- **Bending**. Bending involves straining of a metal sheet or plate to take an angle along a (usually) straight axis.

- **Drawing**. In sheet metalworking, drawing refers to the forming of a flat metal sheet into a hollow or concave shape, such as a cup, by stretching the metal. A blankholder is used to hold down the blank while the punch pushes into the sheet metal, as shown in Figure 18.3(b). To distinguish this operation from bar and wire drawing, the terms cup drawing or deep drawing are often used.

- **Shearing**. This process seems somewhat out-of-place in a list of deformation processes, because it involves cutting rather than forming. A shearing operation cuts the work using a punch and die, as in Figure 18.3(c). Although it is not a forming process, it is included here because it is a necessary and very common operation in sheet metalworking.

Joining

- The term joining is generally used for welding, brazing, soldering, and adhesive bonding, which form a permanent joint between the parts—a joint that cannot easily be separated.

- The term assembly usually refers to mechanical methods of fastening parts together.

Welding

- Welding is a materials joining process in which two or more parts are coalesced at their contacting surfaces by a suitable application of heat and/or pressure.
- Many welding processes are accomplished by heat alone, with no pressure applied; others by a combination of heat and pressure; and still others by pressure alone, with no external heat supplied. In some welding processes a filler material is added to facilitate coalescence.

- The assemblage of parts that are joined by welding is called a weldment. Welding is most commonly associated with metal parts, but the process is also used for joining plastics.

Advantages of Welding

- Welding provides a permanent joint.
- The welded parts become a single entity. The welded joint can be stronger than the parent materials if a filler metal is used that has strength properties superior to those of the parents, and if proper welding techniques are used.
- Welding is usually the most economical way to join components in terms of material usage and fabrication costs. Alternative mechanical methods of assembly require more complex shape alterations (e.g., drilling of holes) and addition of fasteners (e.g., rivets or bolts). The resulting mechanical assembly is usually heavier than a corresponding weldment.
- Welding is not restricted to the factory environment. It can be accomplished ‘‘in the field.’’

Disadvantages of Welding

- Most welding operations are performed manually and are expensive in terms of labor cost. Many welding operations are considered ‘‘skilled trades,’’ and the labor to perform these operations may be scarce.
- Most welding processes are inherently dangerous because they involve the use of high energy.
- Since welding accomplishes a permanent bond between the components, it does not allow for convenient disassembly. If the product must occasionally be disassembled (e.g., for repair or maintenance), then welding should not be used as the assembly method.
- The welded joint can suffer from certain quality defects that are difficult to detect. The defects can reduce the strength of the joint.

TYPES OF WELDING PROCESSES

- They use various types or combinations of energy to provide the required power.
- We can divide the welding processes into two major groups:
- (1) fusion welding and
- (2) solid-state welding.

Fusion Welding

- Fusion-welding processes use heat to melt the base metals. In many fusion welding operations, a filler metal is added to the molten pool to facilitate the process and provide bulk and strength to the welded joint. A fusion-welding operation in which no filler metal is added is referred to as an autogenous weld. The fusion category includes the most widely used welding processes, which can be organized into the following general groups

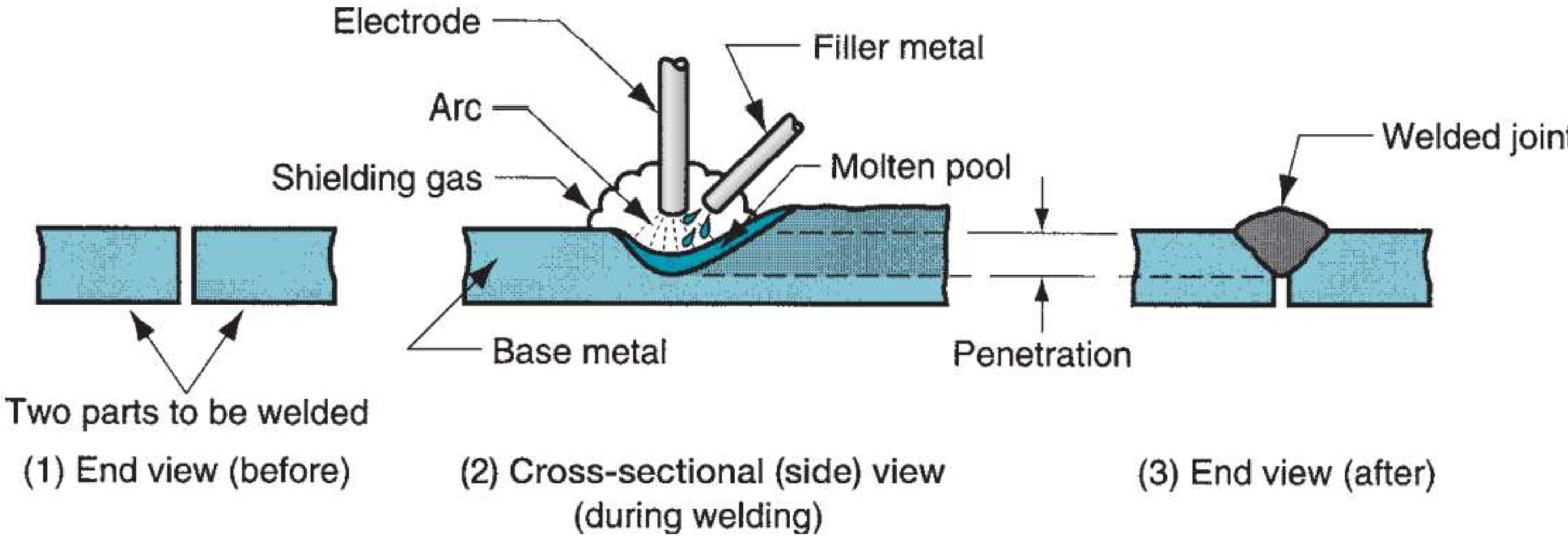
- **Arc welding (AW).** Arc welding refers to a group of welding processes in which heating of the metals is accomplished by an electric arc, as shown in Figure 29.1. Some arcwelding operations also apply pressure during the process and most utilize a filler metal. Resistance welding (RW).
- **Resistance welding** achieves coalescence using heat from electrical resistance to the flow of a current passing between the faying surfaces of two parts held together under pressure.
- **Oxyfuel gas welding (OFW).** These joining processes use an oxyfuel gas, such as a mixture of oxygen and acetylene, to produce a hot flame for melting the base metal and filler metal, if one is used.
- Other welding processes that produce fusion of the metals joined include **electron beam welding** and **laser beam welding**.

Solid-State Welding

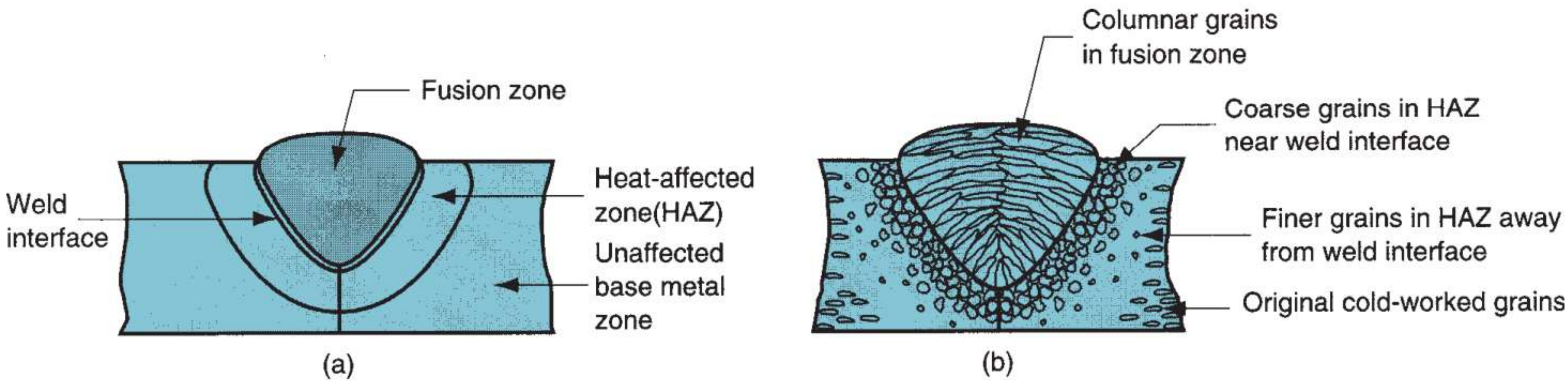
- Solid-state welding refers to joining processes in which coalescence results from application of pressure alone or a combination of heat and pressure. If heat is used, the temperature in the process is below the melting point of the metals being welded. No filler metal is utilized. Representative welding processes in this group include:

- Diffusion welding (DFW). Two surfaces are held together under pressure at an elevated temperature and the parts coalesce by solid-state diffusion.

- Friction welding (FRW). Coalescence is achieved by the heat of friction between two surfaces.
- Ultrasonic welding (USW). Moderate pressure is applied between the two parts and an oscillating motion at ultrasonic frequencies is used in a direction parallel to the contacting surfaces. The combination of normal and vibratory forces results in shear stresses that remove surface films and achieve atomic bonding of the surfaces.

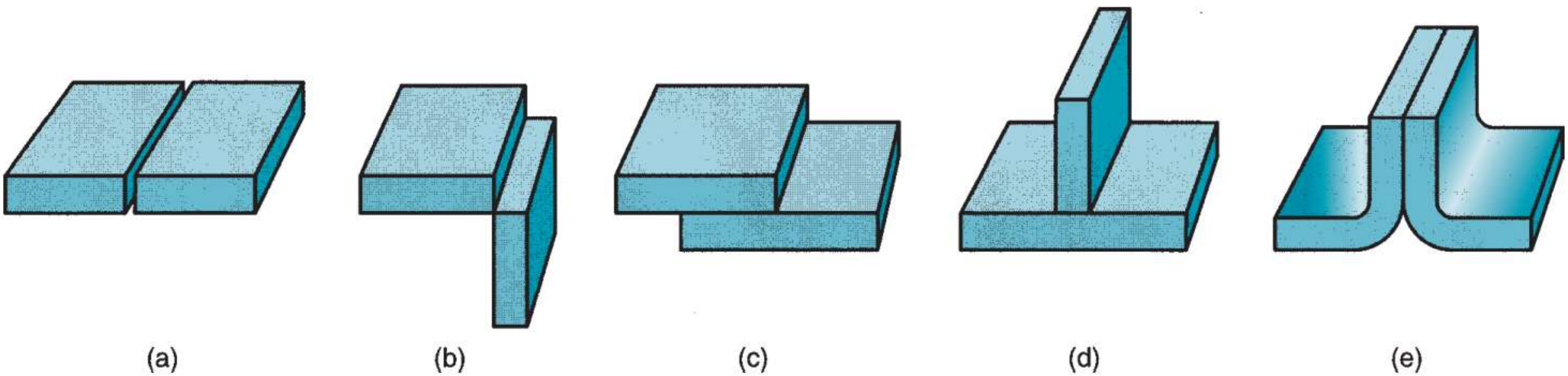


Basics of arc welding: (1) before the weld; (2) during the weld (the base metal is melted and filler metal is added to the molten pool); and (3) the completed weldment. There are many variations of the arc-welding process.



Cross section of a typical fusion-welded joint: (a) principal zones in the joint and (b) typical grain structure.

TYPES OF JOINTS



Five basic types of joints: (a) butt, (b) corner, (c) lap, (d) tee, and (e) edge.

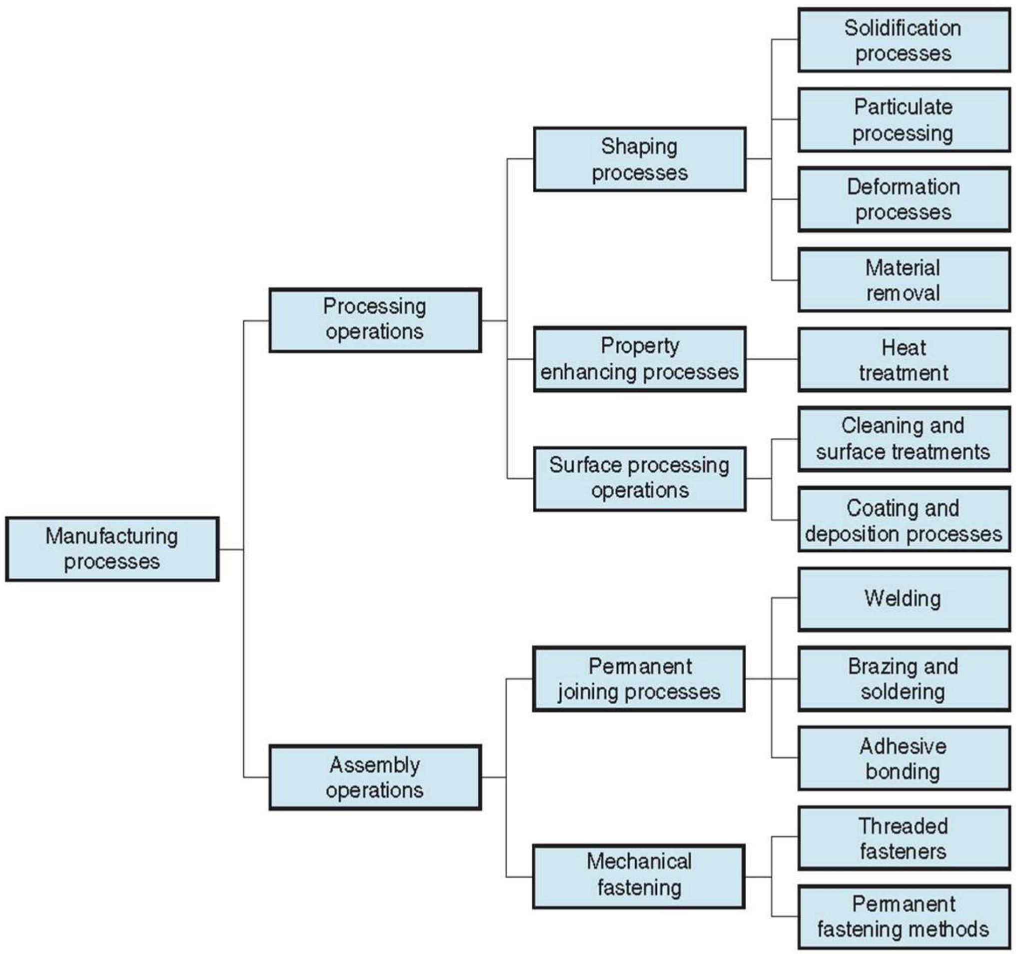
TYPES OF JOINTS

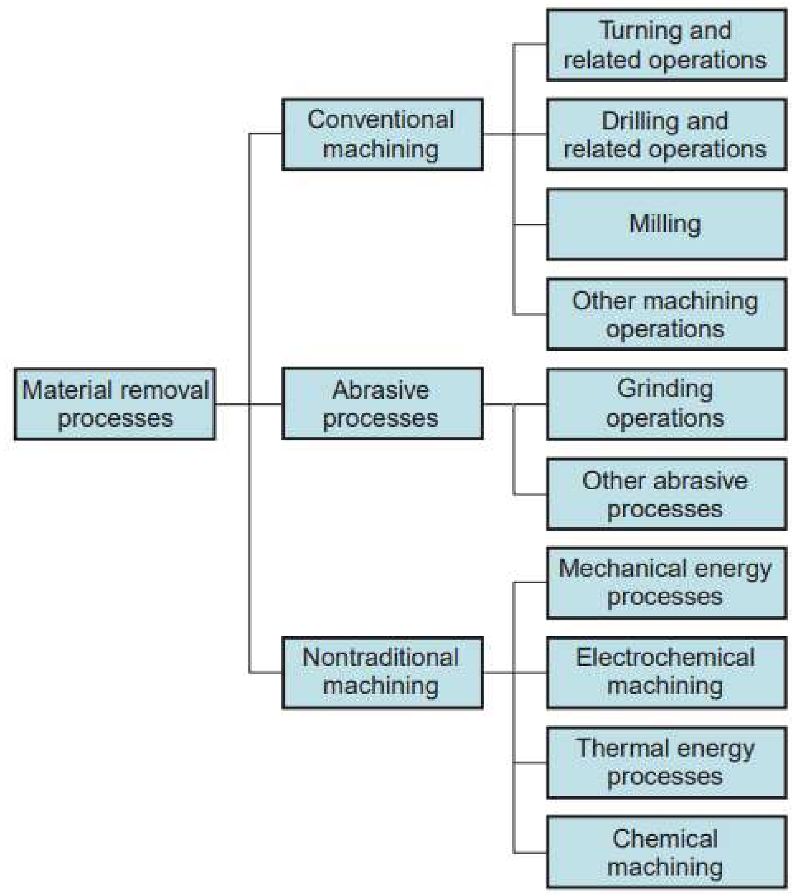
- (a) Butt joint. In this joint type, the parts lie in the same plane and are joined at their edges.
- (b) Corner joint. The parts in a corner joint form a right angle and are joined at the corner of the angle.
- (c) Lap joint. This joint consists of two overlapping parts.
- (d) Tee joint. In a tee joint, one part is perpendicular to the other in the approximate shape of the letter ‘‘T.’’
- (e) Edge joint. The parts in an edge joint are parallel with at least one of their edges in common, and the joint is made at the common edge(s).

Material Removal Processes

- The material removal processes are a family of shaping operations (Figure) in which excess material is removed from a starting workpart so that what remains is the desired final geometry.
- The ‘‘family tree’’ is shown in Figure.

- The most important branch of the family is conventional machining, in which a sharp cutting tool is used to mechanically cut the material to achieve the desired geometry

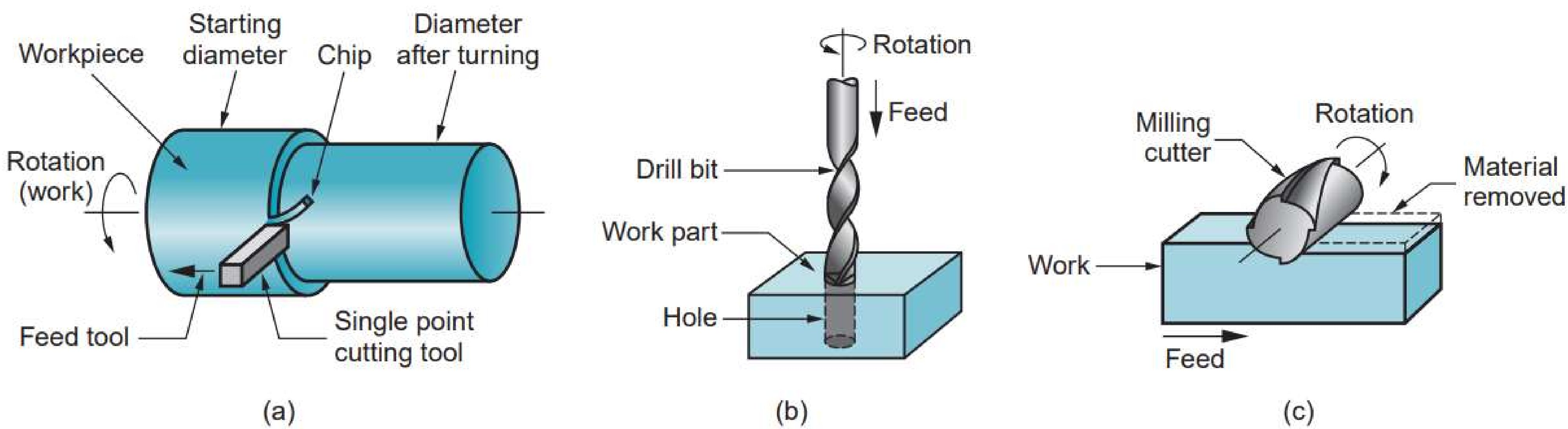

Manufacturing processes
Processing operations
Shaping processes
Solidification processes
Particulate processing
Deformation processes
Material removal
Property enhancing processes
Heat treatment
Surface processing operations
Cleaning and surface treatments
Coating and deposition processes
Assembly operations
Permanent joining processes
Welding
Brazing and soldering
Adhesive bonding
Mechanical fastening
Threaded fasteners
Permanent fastening methods


Material removal processes
Conventional machining
Turning and related operations
Drilling and related operations
Milling
Other machining operations
Abrasive processes
Grinding operations
Other abrasive processes
Nontraditional machining
Mechanical energy processes
Electrochemical machining
Thermal energy processes
Chemical machining

Material Removal Processes

- Excess material removed from the starting piece so what remains is the desired geometry
- Examples: (a) turning, (b) drilling, and (c) milling

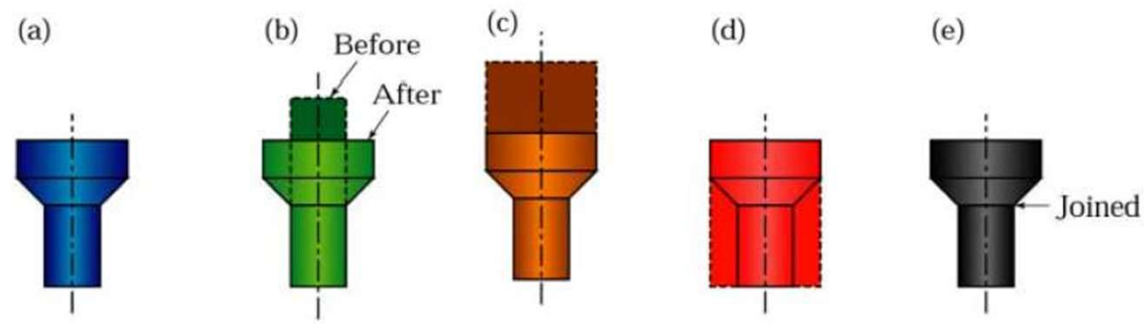
Common machining operations: (a) turning, in which a single-point cutting tool removes metal from a rotating workpiece to reduce its diameter; (b) drilling, in which a rotating drill bit is fed into the work to create a round hole; and (c) milling, in which a workpart is fed past a rotating cutter with multiple edges.



Waste in Shaping Processes

- It is desirable to minimize waste in part shaping
- Material removal processes are wasteful in the unit operations, but molding and particulate processing operations waste little material
- Terminology for minimum waste processes:
  - *Net shape* processes - little or no waste of the starting material and no machining is required
  - *Near net shape* processes - when minimum machining is required

Manufacturing Process Selection



Various methods of making a simple part: (a) casting or powder metallurgy, (b) forging or upsetting, (c) extrusion, (d) machining, (e) joining two pieces (Mass Addition Process).

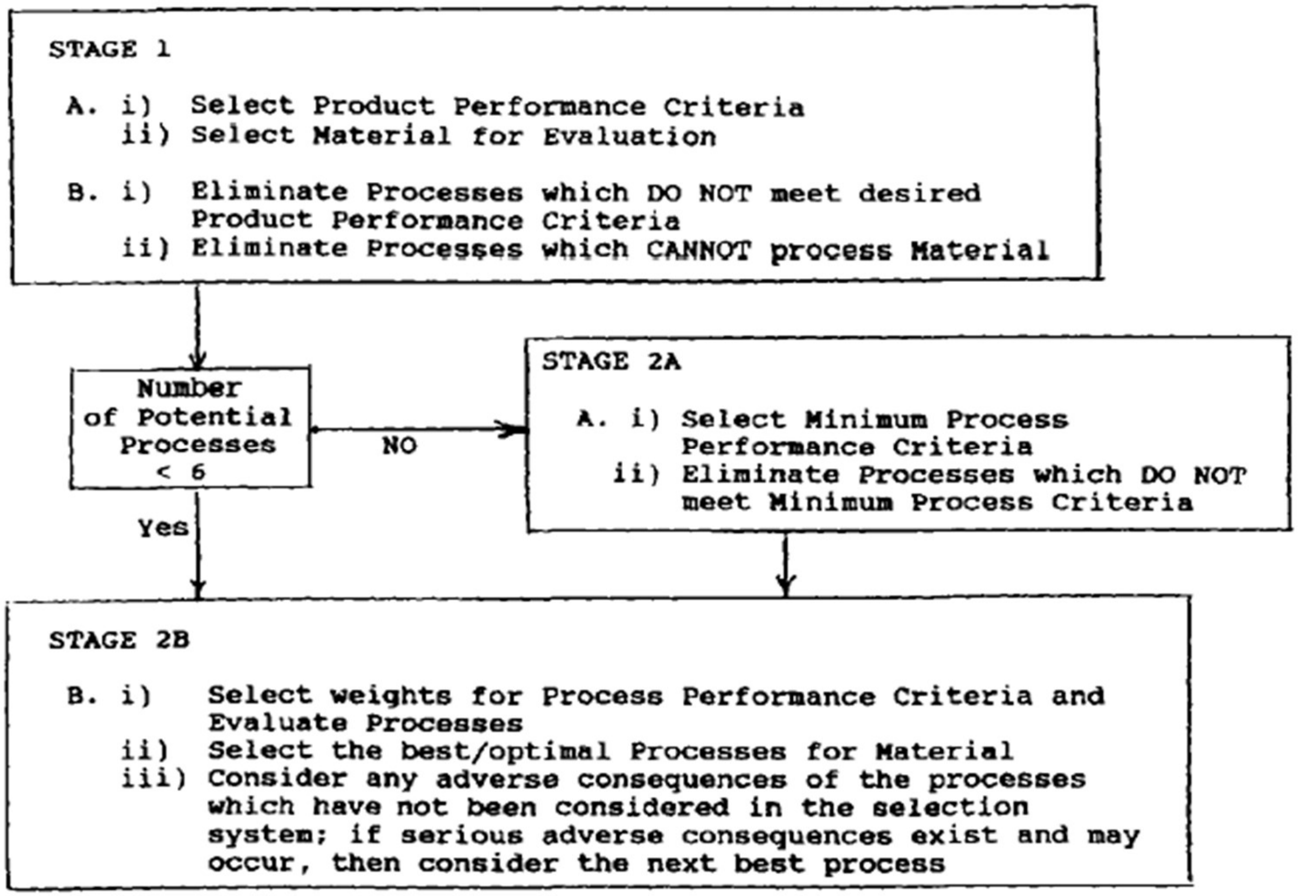
Manufacturing Process Selection

Two stage decision process

- "Feasible" stage ("must" stage)–
  - Can the shape be produced by the process?
  - Can the material be shaped by the process?
- "Optimal" stage ("want" stage) –
  - Eliminate processes that cannot meet the minimum acceptable process performance criteria.
  - Select the best process from the remaining processes under consideration by optimizing process performance criteria.

Process performance criteria: cycle time, material utilization, process flexibility, quality/reliability, operating costs, surface finish, tolerances.

Manufacturing Process Selection



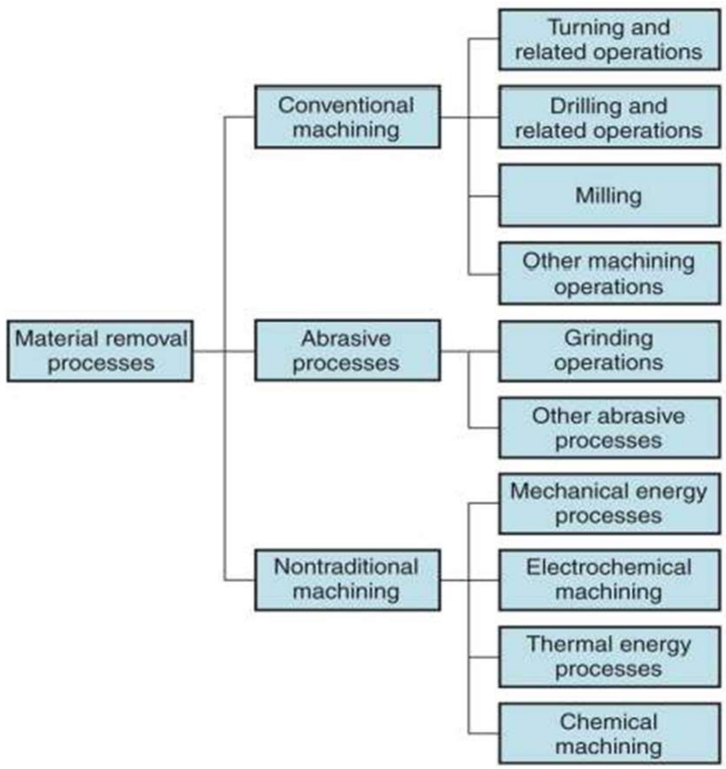
Material Removal Processes

A family of shaping operations, the common feature of which is removal of material from a starting work part so the remaining part has the desired geometry

- Machining – material removal by a sharp cutting tool, e.g., turning, milling, drilling
- Abrasive processes – material removal by hard, abrasive particles, e.g., grinding
- Nontraditional processes - various energy forms other than sharp cutting tool to remove material

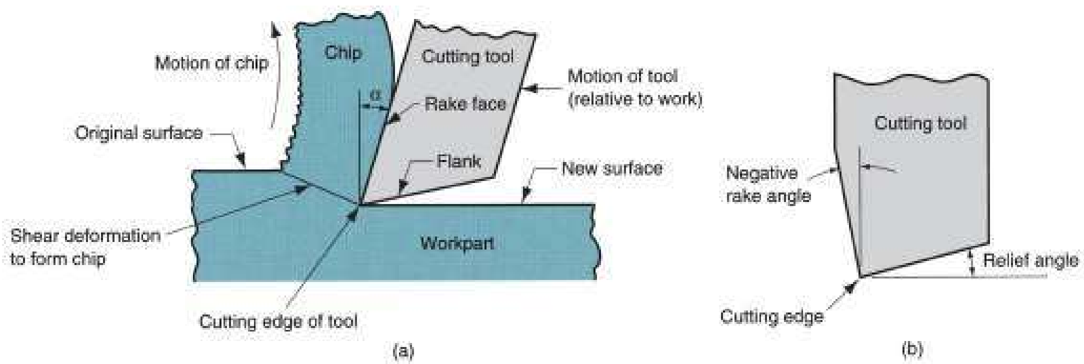
Material Removal Processes

- The family tree



Machining

- Cutting action involves shear deformation of work material to form a chip, and as chip is removed, new surface is exposed: (a) positive and (b) negative rake tools



Why Machining is Important?

- Variety of work materials can be machined
  - Most frequently used to cut metals
- Variety of part shapes and special geometric features possible:
  - Screw threads
  - Accurate round holes
  - Very straight edges and surfaces
- Good dimensional accuracy and surface finish

Disadvantages with Machining

- Wasteful of material
  - Chips generated in machining are wasted material
- Time consuming
  - A machining operation generally takes longer to shape a given part than alternative shaping processes

Machining in the Manufacturing Sequence

- Generally performed after other manufacturing processes, such as casting, forging, and bar drawing
  - Other processes create the general shape of the starting work part
  - Machining provides the final shape, dimensions, finish, and special geometric details that other processes cannot create

Machining Operations

- Most important machining operations:
  - Turning
  - Drilling
  - Milling
- Other machining operations:
  - Shaping and planing
  - Broaching
  - Sawing

MACHINING OPERATIONS

Classification of Machined Parts

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

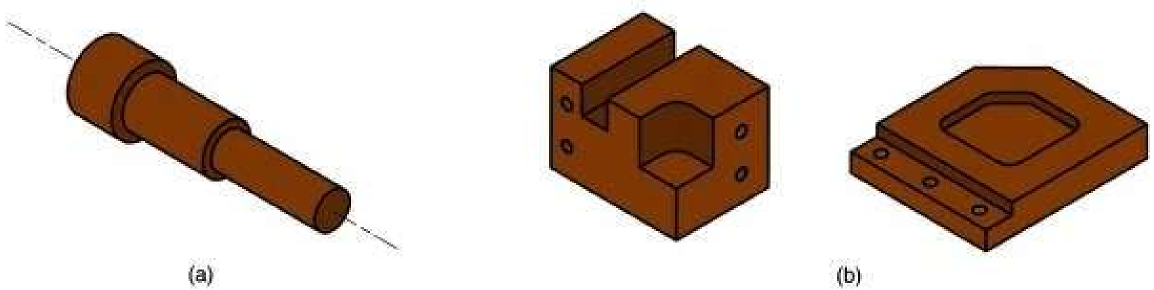


Figure - Machined parts are classified as: (a) rotational, or (b) nonrotational, shown here by block and flat parts

Machining Operations and Part Geometry

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

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

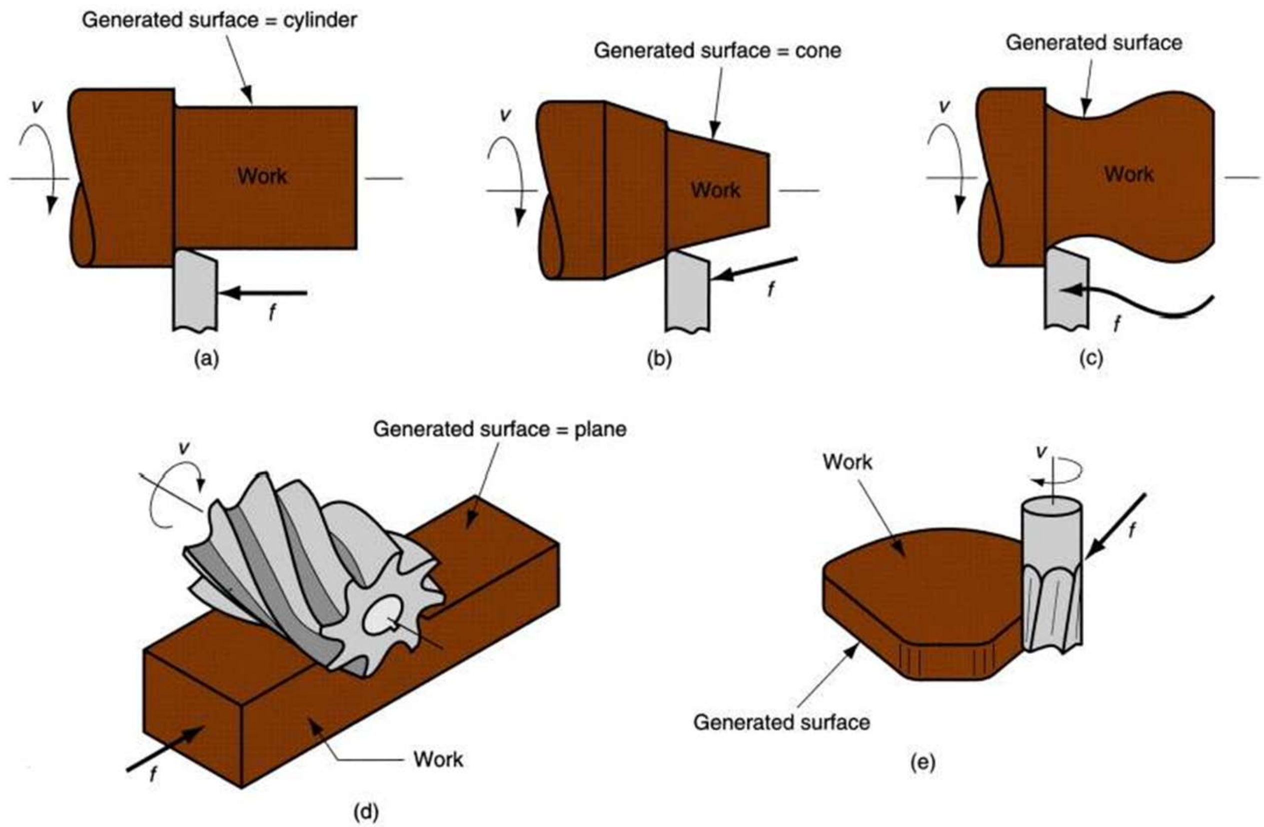


Figure - Generating shape: (a) straight turning, (b) taper turning, (c) contour turning, (d) plain milling, (e) profile milling

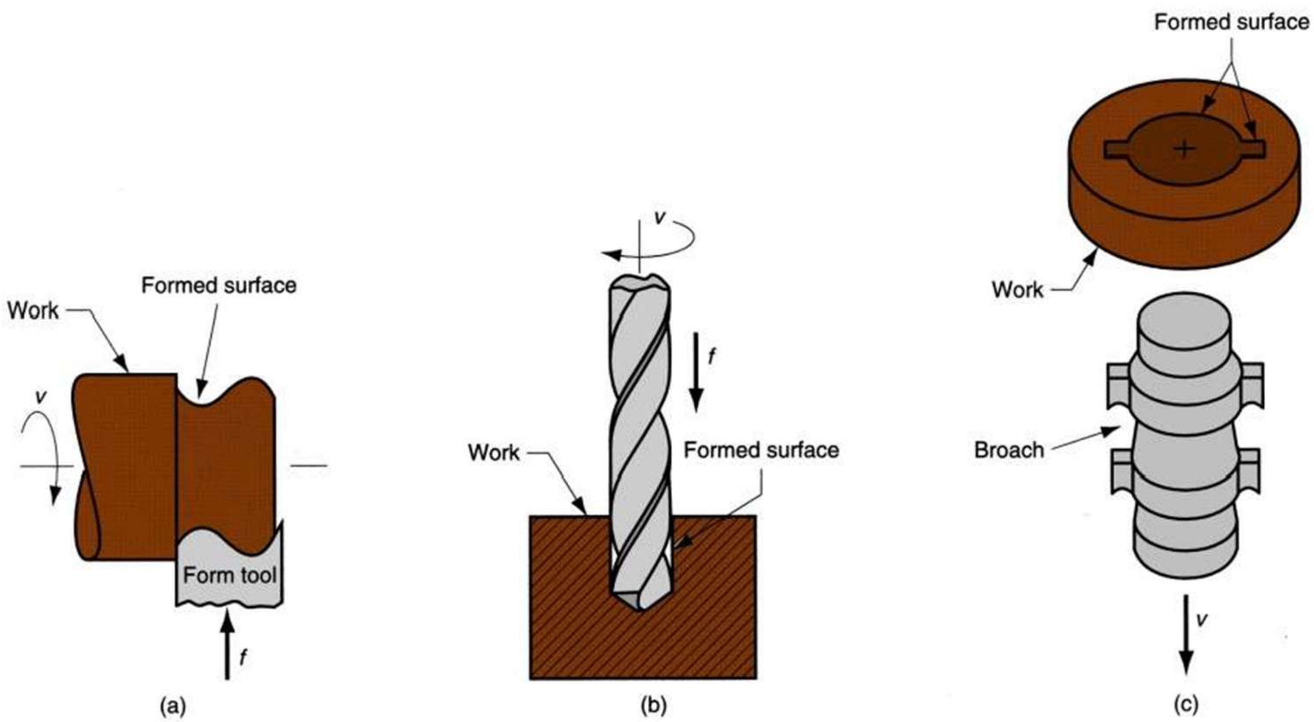


Figure - Forming to create shape: (a) form turning, (b) drilling, and (c) broaching

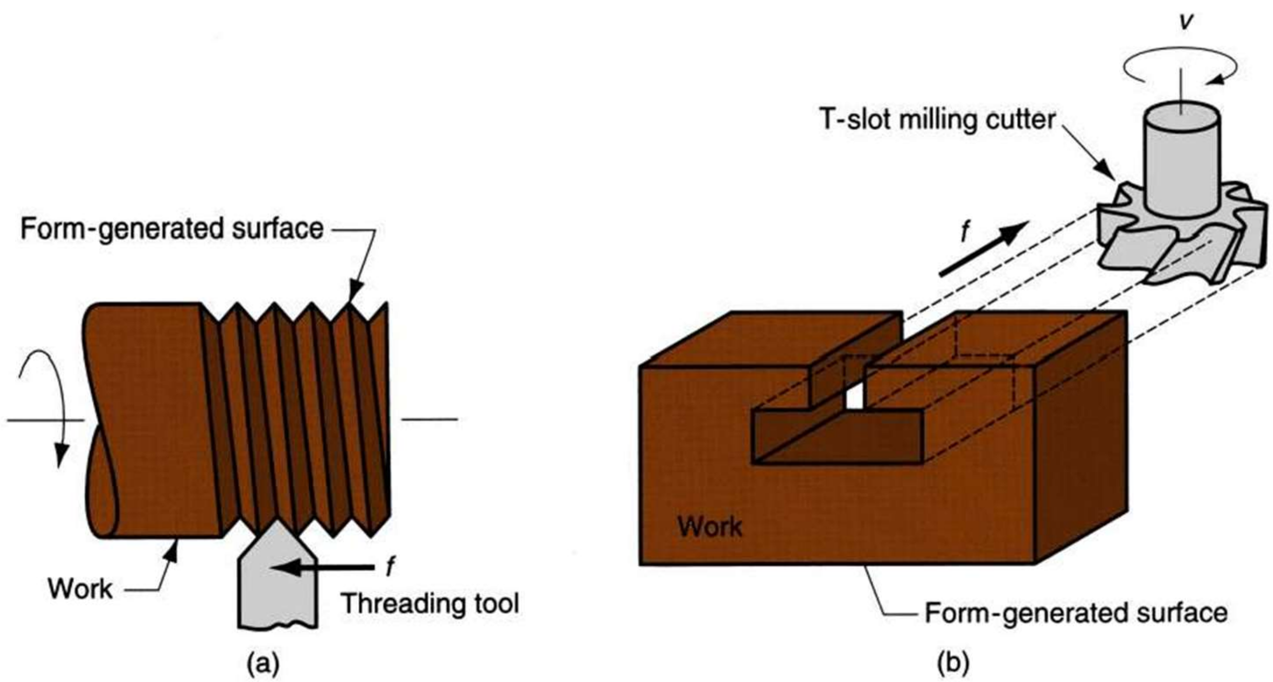
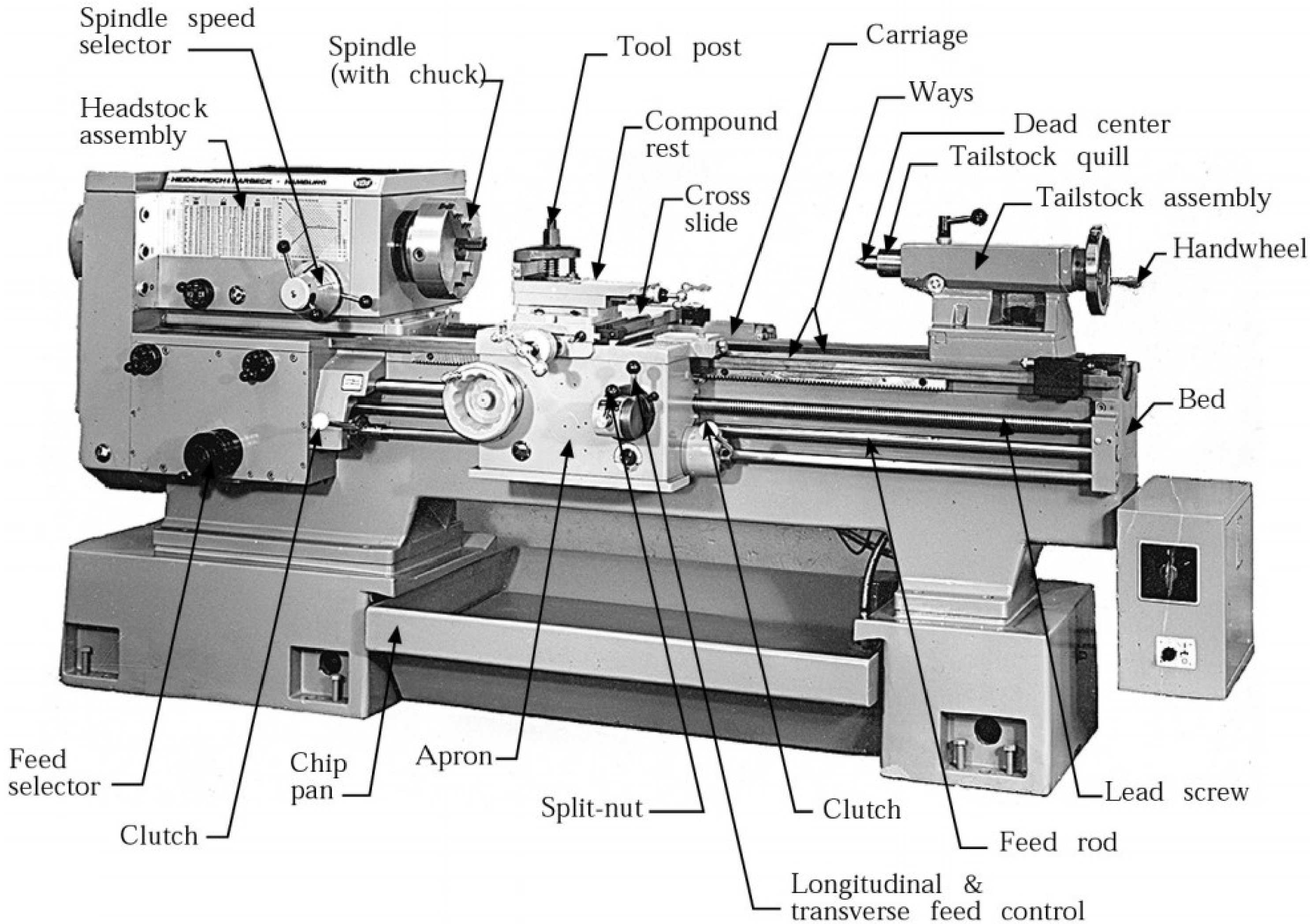


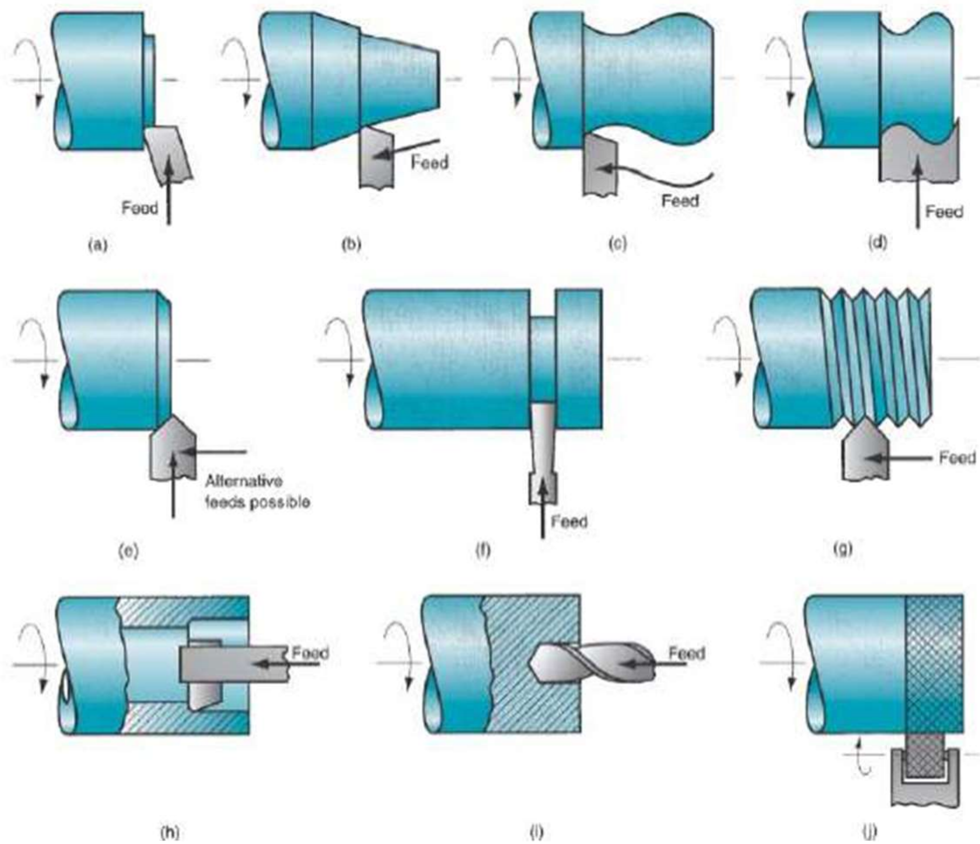
Figure - Combination of forming and generating to create shape:
(a) thread cutting on a lathe, and (b) slot milling

Lathe Parts



Spindle speed selector
Spindle (with chuck)
Tool post
Carriage
Headstock assembly
Compound rest
Ways
Dead center
Tailstock quill
Cross slide
Tailstock assembly
Handwheel
Bed
Feed selector
Chip pan
Apron
Lead screw
Split-nut
Clutch
Clutch
Feed rod
Longitudinal & transverse feed control

Operations Performed on Lathe (Other than Turning)



(a) facing
b) taper turning
(c) contour turning
(d) form turning
(e) chamfering
(f) cutoff
(g) threading
(h) Boring
(i) drilling
(j) knurling

Operations Performed on Lathe (Other than Turning)

Facing: Tool is fed radially inward to create a flat surface

Taper turning: The tool is fed at an angle instead of feeding parallel to the axis of rotation of work

Contour turning: Instead of feeding the tool parallel to the axis of rotation, tool follows a contour that is other than straight, thus creating a contoured form

Form turning: The tool has a shape that is imparted to the work by plunging the tool radially into work

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

Operations Performed on Lathe (Other than Turning)

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

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

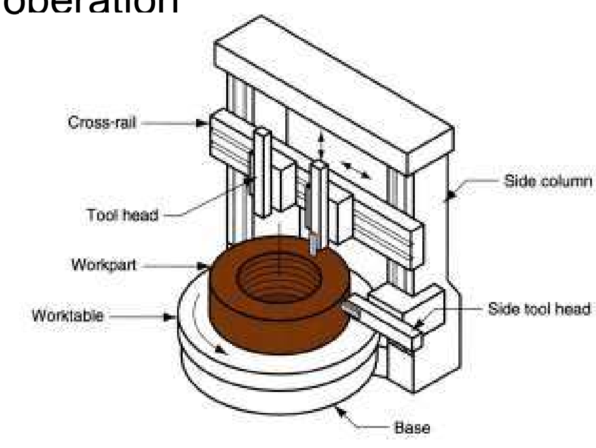
Boring: The tool is fed parallel to the axis of rotation on the inside diameter of an existing hole

Drilling: Drill is fed into the rotating work along its axis

Knurling: Used to produce a regular cross-hatched pattern in the work surface. Not a machining operation.

Boring

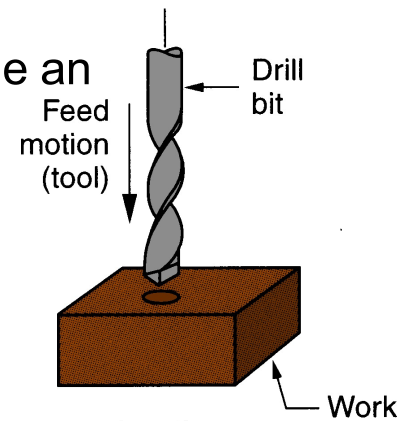
- Difference between boring and turning:
  - *Boring* is performed on the inside diameter of an existing hole
  - *Turning* is performed on the outside diameter of an existing cylinder
- In effect, boring is an internal turning operation
- Boring machines
  - Horizontal or vertical – refers to the orientation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



Drilling

Creates a round hole in a workpart

- Contrasts with boring which can only enlarge an existing hole
- Cutting tool called a *drill* or *drill bit*
- Customarily performed on a *drill press*

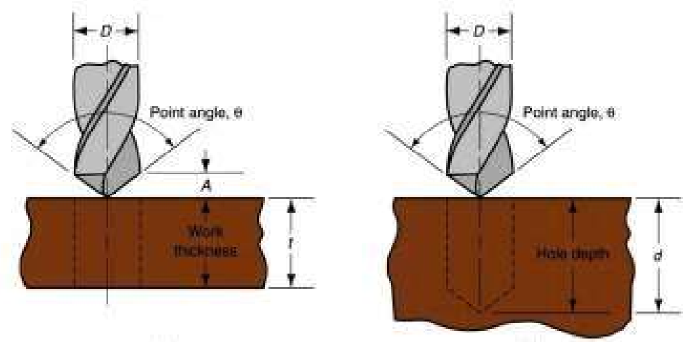


Through-holes

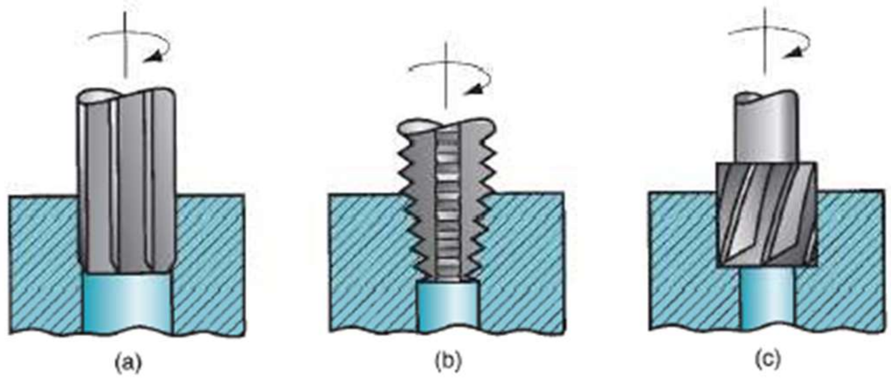
drill exits the opposite side of work

Blind-holes

drill does not exit work on opposite side



Machining Operations Related to Drilling



(a) Reaming (b) Tapping (c) Counterboring

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

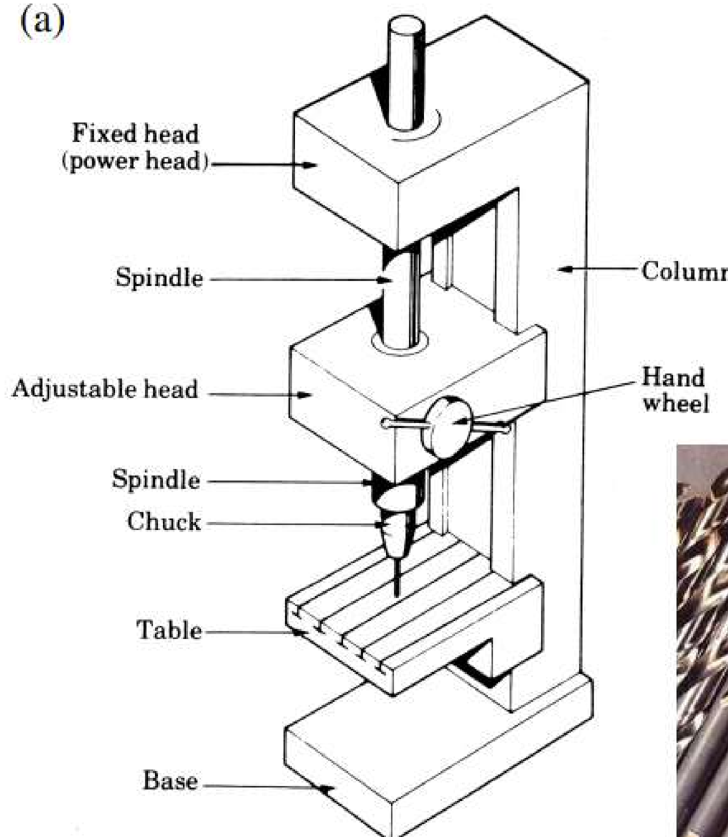
Tapping: Used to provide internal screw threads on an existing hole. Tool called a *tap*

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

Drilling


Clarke
METALWORKER

(a)


Fixed head
(power head)
Spindle
Adjustable head
Spindle
Chuck
Table
Base
Column
Hand
wheel

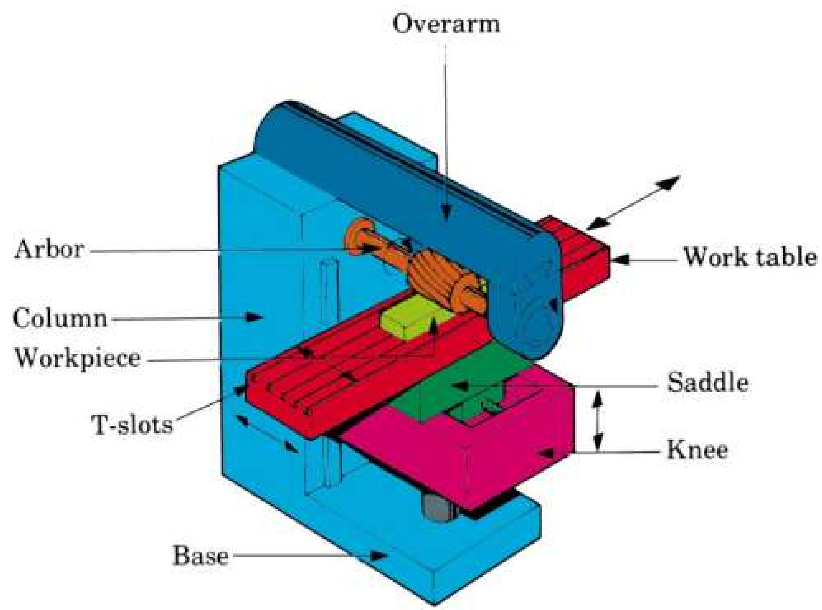

DRILL BITS

Milling

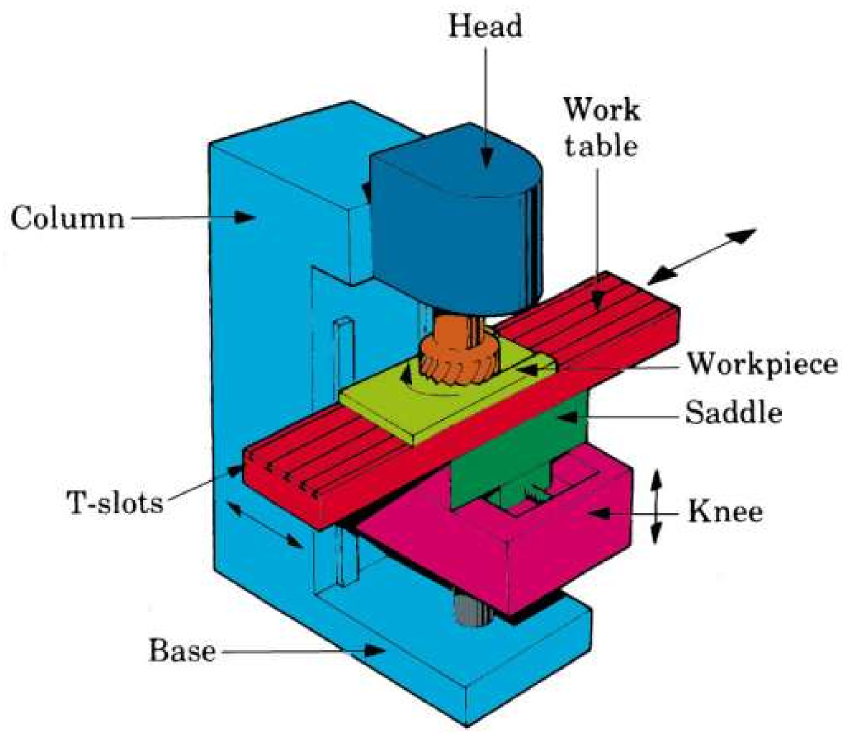
Machining operation in which work is fed past a rotating tool with multiple cutting edges

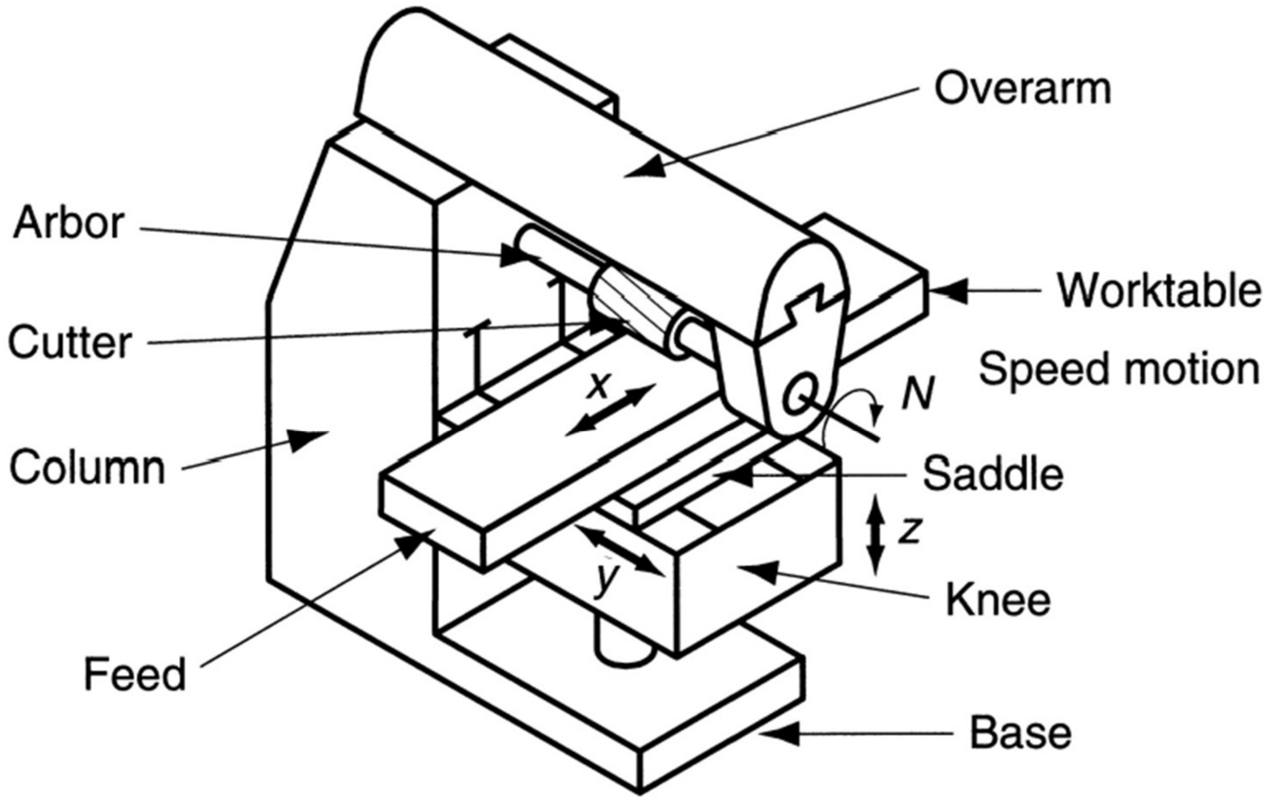
- Axis of tool rotation is perpendicular to feed direction
- Creates a planar surface; other geometries possible either by cutter path or shape
- Other factors and terms:
  - Milling is an *interrupted cutting* operation
  - Cutting tool called a *milling cutter,* cutting edges called "teeth"
  - Machine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

Horizontal Mill



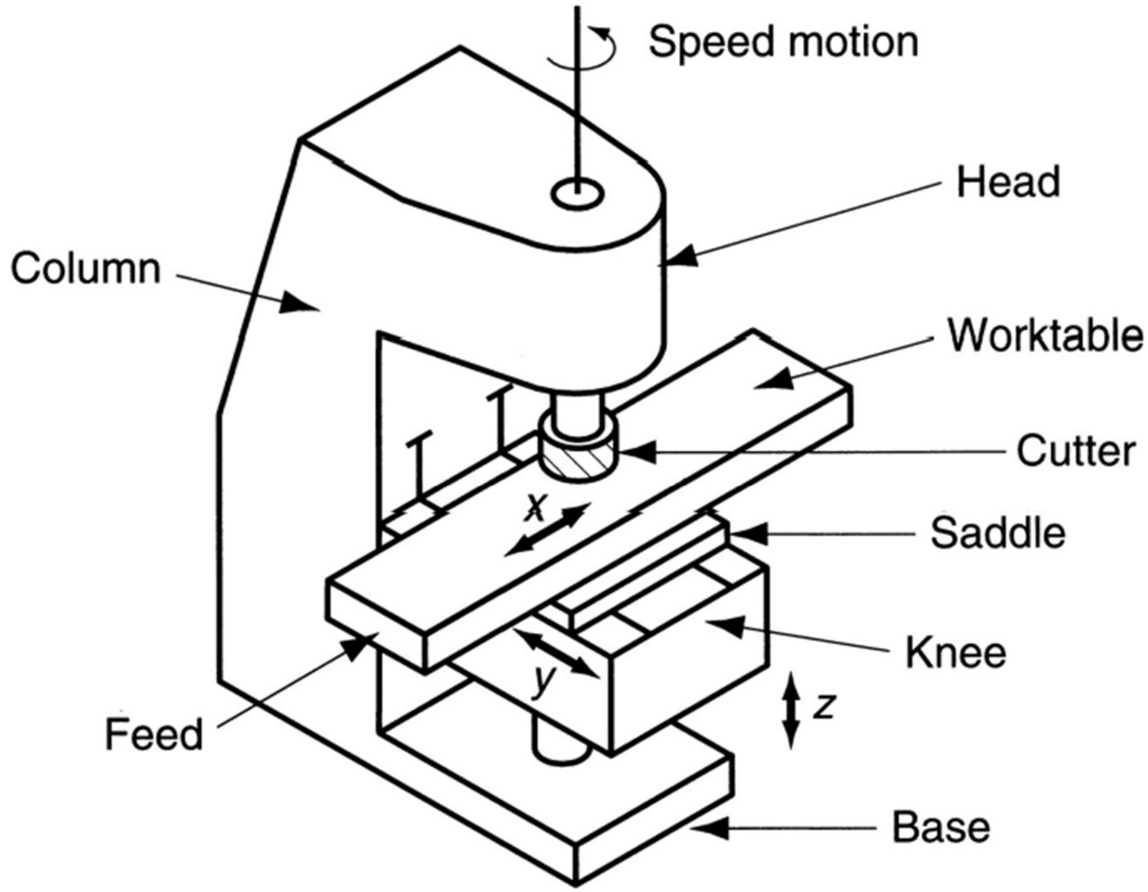
Vertical Mill





(a)

Figure (a) horizontal knee-and-column milling machine

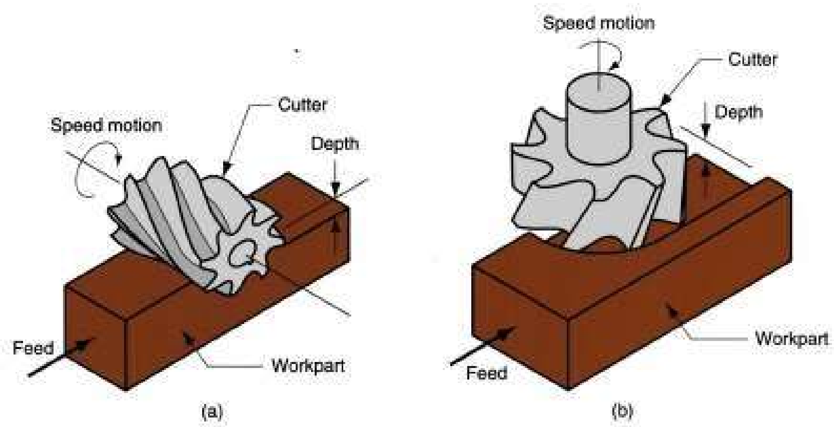


(b)

Figure (b) vertical knee-and-column milling machine

Peripheral Milling vs. Face Milling

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



Peripheral Milling

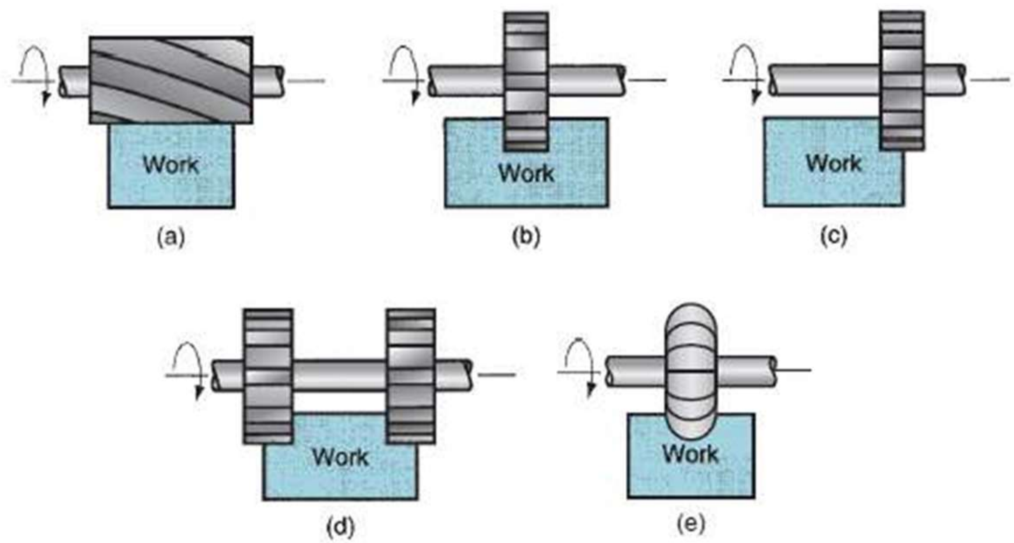
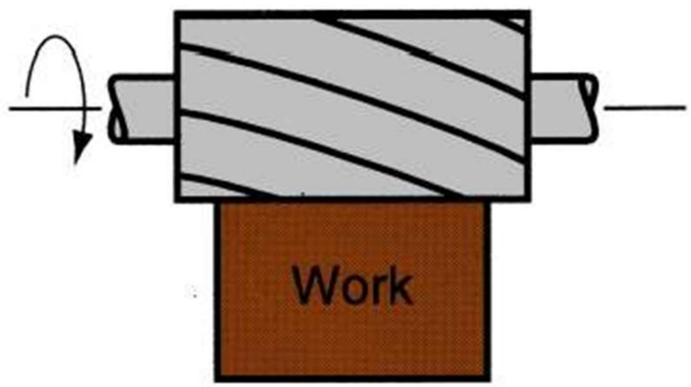


FIGURE 22.18
Peripheral milling: (a) slab milling, (b) slotting, (c) side milling, (d) straddle milling, and (e) form milling.

Slab Milling

The basic form of peripheral milling in which the cutter width extends beyond the workpiece on both sides



(a)

Figure (a) slab milling

Slotting

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

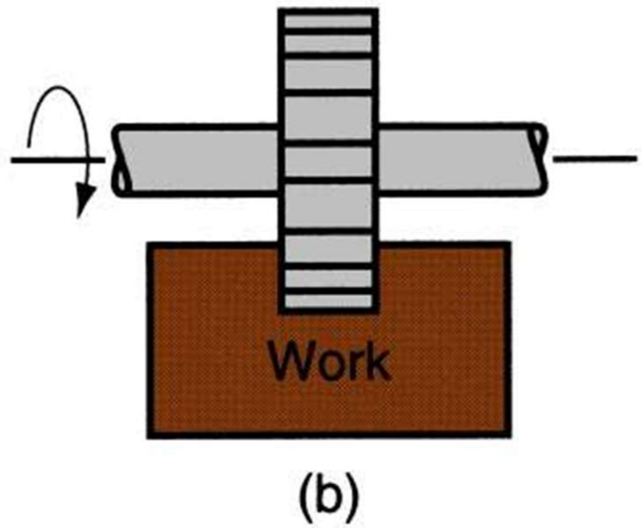
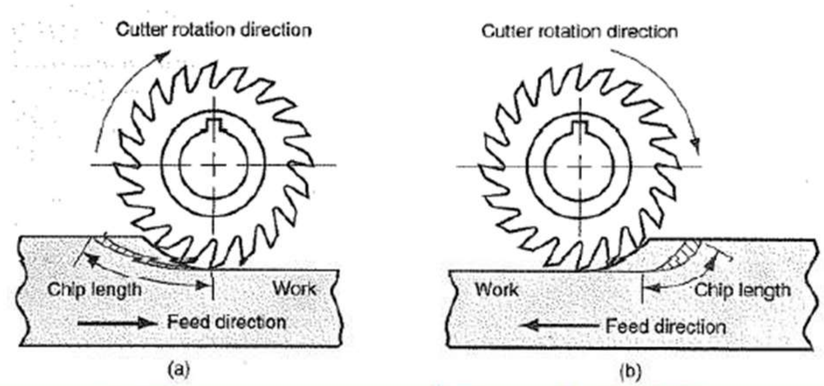


Figure (b) Slotting

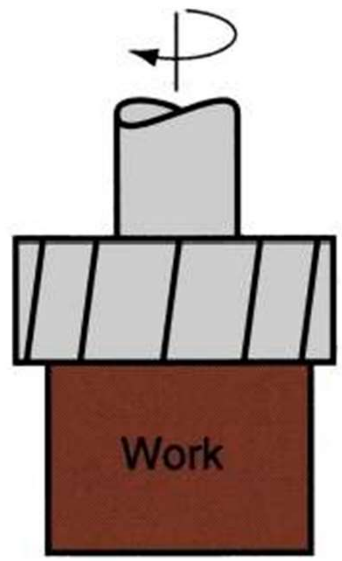
Methods of Peripheral Milling: Two Forms-



Up/conventional milling	Down/climb milling
Cutter teeth is opposite the feed direction	Cutter motion is the same as the feed direction
Chip starts from thin to thick	Chip starts from thick to thin
Chip length is more	Chip length is less
Cutter engaged in the work for longer time/volume of material cut	Cutter engaged for shorted time so better tool life
Lifting of workpart as the teeth exit the w/p	Tends to hold the w/p against the milling m/c table

Conventional Face Milling

Cutter overhangs work on both sides

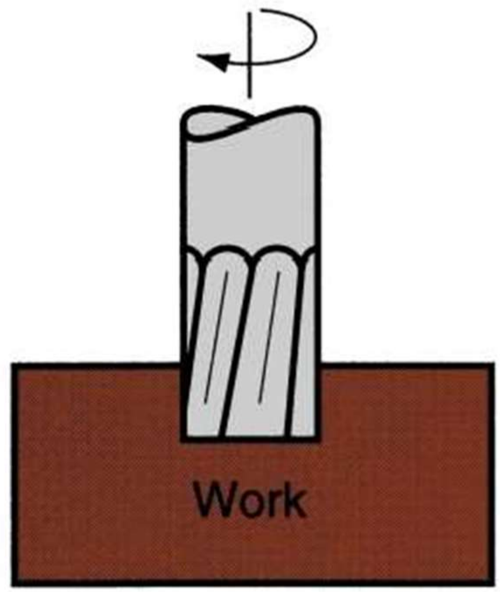


(a)

Figure (a) conventional face milling

End Milling

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



(c)

Figure - (c) end milling

Profile Milling

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

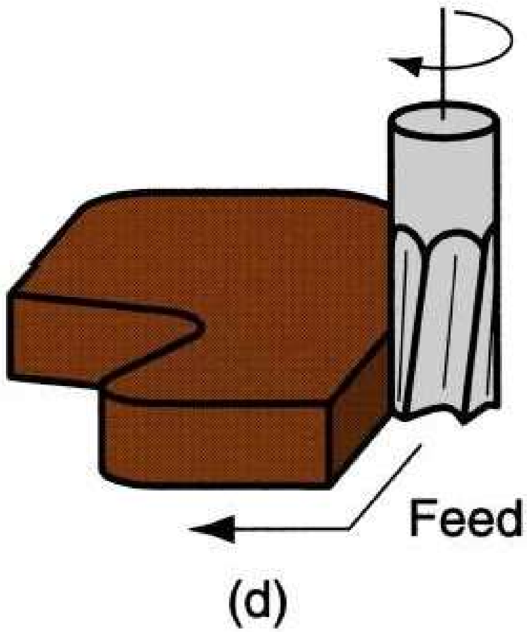


Figure (d) profile milling

Pocket Milling

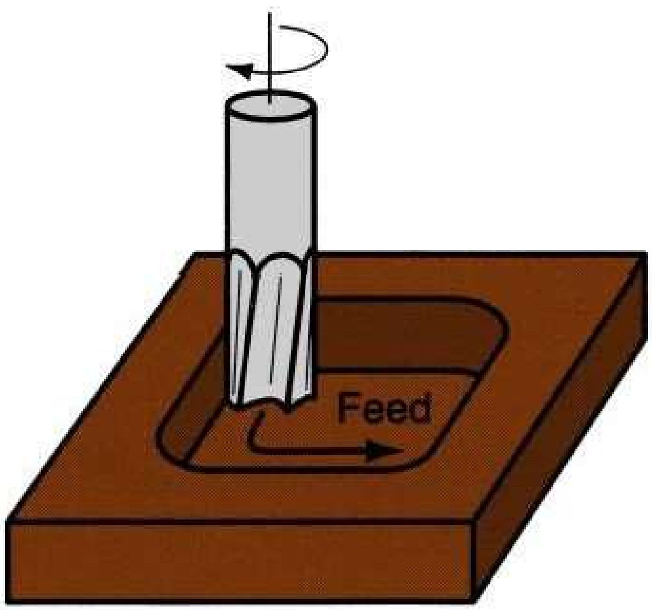


Figure (e) pocket milling

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

Surface Contouring

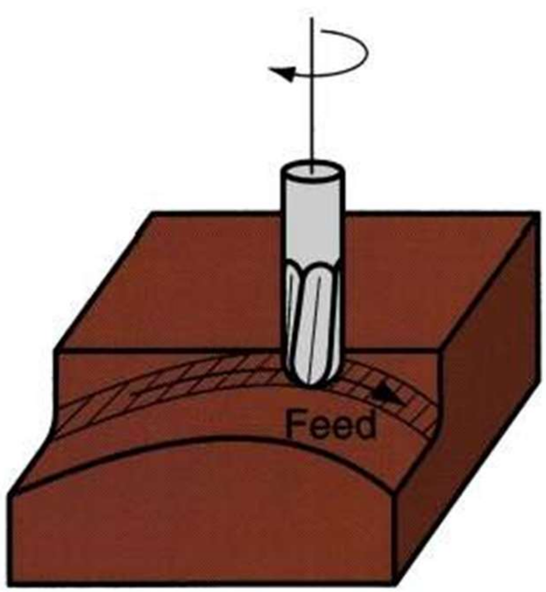


Figure (f) surface contouring

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

Shaping and Planing

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

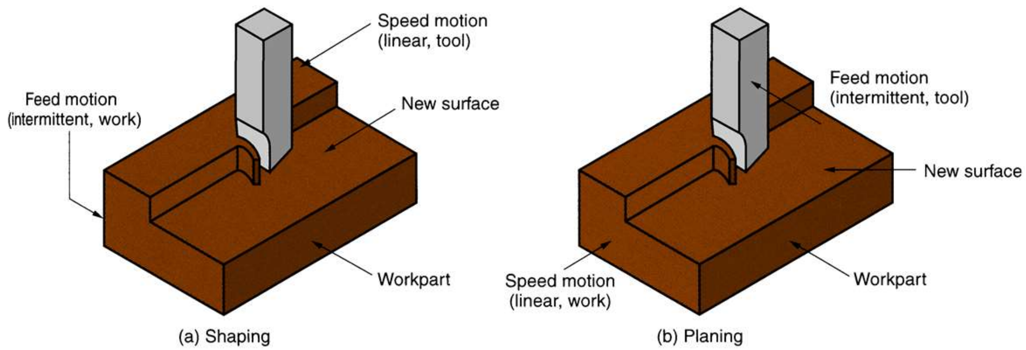


Figure 29 - (a) Shaping, and (b) planing

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
- Usual tooling: single point high speed steel tools

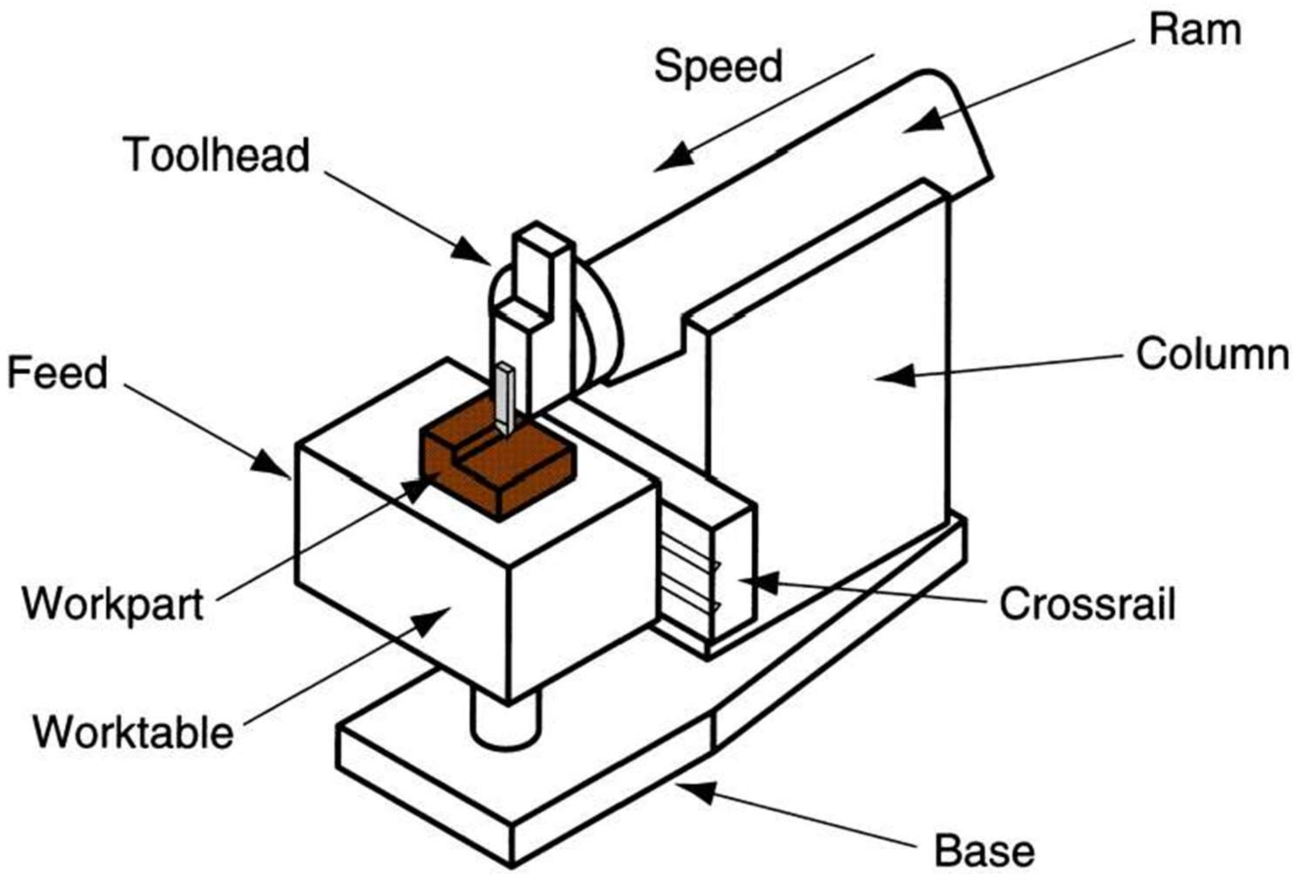
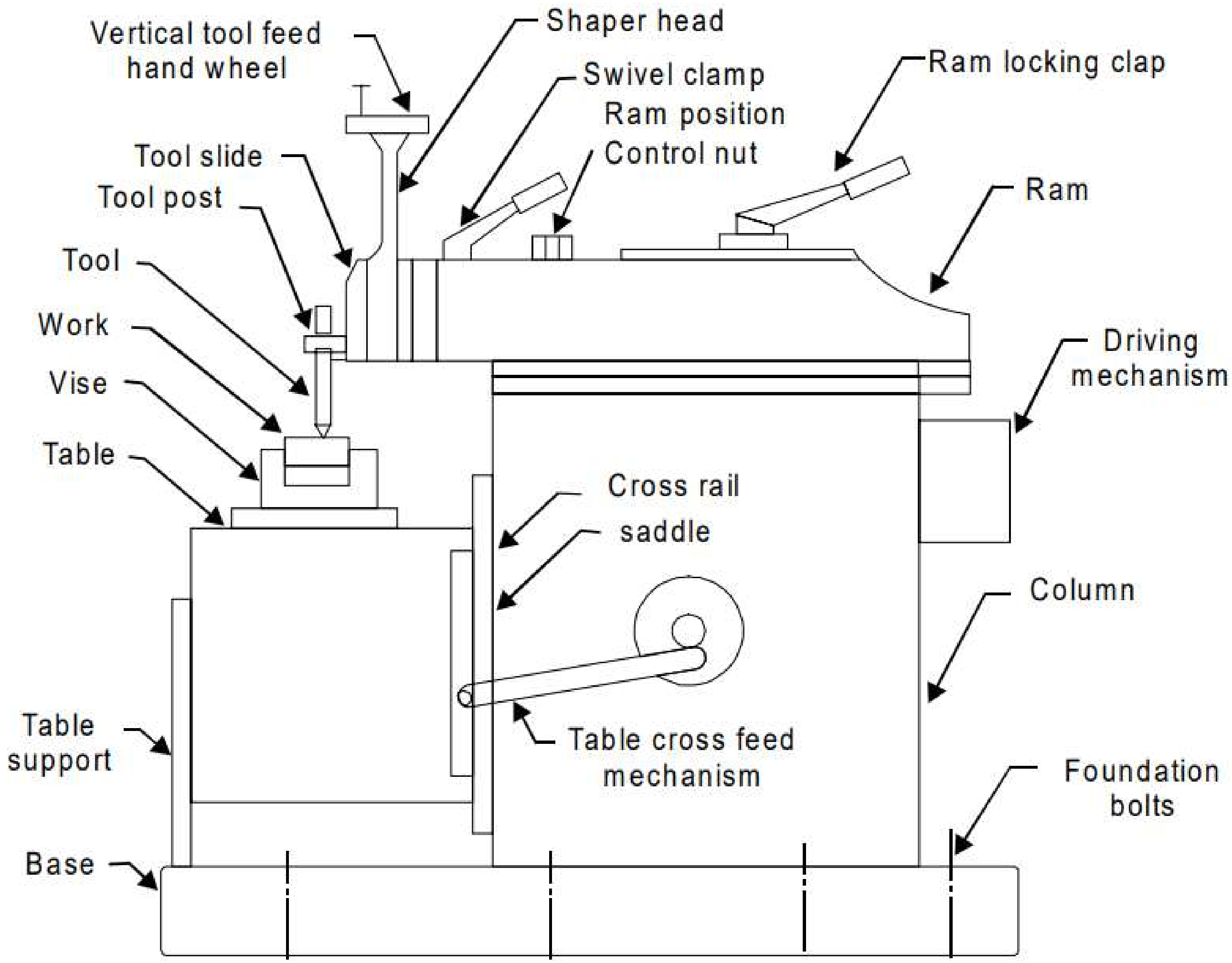
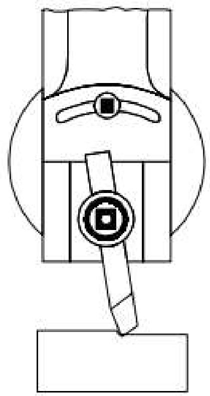
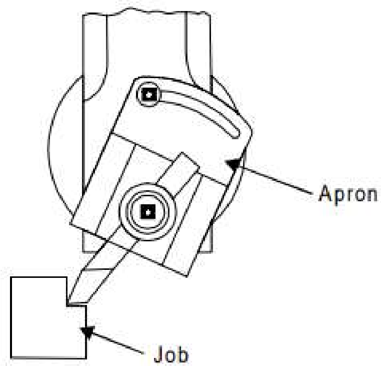


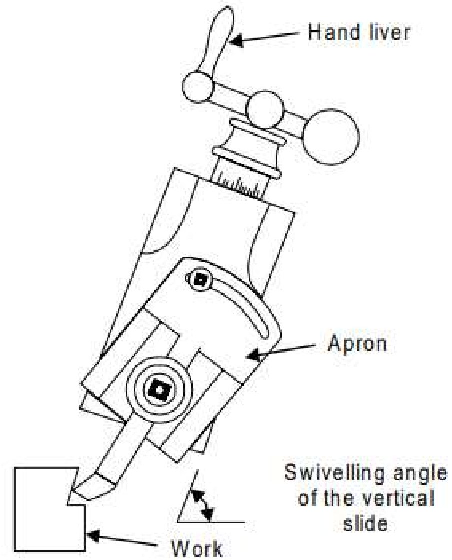
Figure - Components of a shaper



Vertical tool feed hand wheel
Shaper head
Swivel clamp
Ram position
Control nut
Ram locking clap
Tool slide
Tool post
Tool
Work
Vise
Table
Ram
Driving mechanism
Cross rail
saddle
Column
Table support
Table cross feed mechanism
Foundation bolts
Base





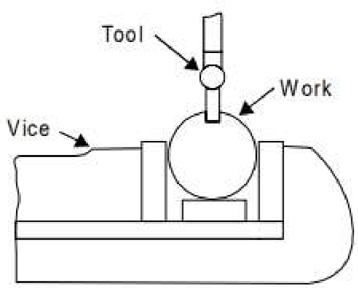


Cutting slots and keyways.

Machining horizontal vertical surface on shaper

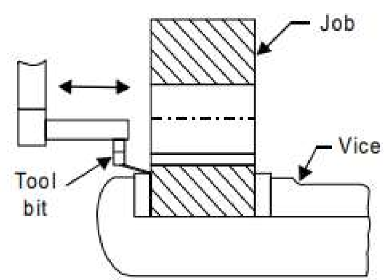
Machining vertical surface on shaper

Machining angular surface on shaper



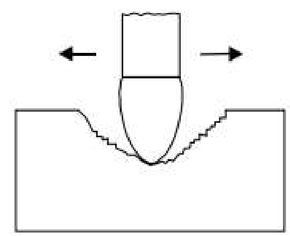
Slot cutting

Slot cutting on shaper



Keyway cutting

Keyway cutting on shaper



Irregular machining

Machining irregular surface on shaper

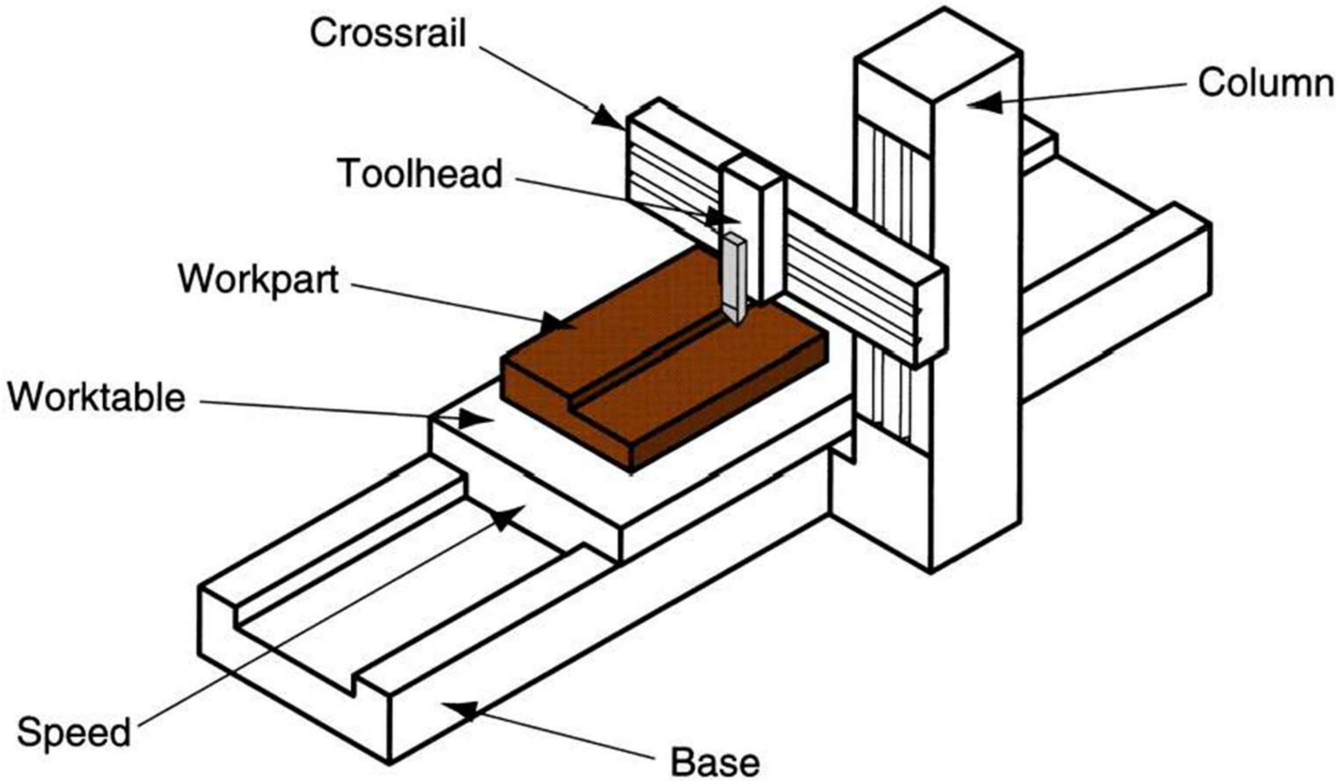


Figure - Open side planer

Difference between Shaper and Planer

S.No.	Shaper	Planer
1	The work is held stationary and the cutting tool on the ram is moved back and forth across the work	In a planer, the tool is stationary and the workpiece travels back and forth under the tool.
2	It is used for shaping much smaller jobs	A planer is meant for much larger jobs than can be undertaken on a shaper. Jobs as large as 6 metre wide and twice as long can be machined on a planer
3	A shaper is a light machine	It is a heavy duty machine.
4	Shaper can employ light cuts and finer feed	Planer can employ heavier cuts and coarse feed,
5	A shaper uses one cutting tool at a time	Several tools can cut simultaneously on a planer
6	The shaper is driven using quick-return link mechanism	The drive on the planer table is either by gears or by hydraulic means
7	It is less rigid and less robust	Because of better rigidity of planer, as compared to that of a shaper, planer can give more accuracy on machined surfaces.

Broaching

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

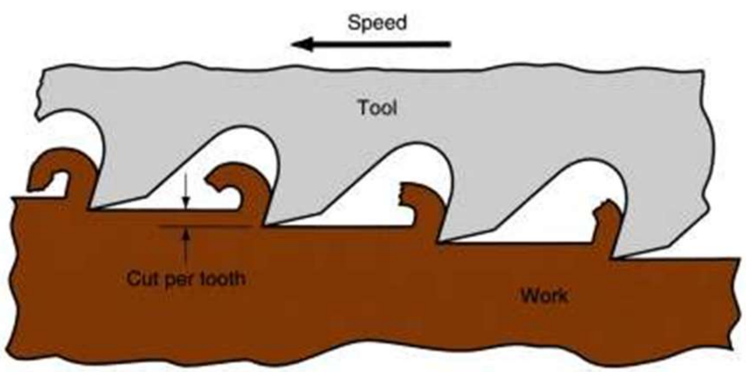


Figure - The broaching operation

Features:

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

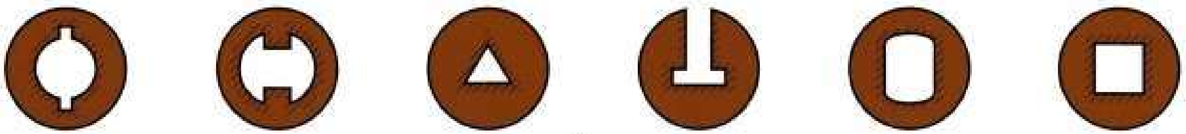


Figure - Work shapes that can be cut by internal broaching; cross-hatching indicates the surfaces broached

Sawing

- Cuts narrow slit in work by a tool consisting of a series of narrowly spaced teeth
- Tool called a *saw blade*
- Typical functions:
  - Separate a workpart into two pieces
  - Cut off unwanted portions of part

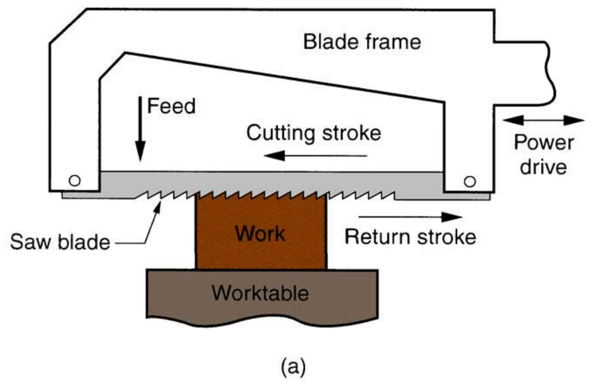


Figure power hacksaw –linear reciprocating motion of hacksaw blade against work

Grinding-Introduction

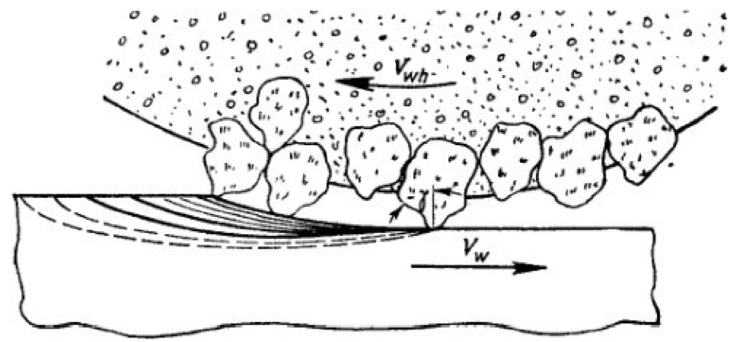
- Abrasive machining involves material removal by the action of hard, abrasive particles.
- The use of abrasives to shape parts is probably the oldest material removal process.

They are important because

- They can be used on all types of materials ranging from soft metals to hardened steels and hard nonmetallic materials such as ceramics and silicon.
- Extremely fine surface finishes (0.025 μm).
- For certain abrasive processes, dimensions can be held to extremely close tolerances.

Types of Abrasive Machining Processes

- ✓ Grinding
- ✓ Honing
- ✓ Lapping
- ✓ Superfinishing
- ✓ Polishing
- ✓ Buffing
- ✓ Abrasive water jet machining
- ✓ Ultrasonic machining



Difference between grinding and milling

- The abrasive grains in the wheel are much smaller and more numerous than the teeth on a milling cutter.

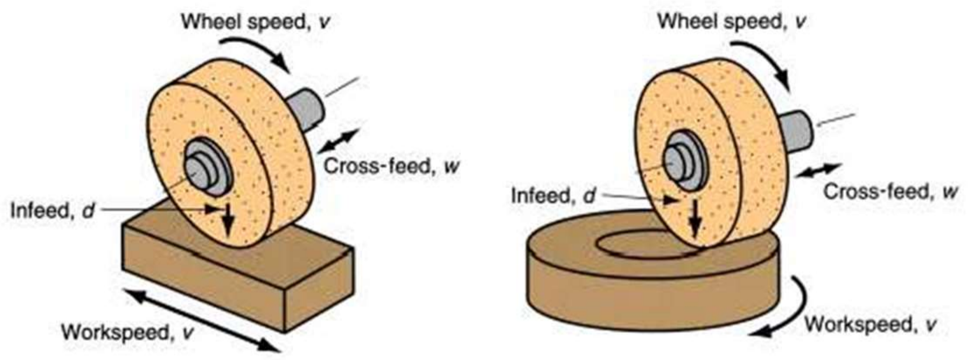
- Cutting speeds in grinding are much higher than in milling.

- The abrasive grits in a grinding wheel are randomly oriented.

- A grinding wheel is **self-sharpening**.

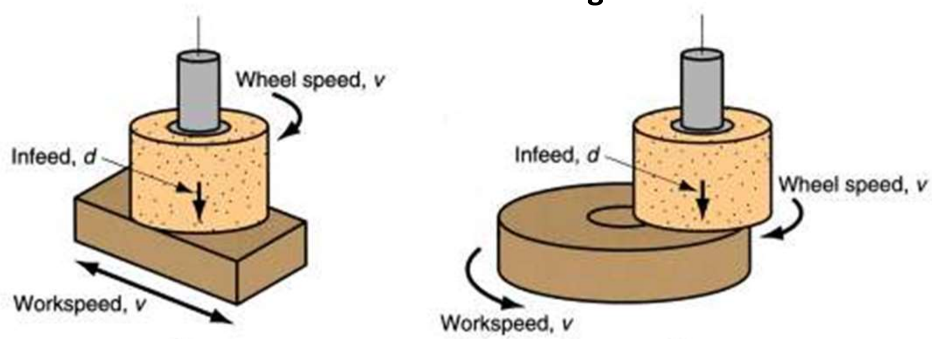
  Particles on becoming dull either fracture to create new cutting edges or are pulled out of the surface of the wheel to expose new grains.

Surface Grinding



(a) (b)

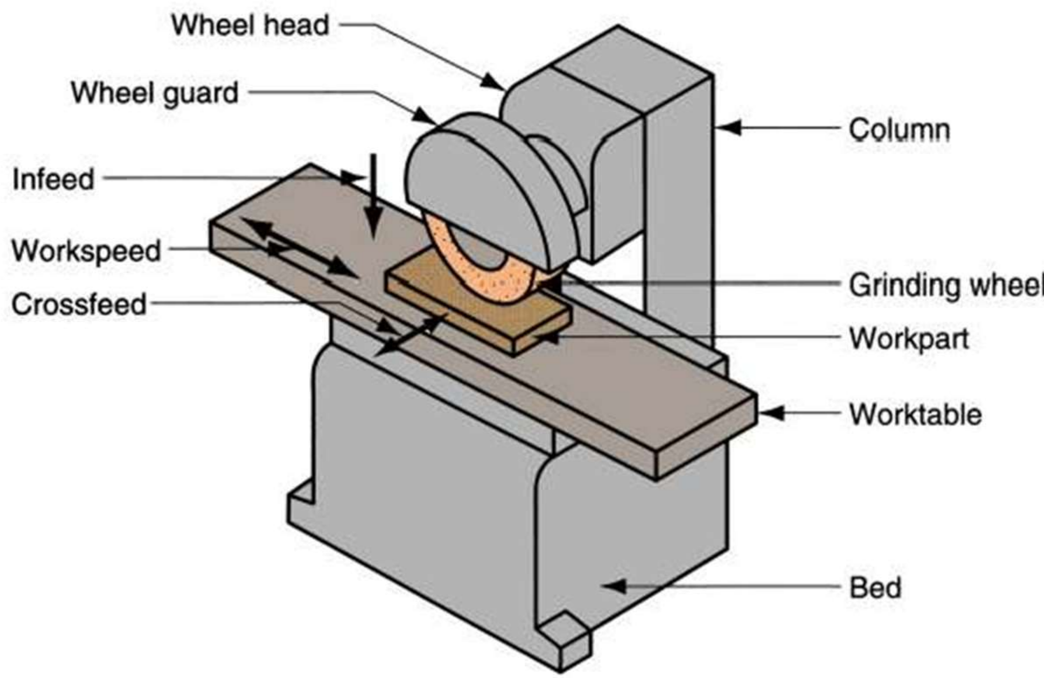
Horizontal Surface Grinding



(c) (d)

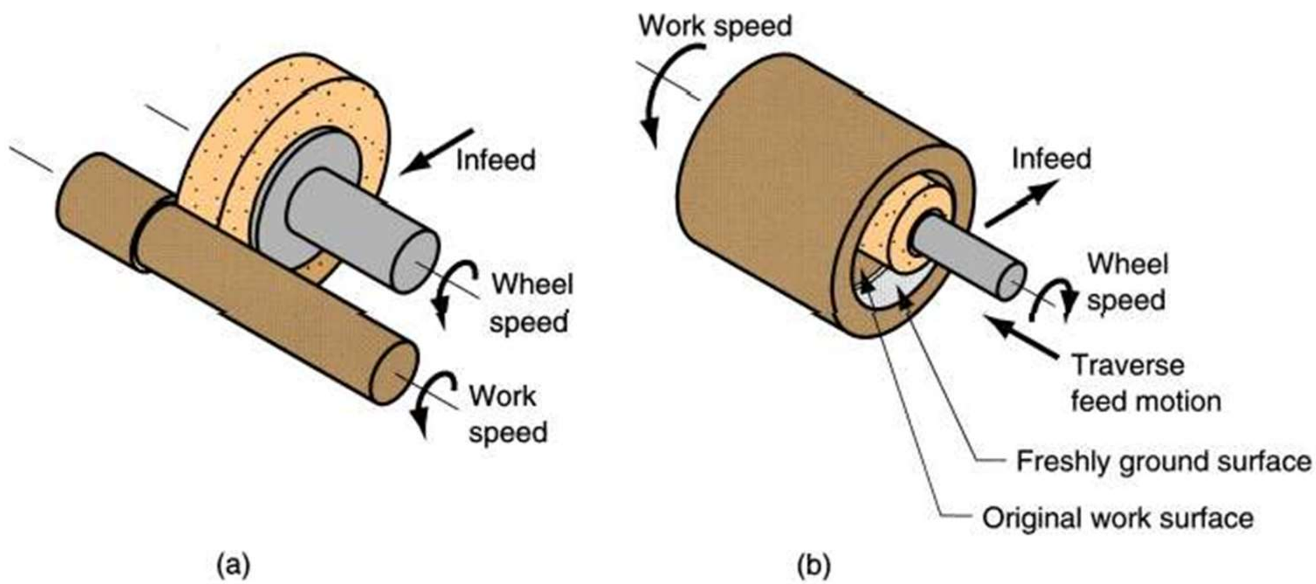
Vertical Surface Grinding

Surface Grinding



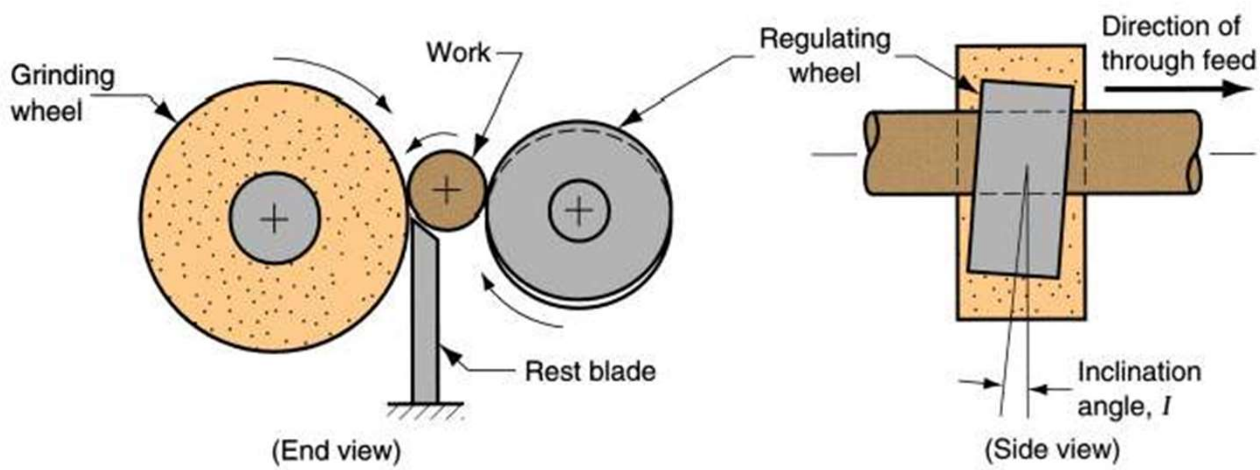
Horizontal Grinding Machine

Cylindrical Grinding



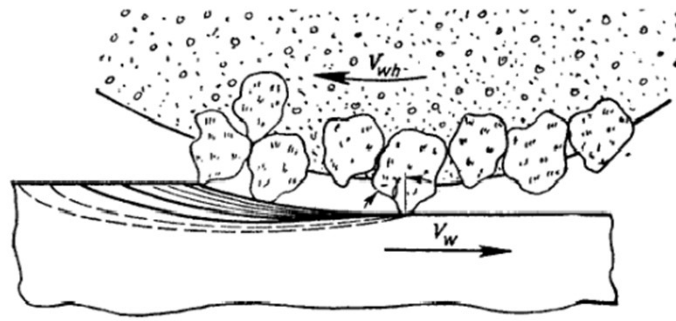
Two types of cylindrical grinding:
(a) external, and (b) internal

External Centerless Grinding



Grinding Wheel and Workpiece Interaction

- Grit-workpiece (forming chip)
- Chip-bond
- Chip-workpiece
- Bond-workpiece



- ✓ Except the grit-workpiece interaction, which is expected to produce chip, the remaining three undesirably increase the total grinding force and power requirement.

- ✓ Therefore, efforts should always be made to maximize grit-workpiece interaction leading to chip formation and to minimize the rest for best utilization of the available power.

Grinding Wheel Parameters

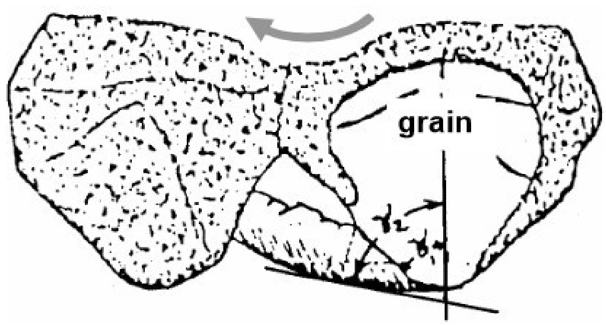
- Type of Abrasive material
- Grain size
- Wheel grade
- Wheel structure
- Bonding material

Abrasive Materials

General Properties
Hardness, wear resistance, toughness, friability

Abrasive	Description	Knoop Hardness
Aluminum oxide (Al_2O_3)	Most common abrasive material (Section 7.3.1), used to grind steel and other ferrous, high-strength alloys.	2100
Silicon carbide (SiC)	Harder than Al_2O_3, but not as tough (Section 7.2). Applications include ductile metals such as aluminum, brass, and stainless steel, as well as brittle materials such as some cast irons and certain ceramics. Cannot be used effectively for grinding steel because of the strong chemical affinity between the carbon in SiC and the iron in steel.	2500
Cubic boron nitride (cBN)	When used as an abrasive, cBN (Section 7.3.3) is produced under the trade name Borazon by the General Electric Company. cBN grinding wheels are used for hard materials such as hardened tool steels and aerospace alloys.	5000
Diamond	Diamond abrasives occur naturally and are also made synthetically (Section 7.5.1). Diamond wheels are generally used in grinding applications on hard, abrasive materials such as ceramics, cemented carbides, and glass.	7000

Effective grit geometry due to material loading at tip



- ➢Grit geometry may undergo substantial change due to mechanical or chemical attrition leading to rounding or flattening of the sharp cutting points.
- ➢ This happens when the work material has hard or abrasive constituent.
- ➢A chip material adhered to the tip of the grit because of some chemical affinity can also change the effective rake angle of the grit leading to high grinding force, temperature and poor performance of the grinding wheel.

SiC and Ferrous Materials

- SiC abrasives are harder than friable Al_2O_3 but they are usually inferior for grinding most ferrous materials.

- This is due to the dissociation of SiC to react with and adhere to iron at elevated temperatures. (Affinity of silicon or carbon for the workpiece)

- Therefore, SiC tends to work better than Al_2O_3 on some ferrous metals with excess carbon.

- Superiority of SiC on some cast irons is due to the presence of small amounts of SiC as a normal constituent in the iron, which would have a more drastic effect on the wear of the softer Al_2O_3.

Grain Size

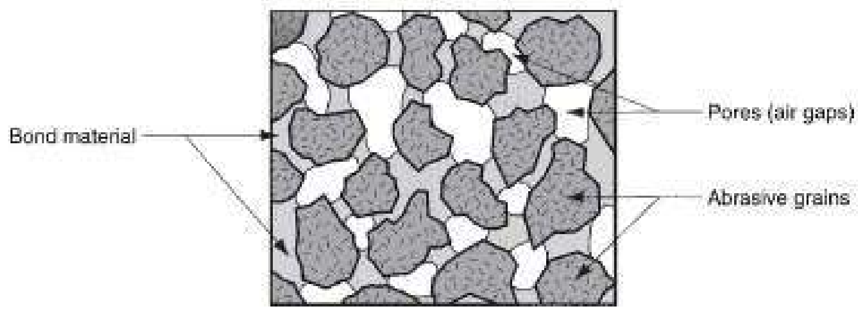
- Grain size is expressed in terms of a SIEVE NUMBER, S_n which corresponds to the number of openings per linear inch.
- The diameter of an abrasive grain is given by $D_g = \frac{0.6}{S_n}$
- The larger the size of grains, more will be material removal, but surface finish will be worse.

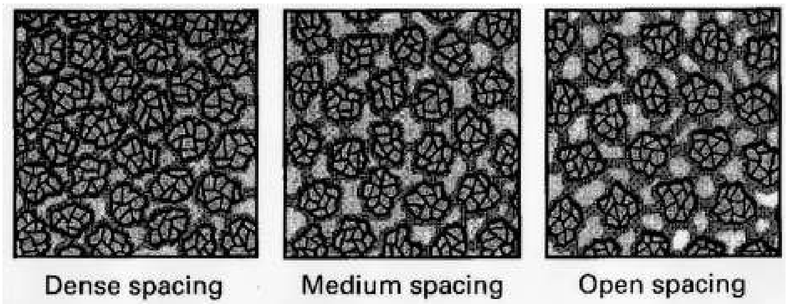
Sieve No.	Type of Grain
10-24	Coarse
30-60	Medium
70-180	Fine
220-600	Very Fine

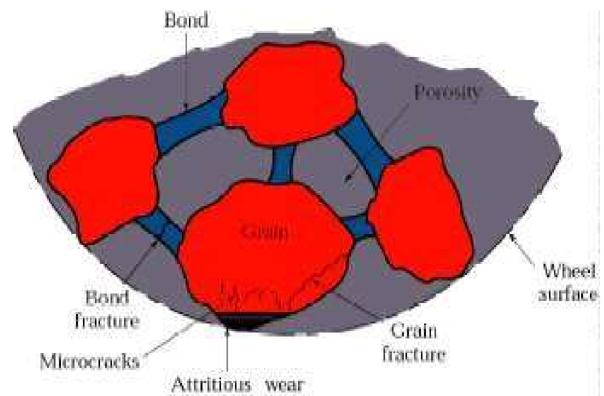
Grinding Wheel Structure

“Open” and “dense”

In what conditions these structures be provided?







Wheel Grade

Indicates the strength of the binding material.

When the work material is hard, the grains wear out easily and the sharpness of the cutting edges is quickly lost. This is known as WHEEL GLAZING.

To avoid this problem, a soft wheel should be used.

- **A-H – Soft Wheel**
- **J-P – Medium Wheel**
- **Q-Z – Hard Wheel**

Bonding Materials

- Must withstand centrifugal forces and high temperatures
- Must resist shattering during shock loading of wheel
- Must hold abrasive grains rigidly in place for cutting yet allow worn grains to be dislodged so new sharp grains are exposed

Vitrified Bond (V) – Strong and Rigid, commonly used.

Resinoid (B) – Provides shock absorption and elasticity. They are strong enough.

Silicate (S) – Provides softness (grains dislodge quickly)

Shellac (E) – Used for making thin but strong wheels possessing some elasticity.

Rubber Bonds (R) – For making flexible wheels.

Metallic Bond (M) – For diamond wheels only.

Bonding Materials

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Grinding Wheel Specification

30 A 46 H 6 V XX

Manufacturer's private marking for wheel (optional).

Bond type: B = Resinoid, BF = resinoid reinforced, E = Shellac, R = Rubber, RF = rubber reinforced, S = Silicate, V = Vitrified.

Structure: Scale ranges from 1 to 15: 1 = very dense structure, 15 = very open structure.

Grade: Scale ranges from A to Z: A = soft, M = medium, Z = hard.

Grain size: Coarse = grit sizes 8 to 24, Medium = grit sizes 30 to 60, Fine = grit sizes 70 to 180, Very fine = grit sizes 220 to 600.

Abrasive type: A = aluminum oxide, C = silicon carbide.

Prefix: Manufacturer's symbol for abrasive (optional).

Grinding Chips

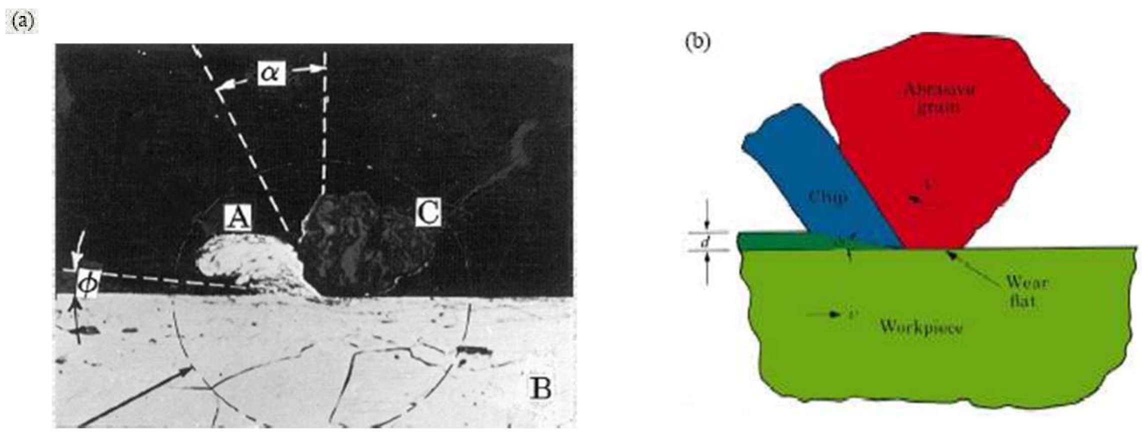
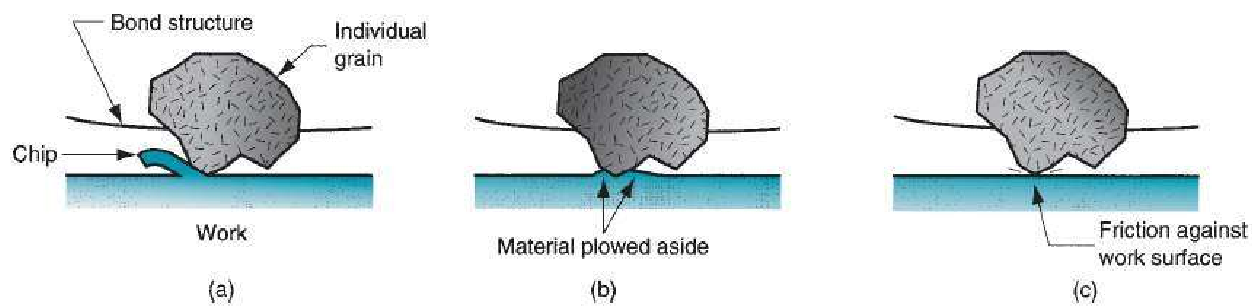


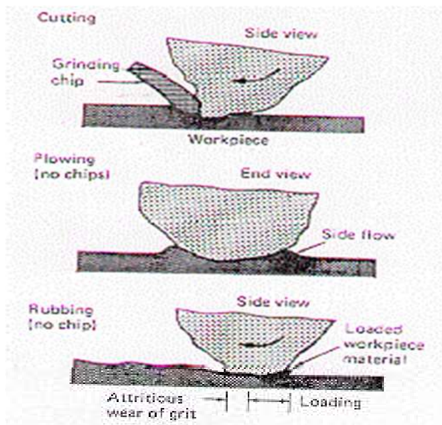
Fig: (a) Grinding chip being produced by a single abrasive grain. (A) chip, (B) workpiece, (C) abrasive grain. Note the large negative rake angle of the grain. The inscribed circle is 0.065mm in diameter. (b) Chip formation by an abrasive grain with a wear flat. Note the negative rake angle of the grain and the small shear angle

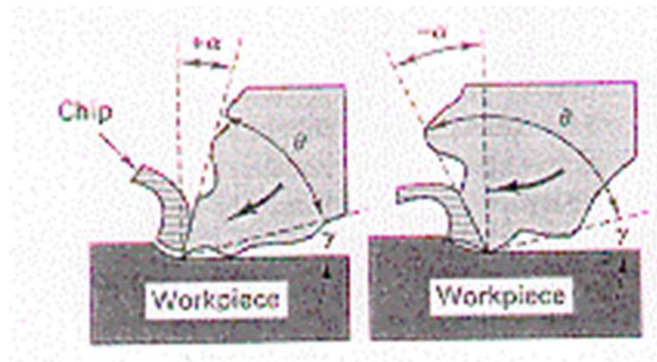
Chip Formation

- Chips in this process are formed by the same mechanism of compression and shear as other machining processes.
- As the grains or abrasives become dull, the cutting forces increase. The increase in the cutting force causes the grains to plow and rub rather than cut. As the plowing and rubbing increases, the grains fracture at the cutting edge to revile a new cutting edge.



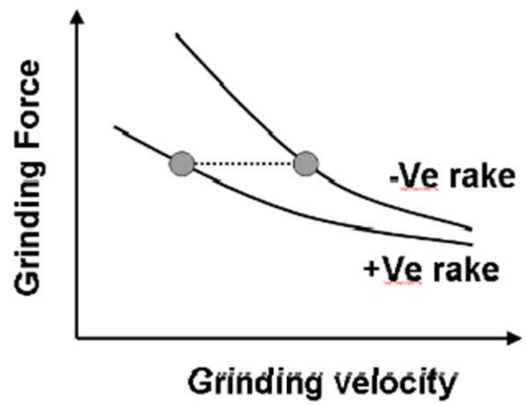
Chip Formation





- The importance of the grit shape can be easily realized because it determines the grit geometry e.g. rake and clearance angle.
- The grits do not have definite geometry and the grit rake angle may vary from +45 to -60 or more.
- Grit with favorable geometry can produce chip in shear mode. However, grits having large negative rake angle or rounded cutting edge do not form chips but may rub or make a groove by plowing leading to lateral flow of the workpiece material.

Effect of grinding velocity and rake angle on force



- A negative rake angle always leads to higher cutting force.

- The difference is narrowed at a high grinding velocity and the grinding force becomes virtually independent of the rake angle.

Automation in Manufacturing

- Automation, in the context of manufacturing, is the use of equipment to automate systems or production processes. The end goal is to drive greater efficiency by either increasing production capacity or reducing costs, often both.
- Automation has become known more as using machines to reduce work performed by humans. It has become associated with electromechanical systems that are programmed to perform many types of processes. While automation may not be right for every manufacturer, most companies are able to find benefits in one of the following types of automation: Fixed, programmed, or flexible.

Types of Manufacturing Automation

Types of Automation in Manufacturing

Fixed	Programmable	Flexible
Large volume, single-part production.	Associated with batch production	Real-time or on-demand production.

Fixed Automation

- Characterized by large volume production and a high barrier of entry, fixed automation often has a set task. Also called hard automation, most programming is contained within individual machines. The speed and sequence of processes are set by the equipment or production line.

- An example of fixed automation can be found in the body-in-white and automotive panels. Major vehicle suppliers might produce over a million parts before changing designs. Additionally, processes such as stamping or casting are used which may not require control systems as sophisticated as automated milling or robotic welding.

- Often the production volume associated with fixed automation does not have time for changeovers. However, if any changes are made to fixed automation it would likely require a line to be shut down and for technicians to manually swap tooling. The expense and time associated with this downtime are high. For low volume or products that have shorter life cycles consider programmable automation.

Programmable Automation

- Characterized by making several dozens to thousands of units, programmable automation is associated with batch production.

- Programmable automation offers the ability to produce more types of parts or products. However, downtime is needed to perform changeovers.

- This downtime is expected and taken into consideration for batch sizes and lead times. However, downtime is expensive and has led to an extension of programmable automation called flexible automation.

Flexible Automation

- Flexible automation is able to perform changeovers automatically. This may limit equipment to run parts that share similar tools or require additional devices to make automated changeovers possible.

- Additionally, since programs need to be changed, flexible automation is often connected to some form of network that increases value by offering remote monitoring or control. Programs are developed offline on a computer. Depending on how the device is connected, a designer could upload, run new programs, or work them into existing production from anywhere in the world.

Examples of Manufacturing Automation

- To remember the different types of automation consider the following examples:

- **Fixed Automation**: Associated with large volume, single-part production. EX: A hobbing machine dedicated to automatically producing one gear.
- **Programmable Automation**: Associated with batch production. EX: A hobbing machine that automatically produces different types of gears, but a changeover will cause downtime to change gears.
- **Flexible Automation**: Associated with real-time or on-demand production. EX: A hobbing machine that automatically produces several gears without the need to be shut down or manual changeovers.
- Automation in manufacturing is growing and continues to shape the factory floor. Manufacturers are striving for a full digital thread from tracking materials supply chains, to production, to delivery. However, before a full digital transformation, it is important to know your goals, and how they align with the benefits of automated manufacturing strategies.

Benefits of Automation in Manufacturing

- Manufacturers are increasingly using automation to drive precision, consistency, and greater operational efficiency. To start, know your goals. The more specific the goals, the easier it is to align with a solution. Goals such as increasing production, while general, indicate that you must know what affects production. Easy and quick to integrate sensors and devices that monitor equipment and produce user-friendly data, graphics, etc. will help connect production lines and serve other benefits:

- Reduce downtime
- Provide predictable maintenance
- Improve decision making

Benefits of Automation in Manufacturing

- Having devices to monitor materials in inventory or at a workstation can reduce downtime due to running out of stock. Being able to see equipment run times might be enough to reduce downtime by adjusting workflow to reduce changeovers, or indicate where an investment in more automation would yield a positive ROI.

- Monitoring can also track equipment performance to indicate when maintenance or failures might occur. Performance tracking can help make smarter operation decisions and schedule maintenance when it will least affect production. Also, automation and monitoring drive more informed business decisions.

Benefits of Automation in Manufacturing

- Having real-time data can help manufacturers understand lead times and provide more accurate estimates and timelines. Additionally, automated devices improve repeatability that can improve quality and reduce variability in production. Overall, automated monitoring offers a more predictable model to make business decisions from, while providing transparency for all stakeholders.

- The future of automation in manufacturing is progressing with robotics, machine vision, IIoT, and other digital technologies. To take advantage of the growth in automation, know your goals, what affects production, and what benefits each technology provides. When in doubt, minimize complexity, follow proper engineering principles, and work with vendors that provide good customer service.

THANK YOU