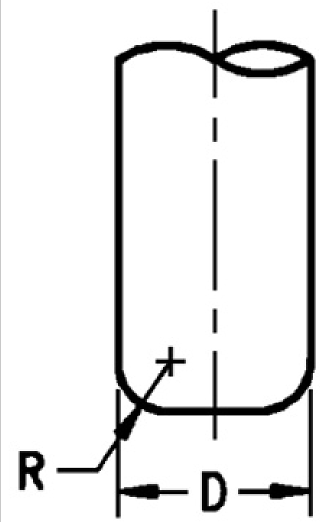
- Open and closed pockets
- Facing operations for small areas
- Counterboring and spotfacing
- Peripheral end milling
- Milling of slots and keyways
- Channel groves, face grooves and recesses
- Chamfering



End Mill Forms

- Ground into required shapes
  - Flat bottom end mill (most common)
    - Used for all operations requiring flat bottom and sharp corner between wall and bottom
  - End mill with full radium (ball nose end mill)
    - Used for 3D machining of various surfaces
  - End mill with corner radium (bull nose end mill)
    - Used for either 3D work or for flat surfaces that require corner radius between wall and bottom

Three common types and the relationship of the radius to the tool diameter.

STANDARD FLAT END MILL	BALL NOSE END MILL	BULL NOSE END MILL
		
R = 0	R = D/2	R < D/2

Common Types of End Mills

- Two-Flute End Mill
  - Have large, open flutes that provide excellent chip flow
  - Recommended for general-purpose milling
  - Always select shortest end mill possible for job to obtain maximum tool rigidity
  - Can have different length lips on end
    - Mill slots, keyways, plunge cut and drill shallow holes

Common Types of End Mills

- Three-Flute End Mill
  - With end teeth
  - Used to plunge into workpiece
  - Used to mill slots, pockets and keyways
  - Minimize chatter and better chip removal
- Roughing End Mill
  - Designed to provide best performance while machining broad range of materials
  - Allows deeper cuts at faster feed rates

Common Types of End Mills

- Multiple-Flute End Mill
  - Have four or more flutes
  - Produces fine finish after roughing cut
  - Center-cutting end teeth allow drilling into work to start machining operation
  - Recommended for pocketing, tracer milling, cam milling, die sinking and slotting

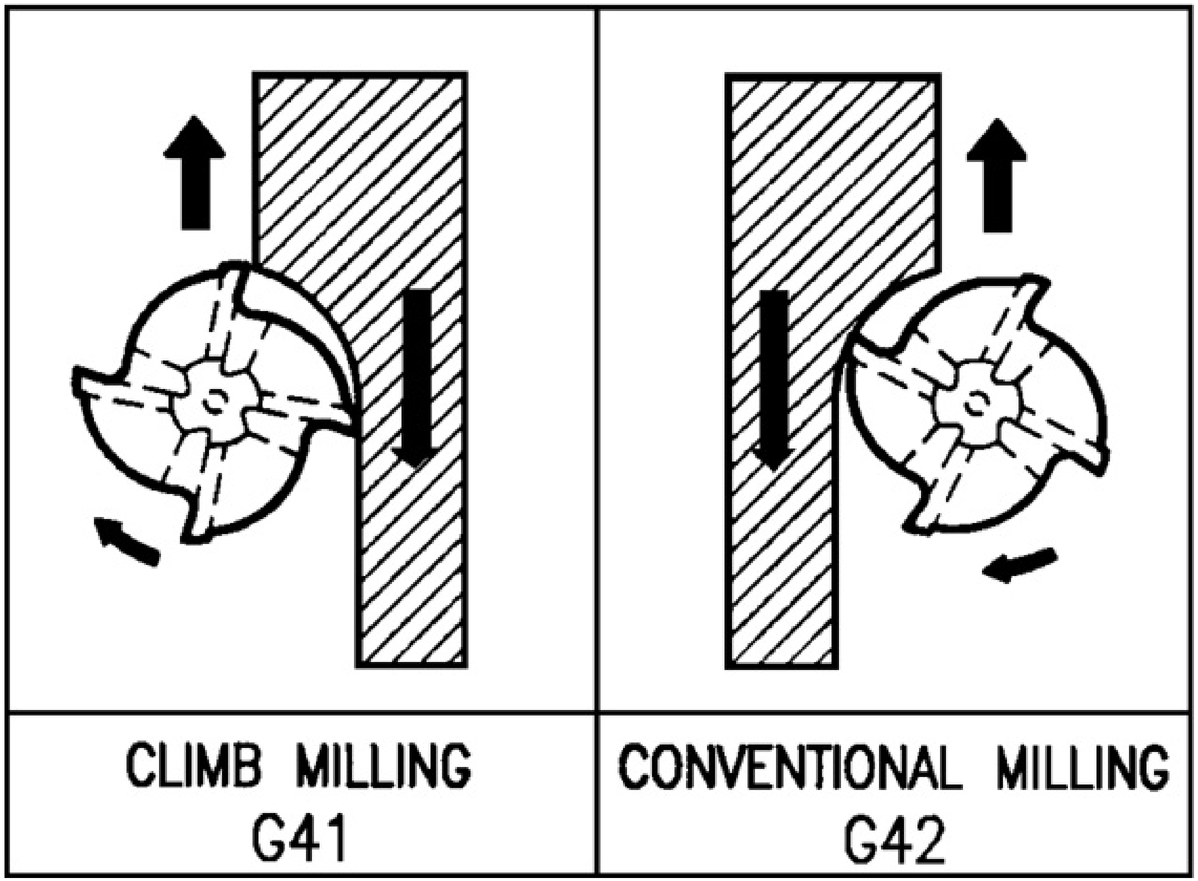
Direction of Cut: Climb

- Cutter rotation and table feed going in same direction
- Vertical milling: cutter tendency to pull work into cutting flutes
- Horizontal milling: cutter pushes work against table
- Maximum thickness of chip occurs at beginning of cut and exits when thin
  - Result – chip absorbs heat generated

Direction of Cut: Conventional

- When cutter rotation and table feed are moving in opposite directions
  - Has tendency to pull or lift workpiece up from table
- Important that work be held securely

Direction of Cut



Milling Cutter Failure

- Excessive heat
  - One of main causes of total cutting edge failure
  - Caused by cutting edges rubbing on workpiece and chips sliding along faces of teeth
  - Ever-expanding cycle
  - Minimized by correct speeds, feeds, and coolant
- Abrasion
  - Wearing-away action caused by metallurgy of workpiece
  - dulls cutting edges and cause "wear lands"

Chipping or Crumbling of Cutting Edges

- Small fractures occur and small areas of cutting edges chip out when cutting forces impose greater load on cutting edges
    - Material left uncut imposes greater cutting load
    - Condition progressive
        - Once started will lead to total cutter failure
- Dull edges increase friction, heat, and horsepower requirements

Major Causes of Chipping and Fracturing of Cutting Edges

- Excessive feed per tooth (FPT)
- Poor cutter design
- Brittleness due to improper heat treatment
- Running cutters backward
- Chattering due to nonrigid condition
- Inefficient chip washout
- Built-up edge break-away

Clogging

- Some workpiece materials have "gummy" composition
  - Chips long, stringy and compressible
- Chips clog or jam into flute area
- Minimize by reducing depth or width of cut, reducing FPT, using tools with fewer teeth, creating more chip space and coolant
  - Coolant applied under pressure to flush out flute area

Built-Up Edges

- Occur when particles of material cold-weld, gall, or otherwise adhere to faces of teeth adjacent to cutting edges
  - Periodically built-up material break away
  - Intermittent break-away takes portion of cutting edge
- Moderated by reducing feed / depth of cut
  - Solution in forceful application of coolant

Work Hardening of Workpiece

- Can cause milling cutter failure
- Result of action of cutting edges deforming or compressing surface of workpiece, causing change in work material structure that increases its hardness
- Important to use sharp tools at generous power feeds and use coolant
- Causes glaze – break by vapor honing or abrading surface with coarse emery cloth

Cratering

- Caused by chips sliding on tooth face adjacent to cutting edge
  - Area of high heat and extreme abrasion due to high chip pressures
  - Sliding and curling of chips erodes groove into tooth face
- Minimized by applying coolant that provides high-pressure film to prevent metal-to-metal contact