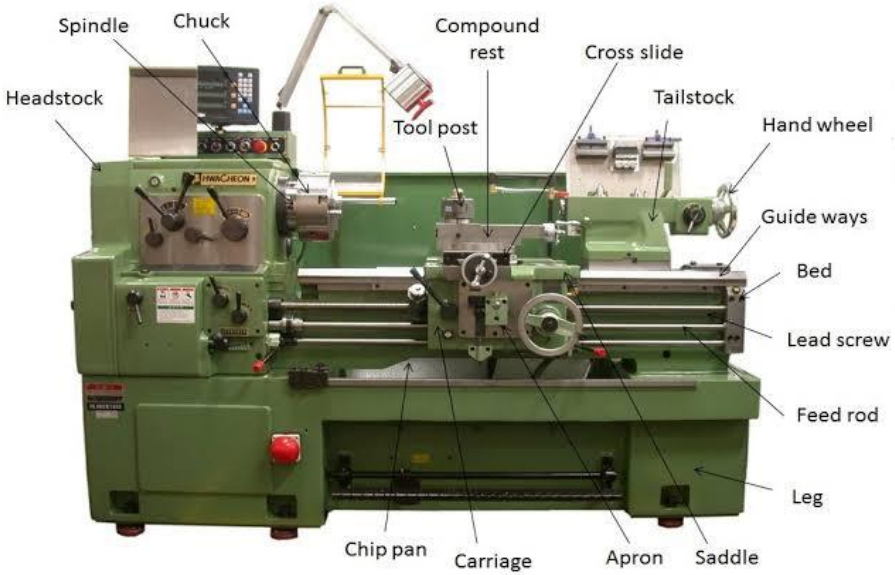
# Overview

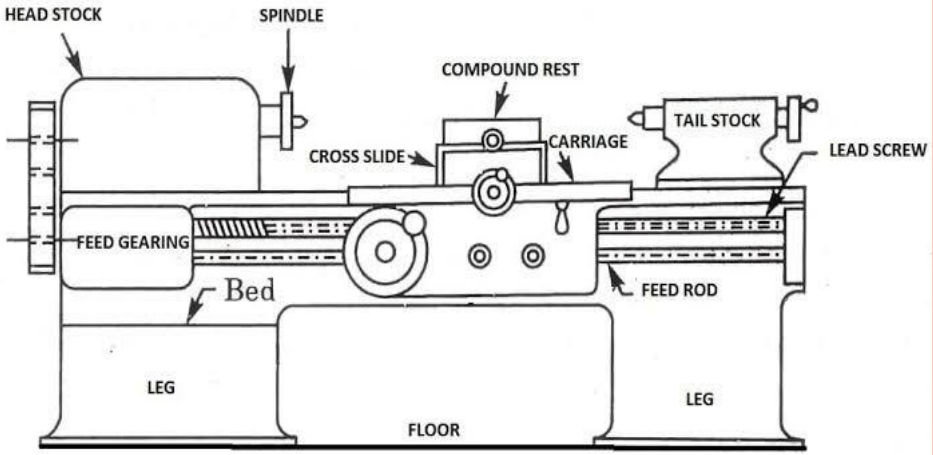
- Introduction to Machines **(Theory of Metal Cutting)**
- Lathe
  - Components, Tools, Working Operations
- Drilling
  - Types of Drilling machine, Working Operations
- Milling Machine
  - Types & Working Operation
- Shaper Machine & Slotter Machine
  - Quick return mechanism, Working Operations
- Grinding Machine **(Surface Finishing Process)**
  - Cutting tools, Types & Working Operations

# LATHE MACHINE

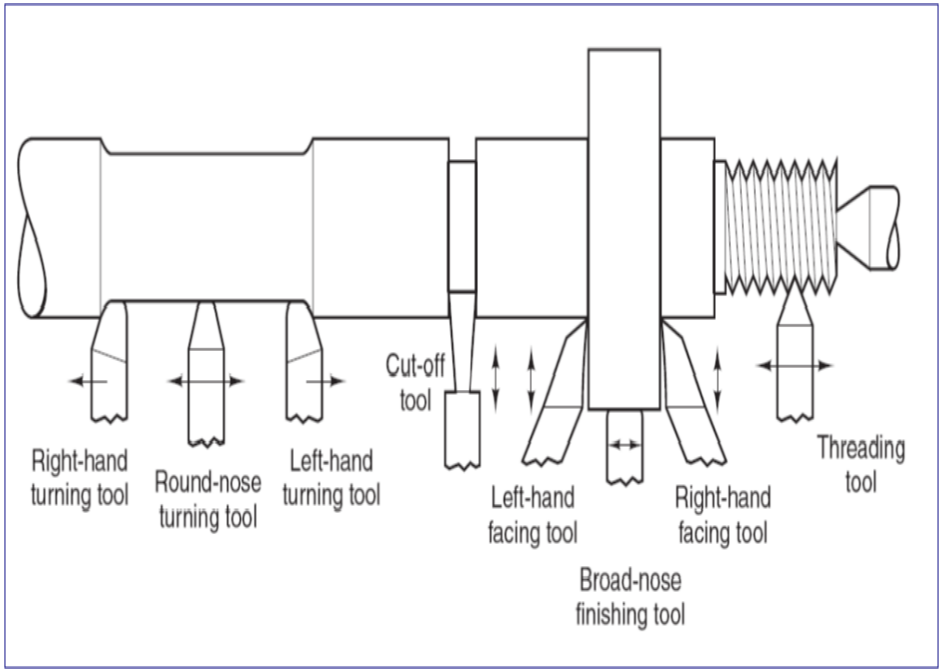
**Machining:** Material removal processes in which a cutting tool **removes unwanted material** from a workpiece to produce the desired shape.

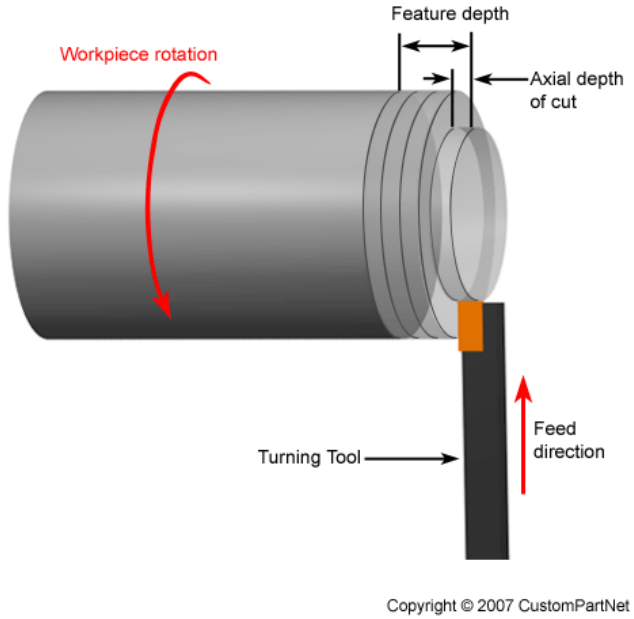
- **Lathe machine** helps in **shaping several materials** into desired shapes.
- **Rotates a work piece about an axis** of rotation to perform **various operations such as cutting, sanding, knurling, drilling, facing, and turning,** with tools that are applied to the workpiece **to create an object with symmetry** about that axis.
- Used in **woodturning, metalworking, metal spinning, thermal spraying**, parts reclamation, pottery and glass-working.



- In lathe machine, **the work piece rotates and the tool remains stationary.**
- Lathe machine operations involve the **turning , drilling, facing, boring threading** and many more.
- **Various tools and different orientation of the tool** is used to get the **desired shape**. All these methods are mainly basic turning operations.
- **To operate the lathe machine,** we must first know about the **feeds, cutting speed, depth of the cut and usage of tool**. Each lathe operation has got its own factors to consider.

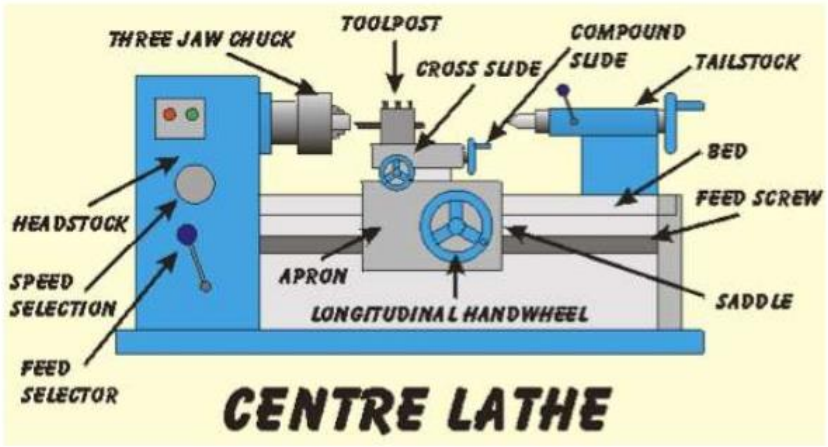



https://www.theengineerspost.com/lathe-machine-operations/
https://openoregon.pressbooks.pub/manufacturingprocesses45/chapter/chapter-unit-1-the-engine-lathe/

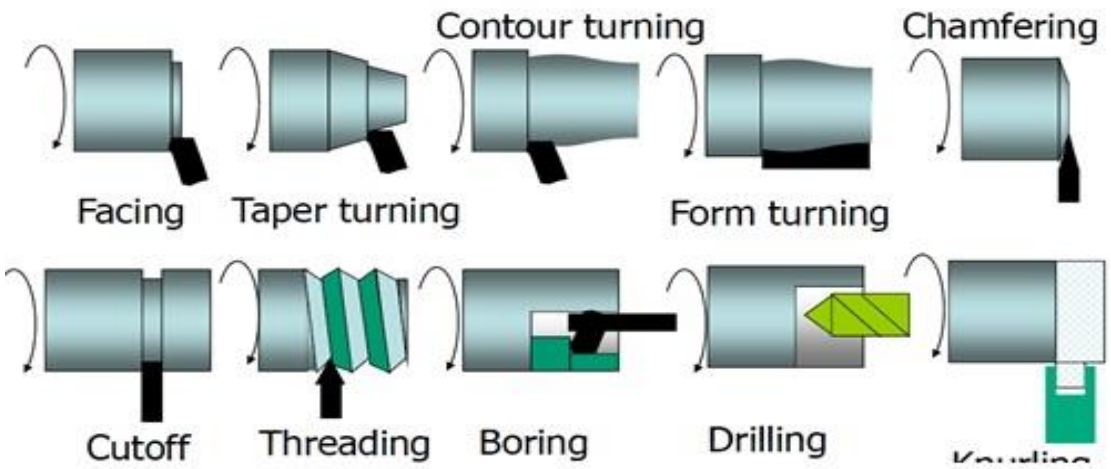
## Lathe machine operations which are performed by holding the work by a chuck or a faceplate or an angle plate

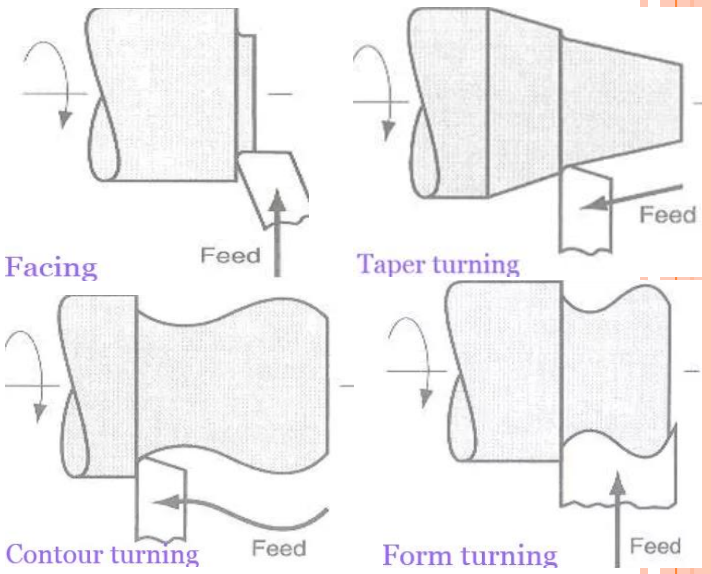
- Drilling
- Reaming
- Boring
- Counterboring
- Taper boring
- Tapping
- Undercutting
- Internal thread cutting
- Parting-off




## Lathe machine operations done either by holding the work piece between centers or by a chuck

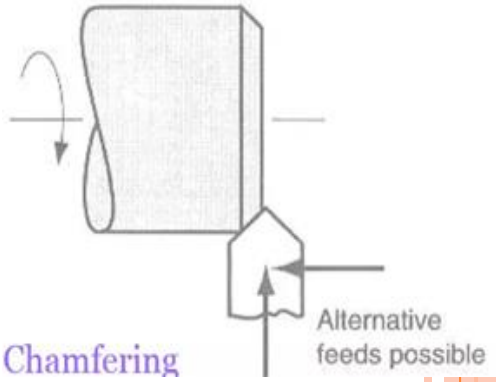
- Turning
  - Plain or Straight Turning
  - Rough Turning
  - Shoulder Turning
  - Taper Turning
  - Eccentric Turning
- Facing
- Chamfering
- Knurling
- Thread cutting
- Filing
- Polishing
- Grooving
- Spinning
- Spring Winding
- Forming

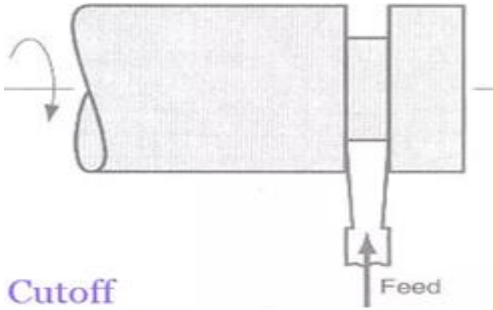


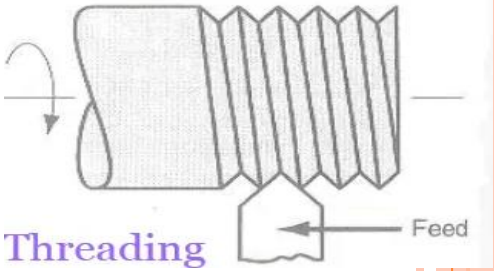



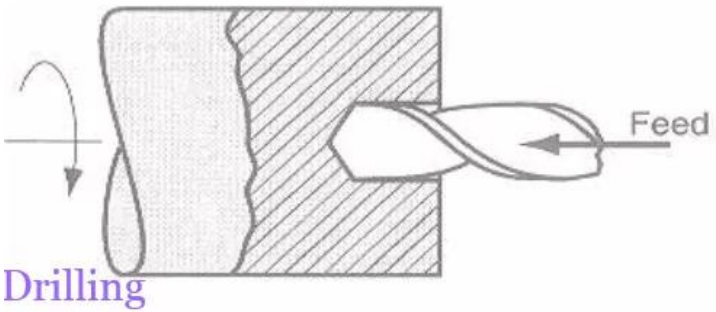

- **Facing** is used to make a **flat surface at the end** of the work piece. The work part should be **rotating and the implied feed should be radial**. Facing: **Radial feed.**
- **Contour turning:** The tool is **not fed in a straight path**. Instead the tool follows **a contour**. A **contoured form** is created in the turned part. **Feed : Contoured feed.** Not parallel to the axis of work piece rotation.
- **Form Turning:** In this method **a special shaped tool** is used . The tool is **inserted radially**. Feed for forming : **Radial**.
- **Tapering:** To cut the metal to nearly **a cone shape** with the help of the **compound slide**.
- **Chamfering:** Only the **cutting edge is used at the corner of cylindrical shapes** which is used for **stress relieving of the workpiece**.

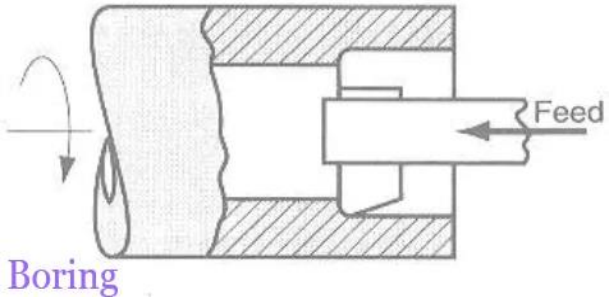
- **Cutoff or Parting:** In parting operation **the tool is fed radially** and the end part of the **workpiece is cut off.**
- **Threading:** A pointed tool is is used **at the outside surface of the workpiece with linear feed.**
- **Drilling and reaming** is done by feeding the **lathe tool along the axis of the rotating** job part.
- **Boring: A single point tool head** is fed linearly to the end of the **workpiece (on the inside diameter).**
- **Knurling:** It is a **metal forming method** which creates a **regular cross hatched pattern**. It is not a machining process. It does not involve **any cutting of the metal.**

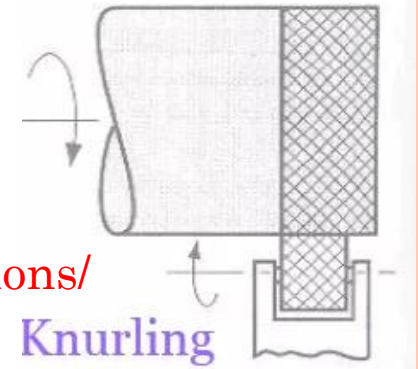



**Notes:** https://www.theengineerspost.com/lathe-machine-operations/

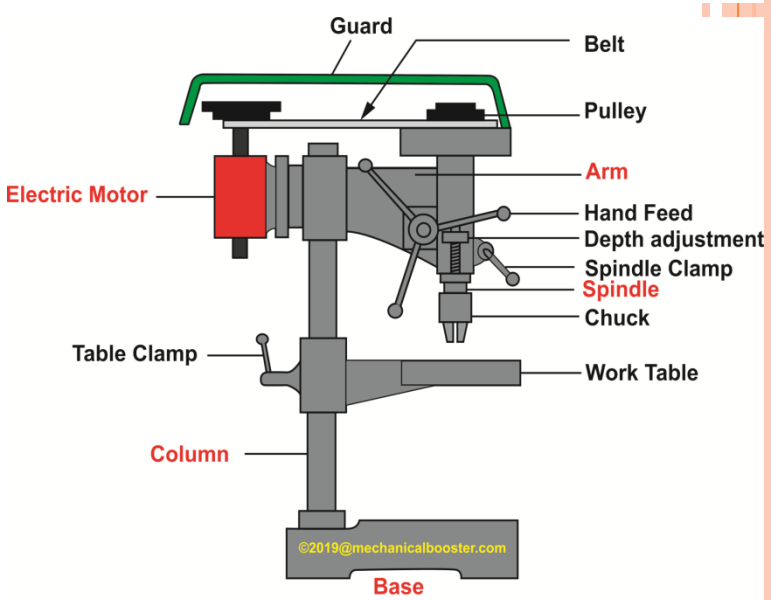
# Drilling Machine

- Used to make a circular hole, **a tool used to drill the holes of different size** and other related operations **using a drill bit**.
- Holes may be drilled **quickly and at a low cost**. The hole is generated by the **rotating edge of a cutting tool known as the drill** which applies a **large force on the work clamped** on the table.
- As the machine uses vertical pressure to originate a hole it is loosely called a **"drill press"**


Drilling Machine

**The main parts of drilling machines are**

- Base
- Column
- Table
- Radial Arm
- Drill head
- Spindle speed and Feed mechanism




Main Parts of Drilling Machine

https://www.theengineerspost.com/types-of-drilling-machine/

# THERE ARE 8 DIFFERENT **TYPES OF DRILLING MACHINE.**

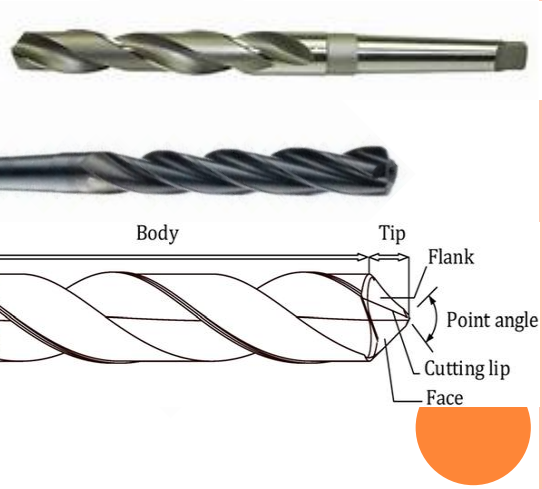
- Portable drilling machine
- Sensitive drilling machine
  - Bench mounting sensitive drilling machine
  - Floor column upright drilling machine
- Upright drilling machine
  - Round column upright drilling machine
  - Box column upright drilling machine
- Radial drilling machine
  - Plain drilling machine
  - Universal drilling machine
  - semi-universal drilling machine
- Gang drilling machine
- Multiple spindle machine
- Automatic drilling machine
- Deep hole drilling machine
  - Vertical deep hole drilling machine
  - Horizontal deep hole drilling machine



https://www.theengineerspost.com/types-of-drilling-machine/2/

# A DRILL IS A FLUTED CUTTING TOOL USED TO ORIGINATED OR ENLARGE A HOLE IN A SOLID MATERIAL. DRILLS ARE MANUFACTURED IN A WIDE VARIETY OF TYPES AND SIZES.

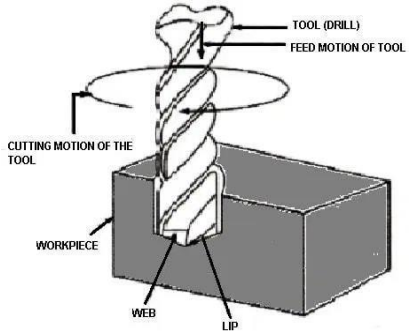
- **The types of drill commonly used are:**
- Flat or spade drill
- Straight fluted drill
- Two-lip twist drill
  - Parallel shank (short series or " jobbers" twist drill)
  - A Parallel shank (stub series) twist drill
  - Parallel shank (long series) twist drill
  - A Parallel shank twist drill
- Taper shank core drill (Three or four fluted)
- Oil tube drill
- Centre drill



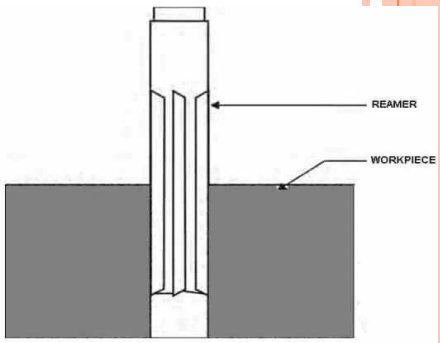

https://www.theengineerspost.com/types-of-drilling-machine/3/

# THE DIFFERENT OPERATIONS THAT CAN BE PERFORMED IN A DRILLING MACHINE ARE:

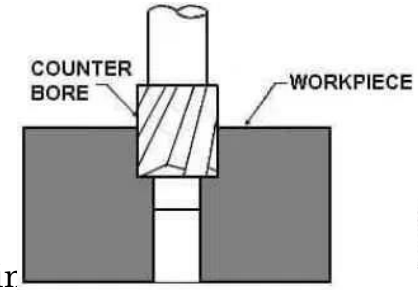
- **Drilling –** producing a cylindrical hole by removing metal
- **Reaming** - sizing and finishing a previously drilled hole
- **Boring** - To enlarge a hole, machine the internal surface
- **Counterboring** - enlarging the end of a hole cylindrically
- **Countersinking** - making a cone-shaped enlargement of the end
- **Spot facing** - smoothing and squaring the surface around a hole
- **Tapping** - cutting internal threads with a tap (cuttir tool)
- **Lapping** - sizing and finishing a small diameter hole
- **Grinding** - to finish a hardened hole
- **Trepanning** - producing a hole by removing metal **along the circumference of a hollow cutting tool**



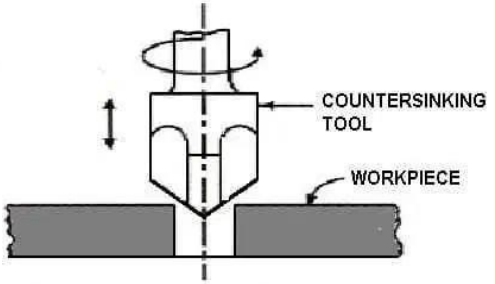
DRILLING OPEERATION



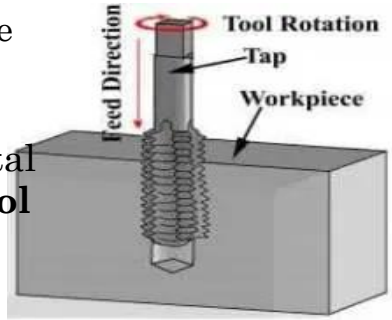
REAMING OPERATION

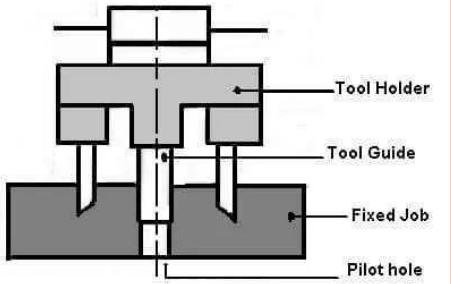


COUNTERBORING OPERATION



COUNTERSINKGING OPERATION

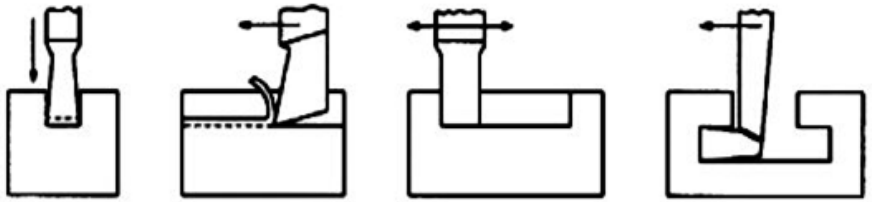


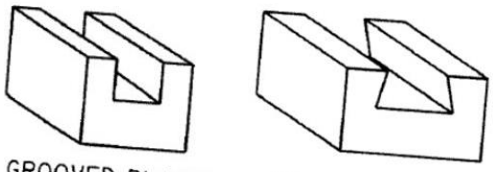
TREPANNING OPERATION

**Notes: https://www.theengineerspost.com/types-of-drilling-machine/4/**

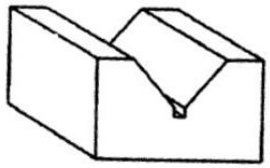
# Shaping Machine



(a) slotting (b) pocketing (c) T-slot cutting



GROOVED BLOCK DOVE TAIL SLIDE

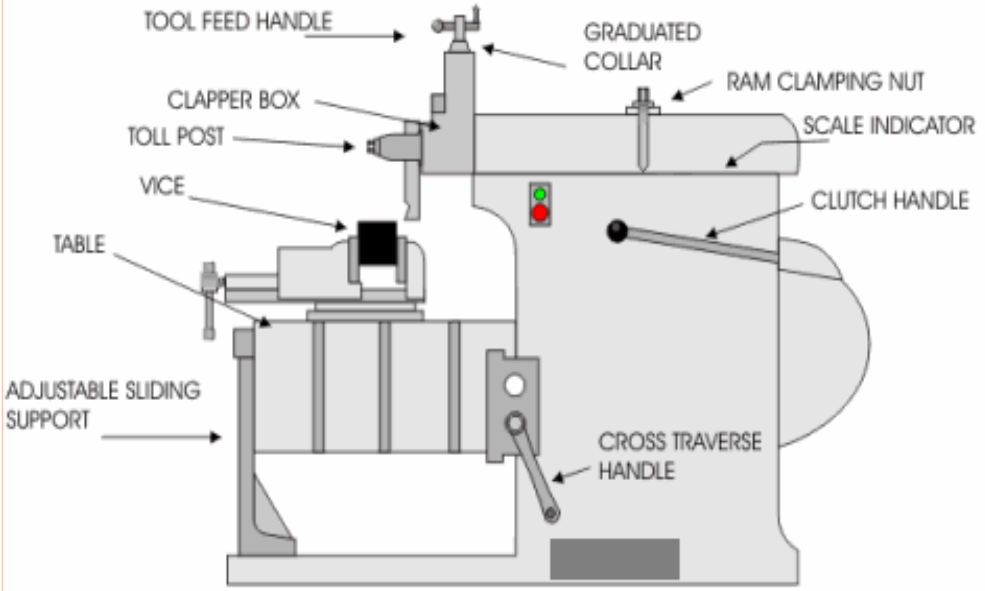


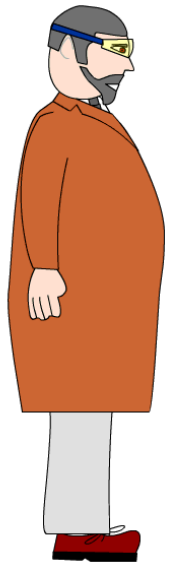
V-BLOCK

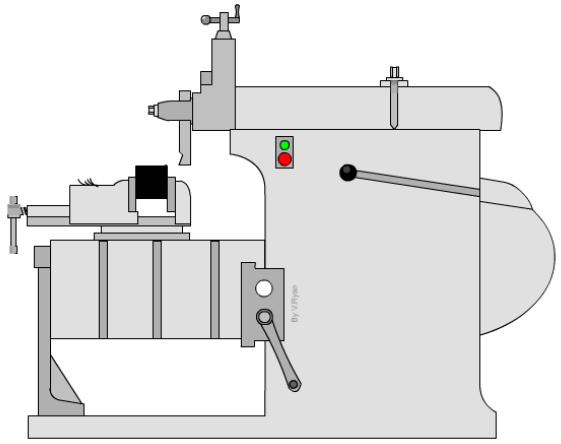
# MANUFACTURING TECHNOLOGY

## Shaping Machine

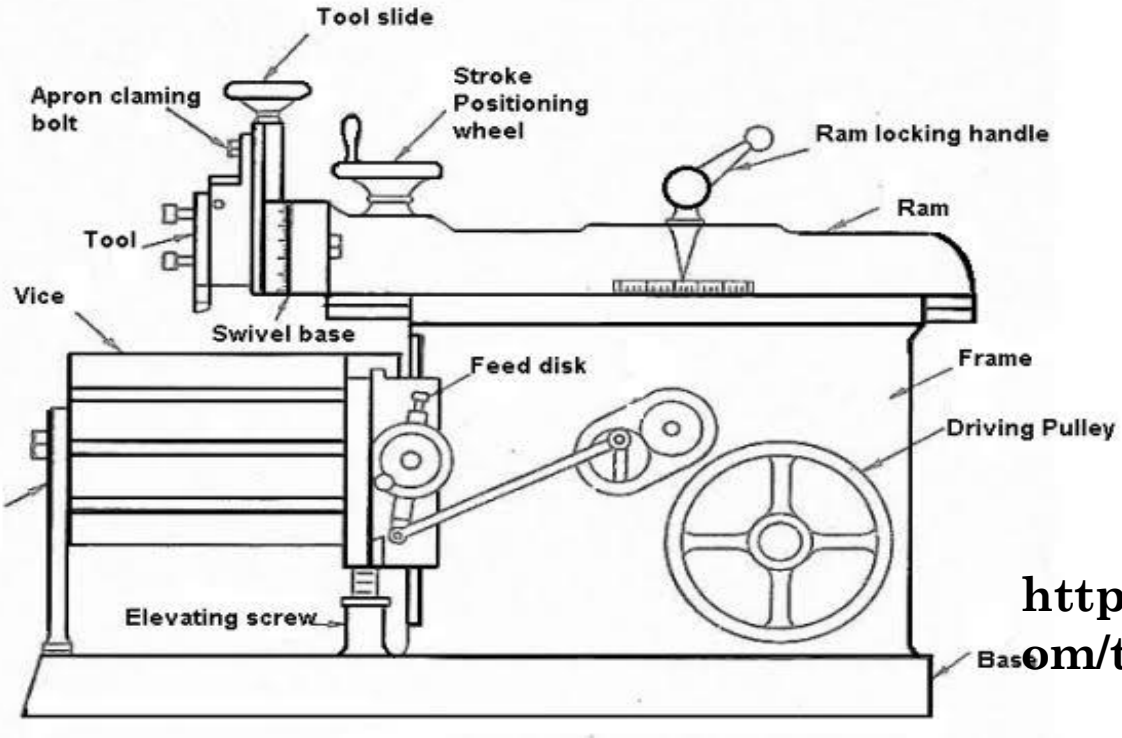
- A shaping machine **is used to machine surfaces**. It can **cut curves, angles and many** other shapes.
- Shaper machine is a **reciprocating type of machine** basically used for producing the horizontal, vertical or flat surfaces.
- It is a popular machine in a factory workshop because its **movement is very simple** although it can produce a variety of work. They are **less common in school workshops**, perhaps because of **their moving parts** which present a high risk.





# Shaping Machine Description




**Main Parts Of Shaper Machine:**

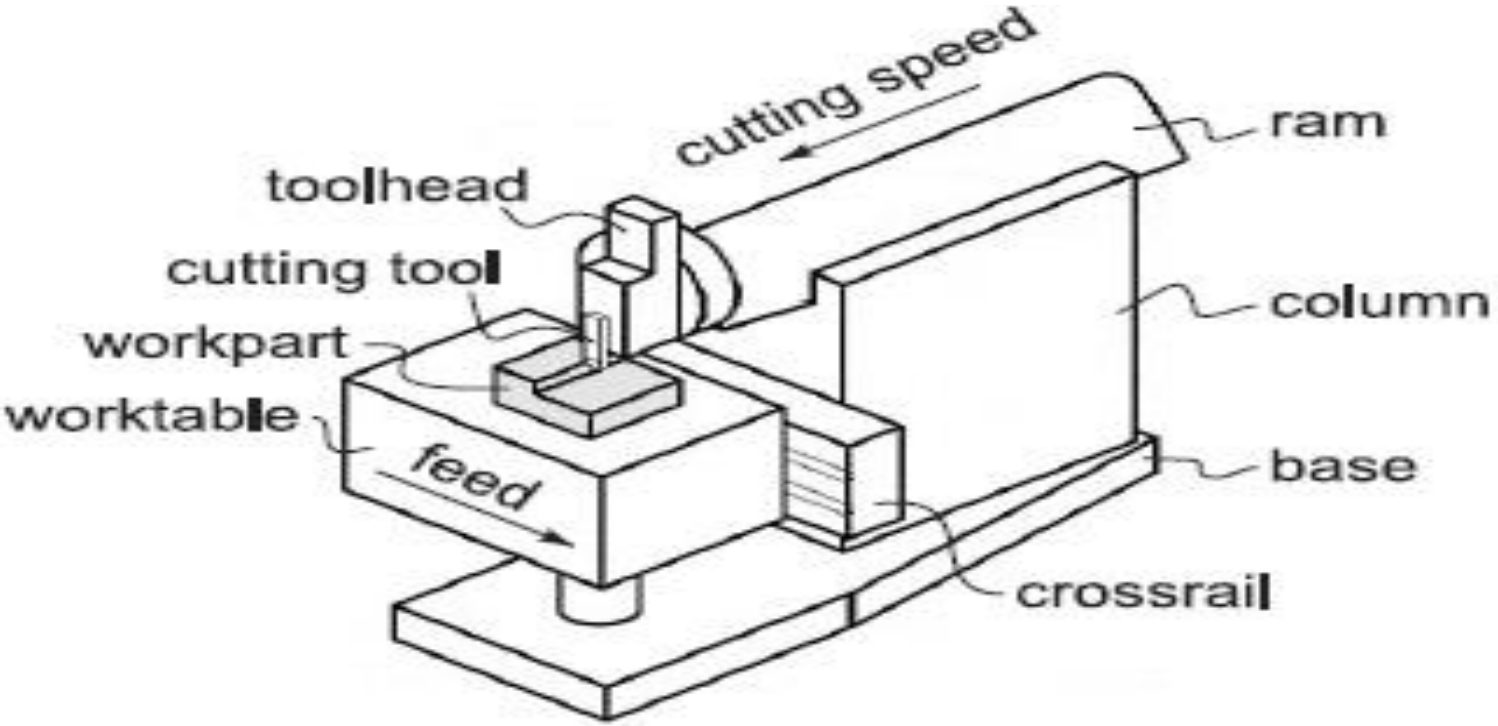
- Base
- Column
- Cross-rail
- Table
- Ram

**https://www.theengineerspost.com/types-of-shaper-machines**

- **Base** is the support required for all machines tools, **take up the entire load** of the machine and **the forces set up** by cutting tool.
- **Column** acts as a **cover to the drive mechanism** and also **supports the reciprocating ram** and the **worktable**
- **Cross rail** is mounted on the **front vertical surface of the column on which saddle is mounted.**
- **Table** is **bolted to the saddle** and **receives crosswise** and **vertical movements** from saddle cross rail
- **Ram reciprocates** on the **column guideways and carries** the tool head with a single point cutting tool

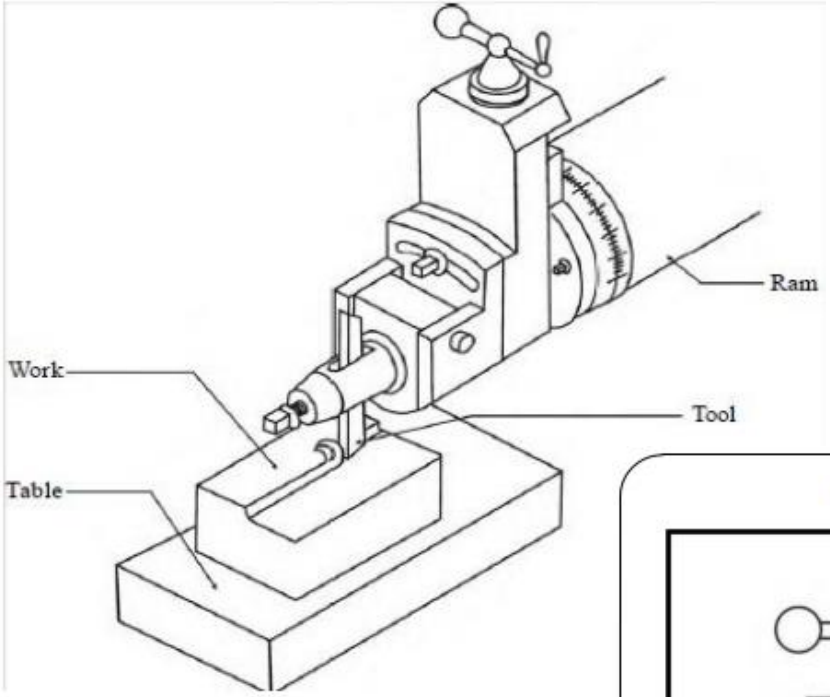
# Manufacturing Technology

- The major components of a shaper are **the *ram*,** which has **the *tool post*** with **cutting tool mounted on its face,** and a ***worktable***, which holds the part and accomplishes **the feed motion.**

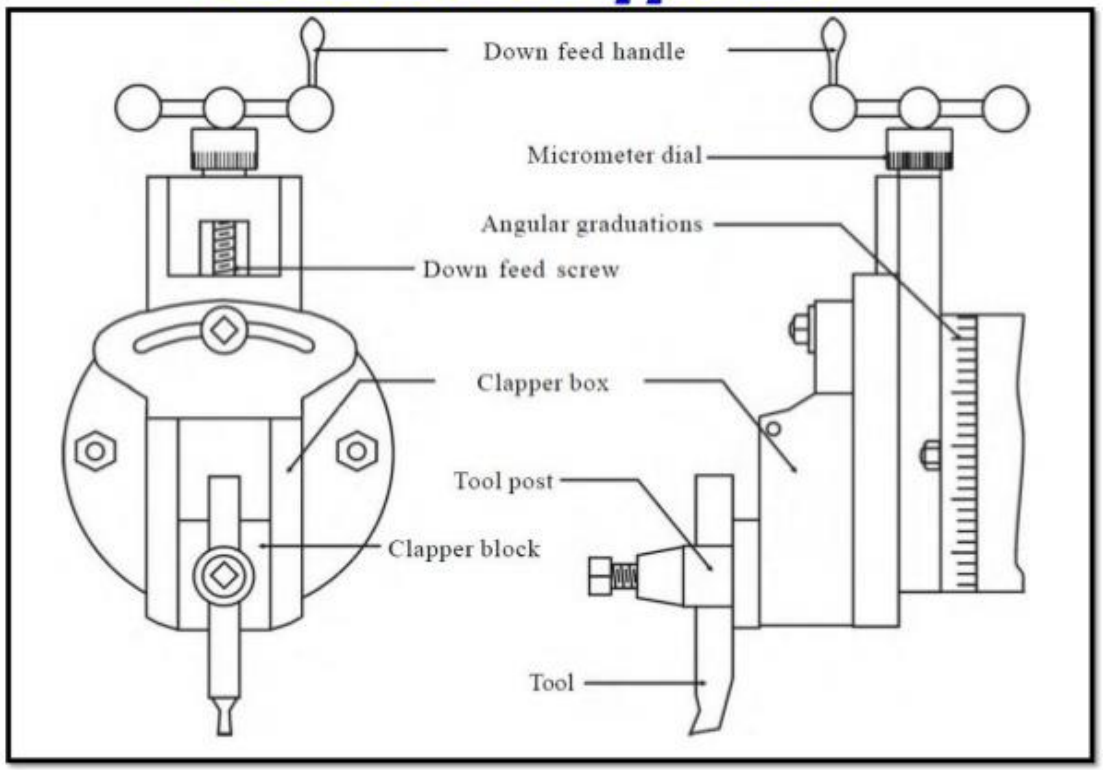



Components of a shaper

## Tool head and clapper box

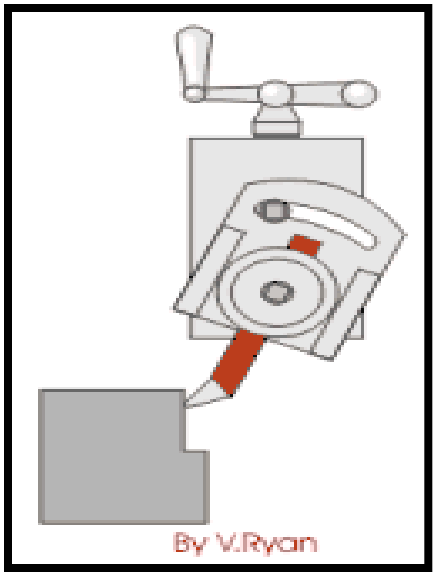



## Tool head and clapper box



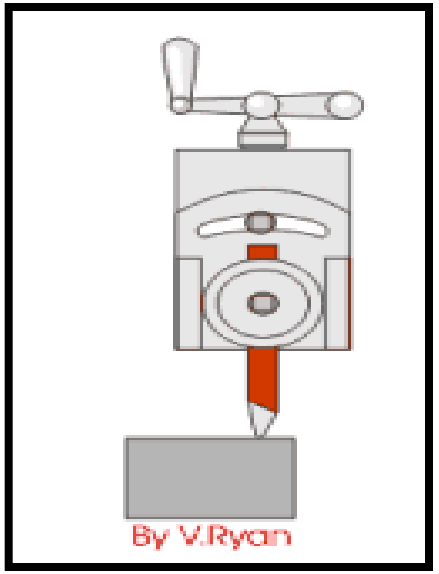
## Shaping Machine operation

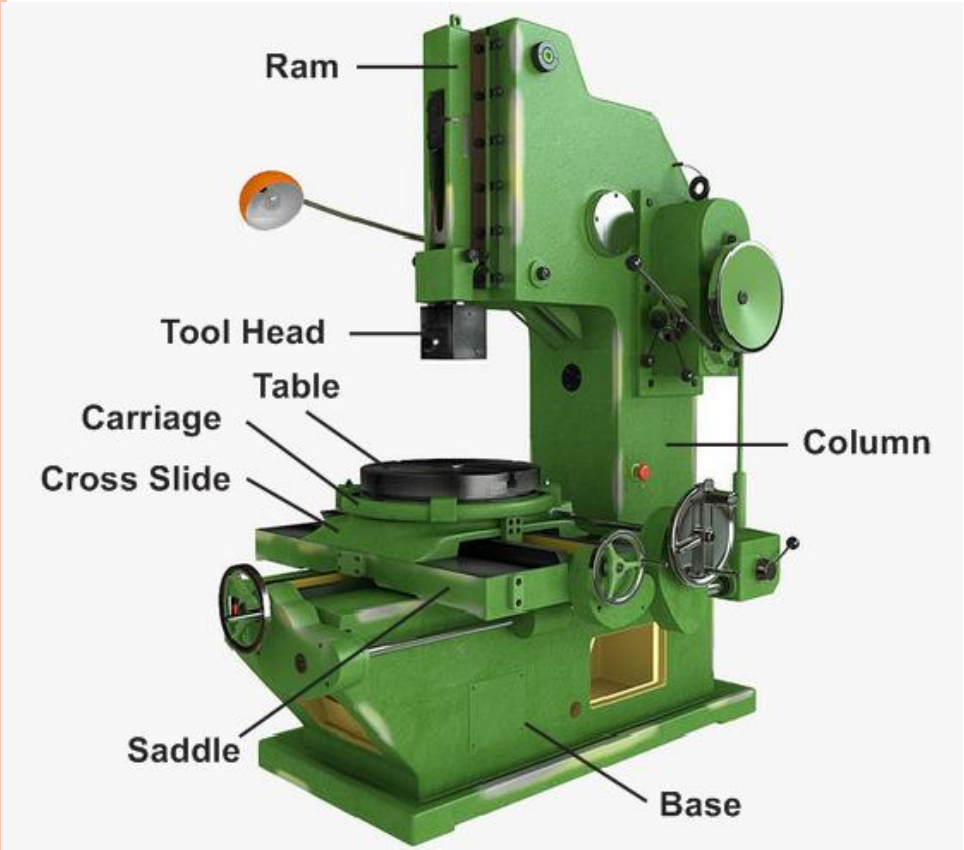
- The **tool feed handle** can be turned to **slowly feed the cutting tool** into the material as the **'ram' moves forwards and backwards**.
- The strong machine **vice holds the material securely**. A small vice would not be suitable as the work could quite easily **be pulled out of position and be damaged**.
- The **vice rests on a steel table** which can be adjusted so that it can be **moved up and down and then locked** in position. **Pulling back on the clutch handle** starts the 'ram' moving forwards and backwards.




The tool post has been turned at an angle so that side of the material can be machined

The tool post is not angled so that the tool can be used to level a surface.






# Slotting Machine

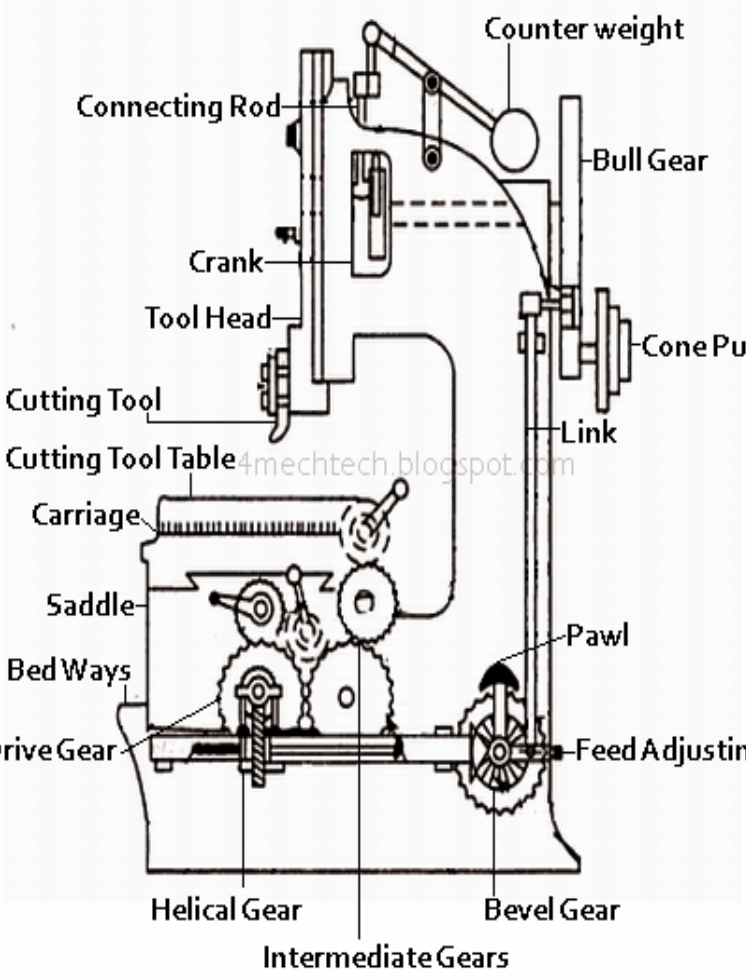
- Slotting machines can simply be considered as **vertical shaping machine**.
- Unlike **shaping and planning machines, slotting machines** are generally used to **machine internal surfaces** (flat, formed grooves and cylindrical).
  - To **cut slots, spline, keyways** both internal/external
  - To machine **internal/external gears**
  - **Internal recess** of circular, concave & convex surface
  - Internal **machining of Blind holes**

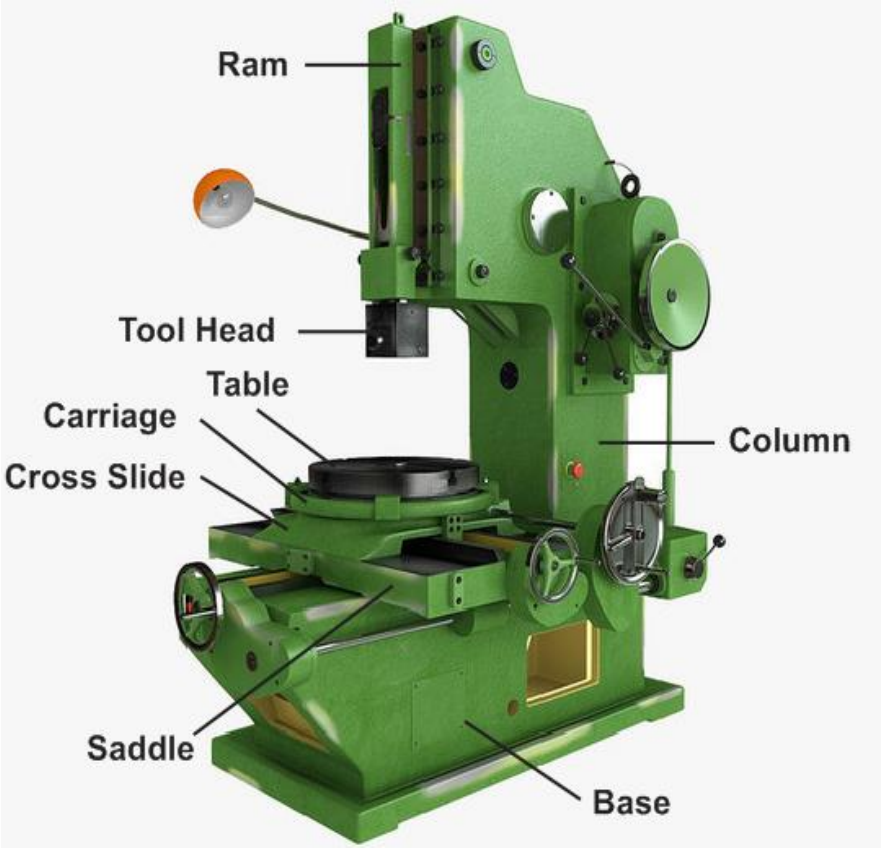
- The major **difference between a slotter machine and a shaper machine** is
  - In a **slotter, the ram holding the tool reciprocates in the vertical axis**.
  - In a **shaper, the ram holding the tool reciprocates in a horizontal axis**.
- A vertical shaper and slotter machines are almost similar to each other as regards their construction, operation, and use.
- The only difference being, in the case of a vertical shaper, the ram holding the **tool may also reciprocate at an angle to the horizontal table in addition to the vertical stroke**. The ram can be swivelled not more than 10° to the vertical.

**The slotter machine is used for**

- Cutting grooves, keyways and slots of various shapes.
- Used for making regular and irregular surfaces both internal and external.
- For handling large workpiece.
- For cutting internal or external gears and many other operations which cannot be easily machined in any other machine tool described before.

# Slotting Machine

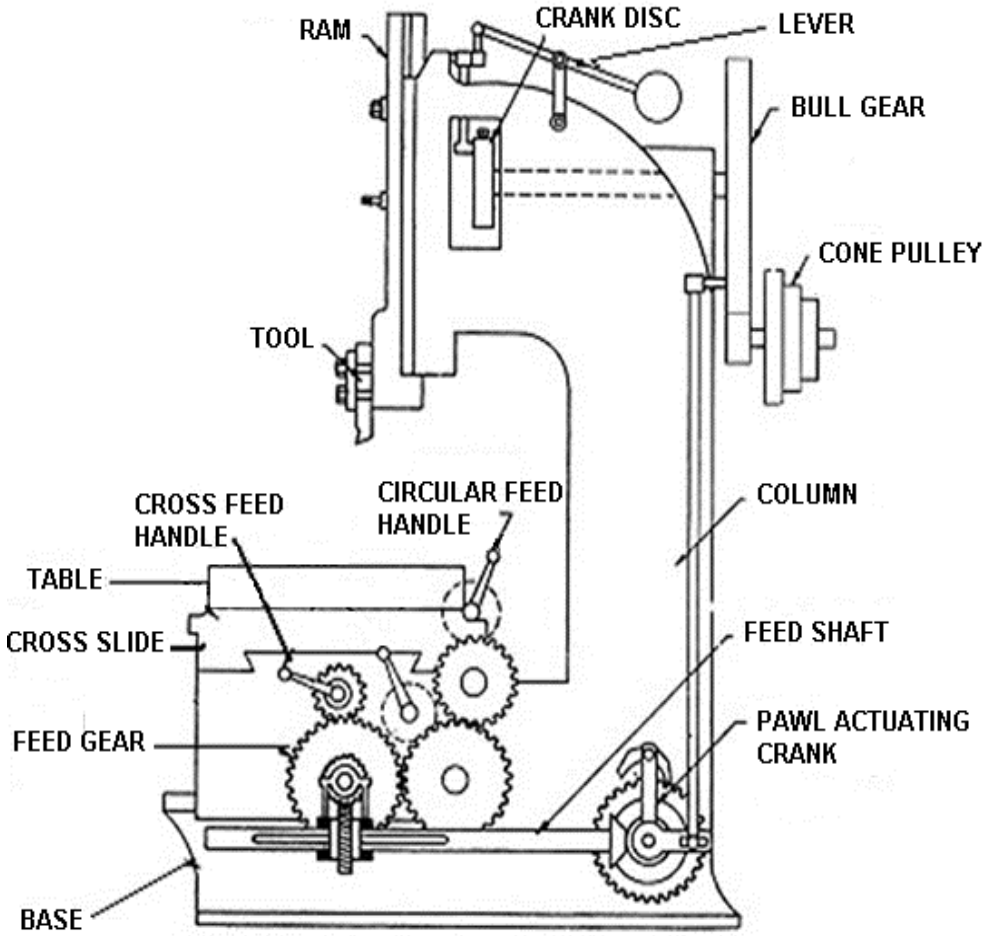



https://www.theengineerspost.com/slotter-machine/

# THE DIFFERENT PARTS OF A SLOTTER MACHINE ARE,

- Base.
- Column.
- Saddle.
- Crosslide.
- Rotating table.
- Ram and tool head assembly.
- Ram drive mechanism.
- Feed mechanism.

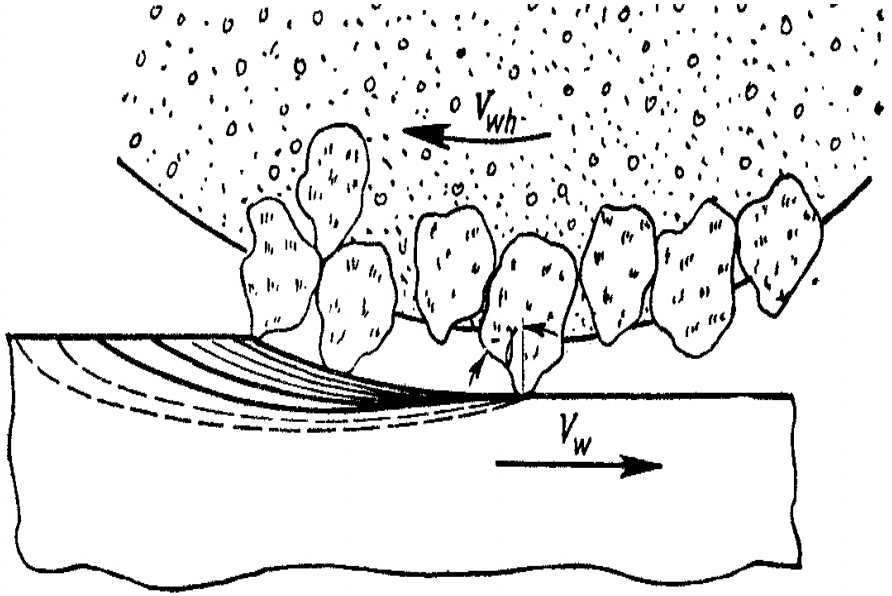



SLOTTER MACHINE

- **Base** is a rigid component on a slotter machine which takes the entire load of the machine while operating. It is made of **cast iron** and it contains **guideways perpendicular to the column face** is accurately finished. This allows the **saddle to easily and accurately move**.
- **Column** is a **vertical and integral rigid** part made of cast iron. It serves as a housing to the feeding mechanism of the table. it also houses the **driving mechanism of the ram**, which reciprocates on its front vertical face.
- **Cross slide:** The component of a slotter machine is mounted on the **guideways of the saddle**, allowing a cross-feeding to be achieved on the table. it allows the **arrangement of the cross-feeding**.
- **Rotating Table:** Designed to **rotate on cross-slide** in order to provide circular feeding to the work. It can **hold the work by clamping**, using fixtures, fixing vice, etc.
- **Ram** slides on the guideways mounted on the front vertical face of the column and it provides a slot for **changing the position of the stroke**. The **tool is mounted** to the ram at the bottom-end of the tool head.
- **Ram Drive:** produces **circular motion** of the motor to the r**eciprocating motion** of the ram in a vertical plane. The arrangement of slower speed is also provided during the cutting or forward stroke and greater speed during the return stroke, which **reduce the idle time**.
- **Feed Drive:** produce the arrangement of **longitudinal and cross-feed** of the table. It also provides the arrangement of **circular or rotary feeding** of the table on a vertical axis.

# Grinding

- **Grinding** is the most common form of **abrasive machining**. It is a material cutting process which **engages an abrasive tool** whose cutting elements are **grains of abrasive material** known as **grit**. These grits are characterized by **sharp cutting points**, high hot hardness, chemical stability and wear resistance.
- The grits are held together by a **suitable bonding material** to give shape of an abrasive tool.



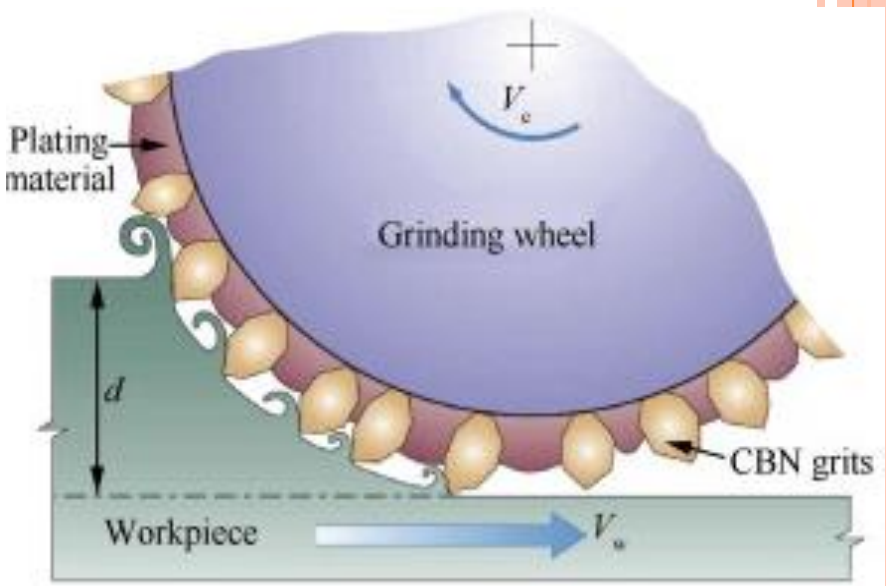




Fig. illustrates the cutting action of abrasive grits of disc type grinding wheel similar to cutting action of teeth of the cutter in slab milling.

# Manufacturing Technology

## Major advantages and applications of grinding

### Advantages

- A grinding wheel requires two types of specification
  - Dimensional accuracy
  - Good surface finish
  - Good form and locational accuracy applicable to both hardened and unhardened material

### Applications

- Surface finishing
- Slitting and parting
- De-scaling , De-burring
- Stock removal (abrasive milling) finishing of flat as well as cylindrical surface
- Grinding of tools and cutters and re-sharpening of the same.

# Manufacturing Technology

## Grinding Machines

- Grinding Machines are also regarded as **machine tools**. A distinguishing feature of grinding machines is the **rotating abrasive tool**.
- Grinding machine is employed to obtain high accuracy along with very **high class of surface finish** on the work piece. However, advent of new generation of grinding wheels and grinding machines, characterized by their rigidity, power and speed enables one to go for **high efficiency deep grinding** (often called as abrasive milling) of not only hardened material but also ductile materials.
- Conventional grinding machines can be broadly classified as:
  - Surface grinding machine
  - Cylindrical grinding machine
  - Internal grinding machine
  - Tool and cutter grinding machine

# Manufacturing Technology

## Grinding wheel

- Grinding wheel consists of **hard abrasive grains** called **grits**, which perform the **cutting or material removal**, held in the weak bonding matrix. A grinding wheel commonly identified by the **type of the abrasive** material used.
- The **conventional wheels** include aluminium oxide and silicon carbide wheels while diamond and CBN (cubic boron nitride) wheels fall in the category of **super abrasive wheel**.

## Specification of grinding wheel

- A grinding wheel requires two types of specification

  + Geometrical specification + Compositional specification

# MANUFACTURING TECHNOLOGY

## Geometrical specification

- This is decided by **the type of grinding machine** and the **grinding operation** to be performed in the workpiece. This specification mainly includes **wheel diameter**, **width and depth of rim** and the **bore diameter**.

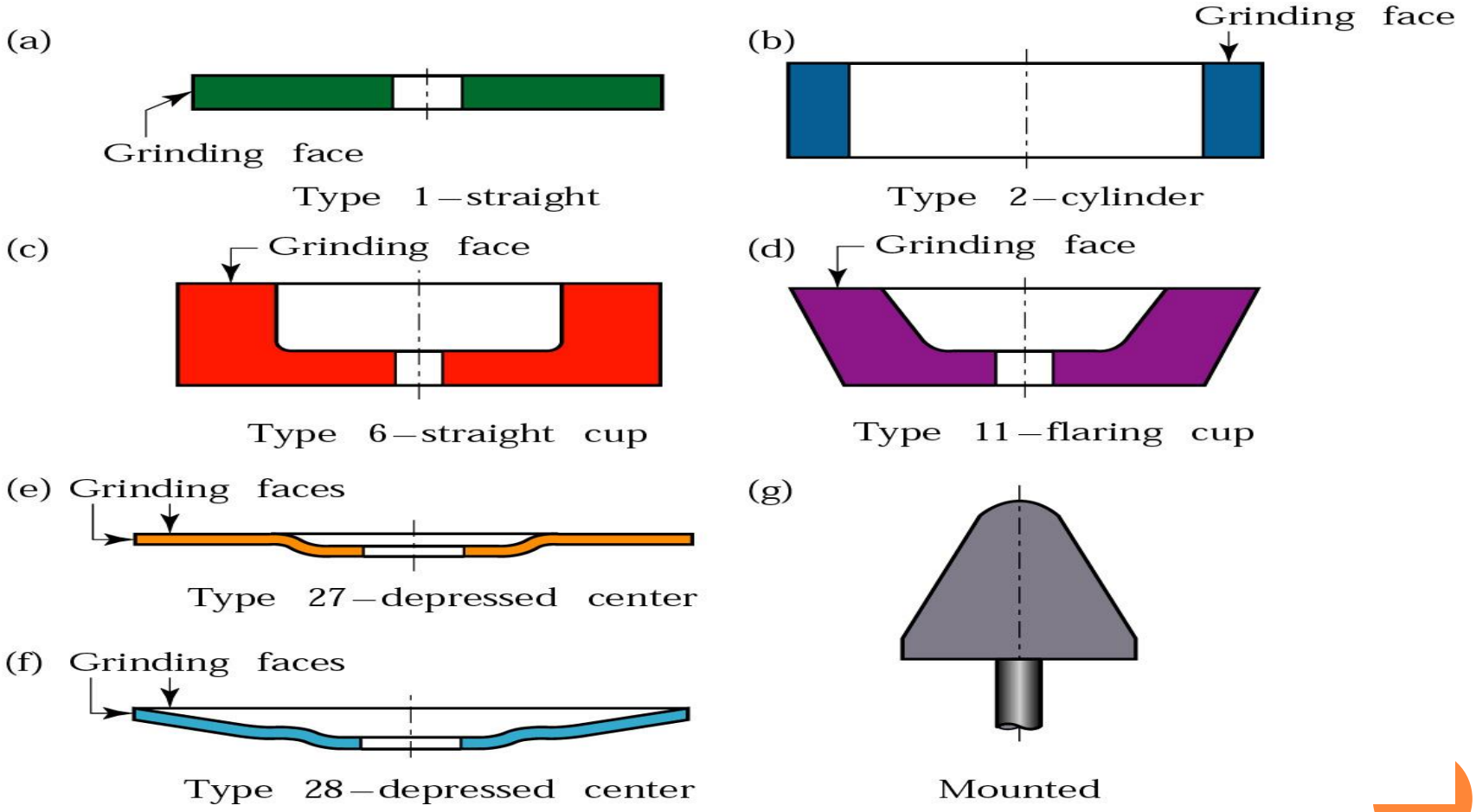
## Compositional specifications

- Specification of a grinding wheel ordinarily means compositional specification. Conventional abrasive grinding wheels are specified encompassing the following parameters.
  - The **type of grit** material
  - The **grit size**
  - The **bond strength** of the wheel, commonly known as wheel hardness
  - The **structure of the wheel** denoting the porosity i.e. the amount of inter grit spacing
  - The **type of bond** material
  - other than these parameters, the wheel manufacturer may add their own identification code prefixing or suffixing (or both) the standard code.

# Manufacturing Technology

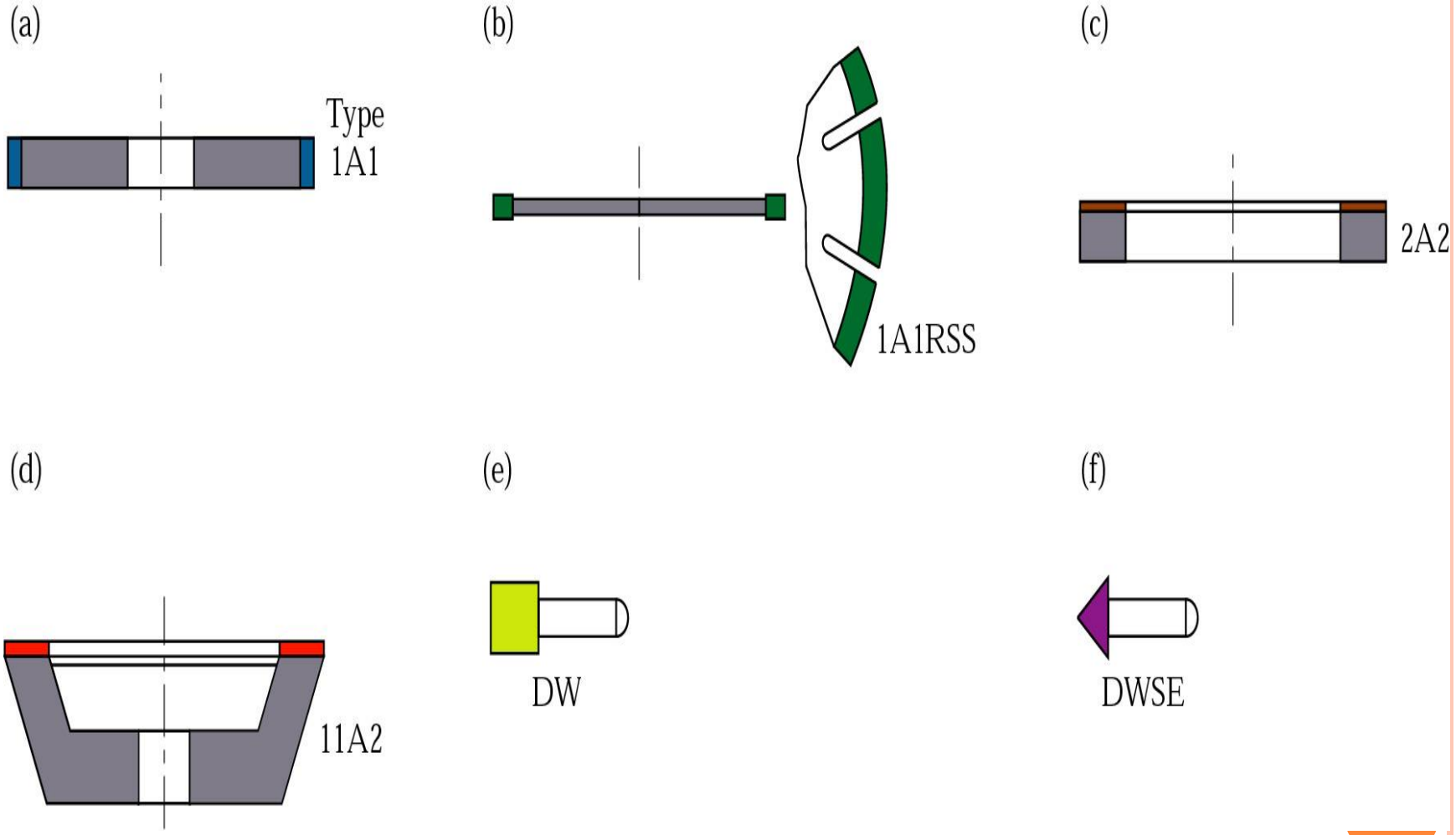
## Types

- Conventional abrasive grinding wheels



# Manufacturing Technology

- Super abrasive grinding wheels



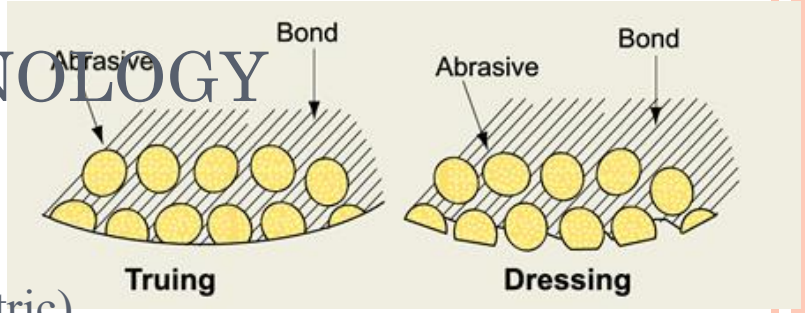

The bonding materials for the super abrasives are (a), (d), and (e) resinoid, metal, or vitrified, (b) metal, (c) vitrified, and (f) resinoid.

# Manufacturing Technology

Selection of Cutting speed and Working speed is based on

- Material to be ground and its hardness.
- Amount of stock removal and finish required.
- Whether the grinding is done wet or dry.
- Wheel speed.
- Area of grinding contact.
- Severity of the grinding operation.

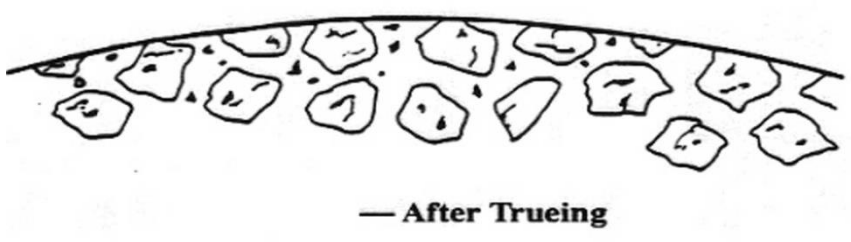
# Manufacturing Technology



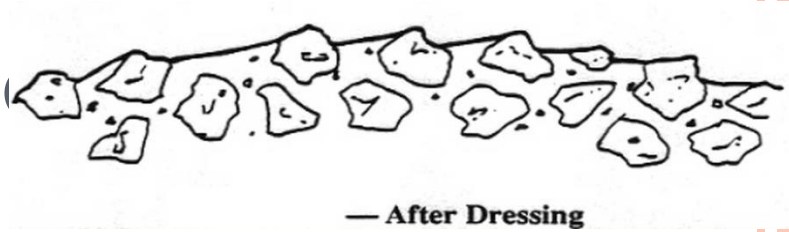

## Truing and dressing of grinding wheel

**Truing** (Make level, square, balanced, or concentric)

- Truing is the act of regenerating the required geometry on the grinding wheel, whether the geometry is a special form or flat profile. Therefore, truing produces the macro-geometry of the grinding wheel.
- Truing is also required on a new conventional wheel to ensure concentricity with specific mounting system. In practice the effective macro-geometry of a grinding wheel is of vital importance and accuracy of the finished work piece is directly related to effective wheel geometry.



# MANUFACTURING TECHN



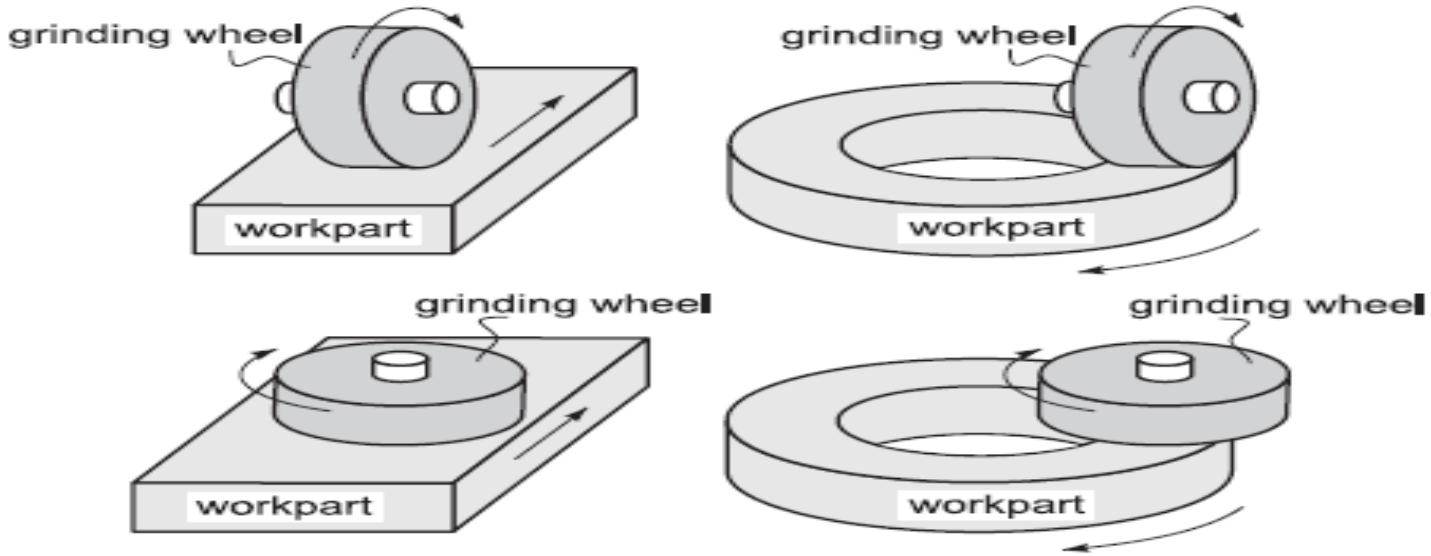

## Dressing

- Dressing is the conditioning of the wheel surface which ensures that grit cutting edges are exposed from the bond and thus able to penetrate into the work piece material. Also, in dressing attempts are made to splinter the abrasive grains to make them sharp and free cutting and also to remove any residue left by material being ground.
- Dressing therefore produces micro-geometry. The structure of micro-geometry of grinding wheel determine its cutting ability with a wheel of given composition. Dressing can substantially influence the condition of the grinding tool.
- Truing and dressing are commonly combined into one operation for conventional abrasive grinding wheels, but are usually two distinctly separate operation for super abrasive wheel.

# Manufacturing Technology

## Surface grinding

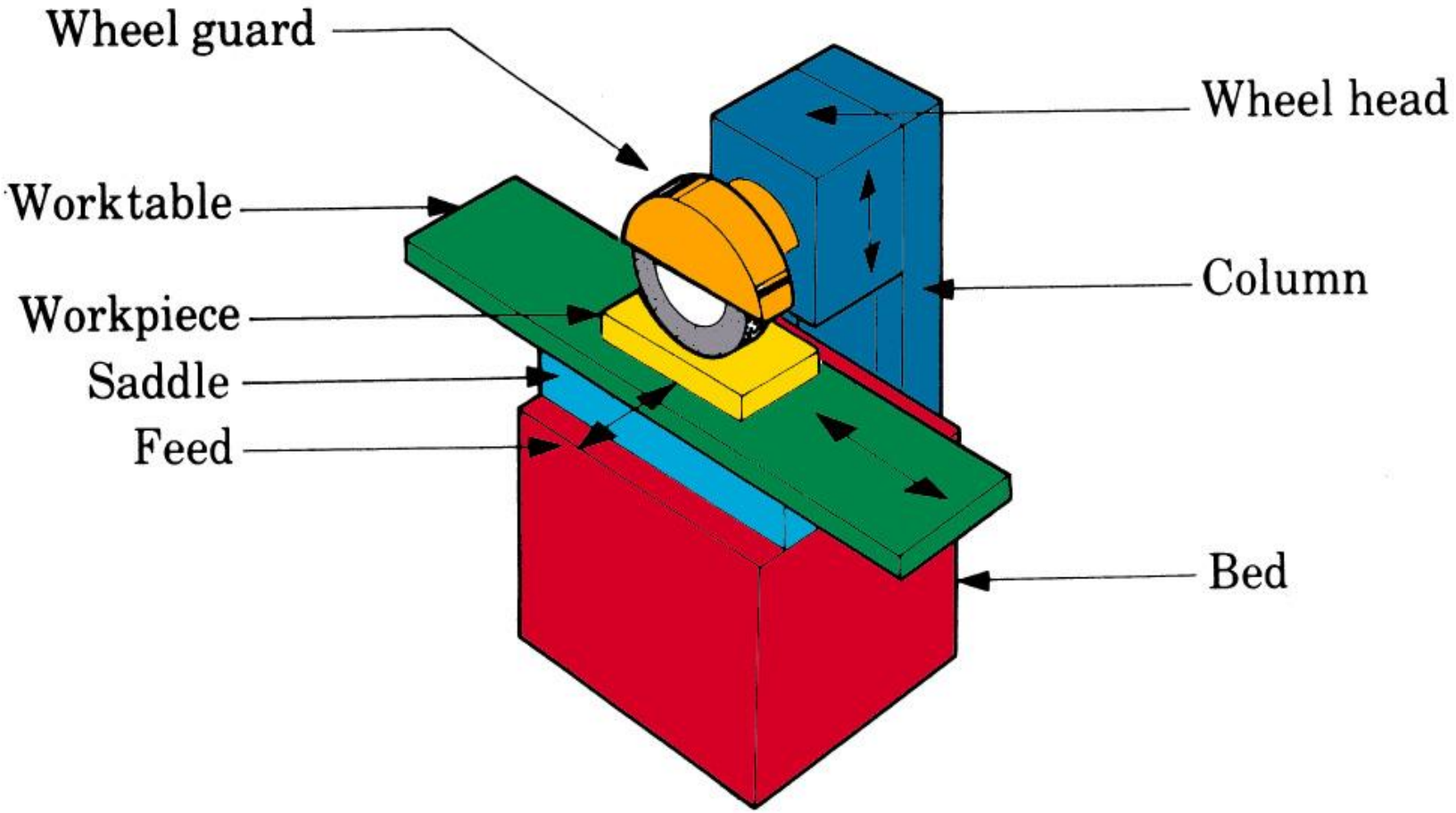
- In surface grinding, the **spindle position is either horizontal or vertical**, and the relative motion of the work piece is achieved **either by reciprocating the work piece past the wheel or by rotating it**.
- The possible combinations of **spindle orientations and work piece motions** yield four types of surface grinding processes illustrated in the figure




Four types of surface grinding with horizontal or vertical spindles, and with reciprocating linear motion or rotating motion of the workpiece.

# Manufacturing Technology

Surface grinding machine

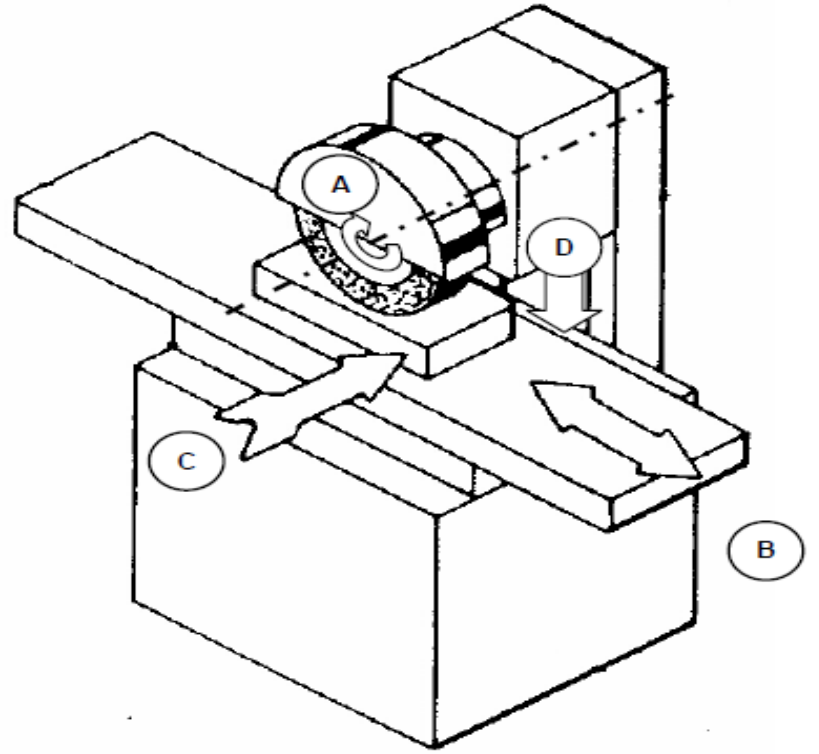



Schematic illustration surface grinding Machine

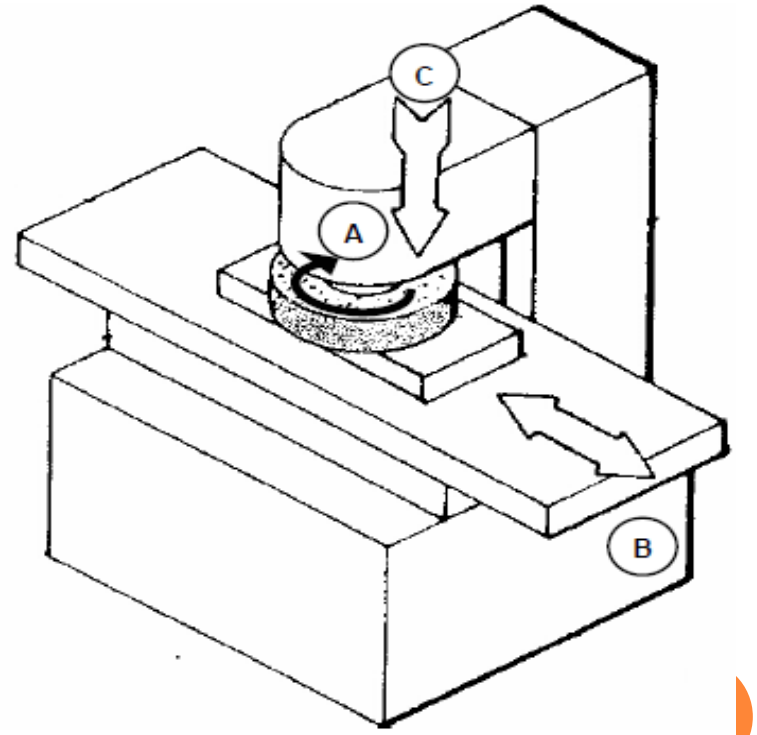
# Manufacturing Technology

## Surface grinding machine

- This machine may be similar to a **milling machine used mainly to grind flat surface**. However, some types of surface grinders are also capable of producing contour surface with formed grinding wheel.



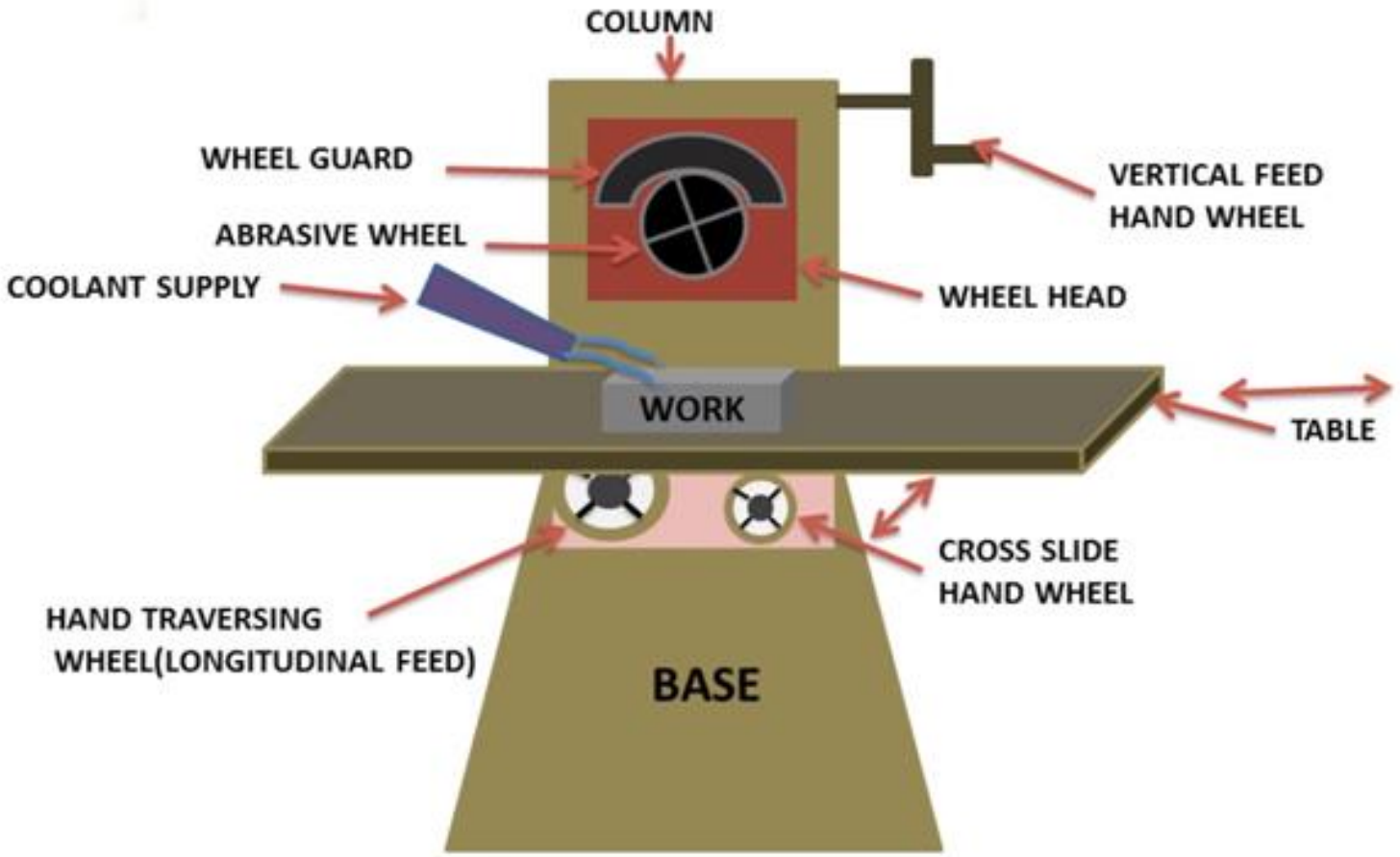

Horizontal Grinding Machine




Vertical Grinding Machine

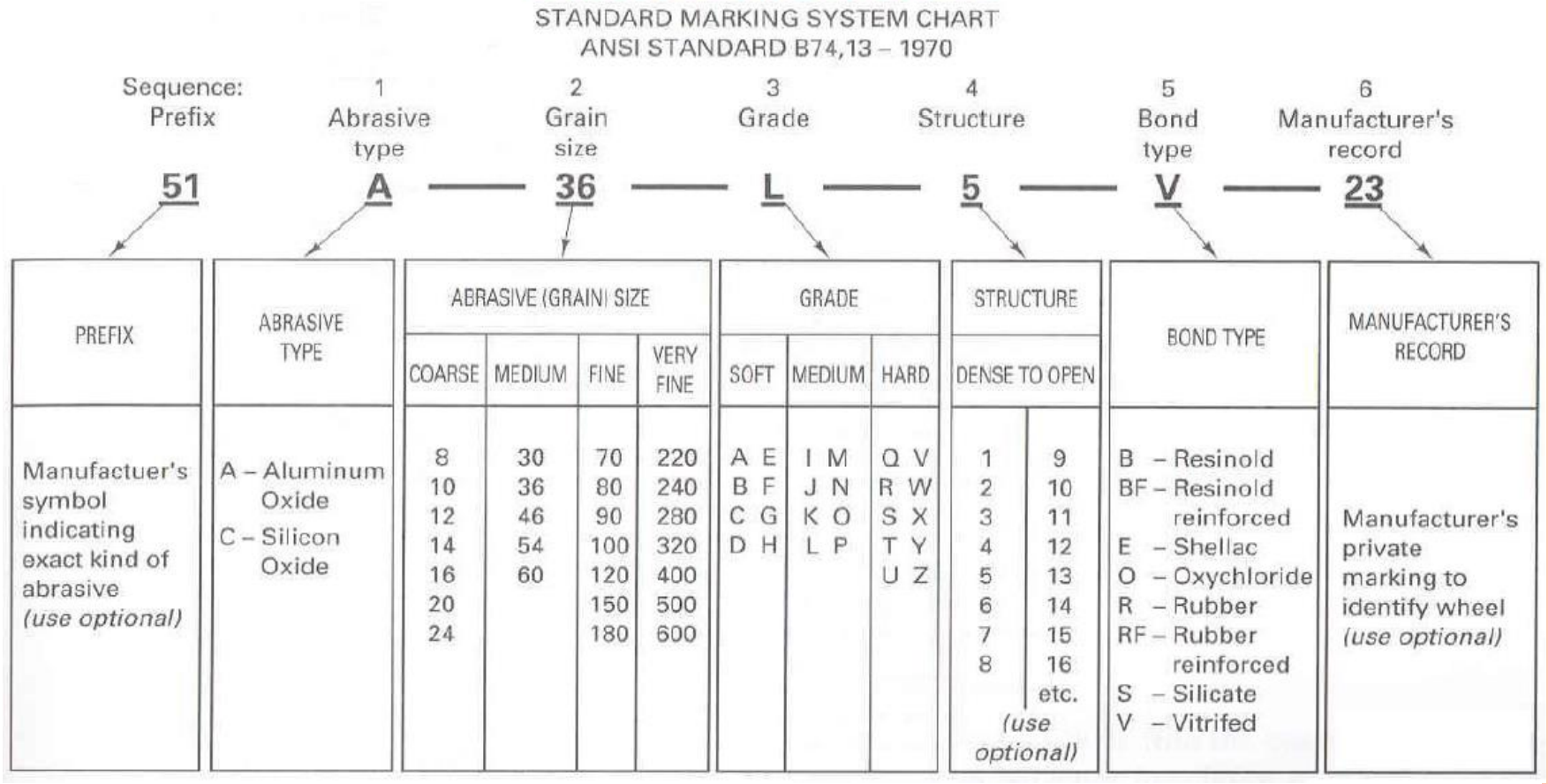
**A: rotation of grinding wheel B: reciprocation of worktable C: transverse feed D: do**

# SURFACE GRINDER



- **Base:** It is bottom most part of the grinding machine. It is generally made of cast iron. It provides support to rest part of the grinding machine.
- **Table:** It is rested on the base. This is the place where the workpiece is kept and held properly to grind. It can move left and right horizontally using a traversing wheel known as Hand Traversing Wheel.
- **Column:** It is a vertical column where abrasive wheel, wheel head and wheel guard are mounted.
- **Abrasive wheel:** Rotates and remove materials from the surface of the workpiece and make it smooth. This wheel is coated with abrasives and thereby can remove materials from workpiece surface easily.
- **Wheel guard:** It is the cover of the abrasive wheel or grinding wheel which protect the worker fro any type of accident.
- **Wheel Head:** It is the compartment that is moved vertically up or down using a traversing wheel called Vertical Feed Hand Wheel . We move this wheel head so that the grinding wheel can touch the workpiece.
- **Coolant supply nozzle:** It is the used to insert nozzle in the grinding machine which cools the work region so that the heat is not dissipated into the workpiece and abrasive wheel.
- **Traversing Wheels:** Hand Traversing Wheel, Cross Side Hand Wheel, Vertical Feed Hand Wheel

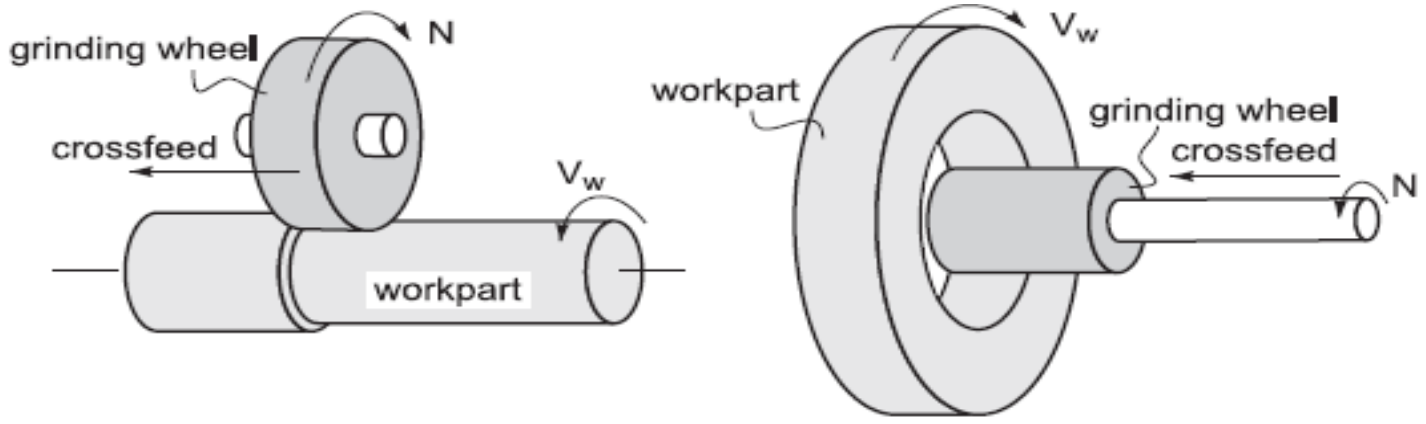
# A STANDARD COMPEREHENSIVE MARKING SYSTEM CHART DEVELOPED BY ANSI



# Manufacturing Technology

## Cylindrical grinding

- In this operation, the external or internal cylindrical surface of a work piece are ground. In *external cylindrical grinding* (also *center-type grinding*) the work piece rotates and reciprocates along its axis, although for large and long work parts the grinding wheel reciprocates.
- In *internal cylindrical grinding*, a small wheel grinds the inside diameter of the part. The work piece is held in a rotating chuck in the headstock and the wheel rotates at very high rotational speed. In this operation, the work piece rotates and the grinding wheel reciprocates.

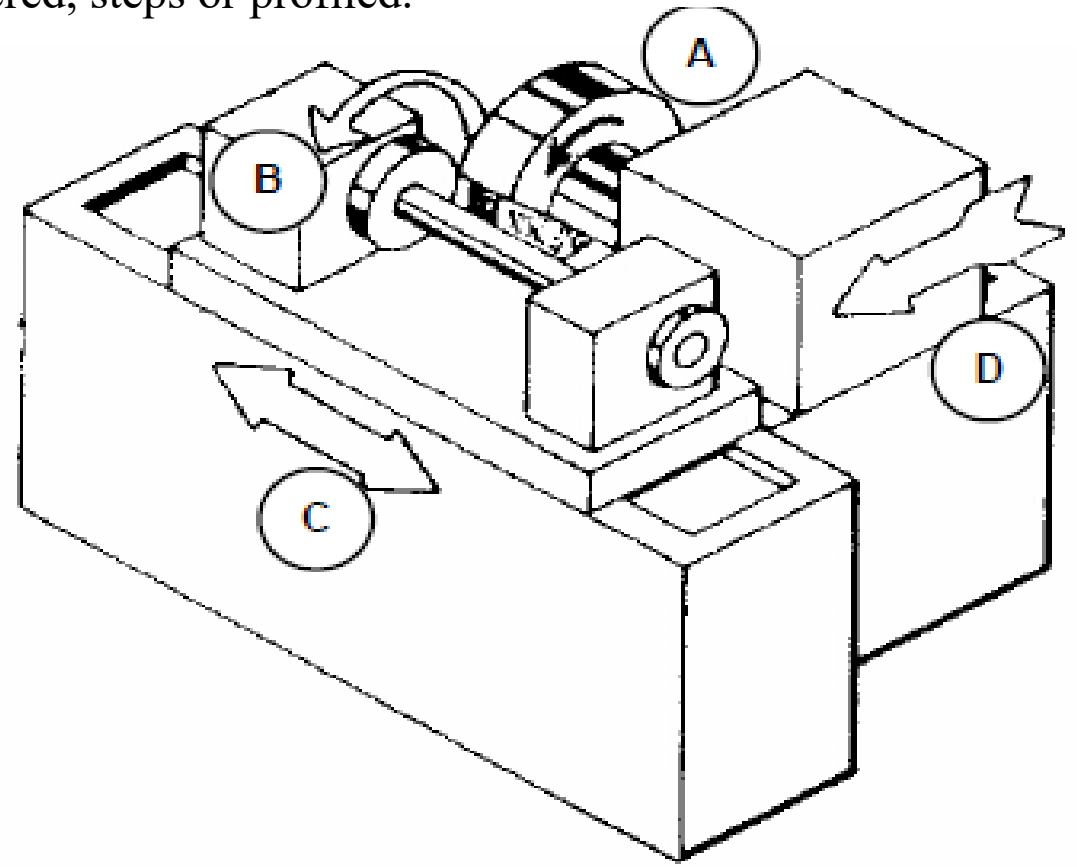



Two types of surface grinding, (*Left*) external, and (*Right*) internal.

# Manufacturing Technology

## Cylindrical grinding machine

- This machine is used to produce external cylindrical surface. The surfaces may be straight, tapered, steps or profiled.

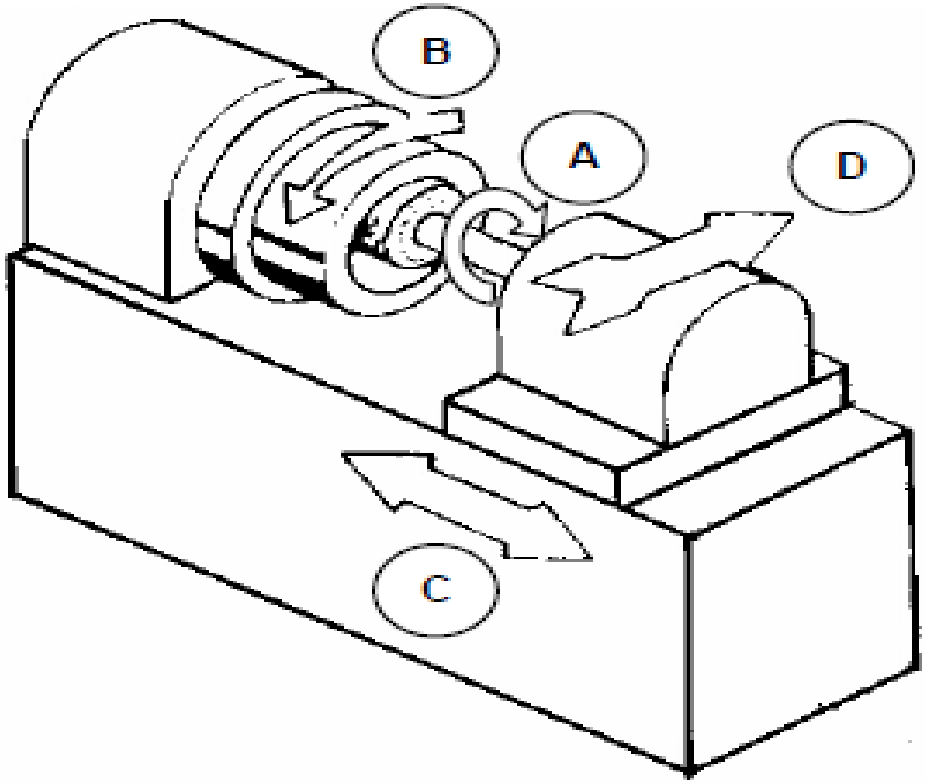


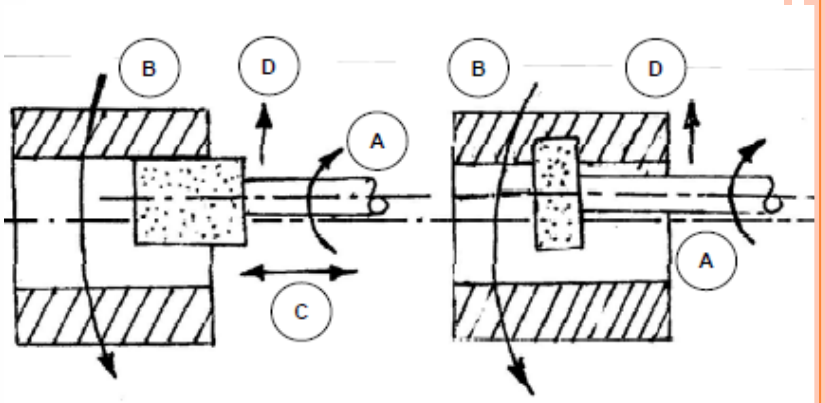

**A: rotation of grinding wheel B: work table rotation C: reciprocation of worktable D**

# Manufacturing Technology

## Internal grinding machine

- This machine is used to produce internal cylindrical surface. The surface may be straight, tapered, grooved or profiled.




**A: rotation of grinding wheel**
**C: reciprocation of worktable**

**B: workpiece rotation**
**D: infeed**

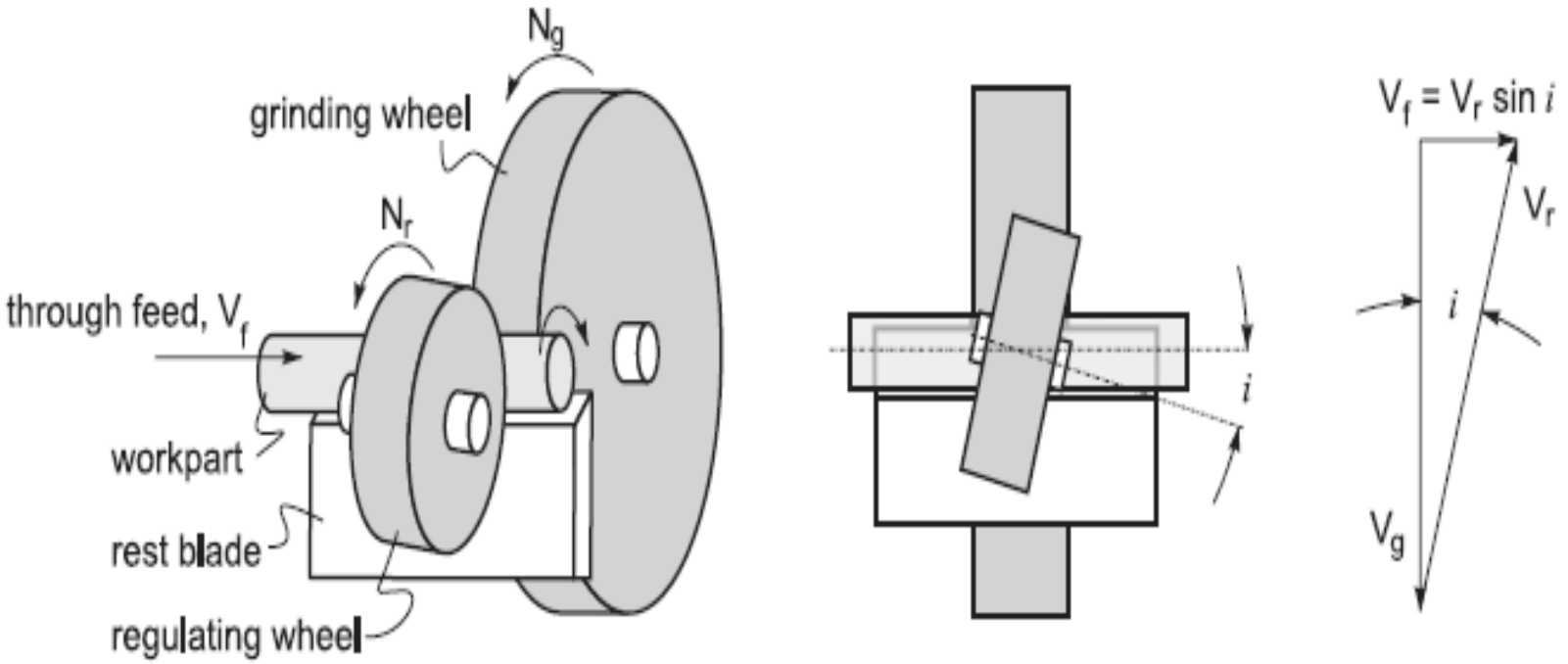
# Manufacturing Technology

## Center less grinding

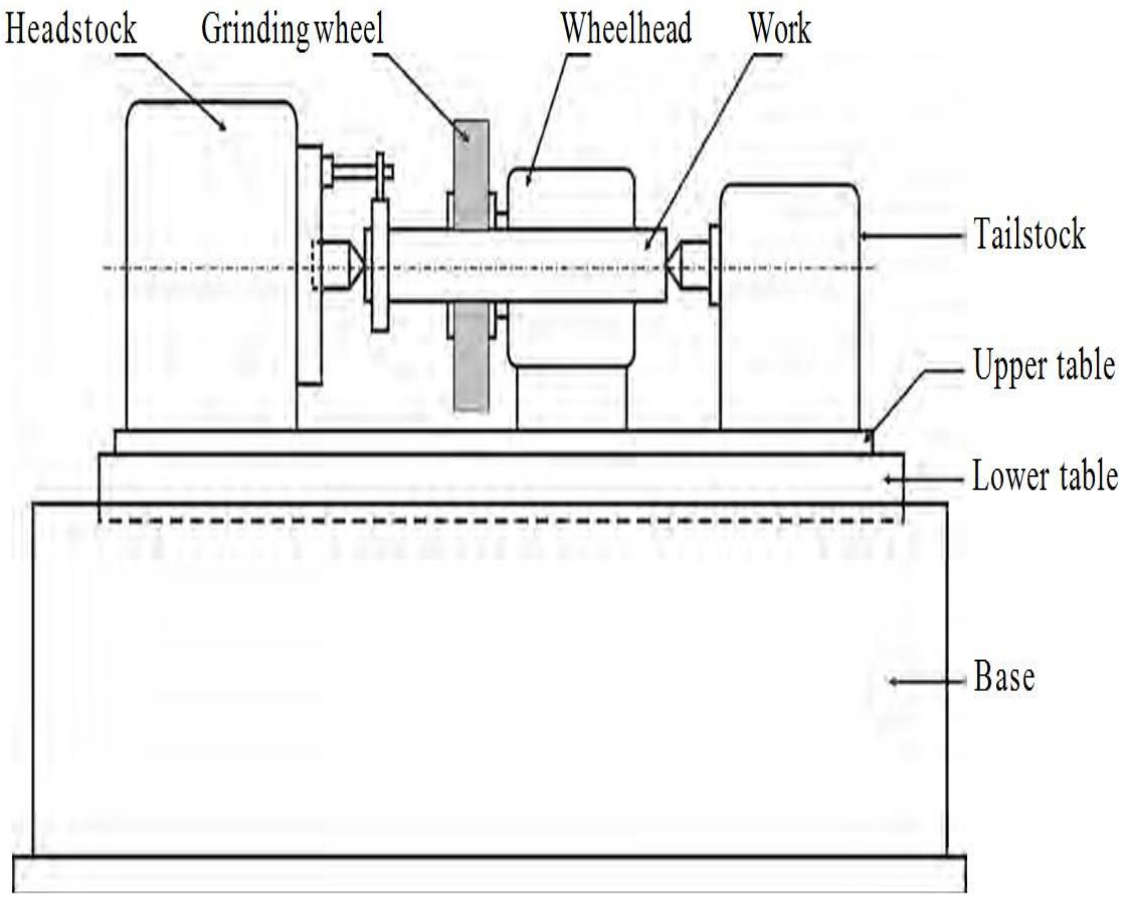
- *Center less grinding* is a process for continuously grinding cylindrical surfaces in which the work piece is supported not by centers or chucks but by a *rest blade*. The work piece is ground between two wheels. The larger *grinding wheel* does grinding, while the smaller *regulating wheel*, which is tilted at an angle *i*, regulates the velocity Vf of the axial movement of the work piece.
- Center less grinding can also be *external* or *internal*, *traverse feed* or *plunge grinding*. The most common type of center less grinding is the *external traverse feed grinding.*

# Manufacturing Technology

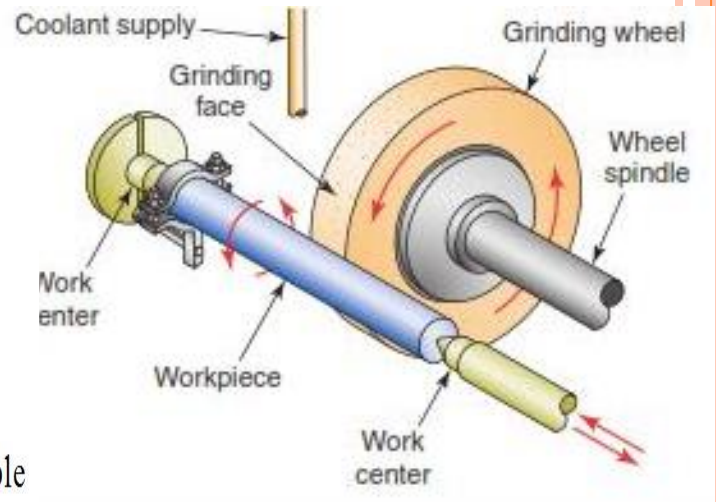
## Center less grinding Machine

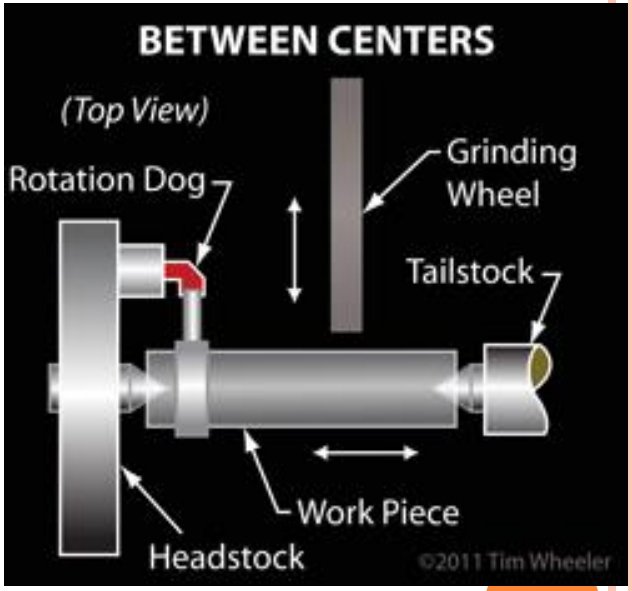



External traverse feed centerless grinding. The regulating wheel is tilted at an angle $i$ to control the velocity of through feed.




Cylindrical Grinding Machine



Cylindrical grinders are generally used to grind external surfaces like cylinders, taper cylinders, faces and shoulders of work.

- **Base:** It is made of cast iron and rests on the floor. It supports the parts mounted on. The top of the base is accurately machined and provides guideways for the table to slide on. The base contains the table driving mechanisms.
- **Tables:** It is mounted on top of the base. There are two tables namely lower table and upper table. The lower table slides on the guideways on the bed. It can be moved by hand or by power within required limits.
- **Headstock:** It is situated at the left side of upper table. It supports the workpiece by means of a centre and drives it by means of a dog. It may hold and drive the workpiece in a chuck. It houses the mechanism meant for driving the work. The headstock of a universal grinding machine can be swiveled to any required angle.
- **Tailstock:** It is situated at the right side of the table. It can be adjusted and clamped in various positions to accommodate different lengths of workpieces.
- **Wheelhead:** This may be moved at right angles to the table ways. It is operated by hand or by power to feed the wheel to the work.The wheelhead carries a grinding wheel.

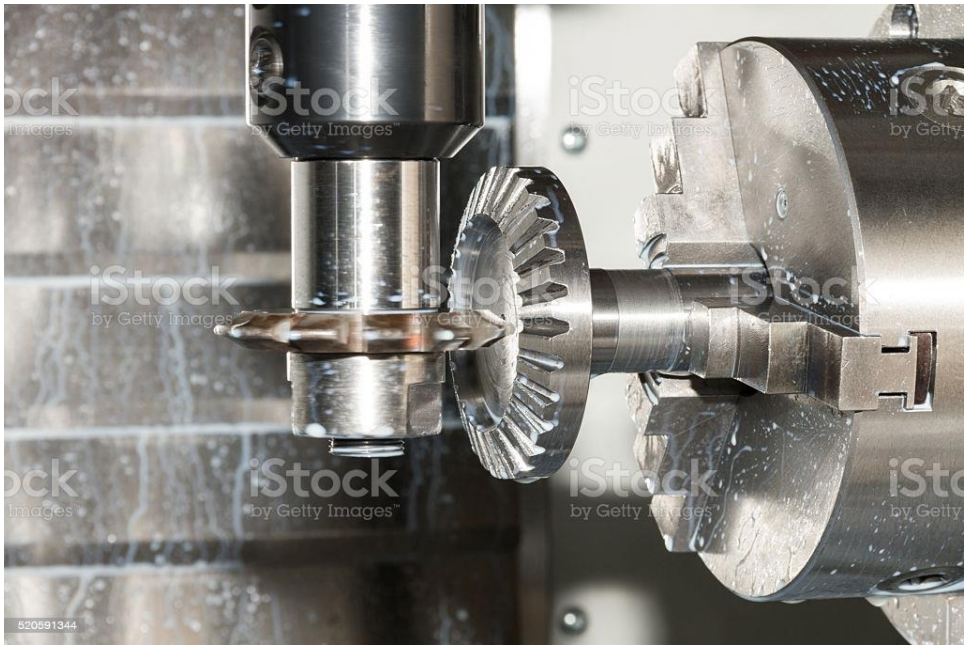
# Manufacturing Technology

## Finishing Operation

- To ensure reliable performance and prolonged service life of modern machinery, its components require to be manufactured not only with high dimensional and geometrical accuracy but also with high surface finish.
- The surface finish has a vital role in influencing functional characteristics like wear resistance, fatigue strength, corrosion resistance and power loss due to friction.
- The finishing operations are assigned as the last operations in the single part production cycle usually after the conventional or abrasive machining operations, but also after net shape processes such as powder metallurgy, cold flash less forging, etc.

# Manufacturing Technology

- Finishing Operations
  - Lapping
  - Buffing
  - Honing
  - Super finishing
  - Wire brushing
  - Polishing
  - Electro polishing
  - Magnetic-field-assisted polishing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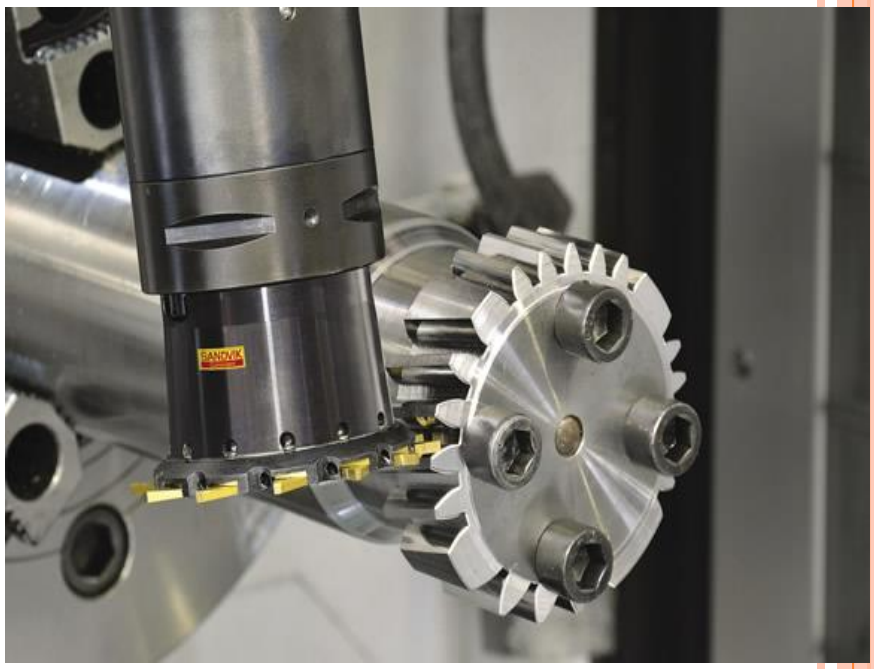
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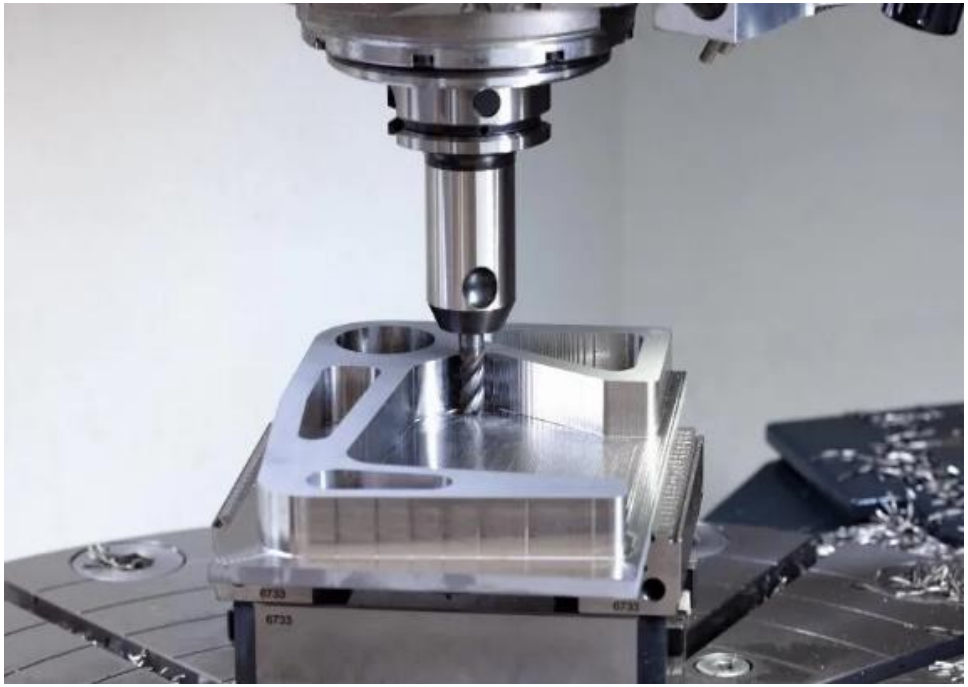
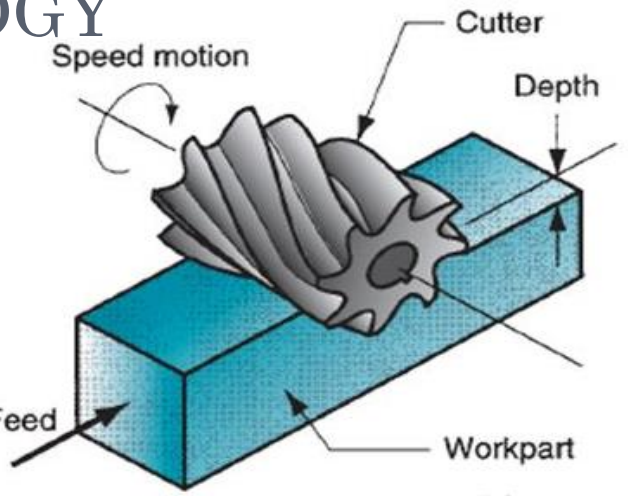


# Manufacturing Technology

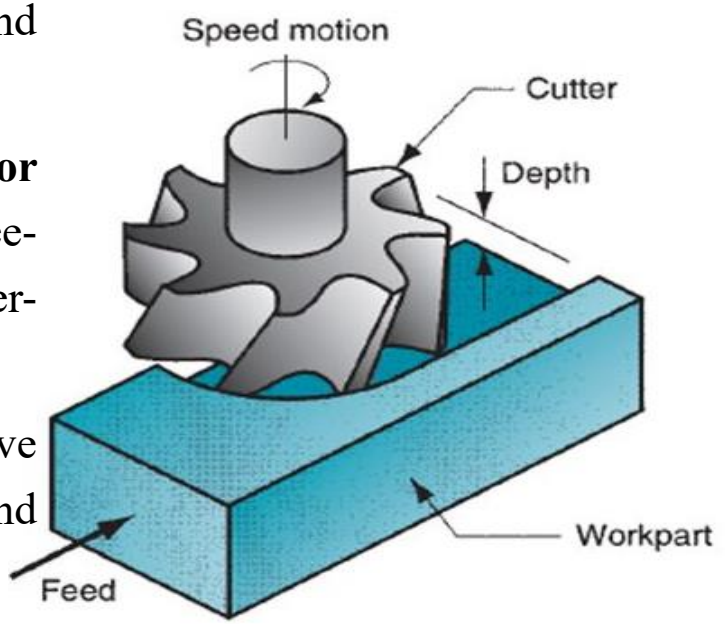
## Milling

### Introduction

- **Milling** is the process of machining **flat, curved, or irregular surfaces** by feeding the work piece against a **rotating cutter** containing a **number of cutting edges**.
- Mill consists basically of a **motor driven spindle**, which mounts and revolves the **milling cutter**, and a **reciprocating adjustable worktable**, which mounts and feeds the work piece.
- Milling machines are basically classified as **vertical or horizontal.** These machines are also classified as knee-type, ram-type, manufacturing or bed type, and planer-type.
- Most milling machines have self-contained electric drive motors, coolant systems, variable spindle speeds, and power-operated table feeds



peripheral milling



face milling

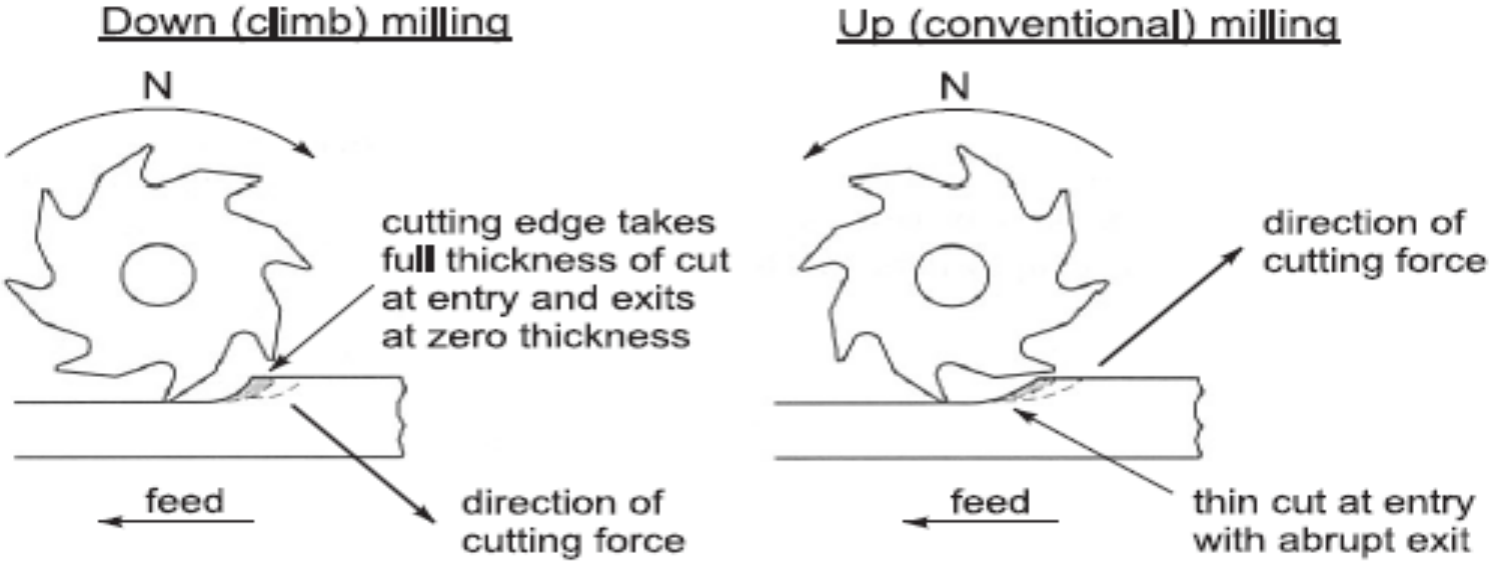
# Manufacturing Technology

- Milling is a process of **producing flat and complex shapes** with the use of **multi-tooth cutting tool**, which is called a **milling cutter** and the **cutting edges** are called **teeth**.
- The **axis of rotation** of the cutting tool is **perpendicular** to the direction of feed, **either parallel or perpendicular** to the machined surface. The machine tool that traditionally performs this operation is called **milling machine.**
- Milling is an **interrupted cutting operation** in which the teeth of the milling **cutter enter and exit the work** during each revolution.
- This interrupted cutting action subjects the teeth to a cycle of impact force and thermal shock on every rotation. The **tool material and cutter geometry** must be designed to withstand these conditions. Cutting fluids are essential for most milling operations.

# Manufacturing Technology

*Types of milling*

- There are two basic types of milling
- *Down* (*climb*) milling, when the cutter rotation is in the same direction as the motion of the work piece being fed.
- *up* (*conventional*) milling, in which the work piece is moving towards the cutter, opposing the cutter direction of rotation



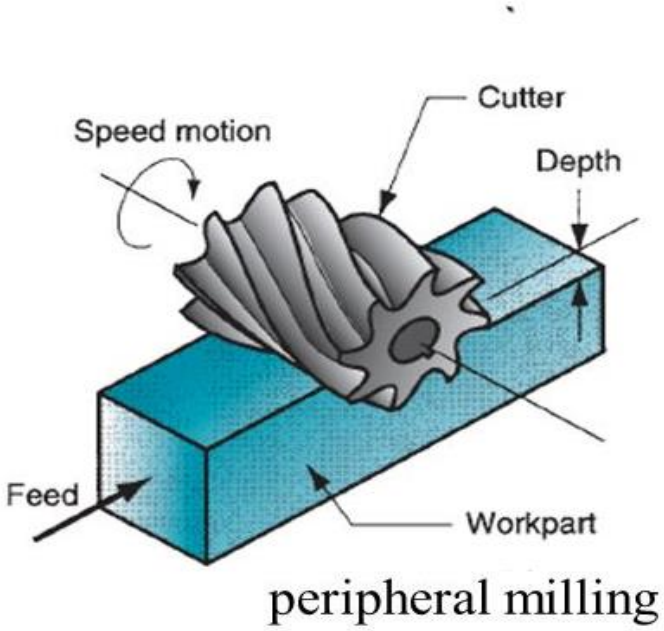

Two types of peripheral milling. Note the change in the cutting force direction.

# Manufacturing Technology

Milling Operations

Milling of Flat Surfaces

- **Peripheral Milling**

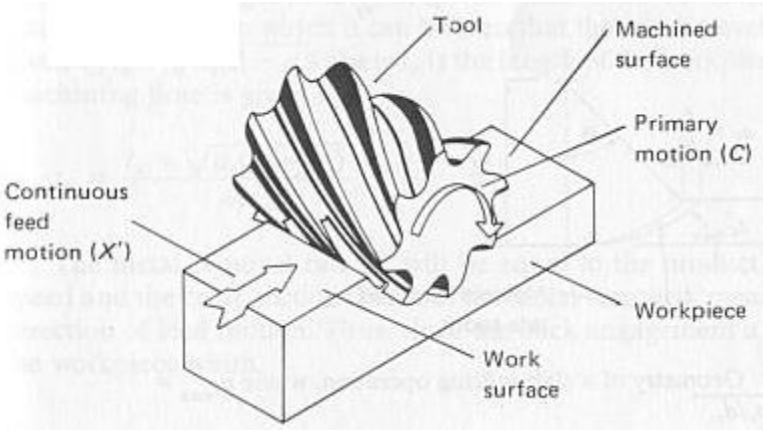


peripheral milling

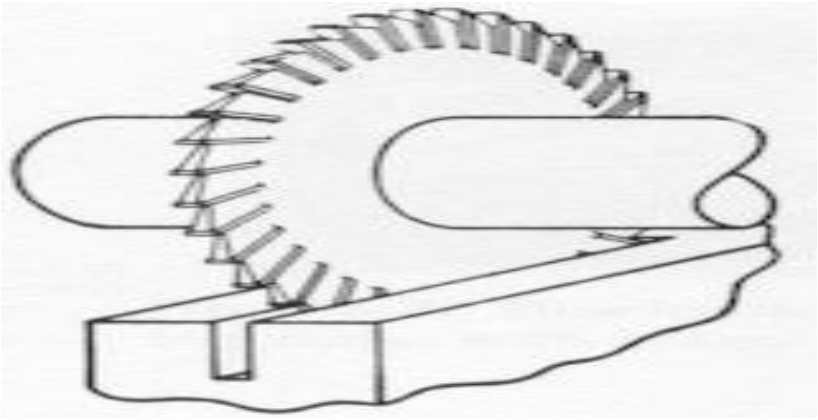
- In *peripheral milling*, also called *plain milling*, the **axis of the cutter is parallel to the surface** being machined, and the operation is performed by **cutting edges on the outside periphery** of the cutter. The primary motion is the rotation of the cutter. The feed is imparted to the work piece.
- In peripheral milling the axis of the cutter rotation is parallel to the work surface to be machined.

# Manufacturing Technology

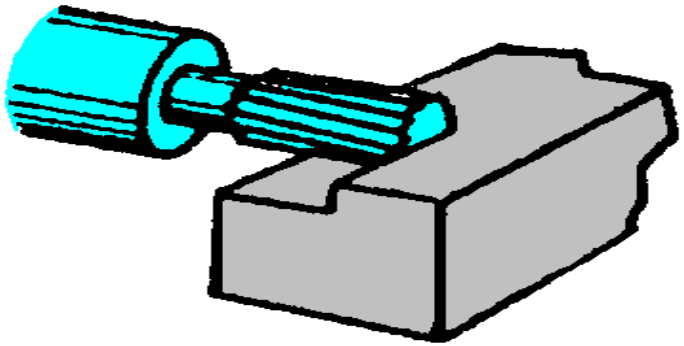
## Peripheral Milling



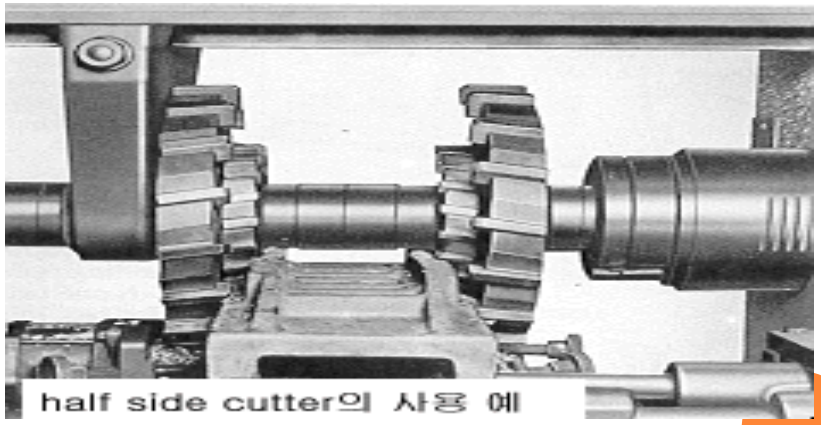

A



B



C



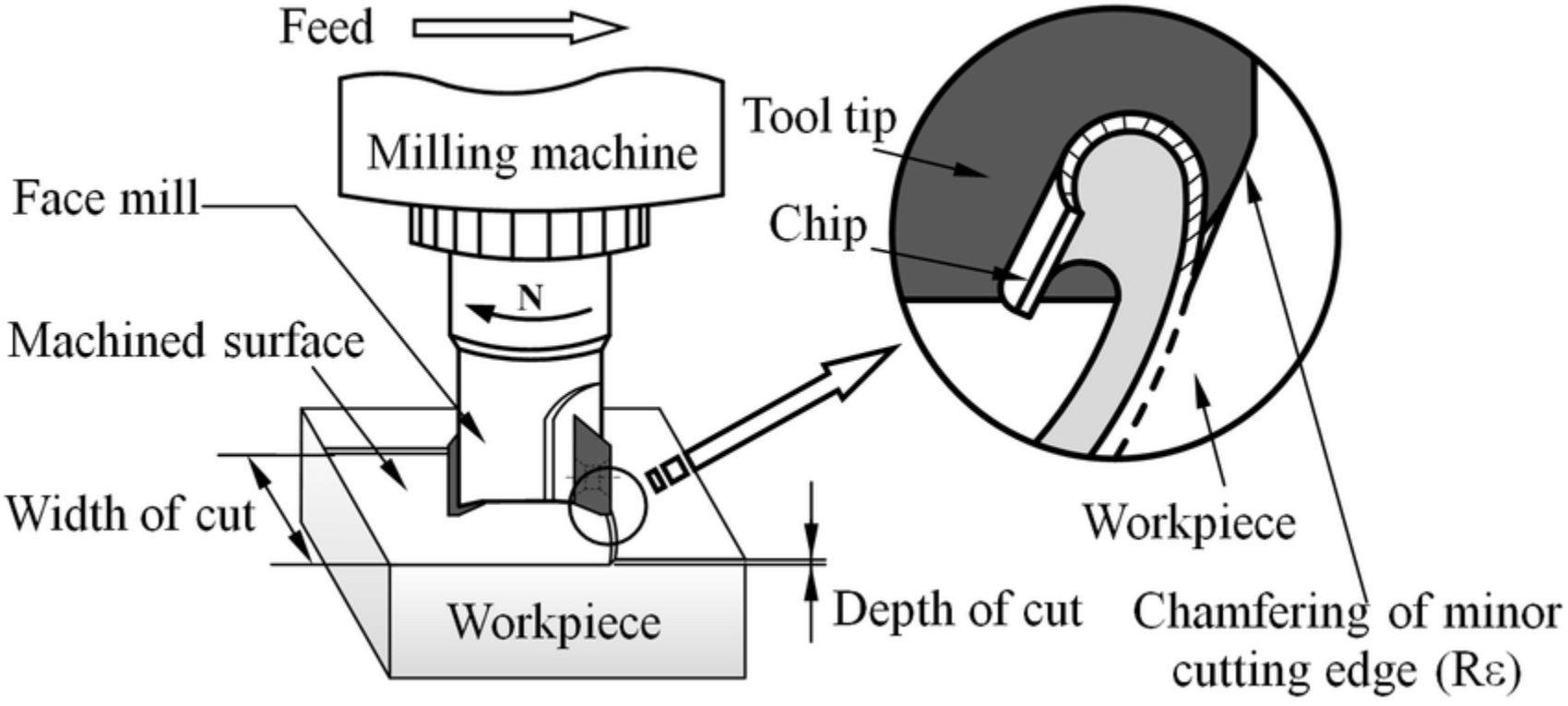

D

**A. Slab milling , B. Slot milling , C. Side milling , D. Straddle milling**

# Manufacturing Technology

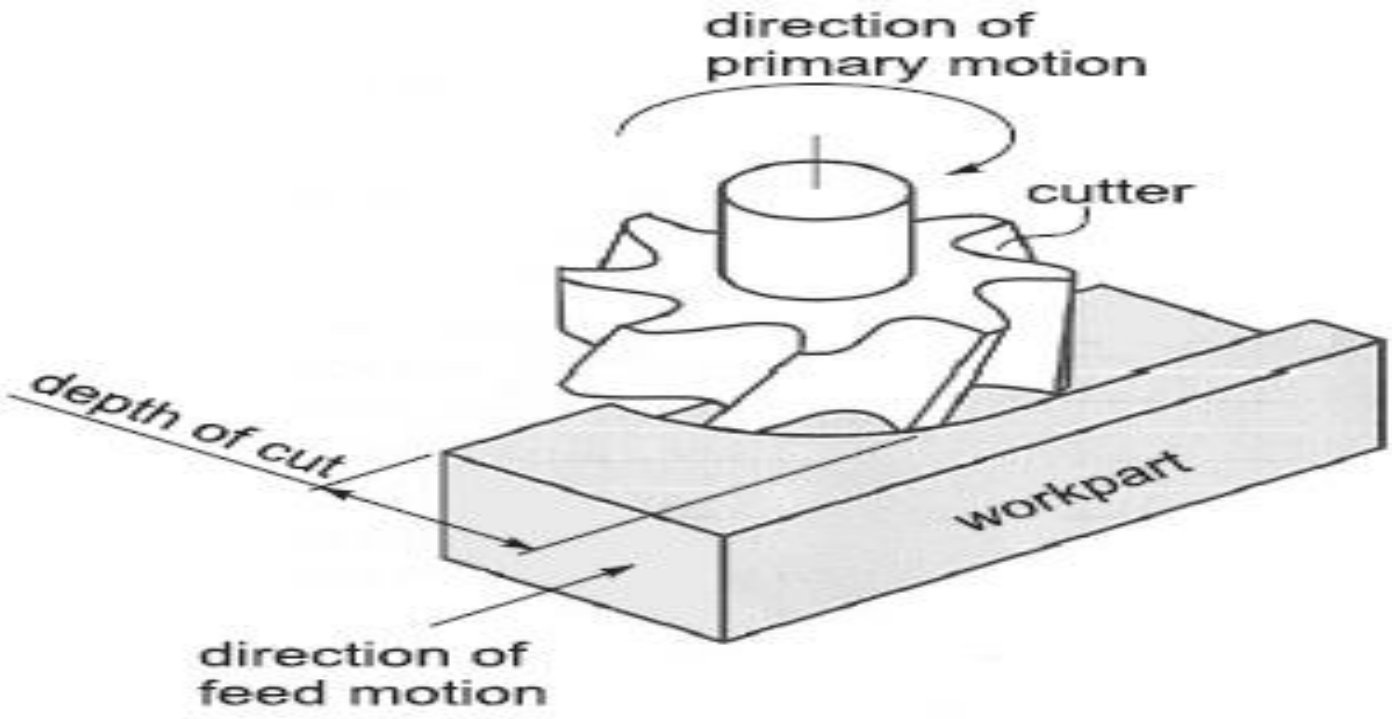
## Advantages of peripheral milling

- More stable holding of the cutter. There is less variation in the arbor torque
- Lower power requirements.
- Better surface finish.



# Manufacturing Technology

Face milling




Partial face milling operation. The face-milling cutter machines only one side of the workpiece.

# Manufacturing Technology

## End milling

- In *end milling*, the cutter, called *end mill*, has a diameter less than the work piece width. The end mill has helical cutting edges carried over onto the cylindrical cutter surface are used to produce pockets, closed or end key slots, etc.

End milling operation used to cut a pocket in an aluminum work part.

# Manufacturing Technology

## Milling of Complex Surfaces

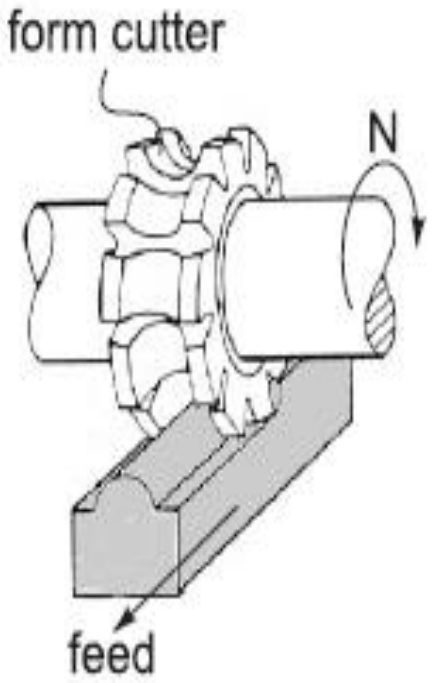
- Milling is one of the few machining operations, which are capable of machining complex *two*- and *three-dimensional surfaces*, typical for dies, molds, cams, etc.
- Complex surfaces can be machined either by means of the cutter path (*profile milling* and *surface contouring*), or the cutter shape (*form milling*).

## Form milling

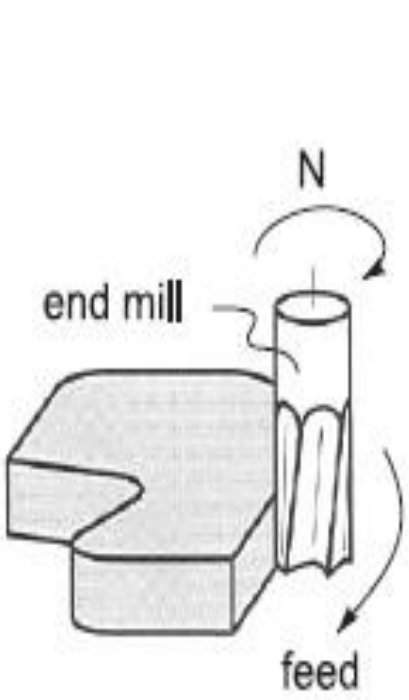
- In form milling, the cutting edges of the peripheral cutter (called *form cutter*) have a special profile that is imparted to the work piece. Cutters with various profiles are available to cut different two-dimensional surfaces. One important application of form milling is gear manufacturing

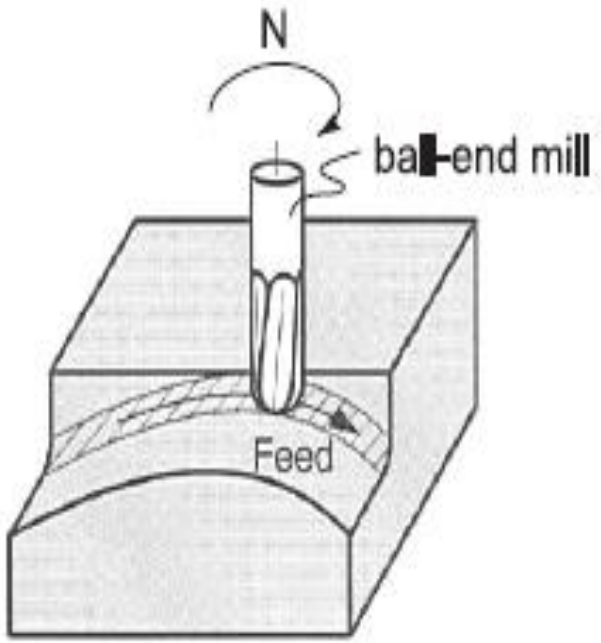
# Manufacturing Technology

## Form Milling




Form milling of two-dimensional surface.

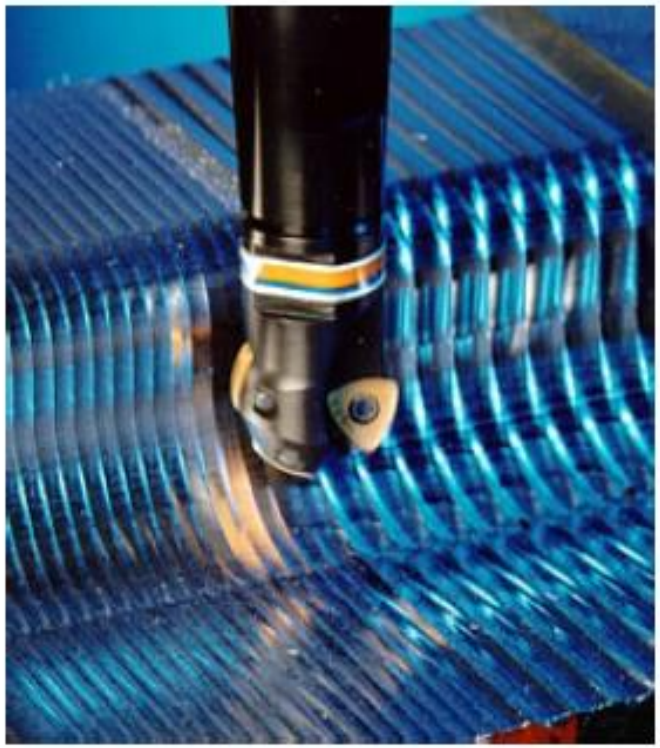


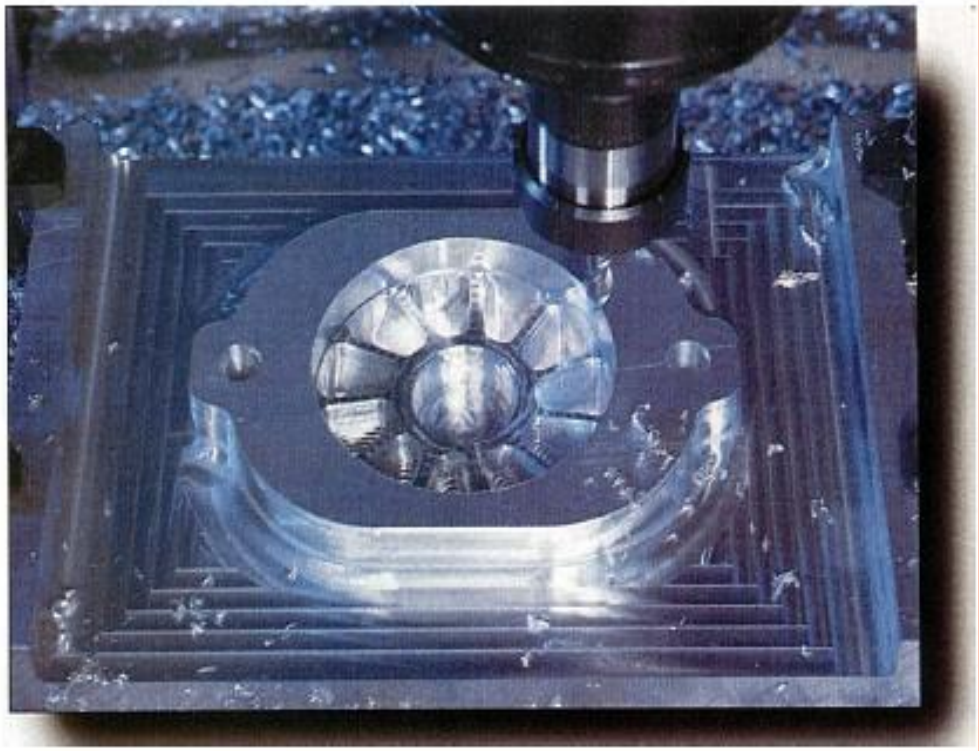

(*Left*) Profile milling of a cam, and (*Right*) Surface contouring of a complex three-dimensional surface.

# Manufacturing Technology

## Surface contouring



Close-up view of a hemispherical ball-end mill with indexed carbide inserts used for rough cutting of a three-dimensional surface.



Surface contouring of die cavity. The cutter used is a high-speed steel ball-end mill.

# Manufacturing Technology

## Milling machines

- The conventional milling machines provide a **primary rotating motion for the cutter held in the spindle,** and a linear feed motion for the work piece, which is fastened onto the worktable.
- Milling machines for machining of complex shapes usually provide both a **rotating primary motion and a curvilinear feed motion for the cutter** in the spindle with a stationary work piece.

## Milling Machine Types

- Various machine designs are available for various milling operations. In this section we discuss only the most popular ones, classified into the following types
  - **Column-and-knee milling machines**
  - **Bed type milling machines**
  - **Machining centers**

# Manufacturing Technology

**Other Classifications**

According to nature of purposes of use

- General Purpose Milling Machine
  - Conventional milling machines, e.g Up and down milling machines
- Single Purpose Milling Machine
  - Thread, cam milling machines and slitting machine
- Special Purpose Milling Machine
  - Mass production machines, e.g., duplicating mills, die sinkers, thread milling etc.

# Manufacturing Technology

**According to configuration and motion of the work-holding table / bed**

Knee type

- small and medium duty machines the table with the job/work travels over the bed (guides) in horizontal (X) and transverse (Y) directions and the bed with the table and job on it moves vertically (Z) up and down.

Bed type

- Usually of larger size and capacity; the vertical feed is given to the milling head instead of the knee type bed

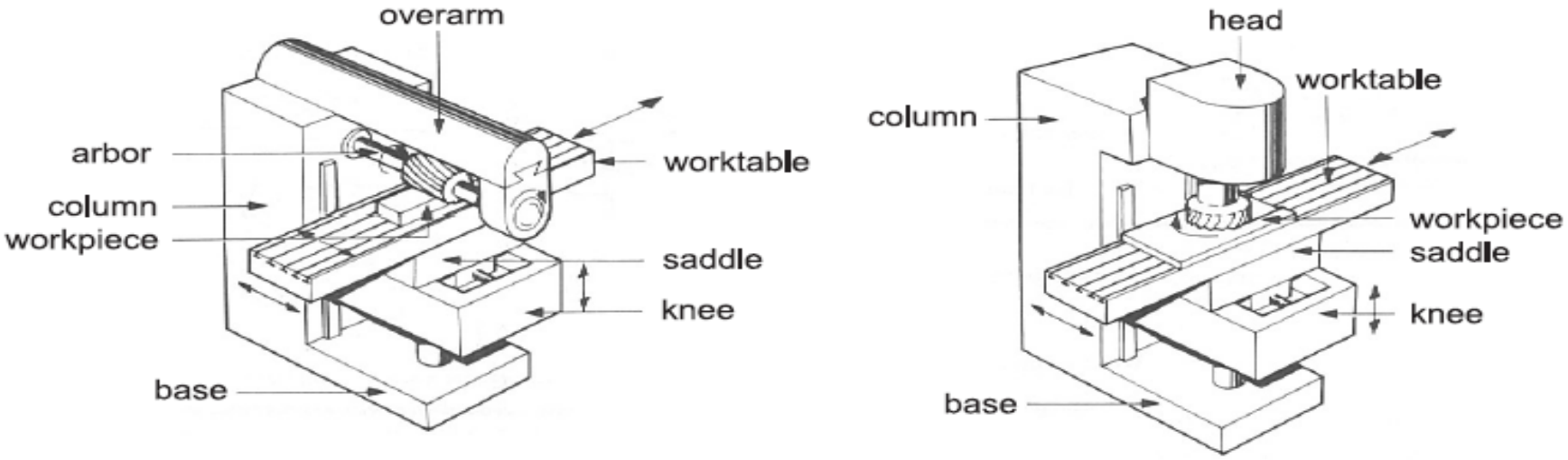
**According to the orientation of the spindle**

- Horizontal Milling Machine
  - Horizontal spindle Feed
- Vertical milling machine
  - Vertical Spindle Feed
- Universal milling machine
  - Both Horizontal and Vertical spindle Feed

# Manufacturing Technology

## Column-and-knee milling machines

- The *column-and-knee milling machines* are the basic machine tool for milling. The name comes from the fact that this machine has two principal components, a *column* that supports the spindle, and a *knee* that supports the work table.
- There are two different types of column-and-knee milling machines according to position of the spindle axis
  - Horizontal &Vertical.

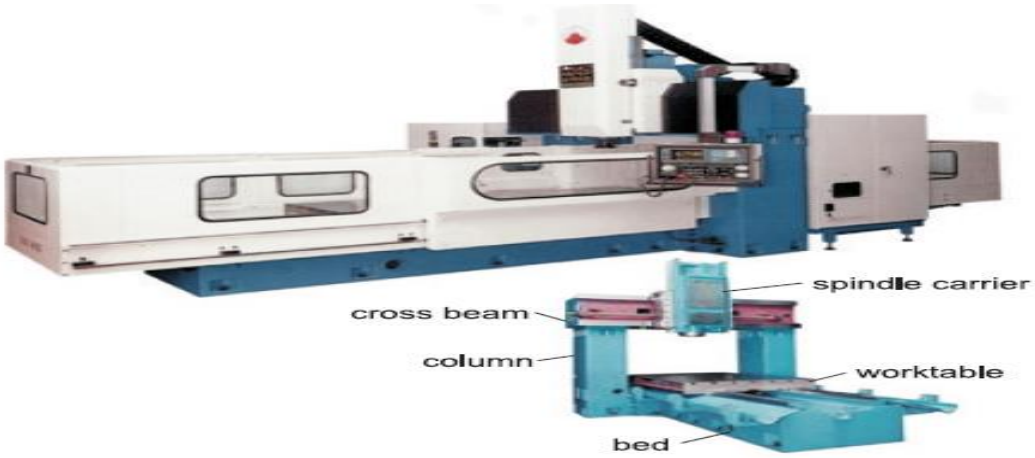



Two basic types of column-and-knee milling machines, (*Left*) horizontal, and (*Right*) vertical.

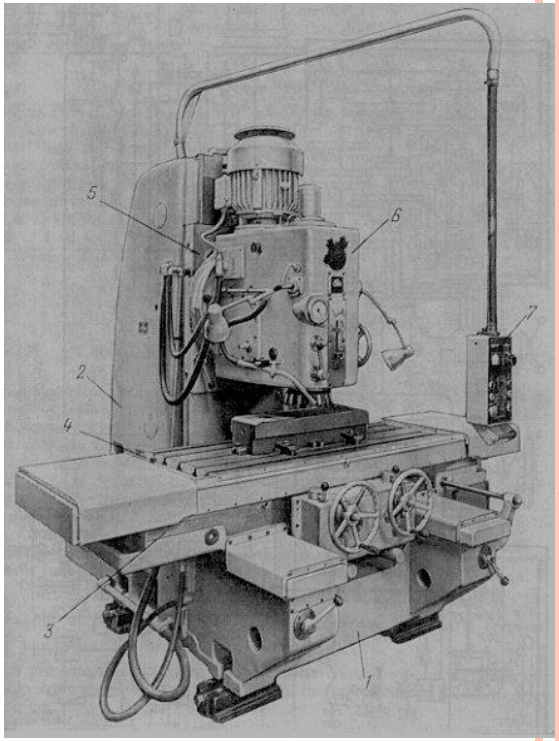
# Manufacturing Technology

## Bed type machines

- In bed type milling machines, the worktable is mounted directly on the bed that replaces the knee. This ensures greater rigidity, thus permitting heavier cutting conditions and higher productivity. This machines are designed for mass production.
- Single-spindle bed machines are called *simplex mills* and are available in either horizontal or vertical models. *Duplex mills* have two spindle heads, and *triplex mills* add a third spindle mounted vertically over the bed to further increase machining capability.




Portal planer mill for heavy machining of large workparts.



# Manufacturing Technology

## Machining centers

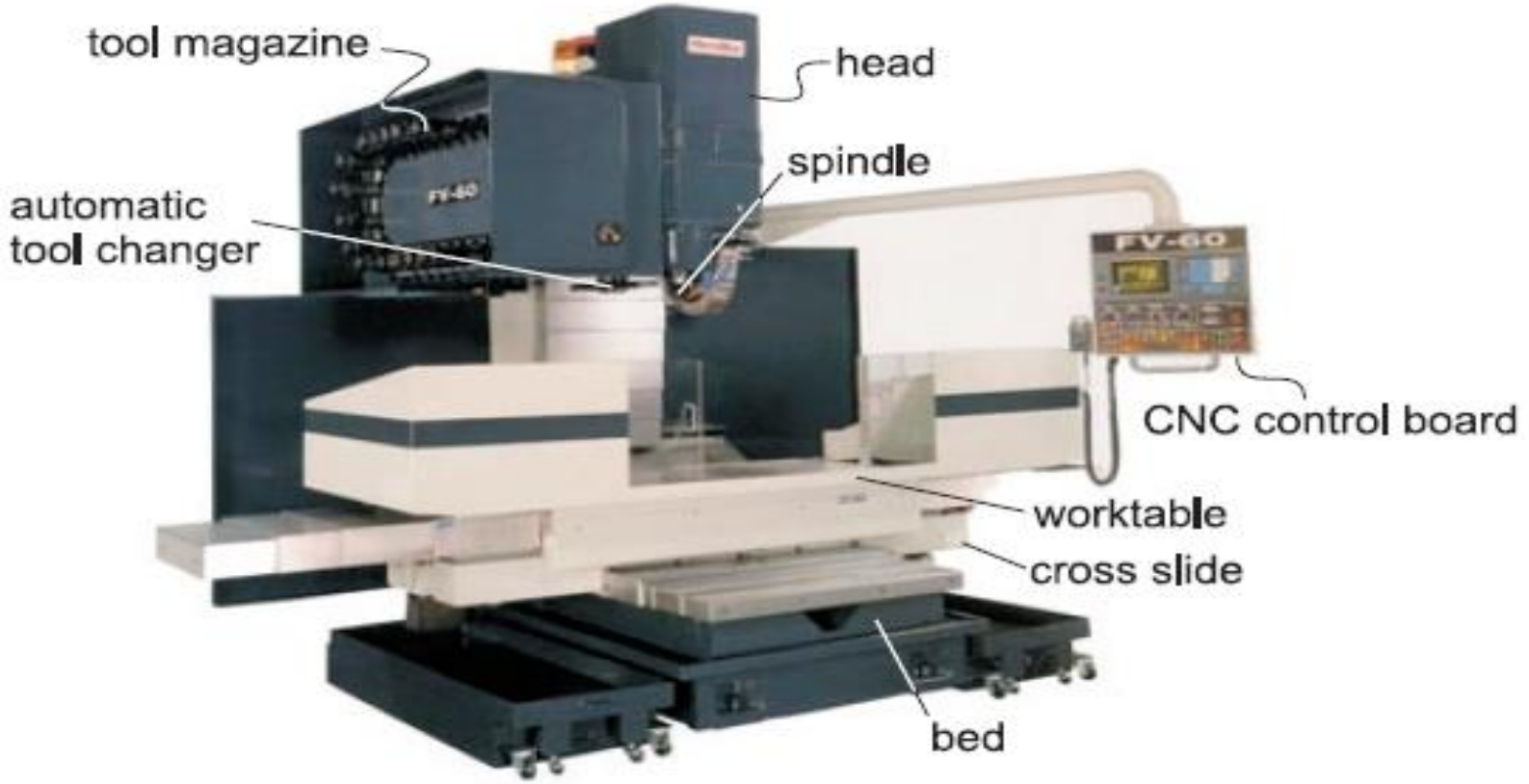
- A machining center is a highly automated machine tool capable of performing multiple machining operations under CNC control.

The features that make a machining center unique include the following

- Tool storage unit called *tool magazine* that can hold up to 120 different cutting tools.
- *Automatic tool changer*, which is used to exchange cutting tools between the tool magazine and machining center spindle when required. The tool changer is controlled by the CNC program.
- *Automatic work part positioning*. Many of machining centers are equipped with a rotary worktable, which precisely position the part at some angle relative to the spindle. It permits the cutter to perform machining on four sides of the part.

# Manufacturing Technology

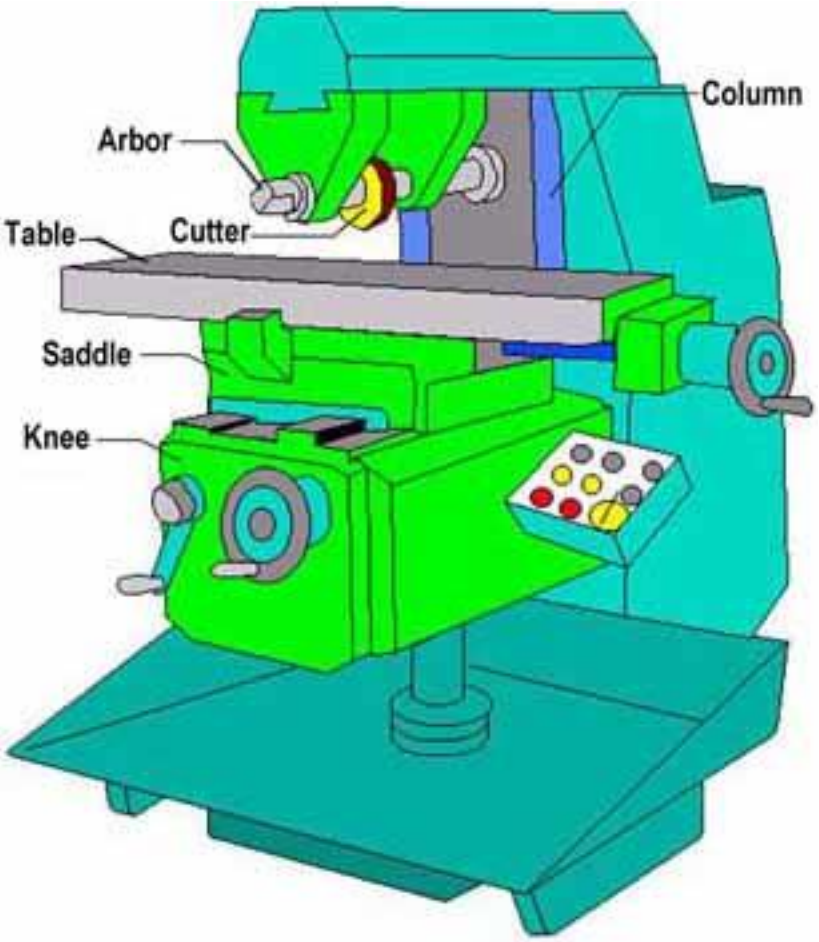
Machining center



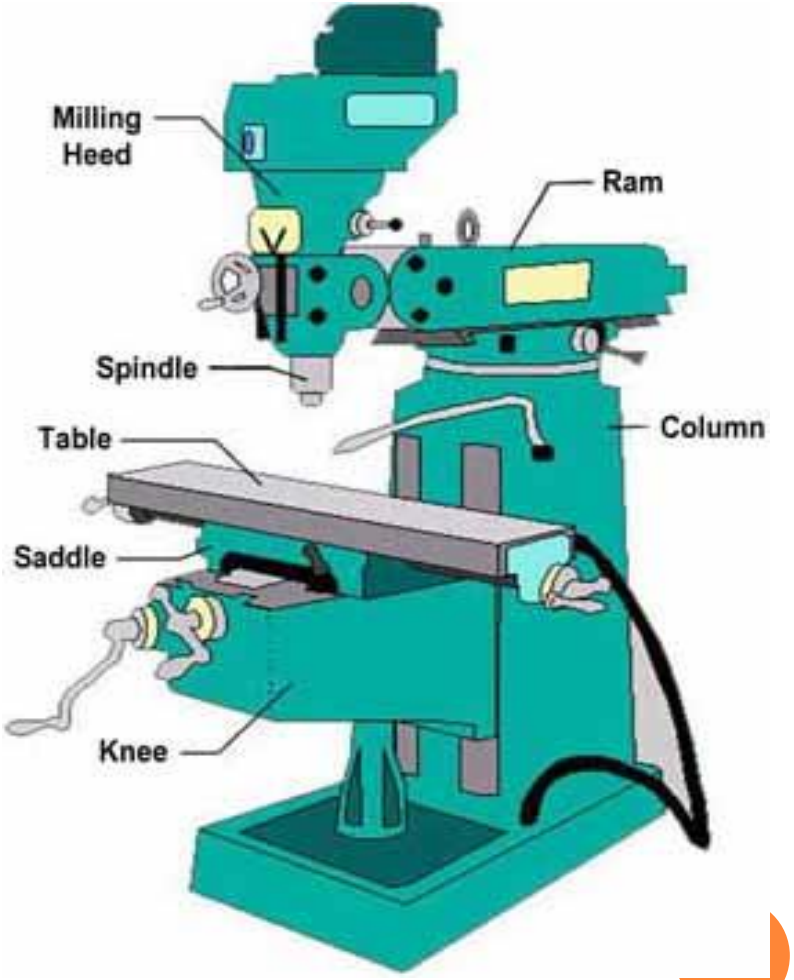

Universal machining center.

# Manufacturing Technology

- Milling Machine Specifications



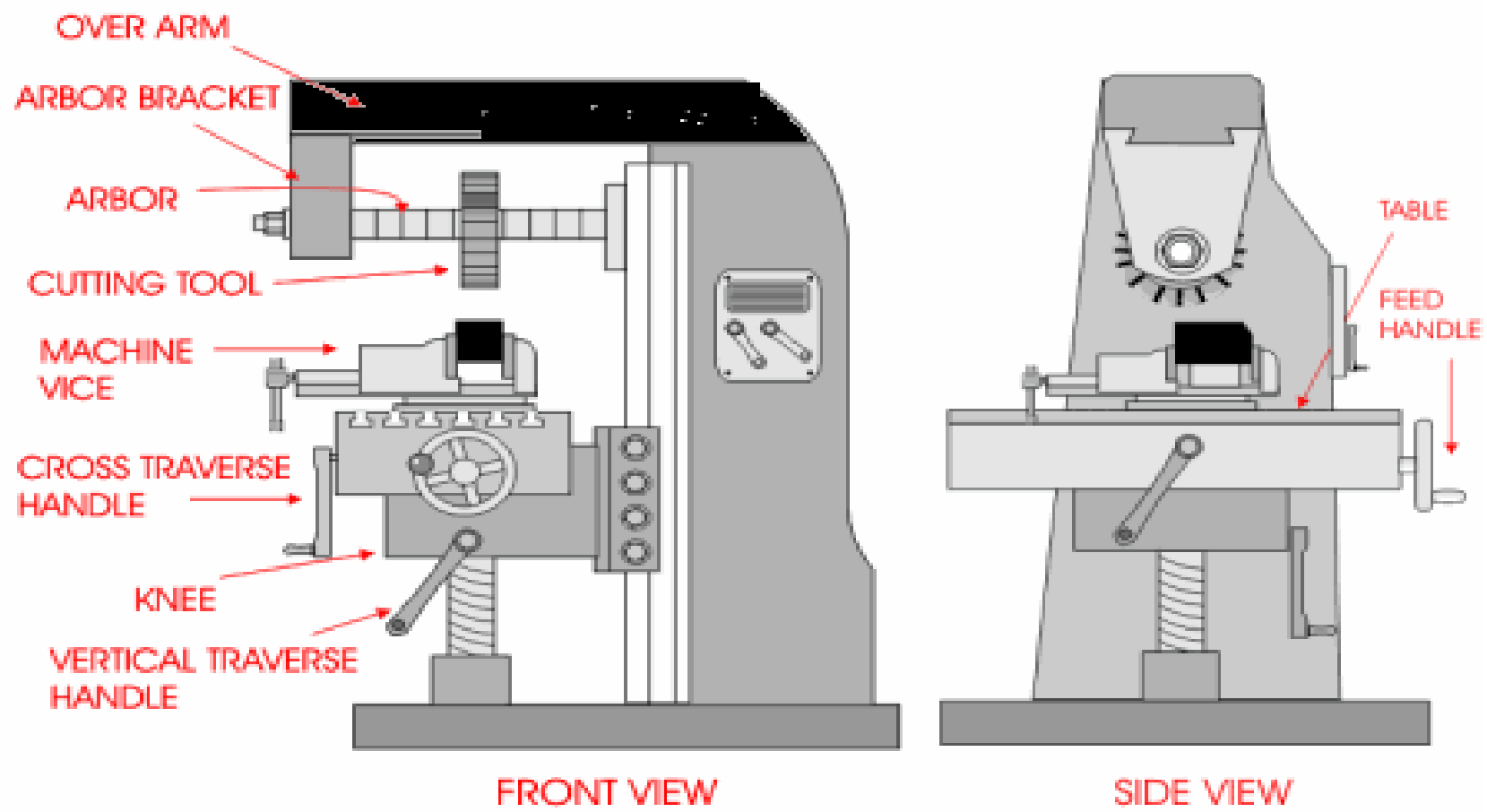

Horizontal Milling Machine




Vertical Milling Machine

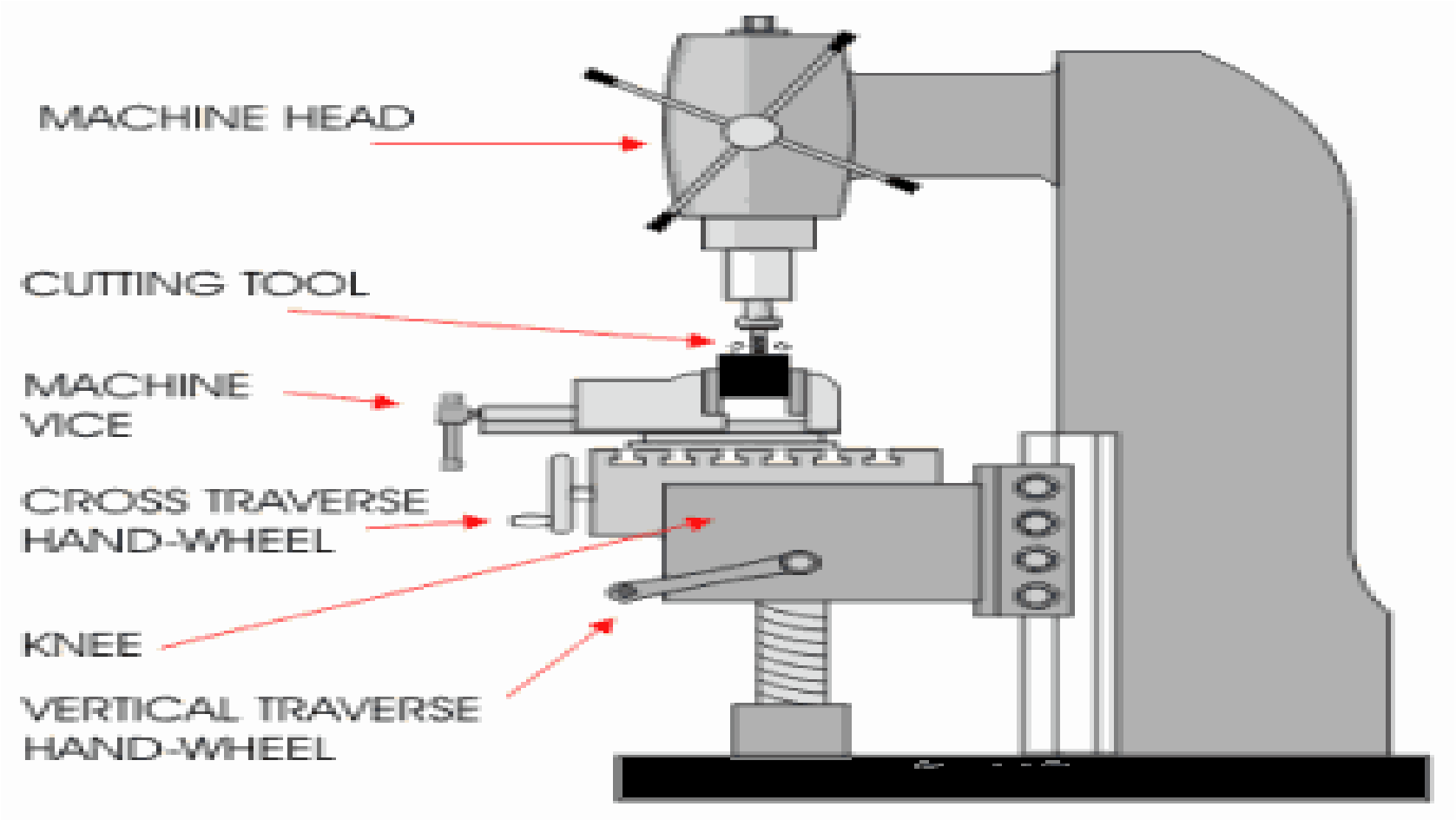
# Manufacturing Technology

- Milling Machine Specifications



# Manufacturing Technology

- Milling Machine Specifications



# Manufacturing Technology

*Milling cutters*

Classification of milling cutters according to their design

- *HSS cutters:* Many cutters like end mills, slitting cutters, slab cutters, angular cutters, form cutters, etc., are made from high-speed steel (HSS).
- *Brazed cutters*: Very limited number of cutters (mainly face mills) are made with brazed carbide inserts. This design is largely replaced by mechanically attached cutters.
- *Mechanically attached cutters:* The vast majority of cutters are in this category. Carbide inserts are either clamped or pin locked to the body of the milling cutter.

# MANUFACTURING TECHNOLOGY

## Milling Cutter Nomenclature

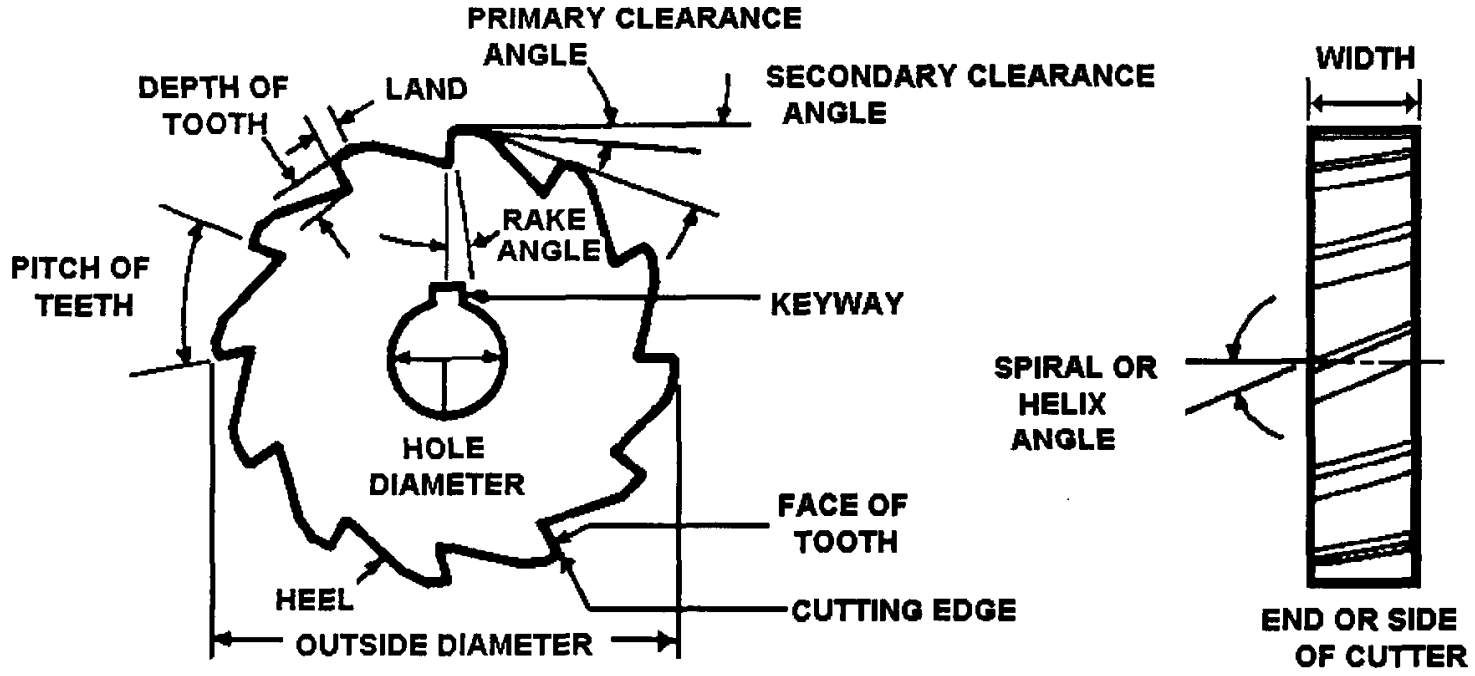



Figure 8-3. Milling cutter nomenclature.

# Manufacturing Technology

## Milling Cutter Nomenclature

- The pitch refers to the angular distance between like or adjacent teeth.
- The pitch is determined by the number of teeth. The tooth face is the forward facing surface of the tooth that forms the cutting edge.
- The cutting edge is the angle on each tooth that performs the cutting.
- The land is the narrow surface behind the cutting edge on each tooth.
- The rake angle is the angle formed between the face of the tooth and the centerline of the cutter. The rake angle defines the cutting edge and provides a path for chips that are cut from the workpiece.
- The primary clearance angle is the angle of the land of each tooth measured from a line tangent to the centerline of the cutter at the cutting edge. This angle prevents each tooth from rubbing against the workpiece after it makes its cut.

# Manufacturing Technology

## Milling Cutter Nomenclature

- This angle defines the land of each tooth and provides additional clearance for passage of cutting oil and chips.
- The hole diameter determines the size of the arbor necessary to mount the milling cutter.
- Plain milling cutters that are more than 3/4 inch in width are usually made with spiral or helical teeth. A plain spiral-tooth milling cutter produces a better and smoother finish and requires less power to operate. A plain helical-tooth milling cutter is especially desirable when milling an uneven surface or one with holes in it.

# Manufacturing Technology

Classification of milling cutters associated with the various milling operations

**Profile sharpened cutters**

- surfaces are not related with the tool shape
  - Slab or plain milling cutter : straight or helical fluted
  - Side milling cutters – single side or both sided type
  - Slotting cutter
  - Slitting or parting tools
  - End milling cutters – with straight or taper shank
  - Face milling cutters

# Manufacturing Technology

## Form relieved cutters

- Where the job profile becomes the replica of the tool-form
  - Form cutters
  - Gear (teeth) milling cutters
  - Spline shaft cutters
  - Tool form cutters
  - T-slot cutters
  - Thread milling cutter

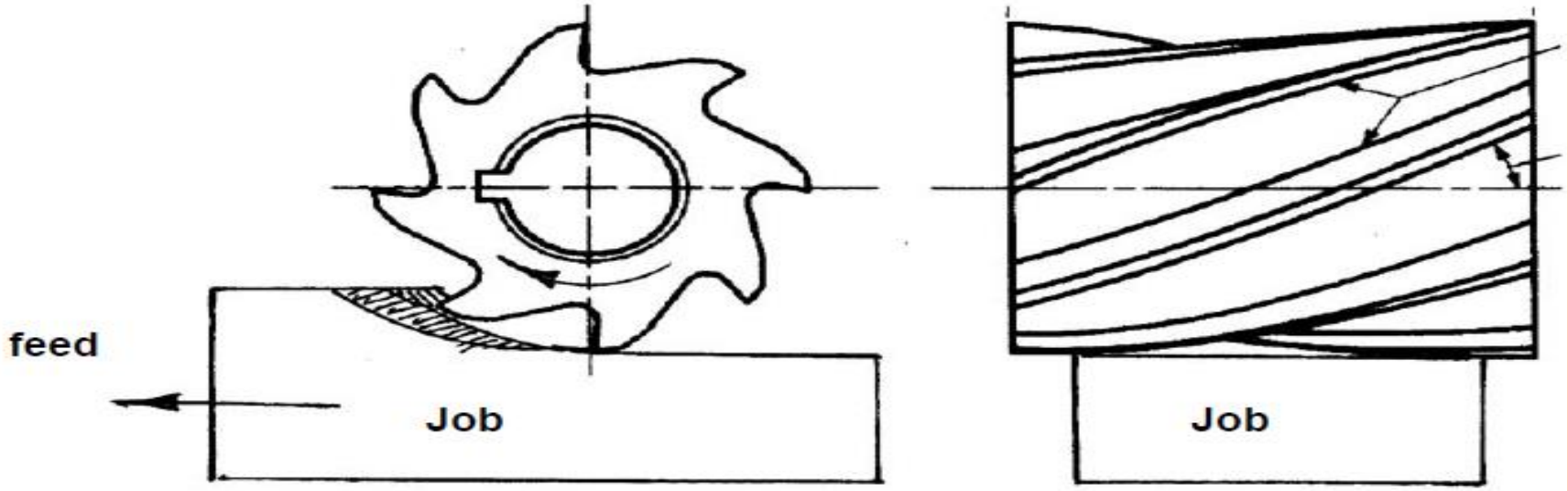
# Manufacturing Technology

## Profile sharpened cutters

- The profile sharpened cutters are inherently used for making flat surfaces or surface bounded by a number of flat surfaces only.

## Slab or Plain milling cutters

- Plain milling cutters are hollow straight HSS cylinder of 40 to 80 mm outer diameter having 4 to 16 straight or helical equi-spaced flutes or cutting edges and are used in horizontal arbour to machine flat surface

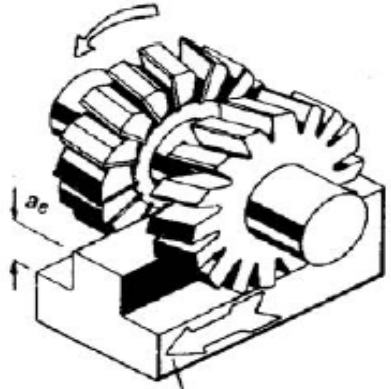



*Machining flat surface by slab milling Cutter*

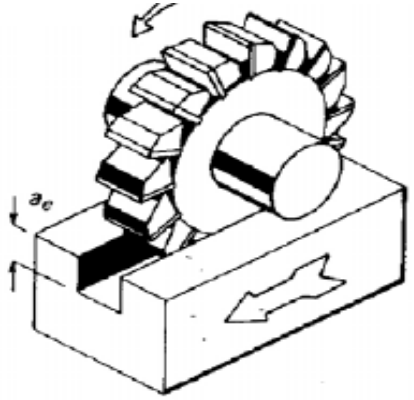
# Manufacturing Technology

## Side and slot milling cutters

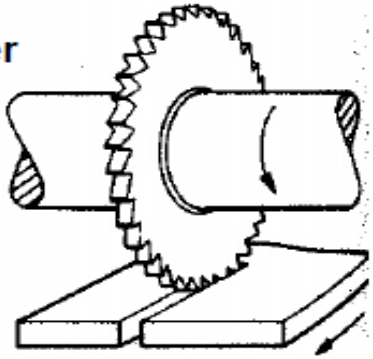
- These arbour mounted disc type cutters have a large number of cutting teeth at equal spacing on the periphery.




(a) parallel facing by two side (single) cutter




(b) slotting by side (double sided) milling cutter



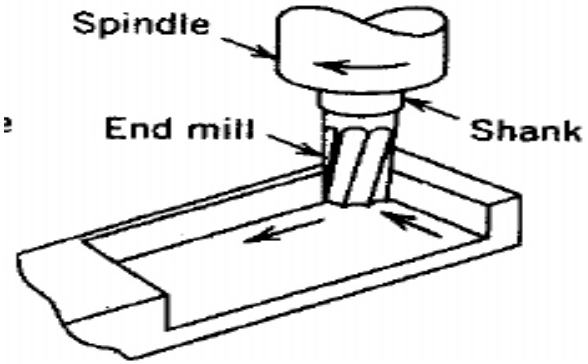
(c) Parting by slitting saw

*Side milling cutters*

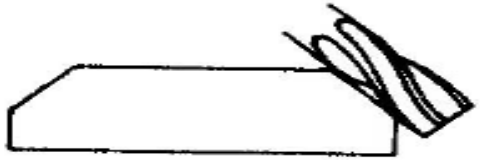
# MANUFACTURING TECHNOLOGY

## End milling cutters

- The end milling cutter, also called an end mill, has teeth on the end as well as the periphery

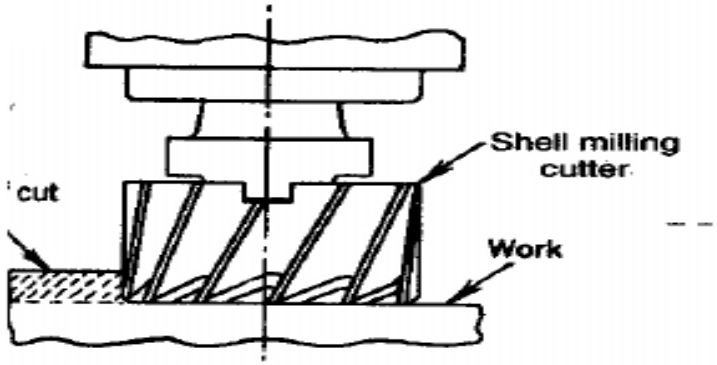



(a) face milling



(b) angular milling

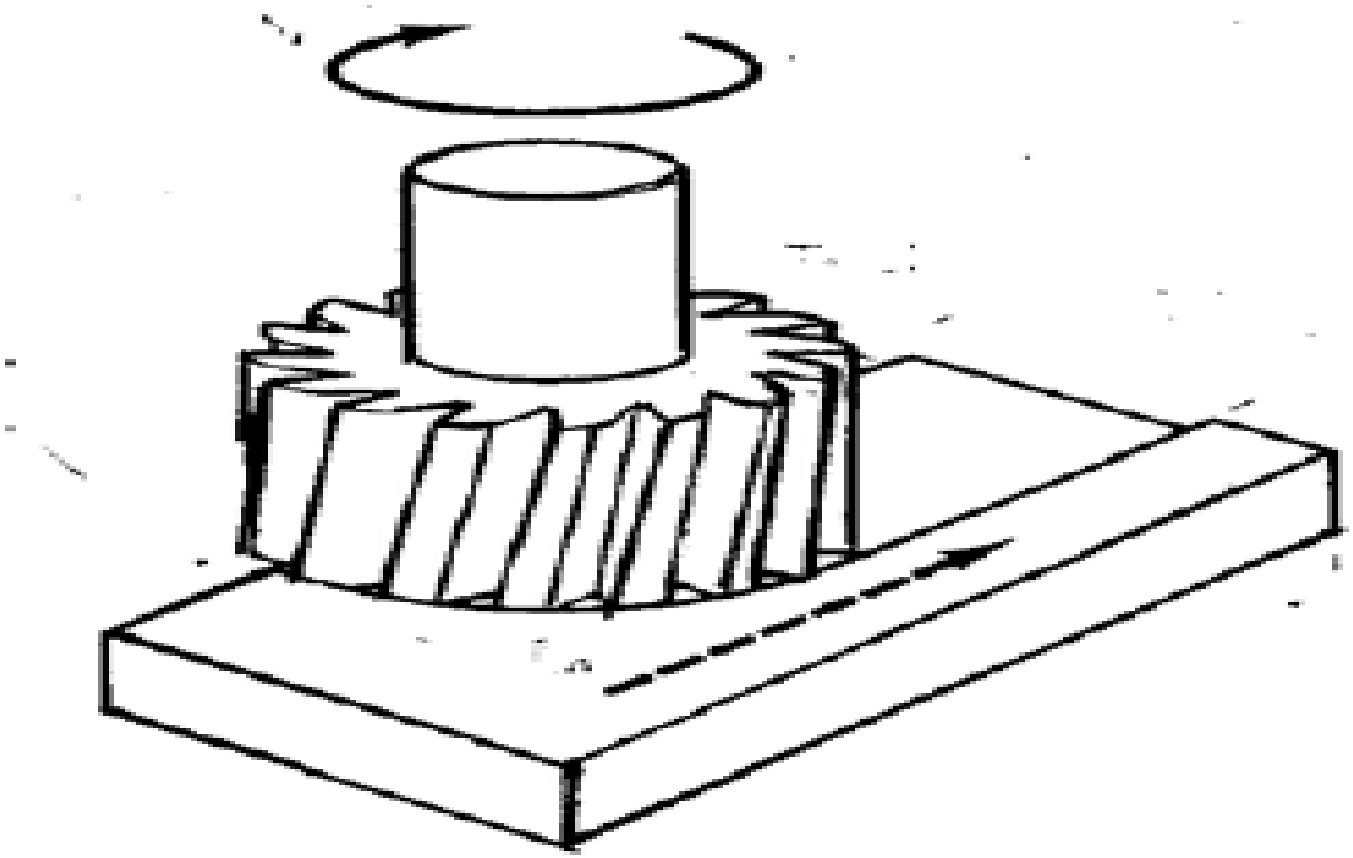
(c) slotting




(d) shell milling

# Manufacturing Technology

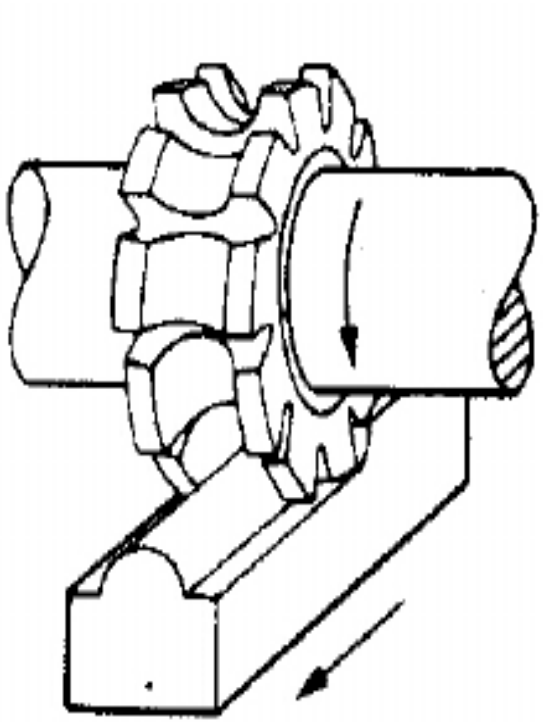
**Face milling cutter**

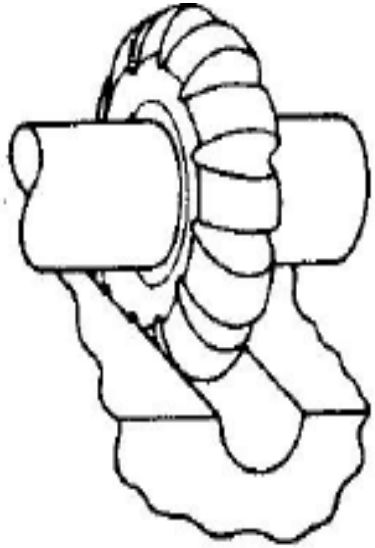


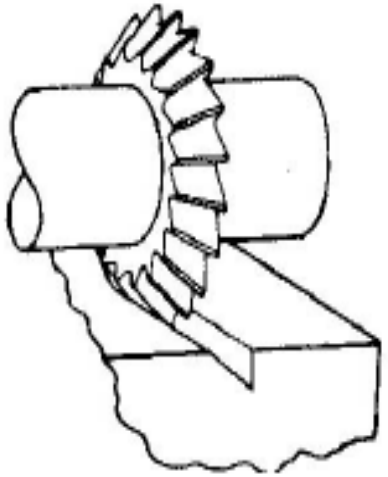
# Manufacturing Technology

**Form relieved cutters**

- Form of the tool is exactly replica of the job-profile to be made
- Clearance  or flank surfaces of the teeth are spiral shaped instead of flat
- Used for making 2-D and 3-D contour surfaces

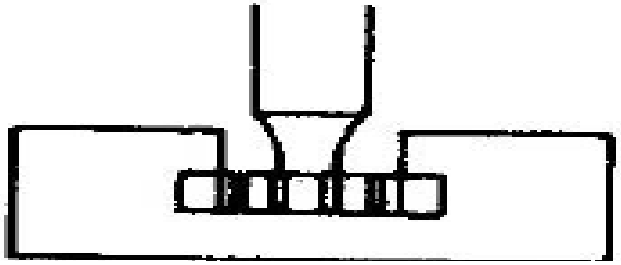


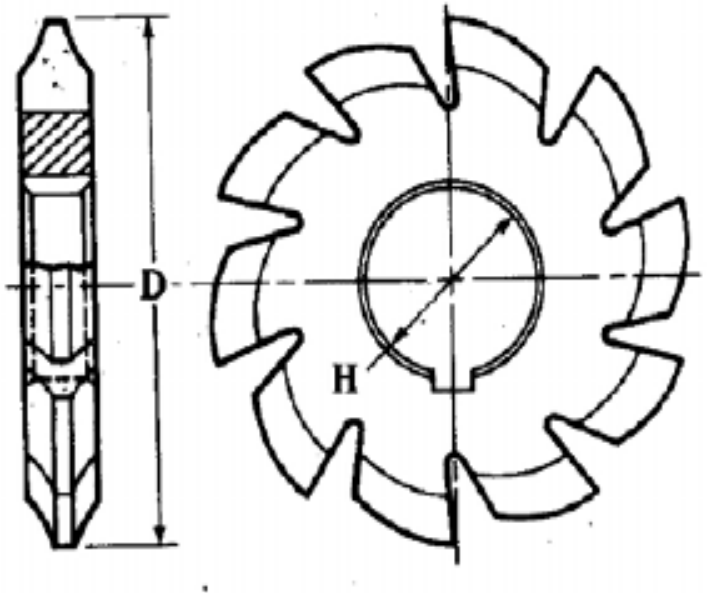


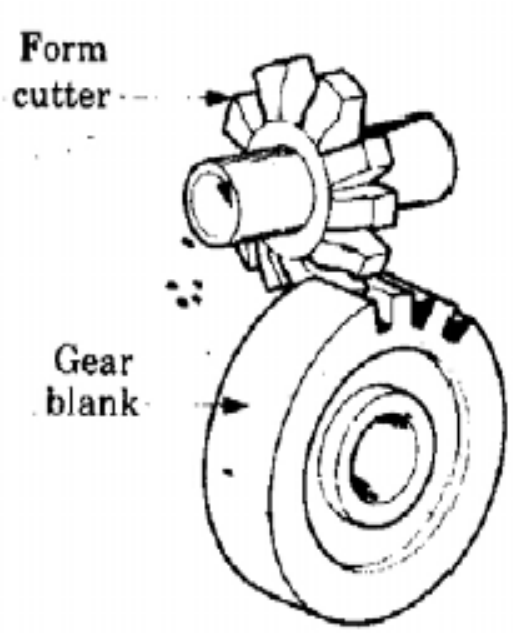


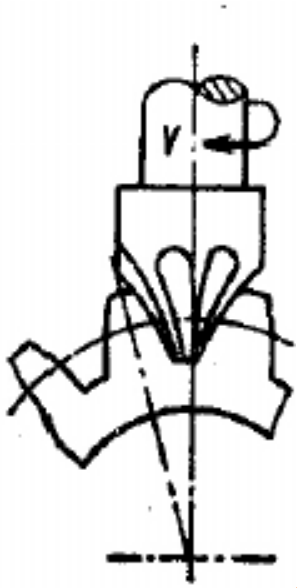
# Manufacturing Technology

*T-slot* & Gear milling cutters



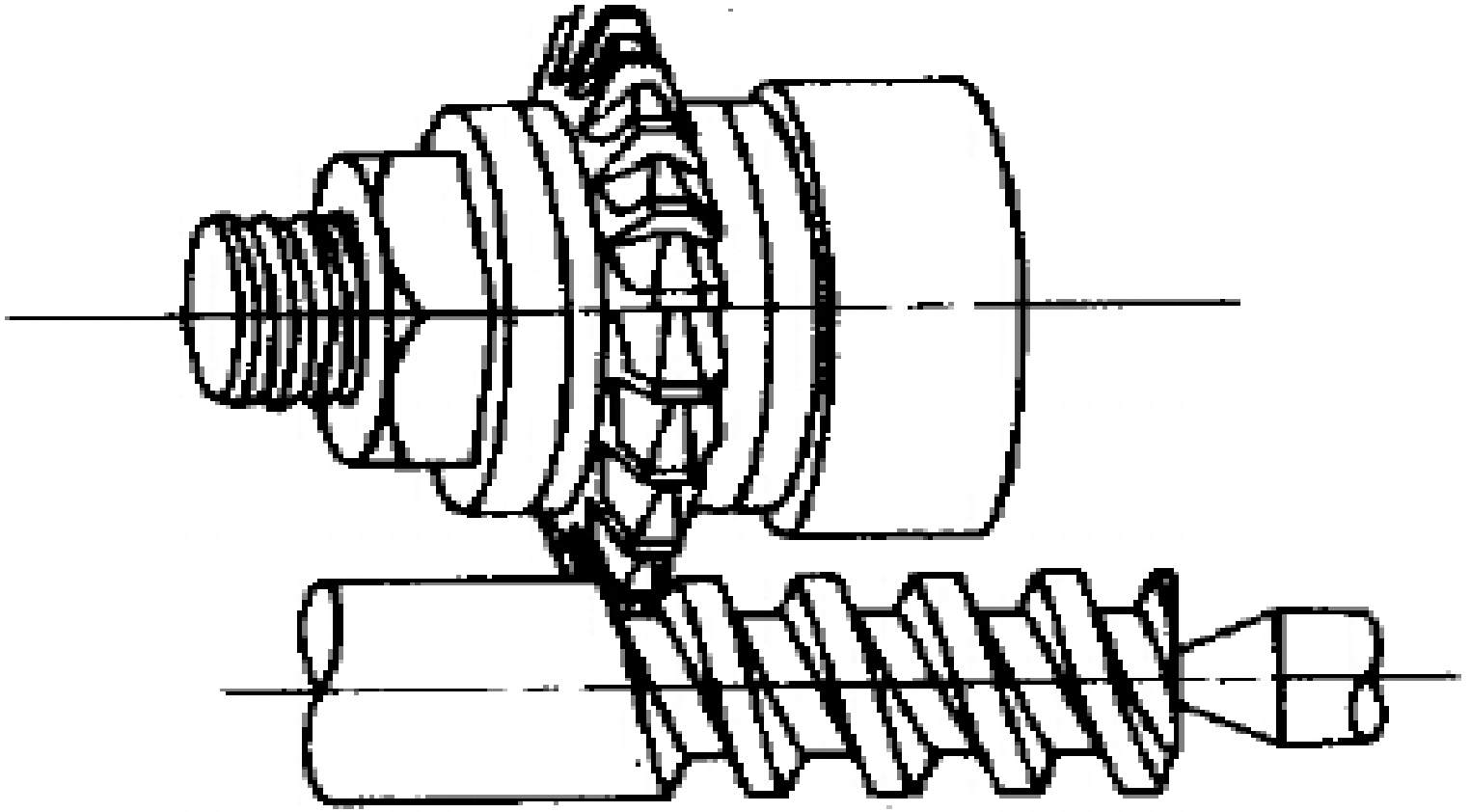


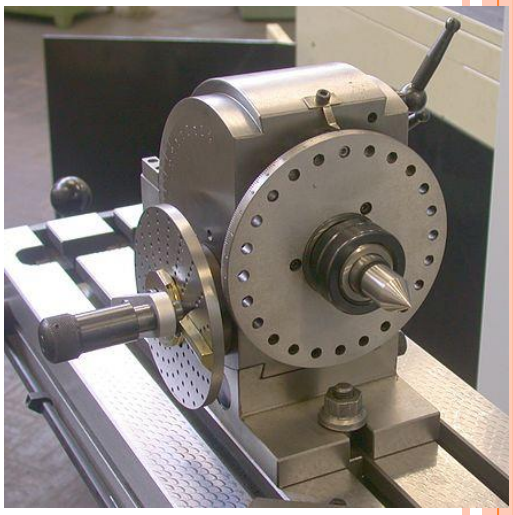
# Manufacturing Technology

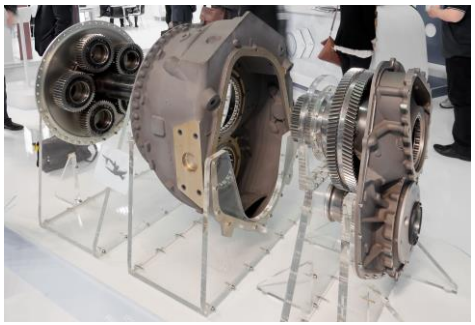
Thread milling cutter

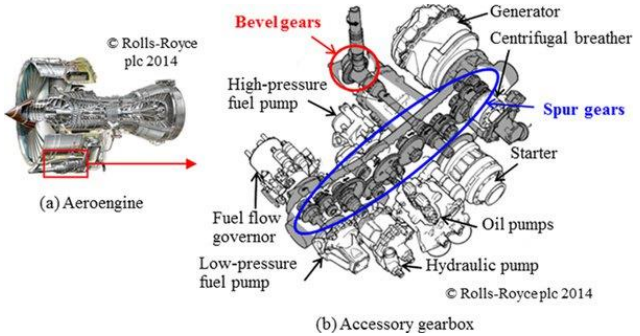


# INDEXING

- Indexing is the process of **evenly dividing the circumference of a circular work piece into equally spaced divisions**, such as in **cutting gear teeth, cutting splines**, milling grooves in reamers and taps, and spacing holes on a circle.
- The index head of the indexing fixture is used for this purpose.



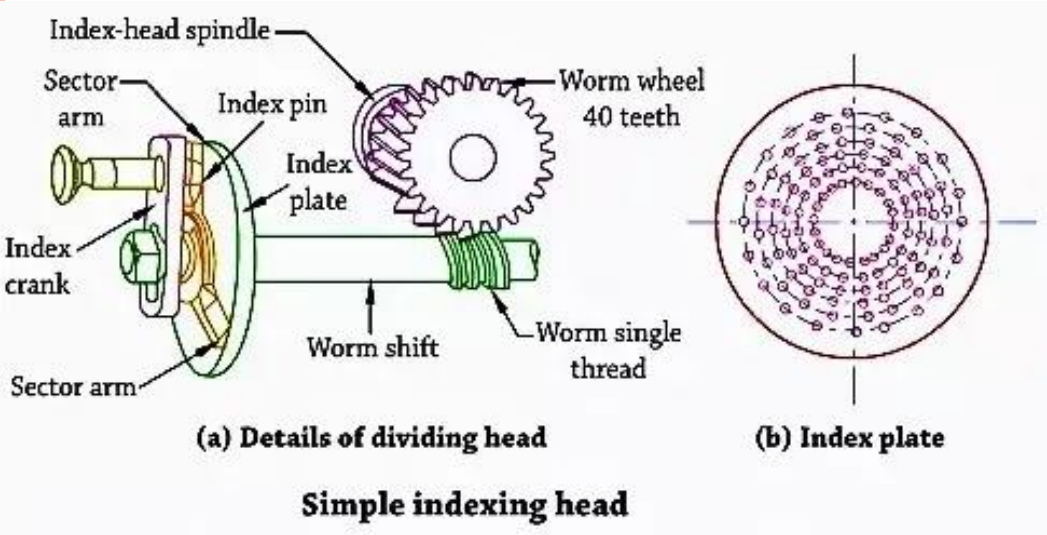



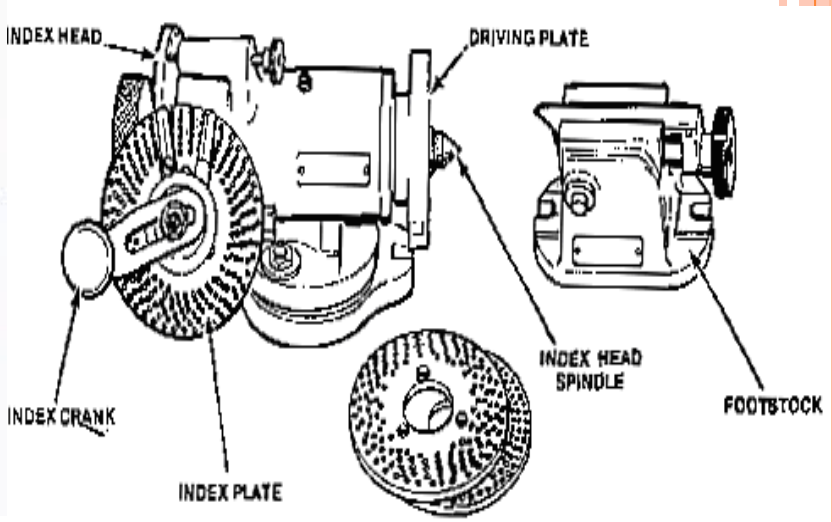



http://www.mechanicalwalkins.com/indexing-mechanism-of-indexing-head-parts-types-and-working/

# Index Head

- The **index head** of the indexing fixture contains an **indexing mechanism** which is used to **control the rotation of the index head spindle** to space or divide a work piece accurately.
- A simple indexing mechanism consists of a **40-tooth worm wheel** fastened to the index head spindle, **a single-cut worm**, **a crank for turning the worm shaft**, and an **index plate** and **sector**.
- Since there are 40 teeth in the worm wheel, **one turn of the index crank causes the worm**, and consequently, the **index head spindle** to make **1/40 of a turn**; so 40 turns of the index crank revolve the spindle one full turn.



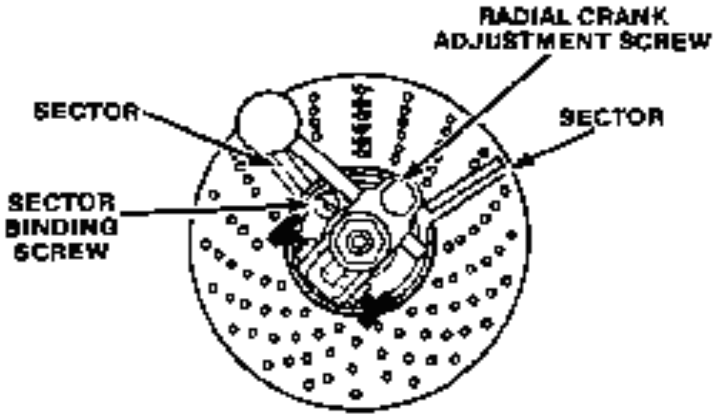



## Index Plate

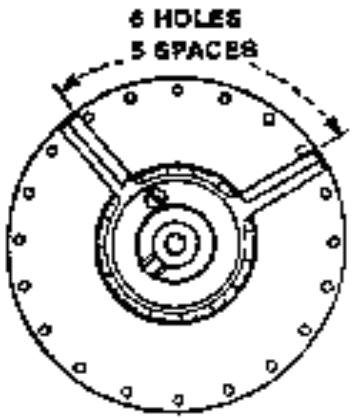
- The indexing plate is a **round plate** with a series of **six or more circles of equally spaced holes**
- **Index pin** on the crank can be inserted in any hole in any circle. With the interchangeable plates regularly furnished with most index heads, the **spacing necessary for most gears, bolt heads, milling cutters, splines**, and so forth can be obtained.

## Sector

- The sector indicates the **next hole in which the pin is to be inserted** and makes it **unnecessary to count holes** when moving the index crank after each cut.
- It consists of two radial, **beveled arms** which can be set at **any angle to each other** and then moved together around the **center of the index plate**.




INDEX PLATE WITH CRANK AND SECTOR




OPERATION OF SECTOR

# Manufacturing Technology

**Index Plate Types**

- **Brown and Sharpe type consists of 3 plates of 6 circles each drilled as follows:**
  - **Plate I - 15, 16, 17, 18, 19, 20 holes**
  - **Plate 2 - 21, 23, 27, 29, 31, 33 holes**
  - **Plate 3 - 37, 39, 41, 43, 47, 49 holes**
- **Cincinnati type consists of one plate drilled on both sides with circles divided as follows:**
  - **First side - 24, 25, 28, 30, 34, 37, 38, 39, 41, 42, 43 holes**
  - **Second side - 46, 47, 49, 51, 53, 54, 57, 58, 59, 62, 66 holes**

# MANUFACTURING TECHNOLOGY

## Indexing Methods

### Simple Indexing or Plain Indexing

- In simple or plain indexing, an index plate selected for the particular application, is **fitted on the worm shaft and locked through a locking pin**
- To index the work through any required angle, the **index crank pin is withdrawn from the hole of the index plate**. Then the work is indexed through the required angle by **turning the index crank through a calculated number of whole revolutions** and holes on one of the hole circles, after which the index pin is relocated in the required hole
- If the number of turns that the crank must be rotated for each indexing can be found from the formula
  - N = 40 / Z
  - Where
  - Z - No of divisions or indexing needed on the work
  - 40 – No of teeth on the worm wheel attached to the indexing plate, since 40 turns of the index crank will turn the spindle to one full turn

# Manufacturing Technology

- Suppose it is desired to mill a gear with eight equally spaced teeth. l/8th of 40 or 5 turns (Since 40 turns of the index crank will turn the spindle one full turn) of the crank after each cut, will space the gear for 8 teeth. If it is desired to space equally for 10 teeth, 1/10 of 40 or 4 turns would produce the correct spacing.
- The same principle applies whether or not the divisions required divide equally into 40. For example, if it is desired to index for 16 divisions, 16 divided into 40 equals 2 8/16 turns. i.e for each indexing we need two complete rotations of the crank plus 8 more holes on the 16 hole circle of plate 1(**Plate I - 15, 16, 17, 18, 19, 20 holes)**

# Manufacturing Technology

## Direct Indexing

- In direct indexing, **the index plate is directly mounted on the dividing head spindle** (no worm shaft or wheel)
- While indexing, the index crank pin is withdrawn from the hole of the index plate than the pin is engaged directly after the work and the indexing plate are rotated to the desire number of holes
- In this method, fractions of a complete turn of the spindle are limited to those available with the index plate
- Direct indexing is accomplished by an additional index plate fastened to the index head spindle. A stationary plunger in the index head fits the holes in this index plate. By moving this plate by hand to index directly, the spindle and the work piece rotate an equal distance. Direct index plates usually have 24 holes and offer a quick means of milling squares, hexagons, taps, and so forth. Any number of divisions which is a factor of 24 can be indexed quickly and conveniently by the direct indexing method.

# Manufacturing Technology

## Differential Indexing

- Sometimes, a number of divisions is required which cannot be obtained by simple indexing with the index plates regularly supplied. To obtain these divisions, a differential index head is used. The index crank is connected to the worm shaft by a train of gears instead of a direct coupling as with simple indexing. The selection of these gears involves calculations similar to those used in calculating change gear ratio for lathe thread cutting.
- Gear Ratio $I = 40/K\ (K - Z)$

  Where

  - K – a number very nearly equal to Z
  - For example if the value of Z is 53, the value of K is 50