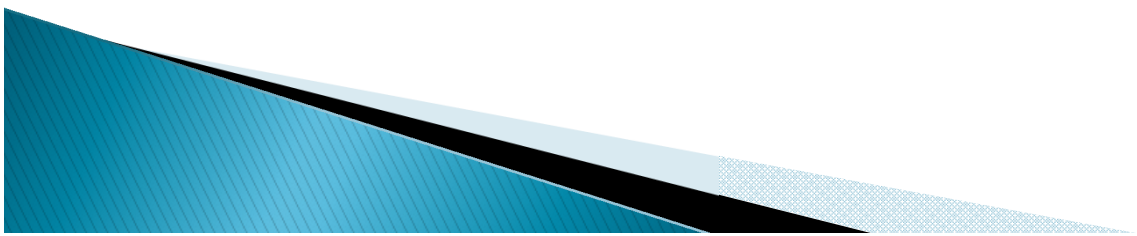
MACHINING OPERATIONS AND MACHINING TOOLS

B – MACHINING OPERATIONS AND MACHINE TOOLS

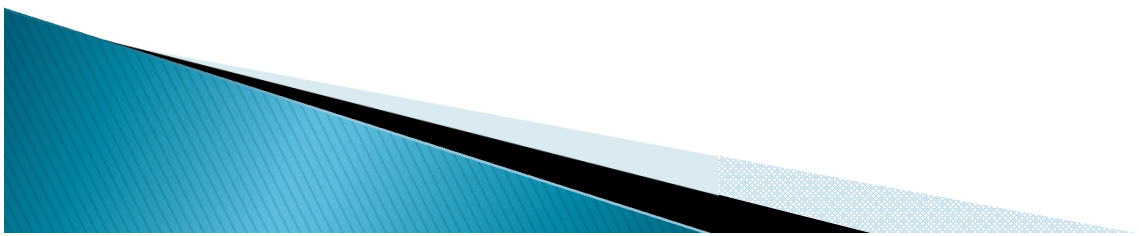
1. Turning and Related Operations
2. Drilling and Related Operations
3. Milling
4. Machining Centers and Turning Centers
5. Other Machining Operations
6. High Speed Machining



Machining

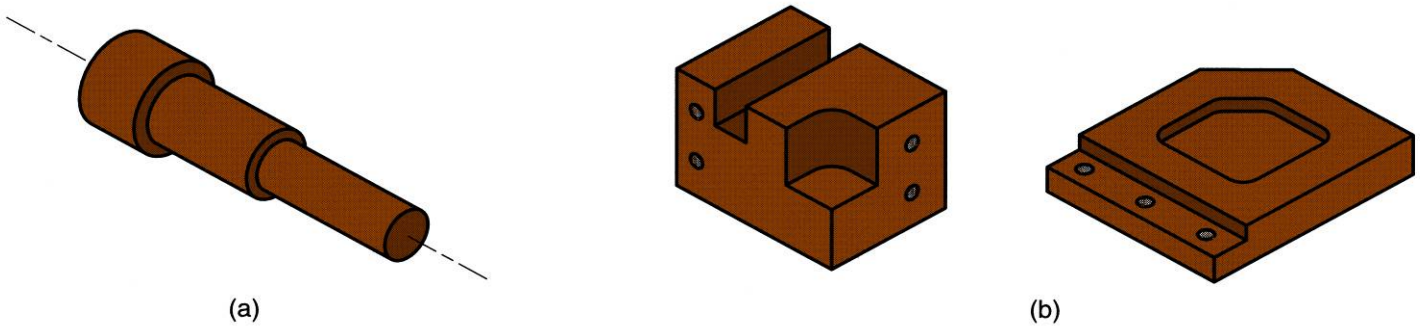
A material removal process in which a sharp cutting tool is used to mechanically cut away material so that the desired part geometry remains

- Most common application: to shape metal parts
- Most versatile of all manufacturing processes in its capability to produce a diversity of part geometries and geometric features with high precision and accuracy
  - Casting can also produce a variety of shapes, but it lacks the precision and accuracy of machining



Classification of Machined Parts

- **Rotational** - cylindrical or disk-like shape
- **Nonrotational** (also called prismatic) - block-like or plate-like

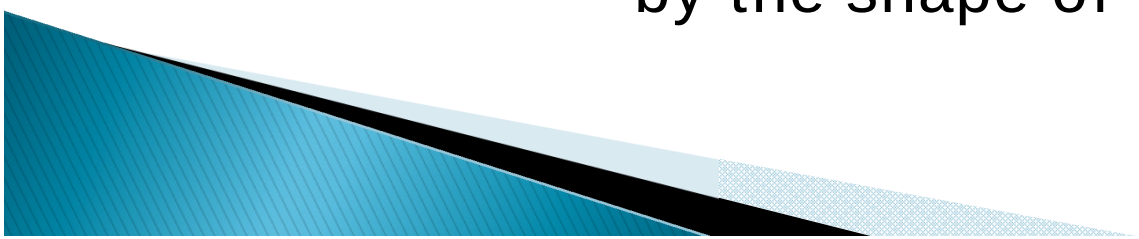


Machined parts are classified as: (a) rotational, or (b) nonrotational, shown here by block and flat parts.

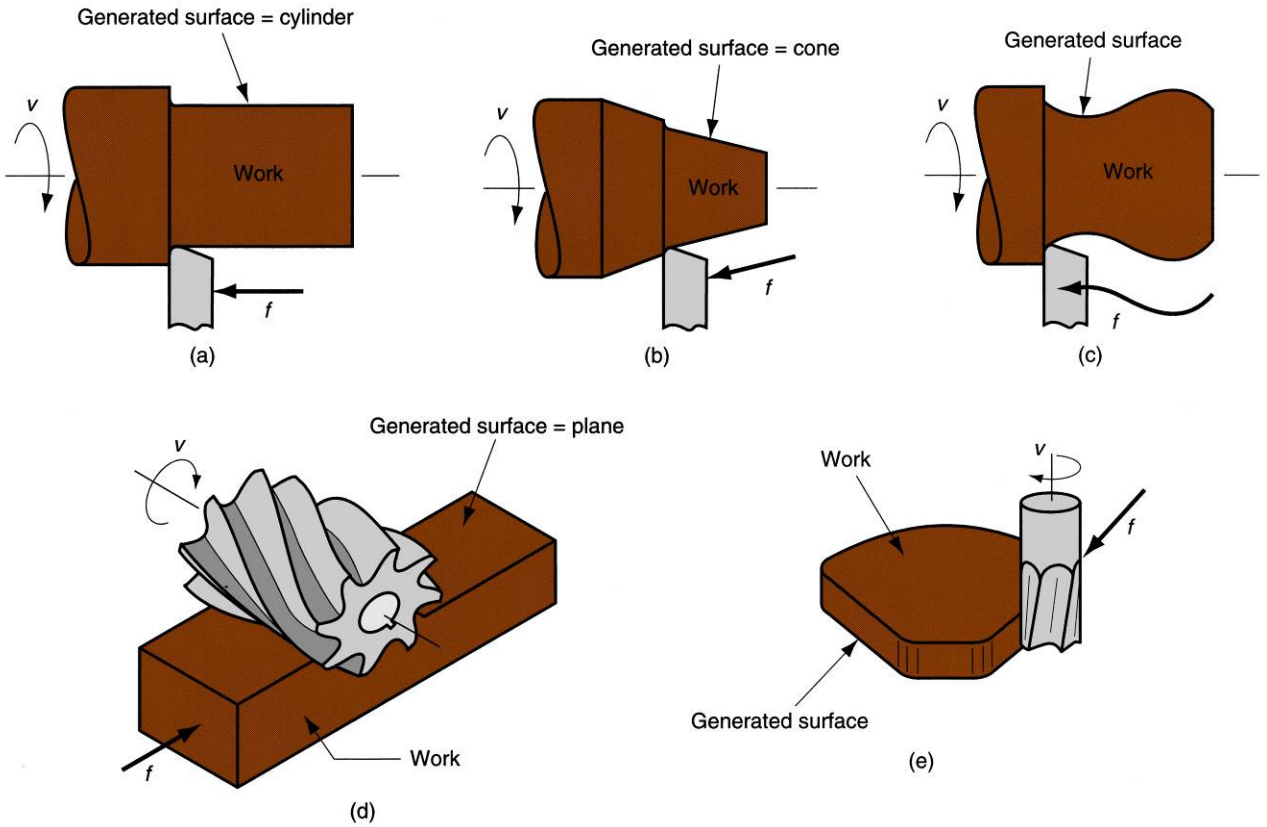
Machining Operations and Part Geometry

Each machining operation produces a characteristic part geometry due to two factors:

1. Relative motions between tool and workpart
   - ***Generating*** – part geometry determined by feed trajectory of cutting tool
2. Shape of the cutting tool
   - ***Forming*** – part geometry is created by the shape of the cutting tool

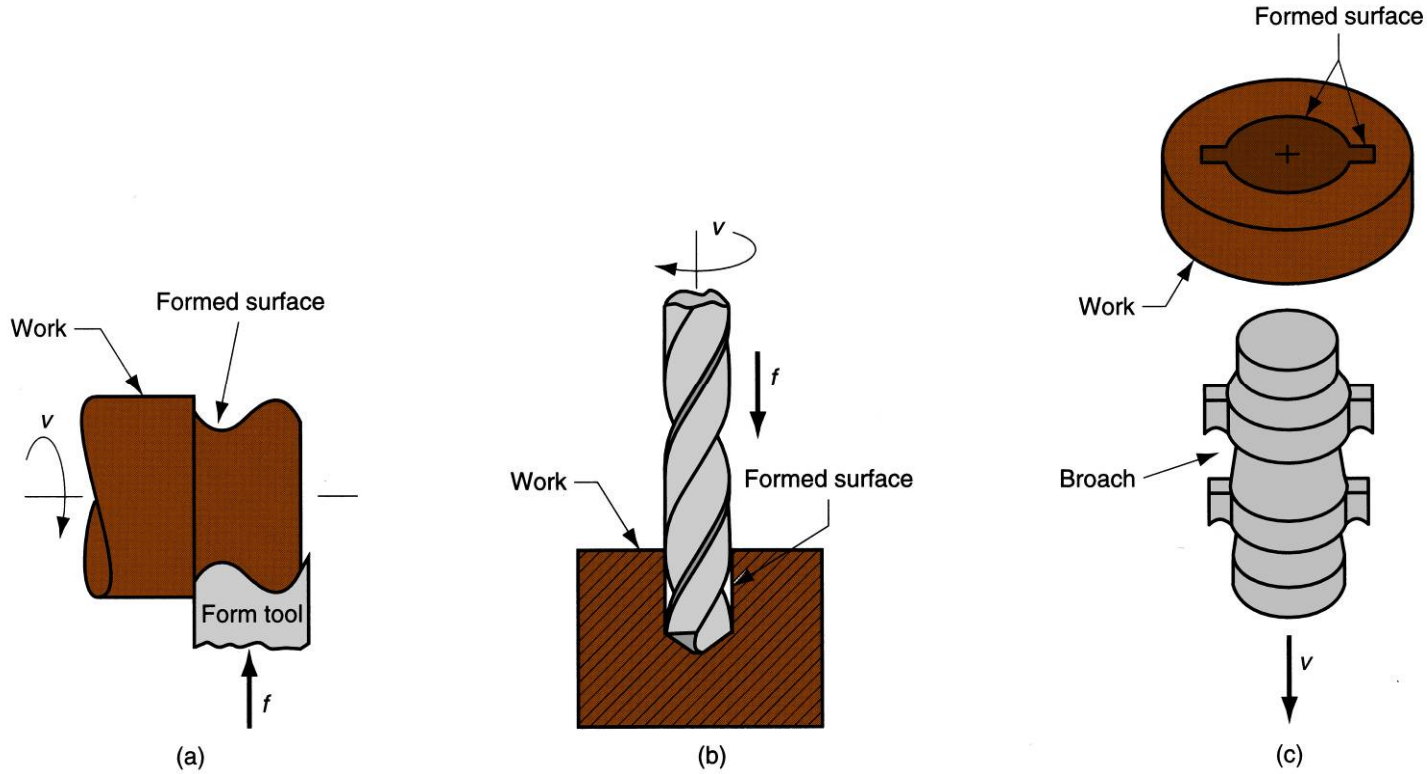


Generating Shape



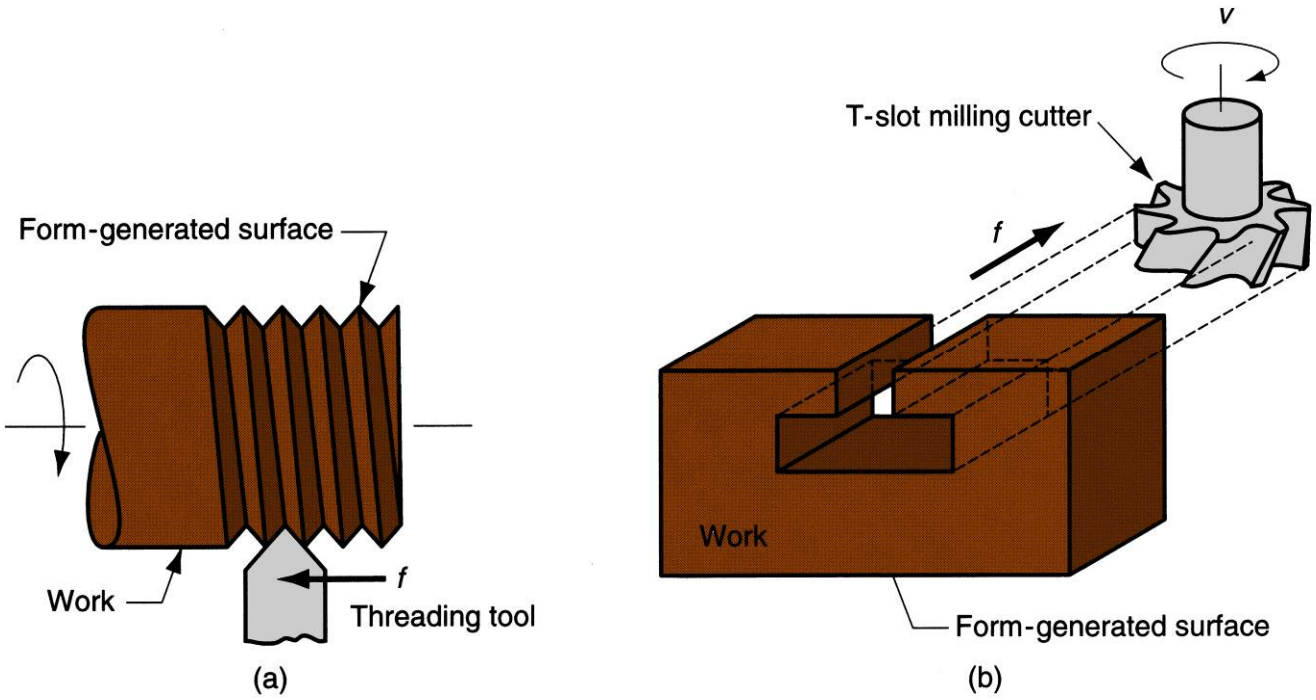
Generating shape: (a) straight turning, (b) taper turning, (c) contour turning, (d) plain milling, (e) profile milling.

Forming to Create Shape



Forming to create shape: (a) form turning, (b) drilling, and (c) broaching.

Forming and Generating

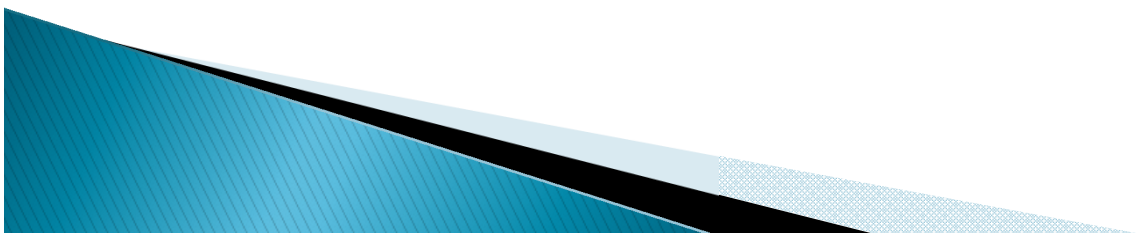


Combination of forming and generating to create shape: (a) thread cutting on a lathe, and (b) slot milling.

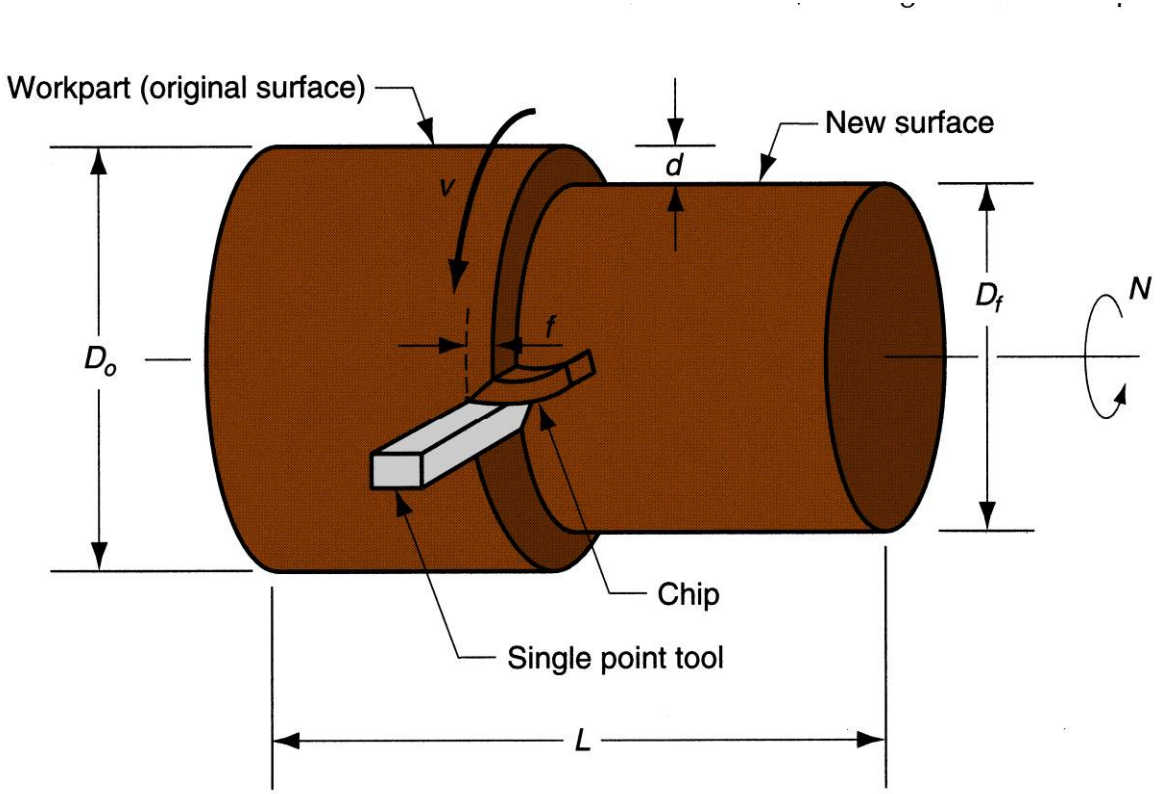
Turning

Single point cutting tool removes material from a rotating workpiece to generate a cylinder

- Performed on a machine tool called a *lathe*
- Variations of turning performed on a lathe:
  - Facing
  - Contour turning
  - Chamfering
  - Threading



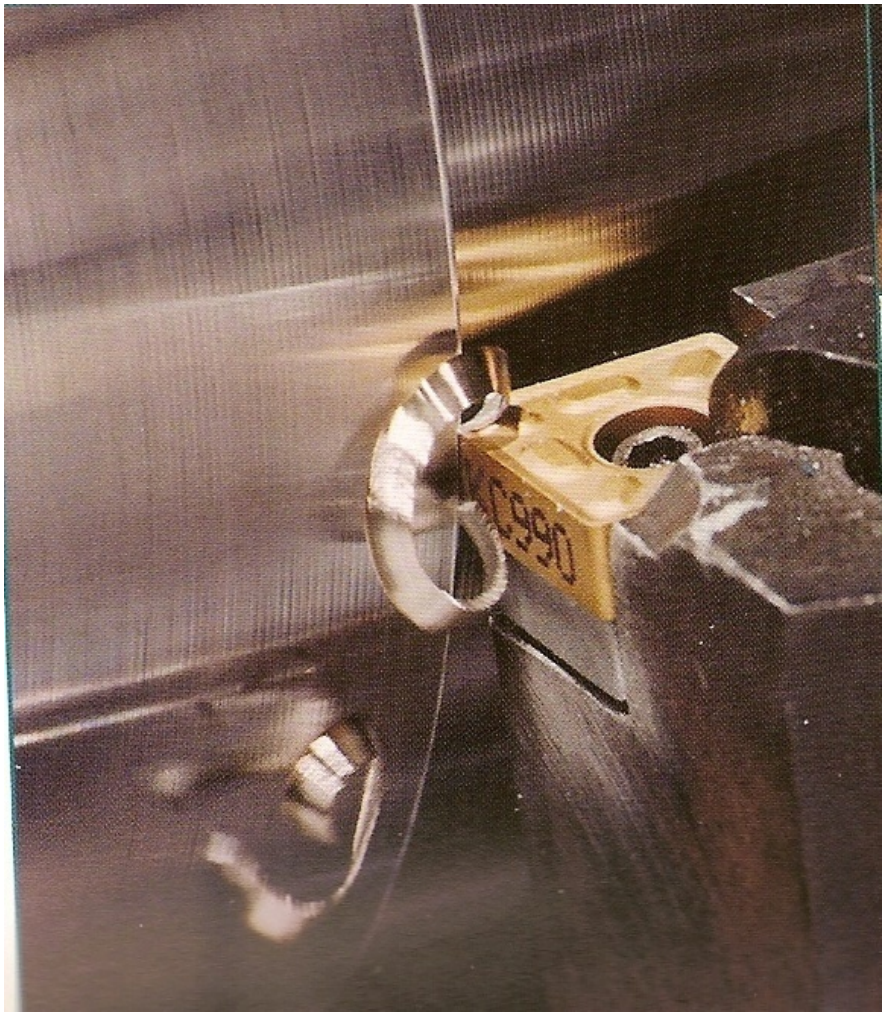
Turning



Turning operation.

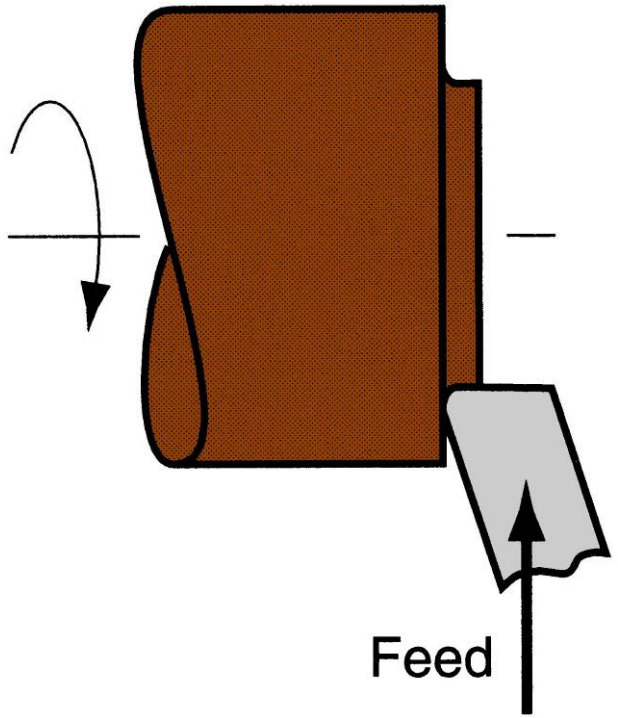
Turning Operation

Close-up view of a turning operation on steel using a titanium nitride coated carbide cutting insert



Facing

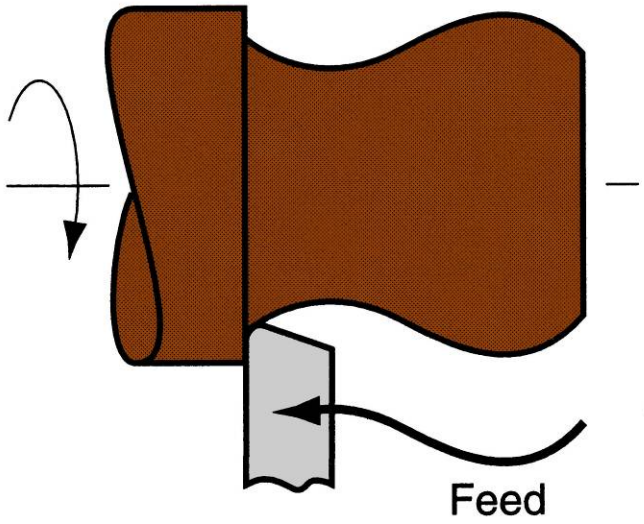
Tool is fed
radially inward



(a)

Contour Turning

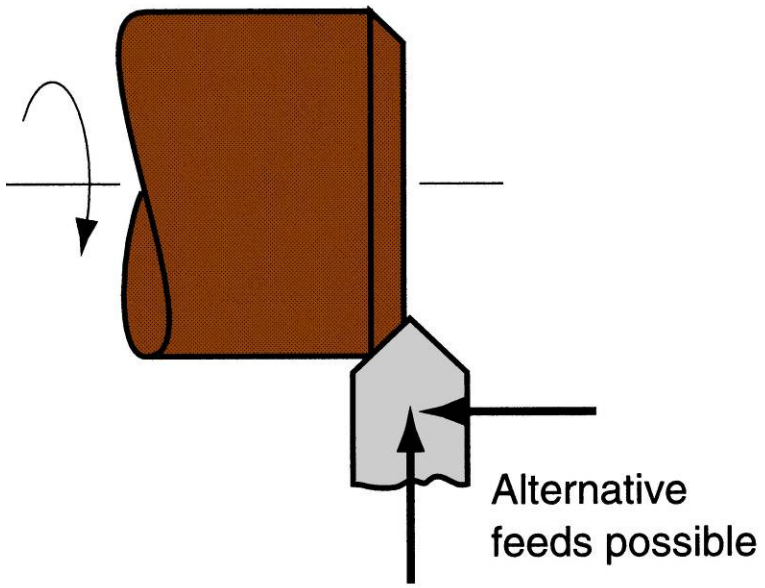
- Instead of feeding tool parallel to axis of rotation, tool follows a **contour** that is other than straight, thus creating a contoured shape



(c)

Chamfering

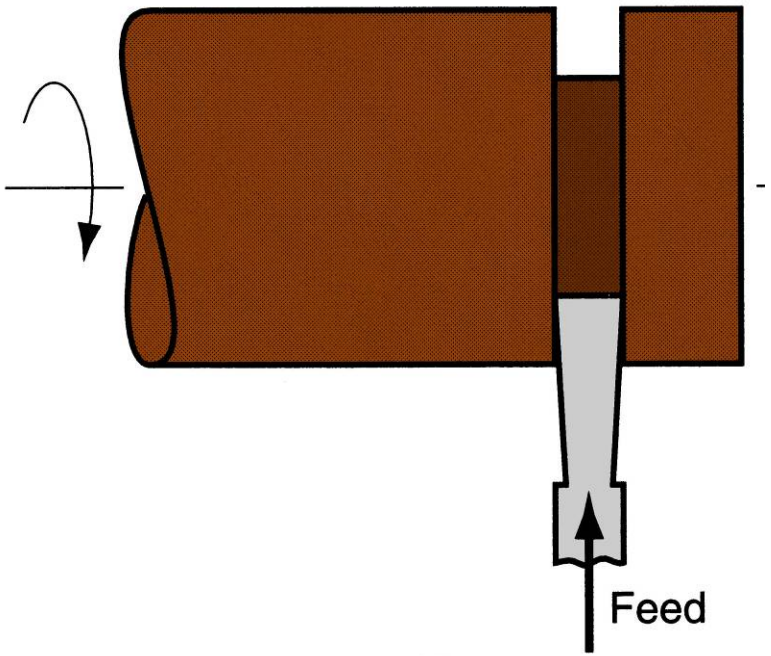
- Cutting edge cuts an angle on the corner of the cylinder, forming a "chamfer"



(e)

Cutoff

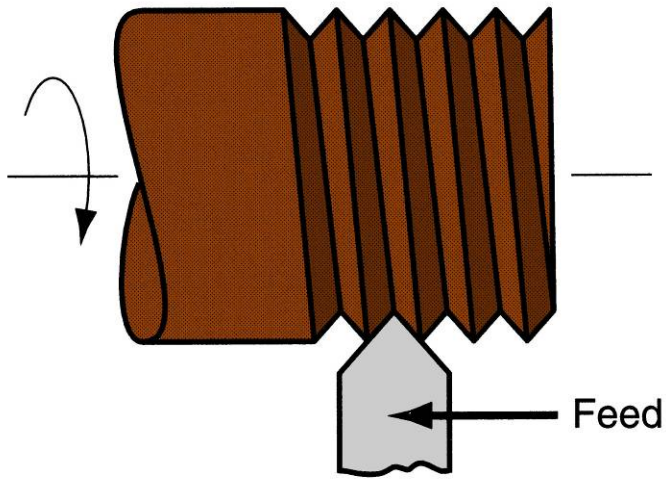
- Tool is fed radially into rotating work at some location to cut off end of part



(f)

Threading

- Pointed form tool is fed linearly across surface of rotating workpart parallel to axis of rotation at a large feed rate, thus creating threads



(g)

Engine Lathe

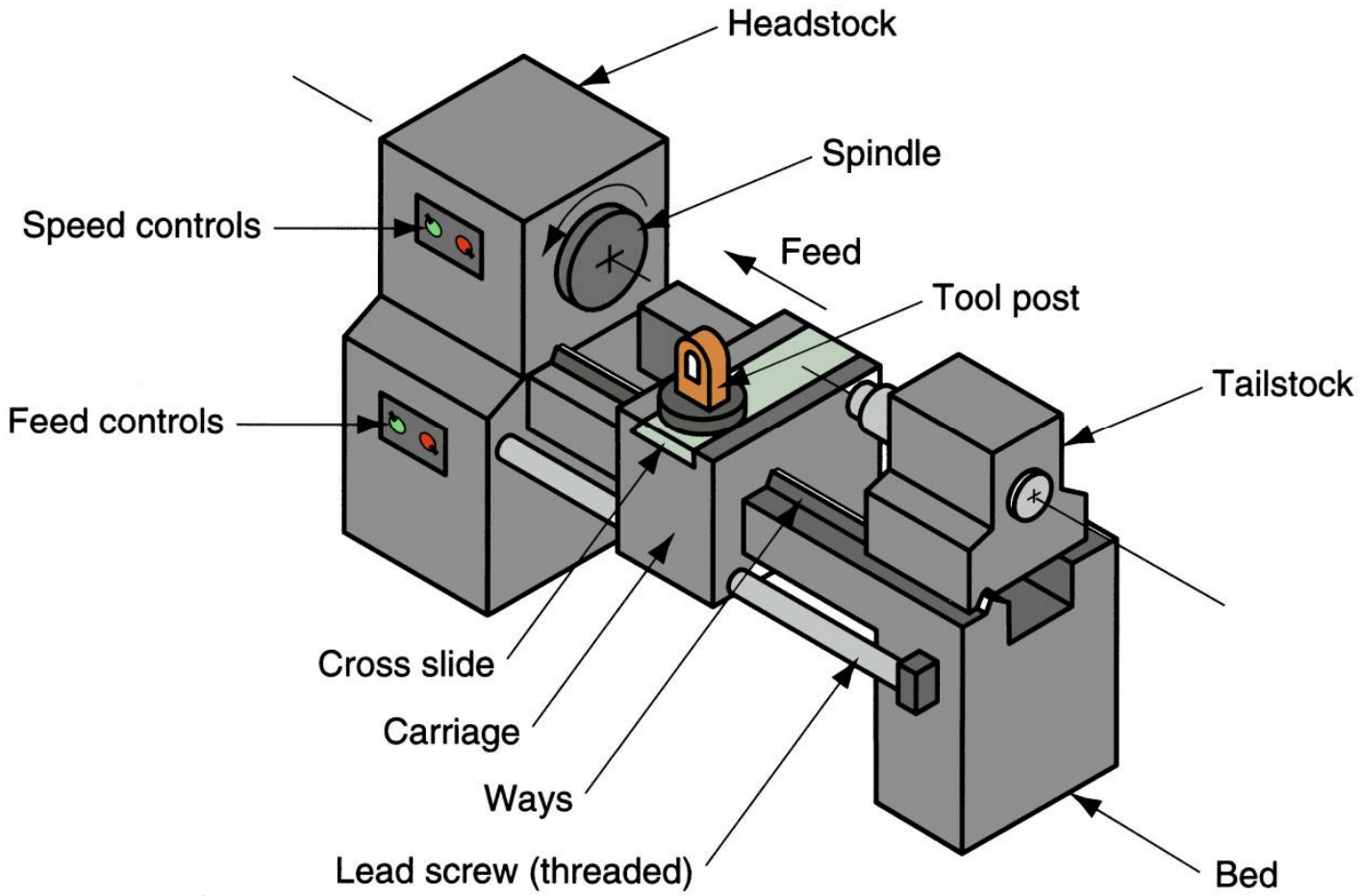
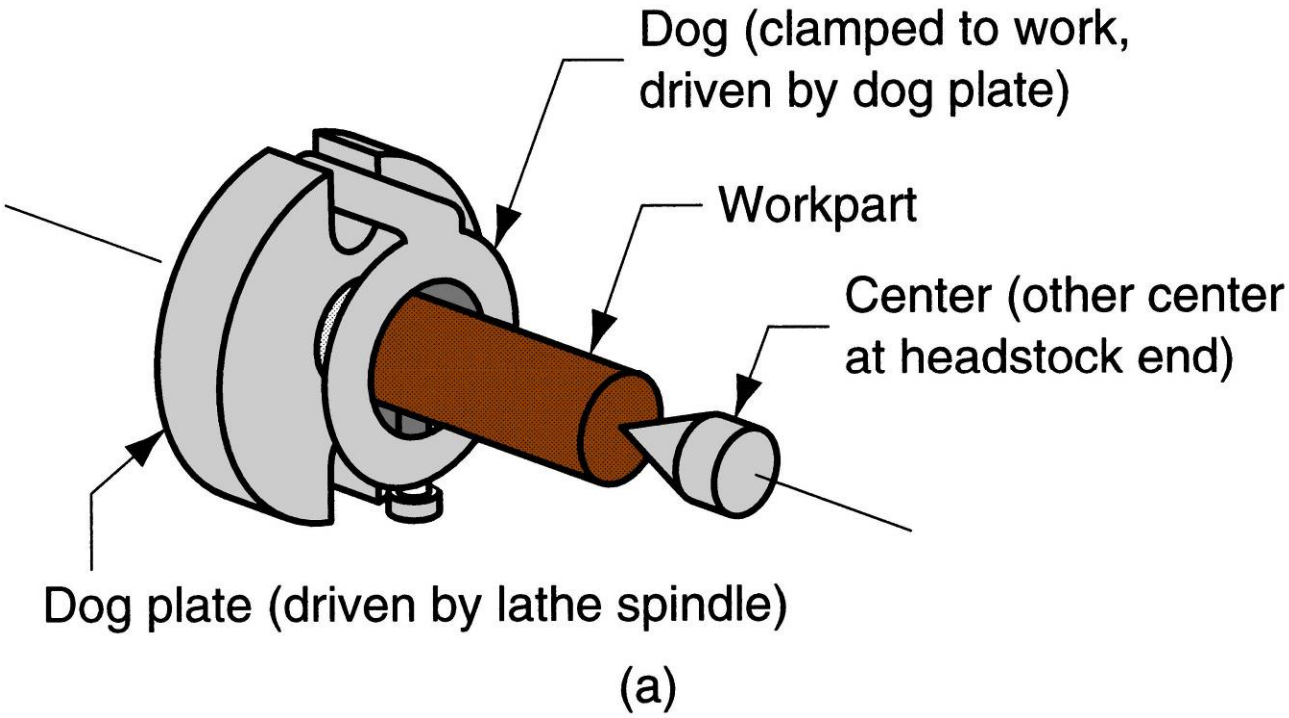


Diagram of an engine lathe, showing its principal components

Methods of Holding the Work in a Lathe

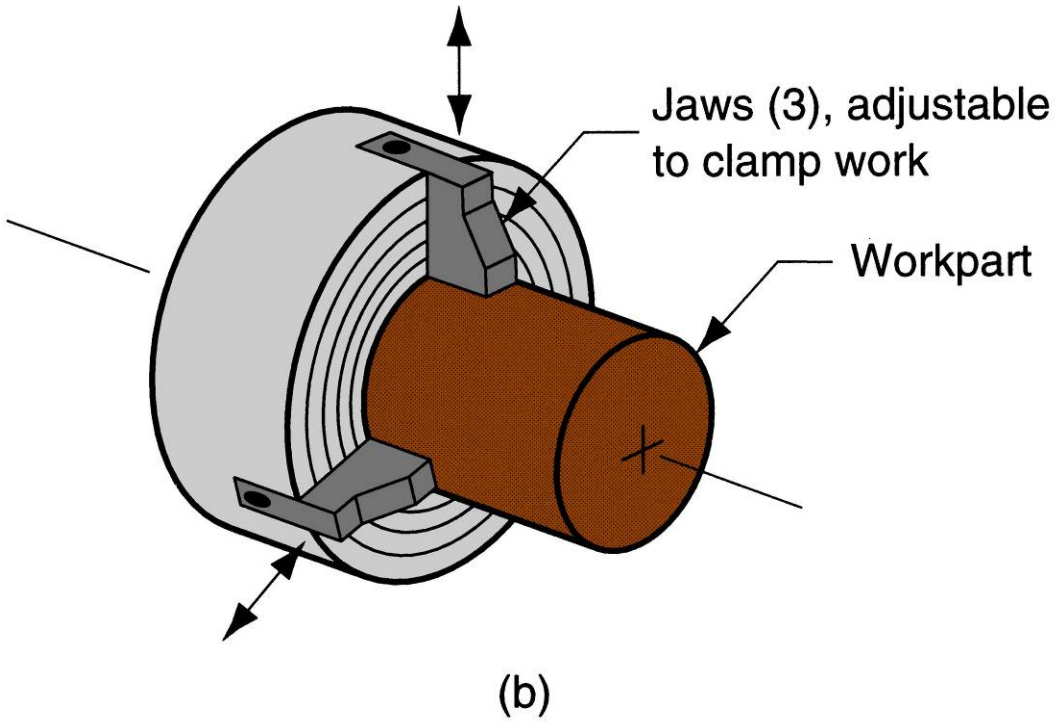
- Holding the work between centers
- Chuck
- Collet
- Face plate

Holding the Work Between Centers



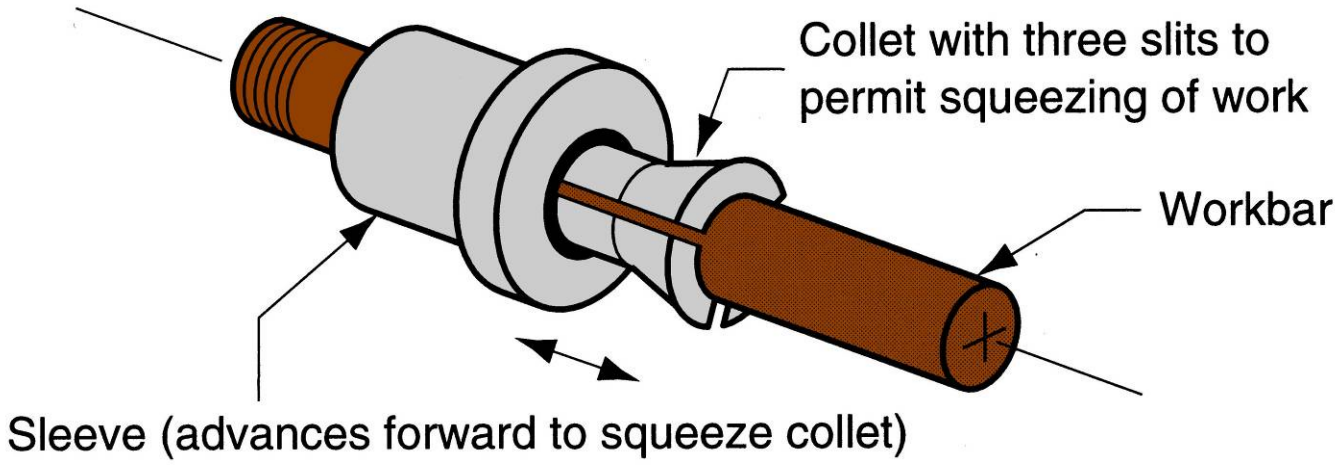
(a) mounting the work between centers using a "dog”

Chuck



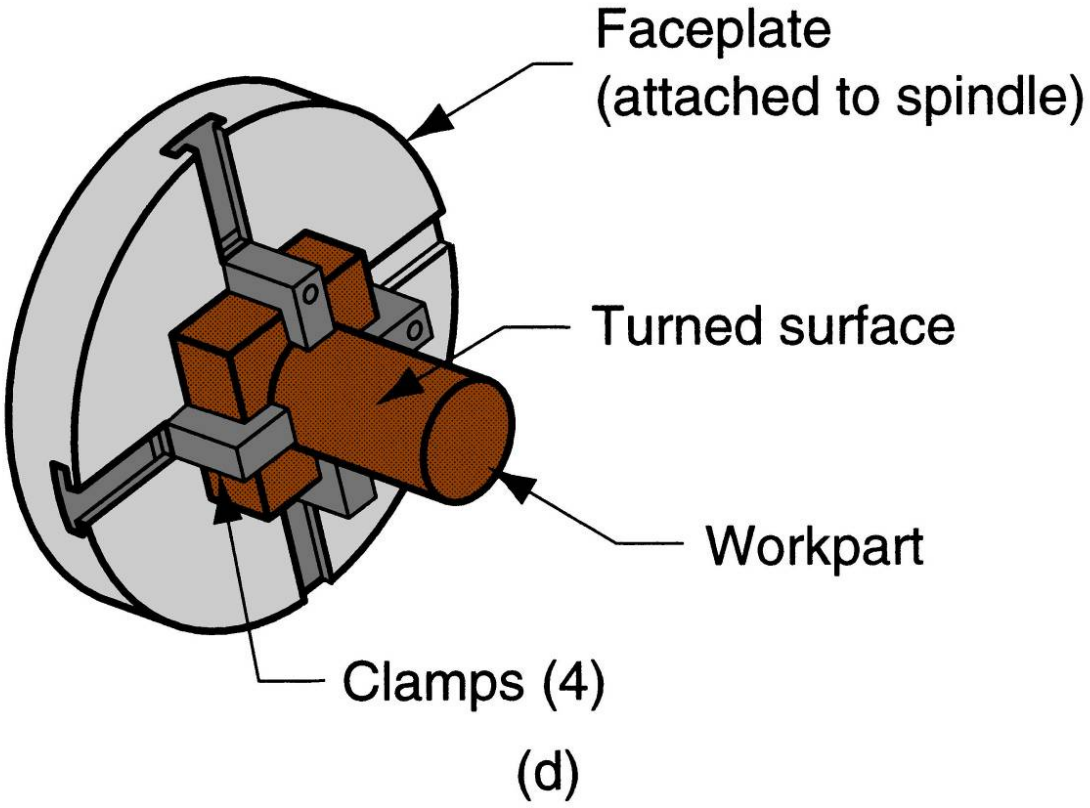
(b) three-jaw chuck

Collet


Collet with three slits to
permit squeezing of work
Workbar
Sleeve (advances forward to squeeze collet)

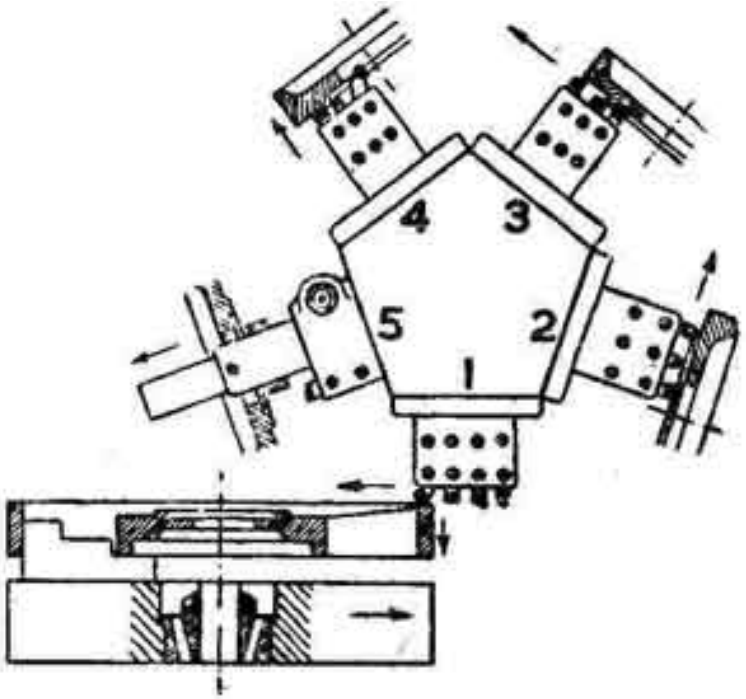
(c)

Face Plate



(d) face plate for non-cylindrical workparts

Turret Lathe

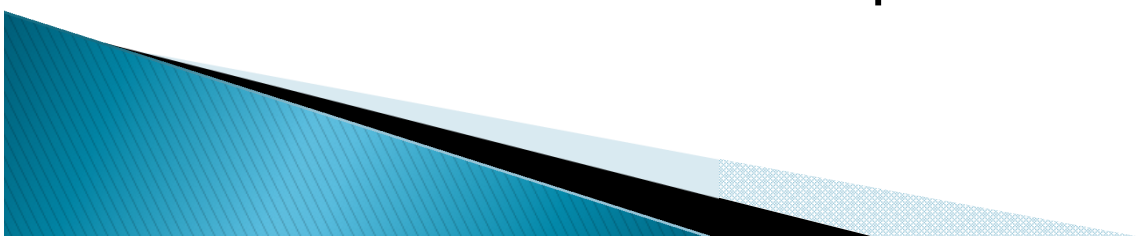


Tailstock replaced by “turret” that holds up to six tools

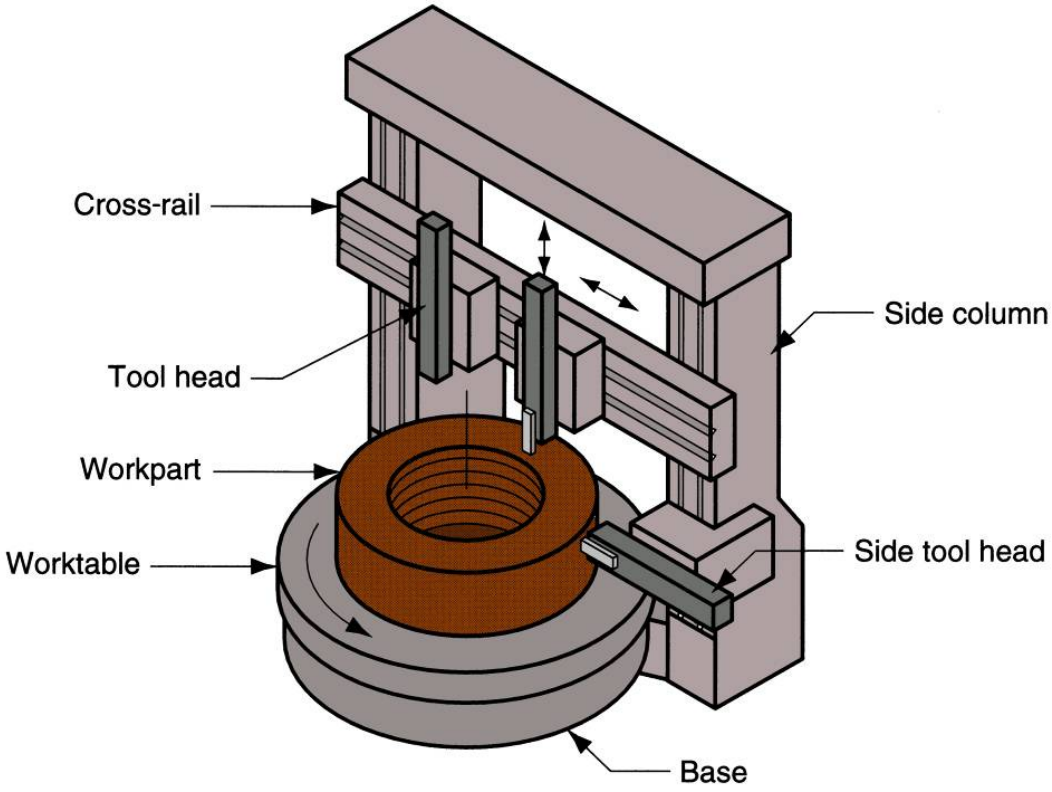
- Tools rapidly brought into action by indexing the turret
- Tool post replaced by four-sided turret to index four tools
- Applications: high production work that requires a sequence of cuts on the part

Boring

- Difference between boring and turning:
  - **Boring** is performed on the inside diameter of an existing hole
  - **Turning** is performed on the outside diameter of an existing cylinder
- In effect, boring is internal turning operation
- Boring machines
  - Horizontal or vertical - refers to the orientation of the axis of rotation of machine spindle



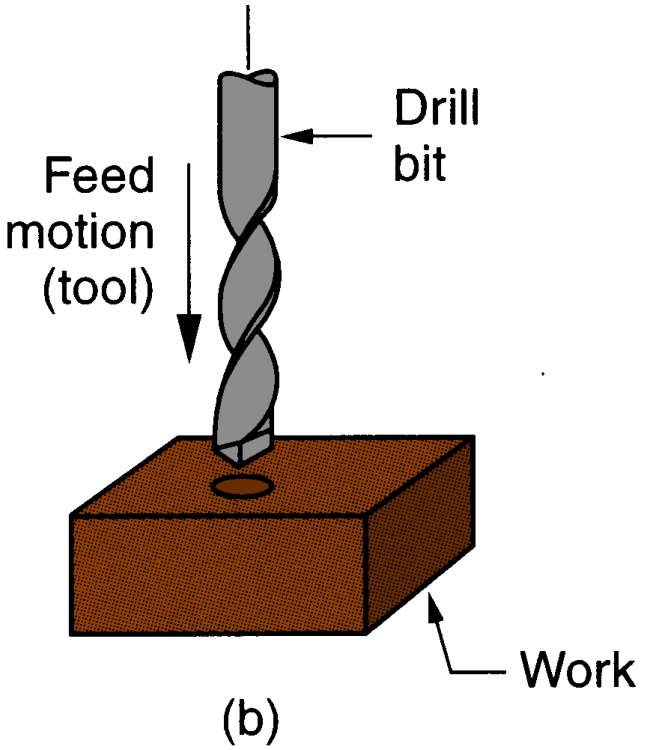
Vertical Boring Mill



A vertical boring mill – for large, heavy workparts.

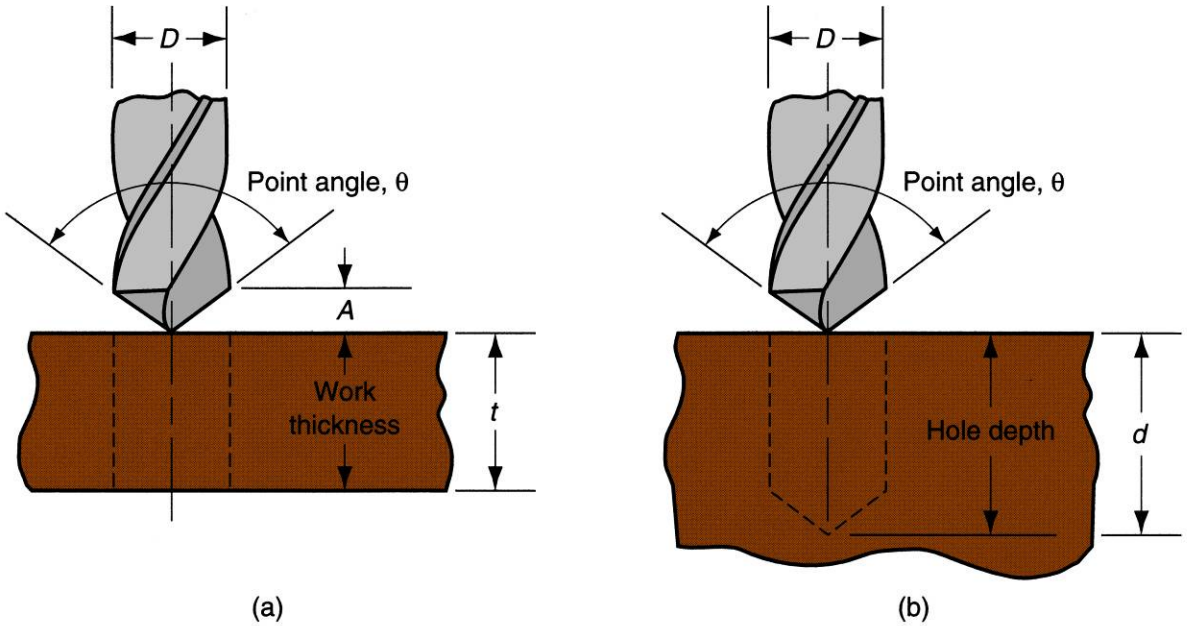
Drilling

- Creates a round hole in a workpart
- Compare to boring which can only enlarge an existing hole
- Cutting tool called a *drill* or *drill bit*
- Machine tool: *drill press*



Through Holes vs. Blind Holes

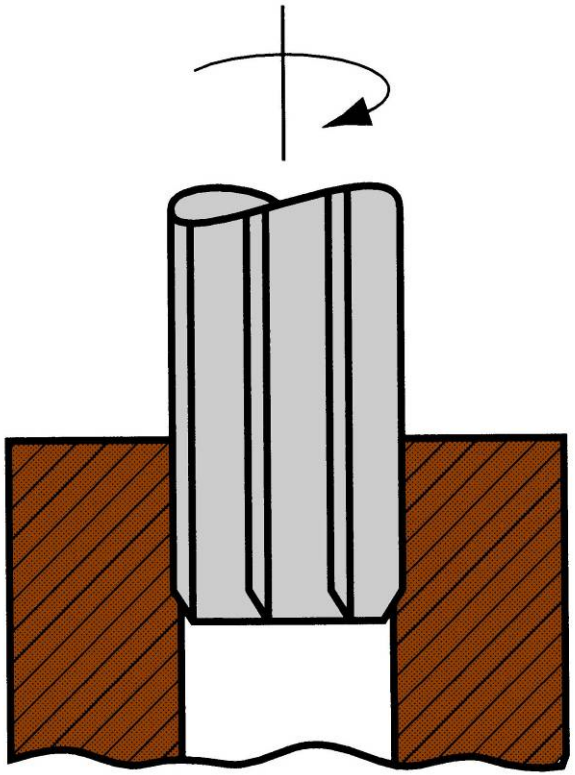
Through-holes - drill exits opposite side of work
Blind-holes – does not exit work opposite side



Two hole types: (a) through-hole, and (b) blind hole.

Reaming

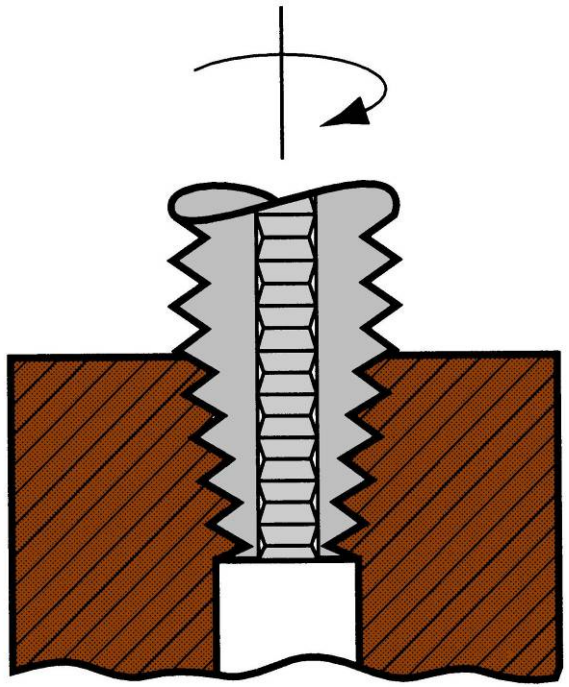
- Used to slightly enlarge a hole, provide better tolerance on diameter, and improve surface finish



(a)

Tapping

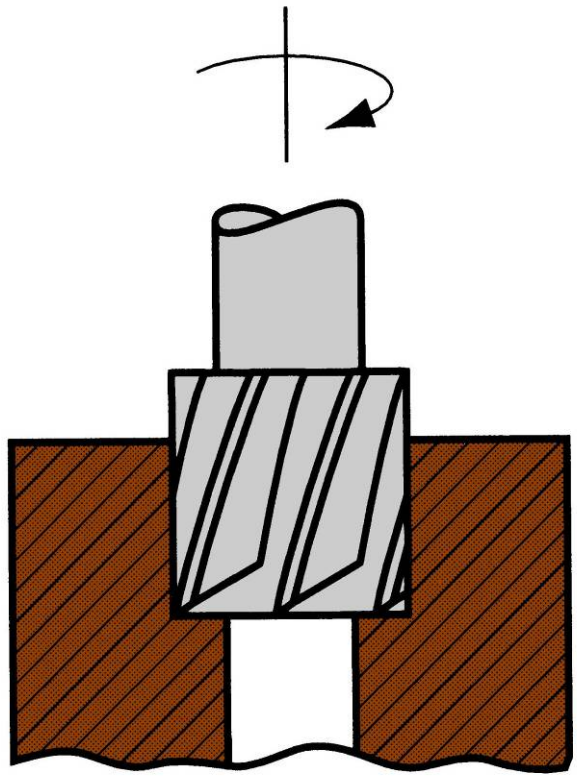
- Used to provide internal screw threads on an existing hole
- Tool called a *tap*



(b)

Counterboring

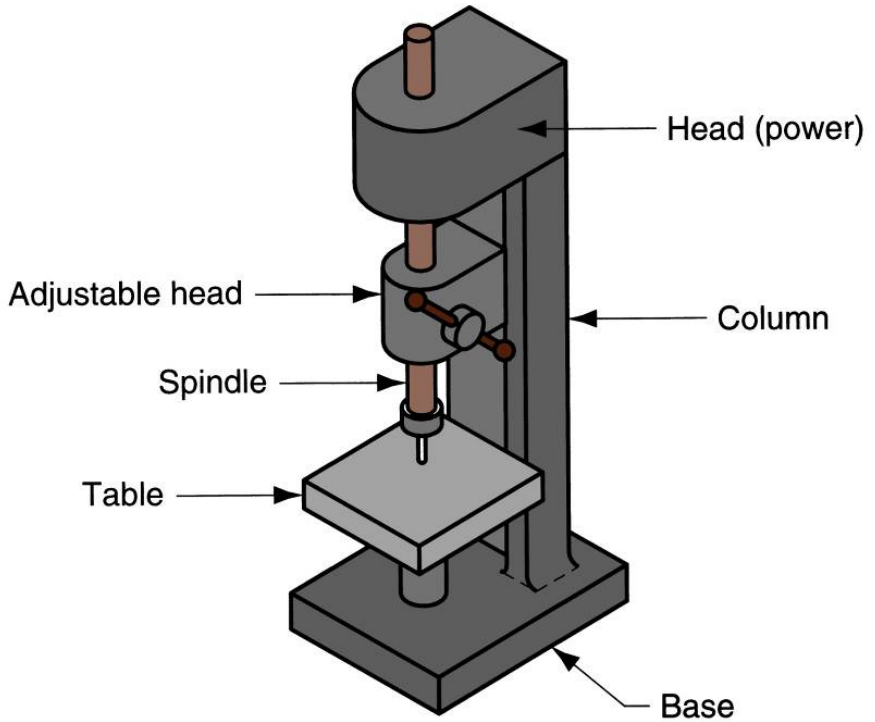
- Provides a stepped hole, in which a larger diameter follows smaller diameter partially into the hole



(c)

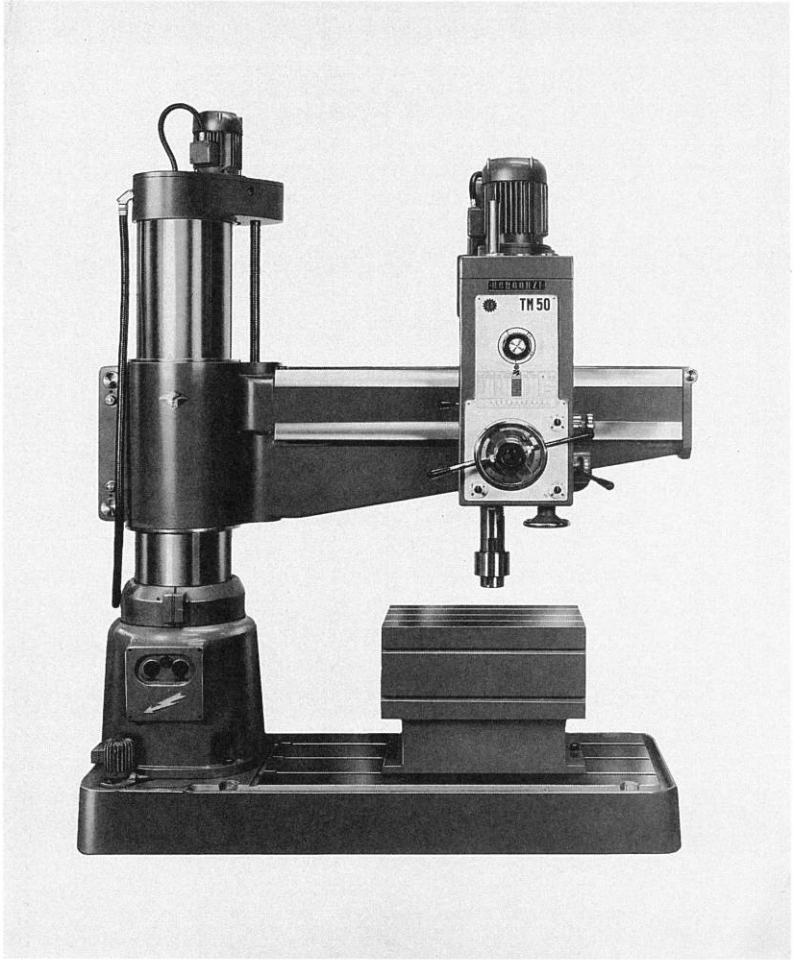
Drill Press

- Upright drill press stands on the floor
- Bench drill similar but smaller and mounted on a table or bench



Radial Drill

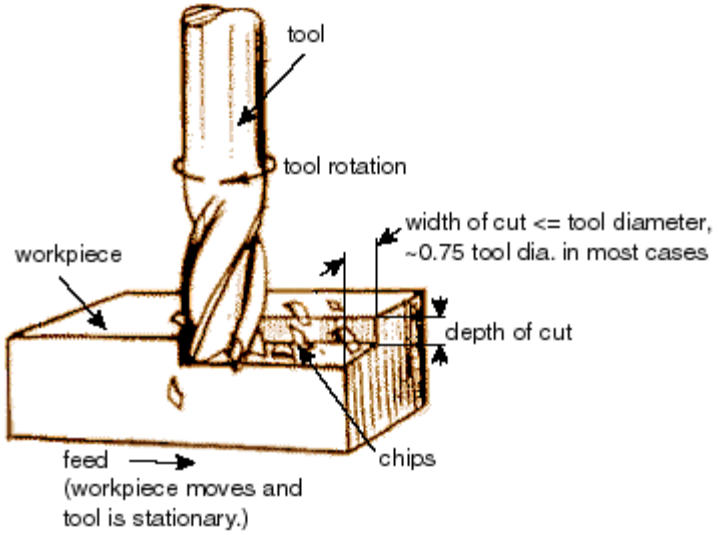
Large drill press designed for large parts



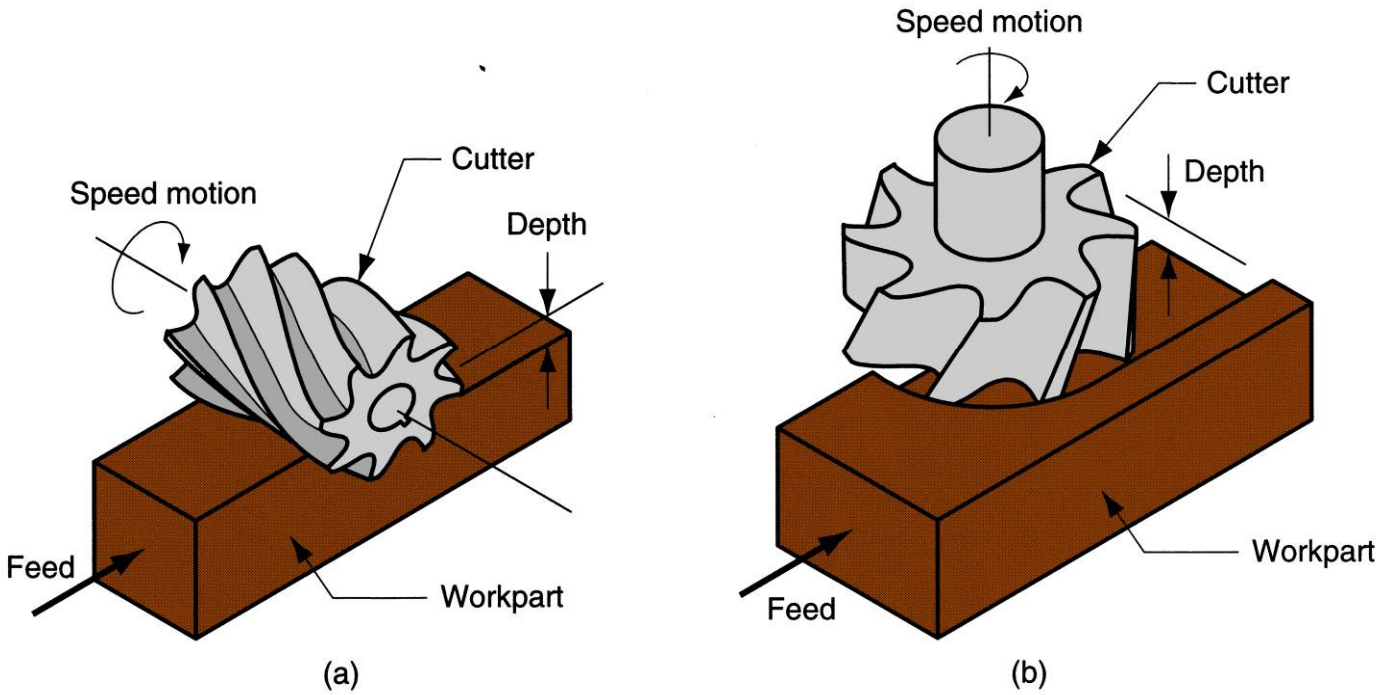
Milling

Machining operation in which work is fed past a rotating tool with multiple cutting edges

- Axis of tool rotation is perpendicular to feed
- Creates a planar surface
  - Other geometries possible either by cutter path or shape
- Other factors and terms:
  - Interrupted cutting operation
  - Cutting tool called a **milling cutter**, cutting edges called "teeth"
  - Machine tool called a milling machine



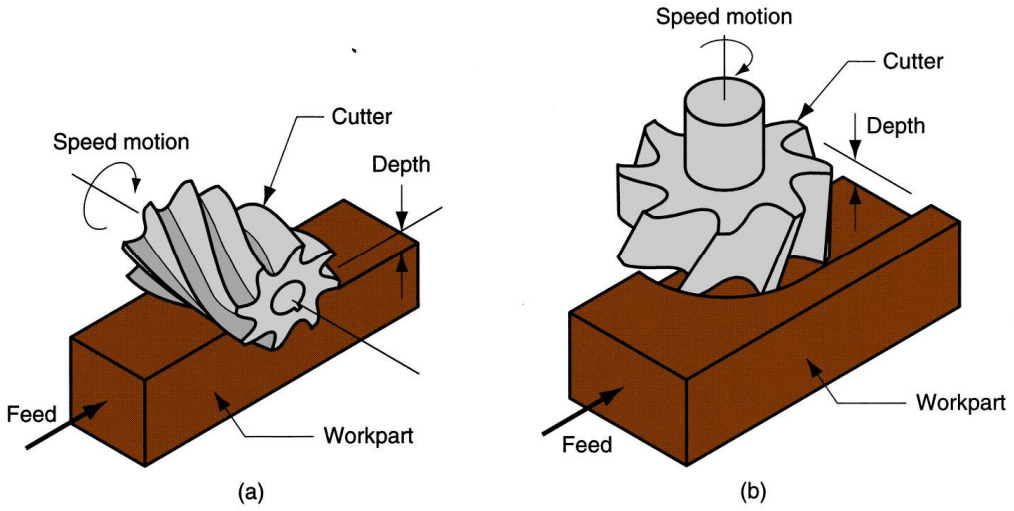
Two Forms of Milling



Two forms of milling: (a) peripheral milling, and (b) face milling.

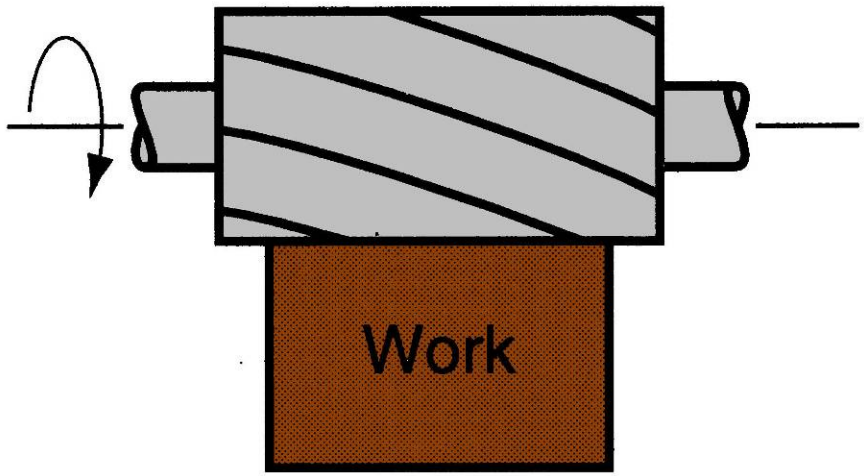
Peripheral Milling vs. Face Milling

- **Peripheral milling**
  - Cutter axis parallel to surface being machined
  - Cutting edges on outside periphery of cutter
- **Face milling**
  - Cutter axis perpendicular to surface being milled
  - Cutting edges on both the end and outside periphery of the cutter



Slab Milling

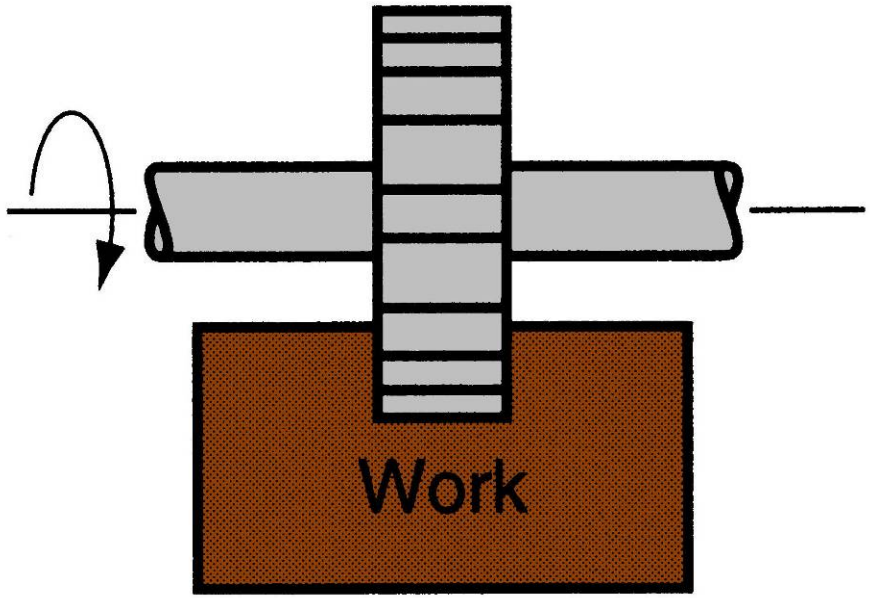
- Basic form of peripheral milling in which the cutter width extends beyond the workpiece on both sides



(a)

Slotting

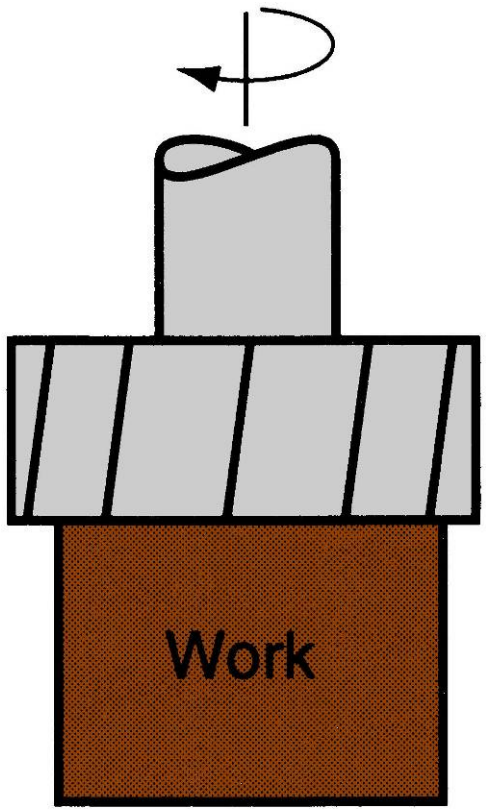
- Width of cutter is less than workpiece width, creating a slot in the work



(b)

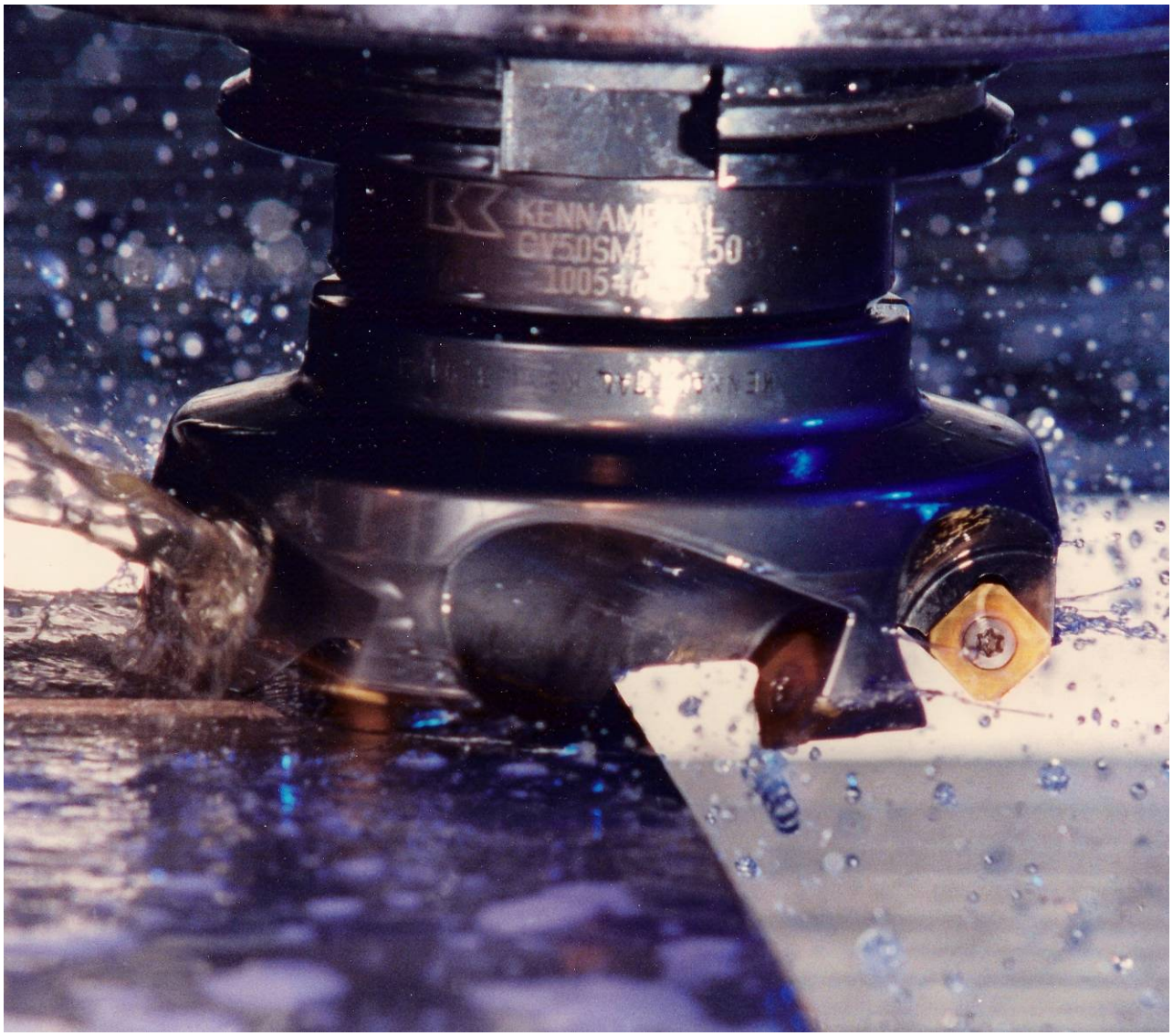
Conventional Face Milling

Cutter overhangs
work on both sides



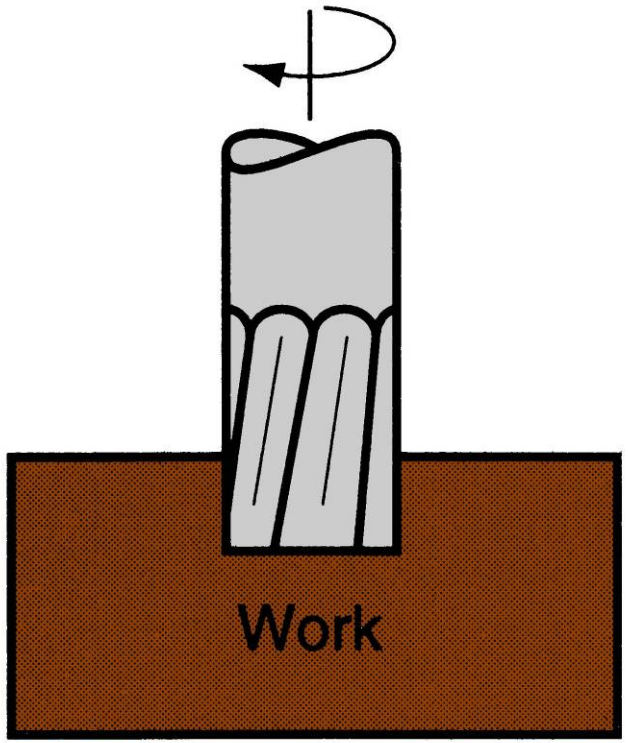
(a)

High speed face milling using indexable inserts



End Milling

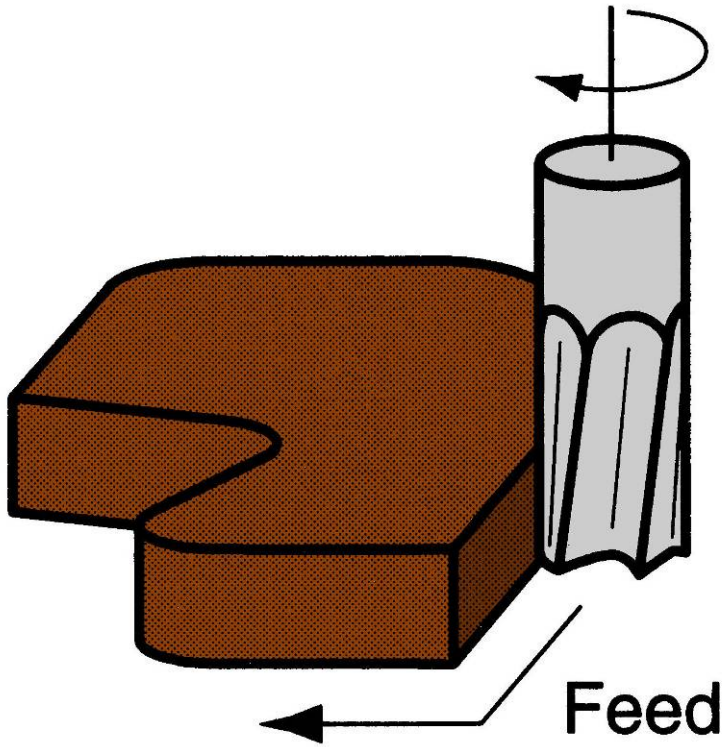
- Cutter diameter is less than work width, so a slot is cut into part



(c)

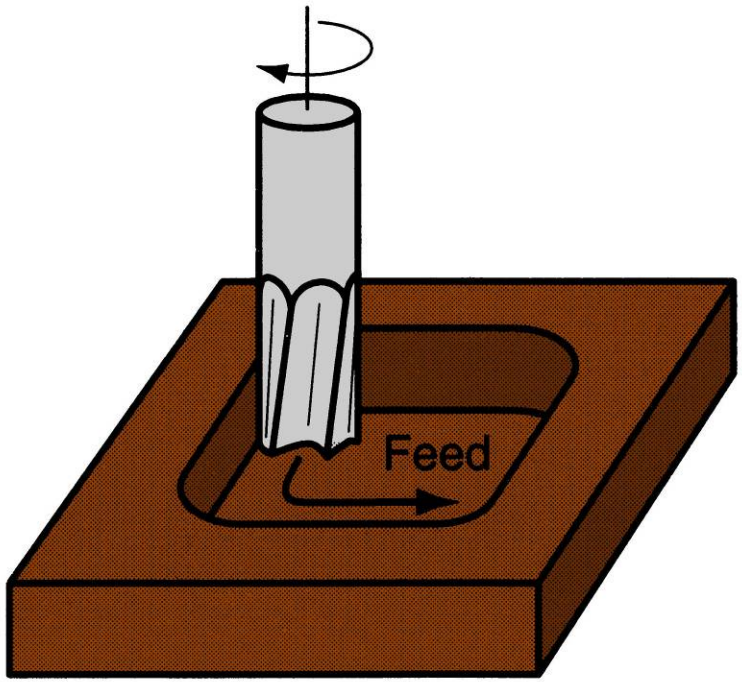
Profile Milling

Form of end milling in which the outside periphery of a flat part is cut



Pocket Milling

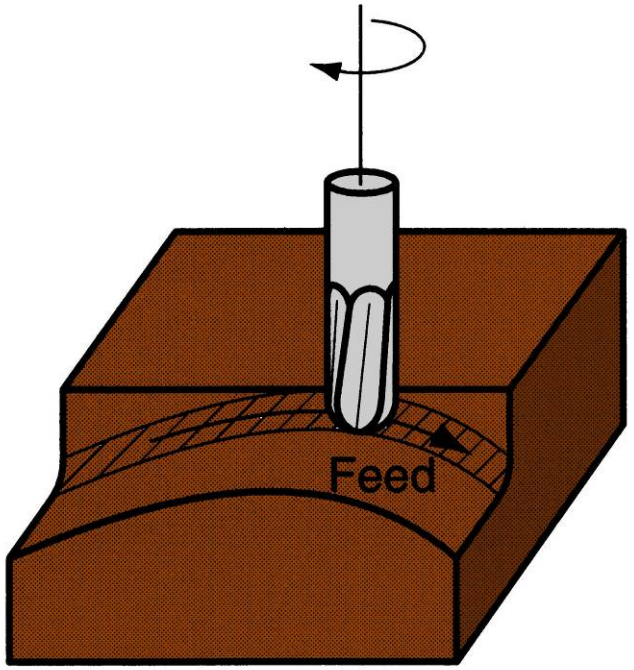
- Another form of end milling used to mill shallow pockets into flat parts



(e)

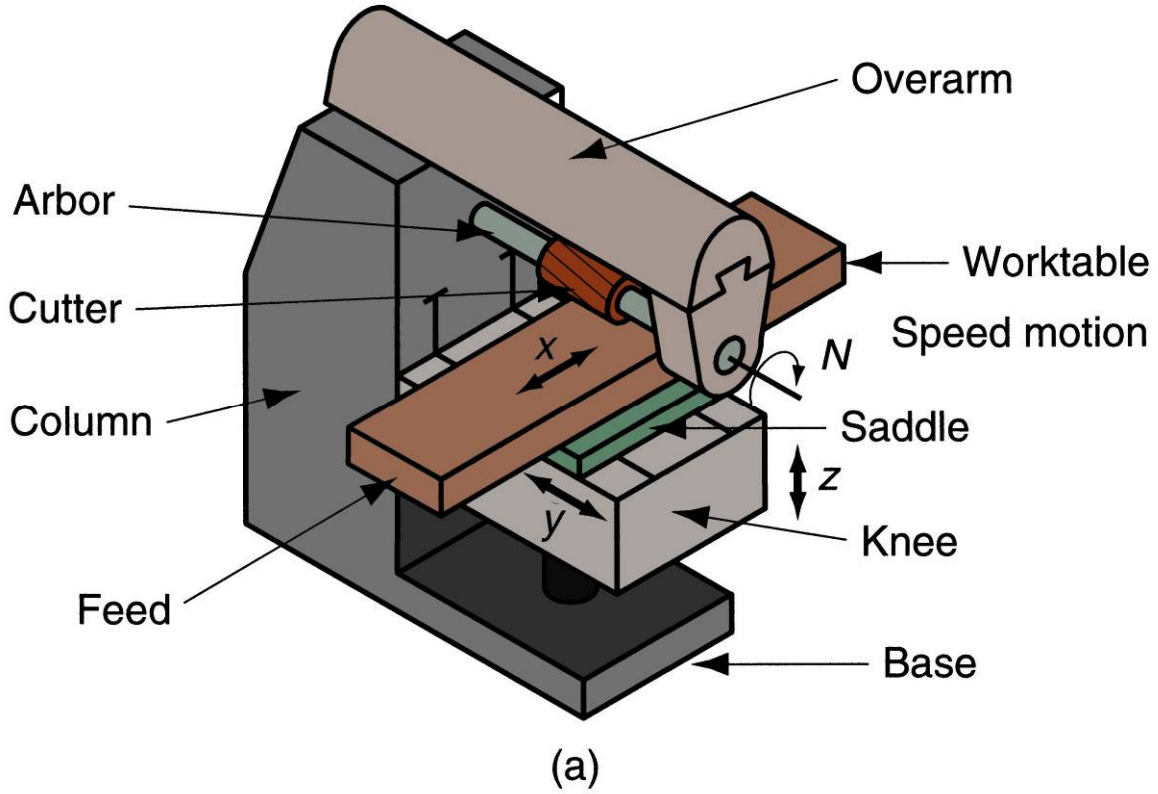
Surface Contouring

- Ball-nose cutter fed back and forth across work along a curvilinear path at close intervals to create a three dimensional surface form



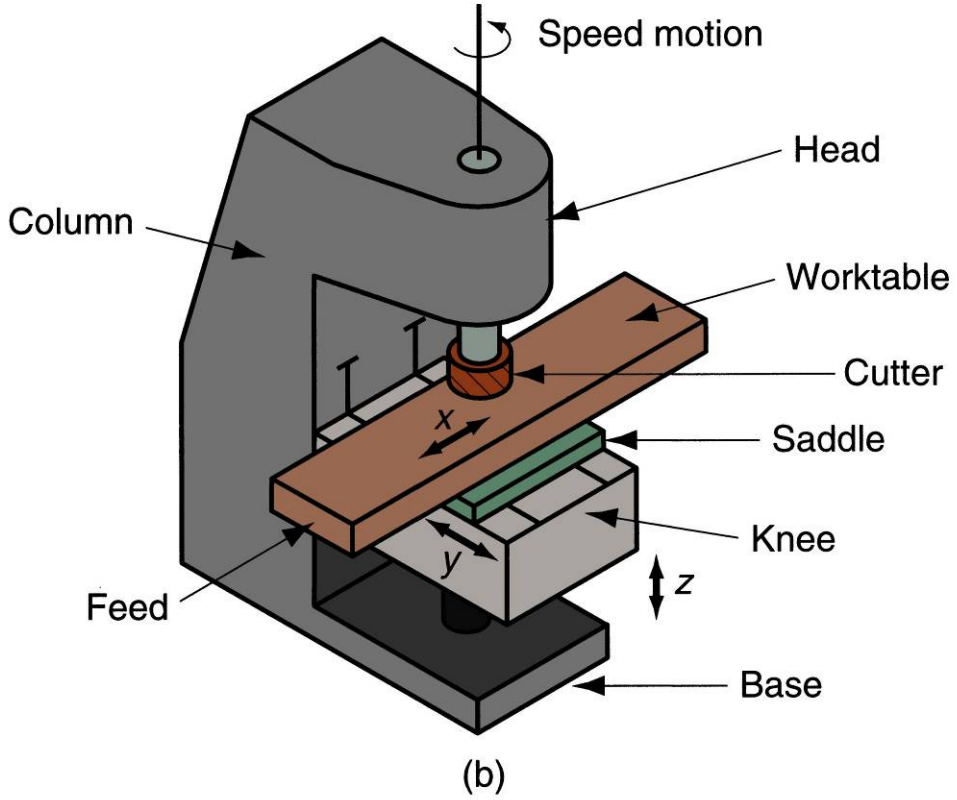
(f)

Horizontal Milling Machine



horizontal knee-and-column milling machine.

Vertical Milling Machine



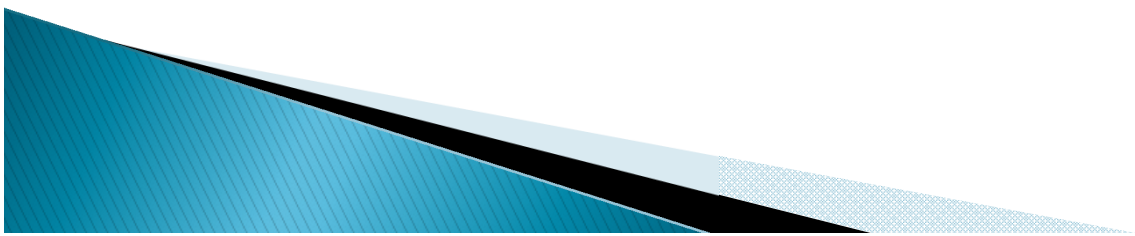
vertical knee-and-column milling machine

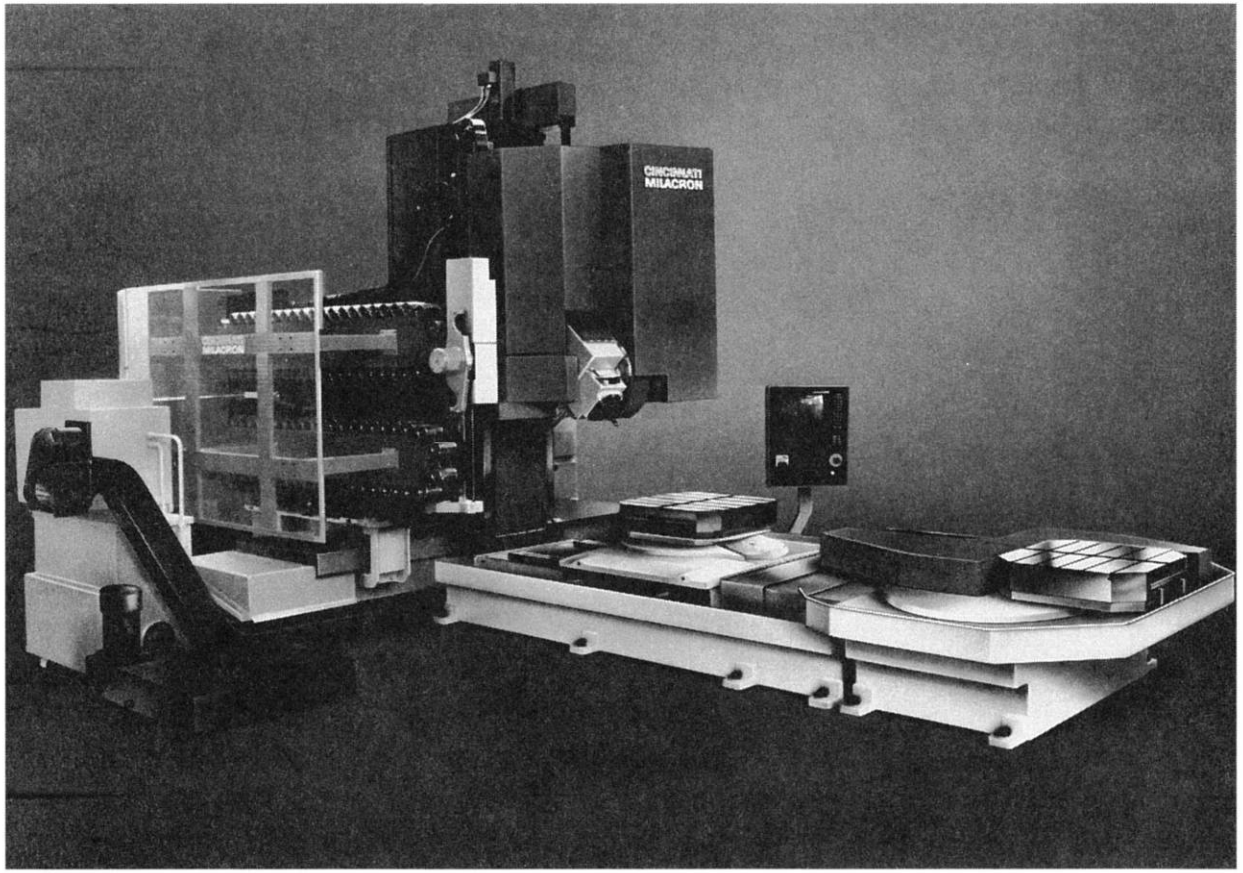
Machining Centers

Highly automated machine tool can perform multiple machining operations under CNC control in one setup with minimal human attention

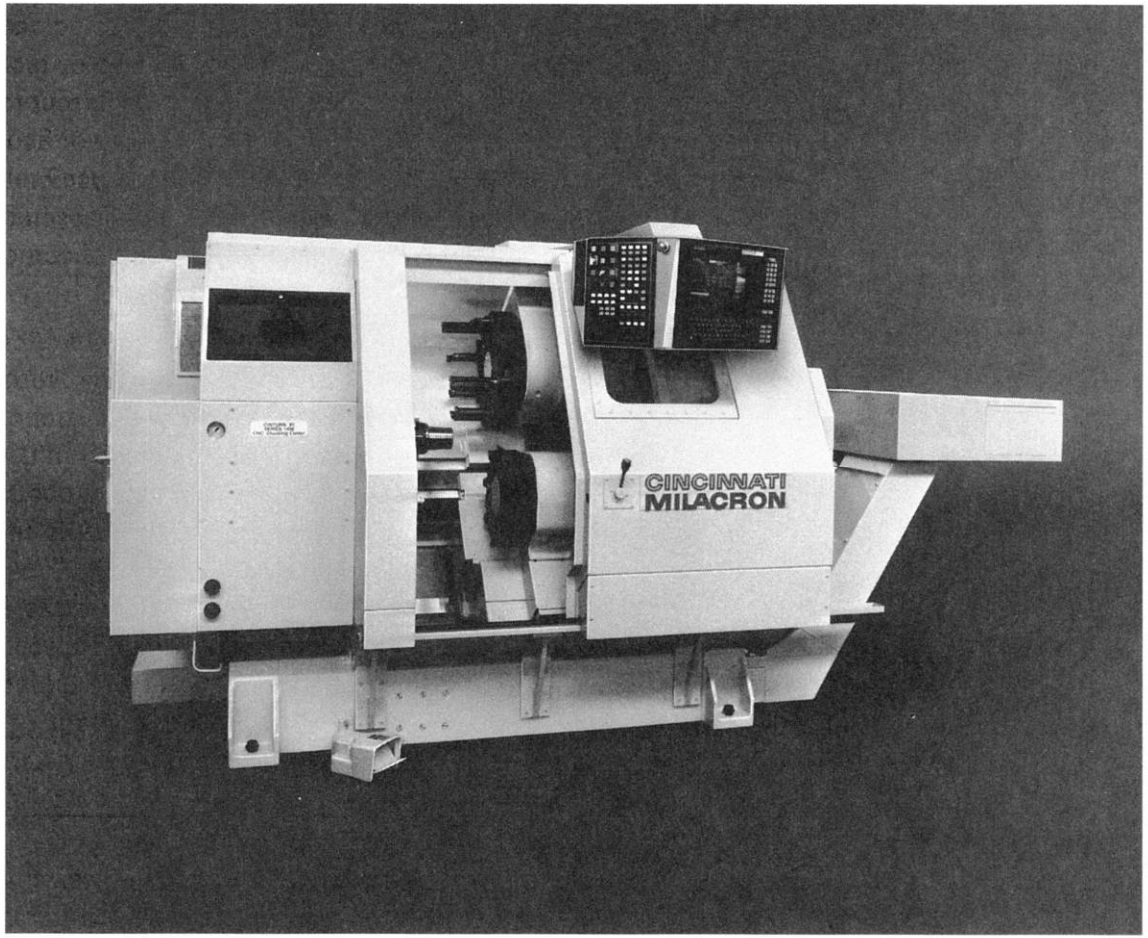
- Typical operations are milling and drilling
- Three, four, or five axes

- Other features:
  - Automatic tool-changing
  - Automatic workpart positioning





Universal machining center; highly automated, capable of multiple machining operations under computer control in one setup with minimal human attention

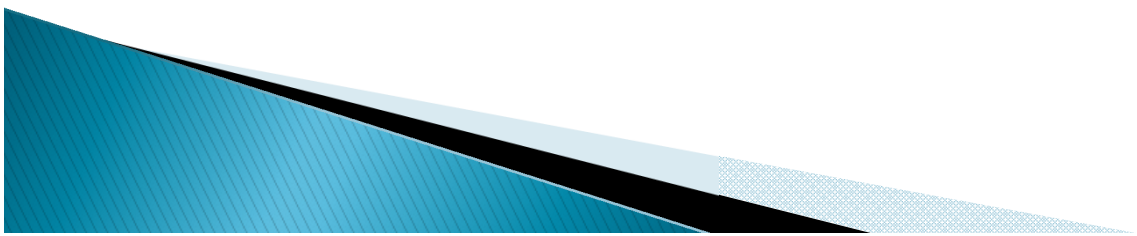


CNC 4-axis turning center; capable of turning and related operations, contour turning, and automatic tool indexing, all under computer control.

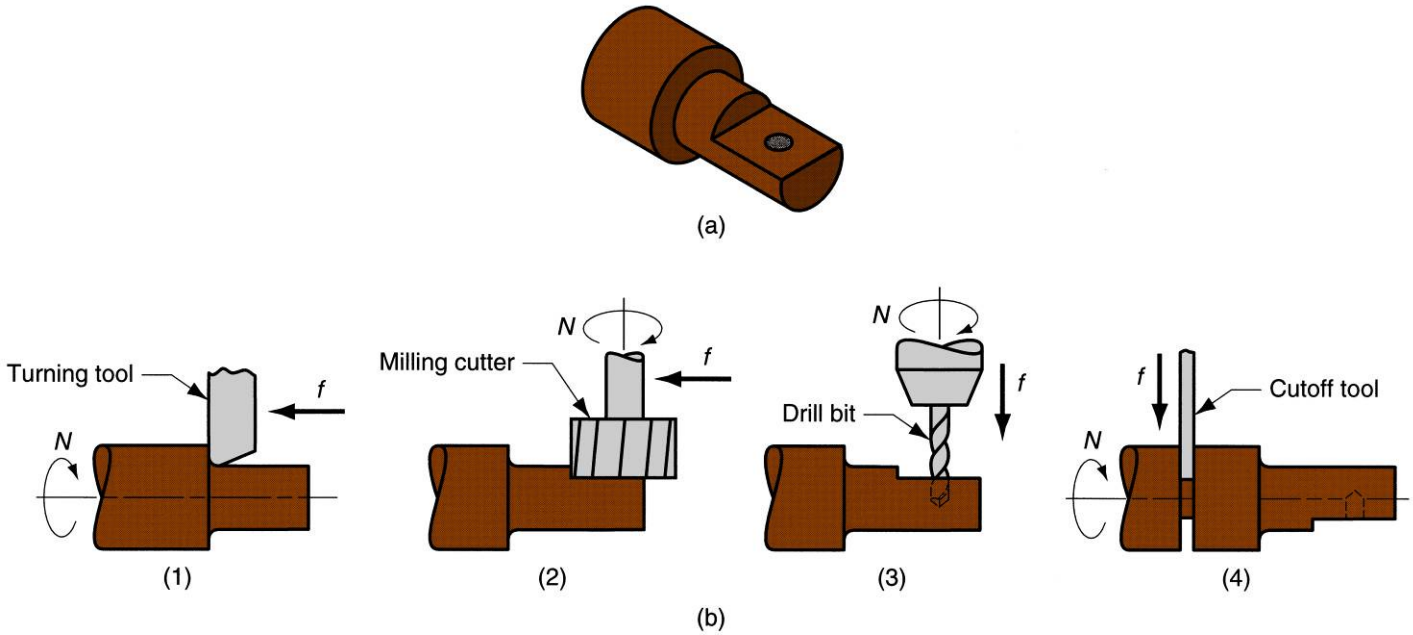
Mill–Turn Centers

Highly automated machine tool that can perform turning, milling, and drilling operations

- General configuration of a turning center
- Can position a cylindrical workpart at a specified angle so a rotating cutting tool (e.g., milling cutter) can machine features into outside surface of part
  - Conventional turning center cannot stop workpart at a defined angular position and does not include rotating tool spindles



Operation of Mill-Turn Center

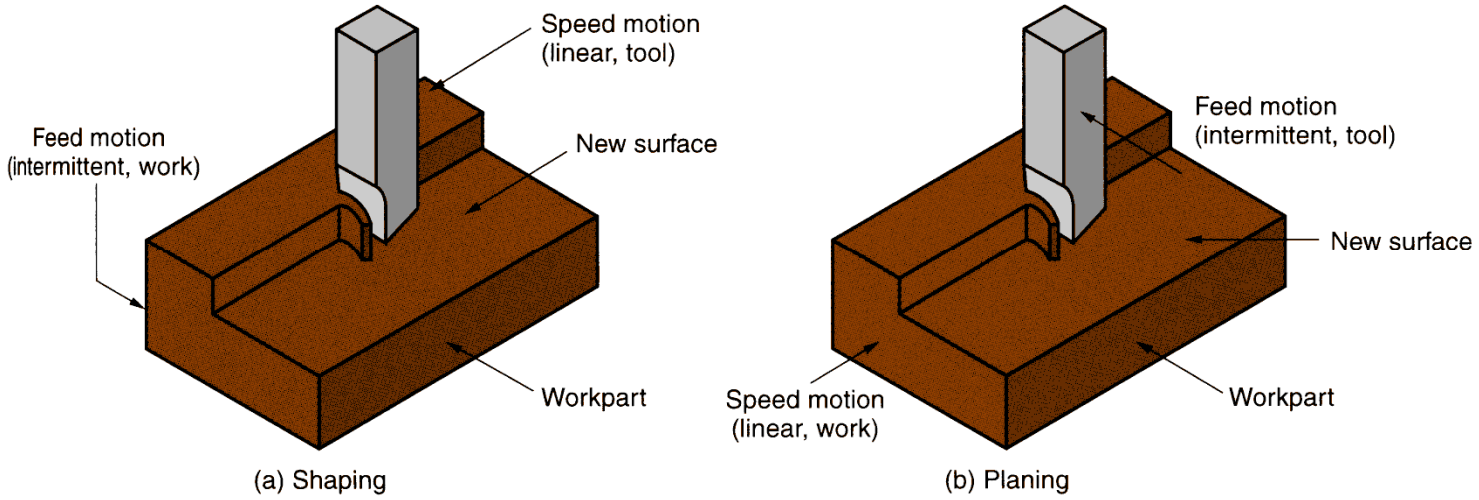


Operation of a mill-turn center: (a) example part with turned, milled, and drilled surfaces; and (b) sequence of operations on a mill-turn center: (1) turn second diameter, (2) mill flat with part in programmed angular position, (3) drill hole with part in same programmed position, and (4) cutoff.

Video Mill-Turn Center

Shaping and Planing

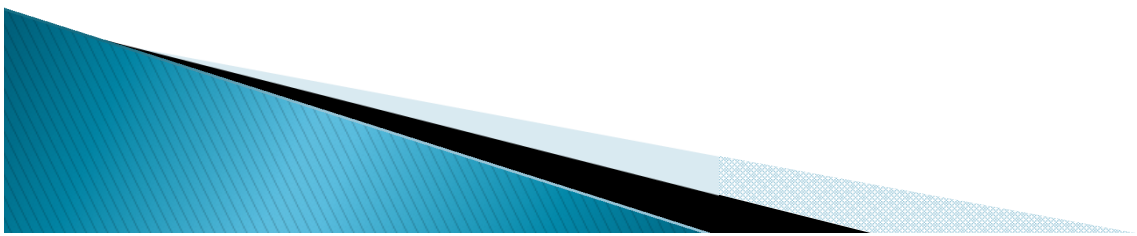
- Similar operations
- Both use a single point cutting tool moved linearly relative to the workpart



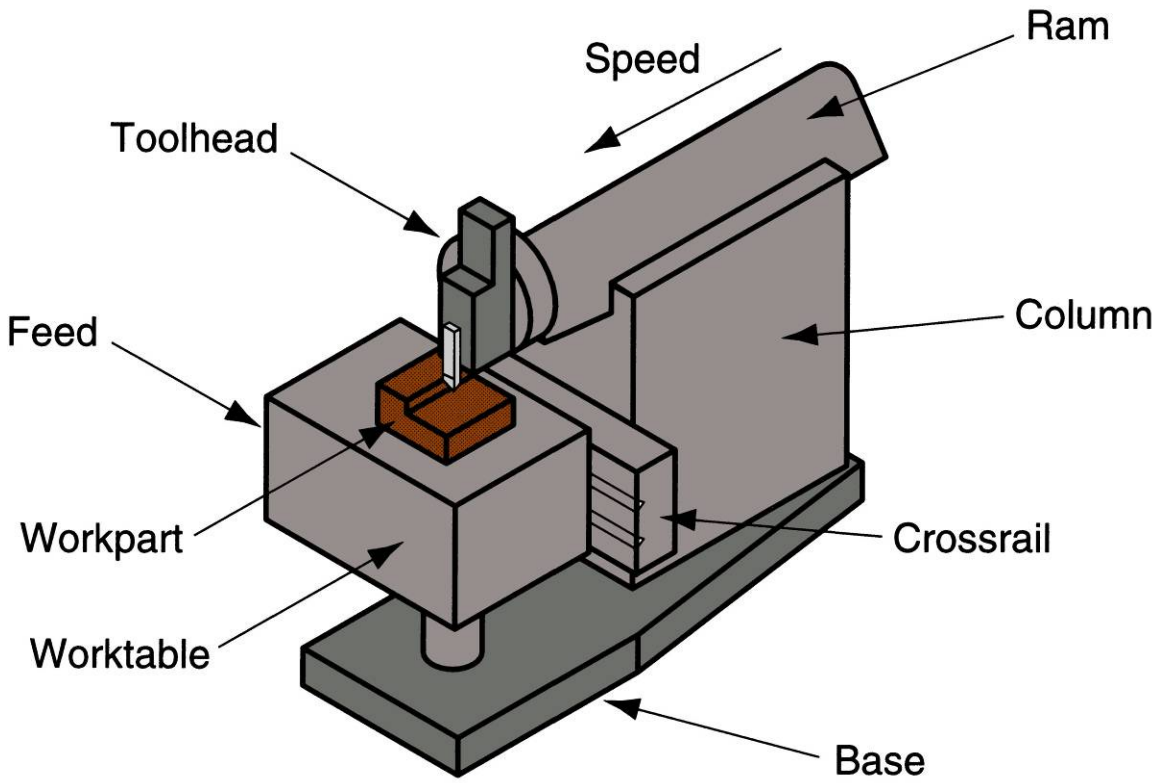
(a) Shaping, and (b) planing.

Shaping and Planing

- A straight, flat surface is created in both operations
- Interrupted cutting
  - Subjects tool to impact loading when entering work
- Low cutting speeds due to start-and-stop motion
- Typical tooling: single point high speed steel tools

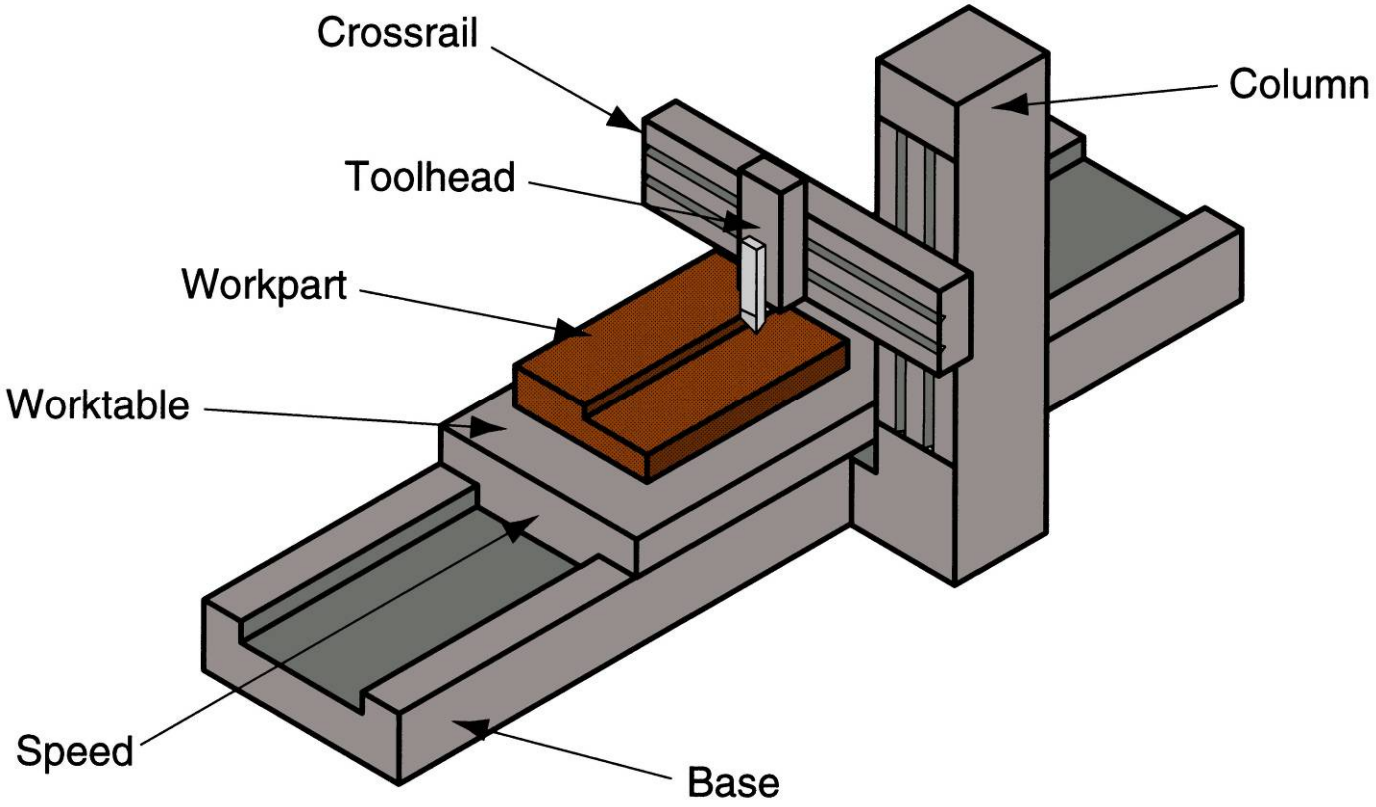


Shaper



Components of a shaper.

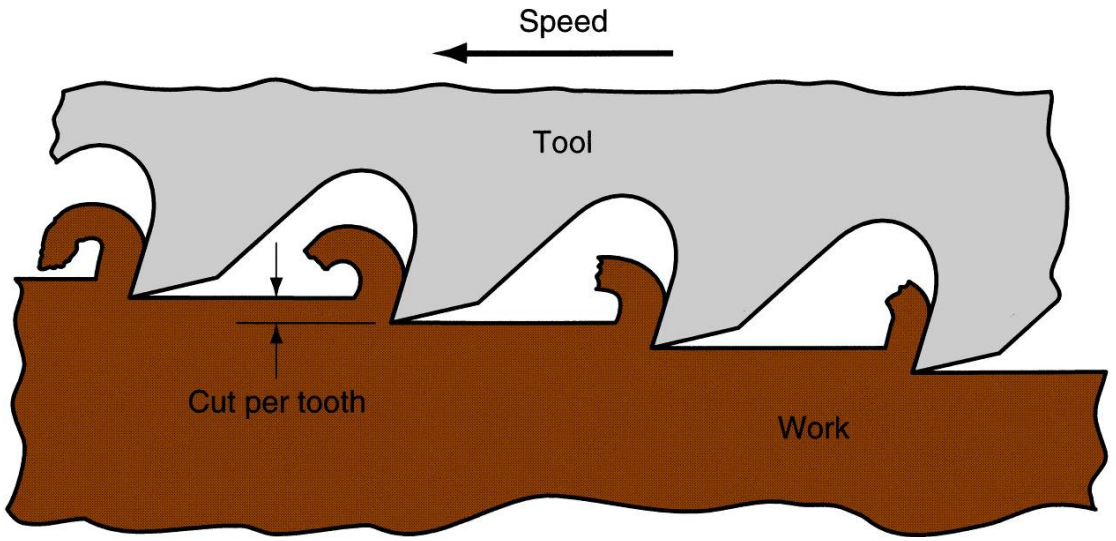
Planer

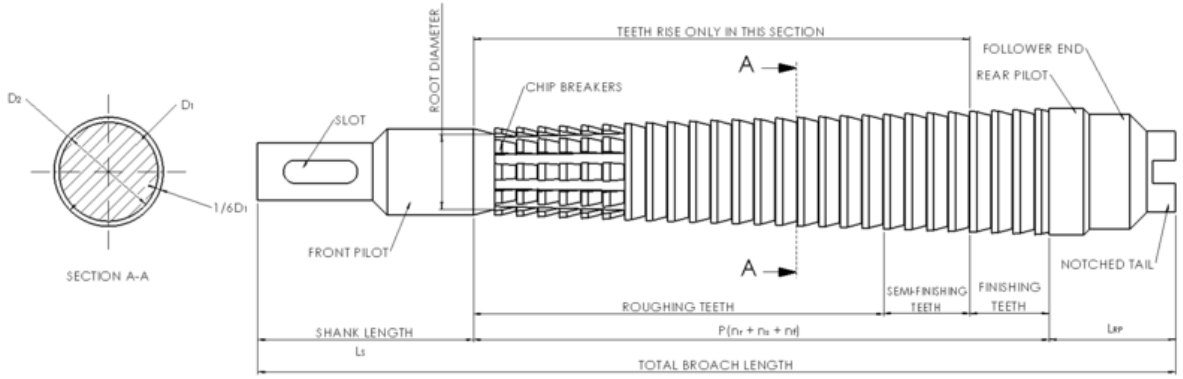


Open side planer.

Broaching

- Moves a multiple tooth cutting tool linearly relative to work in direction of tool axis





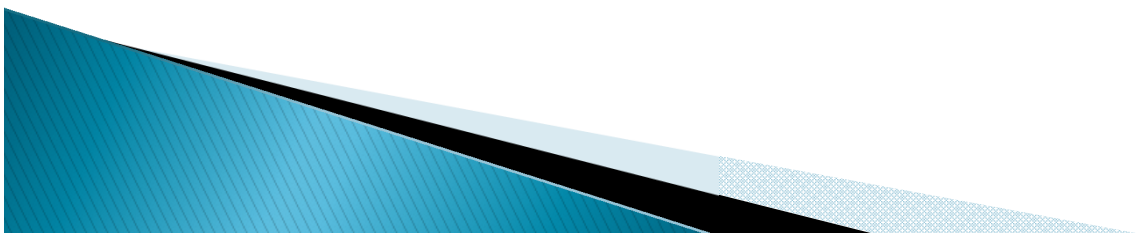
Broaching

Advantages:

- Good surface finish
- Close tolerances
- Variety of work shapes possible

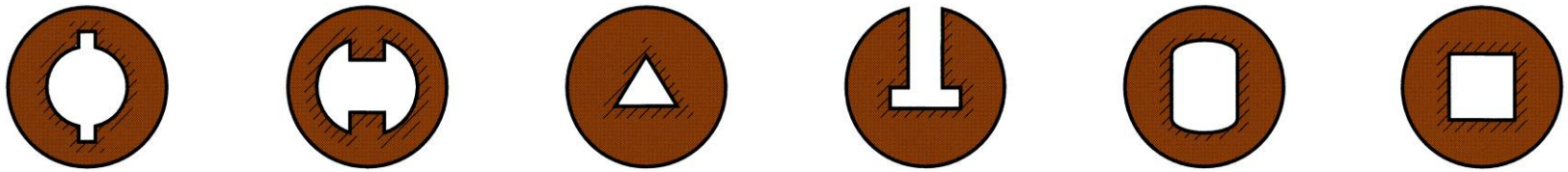
Cutting tool called a ***broach***

- Owing to complicated and often custom-shaped geometry, tooling is expensive



Internal Broaching

- Performed on internal surface of a hole
- A starting hole must be present in the part to insert broach at beginning of stroke



(b)

Work shapes that can be cut by internal broaching; cross-hatching indicates the surfaces broached.