Subject : MACHINE TOOLS AND METROLOGY (MET 307)

Semester : V

Course : B Tech - Mechanical Engineering

Dr. Arun Boby,
Assistant Professor,
Department of Mechanical Engineering,
Mar Athanasius College of Engineering,
Kothamangalam – 686 666, Kerala.

MODULE -1

General Purpose Machine Tools

1. **General classification of machine tools**

- **Conventional or traditional machine tools** like Lathes, Milling machines, etc. are used more widely for faster material removal by shearing or brittle fracturing.
- **Non-conventional or non-traditional machine tools:** like EDM, ECM, USM, etc. which remove material from exotic materials slowly by electro-physical, electro-chemical processes.
- **Modern numerical and computer controlled machine tools**: Like CNC lathe, CNC milling

General Purpose Machine Tools

The basic machine tools which are commonly used for general purposes are:

1. **Lathes**
2. **Drilling machines**
3. **Shaping machines**
4. **Planning machines**
5. **Slotting machines**
6. **Milling machines**
7. **Boring machines**
8. **Hobbing machines**
9. **Gear shaping machines**
10. **Broaching machines**
11. **Grinding machine**

Conventional/ Traditional Machining Process

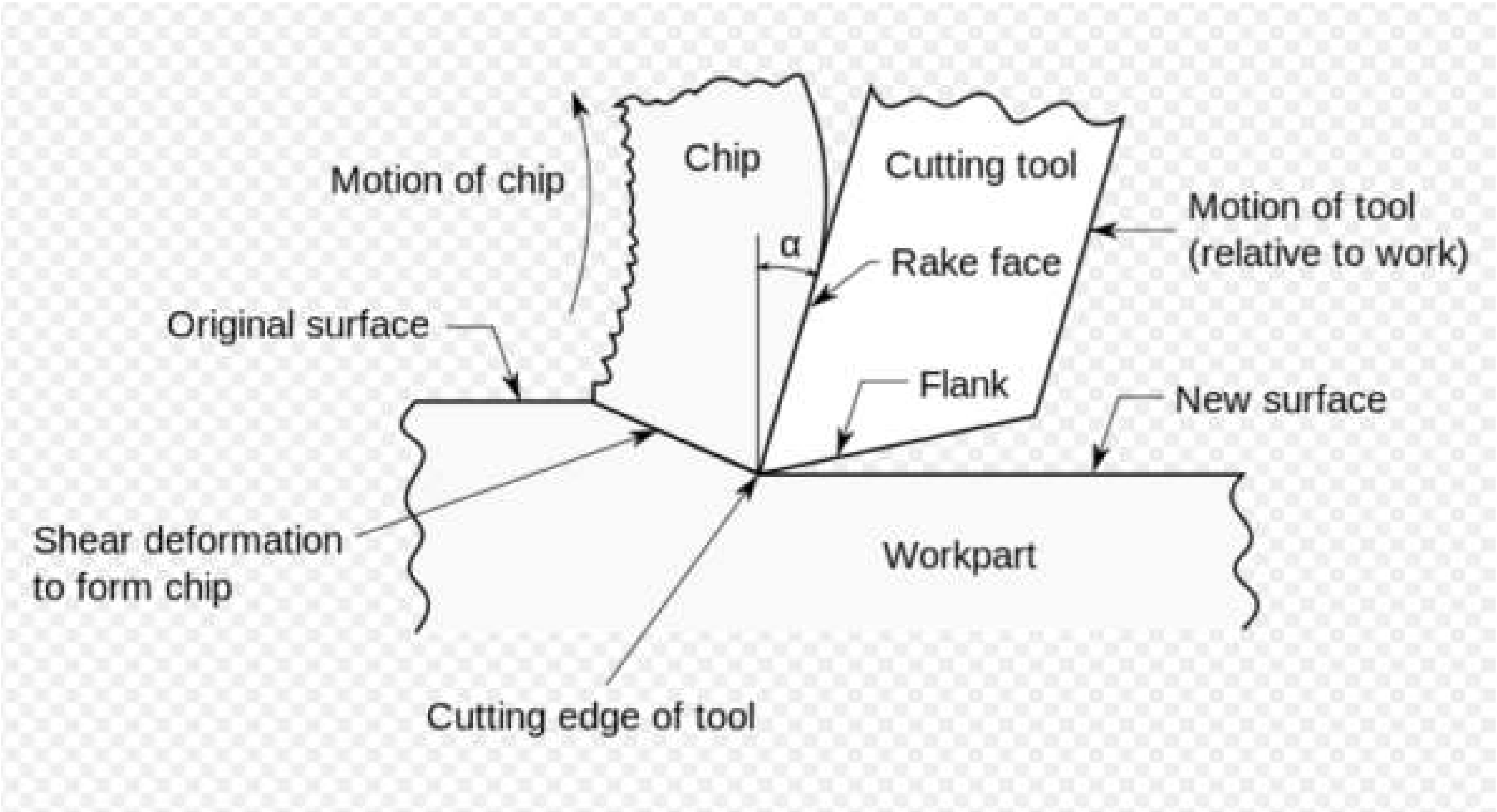
During Traditional or Conventional machining processes, machine tools with a sharp cutting tool, are used to remove material to achieve a desired geometry. Conventional machining processes is a process in which a human operator operates the machine manually by hand such as lathe, slotting machine, shaper machine etc;

Conventional/ Traditional Machining Process

Machining is any of various processes in which a piece of raw material is cut into a desired final shape and size by a controlled material-removal process.

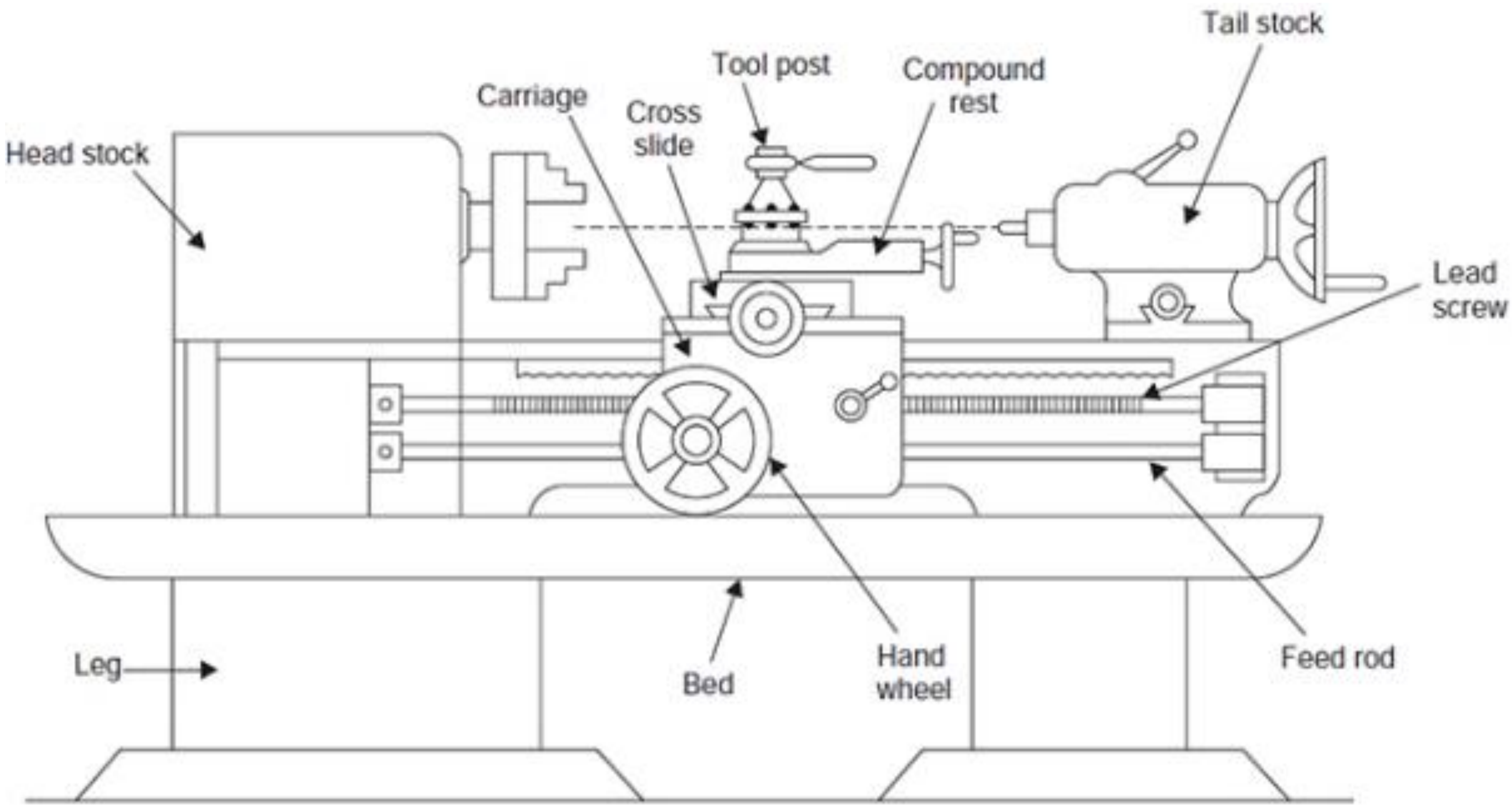
- **Turning**
- **Boring**
- **Drilling**
- **Milling**
- **Broaching**
- **Shaping**
- **Planing**
- **Reaming**

Conventional/ Traditional Machining Process



LATHE

LATHE


Tail stock
Tool post
Compound rest
Carriage
Cross slide
Head stock
Lead screw
Leg
Bed
Hand wheel
Feed rod

Bed

A bed is the main body of the machine. All the main components are bolted on it. It is usually made of cast iron due to its high compressive strength. It is made by the casting process and is bolted to the floor space.

Headstock:

The headstock is usually located on the left side of the lathe and is equipped with gears, spindles, chucks, gear speed control levers, and feed controllers. It mounted in a fixed position on the inner ways, usually at the left end.

Chuck

Allows the mounting of difficult workpieces that are not round, square, or triangular.

Tailstock:

It is also sometimes called a loos headstock or a puppet head. Usually located on the right side of the lathe, the workpiece is supported at the end. Fits on the inner ways of the bed and can slide towards any position of the headstock to fit the length of the workpiece. An optional taper turning attachment would be mounted to it.

Carriage:

The carriage is located between the headstock and the tailstock and contains an apron, saddle, compound rest, cross slide, and tool post. It is used to hold and move the tool post along the bed either towards or away from the headstock.

(i) **Tool Post**: It is used to hold the tool. It has T-slot for holding the tool. The tool post is bolted on the carriage.
(ii) **Compound Rest**: It is used to set the tool at a desired angle for taper turning and other operations.
(iii) **Cross Slide**: The cross slide is used to move the tool perpendicular to the axis of the lathe.
(iv) **Saddle**: The top portion of the carriage is called the saddle. Cross slide is mounted on the saddle.
(v) **Apron**: The front portion of the carriage is called apron. It contains all the moving and control mechanism of the carriage.

Lead Screw

The lead screw is used to move the carriage automatically during threading.

Feed Rod

It is used to move the carriage from left to right and vice versa.

Chip Pan

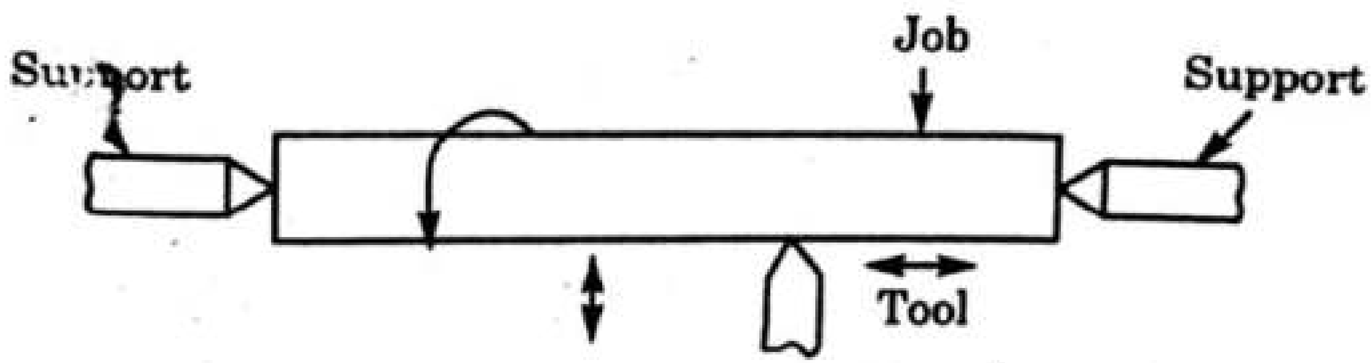
Chip pan is used to collect the chips that are produced during the lathe operation. It is present at the bottom of the lathe

Hand Wheel

It is the wheel that is operated by hand to move the cross slide, carriage,

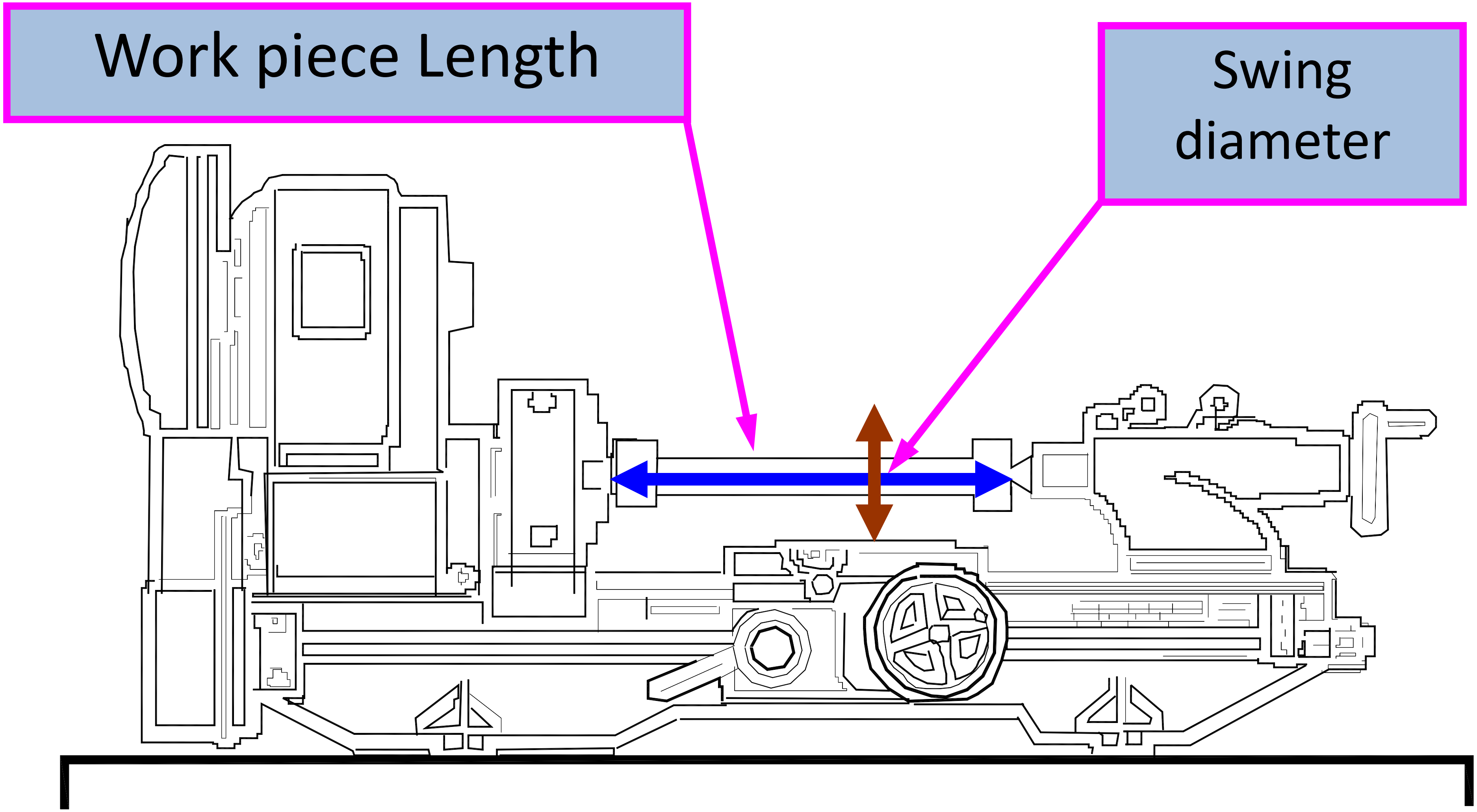
PRINCIPLE AND OPERATION OF LATHE

The basic principle of machining is typically illustrated in Fig below

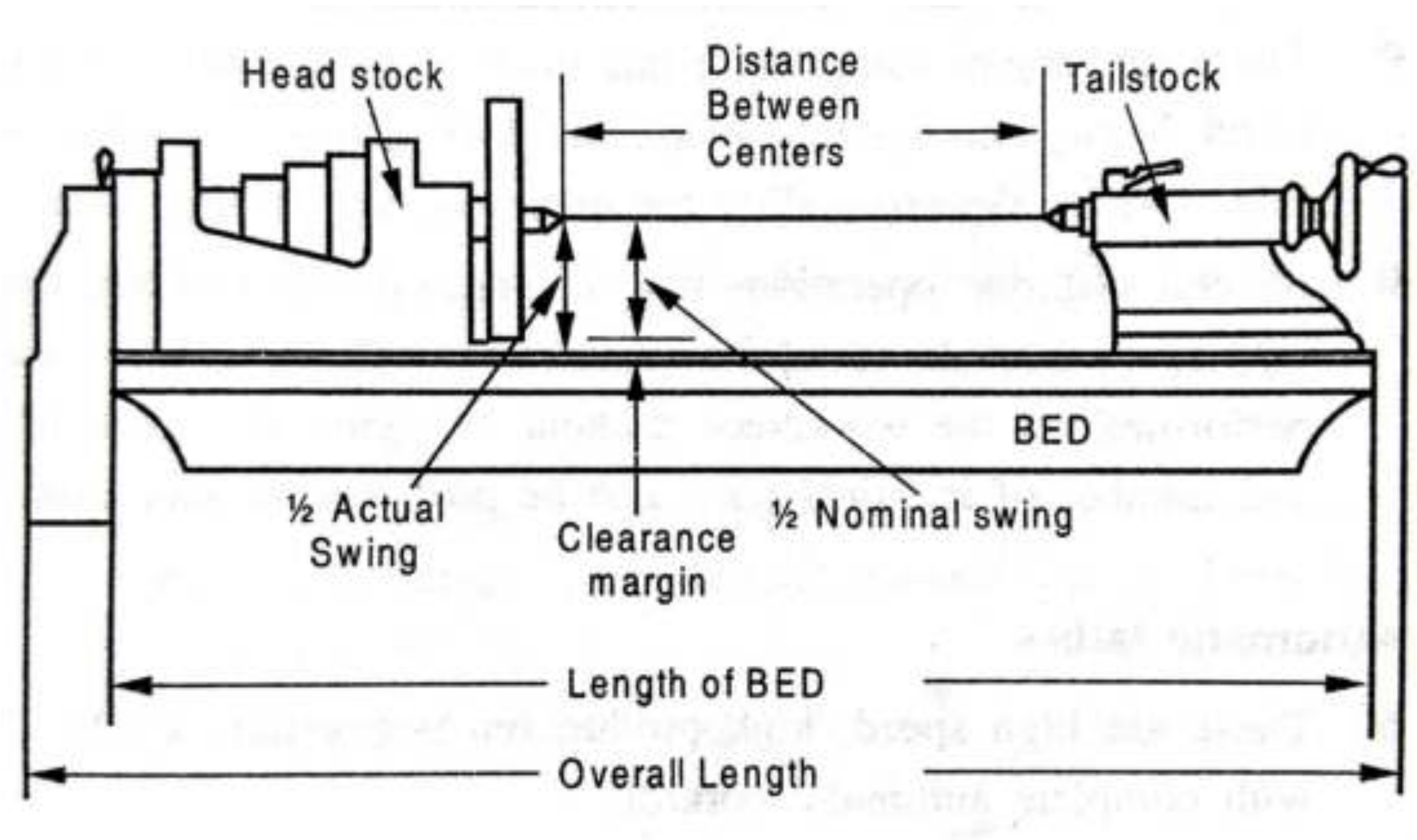


Working Principle: The lathe is a machine tool which holds the workpiece between two rigid and strong supports called centers or in a chuck or face plate which revolves. The cutting tool is rigidly held and supported in a tool post which is fed against the revolving work

Size of Lathe



SIZE AND SPECIFICATION



LATHE SIZE SPECIFICATION

Size of a lathe is specified by the following

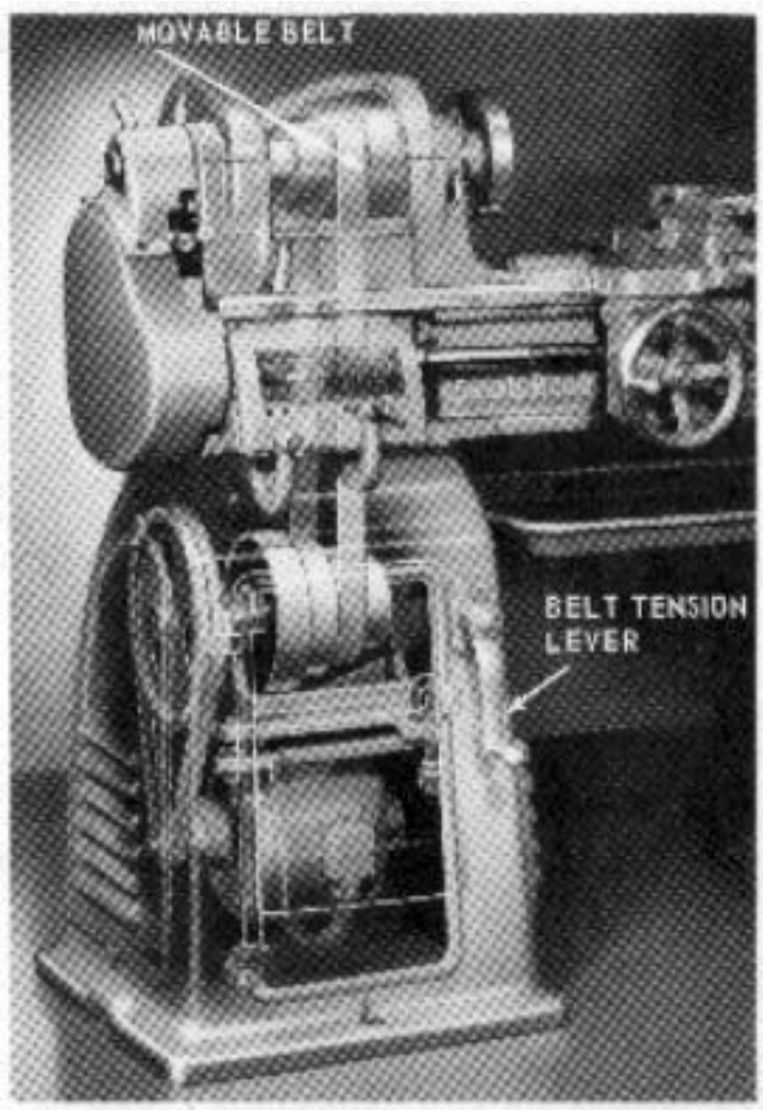
1. Height of the centres measured from the lathe bed
2. Swing diameter over bed:- largest diameter of work which will revolve without touching the bed and is twice the height of the centre measured from bed of the lathe
3. Length between centres: the maximum length which can be mounted between centres
4. Swing diameter over carriage: Largest diameter which will revolve over lathe saddle
5. Length of bed: Approximate floor space occupied by the lathe
6. The bore diameter of the spindle
7. The width of the bed
8. The type of the bed
9. Pitch value of the lead screw
10. Horse power of the motor
11. .Number and range of spindle speeds
12. Number of feeds
13. Spindle nose diameter
14. Floor space required

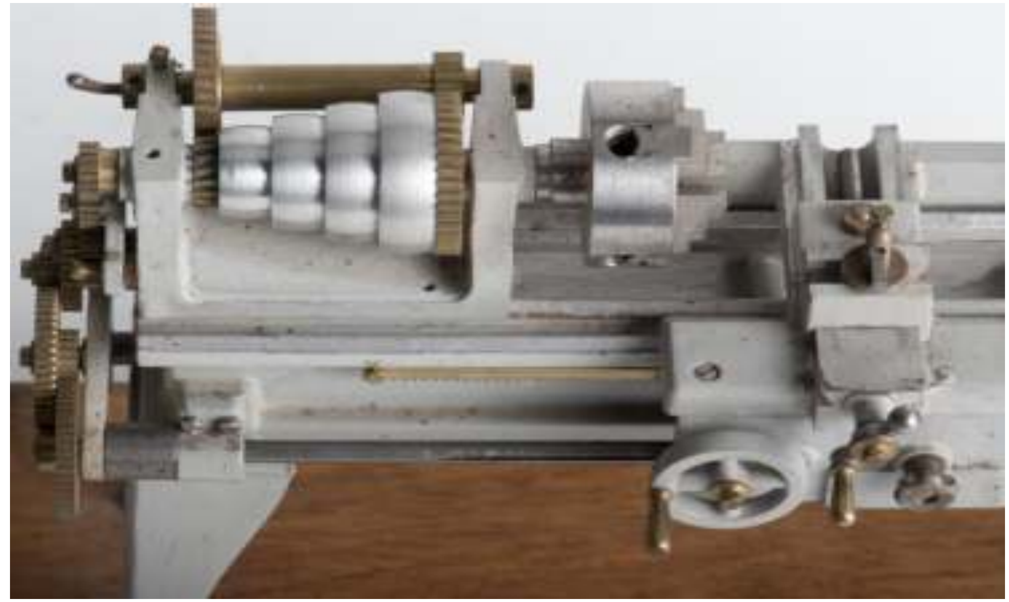
Speed Lathe

Speed lathe

- Simplest in construction of all the types of lathe
- Name due to high speed of headstock spindle
- Consists of a bed, headstock, tailstock and tool-post mounted on an adjustable slide
- No feed box, leadscrew or carriage
- Tool is mounted on adjustable slide and fed to workpiece by hand control
- High spindle speeds from 1200 to 3600 rpm
- Depth of cut and chip thickness is very small
- Only 2 or 3 spindle speeds available
- Used where light cuts and high speeds are necessary

Engine Lathe

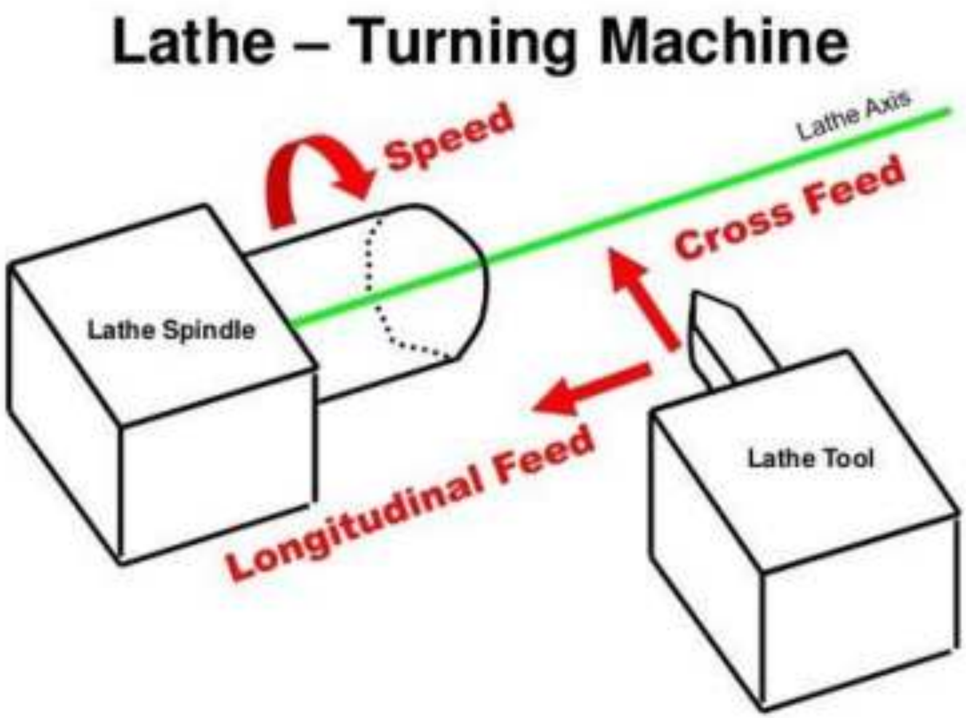




Engine Lathe or centre lathe

- The most common form of lathe, motor driven and comes in large variety of sizes and shapes.
- The word 'Engine' used since earlier lathes were driven by steam engines.
- Has all basic parts similar to speed lathe
- Headstock much more robust in construction
- Additional mechanism for driving lathe spindle at multiple speeds
- Can feed the cutting tool both in cross and longitudinal direction by means of carriage, feed rod and lead screw.

cross-feed and longitudinal feed in lathe




Bench Lathe 2.6'
EKBL3

Bench Lathe

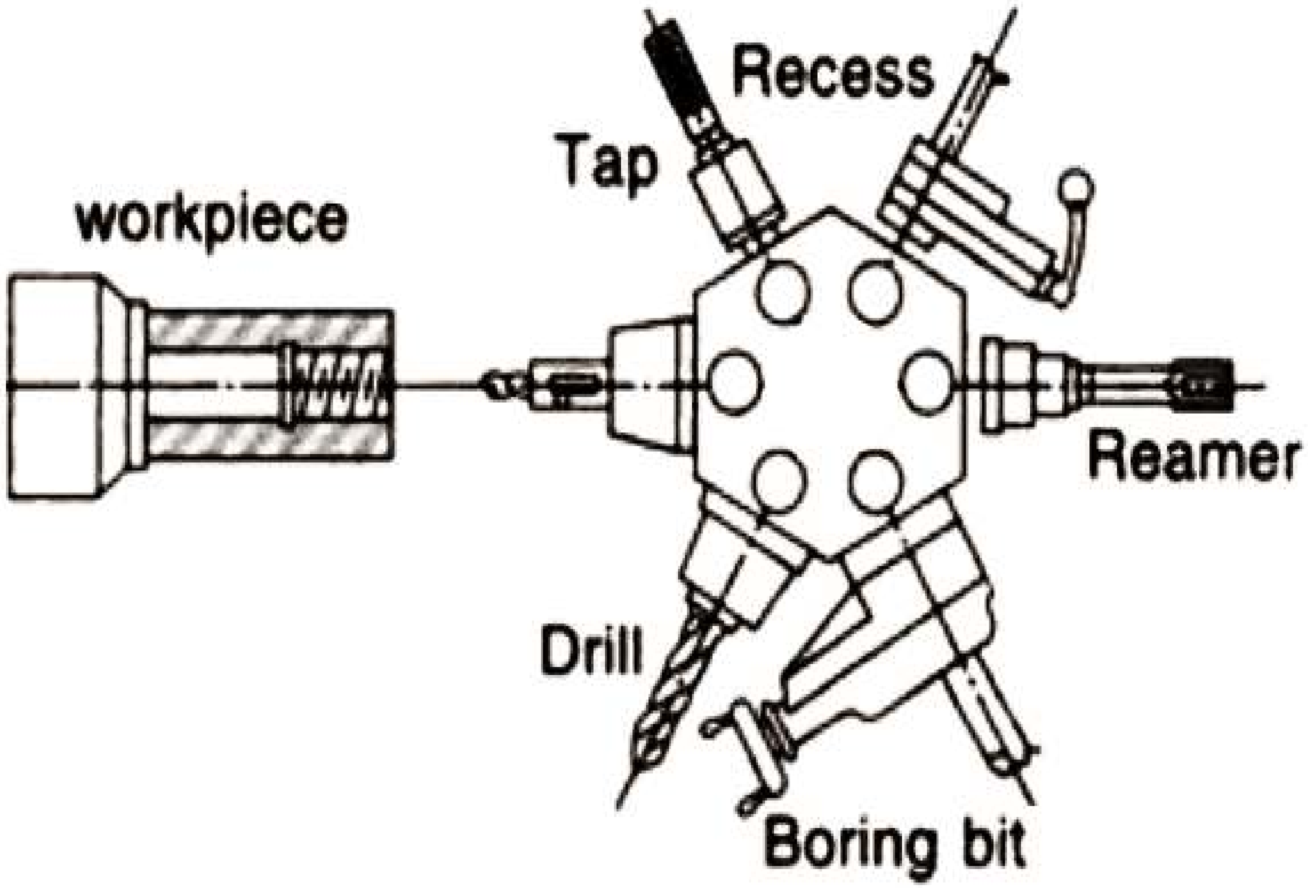
- Small lathe mounted on a bench
- Has all parts of an engine lathe
- Performs all operations
- Difference is only in the size
- Used for small and precision work

Tool room lathe

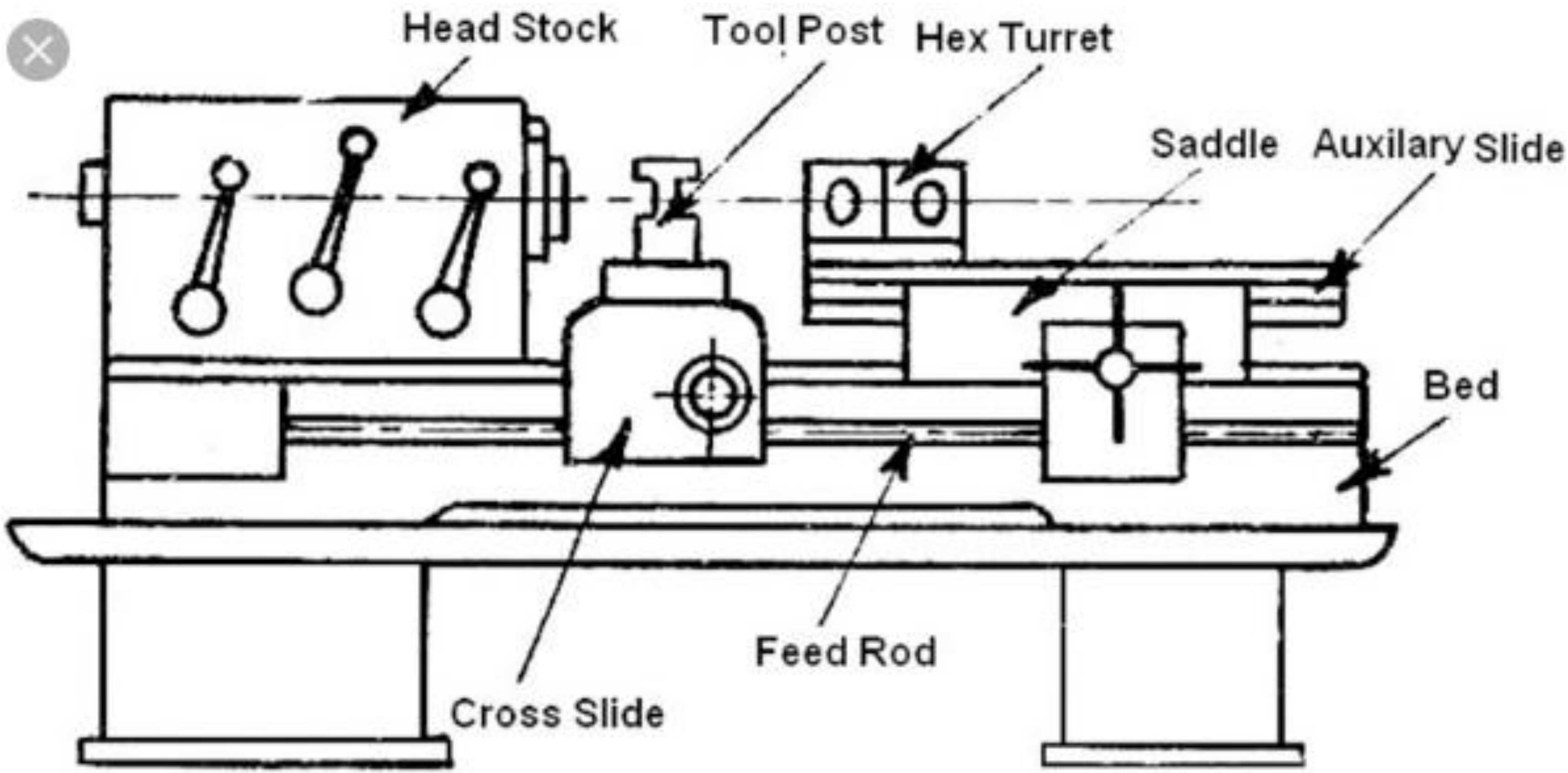
Tool room lathe

- Features similar to engine lathe
- More accurately built and has wide range of spindle speeds – very low to quite high upto 2500 rpm
- Equipped with a chuck, taper turning attachment, collet attachment, relieving attachment, steady and follower rest etc
- Used for precision work on tools, dies, gauges where accuracy is needed.
- Costlier than engine lathe of the same size.

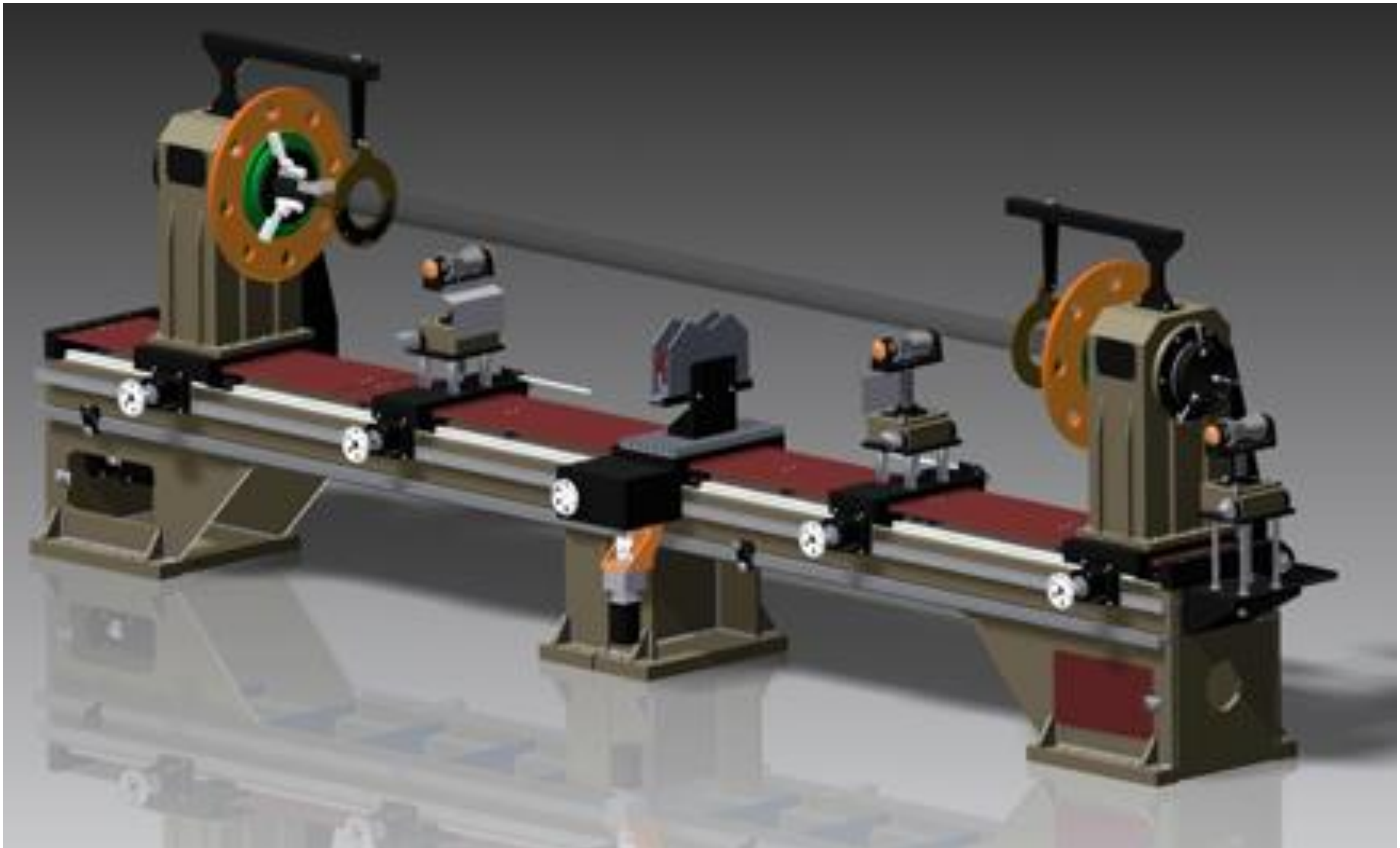
Capstan and turret lathe - tailstock of the engine lathe is replaced by hexagonal turret, so that multiple tools can be fitted and fed into work.



Turret lathe



Special purpose lathe - used for special purpose and for jobs which cannot be machined on a standard lathe.



Automatic lathe - high speed, heavy duty, mass production lathe. Once tool is set, machining is done automatically, to obtain finished product.

TYPES OF LATHE

1. **Speed lathe** - Used for wood working, centering, polishing, spinning etc
2. **Engine lathe** – Medium size lathe with belt drive/ individual motor drive/ gear head drive.
3. **Bench lathe** - Small lathe used for small and precision work.
4. **Tool room lathe** - Similar to engine lathe, used for precision work on dies, tools, gauges etc
5. **Capstan and Turret lathe** - Tailstock of the engine lathe is replaced by hexagonal turret, so that multiple tools can be fitted and fed into work.

TYPES OF LATHE

6. **Special purpose lathe** - used for special purpose and for jobs which cannot be machined on a standard lathe.
7. **Automatic lathe** - high speed, heavy duty, mass production lathe. Once tool is set, machining is done automatically, to obtain finished product.

Types of lathe

Cutting Speed, Feed & Depth of Cut

Cutting Speed (V):

It is the speed at which the metal is removed by the cutting tool from the workpiece. It is expressed in meter/min. or mm/min.

Cutting speed (V) = π DN/60 × 1000 mm/min.

Where, D = diameter of the workpiece (mm) & N = rpm of the work

Feed (f):

It is the relative motion of tool in one revolution of workpiece. It is expressed in mm/rev. (tool's distance travelled during one spindle revolution)

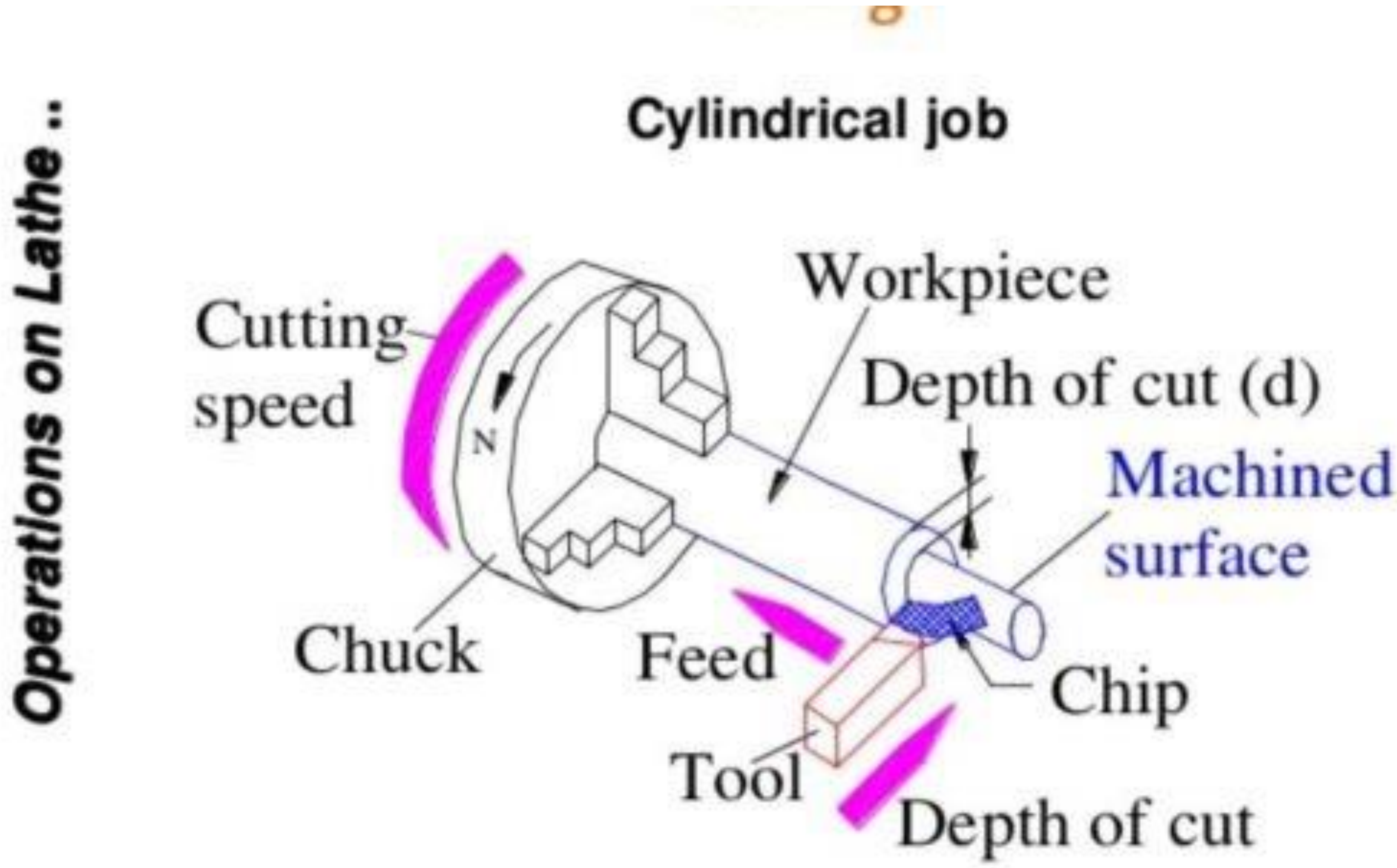
Depth of Cut (t):

It is the total amount of metal removed per pass of the cutting tool. It is expressed in mm.

Depth of cut (t) = D-d/2 mm

where, D = outer diameter, (mm) & d = Inner diameter (mm)

Cutting Speed, Feed & Depth of Cut



Lathe Accessories

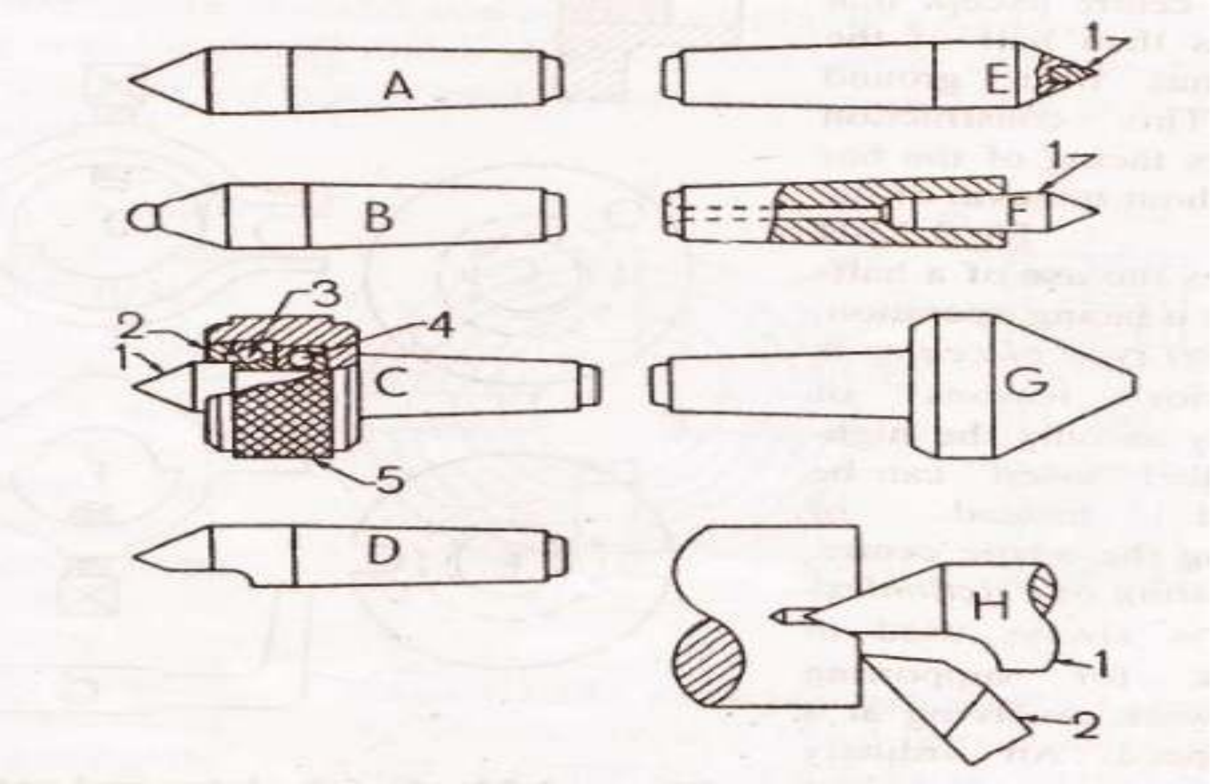
- Divided into two categories
  1. Work holding, supporting and driving devices
     - Lathe centers, chucks, faceplates
     - Lathe dogs,
     - Mandrels, steady and follower rests.
  2. Tool holding devices
     - Straight and offset tool holders
     - Threading tool holders, boring bars
     - Turret-type tool posts.

Lathe Centers

Lathe Centers

- Work to be turned between centers must have center hole drilled in each end
  - Provides bearing surface
- Support during cutting
- Most common have solid Morse taper shank 60º centers, steel with carbide tips
- Care must be taken to adjust and lubricate occasionally.

Types of Lathe Centers

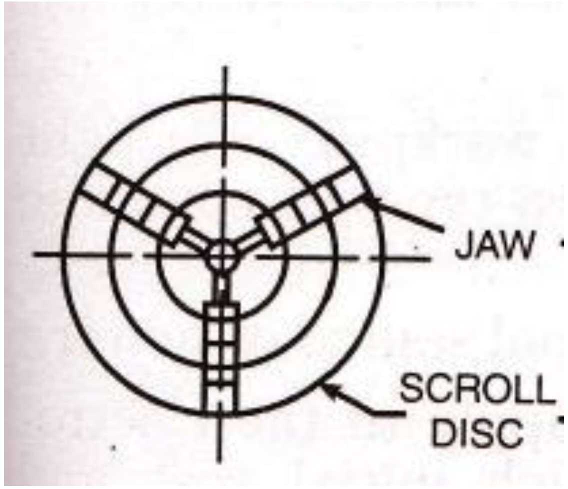


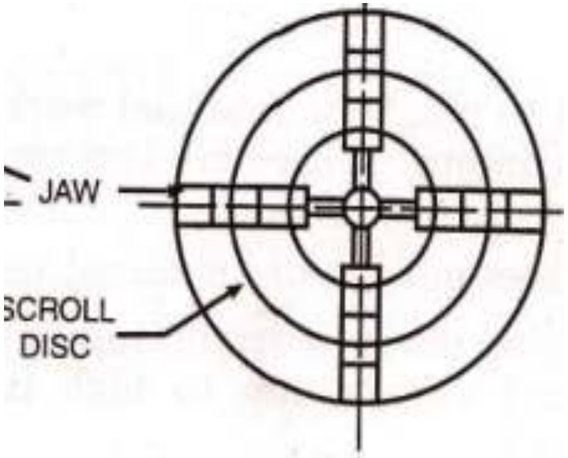
a) Ordinary centre, b) Ball centre,
c) Frictionless centre, d) Half centre, e) Tipped centre.

Chucks

1) 3 Jaw/ Universal chuck

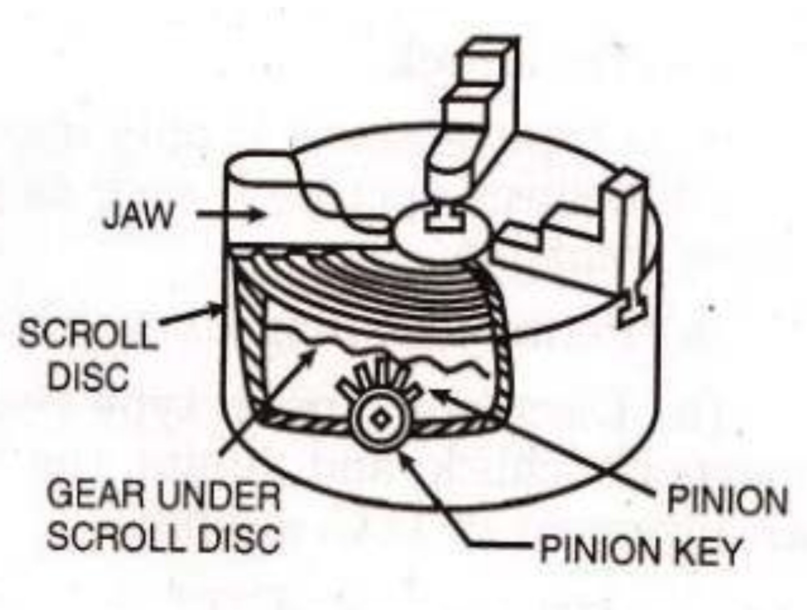
2) 4 Jaw chuck



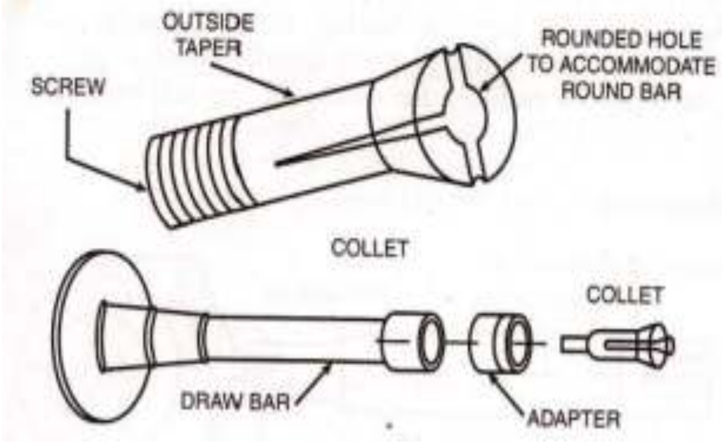


Chucks

3). Combination chuck



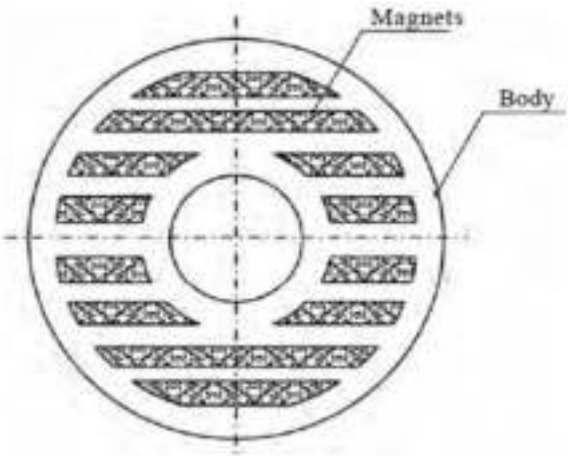
4). Collet chuck



Chucks

5 Magnetic Chuck

Thin & Fragile work pieces can be turned effectively by using a magnetic chuck

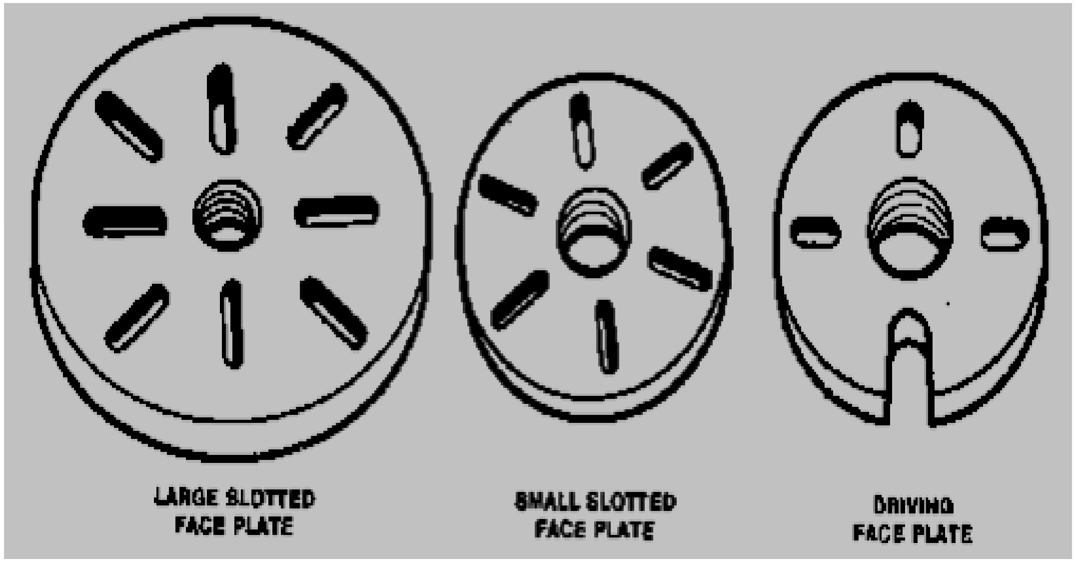


The magnetic chuck is used for gripping very lean pieces. These lean pieces are made up of magnetic material which cannot be gripped in an ordinarily chuck. Many a times there is a chance of bending, buckling, twisting or any kind of deformation of the work piece due to pressure of the jaws of ordinary chucks. When the lathe is turned on, the magnetic flux passes through the work piece and holds it. When the lathe is turned off the magnets are removed. The magnets are then brought in contact with high permeable items known as keepers. These keepers short-circuit the flux, thereby preventing the flux from passing through the work piece.

Face Plate

It contains more open slots or T-slots so that bolts may be used to clamp the workpiece to the face of the plate.

The face plate is used for holding work pieces which can not be conveniently held in a chuck.



Lathe dogs

- Most commonly used for round work pieces
- Available with square-head setscrews of headless setscrews

1. Standard bent-tail lathe dog

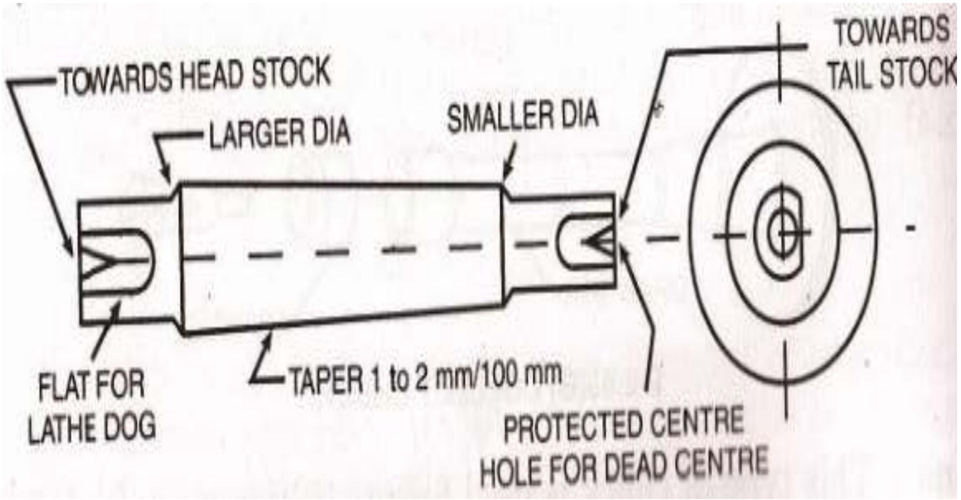
2. Straight-tail lathe dog

Standard bent-tail lathe dog

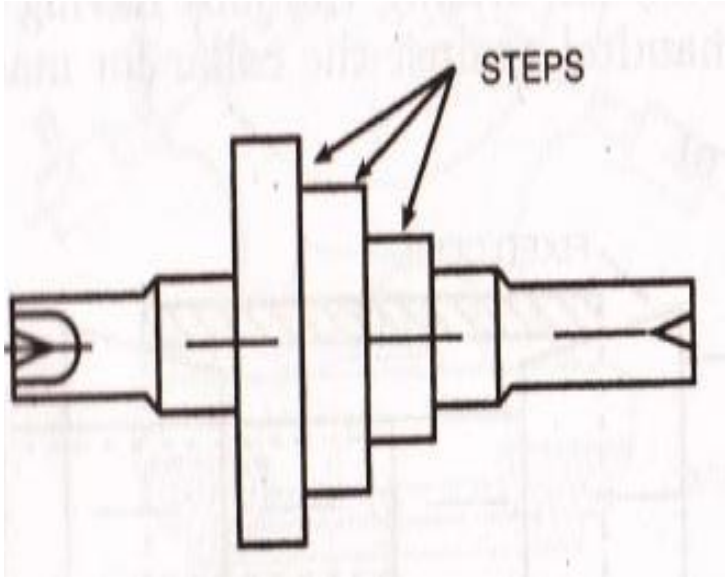
Mandrel

(The Mandrels are steel shapes that are useful for holding rotating previously drilled or stepped turned or bored workpieces, for further operations. Mandrels have got flattened ends for easy gripping by the carriers.)

Plain mandrel

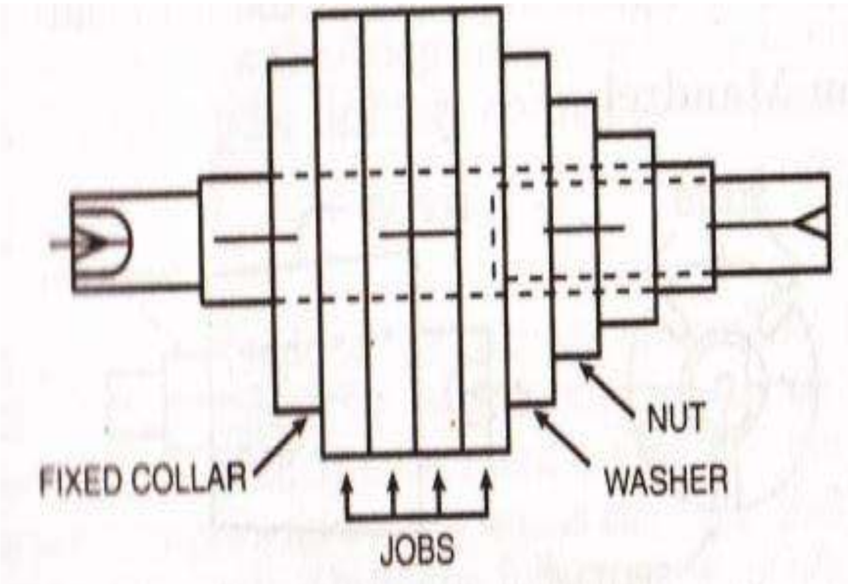


Step mandrel

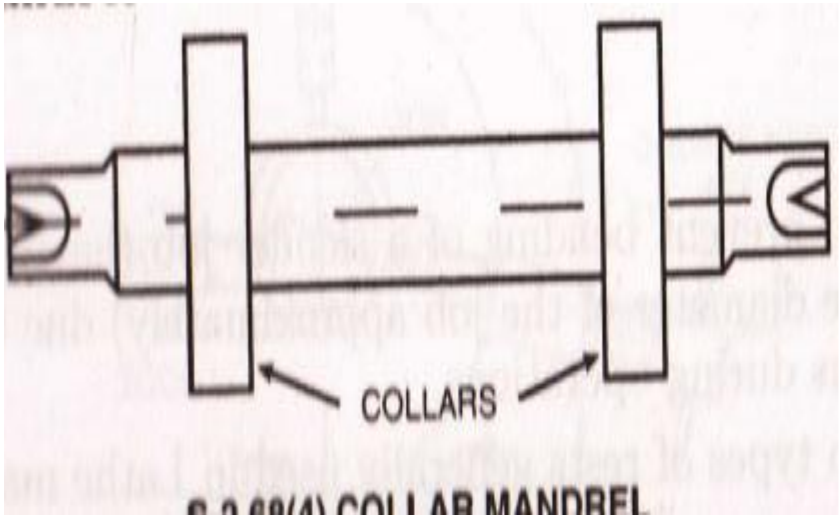


Mandrel

Gand mandrel

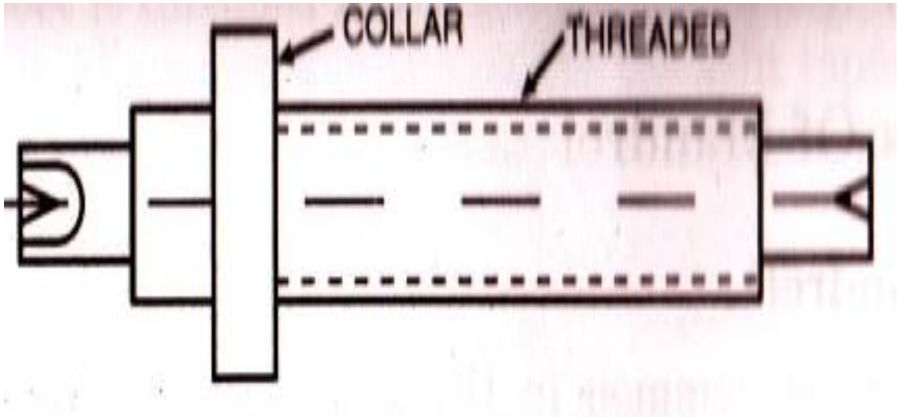


Collar mandrel

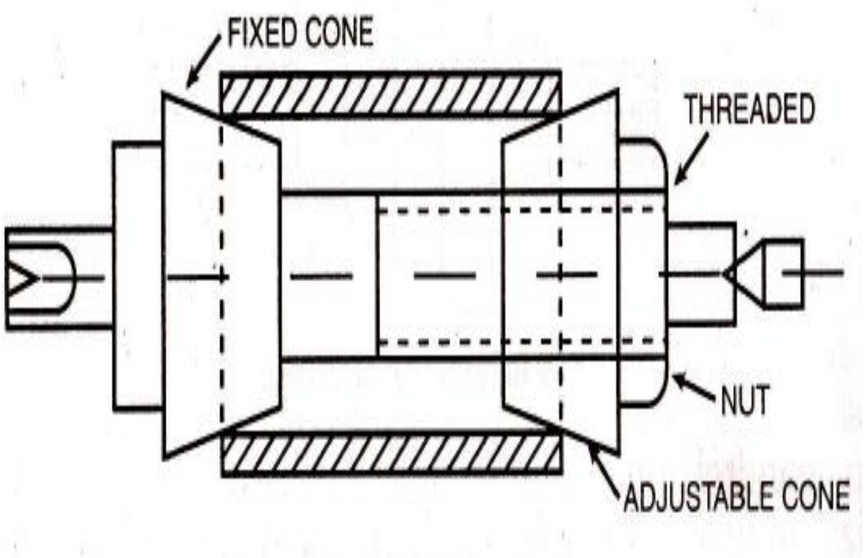


Mandrel

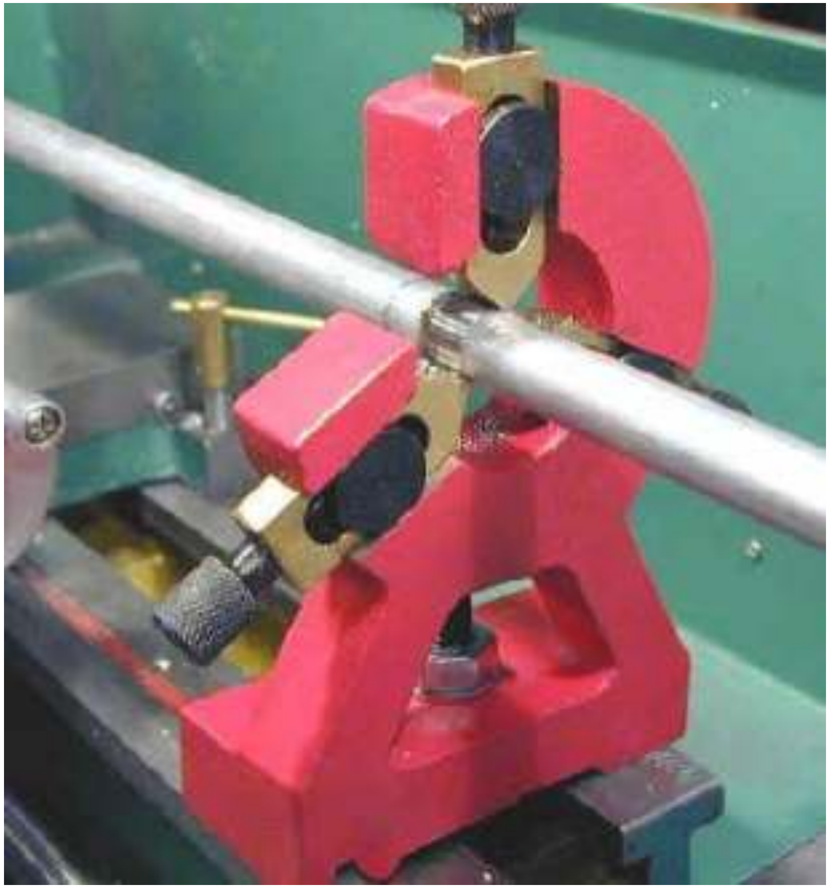
Screwed mandrel



Cone mandrel



Steady Rest



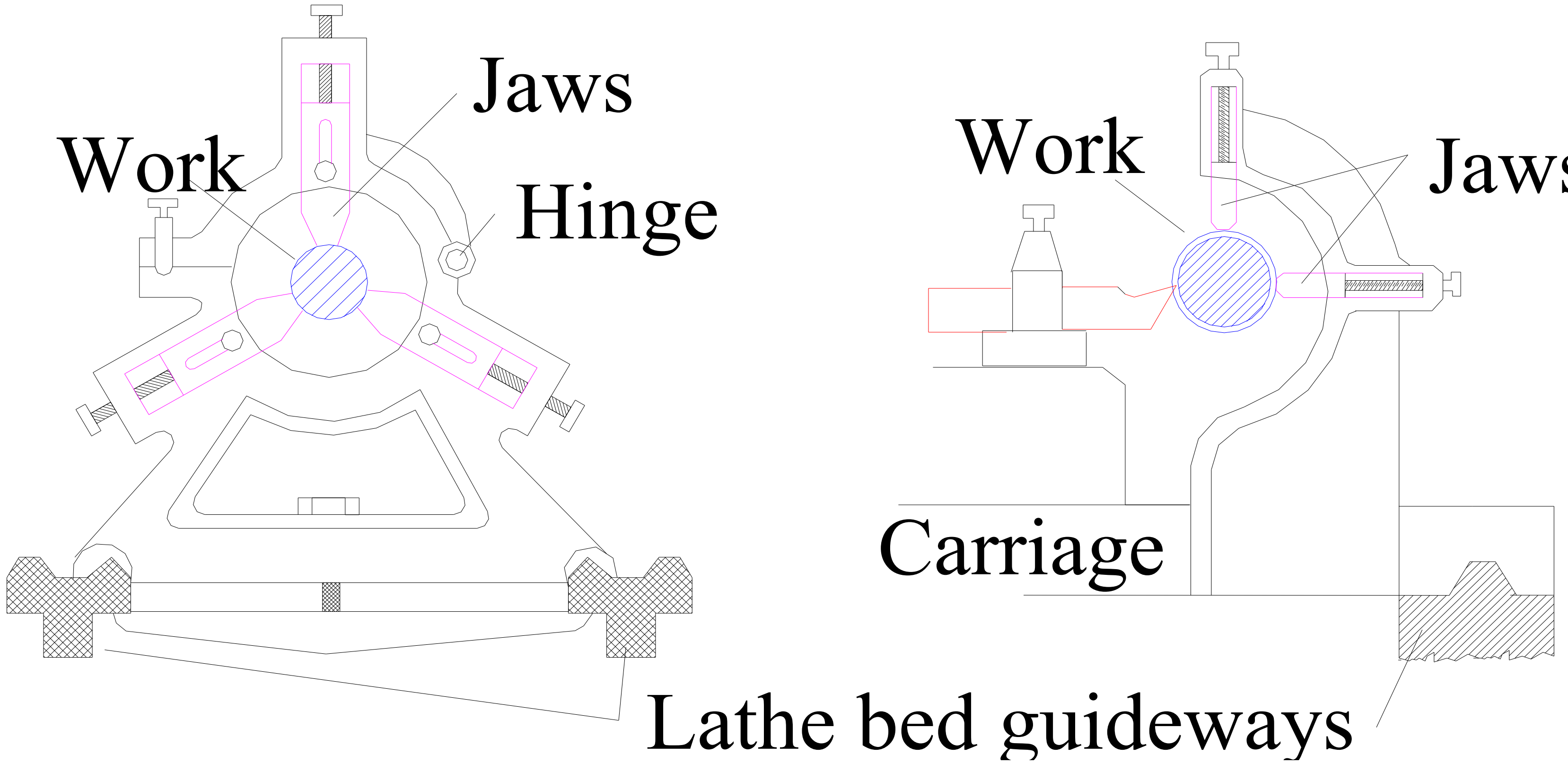
Steady rests are needed **when the length and stiffness of a workpiece makes it difficult to machine without distorting or deflecting the part**. This damage is the result of cutting or forming tool pressures that are simply too great for the part to withstand without additional support

Follower Rest

The purpose of the follower rest is **to keep long or small diameter work from deflecting when a cutting tool is applied to it**. It is attached to the lathe saddle and moves as the saddle moves, keeping the point of support directly behind the cutting tool.

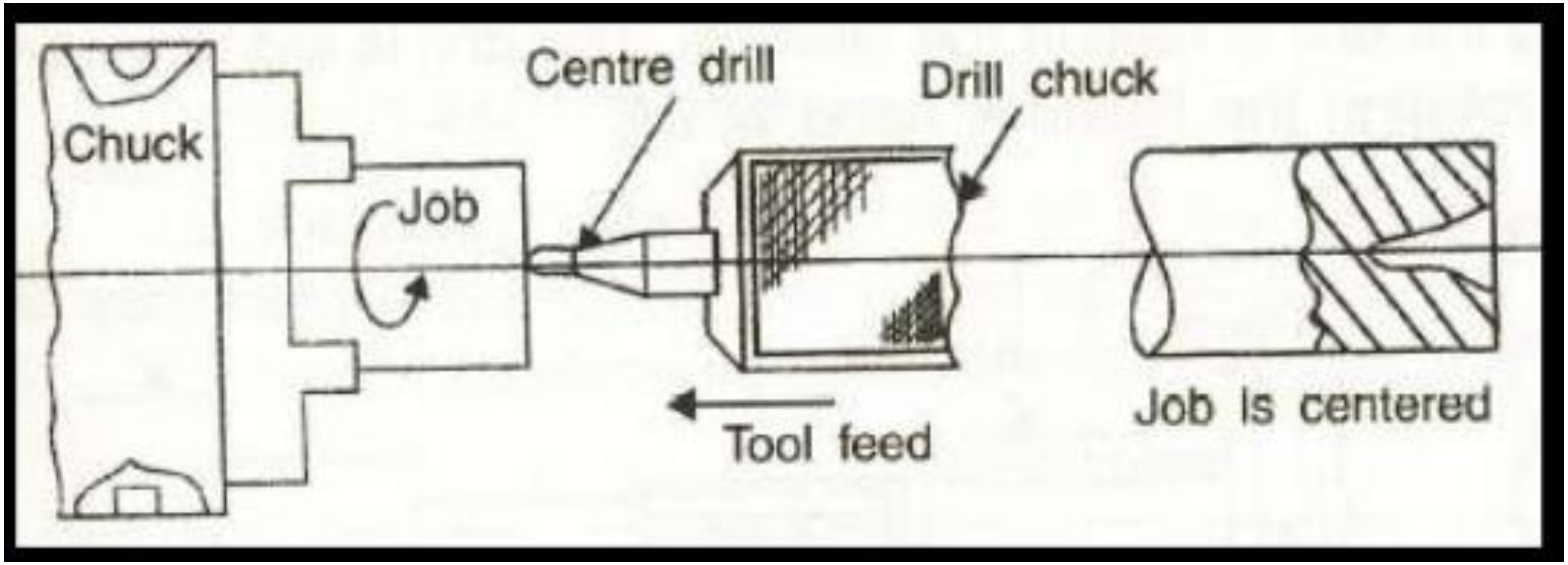
Steady Rest

Follower Rest



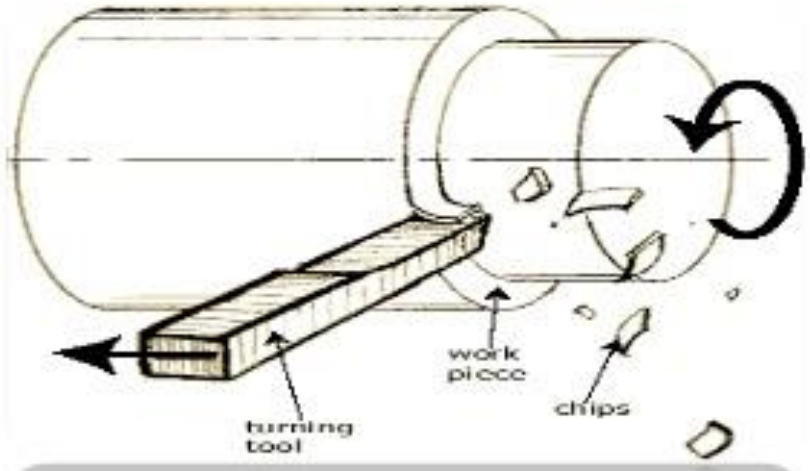
Lathe Accessories

Lathe operations
1. Centering



Centering is the operation of producing conical holes in the workpieces.

TURNING



Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the

work piece, usually to a specified dimension, and to produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters.

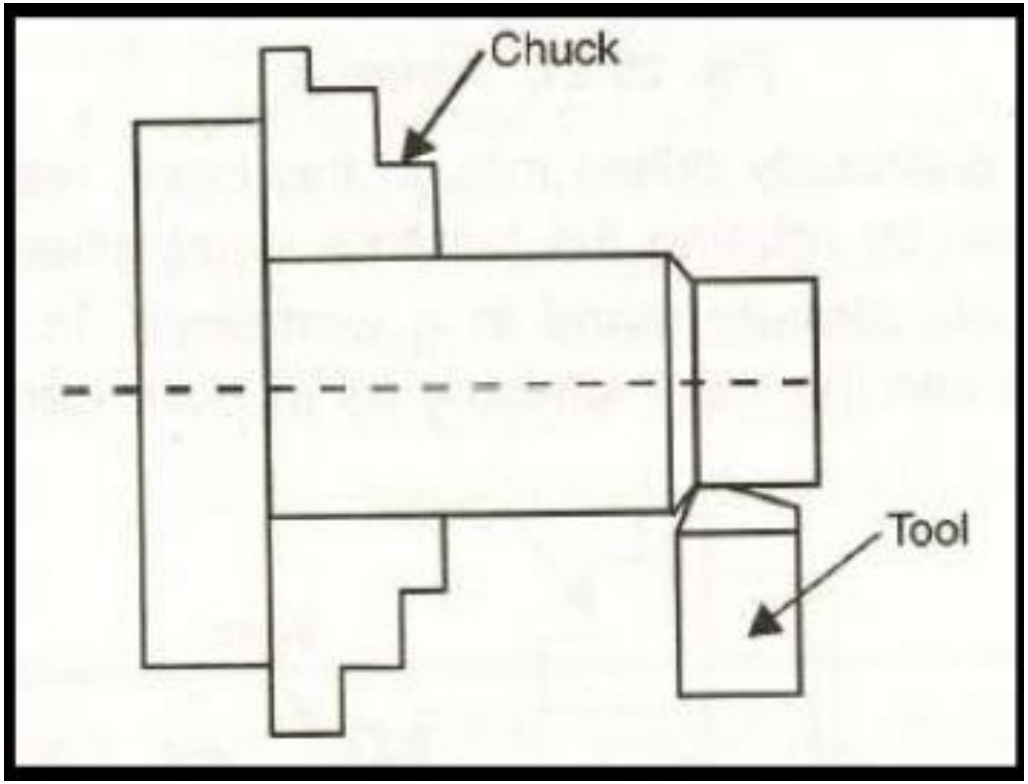
Turning

A single point cutting tool removes material from a rotating workpiece to generate a rotationally symmetric shape

- Types of cuts:
  - Facing
  - Contour turning
  - Chamfering
  - Parting (Cut-off) / Grooving
  - Threading

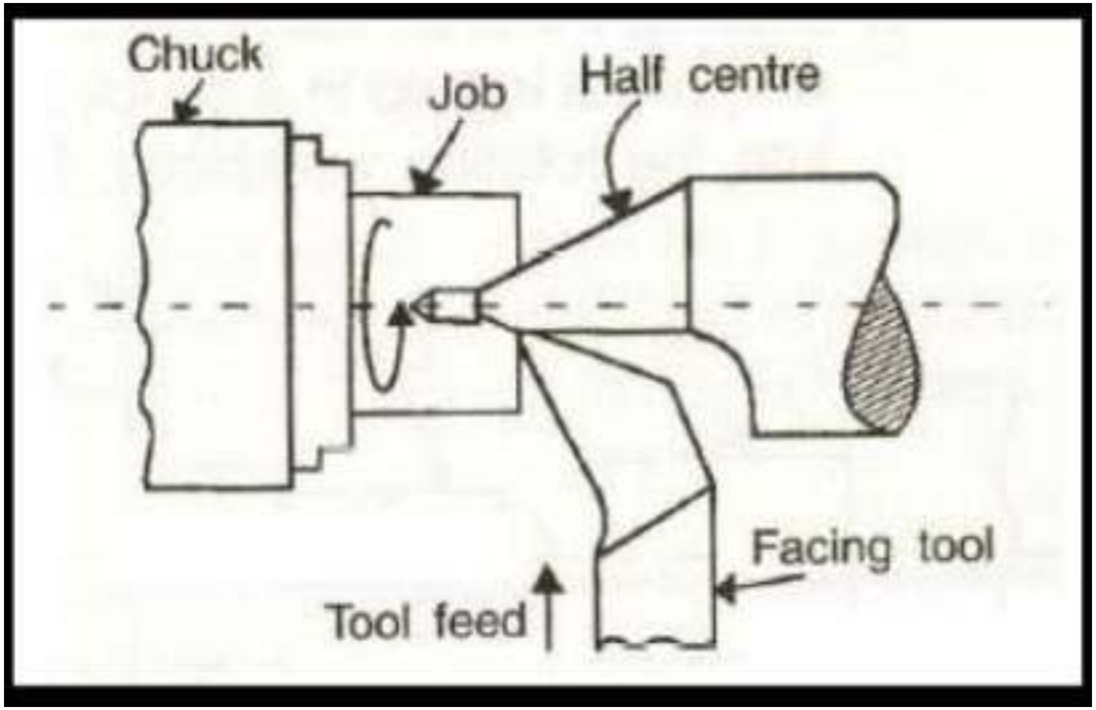
Lathe operations

2. Plain turning



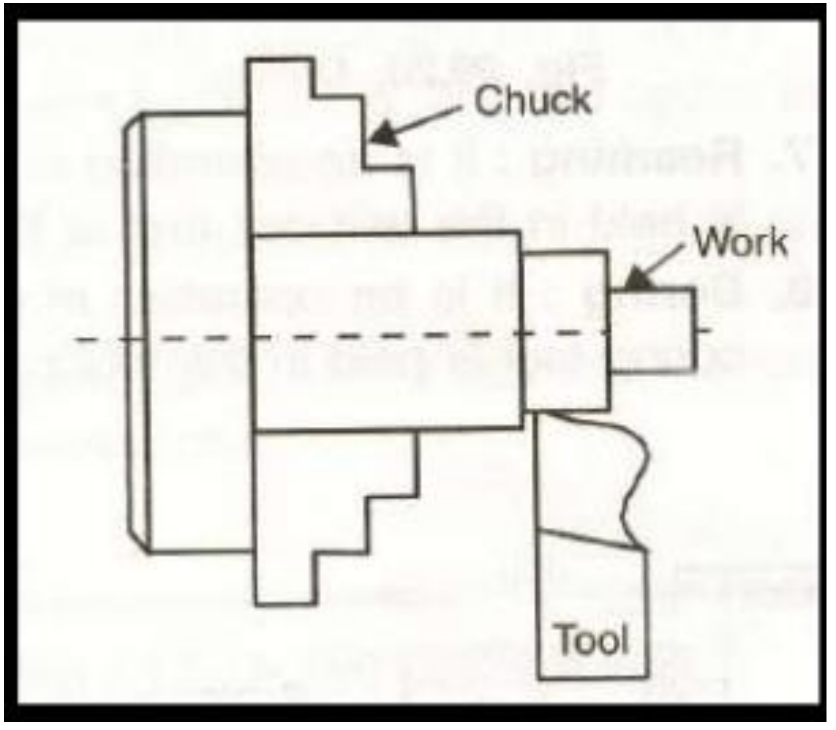
A single-point turning tool moves axially, along the side of the workpiece, removing material until the end diameter is reached.

Lathe operations
3. Face turning



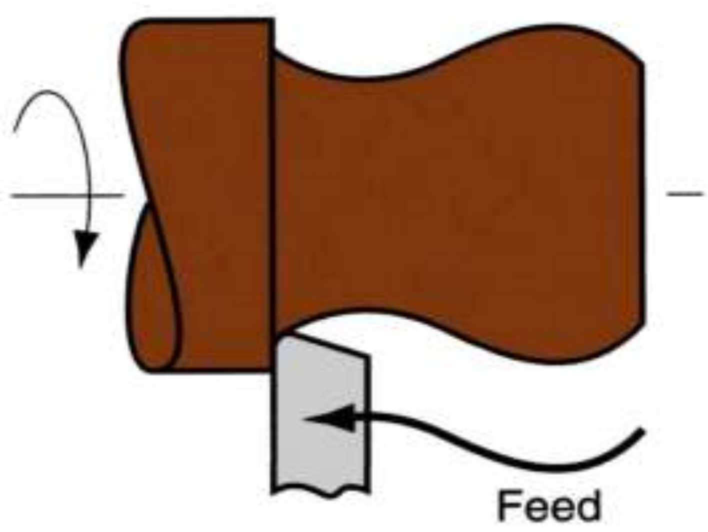
It is the machining of the ends of a workpiece to make the ends smooth. For this operation, the cutting tool is fed perpendicular to the lathe or workpiece axis by means of cross slide

Lathe operations
4. Step turning



In stepped turning, the workpiece is turned in such a way that throughout the turning length it forms the steps of different diameters.

Lathe operations
5. Contour turning

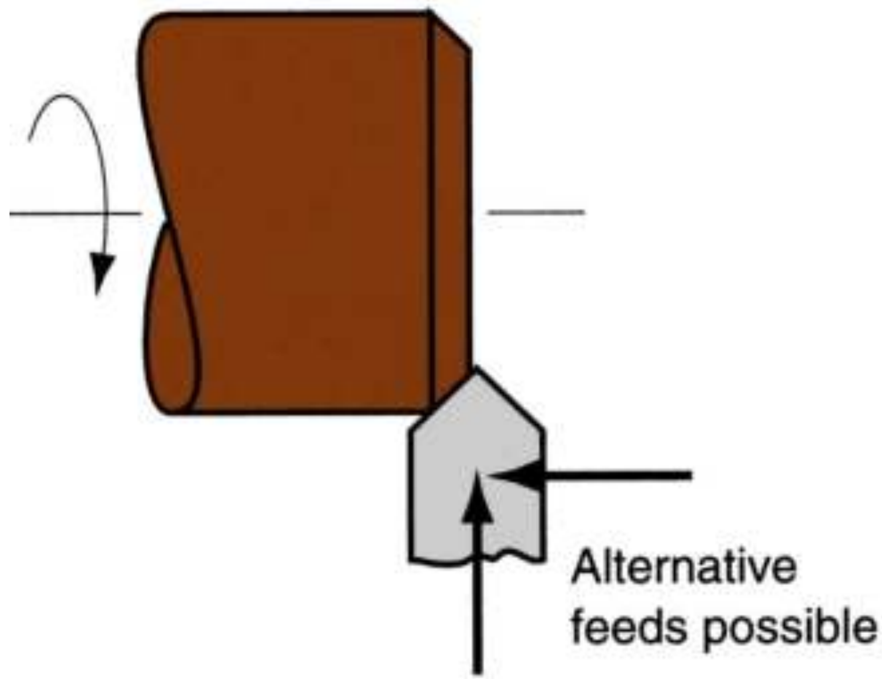


(c)

In contour turning operation, the cutting tool axially follows the path with a predefined geometry. Multiple passes of a contouring tool are necessary to create desired contours in the workpiece. However, form tools can produce the same contour shape is a single pass

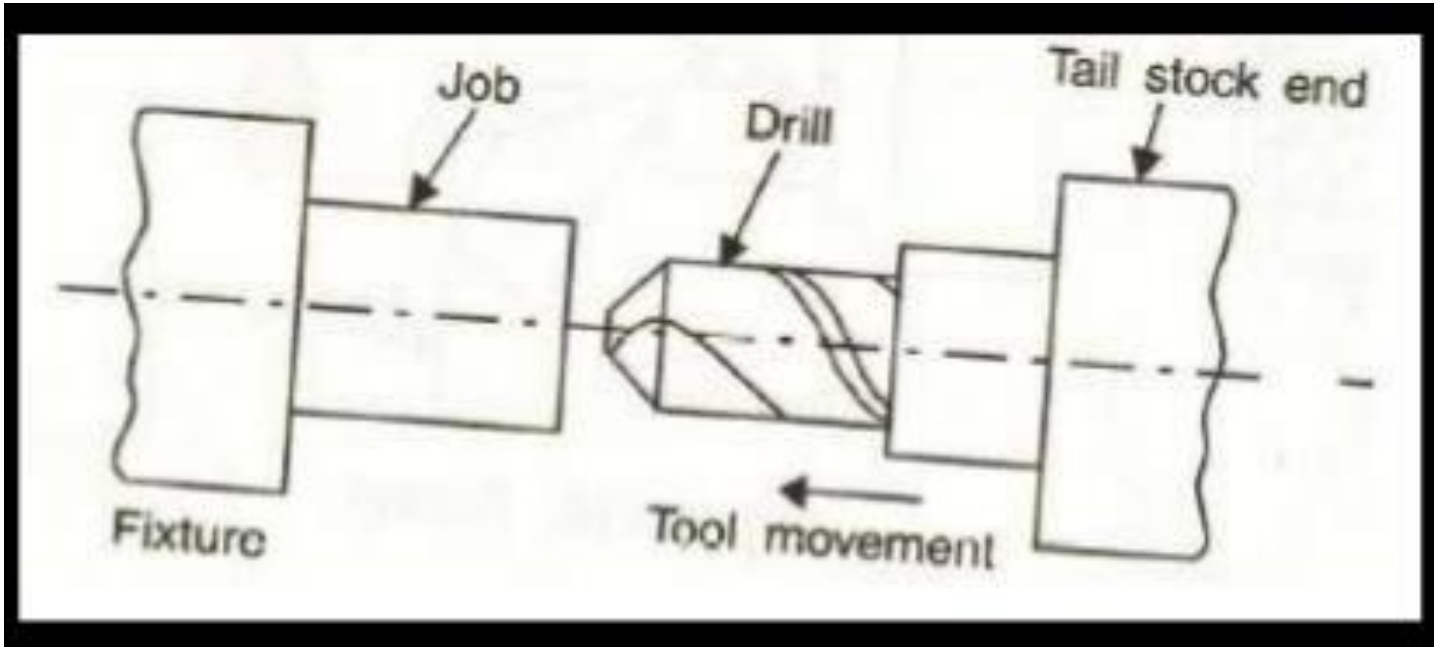
Lathe operations

6. Chamfering



It is the operation of getting a bevelled surface at the edge of a cylindrical workpiece. This operation is done to remove burrs to protect the end of workpiece from being damaged and to have better look. This operation is done in case of bolt ends and shaft ends.

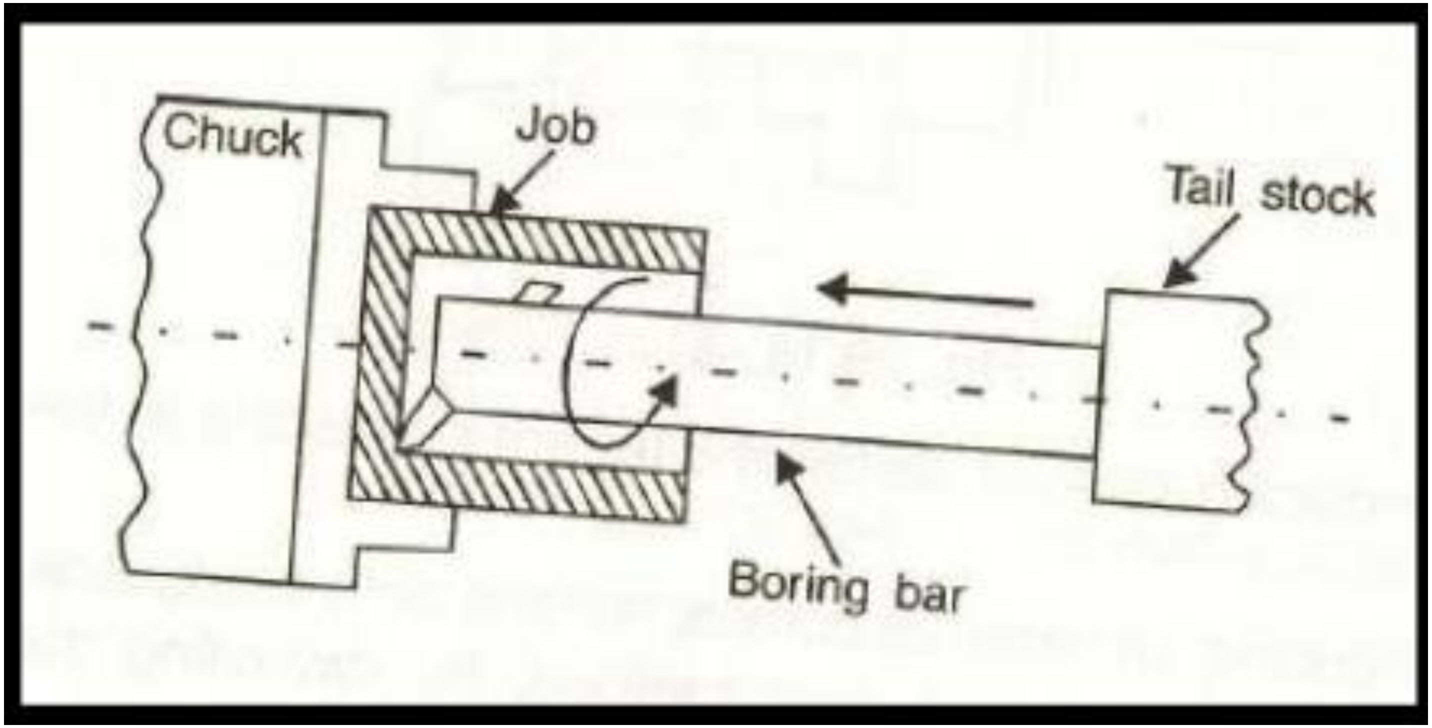
Lathe operations
7. Drilling



A drill enters the workpiece axially through the end and cuts a hole with a diameter equal to that of the tool

Lathe operations

8. Boring



Boring process is performed to enlarge initial hole made by drilling process or to convert cylindrical hole to a tapper hole.

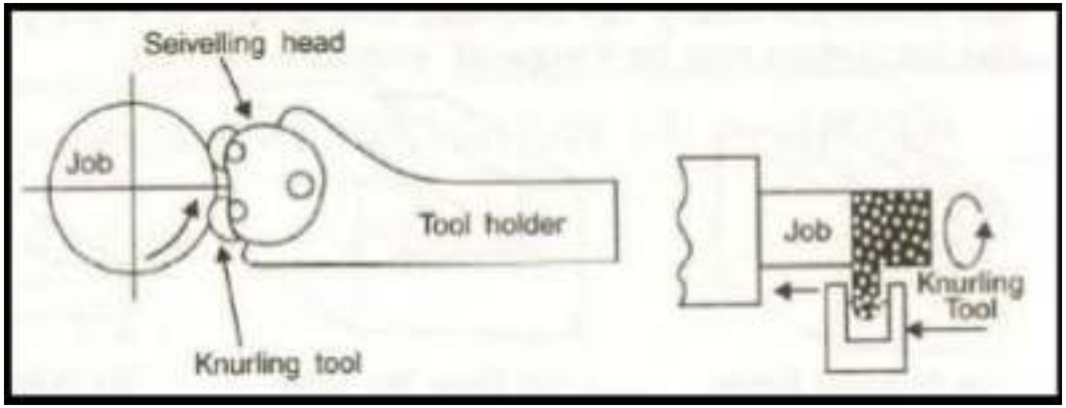
Knurling

Process of impressing a diamond-shaped or straight-line patter into the surface of the workpiece

- Improve its appearance
- Provide better gripping surface
- Increase workpiece diameter when press fit required

Lathe operations

9. Knurling



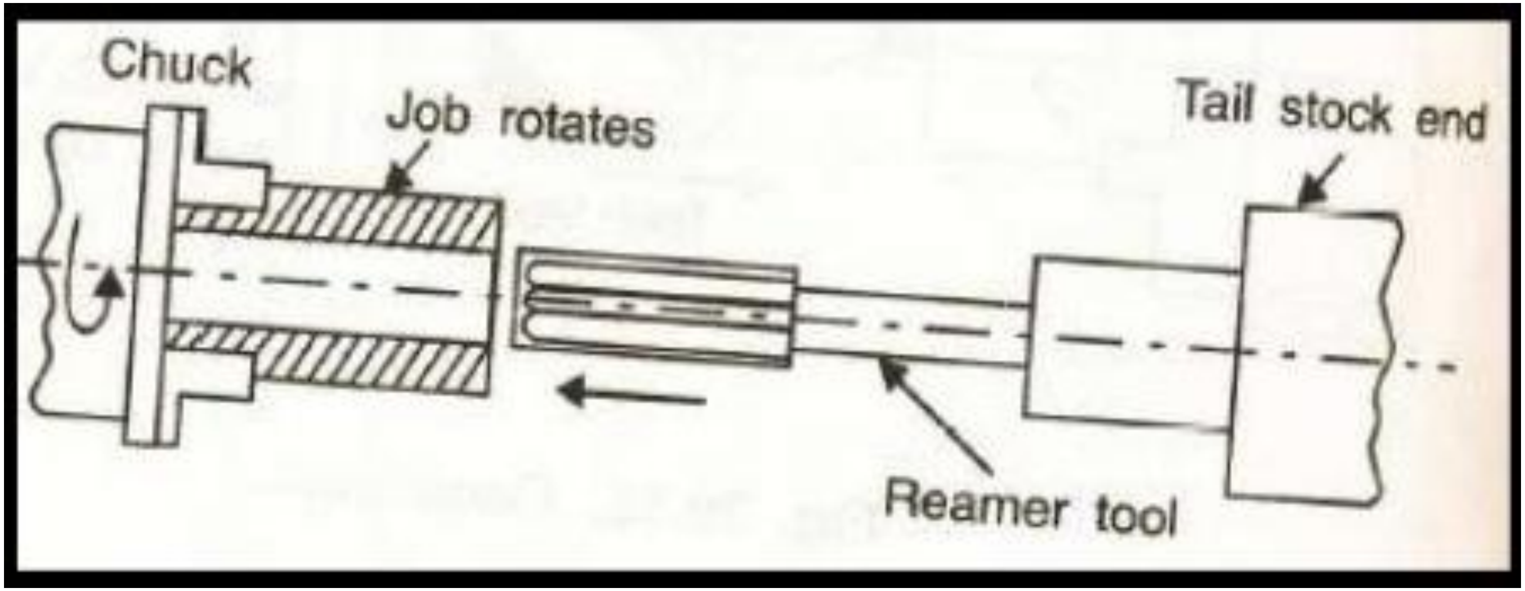
Knurling tool with one pair of rolls

It is an operation of obtaining a diamond shape on the workpiece for the gripping purpose. This is done to provide a better gripping surface when operated by hands.

Knurling

- Diamond- and straight-pattern rolls available in three styles
  - Fine
  - Medium
  - Course

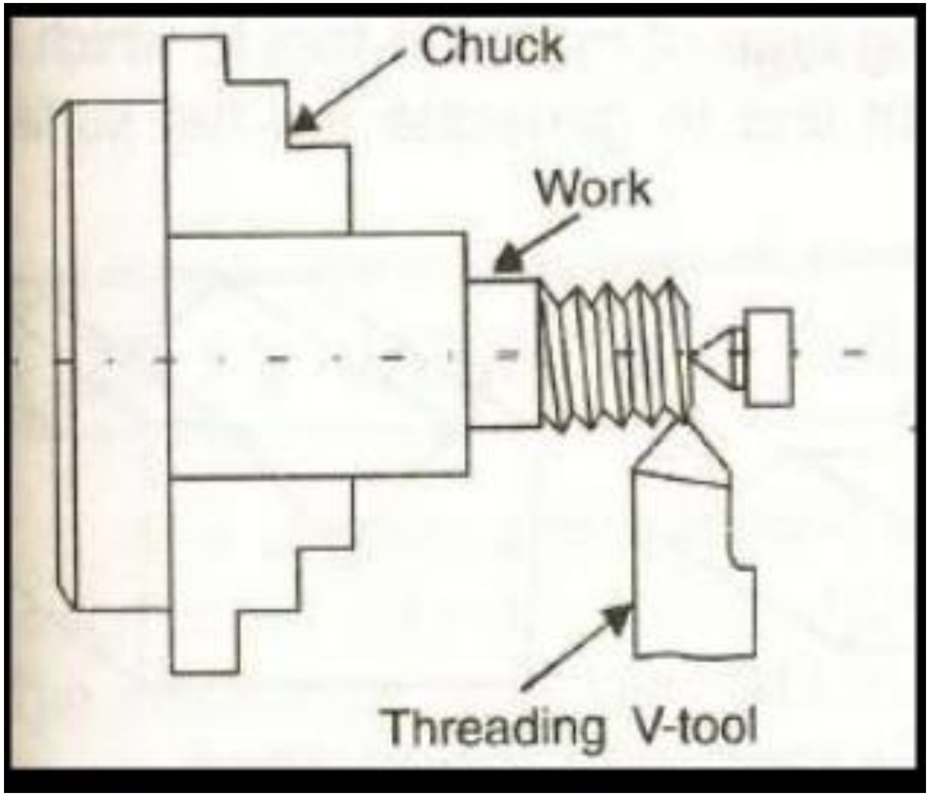
Lathe operations
10. Reaming



Reaming is a sizing operation that enlarges the hole in the workpiece. In reaming operations, reamer enters the workpiece axially through the end and expands an existing hole to the diameter of the tool. Reaming removes a minimal amount of material and is often performed after drilling to obtain both a more accurate diameter and a smoother internal finish.

Lathe operations

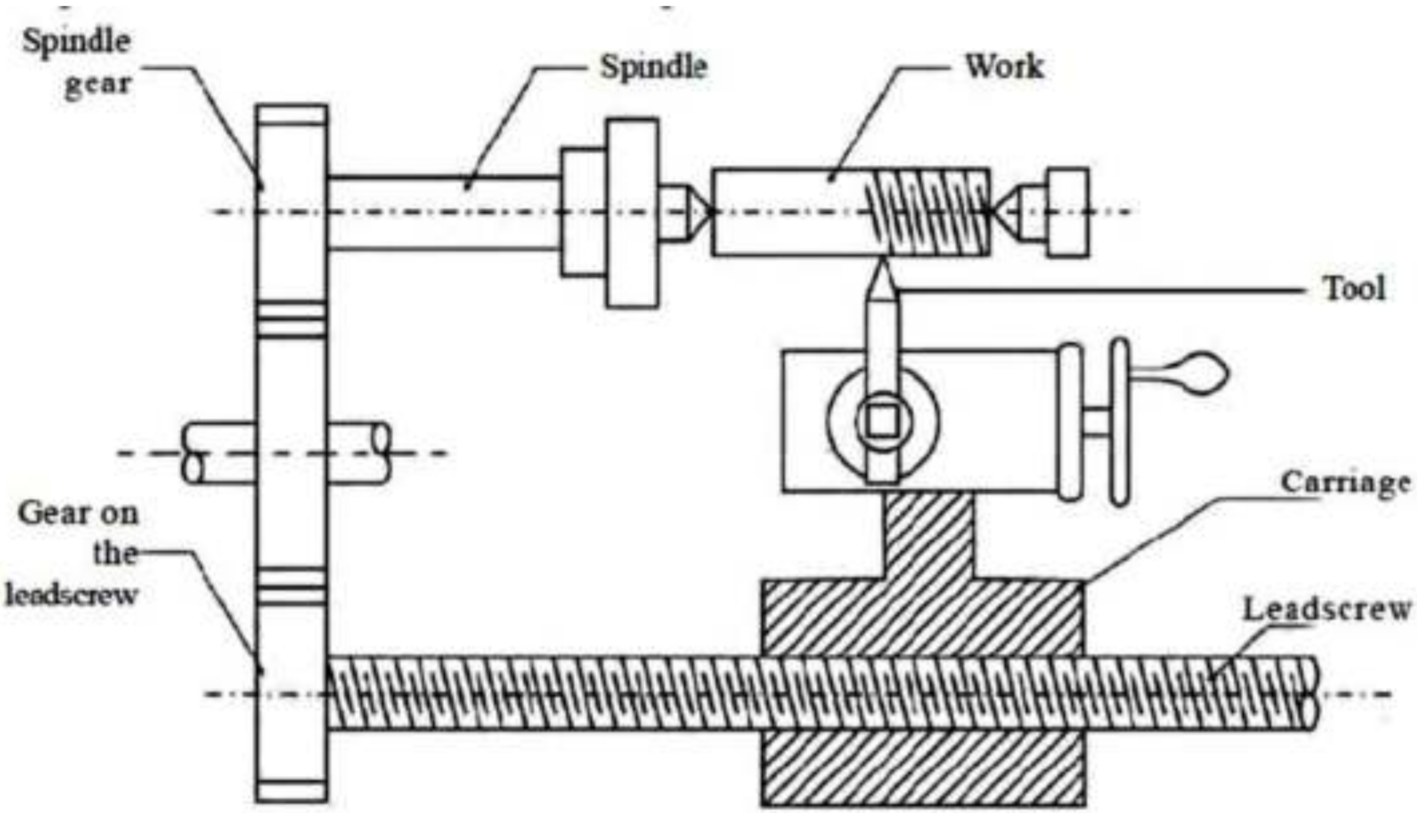
11. Threading



Threading is a turning operation in which a tool moves along the side of the workpiece, cutting threads in the outer surface. A thread is a uniform helical groove of specified length and pitch. Deeper threads need multiple passes of a tool.

THREAD CUTTING

Threading is the act of cutting of the required form of threads on the internal or external cylindrical surfaces.



Lathe operations

12. Form Turning

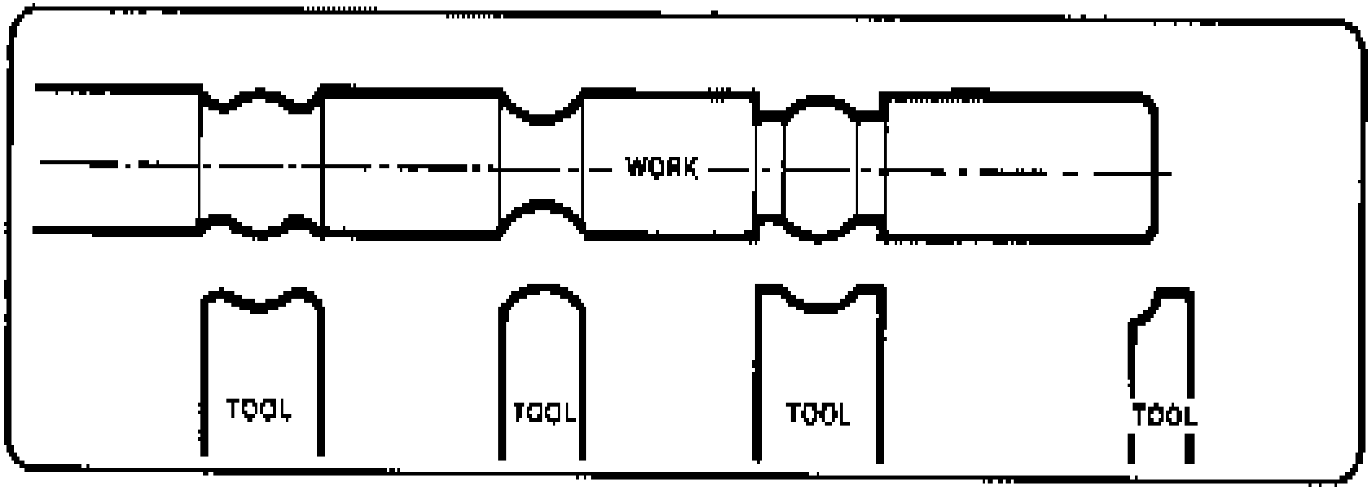


Figure 7-60. Forming tools.

Form turning is used to impart an irregular shape on a workpiece using a specially ground tool

Grooving

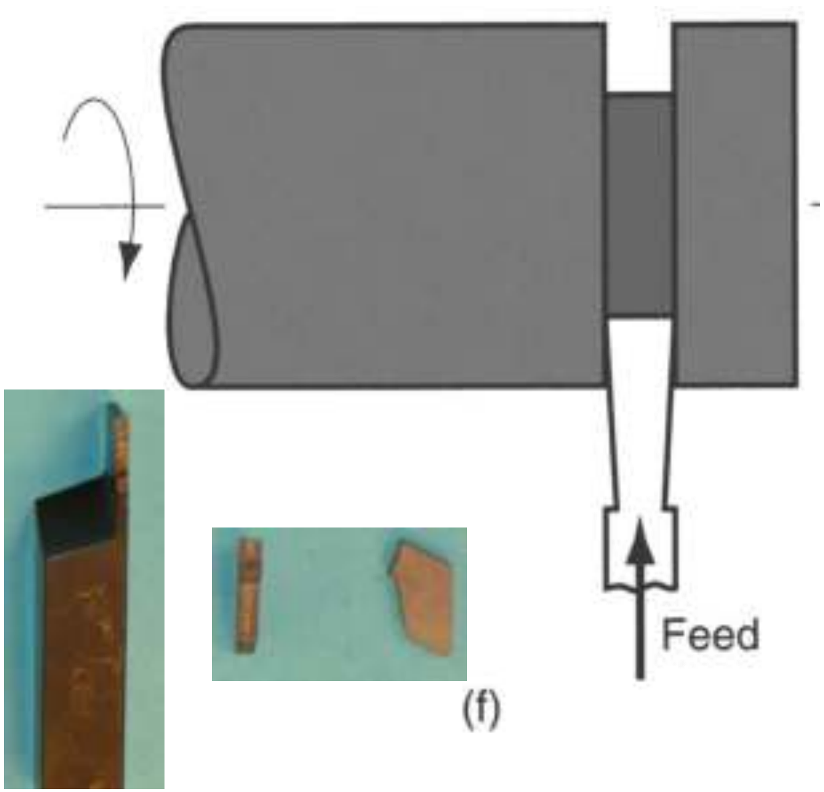


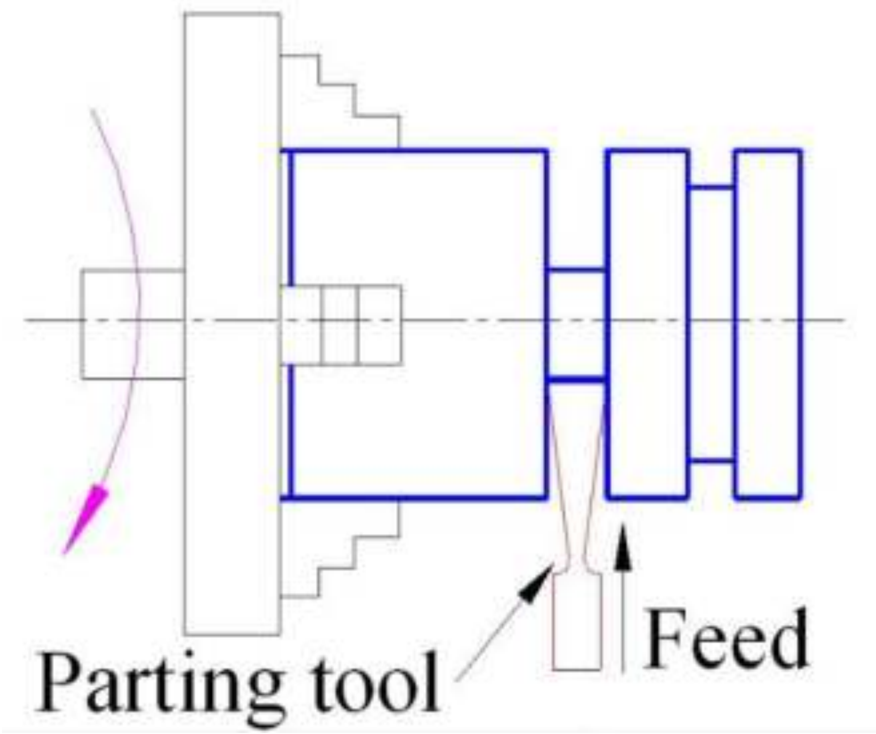
Figure 22.6 (f) cutoff

Tool is fed radially into rotating work at some location to cut off end of part, or provide a groove

Grooving is a turning operation that creates a narrow cut, a "groove" in the workpiece. The size of the cut depends on the width of a cutting tool

Lathe operations

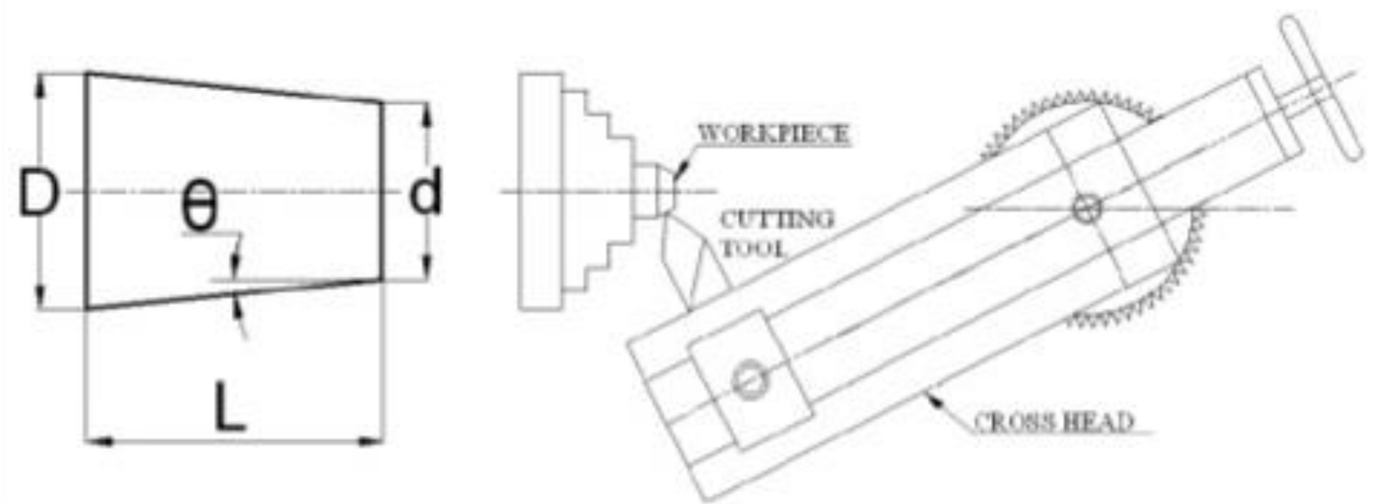
13. Parting off



This operation involves cutting the work-metal into two parts by using parting off tool. Feed to the cutting tool is given in same manner as in case of facing operation.

Lathe operations

14. Taper turning



$$\tan(\theta) = \frac{(D-d)}{2L}$$

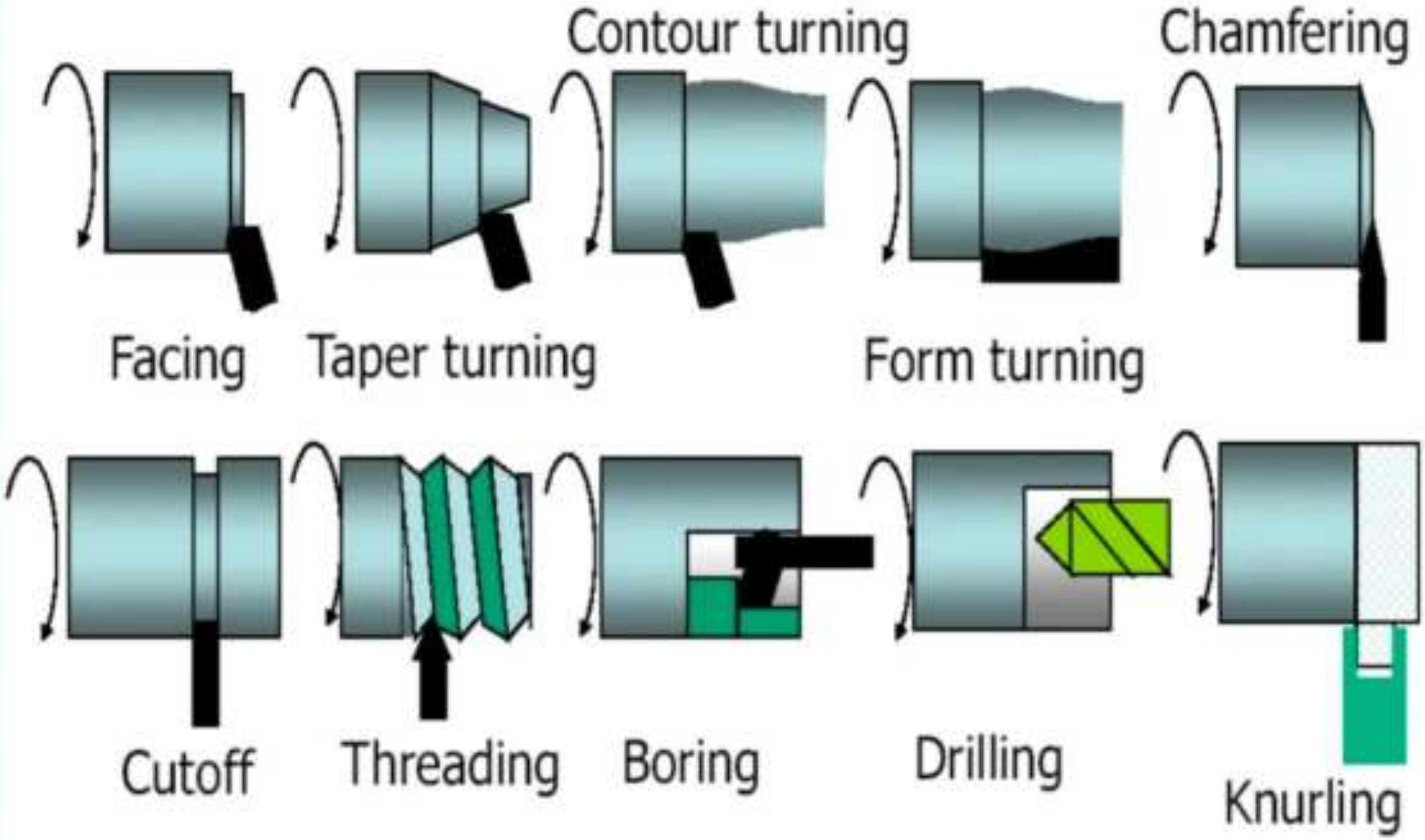
where, D = Larger diameter of workpiece.
d = Smaller diameter of workpiece.
L = axial length of the workpiece on which taper is to be performed.

Taper = tan (θ).

A ”taper” is the uniform increase or decrease in the diameter of the workpiece and measured along with its length.

Taper turning means to produce a conical shape by a gradual reduction in diameter from a cylindrical workpiece.

Operations


Contour turning
Chamfering
Facing
Taper turning
Form turning
Cutoff
Threading
Boring
Drilling
Knurling

Machine tools & Operations

MACHINE TOOL	OPERATION
Turning Tool	Continuous turning, step turning, taper turning, eccentric turning, grooving & chamfering.
Facing Tool	Facing operation.
Knurling Tool	Knurling operation.
Drilling Tool	Drilling, reaming.
Boring Tool	Boring operation.
Threading Tool	Internal and external threading.
Parting Tool	Parting operation.
Tool Post Grinding	Grinding operation.

Turning Tool

Turning tool is used for removing material from the outside diameter of a work piece to obtain finishing surface. The feed of the tool for turning operation is along the axis of the lathe.

Facing Tool

Facing tool is used for reduce the length of job. The tool move to perpendicular to the axis of the lathe

Knurling Tool

Knurling tool which used displacing metal into a particular pattern for the purpose creating a hand grip or roughened surface of the work piece by cross.

Drilling Tool

Drilling tool which used making a holes produce in solid metal. The tool used for drilling is called a **drill**.

Boring Tool

Boring tool is mainly used for enlarges a hole. Low speed but high torque are characteristic of large because the boring tool has a larger radius than a drill.

Threading Tool

Threading tool which is used for the make internal or external threads on the work piece. Thread shape depend on the threading tool.

Parting Tool

Parting tool use a blade like cutting tool plunged directly into the work piece to cut off the work piece at a specific length.

Grinding Tool

Grinding Tool post is attachment for Lathe machine which used to grinding or finish a surface of the work piece.

According to the method of using the tool

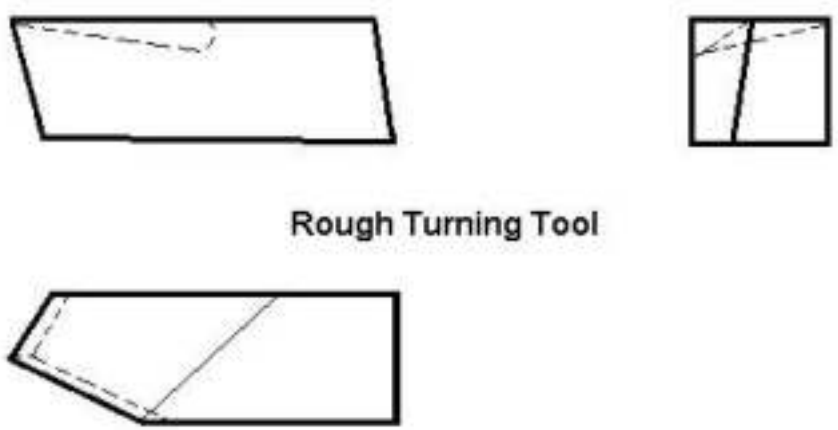
1. Turning Tool

There are mainly two classes of turning tool:

Rough turning tool.

Finish turning tool.

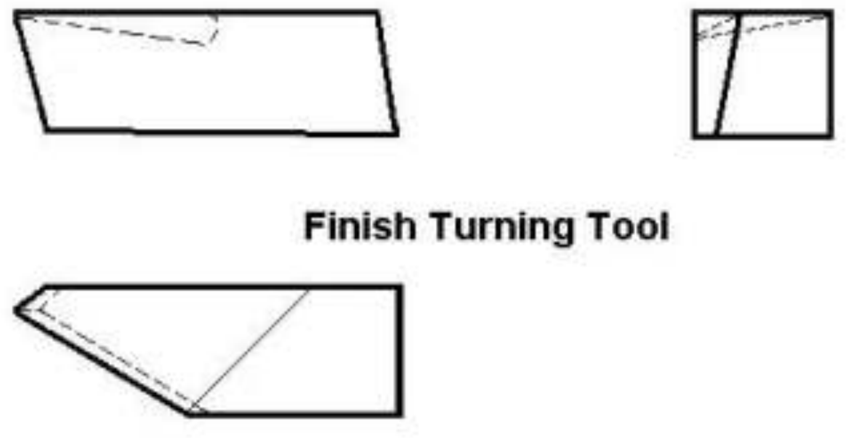
1.1 Rough Turning Tool



Rough Turning Tool

The main function of a rough turning tool is to remove the maximum amount of metal in minimum time that the tool, work, and the machine will permit. The cutting angle is so ground that it can withstand maximum cutting pressure.

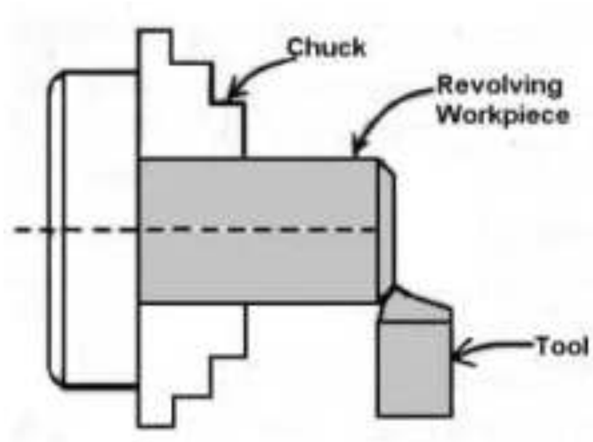
1.2 Finish Turning Tool



Turning tool is used to remove the very small amount of metal. A tool angle is so ground that it can produce a very smooth and accurate surface.

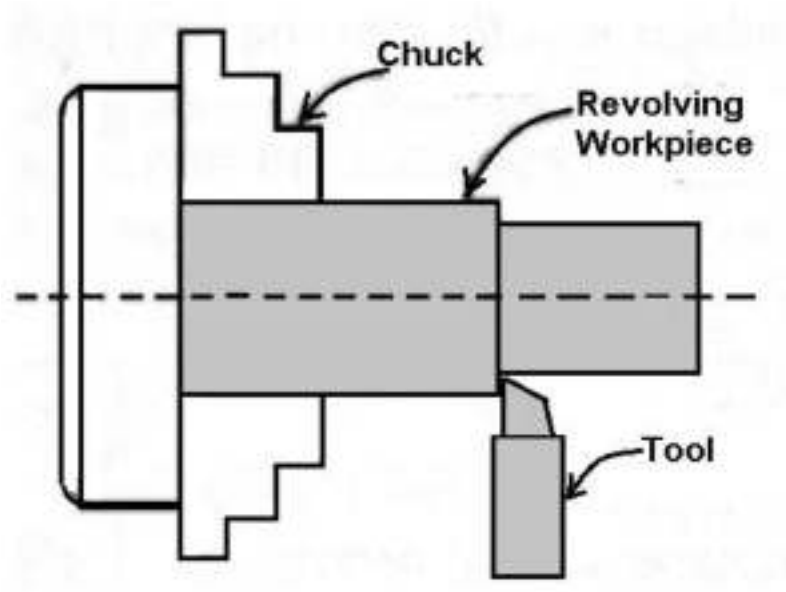
2. Chamfering Tool

Straight turning tools are also used as a chamfering tool when the cutting edges are set at an angle of the chamfer.



Chamfering

3. Shoulder Turning Tool



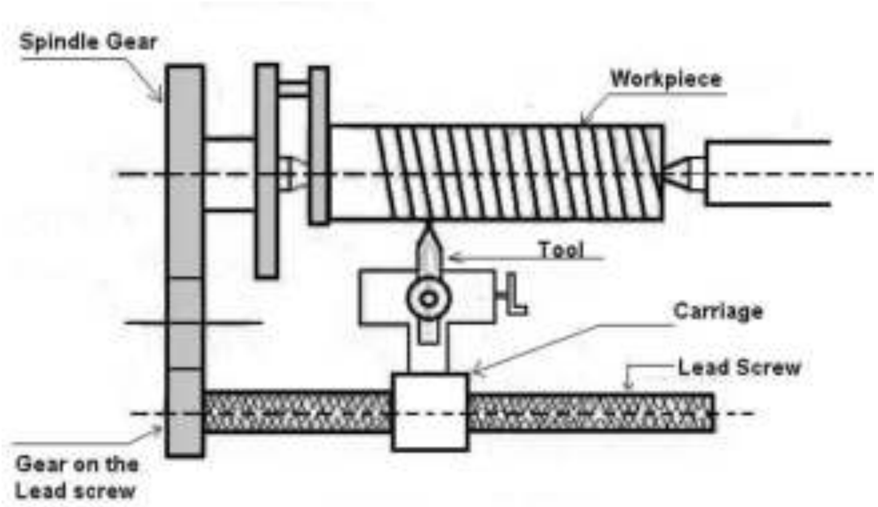
Shoulder Turning

A square shoulder is turned by a knife-edge turning tool or facing tool. A bevelled shoulder may be turned by a straight turning tool having a side cutting edge angle and zero nose radius. A filleted shoulder is turned by a straight turning tool with a nose radius corresponding to the fillet radius of the work.

4. Thread Cutting Tool

4.1 External Thread Cutting Tool

Metric, B.S.W or American “V” thread are formed by a single point thread cutting tool. Its cutting edges sharpened to the shape and size of the thread to be cut.



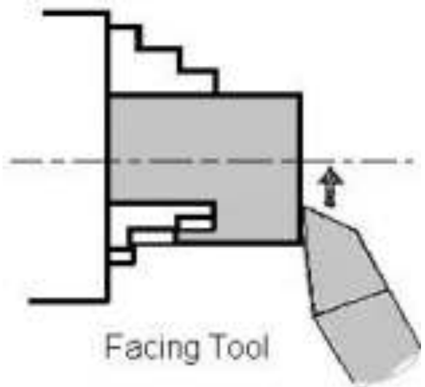
Thread Cutting

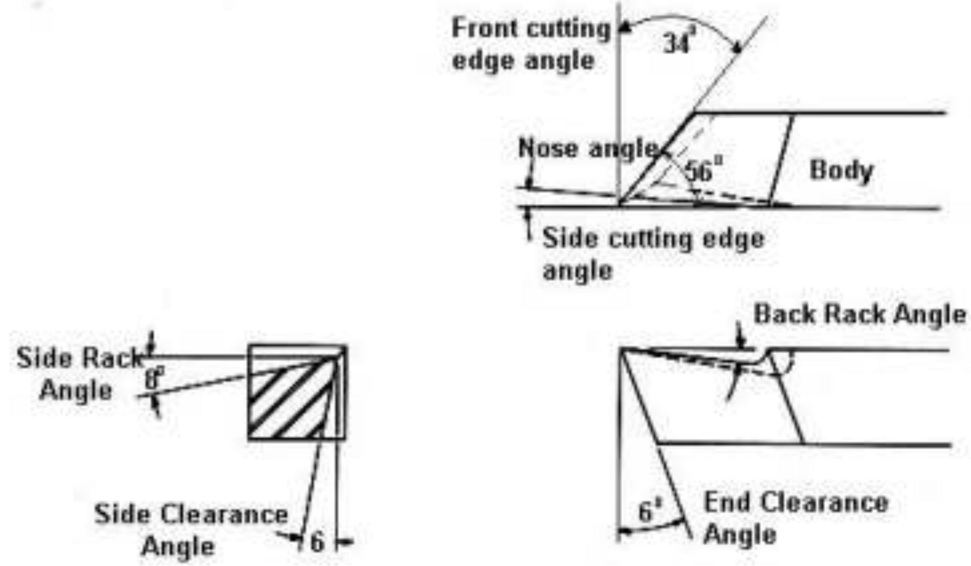
4.2 Internal Thread Cutting Tool

The cutting edge of the tool is exactly similar to an external thread cutting tool but the front clearance angle is sufficiently increased as in a boring tool.

5. Facing Tool

A facing tool removes metal by its side cutting edges. So no top rake in necessary in a facing tool.

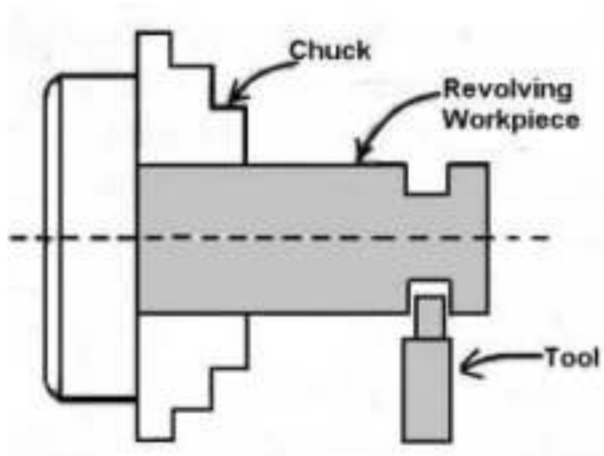




The tool has 2° side cutting edge angle and 34° end cutting edge angle can be accommodated in the space between the end of the work and 60° dead centre leaving a clearance of 2° on both sides.

6. Grooving Tool

Grooving tool is similar to a parting-off tool. The cutting edges are made square, rounded or “V” shape according to the shape of the groove to be cut.

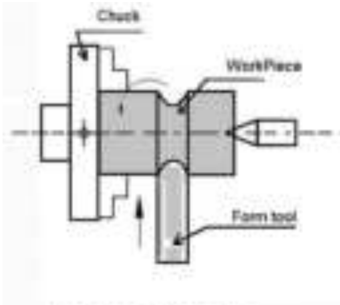


Grooving

7. Forming Tool

Circular Form Tools

These tools are preferred in production work as a very long cutting surface can be used resulting in longer tool life.



Forming Operation

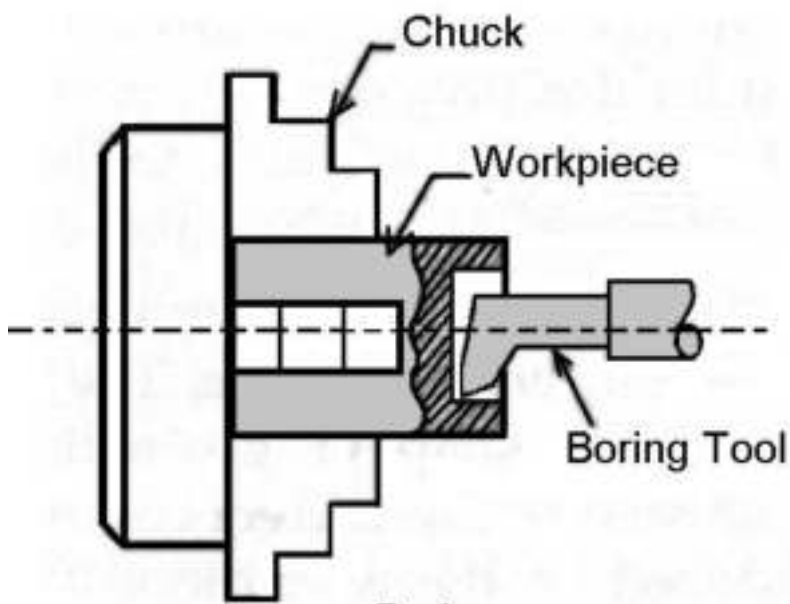
The centre of the tool is set slightly above the centre line of the work to provide an effective front clearance angle on the tool. The tool will rub against the work if the centres are of the same height.

The tool centre is usually higher than the centre line of the lathe by 1/20 to 1/10 of the tool diameter. This height is termed ‘offset’. Regrinding is done by grinding the flat only.

8. Boring Tool

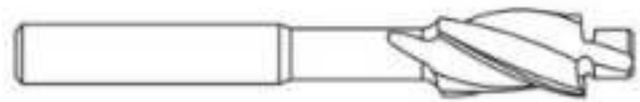
A boring tool is similar to a left-hand external turning tool so far its cutting edge is concerned.

The tool may be a bit type inserted in a boring bar or holder, or forged type having a tool shank.



Boring

9. Counterboring Tool
The counterboring operation can be performed by an ordinary boring tool. The tool cutting edge is so ground that it can leave a shoulder after turning. A counterbore having multiple cutting edges is commonly used.



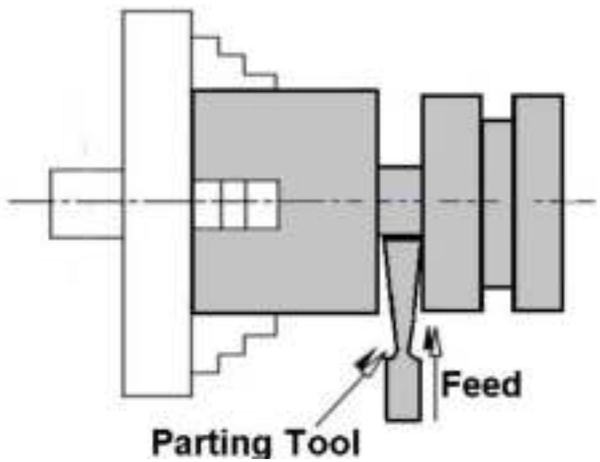
COUNTERBORING TOOL

10. Undercutting Tool
Undercutting or grooving tool has a point and form of the cutting edge exactly similar to the form of the required groove.

Clearance angle is given at all the sides of the tool. For the recessing groove cutting edge, the longitudinal feed is employed. The front clearance angle depends upon the bore of the work.

11. Parting Off Tool

A parting off tool is normally forged and used as bits for cemented carbide tipped tools. Parting off tool is made as narrow as possible to remove the minimum of metal.



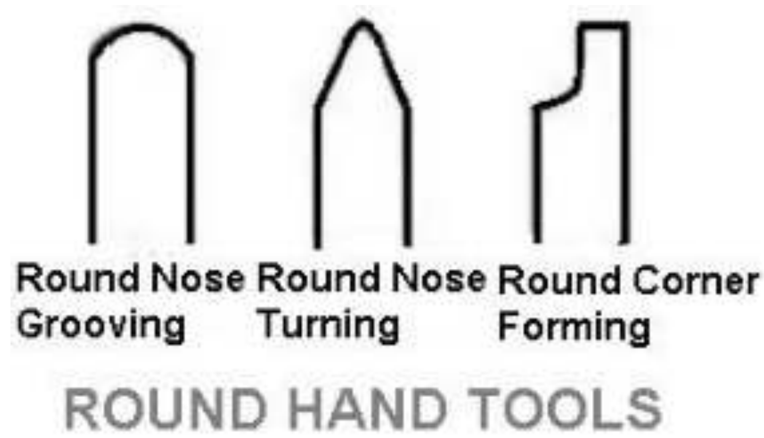
The width of the cutting edge range from 3 to 12 mm only. The length of the cutting tool which inserts into the work should be slightly longer than the radius of the bar stock being machined.

As the tool penetrates deep into the work, clearance is provided all around the tool cutting edge to prevent it from rubbing against the work surface.

As the tool is purely ended cutting it has no side rake slight back rake is provided on the tool to promote an easy flow of the ships

According to The Method of Applying Feed

Right-hand tool
Left-hand tool
Round Nose

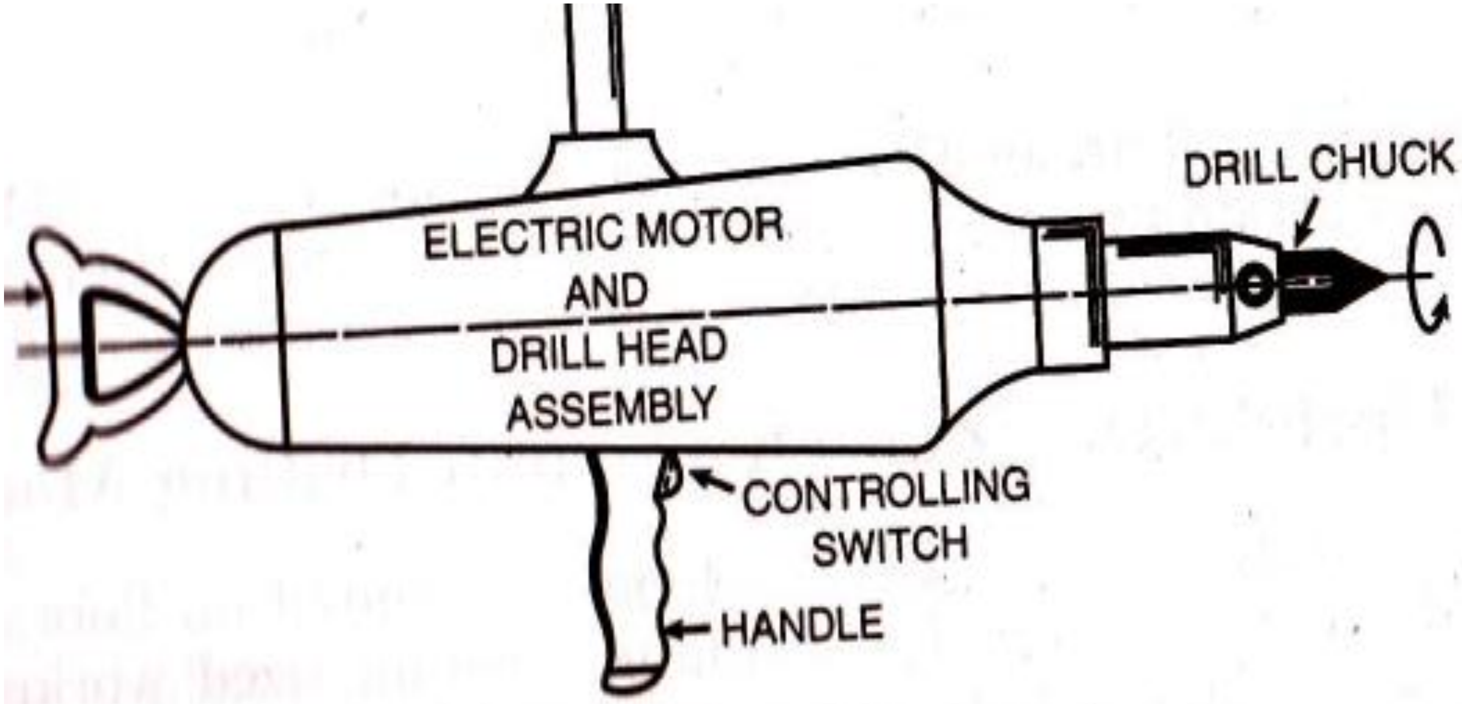


Drilling Machine

- **Types**

1. **Portable drilling machine**
2. **Sensitive drilling machine**
   a. Bench mounted
   b. Floor mounted
3. **Upright drilling machine**
   a. Round column section
   b. Box column section
4. **Radial drilling machine**
   a. Plain
   b. Semi universal
   c. universal
5. **Gang drilling machine**
6. **Automatic drilling machine**

Portable drilling machine



Sensitive drilling machine

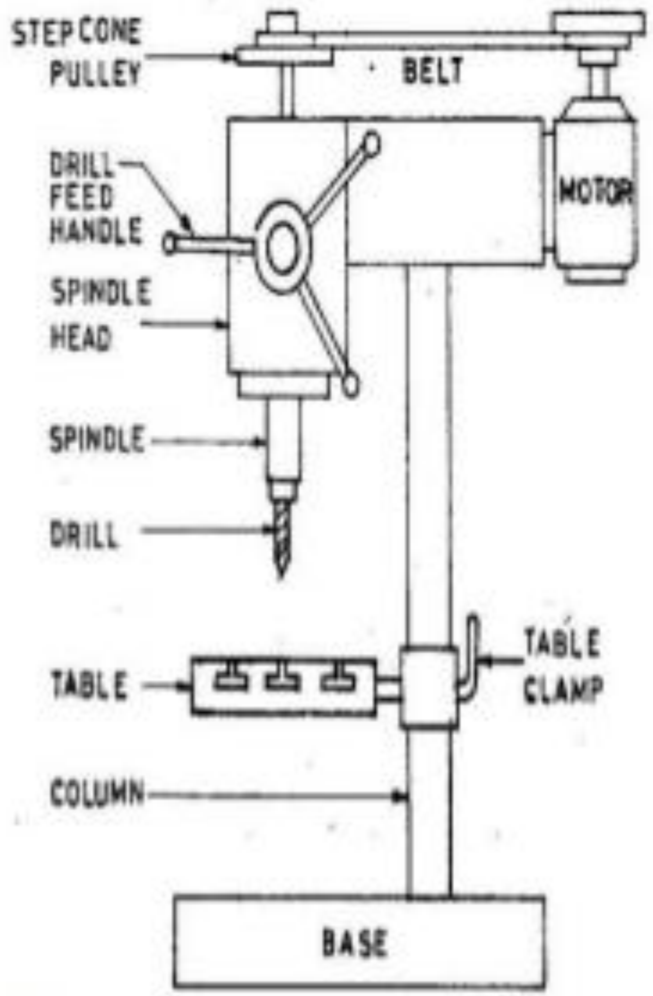
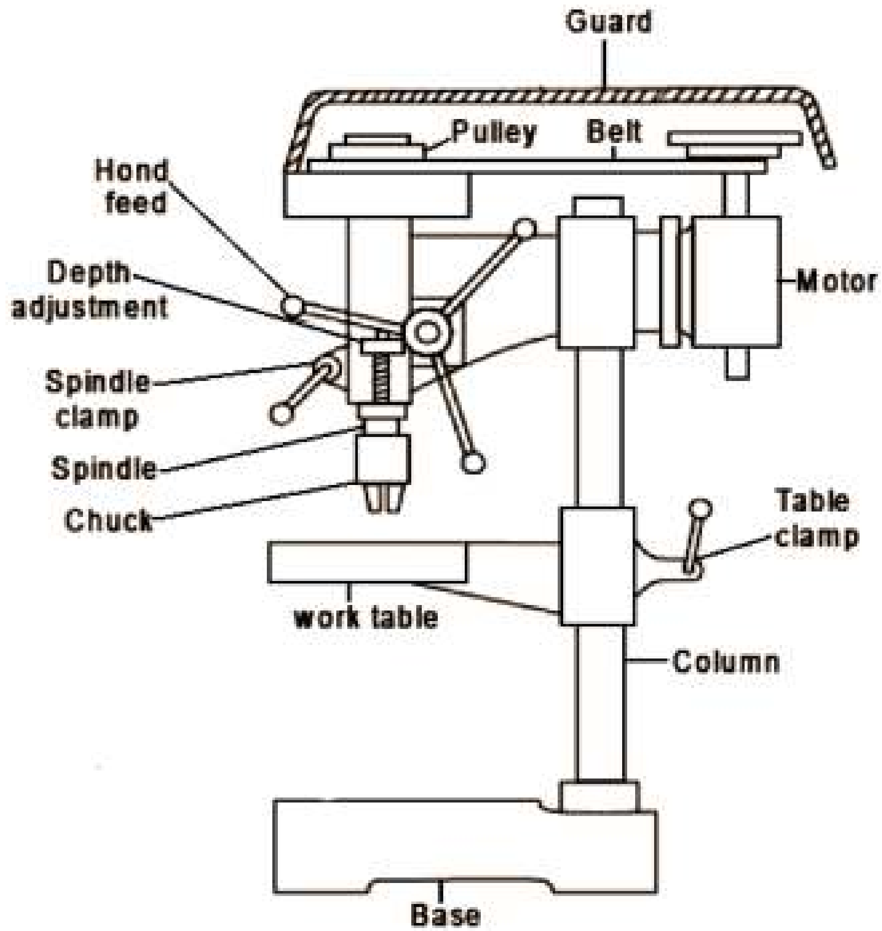
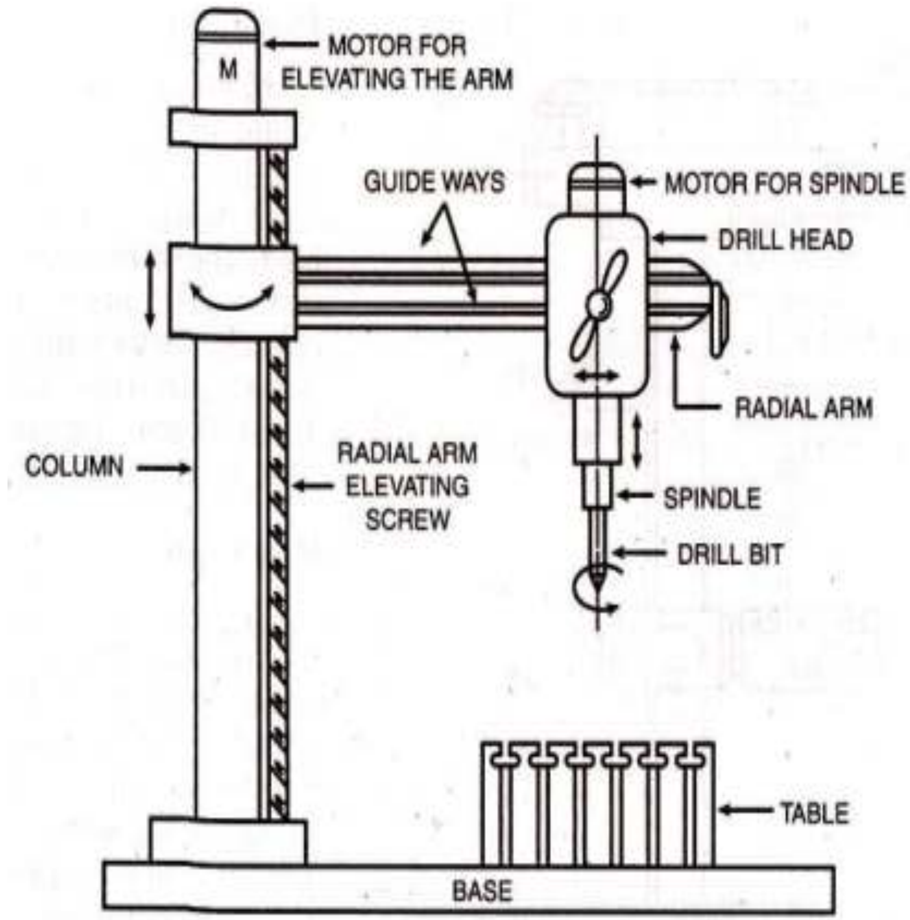


Fig.

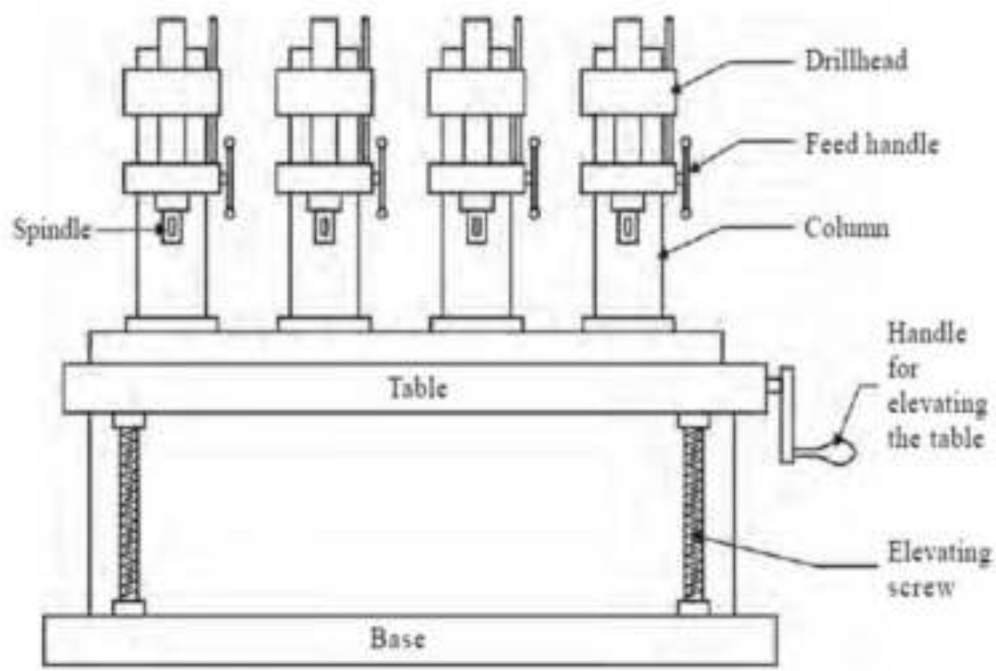
Upright Drilling machine



Radial drilling machine

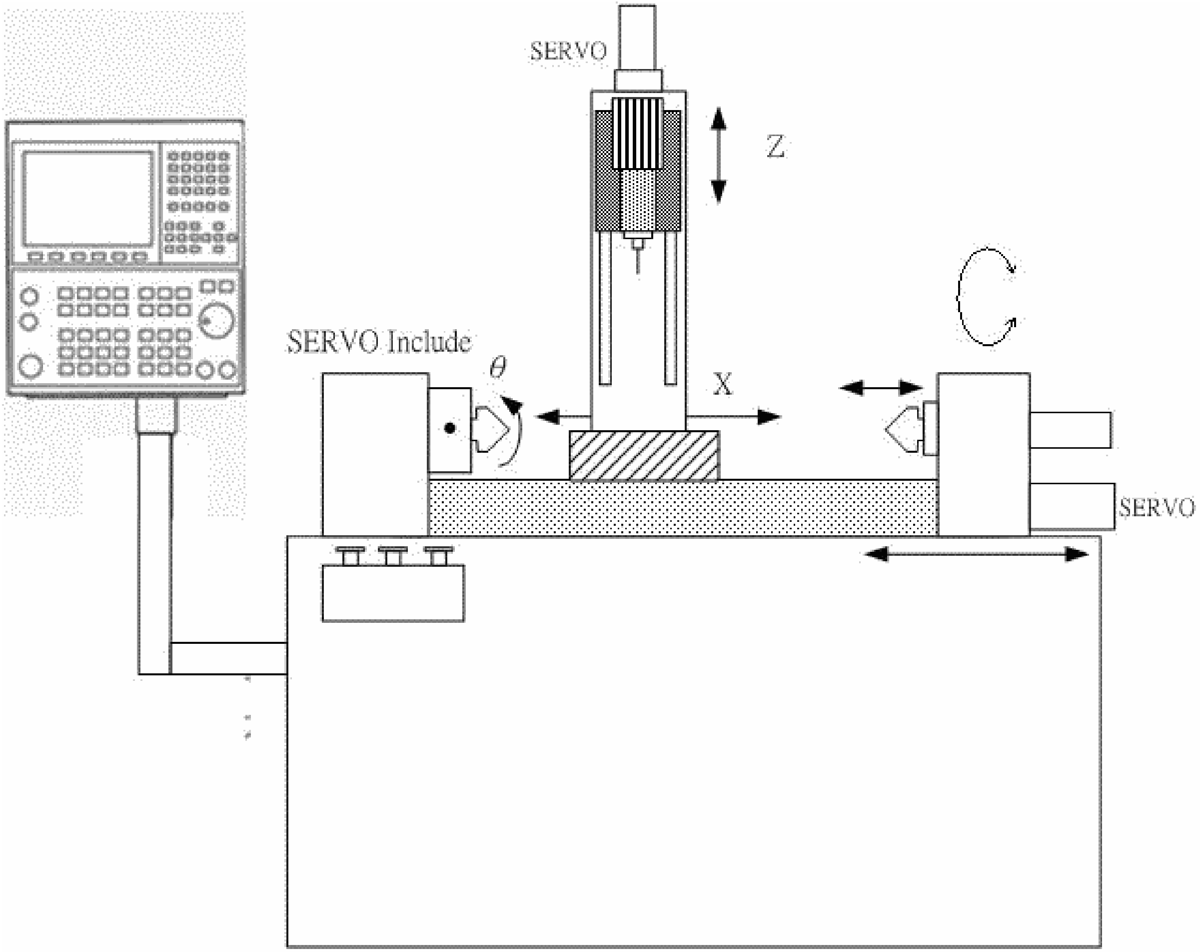


Gang drilling machine



Automatic drilling machine

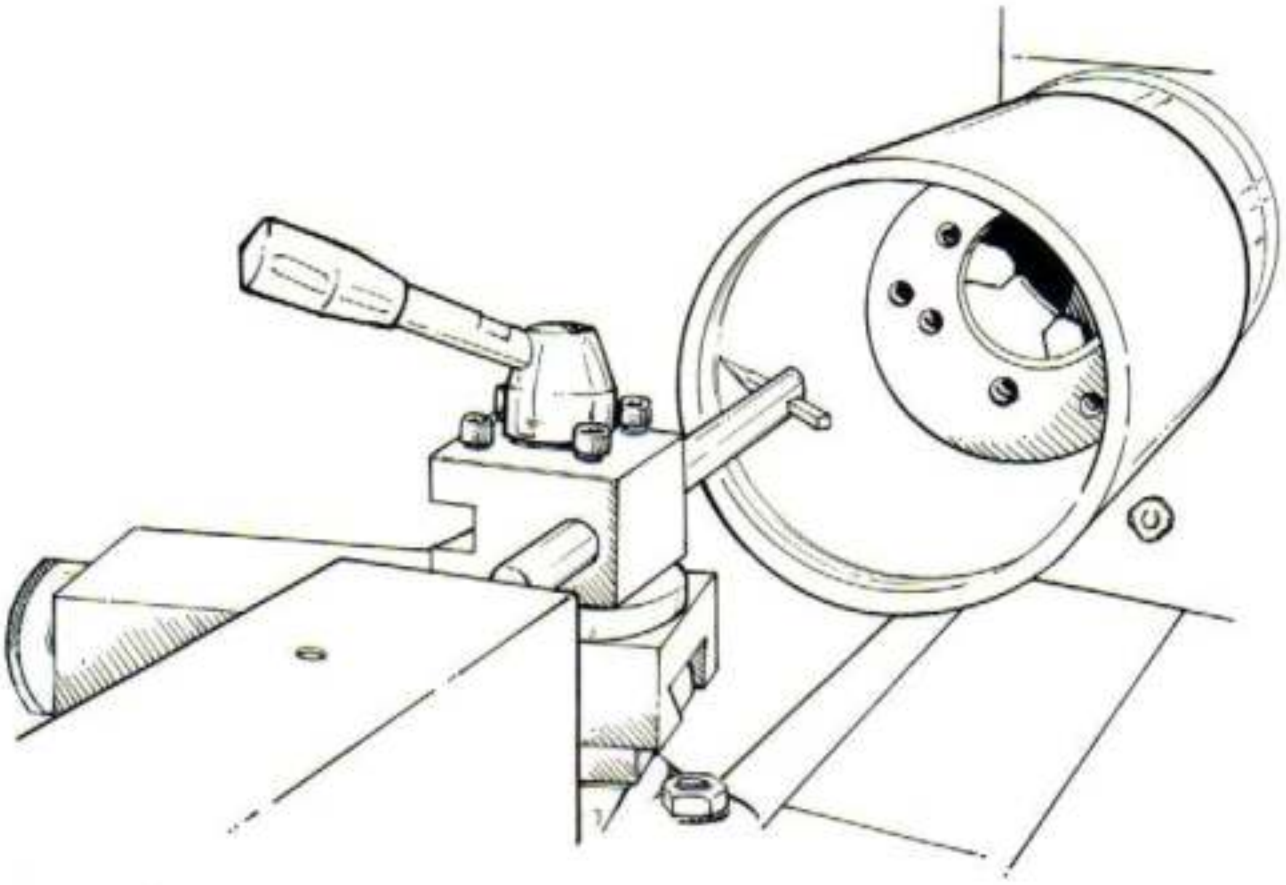
Automatic drilling machine



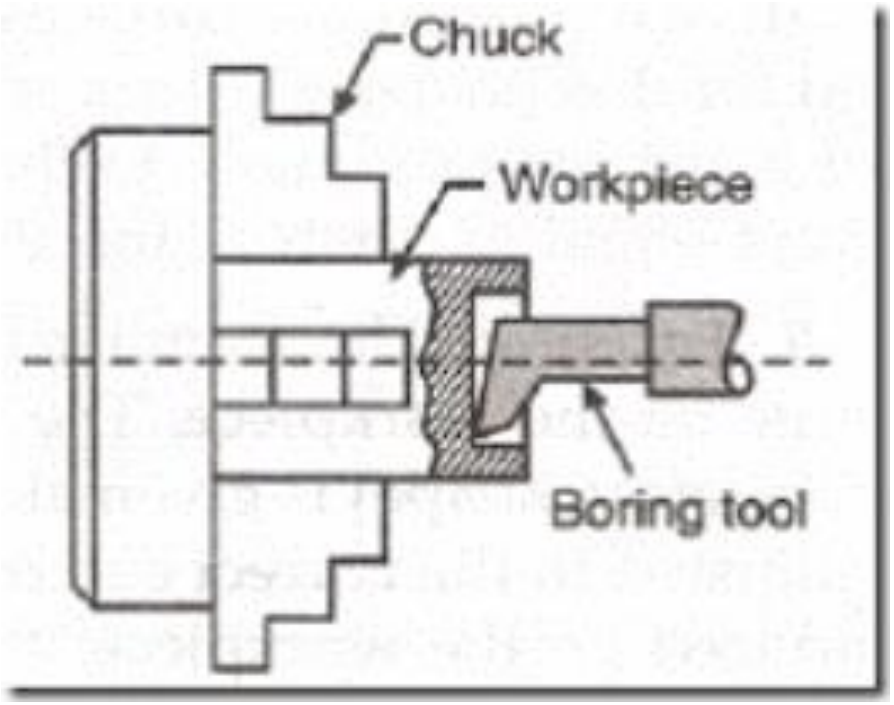
BORING MACHINE

- Boring machine is a heavy machine tool used to bore holes on heavy and large parts.
- E.g.: Steam engine cylinders, Machine housings etc…

Horizontal Boring



Horizontal Boring



TYPES OF BORING MACHINES

1. Horizontal Boring Machine (HBM)
   - Table type HBM
   - Planer type HBM
   - Floor Type HBM
2. Multi Spindle boring machine
3. Vertical Boring Machine (VBM)
   - Standard VBM
   - Vertical turret type VBM
4. Precision boring machine
5. Jig boring machine

Horizontal Boring Machine (HBM)

Horizontal Boring Machine (HBM)

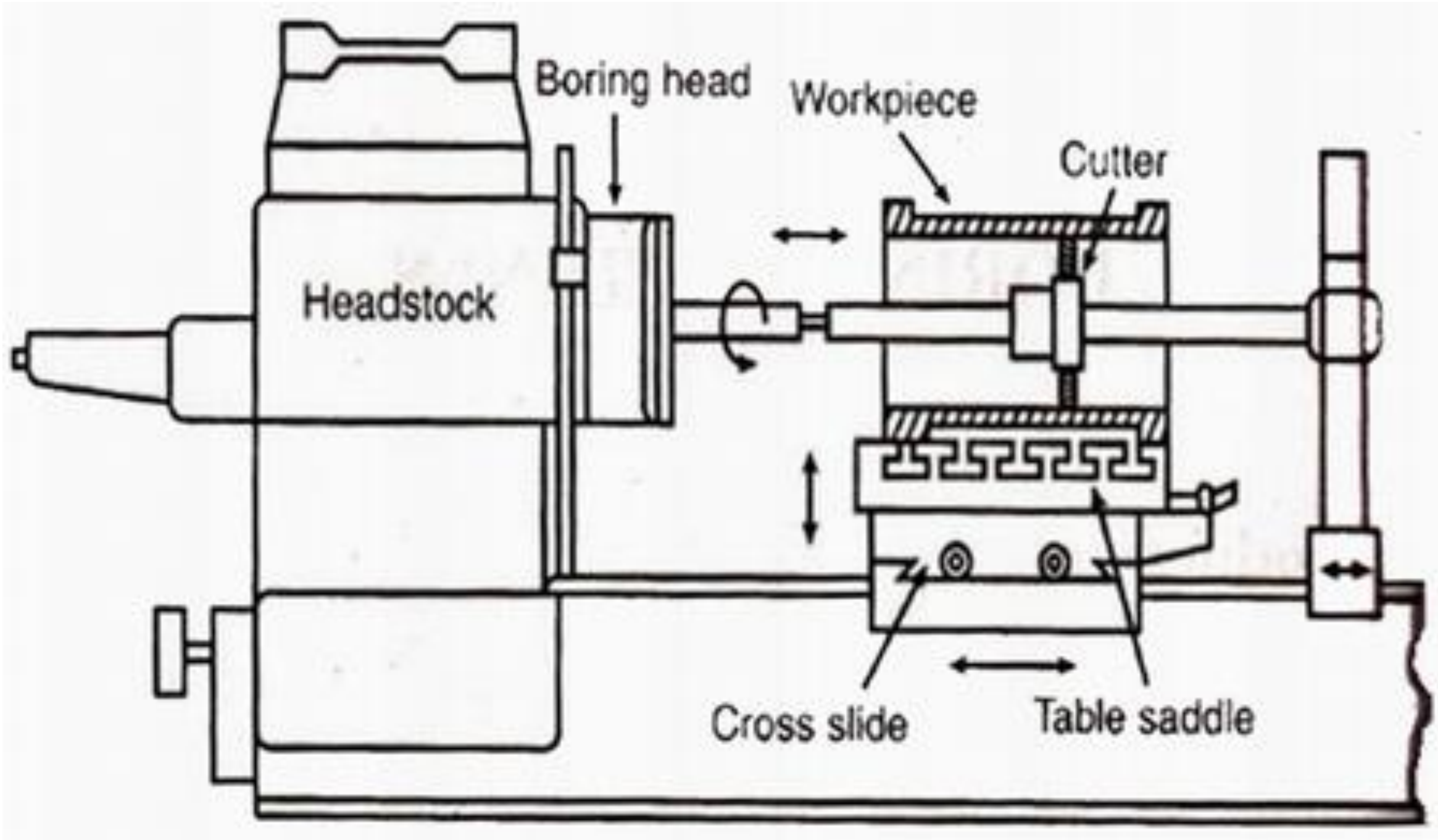
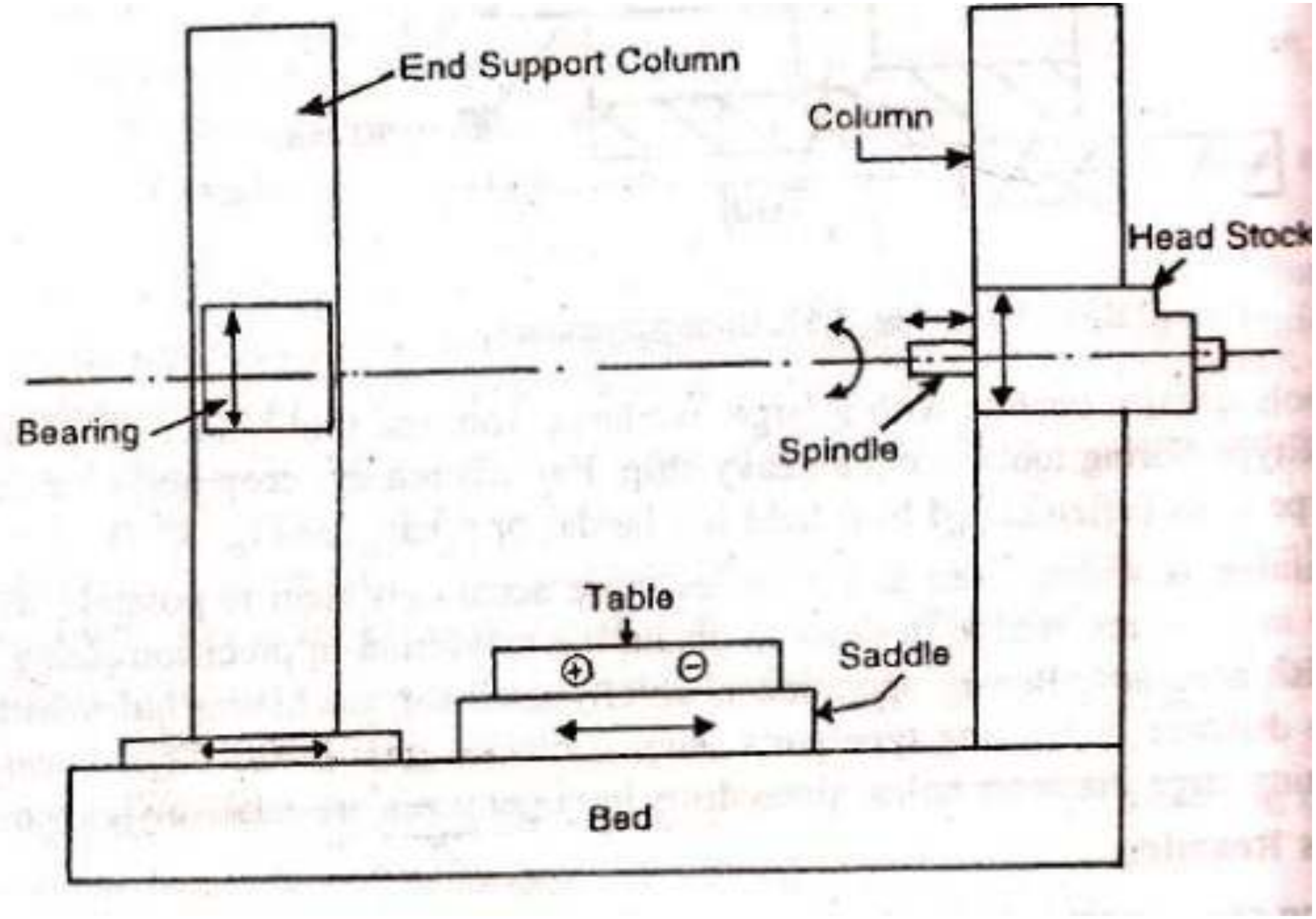
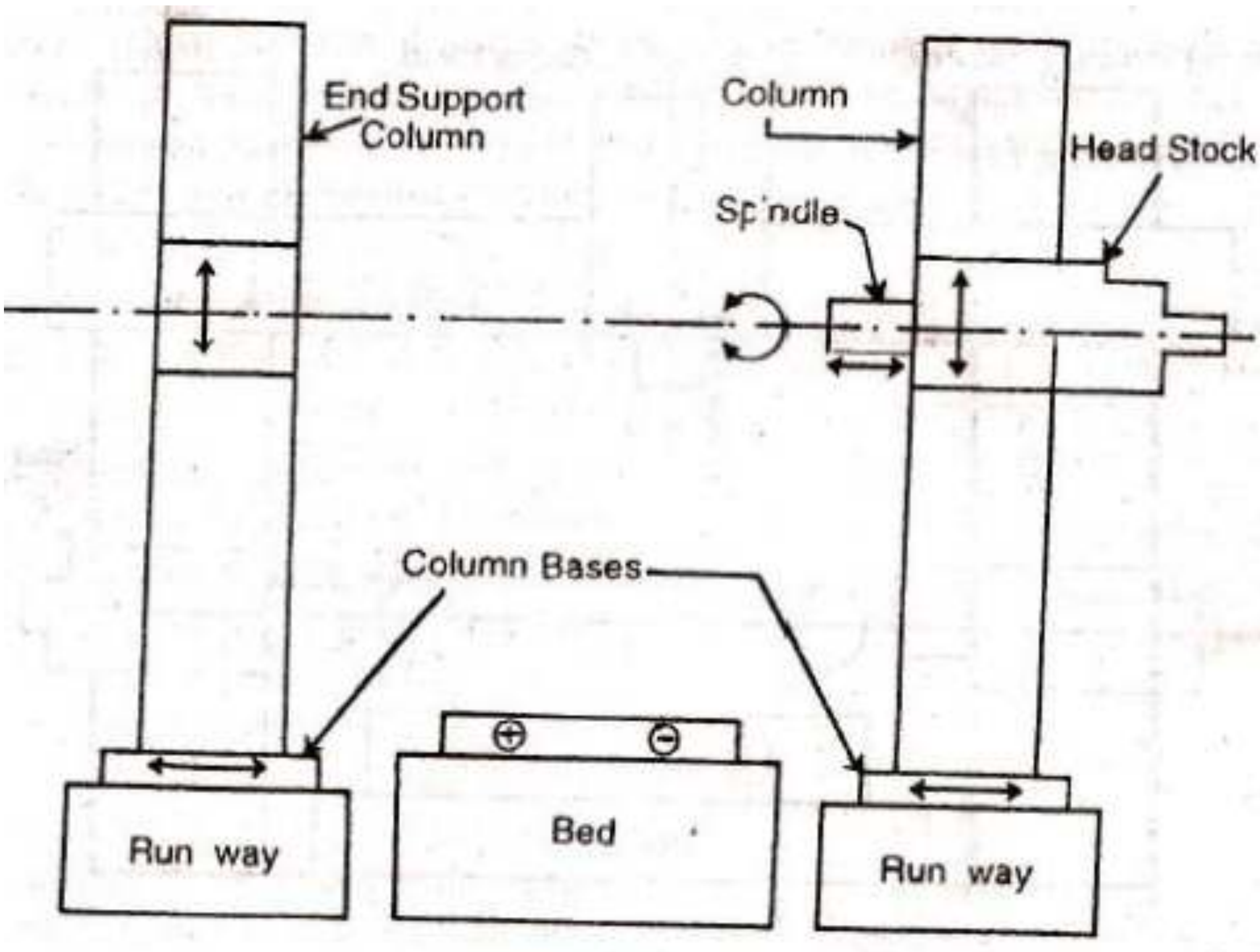


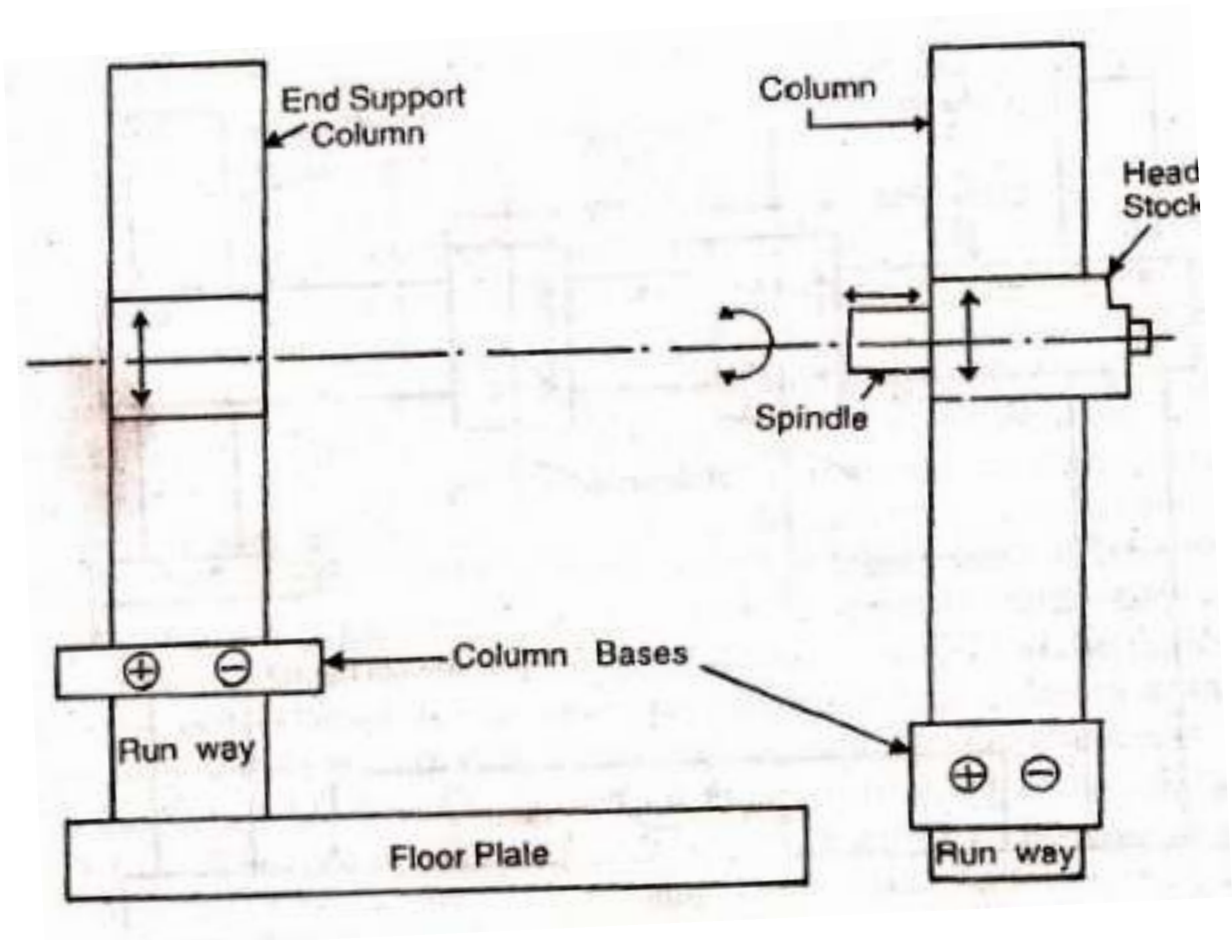
Table Type HBM



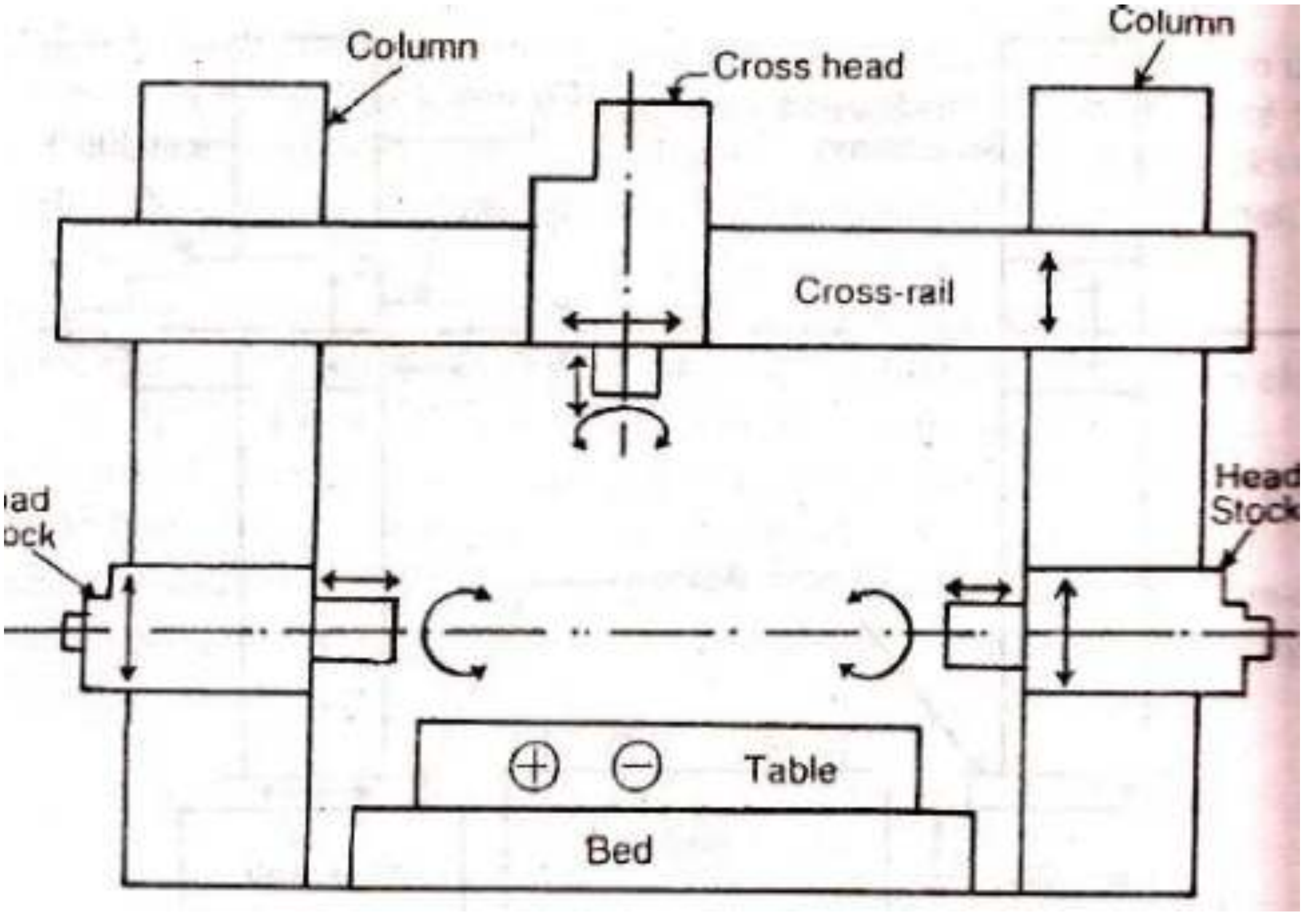
Planer type HBM



Floor Type HBM



Multi Spindle boring machine



Vertical Boring Machine (VBM) Standard type

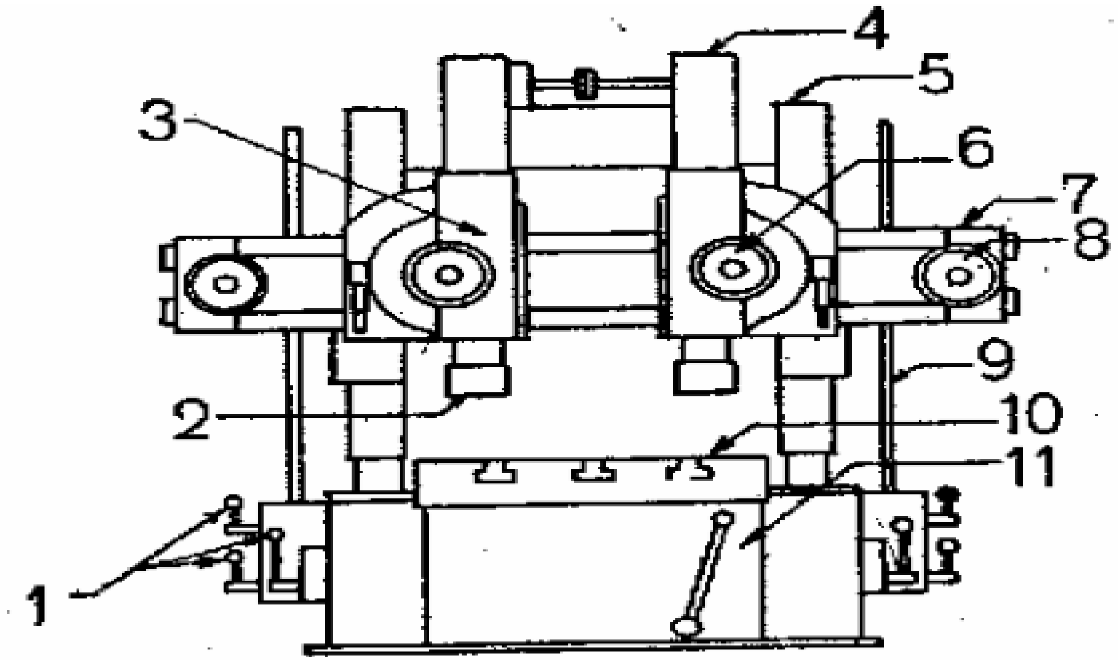
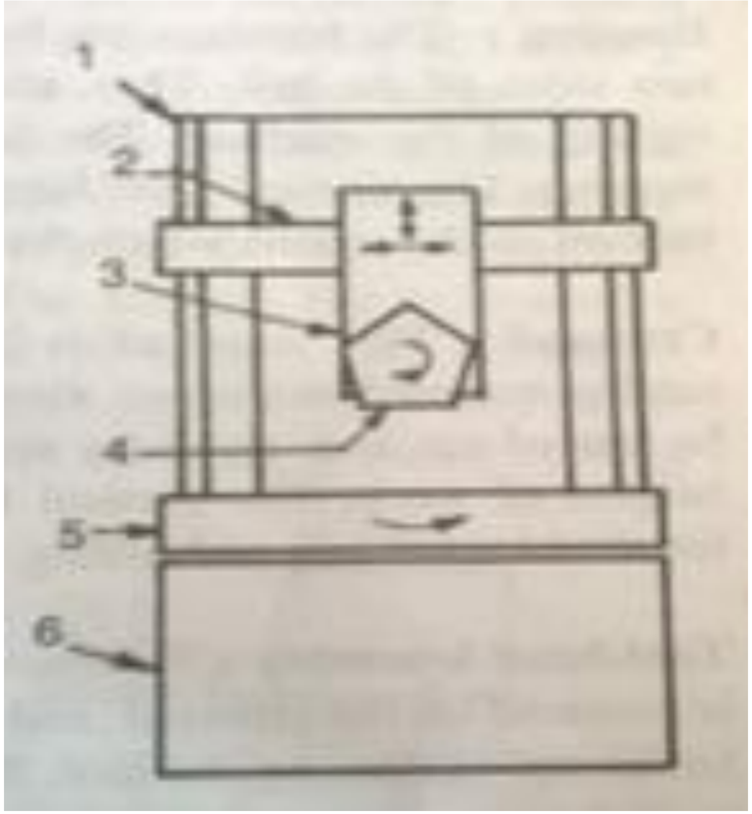


Fig. 6.16. Vertical boring machine

1. *Feed adjusting levers,* 2. *Tool box,* 3. *Tool head assembly,* 4. *Ram,* 5. *Housing,* 6. *Handwheel for ram adjustment,* 7. *cross rail,* 8. *Fine hand adjustment for ram,* 9. *Crossrail elevating screw,* 10. *Table,* 11. *Bed.*

Vertical Boring Machine (Turret type)

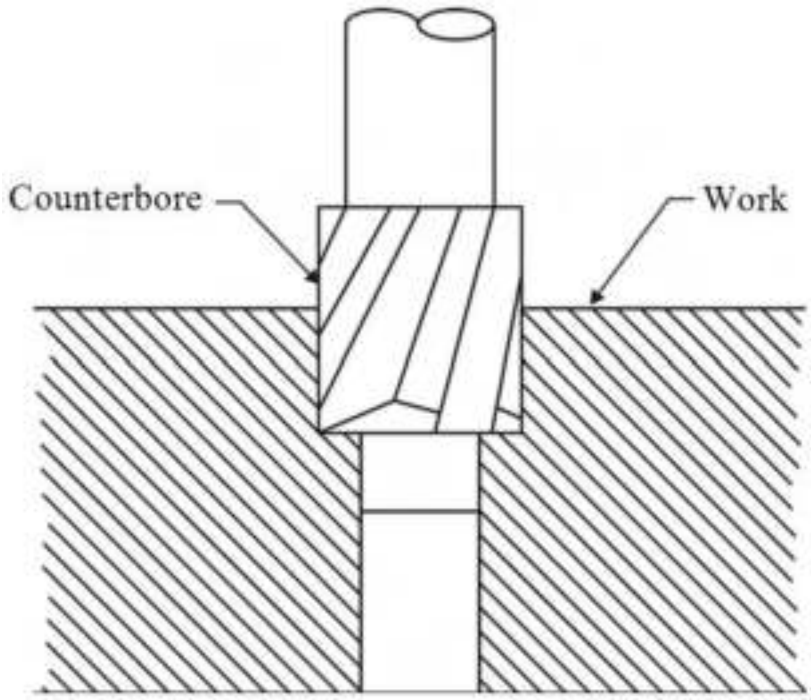


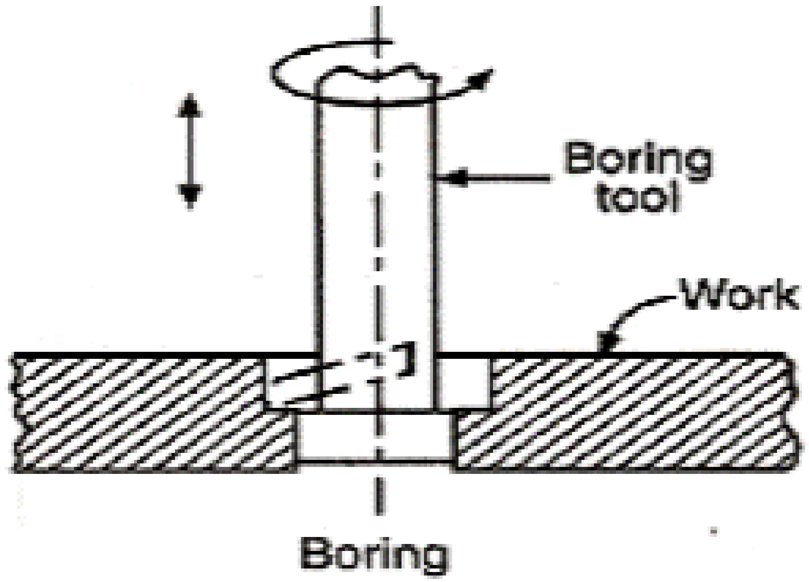
- **Precision Boring Machine**
- A precision boring machine uses single point cutting tool to machine surfaces rapidly and accurately.
- Carbide & diamond tipped tools are used at vey high cutting speed to bore accurate holes with excellent surface finish.
- **Jig boring machine**
- Jig boring machine is used for production of jigs, fixtures, tools and other precision parts which require high degrees of accuracy.
- The machining accuracy is in the range of 0.0025 mm.

Boring machine operations

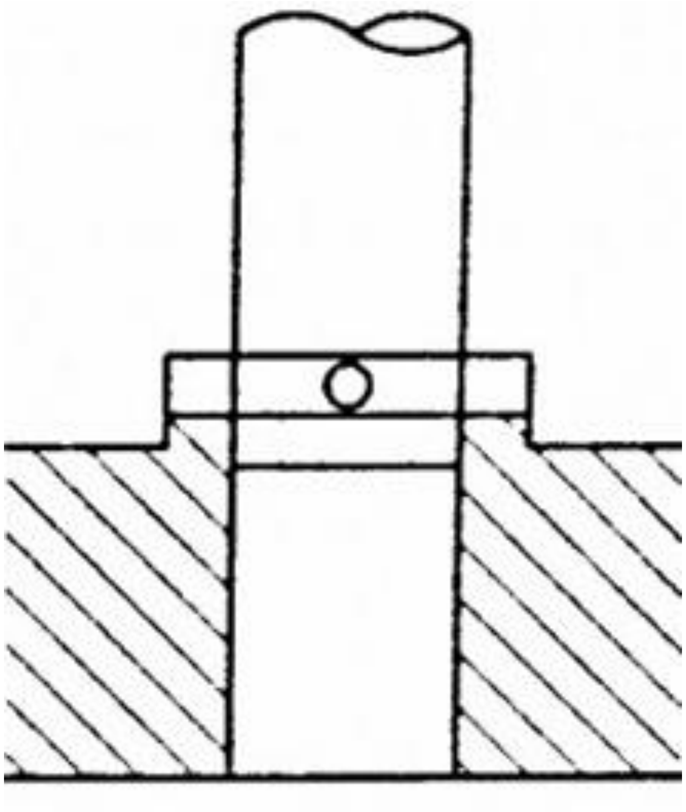
1. Counter boring
2. Spot facing
3. Counter sinking
4. Trepanning
5. Reaming
6. Tapping

Counter boring

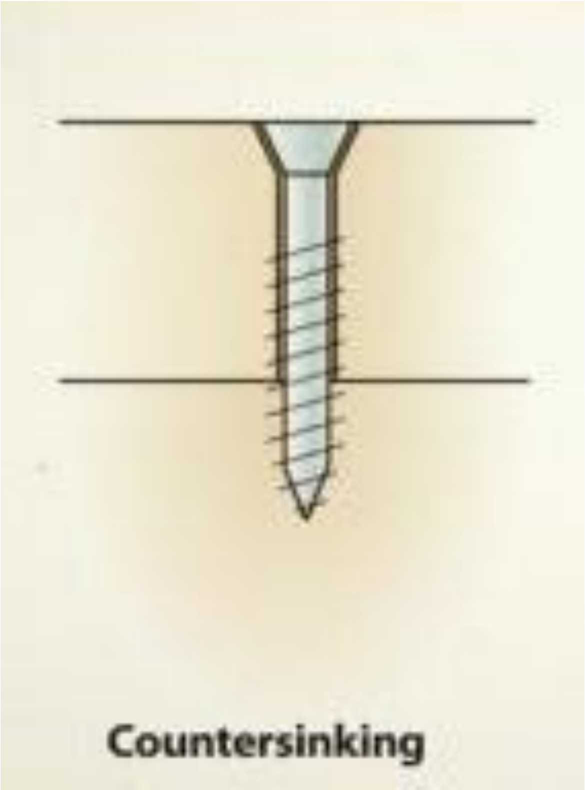




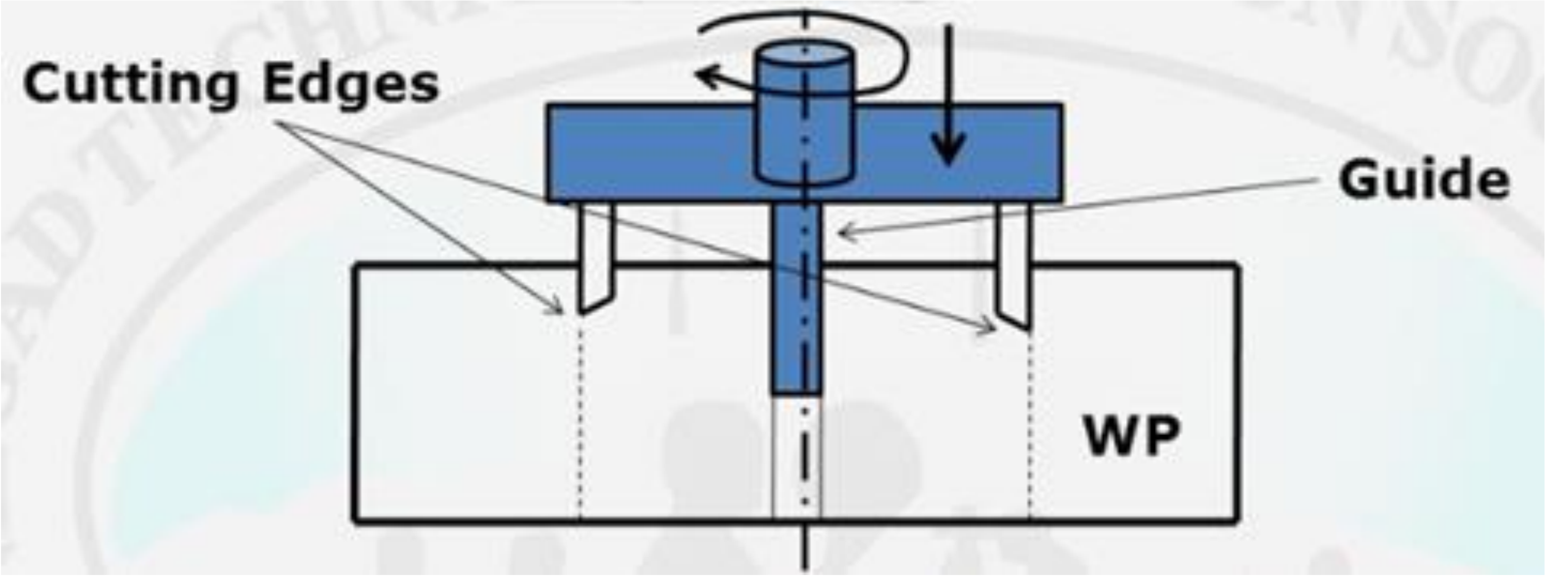
Spot facing



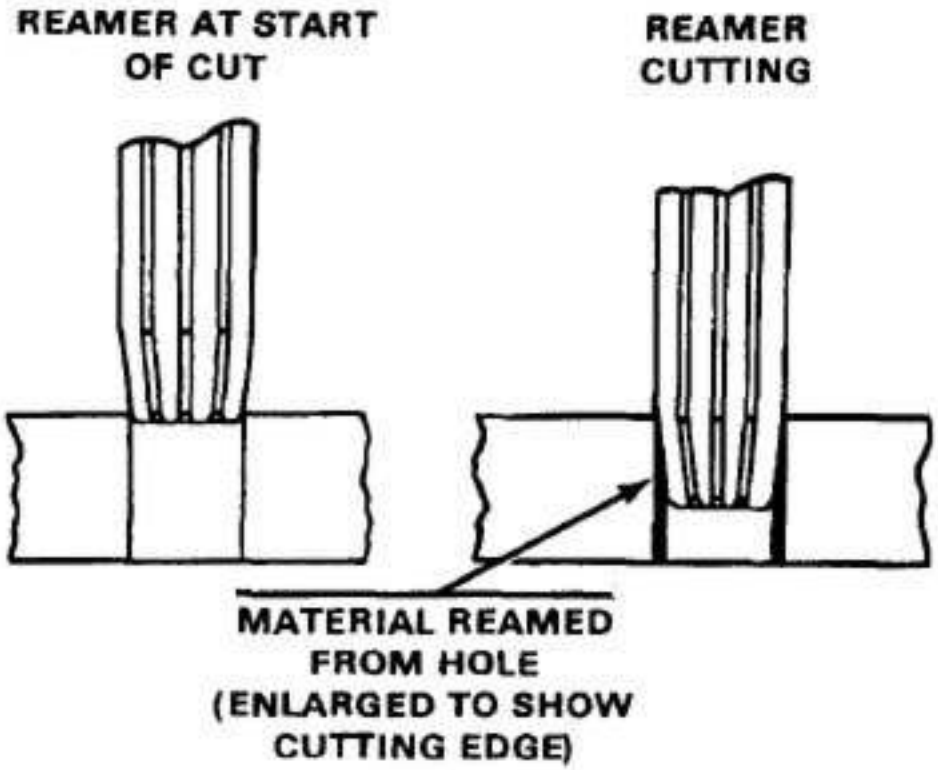
Counter Sinking



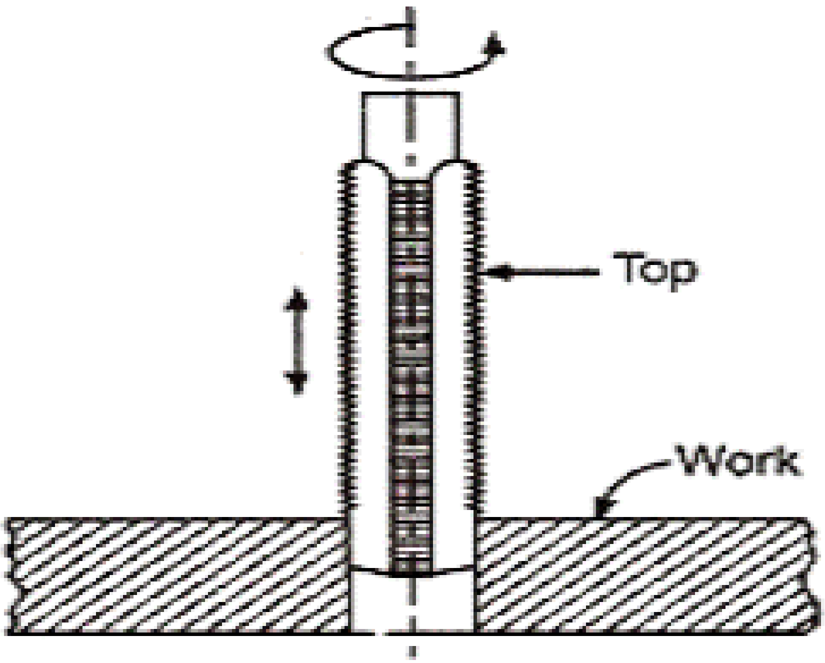
Trepanning



Reaming


REAMER AT START
OF CUT
REAMER
CUTTING
MATERIAL REAMED
FROM HOLE
(ENLARGED TO SHOW
CUTTING EDGE)

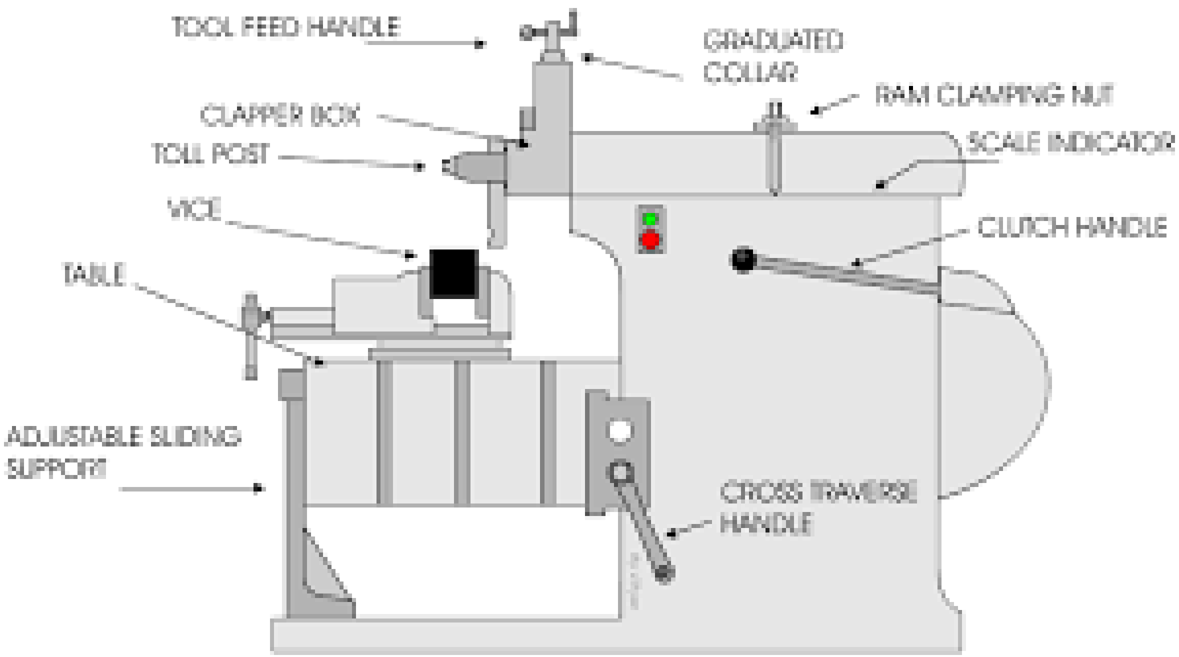
Tapping



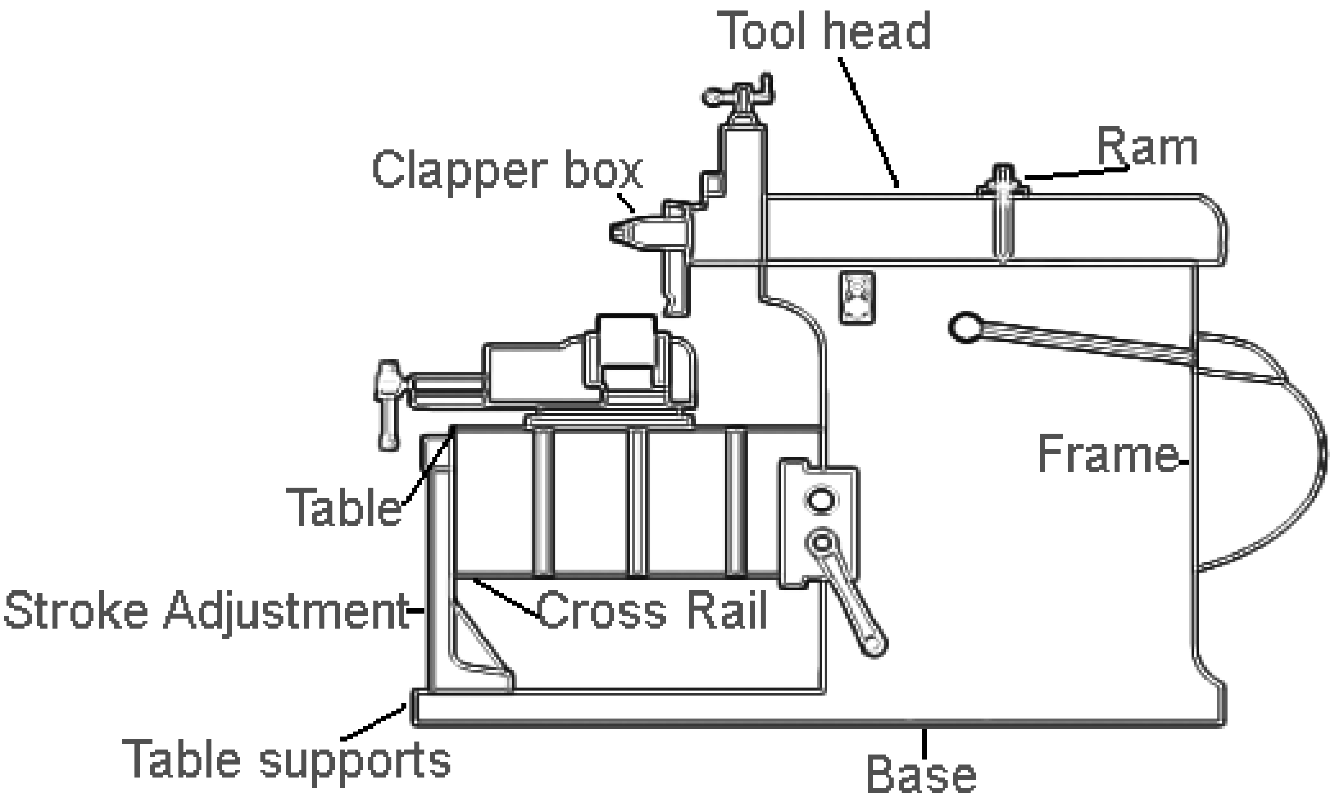
Tapping

Shaping Machine

Shaping Machine



Shaping Machine



Shaping Machine - Classifications

A) According to the type of mechanism used for providing reciprocating motion to the ram:

1. Crank type 2. Geared type 3. Hydraulic type

B) According to position & travel of ram:

1. Horizontal type 2. Vertical type

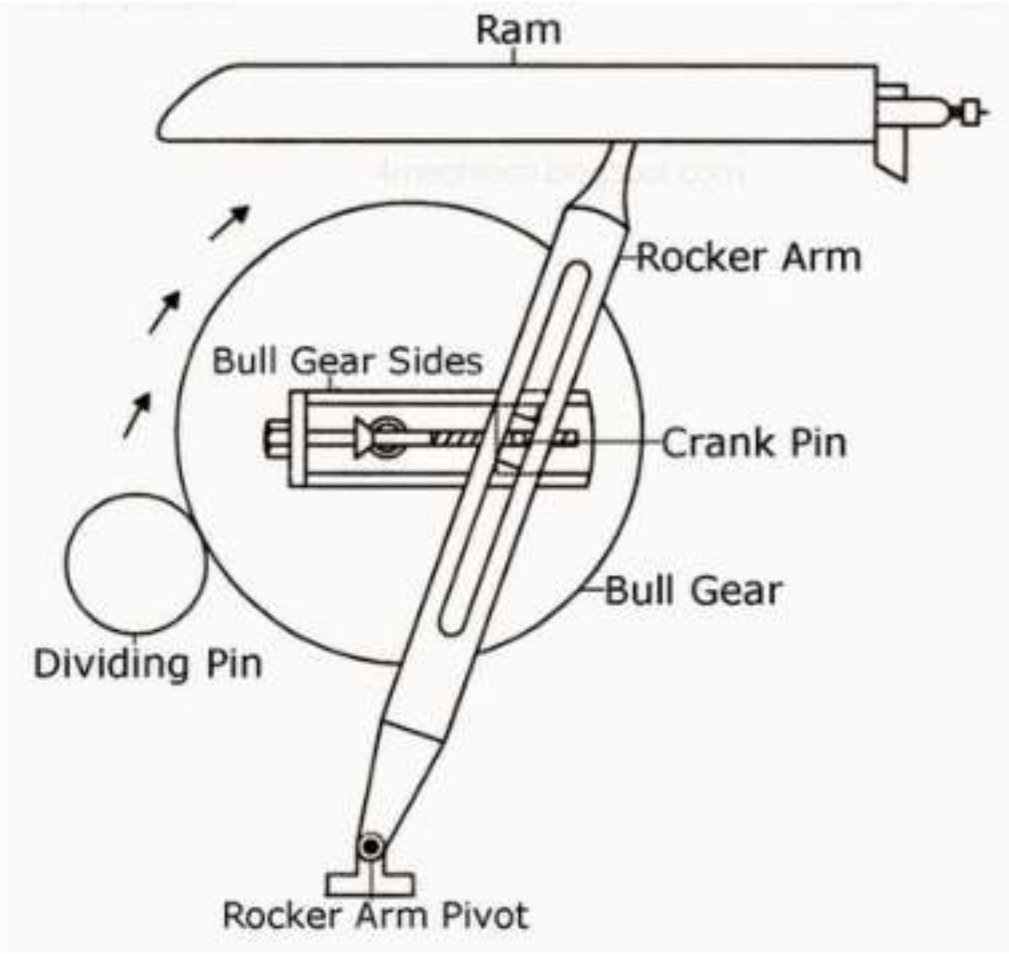
C) According to type of table used:

1. Standard shaper 2. Universal shaper

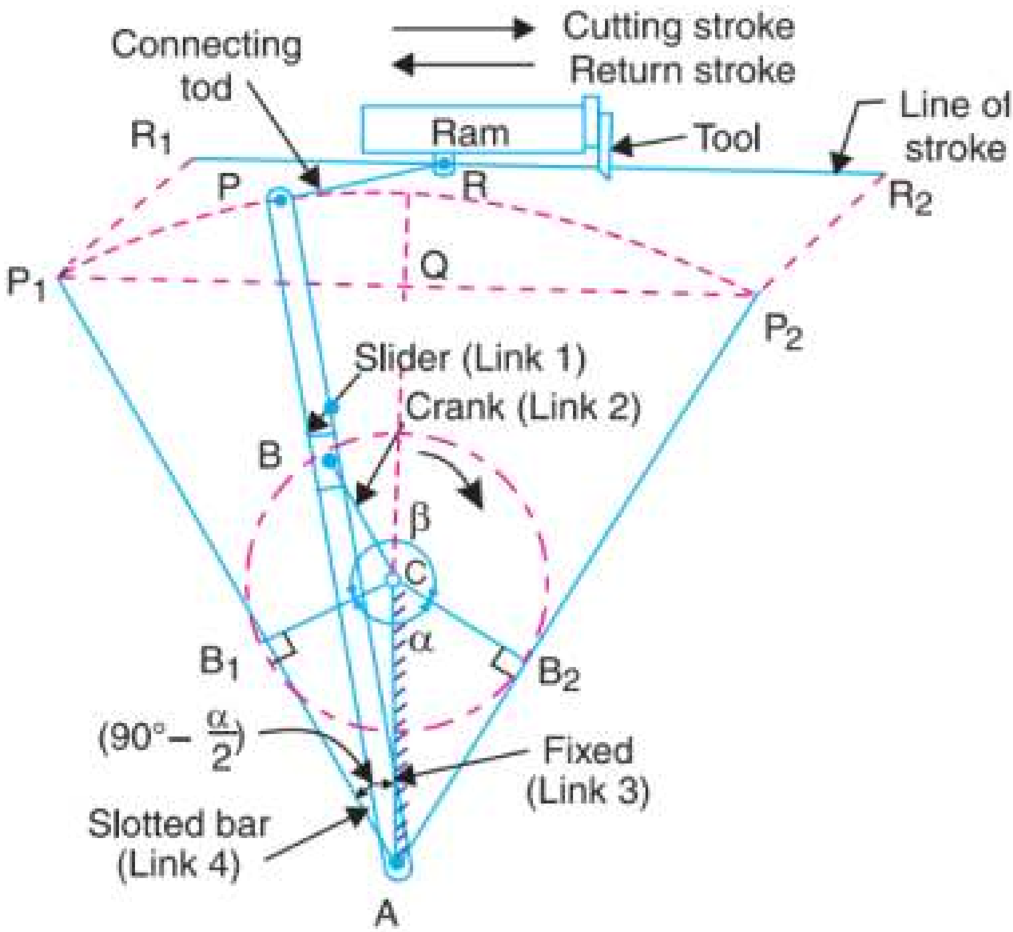
D) According to type of cutting stroke:

1. Push type 2. Draw type

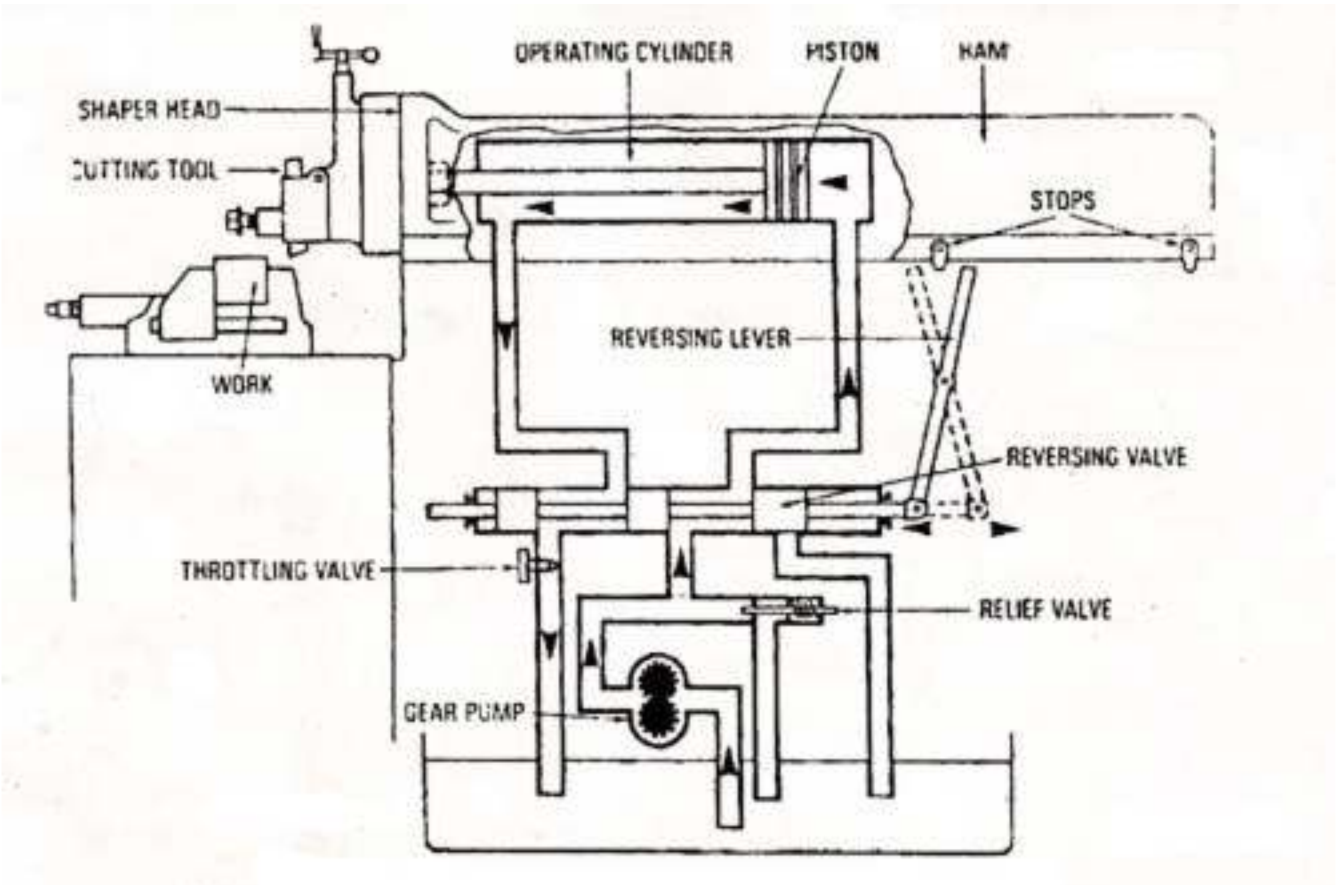
Crank and slotted link mechanism



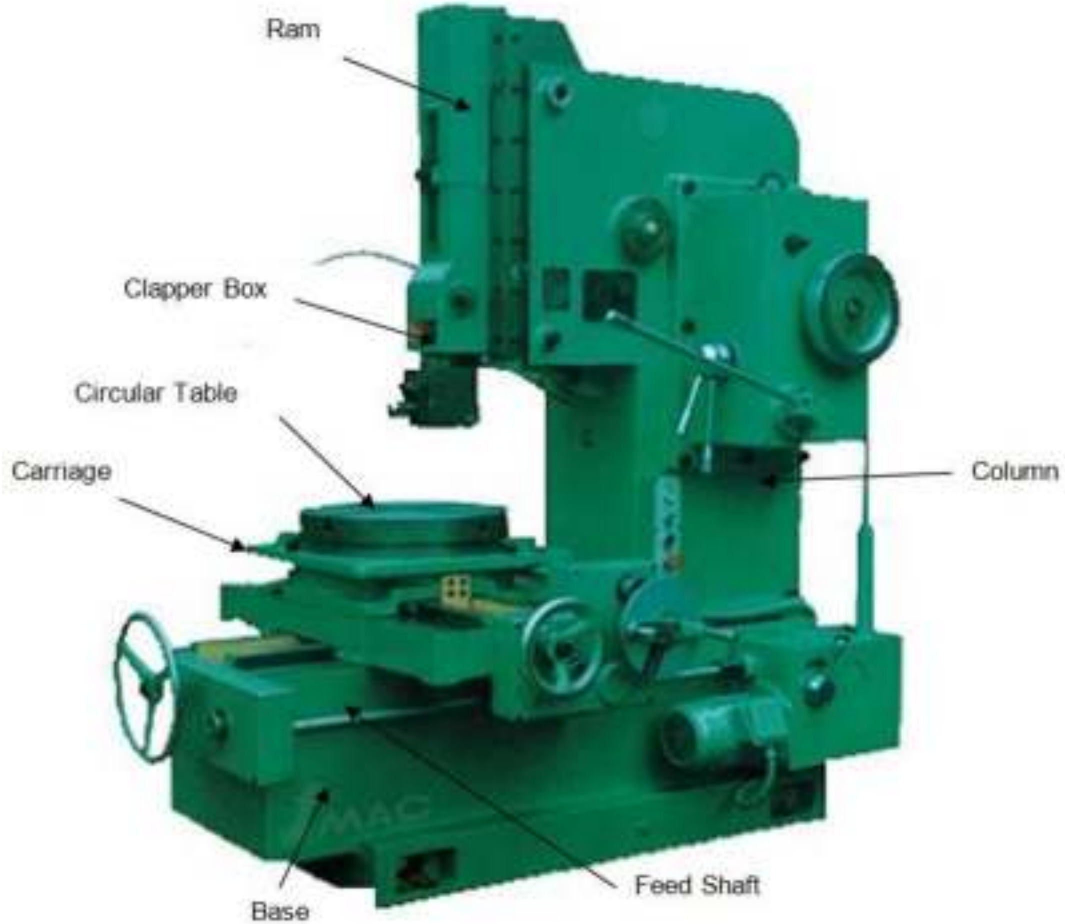
Quick return motion mechanism



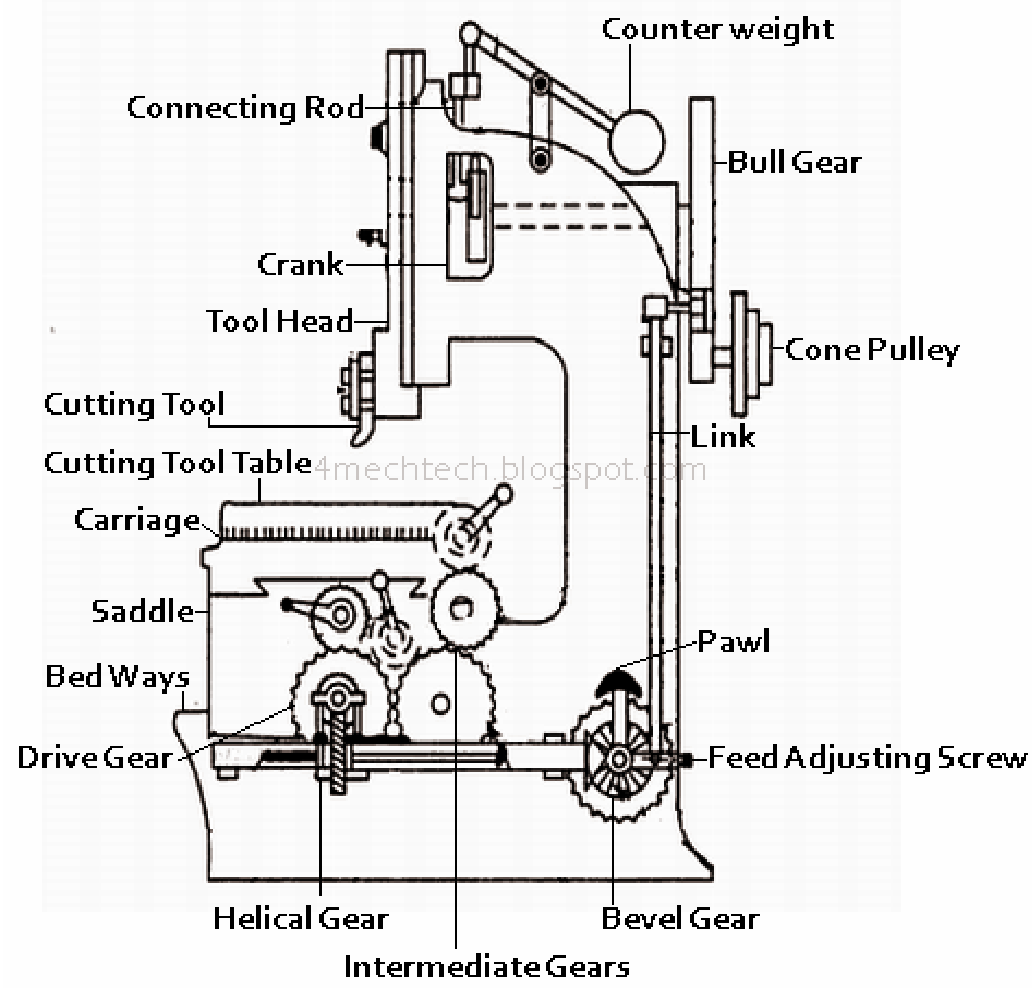
Hydraulic Shaper



Slotting Machine

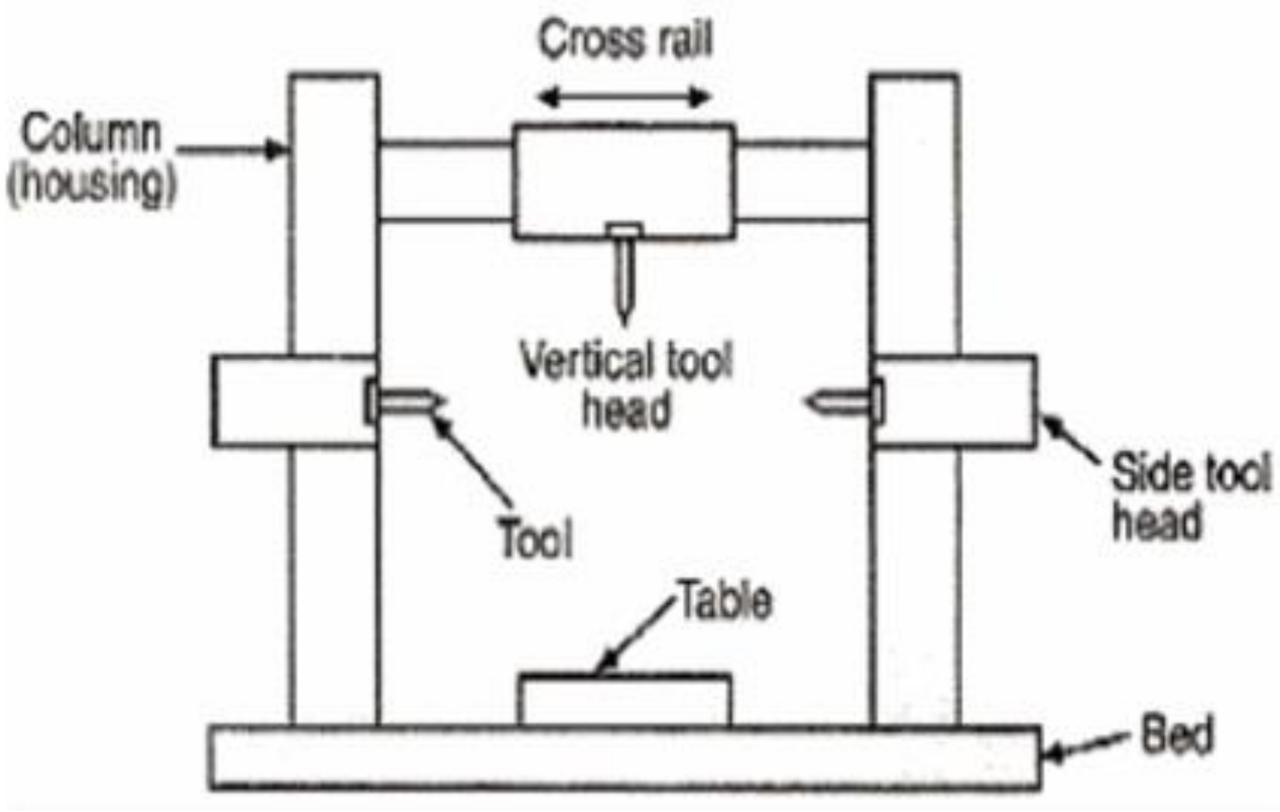


Slotting Machine

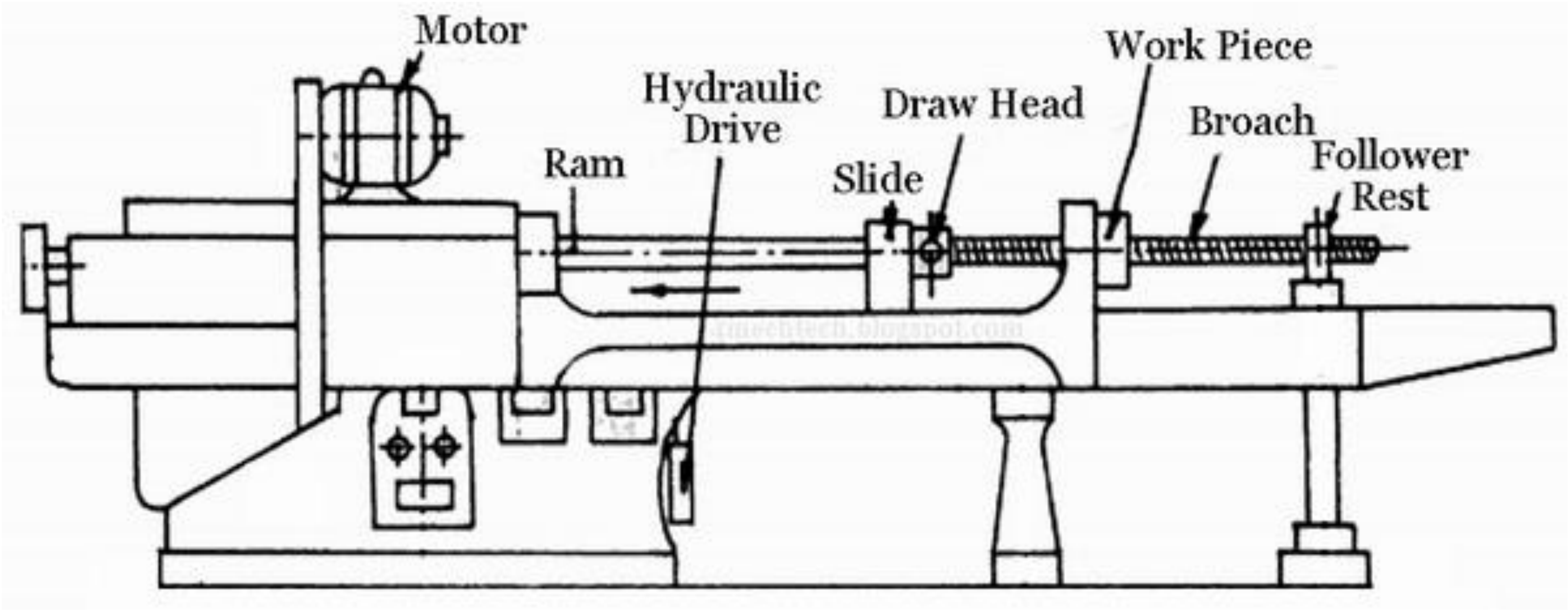


Planing Machine

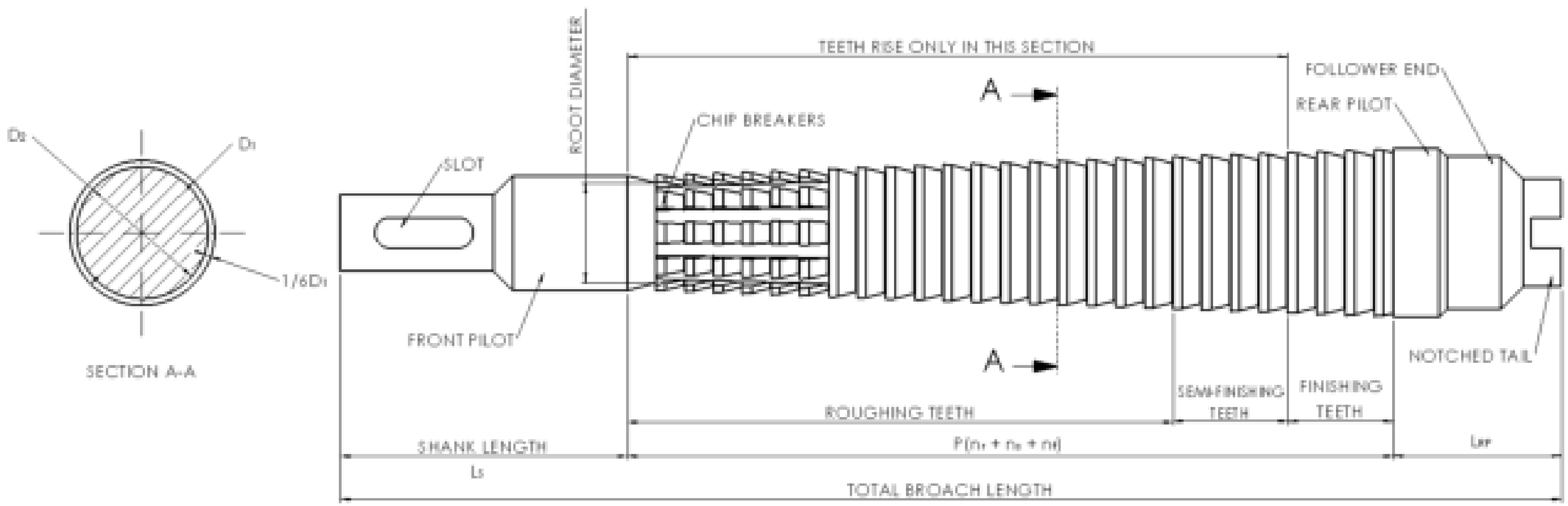
Planing Machine



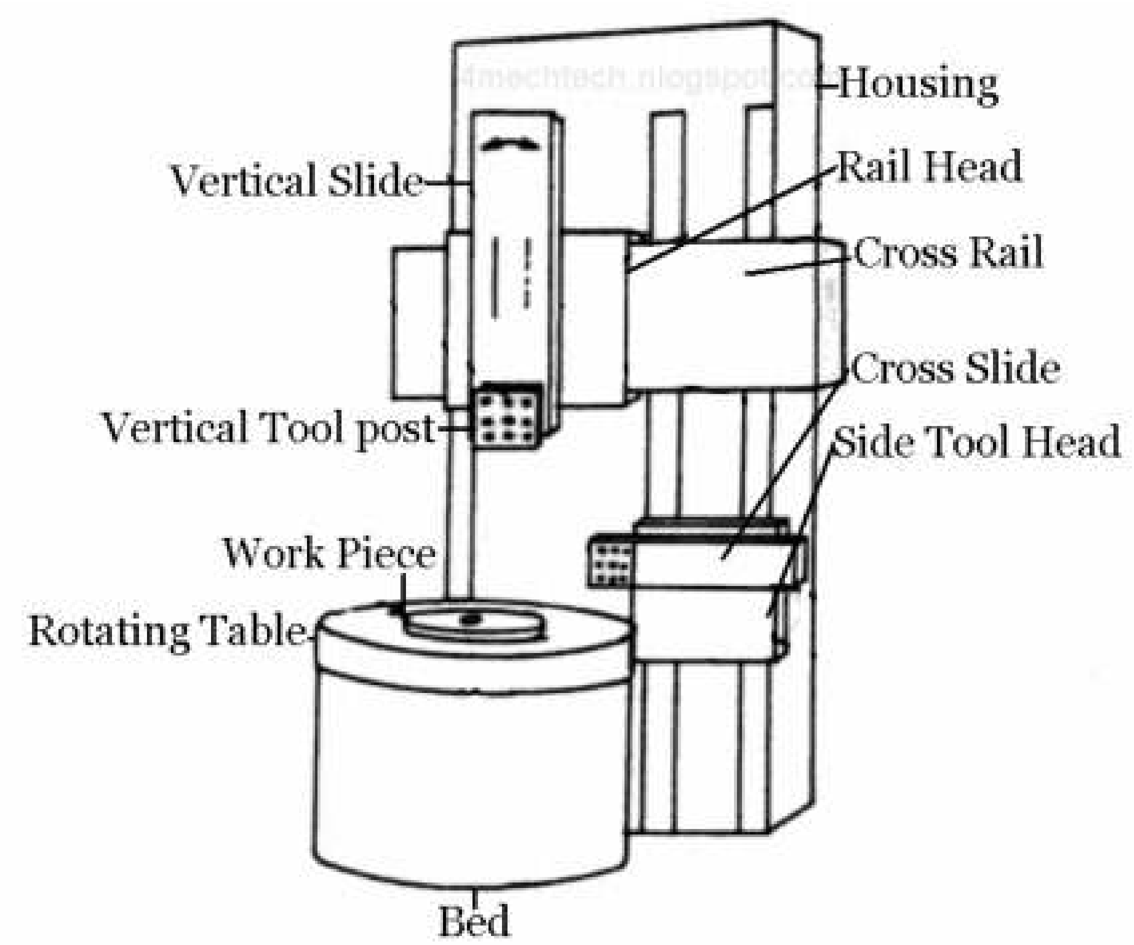
Horizontal Broaching Machine



Geometry of broaching tool (Broach)



Vertical Broaching Machine



MODULE - 2

Milling Machine

- A milling machine is a machine tool that remove metal as the work is fed against a rotating multipoint cutting tool called milling cutter.

Types of Milling Machines

- **Column & knee type**

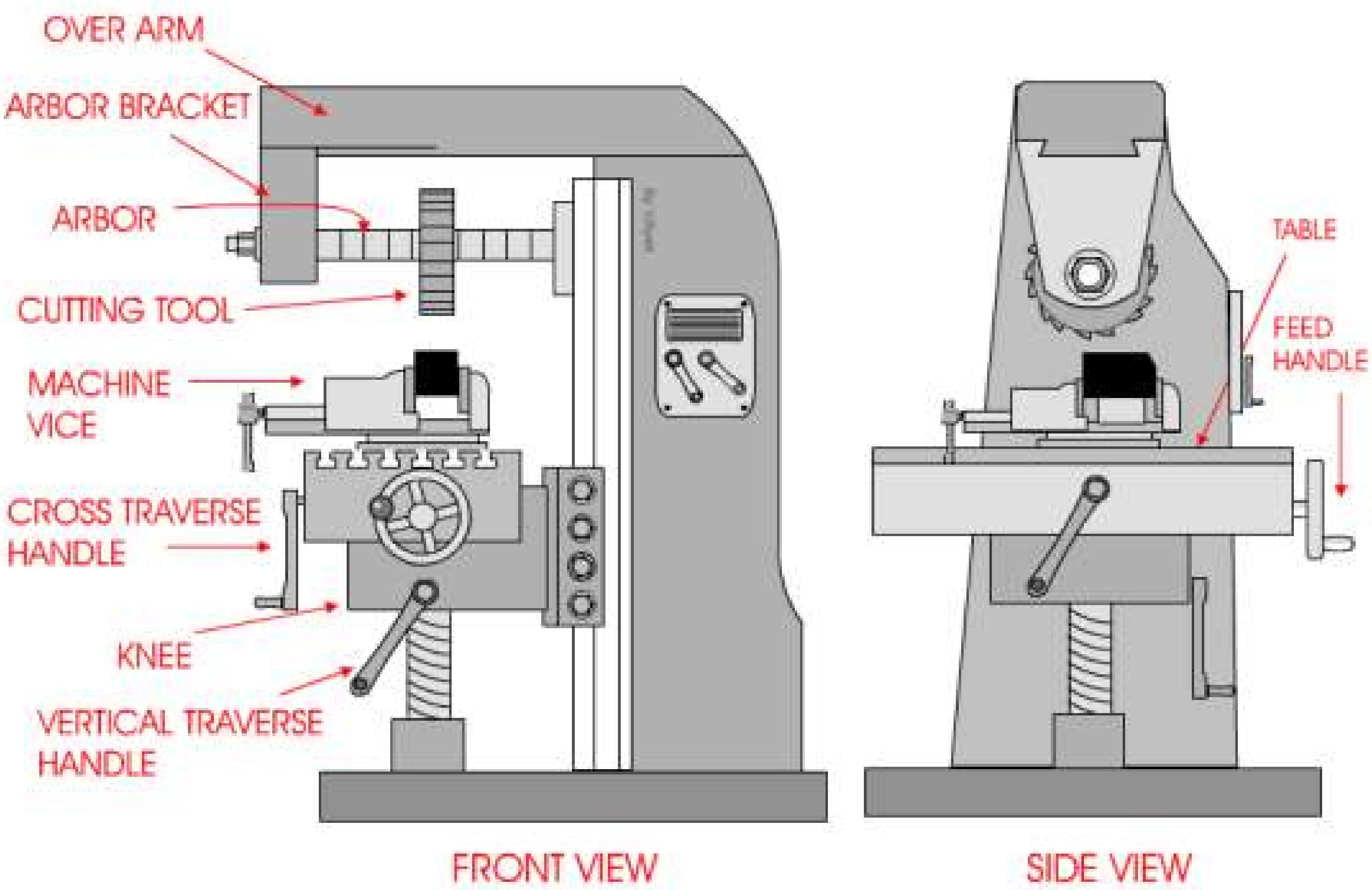
1. Hand milling machine (Hand feed for table movement)
2. Plain milling machine (Hand feed / Power operated table)
3. Universal milling machine (Table can be swiveled / rotated)
4. Omniversal milling machine (Table can be swiveled + tilted)
5. Vertical milling machine (Tool rotates on vertical axis)

- **Manufacturing or Fixed bed type**

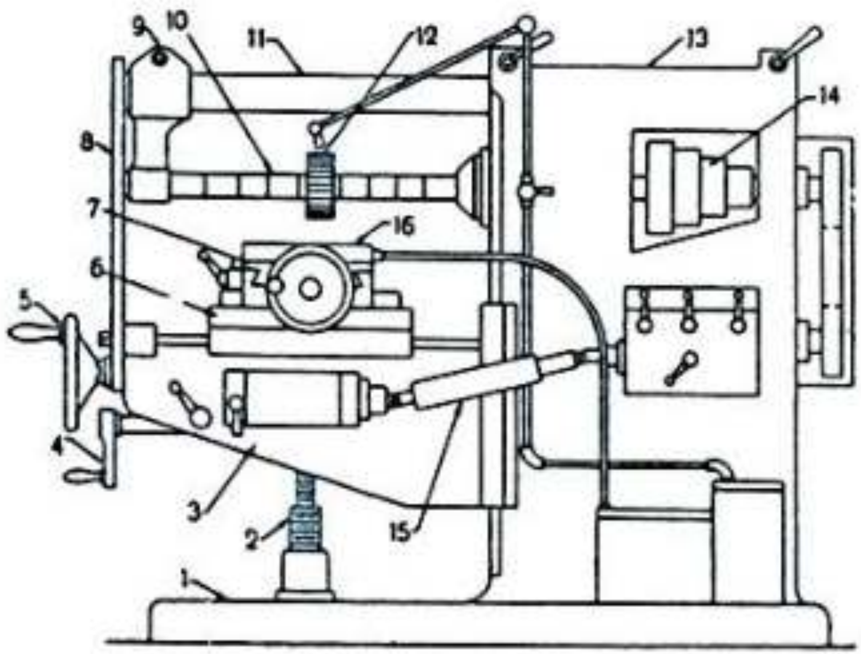
1. Simplex milling machine (One spindle)
2. Duplex milling machine (Two spindle)
3. Triplex milling machine (Three spindles)

- **Planer type** (Tool reciprocates)

Horizontal milling machine



Column & Knee type milling machine



1. Base, 2. Elevating screw, 3. Knee, 4. Knee elevating handle, 5. Crossfeed handle, 6. Saddle, 7. Table, 8. Front base, 9. Arbor support, 10. Arbor, 11. Overhanging arm, 12. Cutter, 13. Column, 14. Conepulley, 15. Telescopic feed shaft.

Vertical milling machine

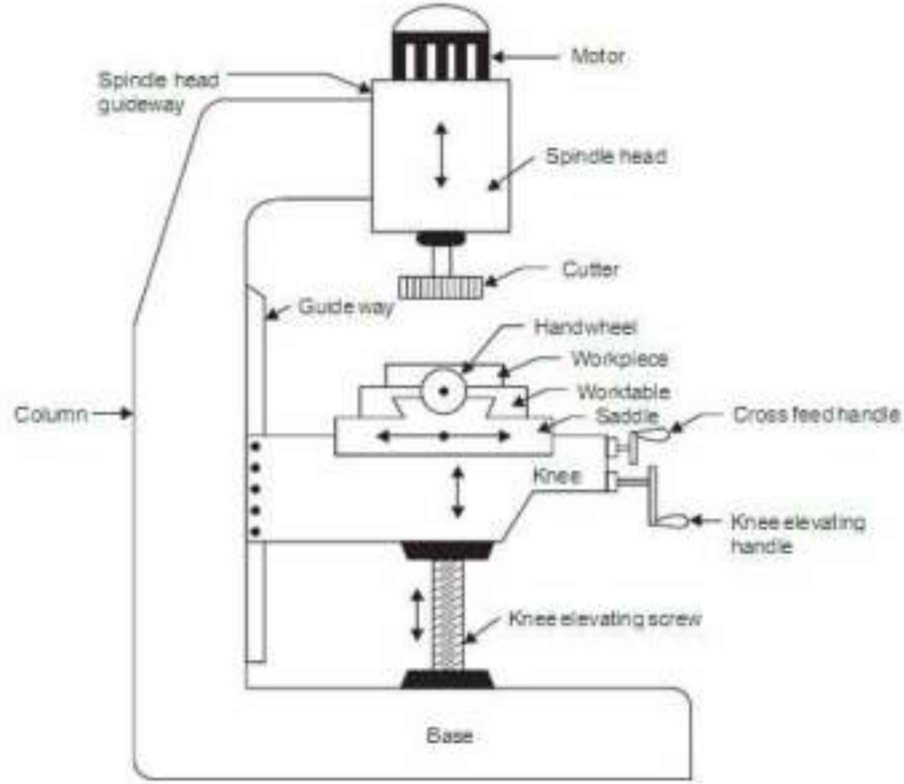


Fig. 4.10 Vertical milling machine

Grinding

- Grinding is a metal cutting operation performed by means of a rotating abrasive wheel that acts as tool.
- Grinding is used to finish work pieces to attain high surface quality, accuracy of shape and dimension.

Grinding machine

- Grinding machines are classified according to

1. Quality of surface finish obtained
2. Type of surface generated / work done

Grinding machine classifications

- Quality of surface finish obtained

1. Rough grinders

- Machines whose main purpose is removal of stock without any reference to the accuracy of the results.

2. Precision grinders

- Machines which finish parts to a very accurate dimensions.

Grinding machine classifications

- Type of surface generated / work done

1. **Cylindrical grinders**
   - Centre type
   - Centre less type
2. **Internal grinders**
   - Chuck type
   - Centre less type

3. Surface grinders

a) Reciprocating table

i) Horizontal spindle

ii) Vertical spindle

b) Rotating table

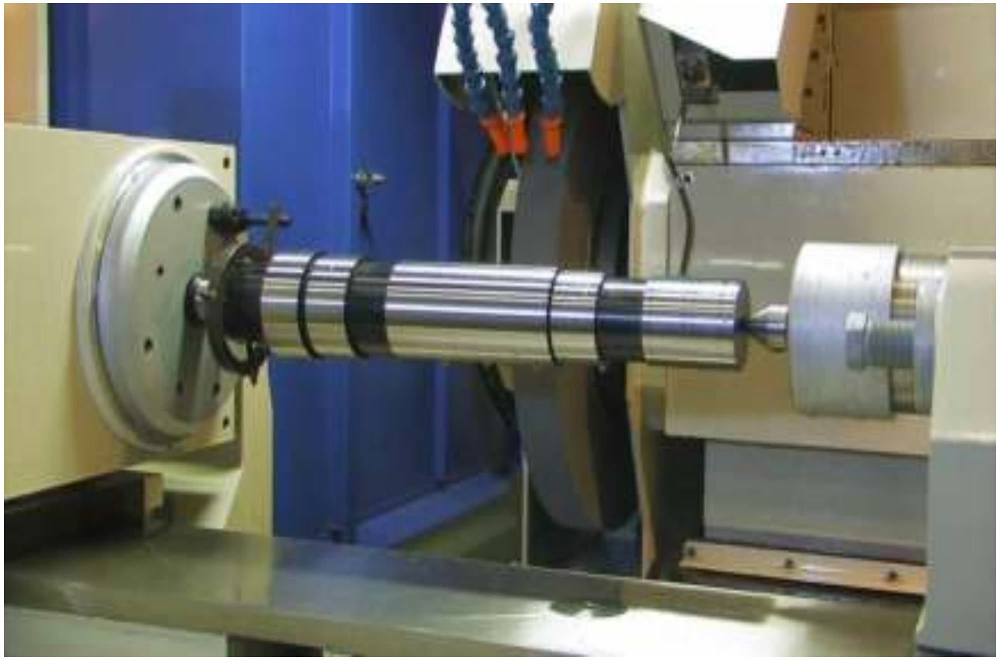
i) Horizontal spindle

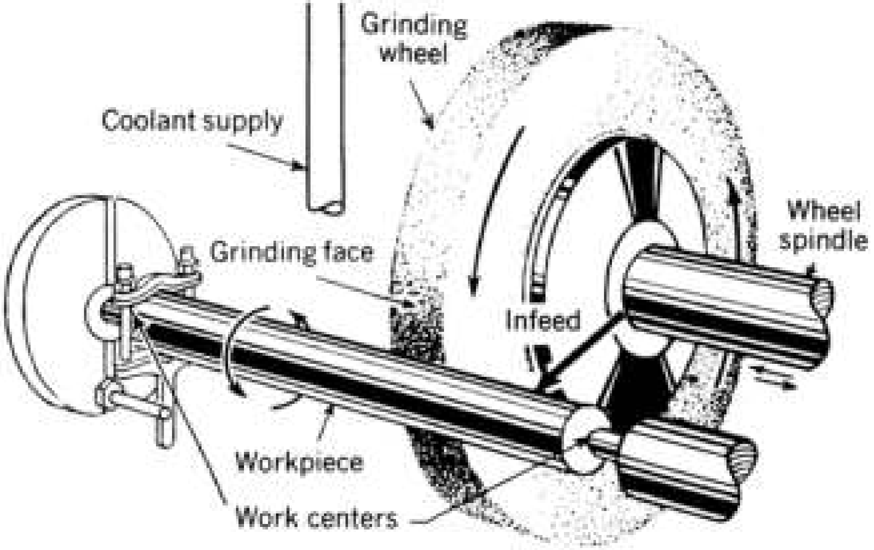
ii) Vertical spindle

4. Tool & cutter grinders

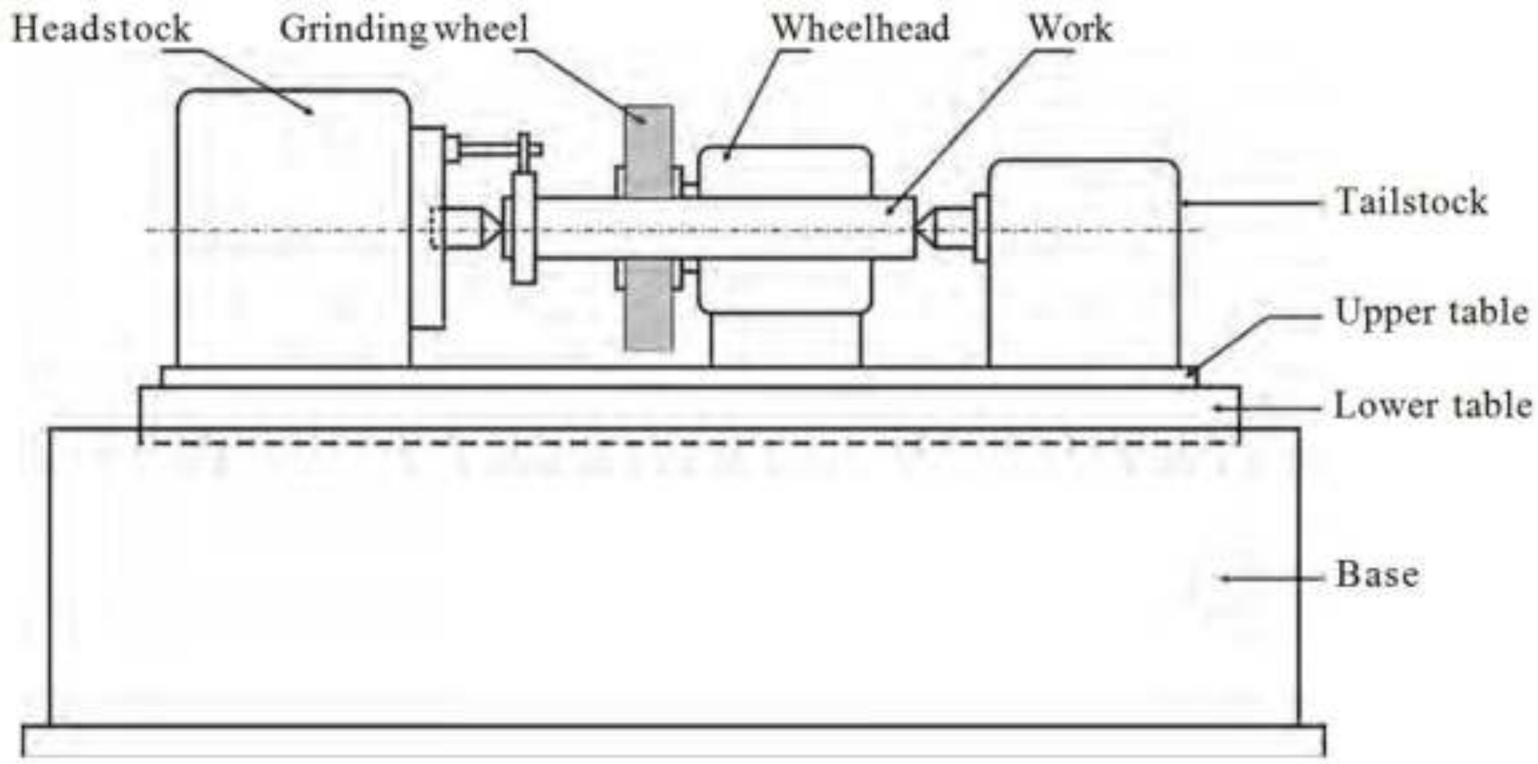
Centre type cylindrical grinders

Centre type cylindrical grinding



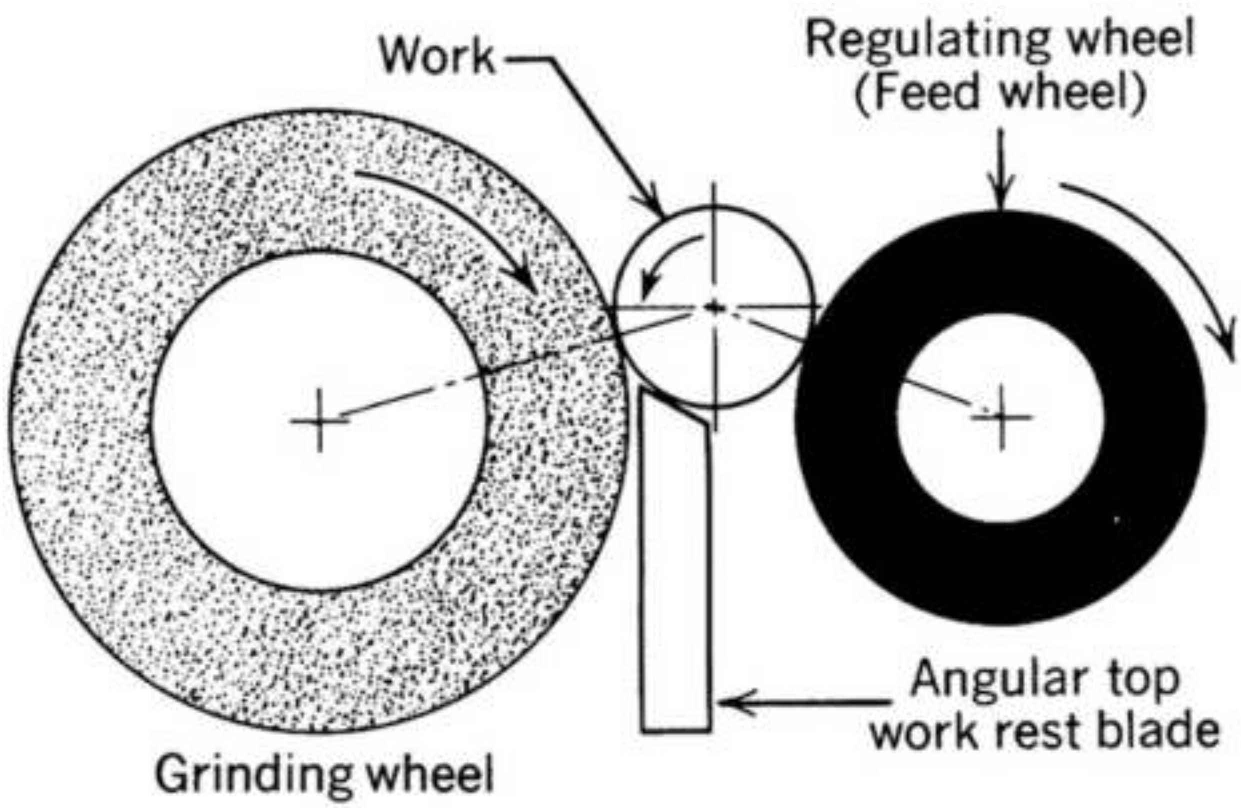


Centre type external cylindrical grinding machine

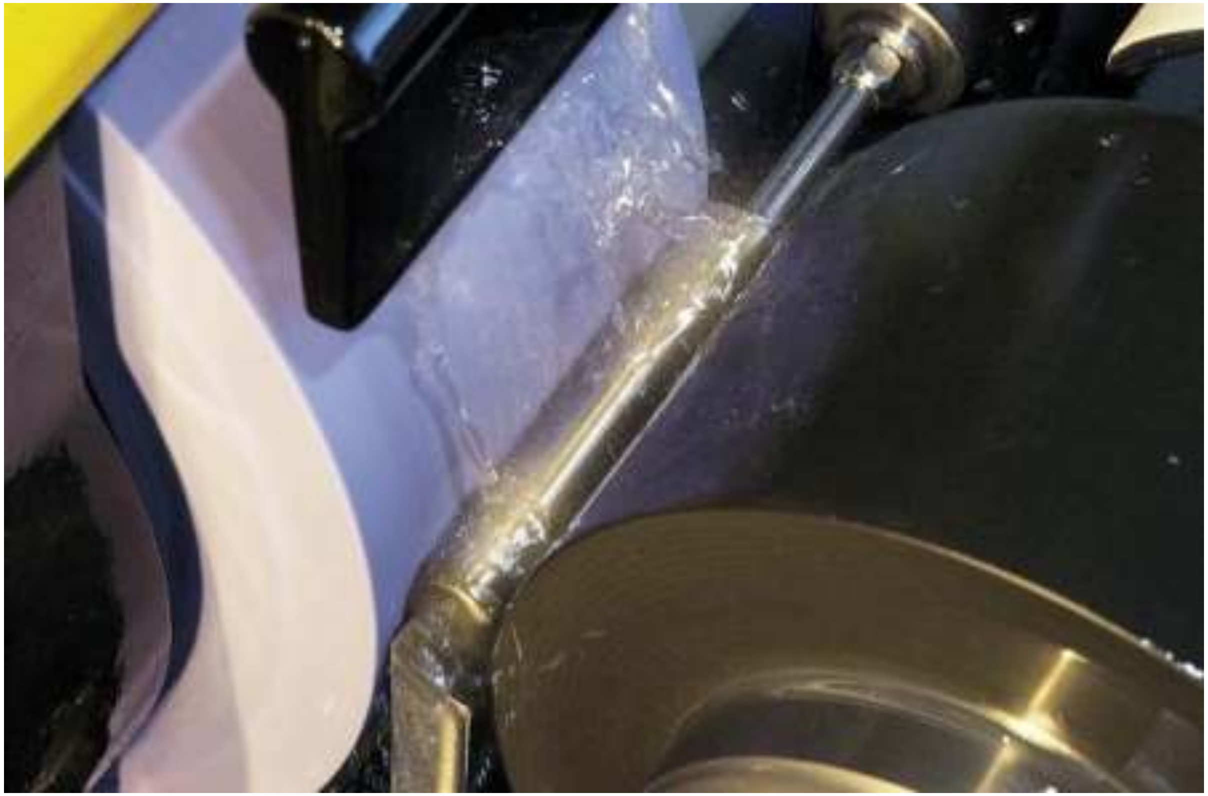


Cylindrical Grinding Machine

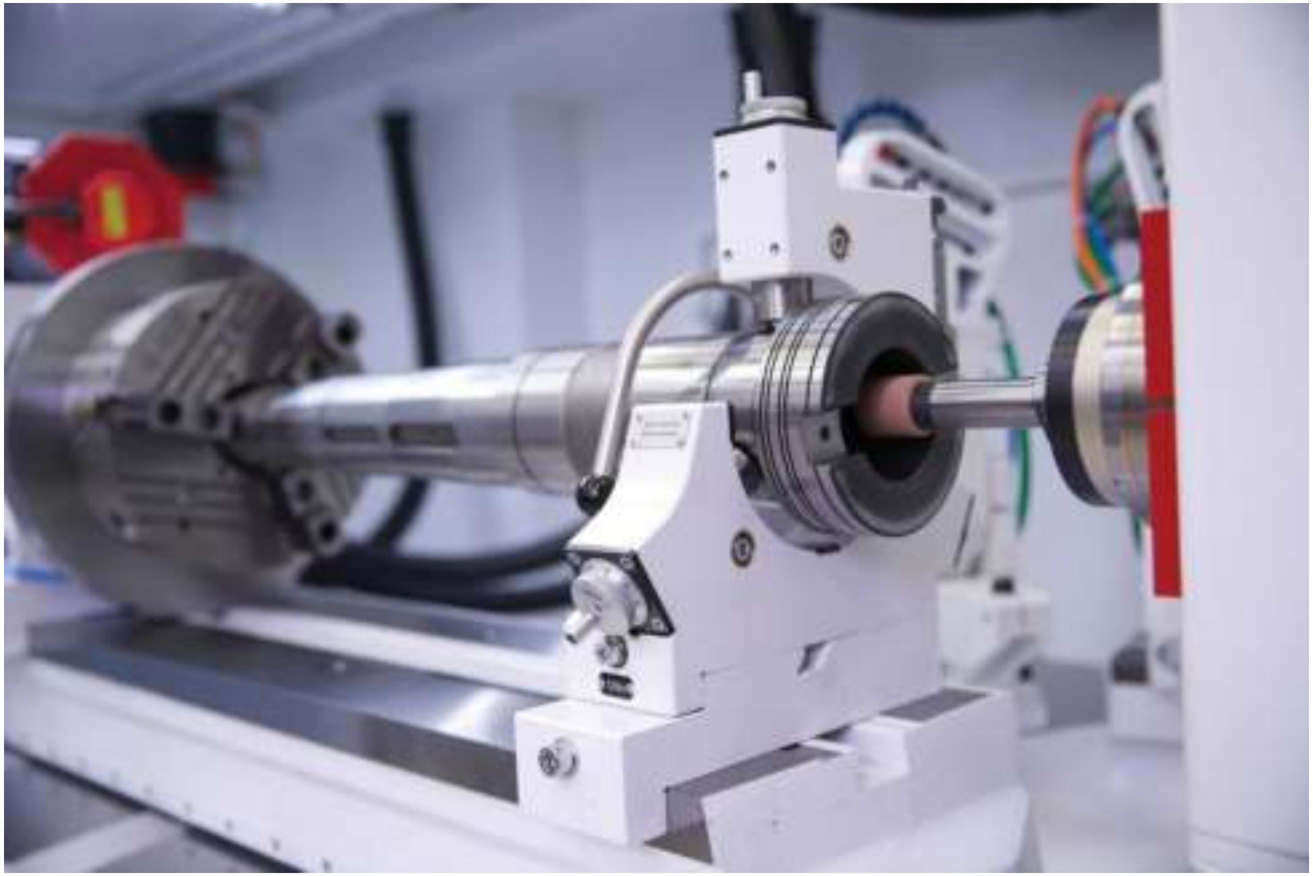
Centre less type external cylindrical grinding



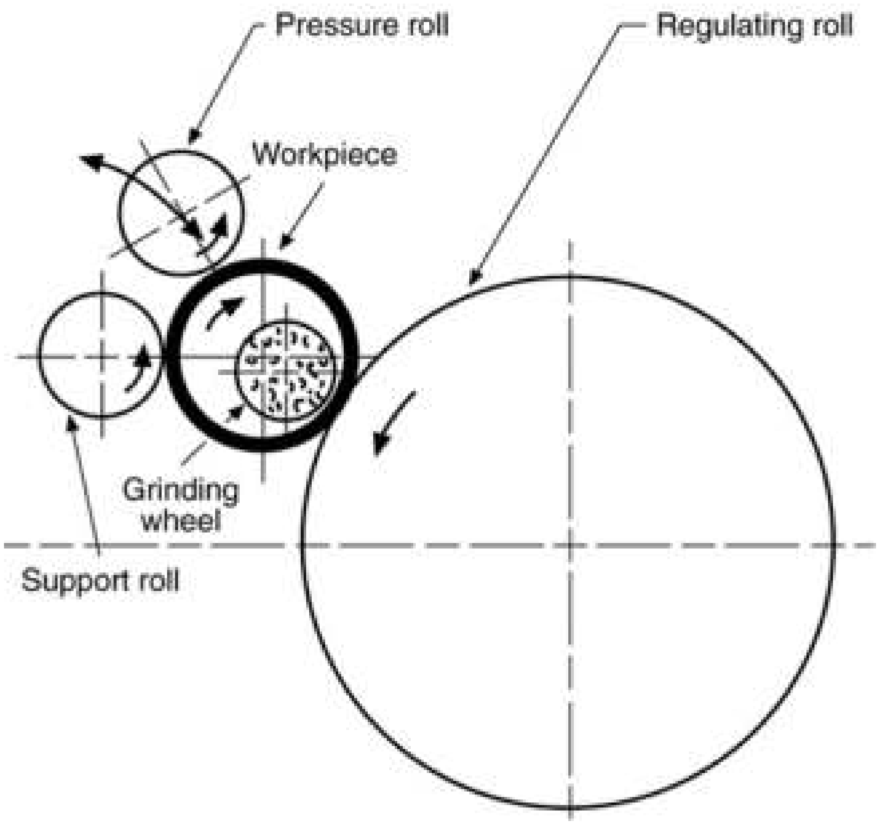
Centre less type external cylindrical grinding



Chuck type internal cylindrical grinding

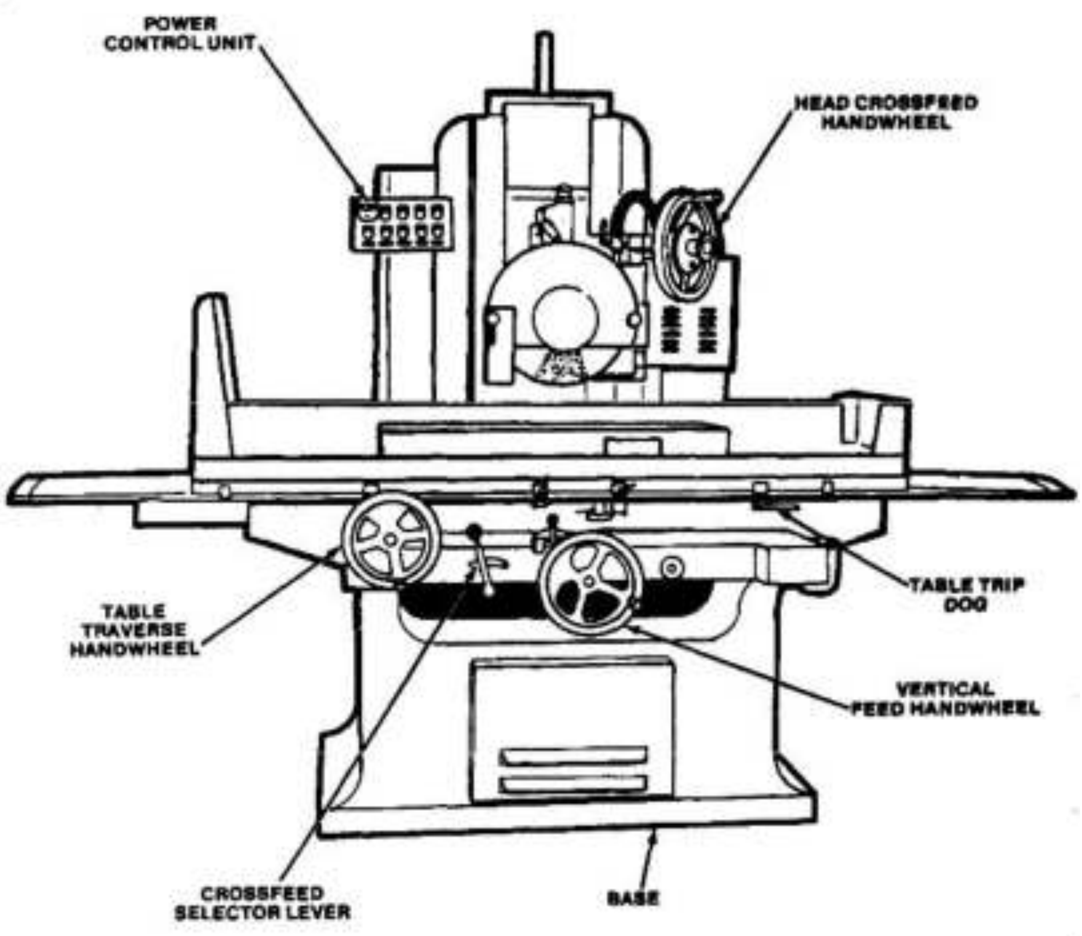


Internal centre less type cylindrical grinding



Horizontal Grinding Machine

Horizontal Grinding Machine



Horizontal Grinding Machine

1. Reciprocating table   2. Rotary table

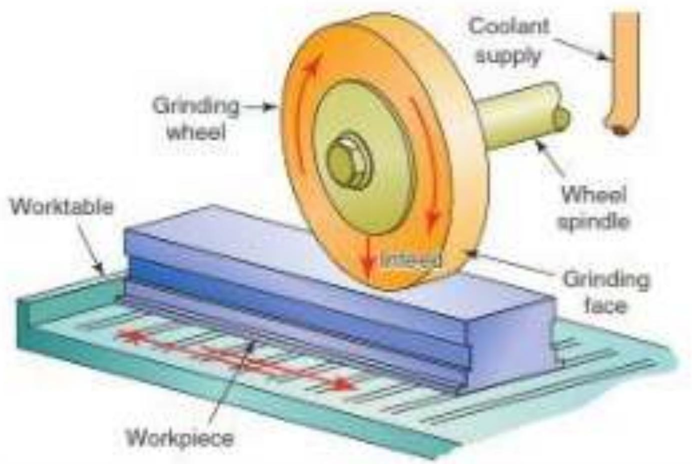


Figure L-1 Principle of the type I surface grinder.

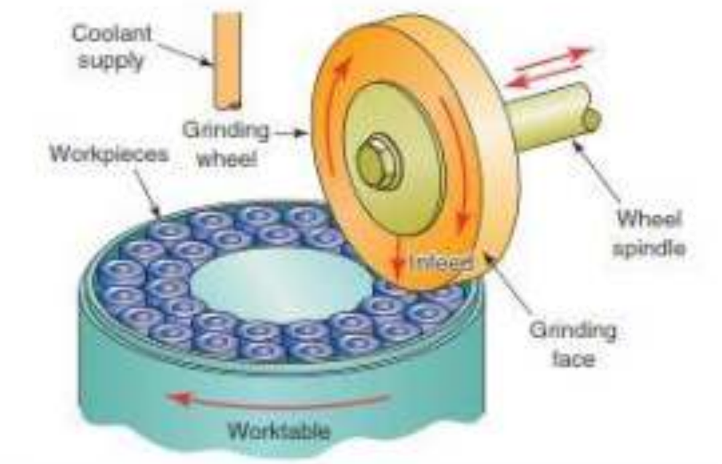


Figure L-3 Principle of the type II surface grinder. Sometimes circular parts are centered on this grinder; the resulting concentric scratch pattern is excellent for metal-to-metal seals of mating parts.

Vertical Grinding Machine

Vertical Grinding Machine

1. Reciprocating table   2. Rotary table

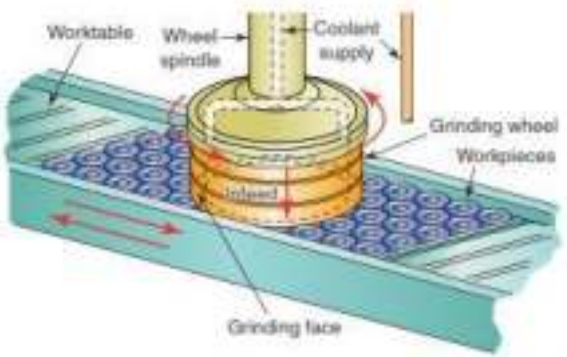


Figure L-4 Principle of the type III surface grinder, which has a vertical spindle and a reciprocating table.

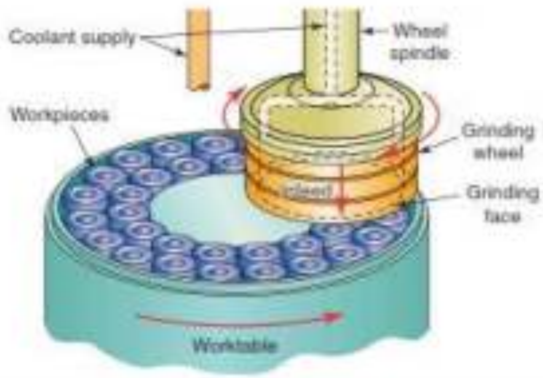
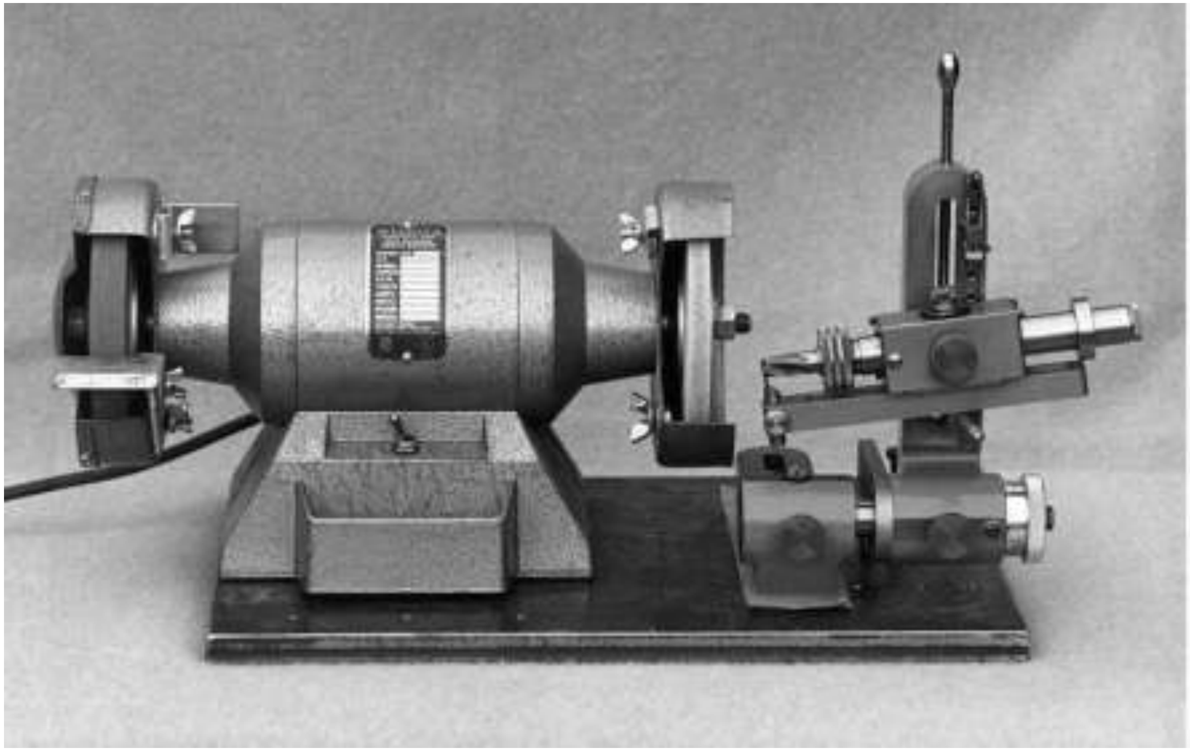


Figure L-5 Principle of the vertical spindle rotary grinder.

Tool / Cutter grinder



Grit / Grain of grinding wheel

- **Grit or grain**: It indicates the size of the abrasive grains used in making a wheel
- Coarse wheels are used for fast removal of materials with low surface finish
- Fine grain wheels produces excellent surface finish

Size of the Abrasive Grain

Coarse	Medium	Fine	Very Fine
8	30	70	220
10	36	80	240
12	46	90	280
14	54	100	320
16	60	120	400
20	-	150	500
24	-	180	600

Grade of grinding wheel

- Grade refers to the tenacity or hardness of the abrasive particles used for making the grinding wheel.

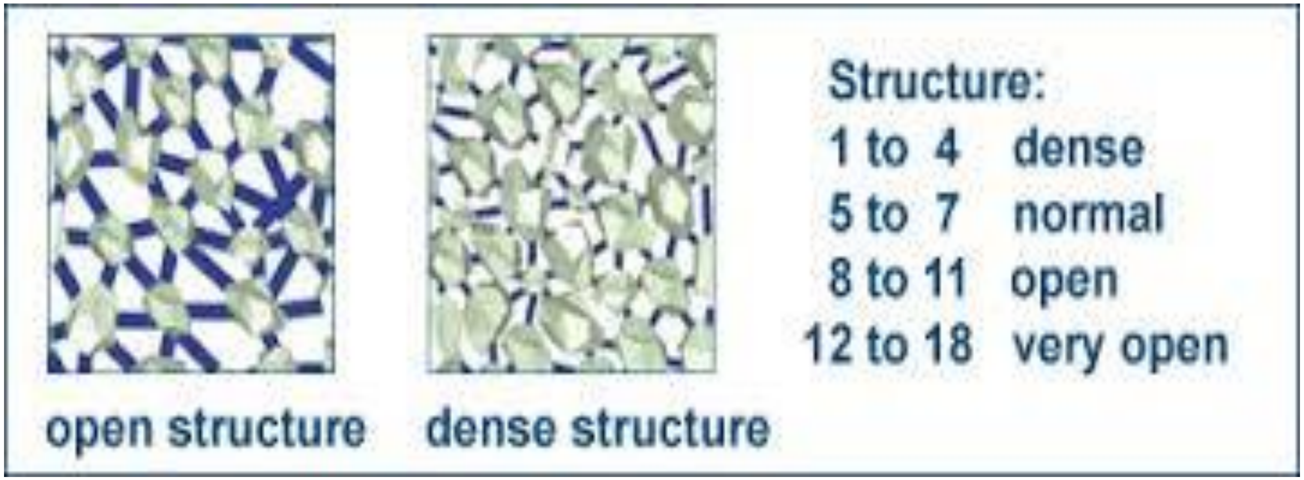
Grades

"D" to "H" > soft

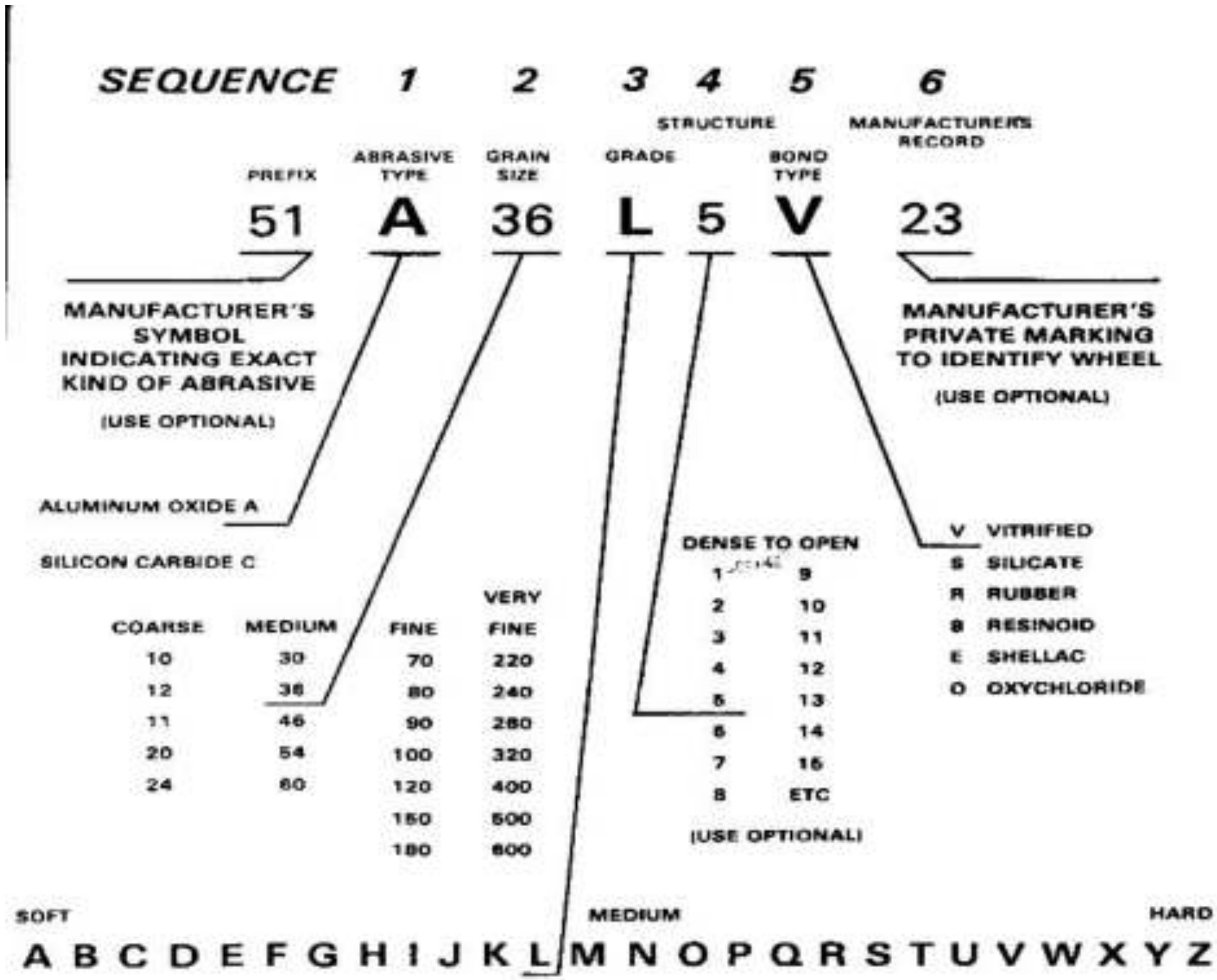
"I" to "P" > medium

"R" to "V" > hard

Structure of grinding wheel



Grinding wheel specification



Super finishing processes

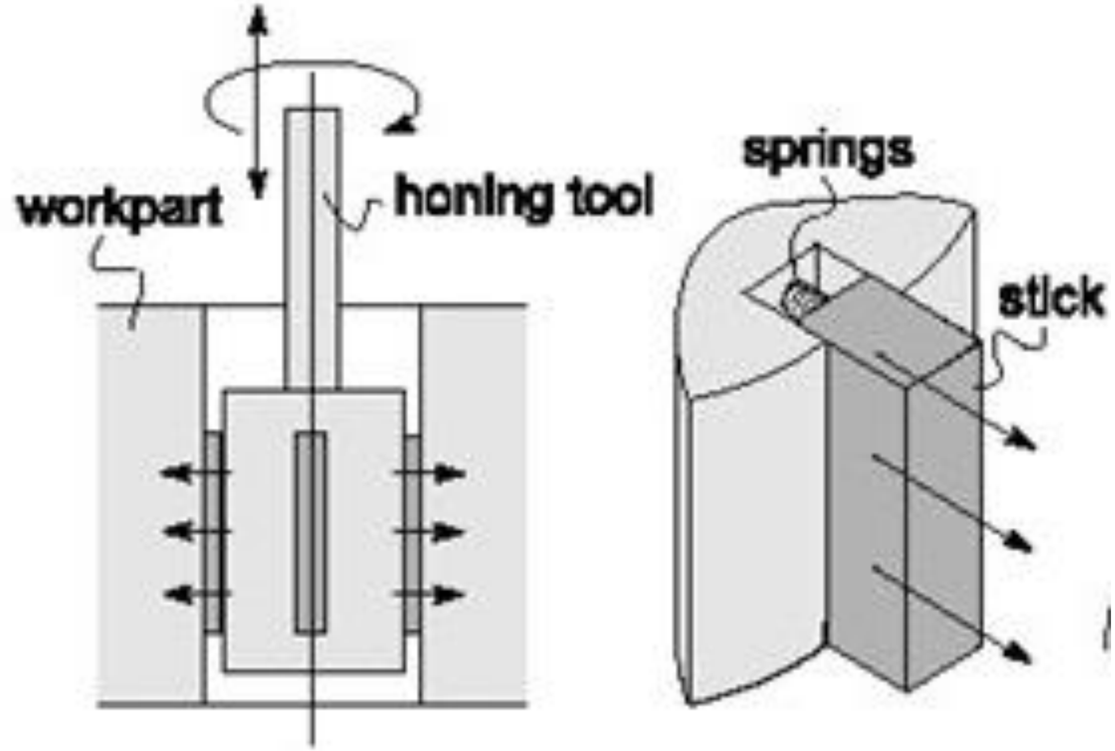
1. Honing
2. Lapping
3. Burnishing

Horning / Honing

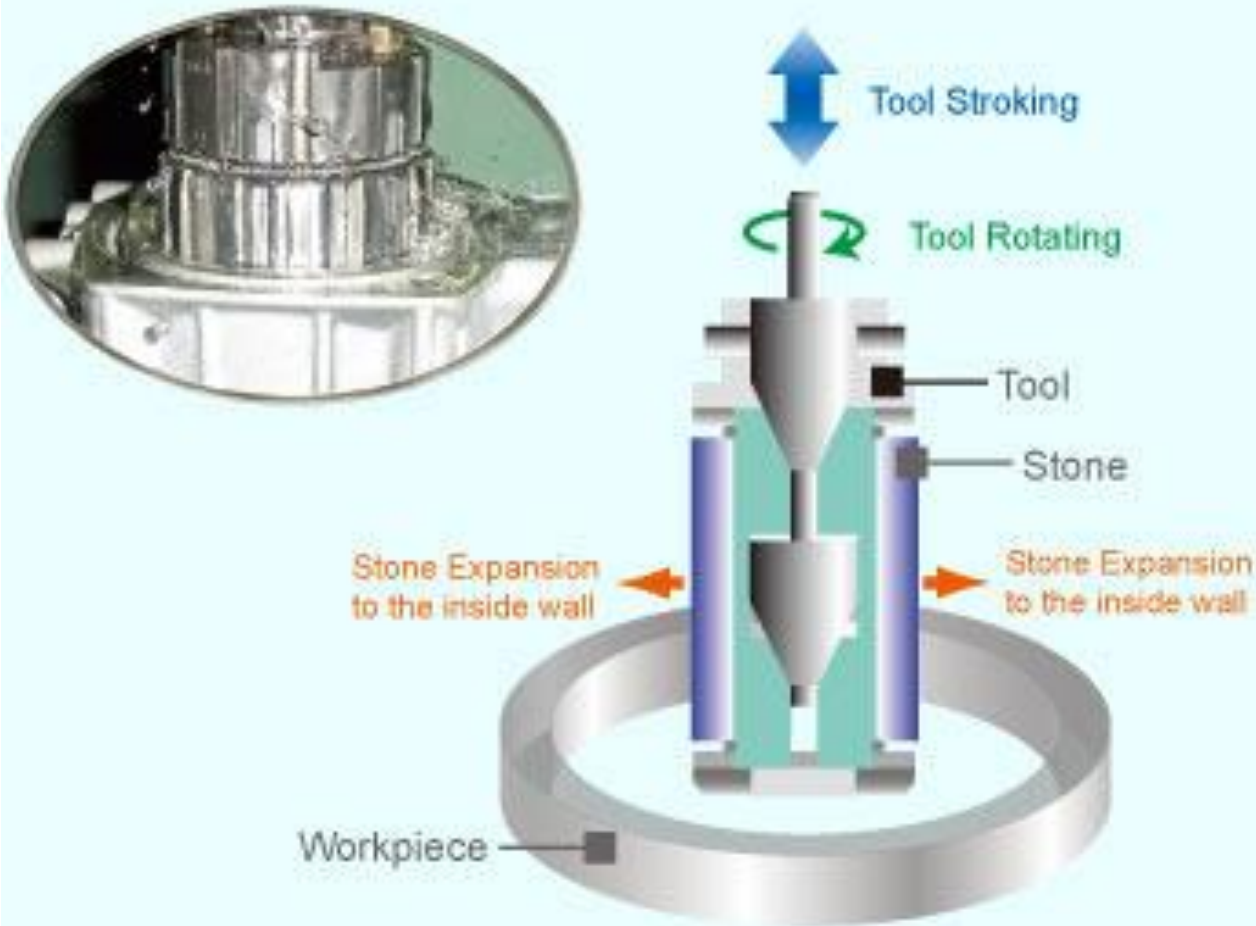
- “HONING” is a kind of grinding process mainly used to grind the inside wall of the workpiece (metal like cast iron or aluminum is common) by abrasive stones. Metal removal is accomplished by pushing multi-stone set into the honing head of the tool against the inside wall and grinding the surface by rotating and stroking the tool with showering honing oil on it.

Honing tool

Honing process



Honing Theory

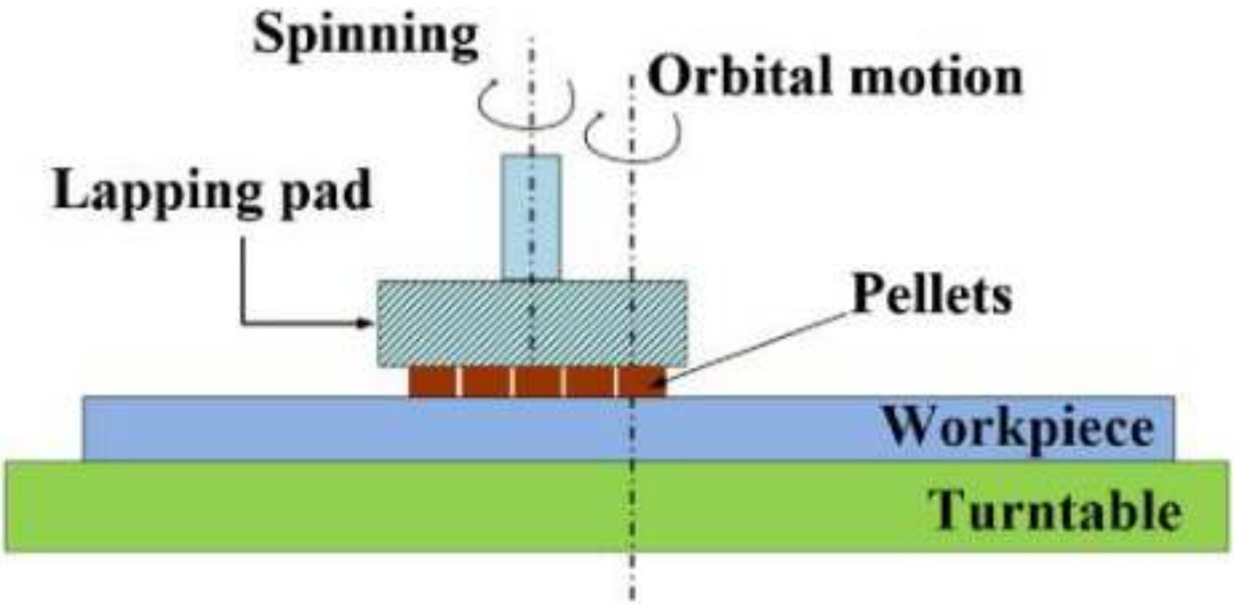


Honing

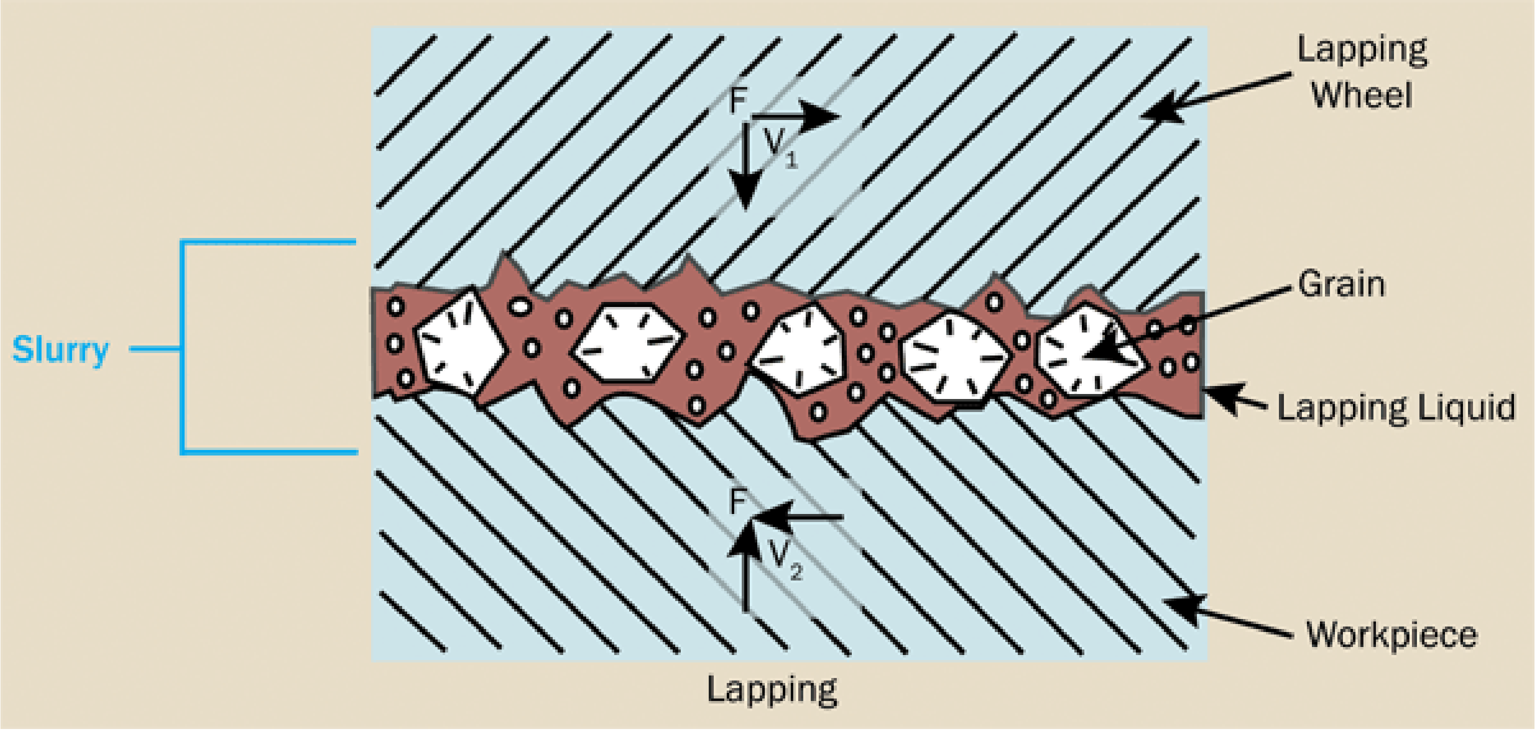
Lapping

- **Lapping** is a machining process, in which two surfaces are rubbed together with an abrasive between them, by hand movement or using a machine.

Lapping process

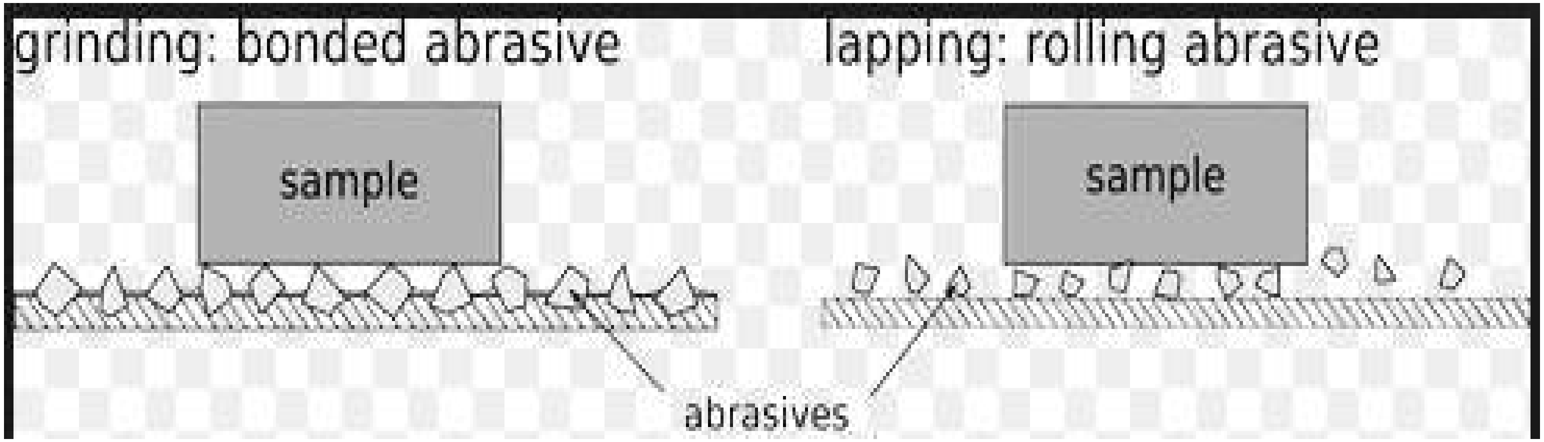


Material Removal During Lapping



Abrasives used

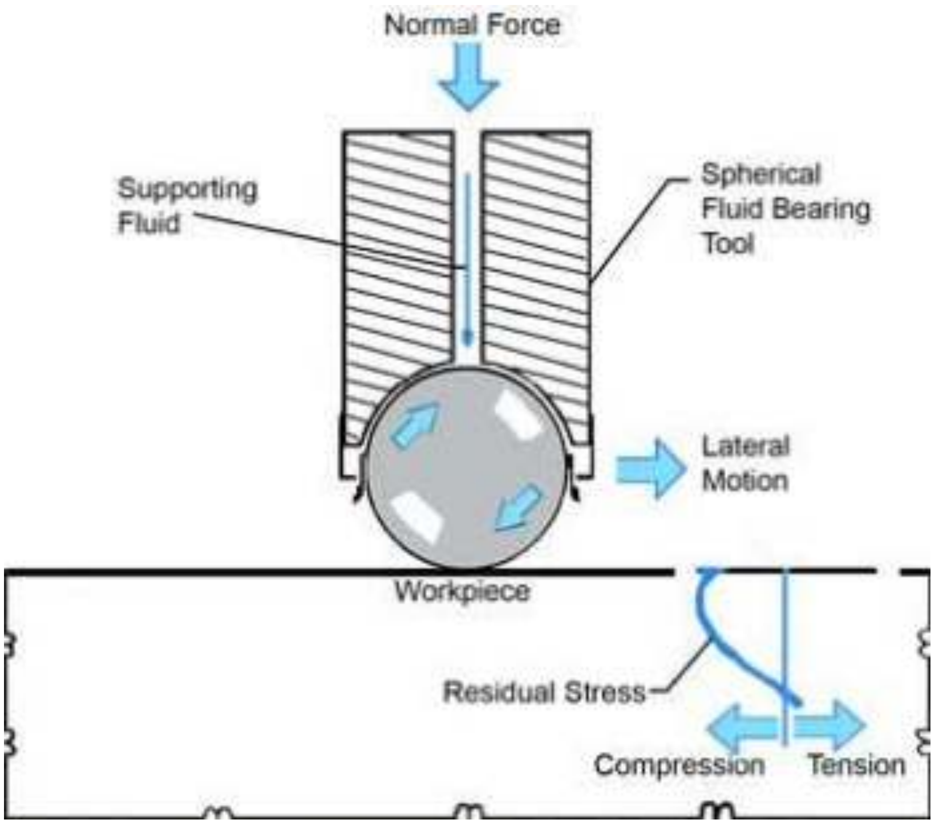
Grinding Vs Lapping



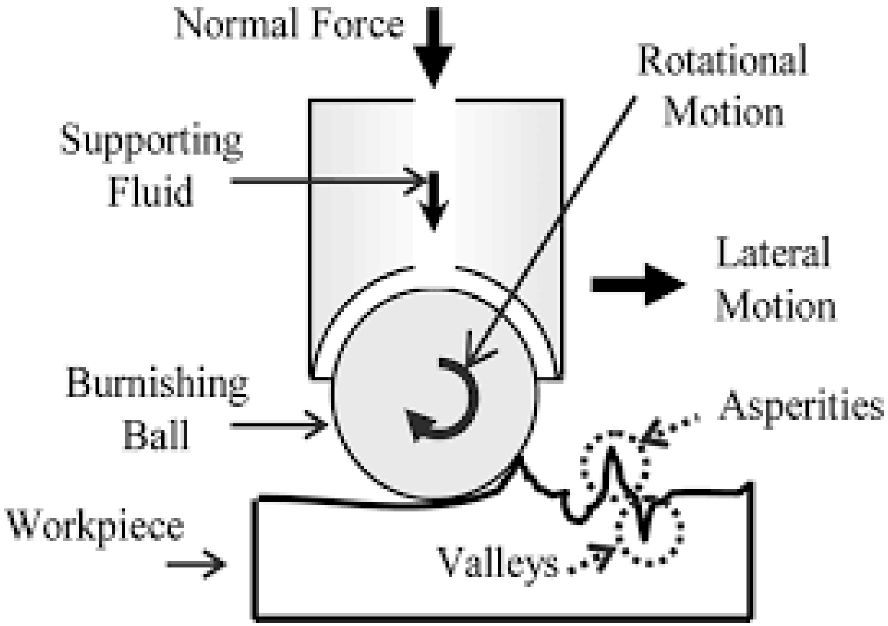
Burnishing

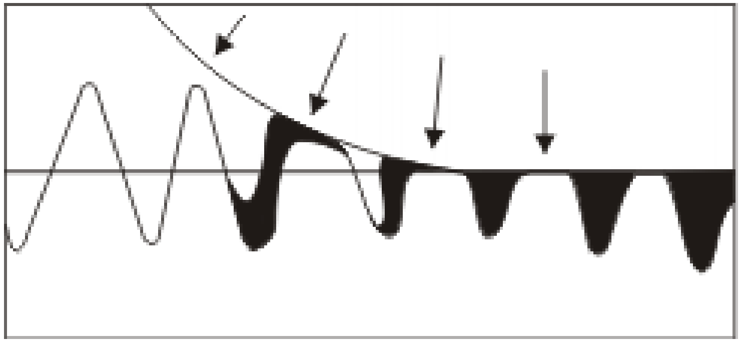
- Roller Burnishing is a Super-finishing process. It is a Cold Working process which produces a fine surface finish by the planetary rotation of hardened rollers over a bored or turned metal surface.

Burnishing process



Burnishing process





MODULE - 3

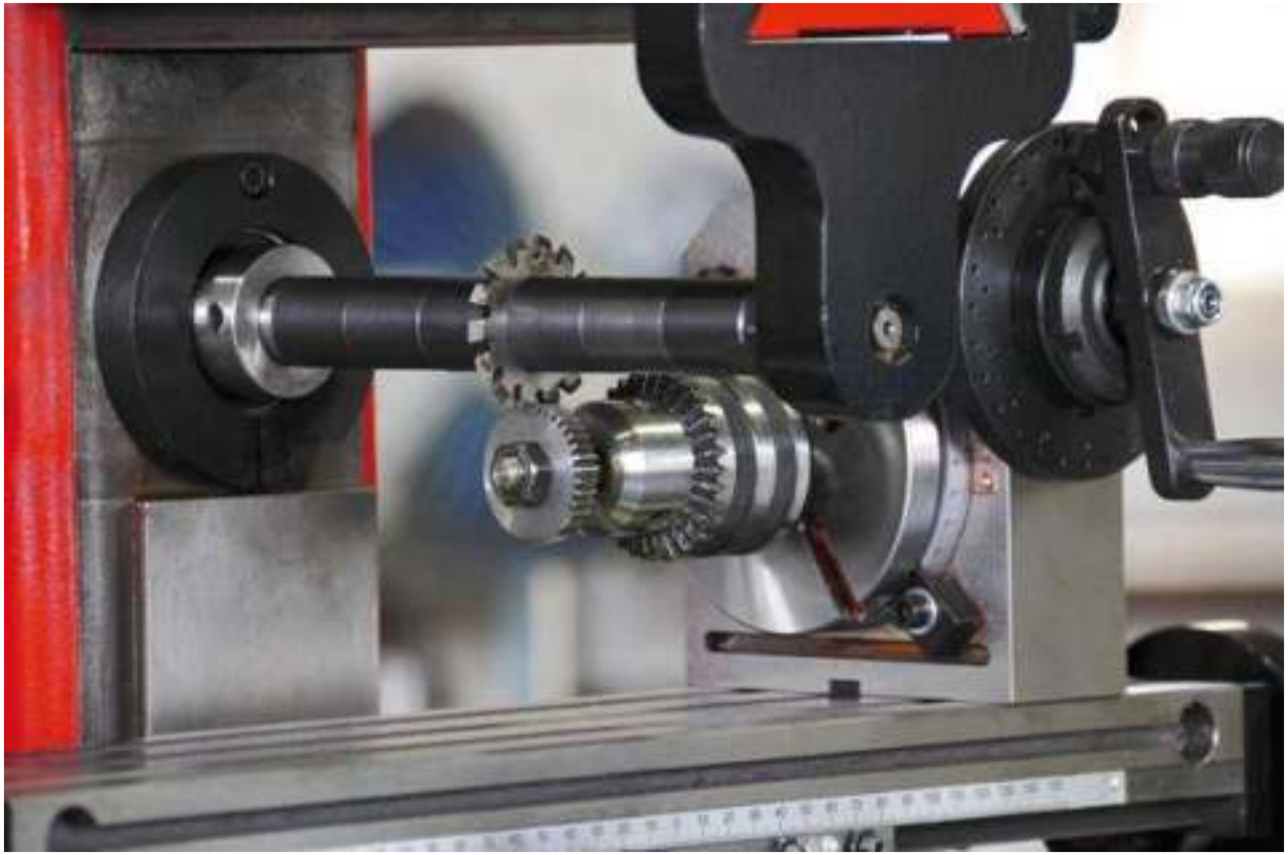
Gear cutting process

1. Gear milling
2. Gear hobbing
3. Gear shaping

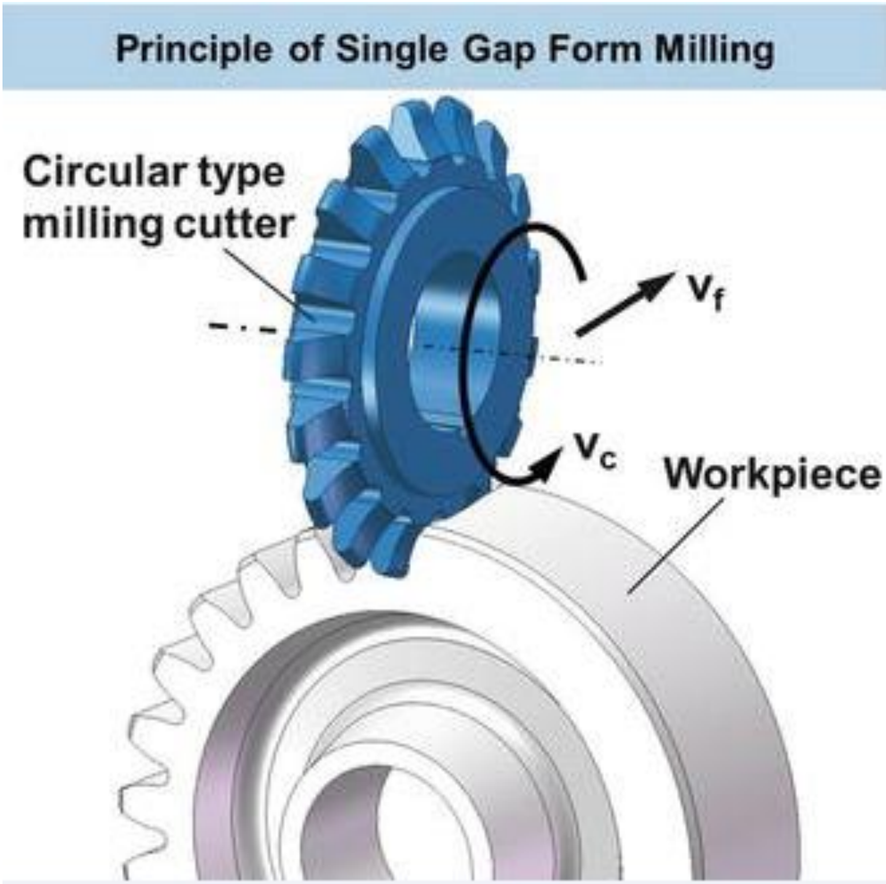
Gear Milling

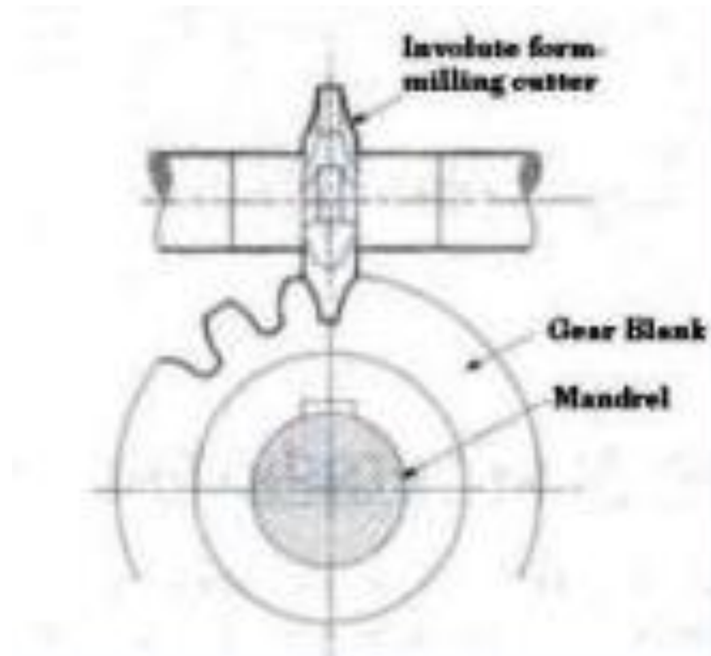
- A milling machine equipped with a suitable milling cutter is used during the process. As the multi point cutting tool rotates against the blank gear, gear tooth of required profile are machined.

Gear Milling



Gear Milling





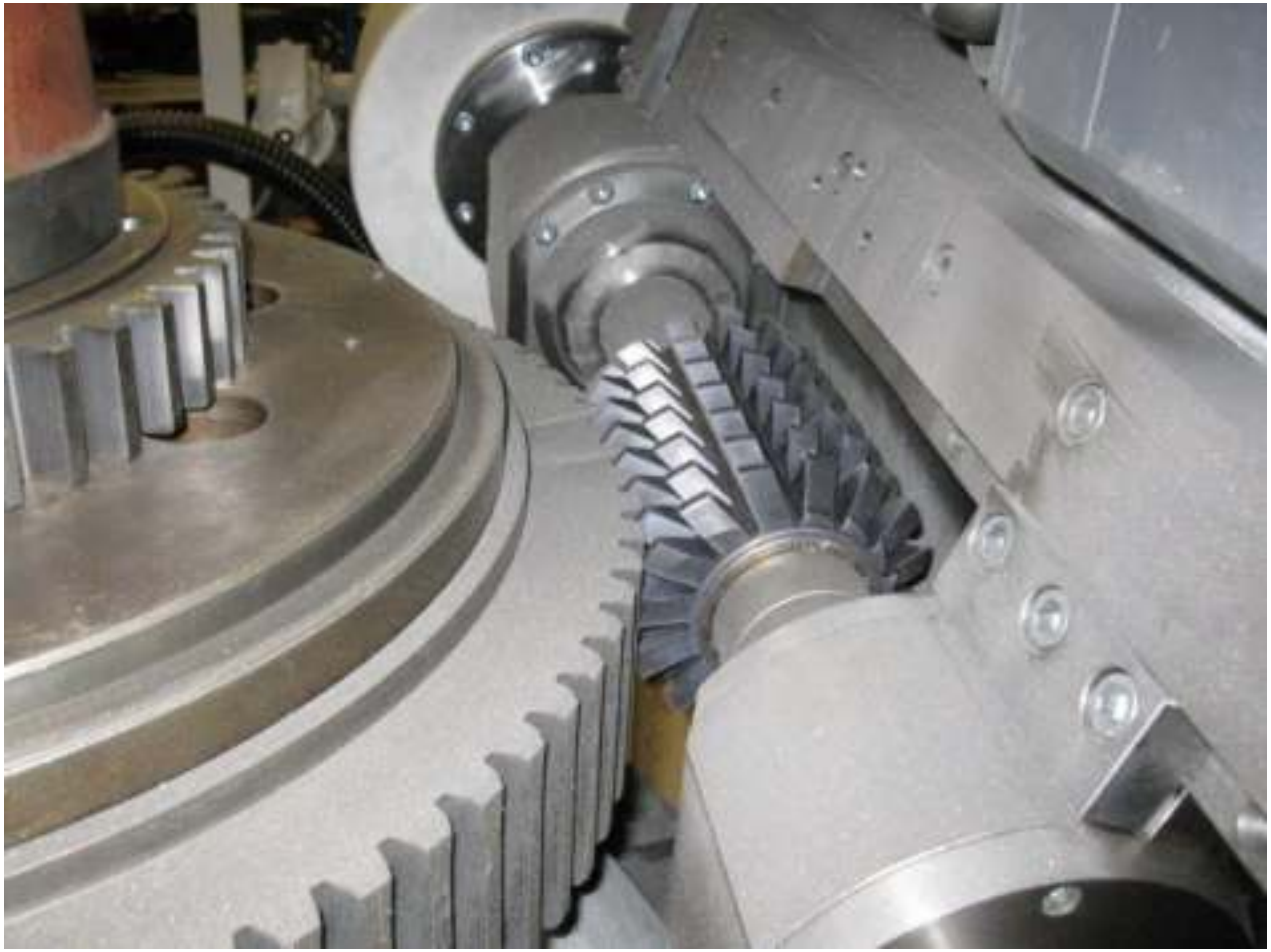
Milling Cutter

Gear Hobbing

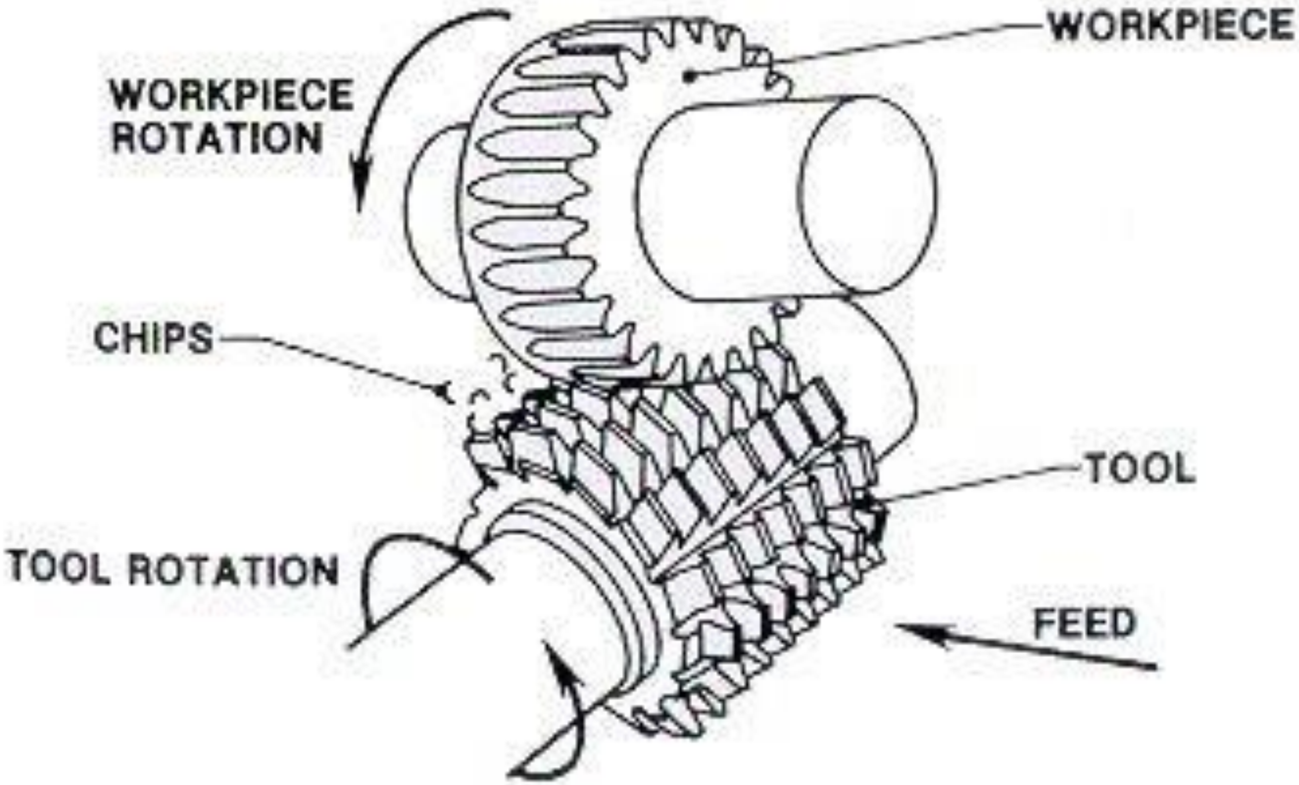
- Hobbing is a machining process for cutting gears, cutting splines, and cutting sprockets on a hobbing machine, which is a special type of milling machine. The teeth or splines are progressively cut into the workpiece by a series of cuts made by a cutting tool called a hob.

Gear Hobbing

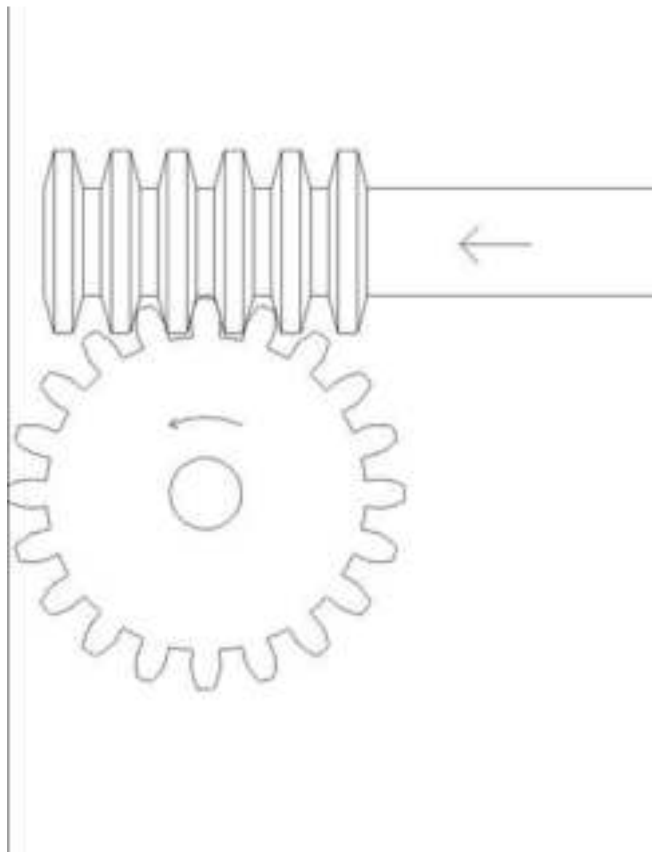
Gear Hobbing



GEAR HOBBING

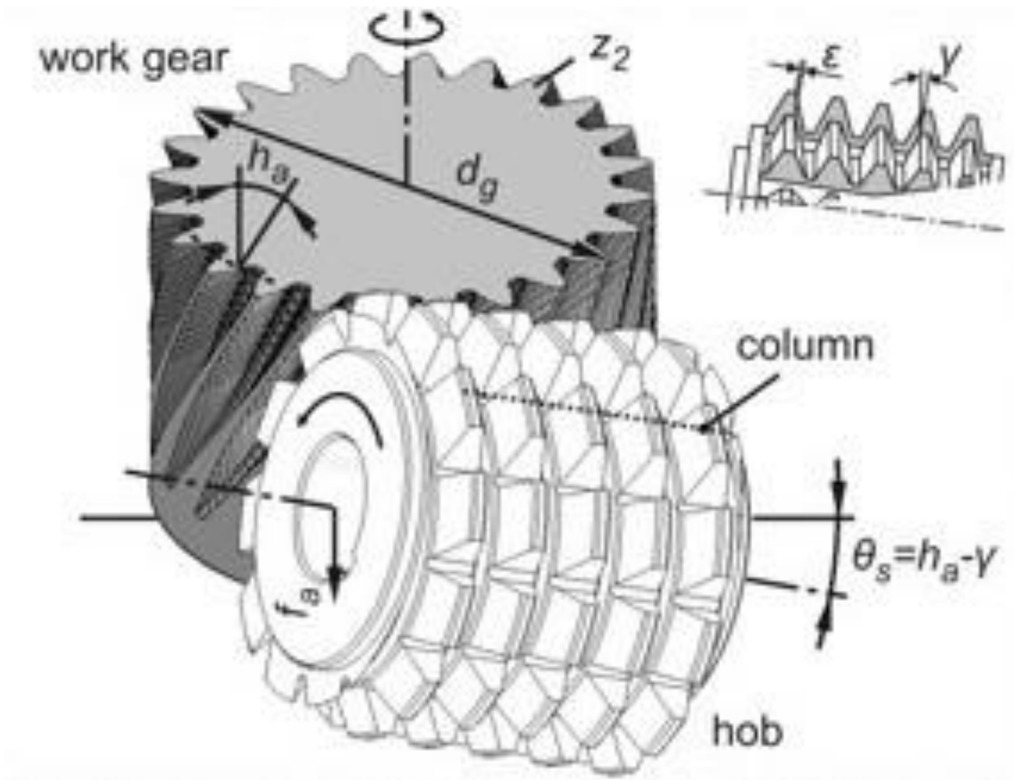


Gear Hobbing

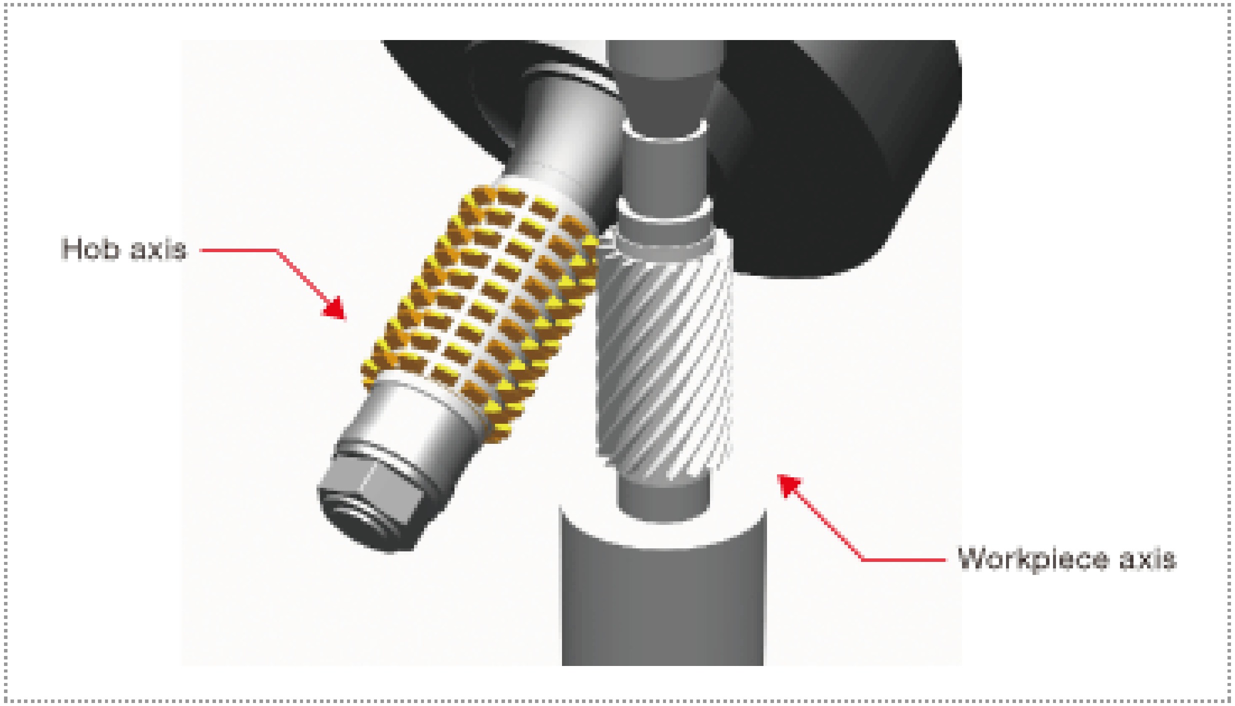


Gear hob

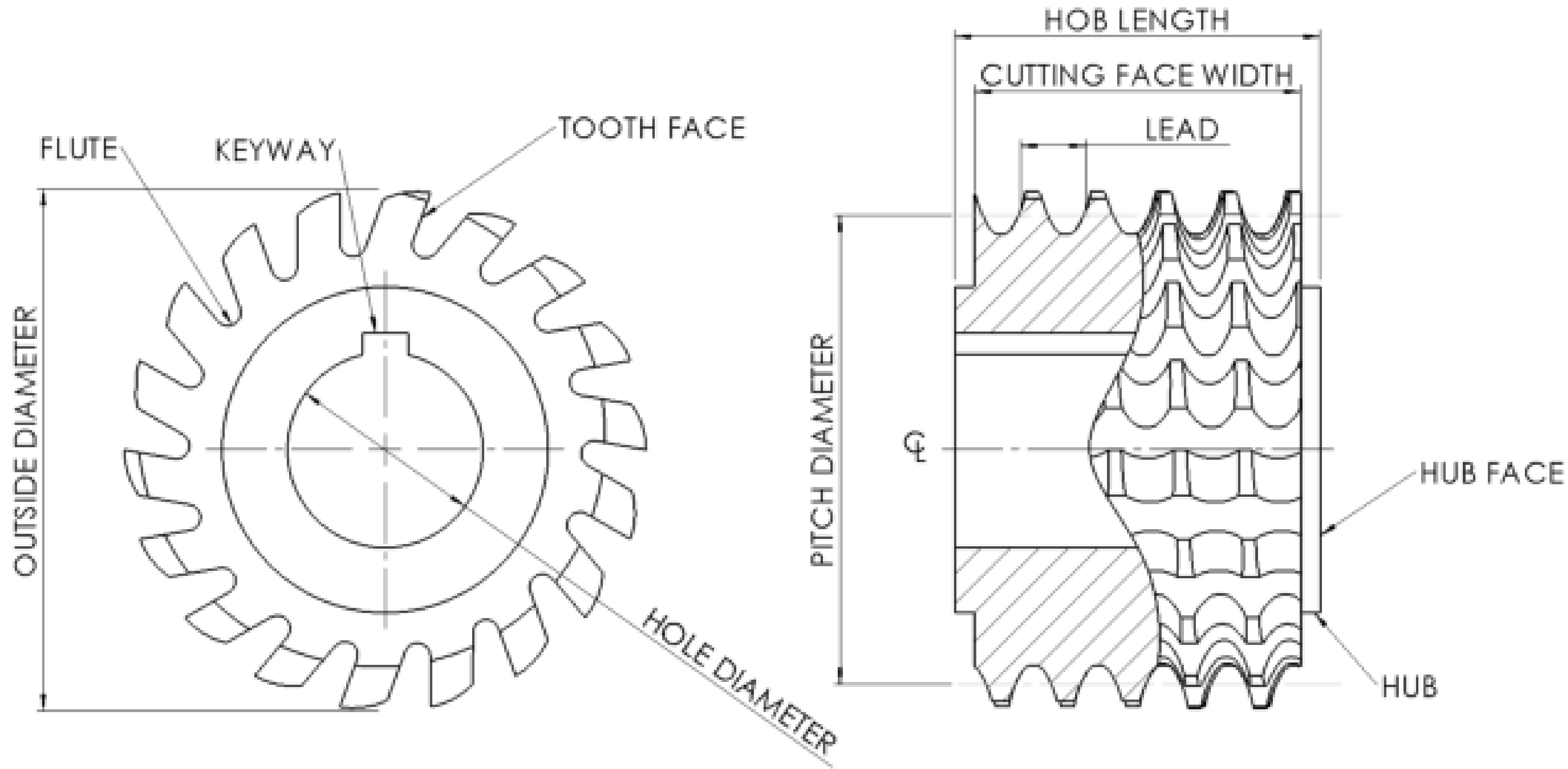
Helical gear hobbing



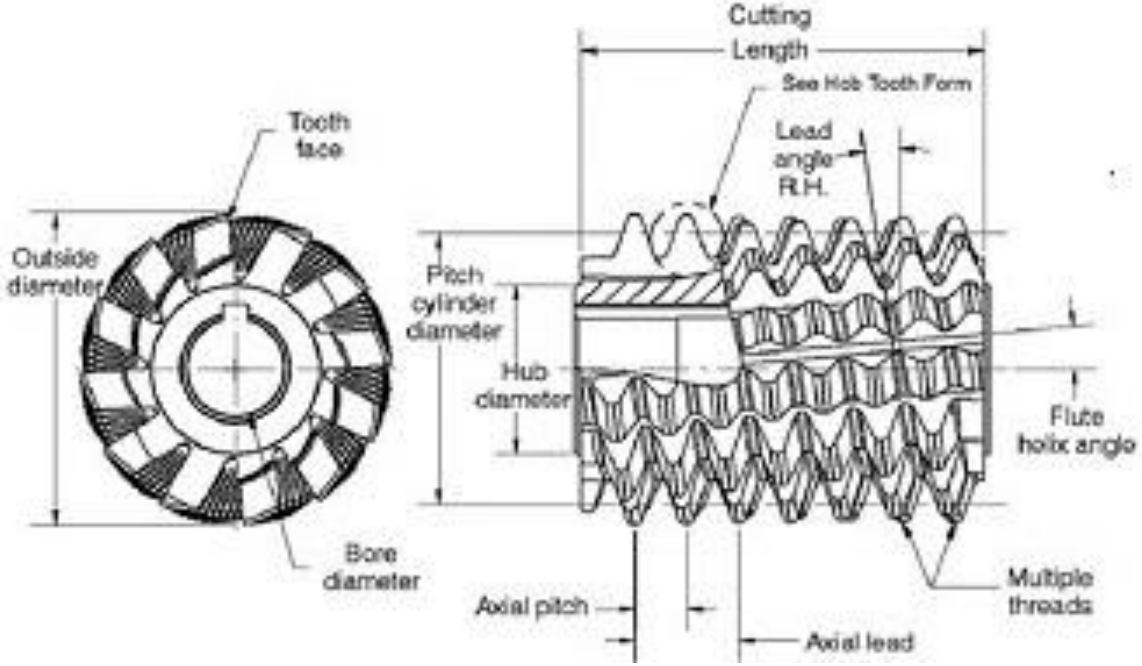
Helical gear hobbing



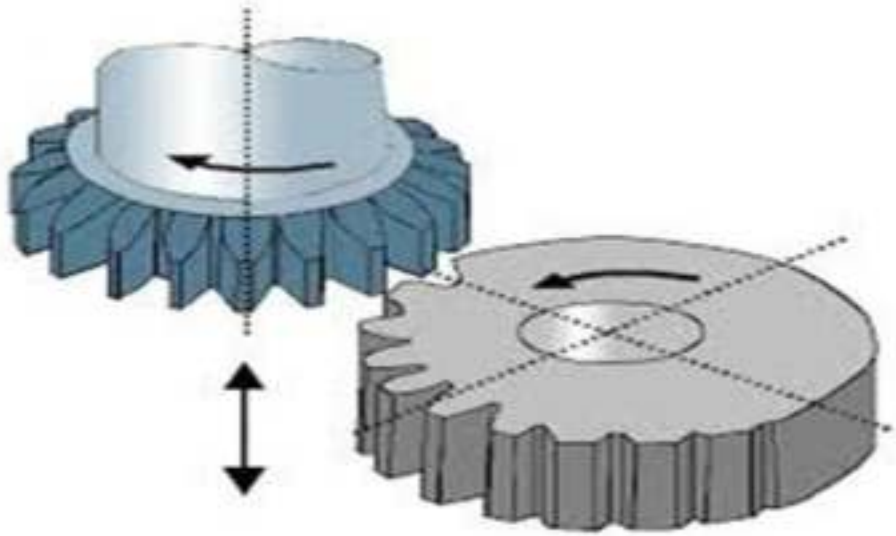
Hob dimensions



Hob nomenclature

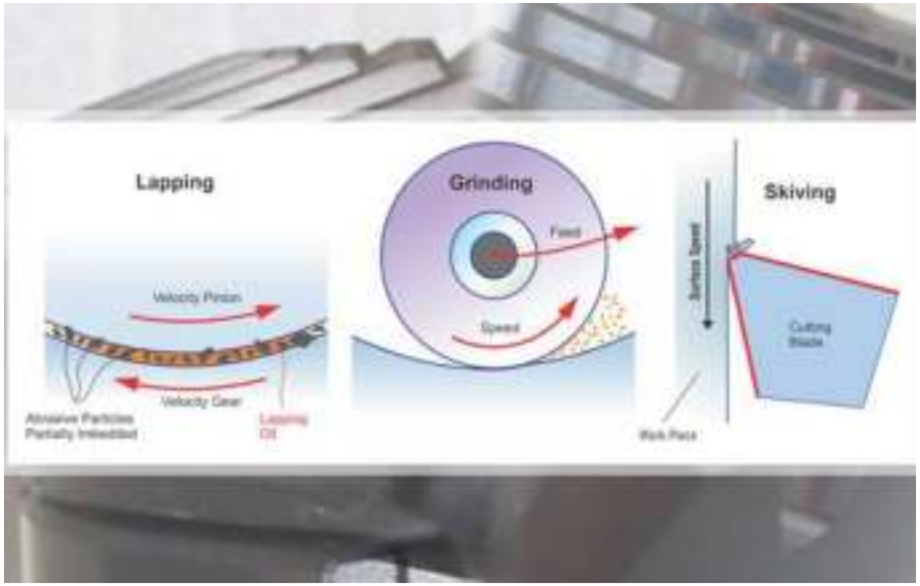


Gear Shaping



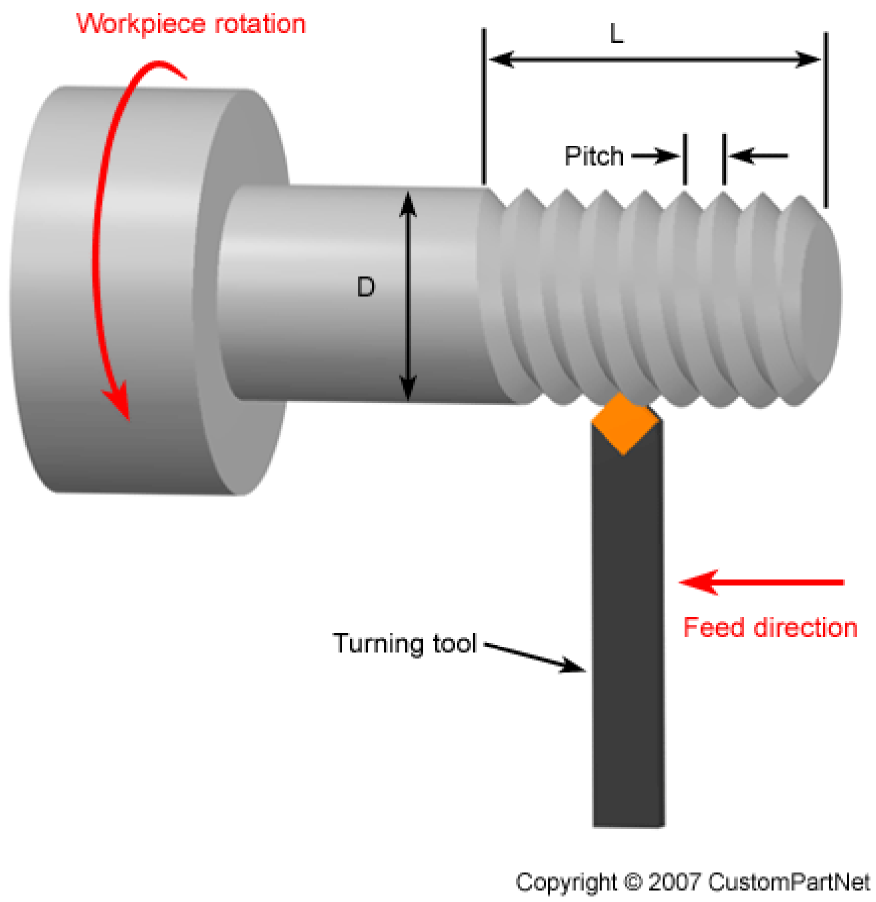
GEAR SHAPING PROCESS

Gear finishing process



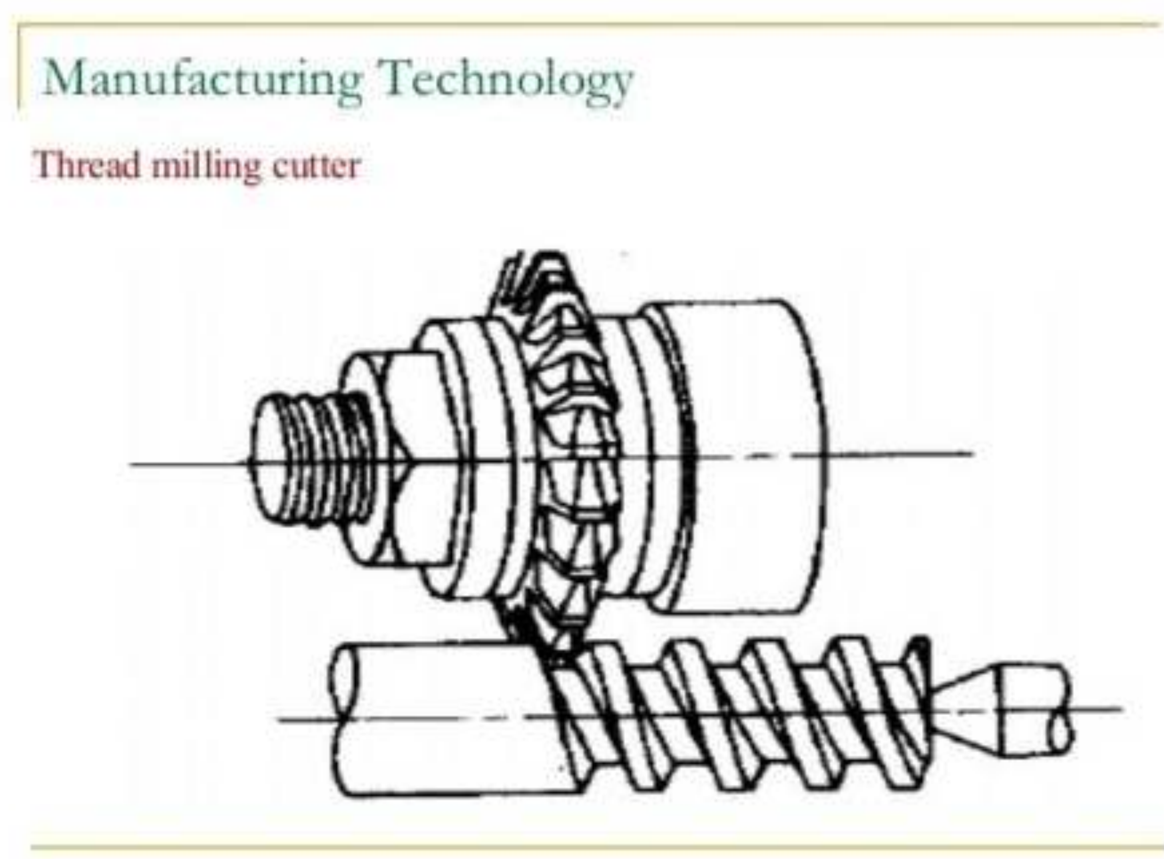
Thread Production Process

1. Lathe



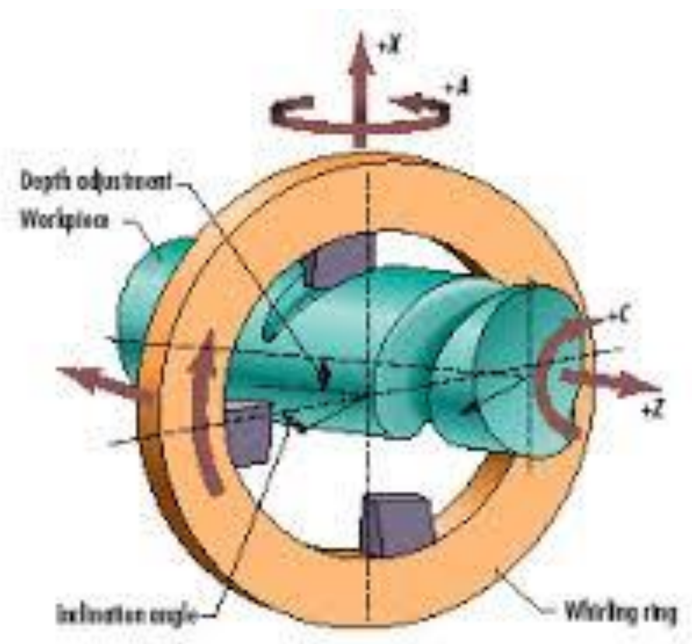
Thread Production Process

2. Thread Milling



Thread Production Process

3. Thread Whirling



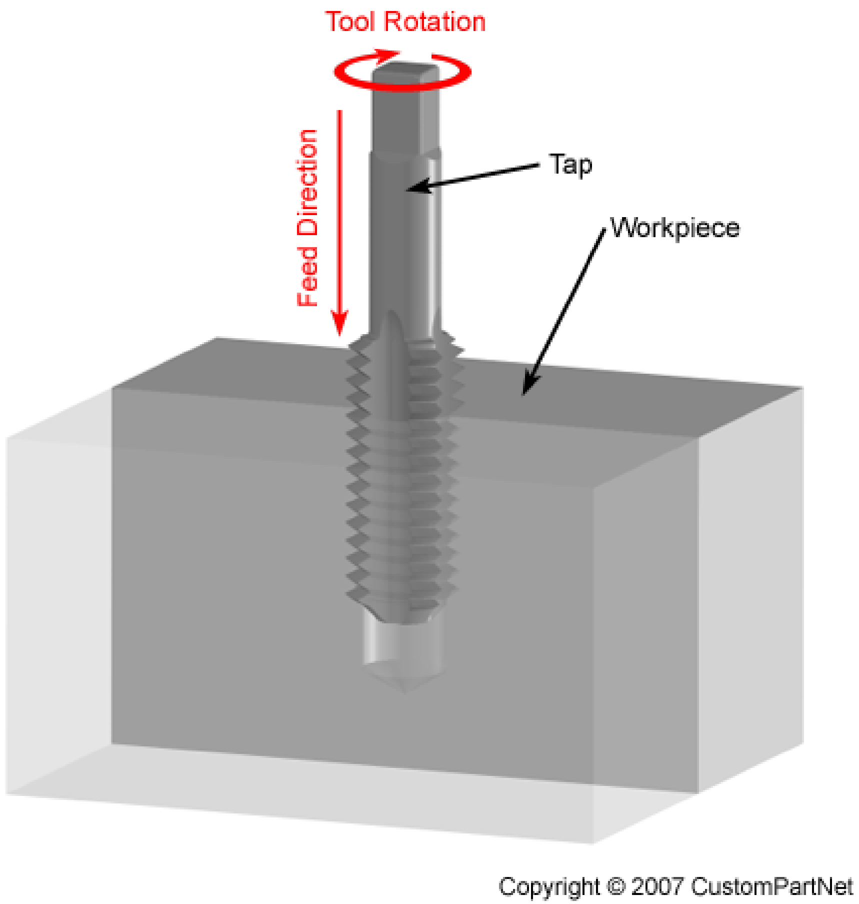
Thread Production Process
3. Thread Whirling

Thread Production Process

4. Die Threading

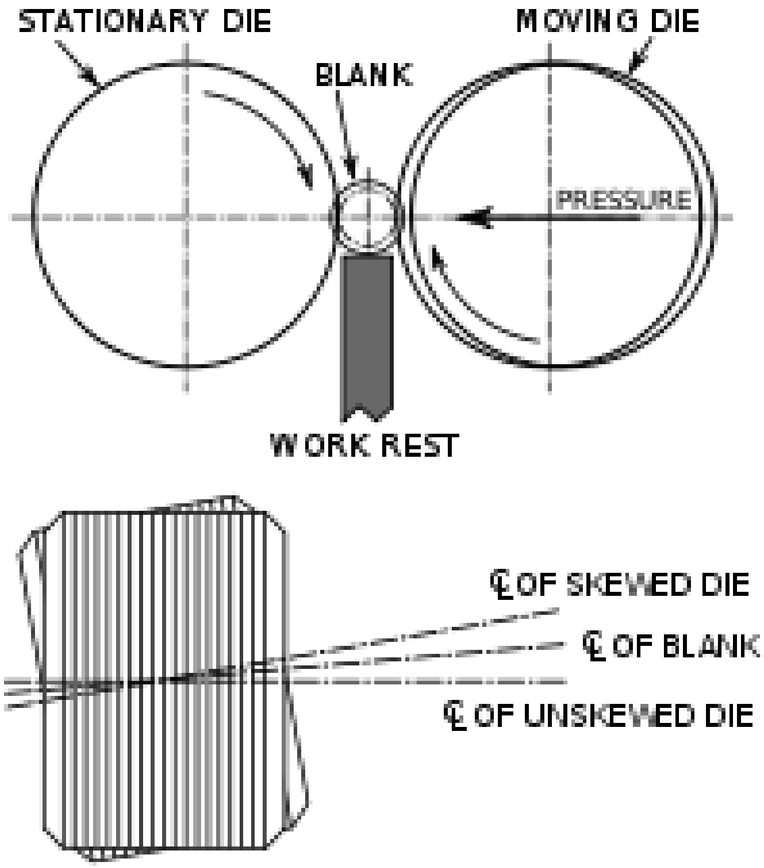
Thread Production Process

5. Tapping



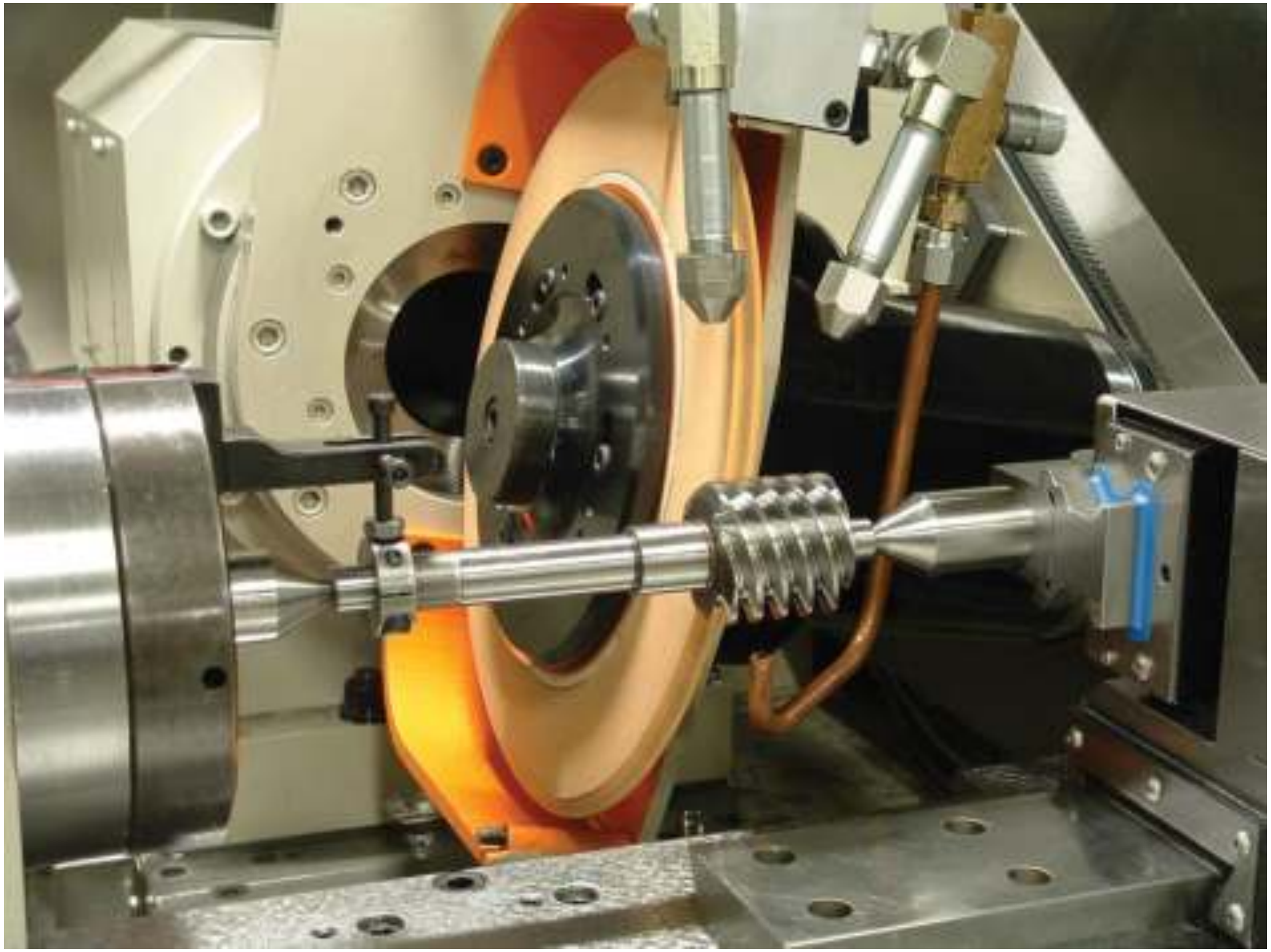
Thread Production Process

6. Thread rolling



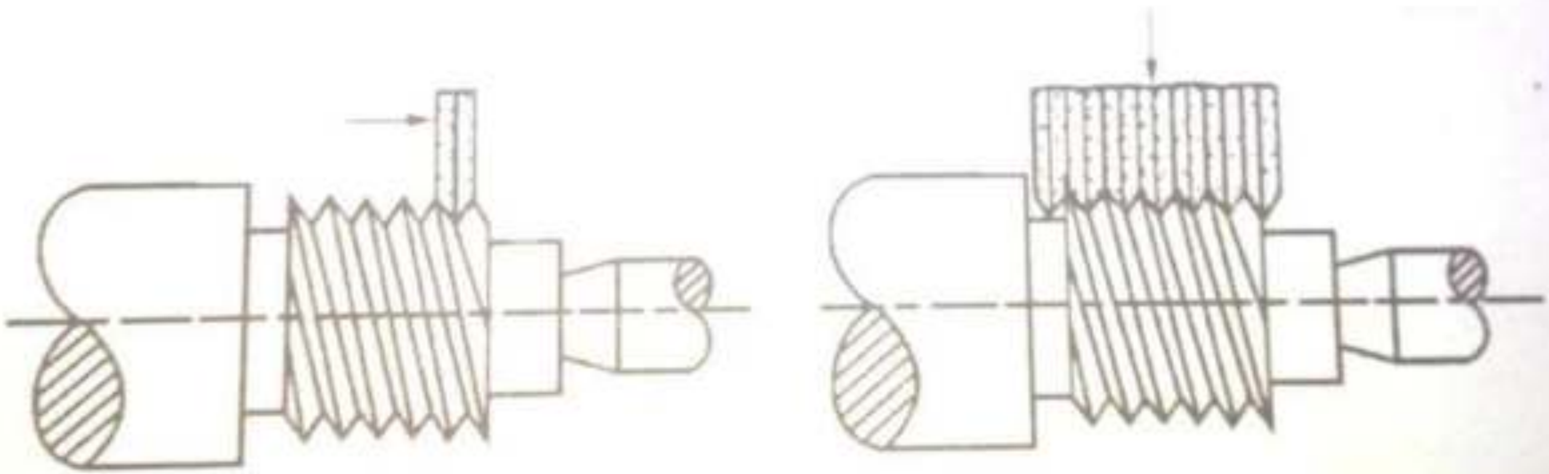
Thread Production Process

7. Thread grinding



Thread Production Process

7. Thread grinding



(a) Single Wheel Grinding

(b) Plunge Cut Grinding

THANK YOU…

METROLOGY

Introduction

- The process of expressing anything(object, property, etc) in terms of numbers or obtaining quantitative information about anything is called as measurement.
- For this an internationally accepted predefined standard i.e unit is necessary for every kind of quantity measured. Further, an instrument or apparatus is required to measure that quantity in terms of that corresponding unit.
- The science of measurement is called as metrology and when related to practice of engineering, it is called engineering metrology.

Metrology is mainly concerned with …..

1. Establishing the units of measurements, reproducing these units in the form of standards, and ensuring the uniformity of measurements
2. Developing methods of measurements
3. Errors of measurements
4. Measuring instruments and devices
5. Accuracy of measuring instruments and their care
6. Industrial inspection and its various techniques
7. Design, manufacturing and testing of gauges of all kinds

Need for measurement

- To ensure the interchangeability of the parts. i.e any two mating parts taken at random should satisfactorily mate with each other.
- To ensure the efficiency use of resources
- To provide quality products to the end use

Process of Measurement

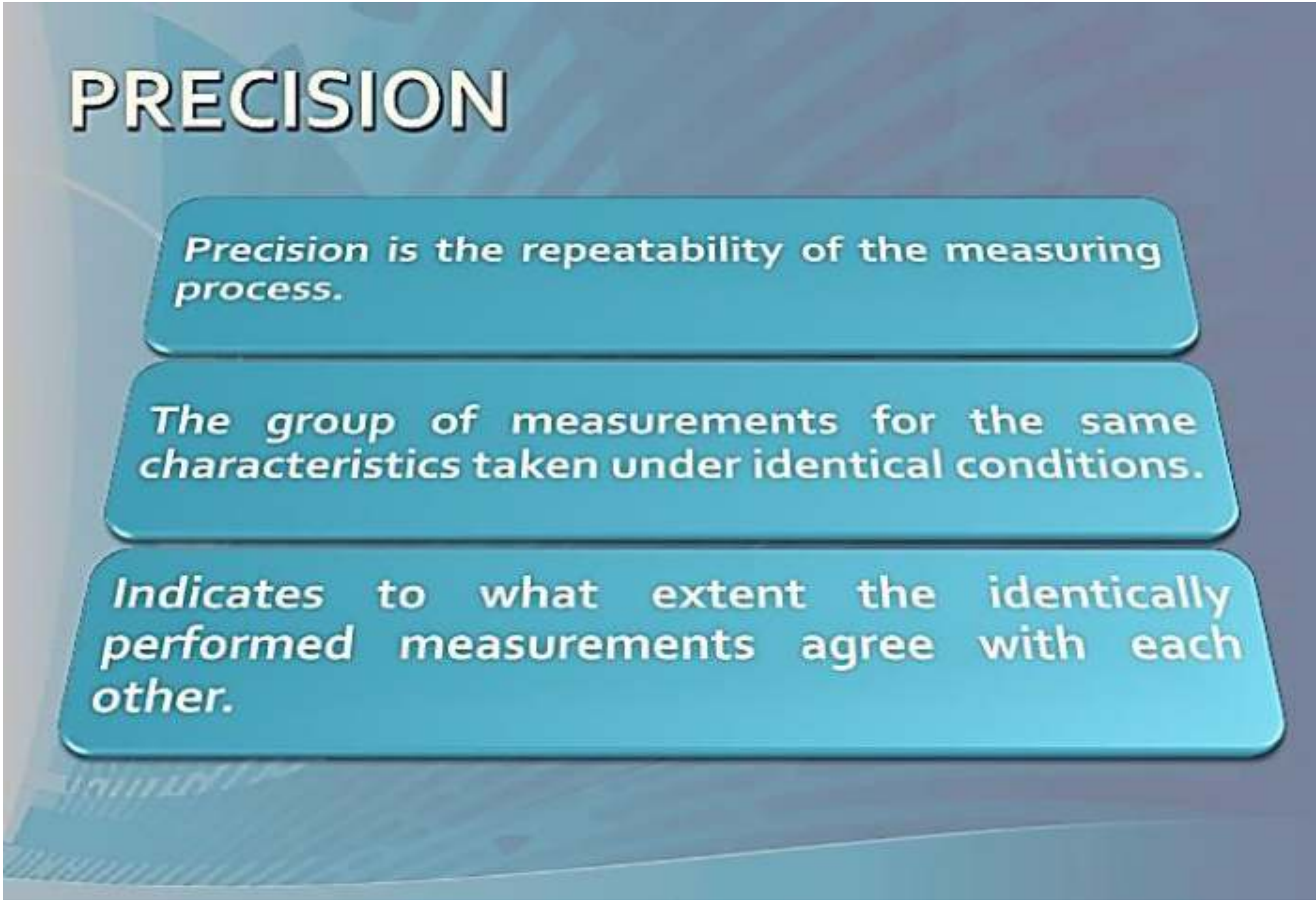
Definition

The sequence of operations necessary for the execution of measurement is called process of measurement.

Elements of measurement

1. **Measurand**: is the physical quantity or property like length, angle, diameter, thickness etc to be measured.
2. **Reference**: It is the physical quantity or property to which quantitative comparisons are made.
3. **Comparator**: It is the means of comparing measurand with some reference.

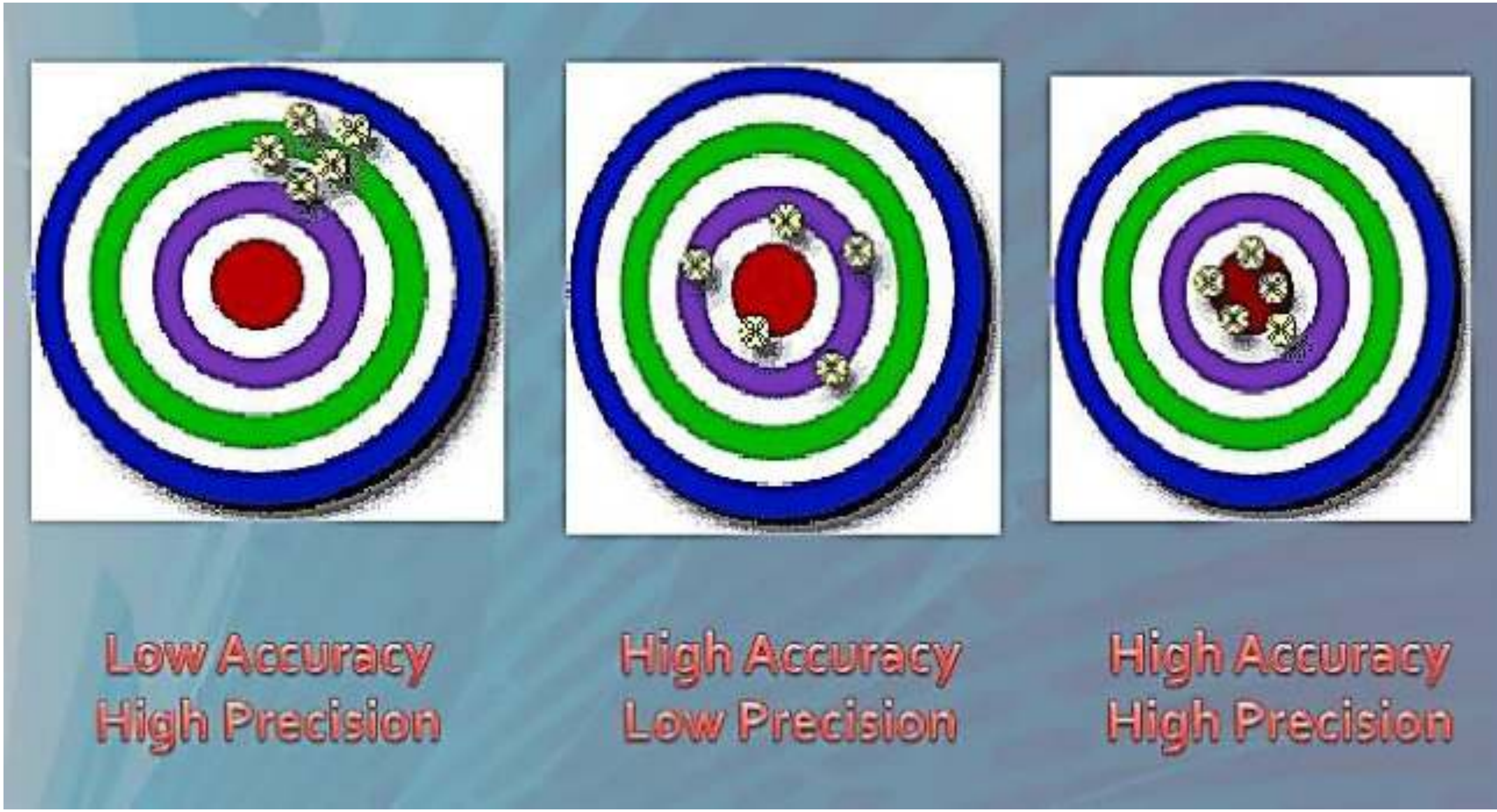
Terminologies in Measurement

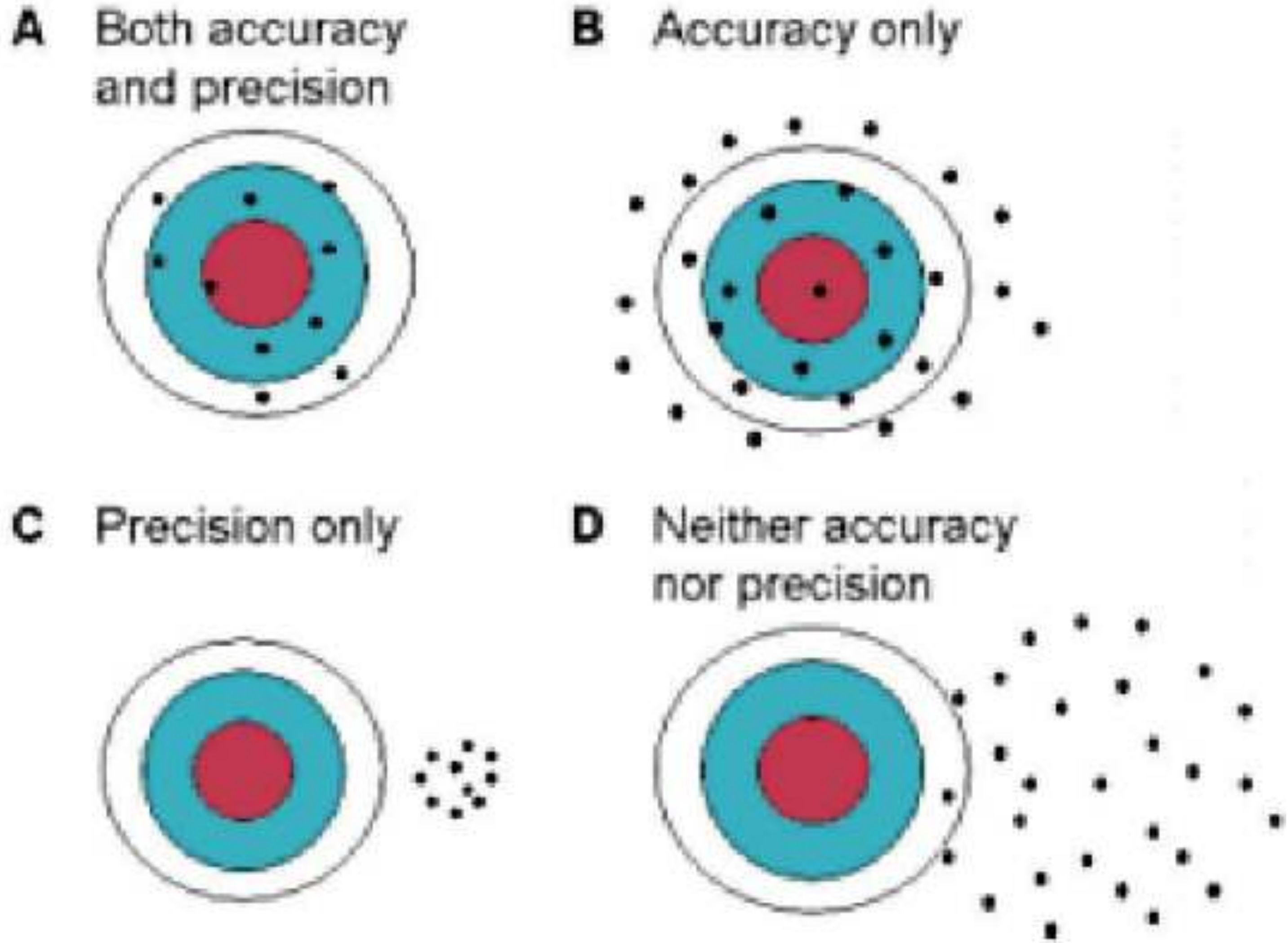


ACCURACY

It is the degree to which the measured value of the quality characteristic agree with the true value.

The difference between the true value and the measured value is known as error of measurement.


Low Accuracy
High Precision
High Accuracy
Low Precision
High Accuracy
High Precision


A Both accuracy and precision
B Accuracy only
C Precision only
D Neither accuracy nor precision

SENSITIVITY

Sensitivity may be defined as the rate of displacement of the indicating device of an instrument, with respect to the measured quantity

Sensitivity of an instrument is the ratio of the scale spacing to the scale division value.

It is also called as amplification factor or gearing ratio.

Sensitivity refers to the ability of measuring device to detect small difference in a quantity being measured. High sensitivity instruments may lead to drifts due to thermal or other effects, and the indications may be less repeatable or less precise than that of the instrument of lower sensitivity

CALIBRATION

Calibration is the process of establishing the relationship between a measuring device and the units of measure.

This is done by comparing a device or the output of an instrument to a standard having known measurement characteristics.

CALIBRATION

Calibration is the set of operations that establish, under specified conditions, the relationship between the values of quantities indicated by a measuring instrument and the corresponding values realized by standards.

Standard

Standard is defined as “something that is set up and established by authority as a rule for the measurement of a quantity, weight, value or quality”.

Example: A meter is standard established by an S.I (System International) organization for measure length.

LINE STANDARD

When length is measured as the distance between centers of two engraved lines, it is called Line Standards. Both material Standards, yard and metre are line standards.

Characteristics of Line Standards

1. A scale is quick and easy to use
2. The scale markings are subjected to wear. However, the leading ends are subjected to wear and this may lead to undersize measurements.
3. The engraved lines themselves possess thickness and it is not possible to take measurement with high accuracy limited to +0.2 mm.
4. Scales are subjected to parallax error(Reading error).
5. Hence it is requires assistance of magnifying glass or microscope to achieve sufficient accuracy.
6. A scale does not possess “built in” datum. Therefore it is not possible to align the scale with the axis of measurement.

END STANDARD

When length is expressed as the distance between centers of two flat parallel faces, it is called End Standards.

Characteristics of End Standards

1. They require more time for measurement and measure only one dimension at a time.
2. They are subjected to wear on their measuring faces.
3. These standards are highly accurate for measurement of close tolerance upto + 0.001 mm.
4. They are not subjected to parallax error (reading error).
5. End standards have “built in” datum. Hence can be easily aligned with the axis of measurement.
6. Group of slip gauges can be wrung together to build up a given size; fault wringing and careless use may lead to inaccurate result.

Differentiate between Line and End Standards

Sl no	Characteristics	Line Standard	End Standard
1.	Principle	Length is expressed as distance between 2 lines	Length is expressed as distance between 2 ends
2.	Accuracy	Ltd. To ± 0.2mm.	Highly accurate of closed tolerances to ±0.001mm
3.	Ease	Quick and easy	Time consuming and requires skill
4.	Effect of wear	Wear at only the ends	wear at measuring surfaces
5.	Alignment	Cannot be easily aligned	easily aligned
6.	Cost	low cost	high cost
7.	Parallax Effect	Subjected to parallax effect	not subjected to parallax effect

WAVELENGTH STANDARD

- In the 7th General Conference of Weights and Measures in **1927** has approved, the definition of standard of length relative to the meter is expressed in terms of wavelength of red cadmium as an alternative to the International Prototype Meter.
- Later in 11th General Conference of Weights and Measures in **1960**, Orange radiation of isotope krypton-86 was chosen for new definition for Length has approved.
- According to this standard Meter as defined as equal to 1650763.73 Wavelength of the red orange radiation of isotope krypton 86 gas.

CHARACTERISTICS OF WAVELENGTH STANDARD

- Not a material standard and hence it is not influenced by effects of variation of environmental conditions like temperature, pressure
- It need not be preserved or stored under security and thus there is not fear of being destroyed.
- It is subjected to destruction by wear and tear.
- It gives the unit of length which can be produced consistently at all times.
- The standard facility can be easily available in all standard laboratories and industries
- Can be used for making comparative measurements of very high accuracy.

Errors in Measurement

Errors in Measurement

- No Measurement is exact.
- Necessary to state not only the measured dimension but also accuracy of determination.
- Errors inherent in the method of measurement used should be kept to a minimum.

Some Simple but Embarrassing Errors

- Misreading an instrument
- Arithmetic errors
- Errors in units

Types of Errors

- Controllable Errors
  - Environmental Conditions
  - Elastic Deformation Due to Loading
  - Alignment Errors
  - Parallax Errors
- Non-Controllable Errors
  - Scale Errors
  - Reading Errors
  - Linearity
  - Hysteresis
  - Repeatability & Random Errors

Controllable Errors - Environmental

- Temperature
- Pressure
- Humidity
- Vibration
- Dirt
- CO_2 content
- Refractive index of atmosphere

Controllable Errors - Environmental

- Temperature
  - International Standard of Measurement – 20ºC (68ºF)
  - Allow for temperature stabilization after handling
- 20 minutes per 25mm length for high precision measurement
- Temperature Compensation

$$\text{Error} = l\alpha(t - t_s)$$

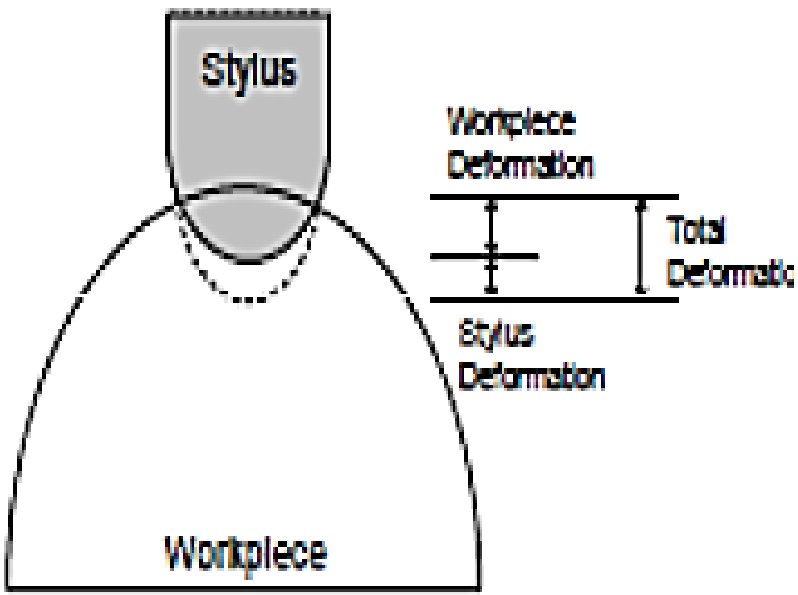
l = nominal length

α = thermal coefficient of expansion

$(t - t_s)$ = deviation from standard temperature

Controllable Errors - Loading

- Stylus Pressure: The pressure by which the workpiece is pressed by measuring.



$$\text{Deflection} = 1.774 W^{2/3} (k_1 + k_2)^{2/3} \left(\frac{1}{R_1} + \frac{1}{R_2} \right)^{1/3}$$

W = Stylus pressure

$$k_1 = \frac{1 - \upsilon_1^2}{E_1}$$

$$k_2 = \frac{1 - \upsilon_2^2}{E_2}$$

R_1 = Radius of Stylus

R_2 = Radius of Workpiece

E_1 = Stylus Modulus of Elasticity

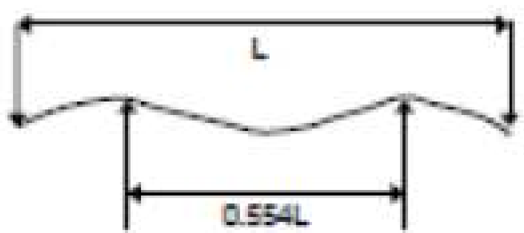
E_2 = Workpiece Modulus of Elasticity

υ_1 = Stylus Poisson's Ratio

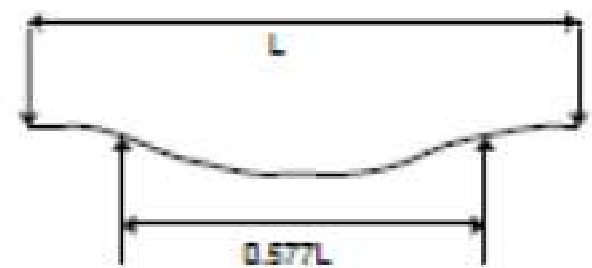
υ_2 = Workpiece Poisson's Ratio

Controllable Errors - Loading

- Effects of Supports
  - Large objects will sag under their own weight
  - Optimal placement of supports
  - Minimization of deflection
  - Placement of Supports



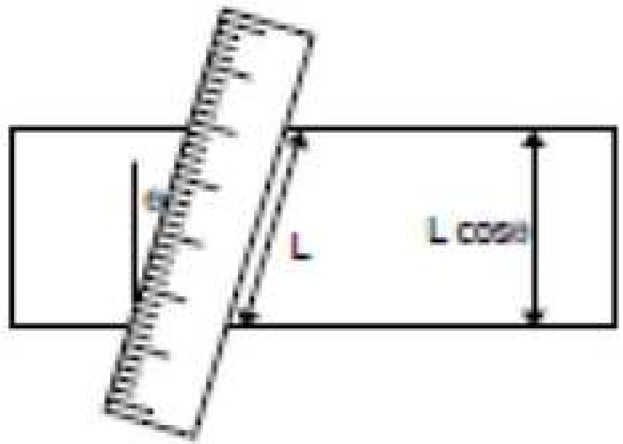
Deflection at ends = Deflection at center



Zero slope at ends

Controllable Errors – Cosine Errors (Alignment Errors)

- Cosine Error –
  - The error generated when the scale and desire dimension are not aligned.



Controllable Errors – Abbe Error (Alignment)

- Ernst Abbe (1840 – 1905)

  - A co-founder of Zeiss, Inc.
  - Provided numerous technical innovations in optical theory.
  - Proposed the Principle of Alignment

Controllable Errors – Abbe Error (Alignment)

- **<u>Abbe's Principle of Alignment:</u>**

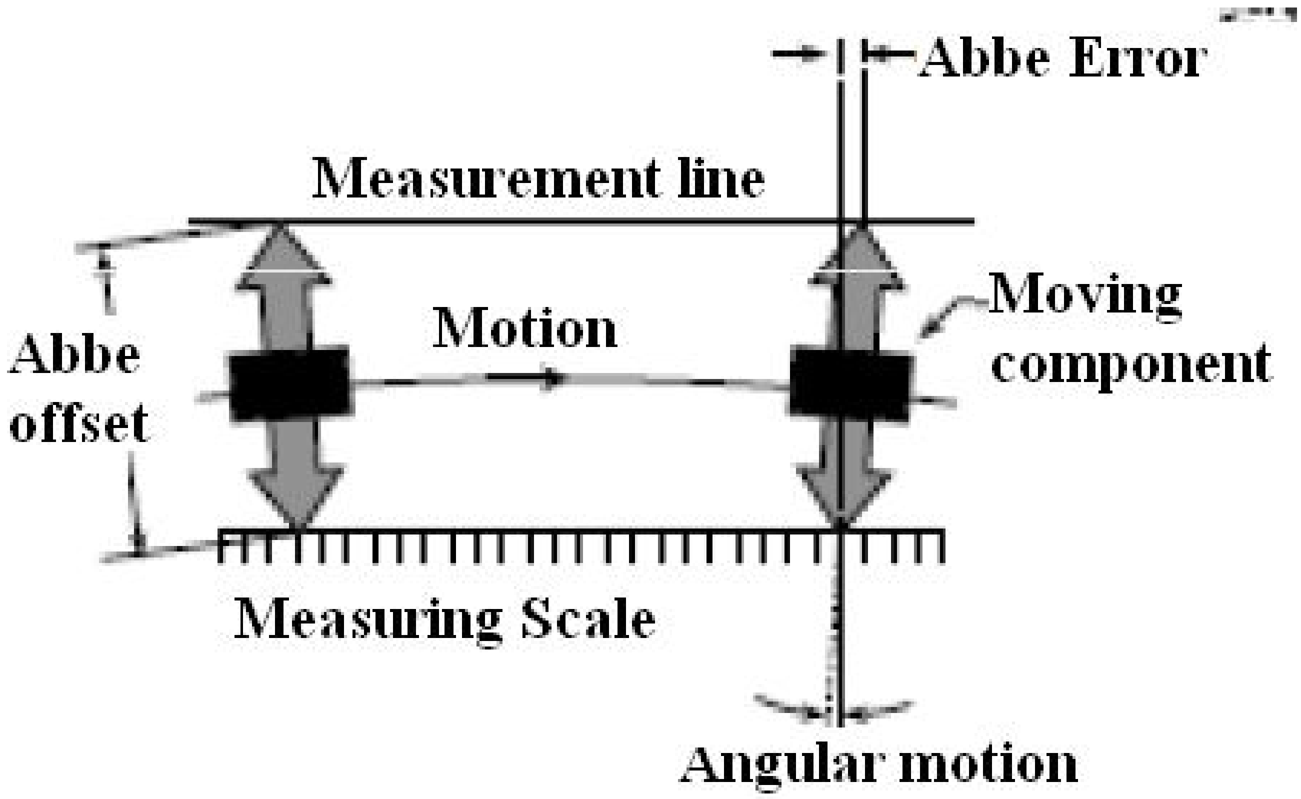
  The scale of a linear measuring system should be collinear with the spatial dimension or displacement to be measured. If this is not the case, the measurement must be corrected for the associated Abbe Error.

- **<u>Abbe Error:</u>**

Abbe Error = (Abbe offset)*(sine of angular disorientation)

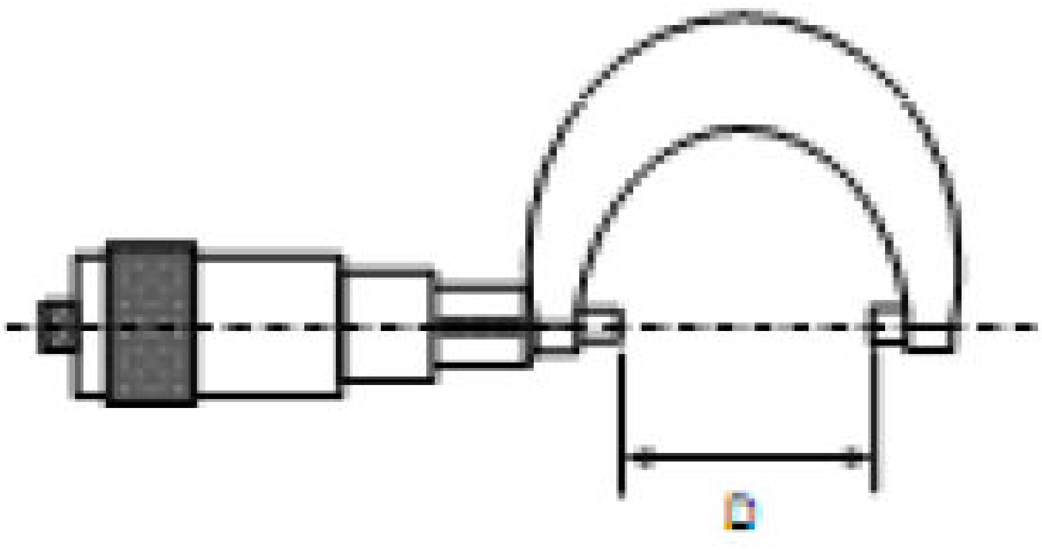
- **<u>Abbe Offset:</u>**
  - The distance between the desired point of measurement and the reference line of the measuring system.

Controllable Errors – Abbe Error (Alignment)



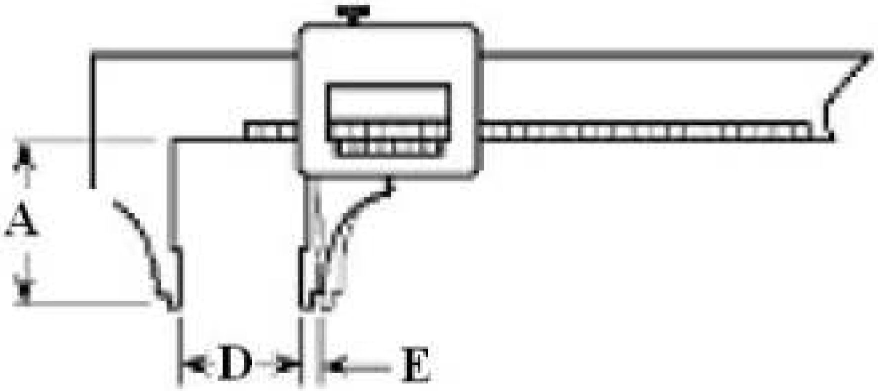
Controllable Errors – Abbe Error (Alignment)

- Abbe Principle – Micrometer a Good Result
  - Graduations are located along the same axis as the measurement.



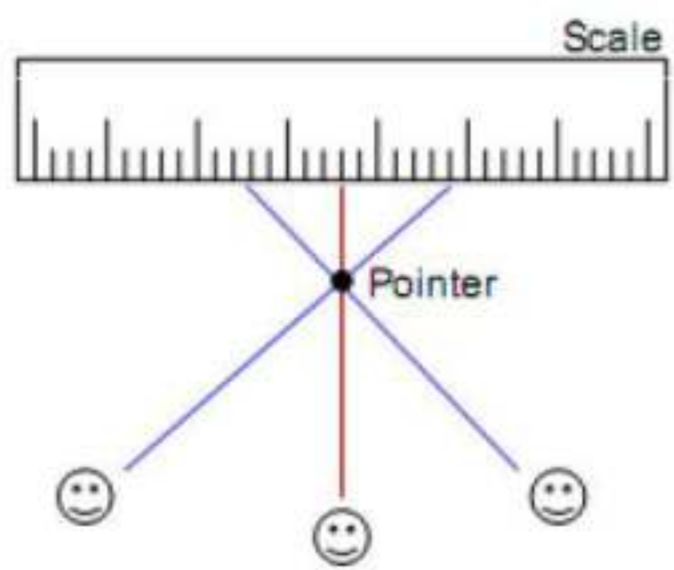
Controllable Errors – Abbe Error (Alignment)

- Abbe Principle – Caliper a Bad Result
  - Graduations are not on the same axis as the measurement
  - Abbe Error (E) = A*sin(θ)



Controllable Errors - Parallax

- Parallax Error
  - The error that occurs when the pointer on a scale is not observed along a line normal to the scale



Random Errors

- Random errors are due to imprecision of measurements and can lead to a reading above or below the "true" value.
- Examples:
  - poor technique, different reaction times etc.
- These can be reduced by the use of more precise measuring equipment or through repeat measurements.

Systematic Error

- Have definite value and an assignable cause, can be measured.
- Are of the same magnitude for replicate measurement made in the same way
- Affect the accuracy of result
- Causes the mean of the data set to differ from the accepted value
- Generally unidirectional w.r.t true value i.e. either too high or too low located in same side(same sign error/ bias) under the control of analytical chemist and can be corrected after careful investigation.
- Reproducible and can be predicted and also can be avoidable after careful investigation

Random and Systematic Error

Random Error

1) fluctuations in the person's current mood.
2) misreading or misunderstanding the questions
3) measurement of the individuals on different days or in different places.

These error may cancel out as you collect many samples

Systematic Error

Sources of error including the style of measurement, tendency toward self-promotion, cooperative reporting, and other conceptual variables are being measured.

Random Errors

Random errors in experimental measurements are caused by unknown and unpredictable changes in the experiment. These changes may occur in the measuring instruments or in the environmental conditions.

Examples of causes of random errors are:

- electronic noise in the circuit of an electrical instrument,
- irregular changes in the heat loss rate from a solar collector due to changes in the wind.

Systematic Errors

- Systematic errors in experimental observations usually come from the measuring instruments. They may occur because: there is something wrong with the instrument or its data handling system, or
- because the instrument is wrongly used by the experimenter.

1. Two types of systematic error can occur with instruments having a linear response: **Offset** or **zero setting error** in which the instrument does not read zero when the quantity to be measured is zero.
2. **Multiplier** or **scale factor error** in which the instrument consistently reads changes in the quantity to be measured greater or less than the actual changes.

Example

Random errors You measure the mass of a ring three times using the same balance and get slightly different values: 17.46 g, 17.42 g, 17.44 g Take more data.

Random errors can be evaluated through statistical analysis and can be reduced by averaging over a large number of observations.

Systematic errors The cloth tape measure that you use to measure the length of an object had been stretched out from years of use. (As a result, all of your length measurements were too small.)The electronic scale you use reads 0.05 g too high for all your mass measurements (because it is improperly tared throughout your experiment).

•**Systematic errors** are difficult to detect and cannot be analyzed statistically, because all of the data is off in the same direction (either to high or too low). Spotting and correcting for systematic error takes a lot of care.

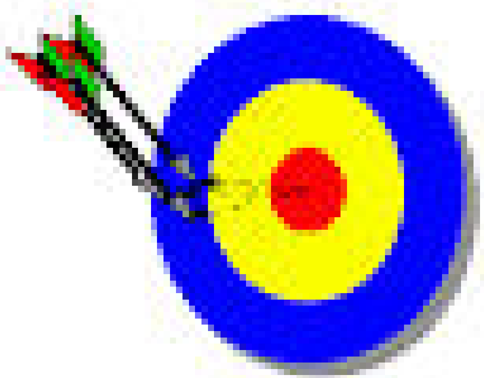
Two Types of Error

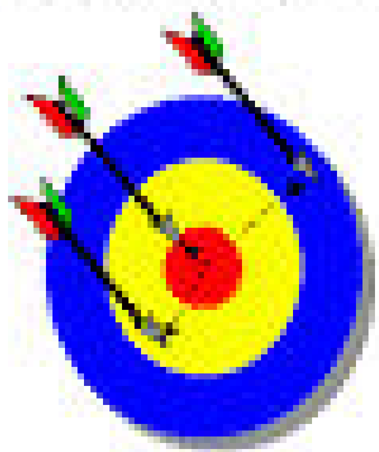
<u>systematic error</u>

- poor accuracy
- definite causes
- reproducible

<u>random error</u>

- poor precision
- nonspecific causes
- not reproducible





Summary

- All measurements are subject to error
- The possible deviation from the stated measurement should be estimated and given as an accuracy of determination
- Accuracy of determination can be improved by repeating the measurement a number of times and stating the mean value
- Statistical methods can be used to express the confidence in a particular measurement.

Linear Measurement

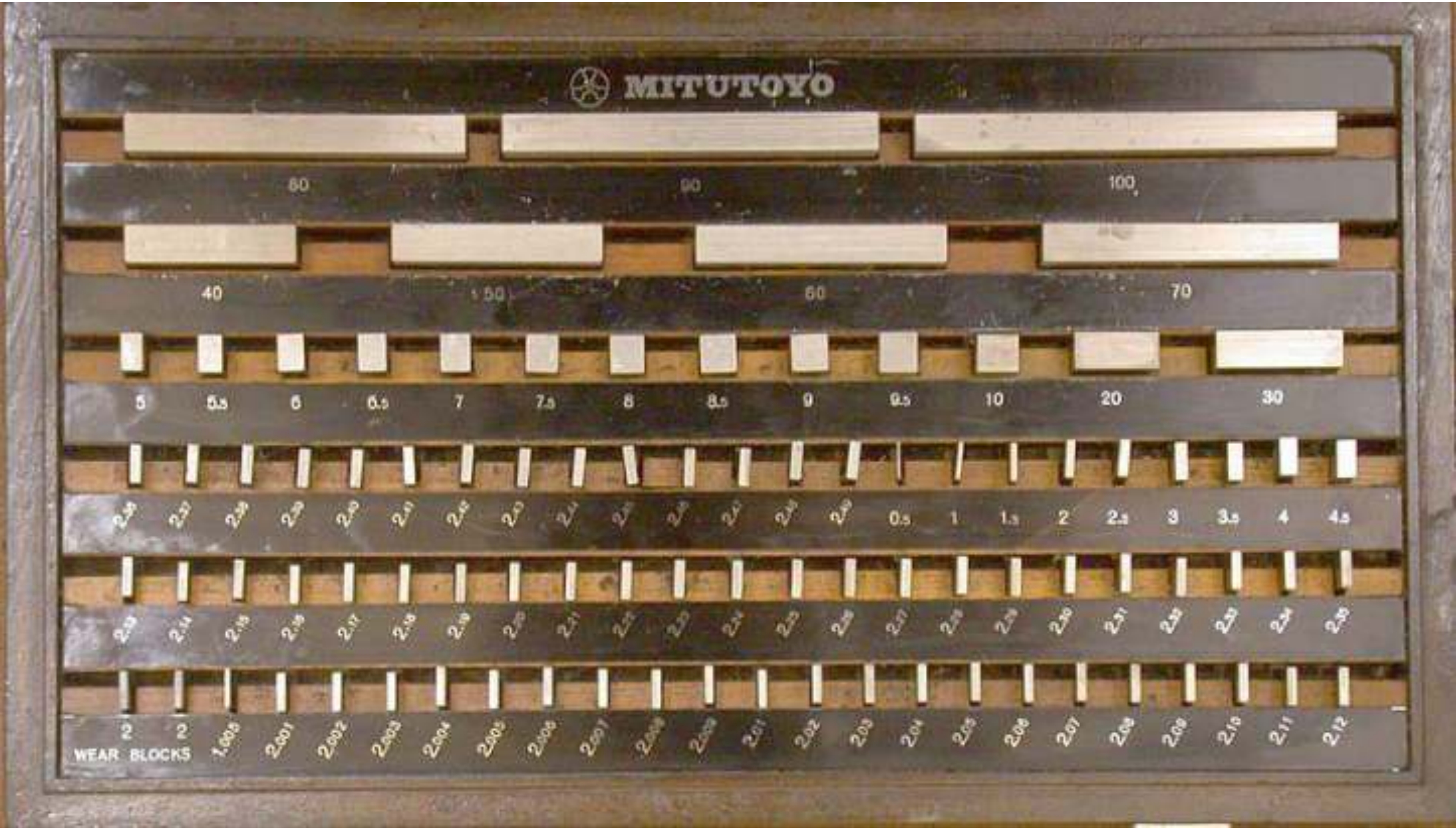
SLIP GAUGE

INTRODUCTION

- A **slip gauge** (also known as a **gage block**, **Johansson gauge**, **gauge block** , or **Jo block**) are a system for producing precision lengths.

- Invented in 1896 by Swedish machinist Carl Edvard Johansson.

- They are used as a reference for the calibration of measuring equipment used in machine shops, such as micrometers, sine bars, calipers, and dial indicators (when used in an inspection role).



MITUTOYO
80
90
100
40
50
60
70
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
20
30
0.5
1
1.5
2
2.5
3
3.5
4
4.5
2
2
WEAR BLOCKS
1,0005
2,001
2,002
2,003
2,004
2,005
2,006
2,007
2,008
2,009
2,01
2,02
2,03
2,04
2,05
2,06
2,07
2,08
2,09
2,10
2,11
2,12

STRUCTURE

- Each gauge block consists of a block of metal or ceramic with two opposing faces precisely flat and parallel, a precise distance apart.

- Standard gauge blocks are made of a hardened steel alloy, while calibration gauge blocks are often made of tungsten carbide or chromium carbide because it is harder and wears less.

- Gauge blocks come in sets of blocks of various lengths, along with two wear blocks, to allow a wide variety of standard lengths to be made up by stacking them.

WRINGING

Wringing is the process of sliding two blocks together so that their faces lightly bond.

It is believed to be a combination of:

- Air pressure applies pressure between the blocks because the air is squeezed out of the joint.
- Surface tension from oil and water vapour that is present between the blocks.
- Molecular attraction occurs when two very flat surfaces are brought into contact.
- This force causes gauge blocks to adhere even without surface lubricants, and in a vacuum.

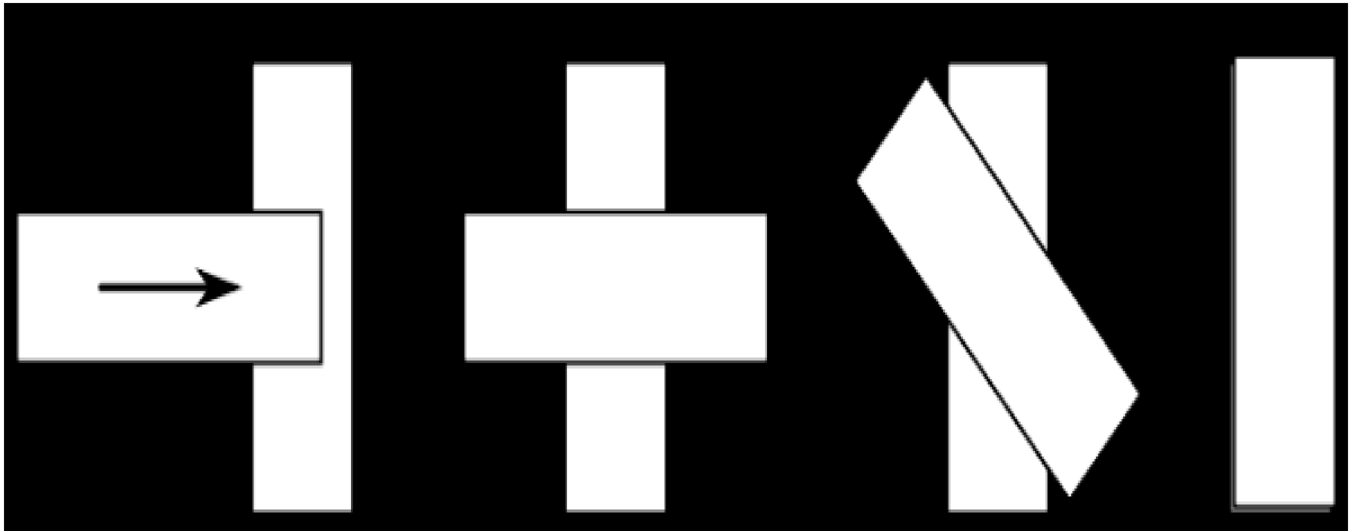
The process of wringing involves four steps:

1. Wiping a clean gauge block across an oiled pad.

2. Wiping any extra oil off the gauge block using a dry pad.

3. The block is then slid perpendicularly across the other block while applying moderate pressure until they form a cruciform.

4. Finally, the block is rotated until it is inline with the other block.



- Use the blocks are re-oiled or greased to protect against corrosion.

- The ability for a given gauge block to wring is called *wringability*.

- It is officially defined as "the ability of two surfaces to adhere tightly to each other in the absence of external means."

CLASSIFICATION OF SLIP GAUGE

Slip gauges are classified according to their guaranteed accuracy :

- AA for master slip gauges, A for reference purpose, and B for working slip gauges.

As regards grades or classes of slip gauges, these could also be designed in five grades :

- **Grade 2.** This is the workshop grade. Typical uses include setting up machine tools, positioning milling cutters and checking mechanical widths.

- **Grade 1:** Used for more precise work, such as that carried out in a good-class toolroom. Typical uses include setting up sine bars and sine tables and checking gap gauges.

- **Grade 0:** This is more commonly known as the Inspection grade, and its use is confined to toolroom or machine shop inspection.

- **Grade 00:** This grade would be kept in the Standard Room and would be kept for work of the highest precision only.

- Calibration grade : This is a special grade, with the actual sizes of the slips stated or calibrated on a special chart supplied with the set

BASIC FORMS OF SLIP GAUGES

- There are rectangular, square with centre hole, and square without centre hole.

- Rectangular form is the more widely used (32 mm x 9 mm.).

- Due to their large surface area, square slip gauges wear longer and adhere better to each other when wrung to high stacks.
- Square blocks with centre holes are used to permit the use of tie rods as an added assurance against the wrung stocks falling apart while handling.

WORKING WITH SLIP GAUGES

- In use, the blocks are removed from the set, cleaned of their protective coating (petroleum jelly or oil) and *wrung together* to form a stack of the required dimension, with the minimum number of blocks.
- Gauge blocks are calibrated to be accurate at 68 °F (20 °C) and should be kept at this temperature when taking measurements.
- The wear blocks, made of a harder substance like tungsten carbide, are included at each end of the stack, whenever possible, to protect the gauge blocks from being damaged in use.

In metric units, sets of 103, 76, 48 and 31 pieces are available.

Metric unit sets of 103 pieces are made up as follows :

49 pieces with a range of 1.01 mm to 1.49 mm in steps of 0.01 mm.

49 pieces with a range of 0.50 to 24.50 mm in steps of 0.50 mm.

4 pieces of 25, 50, 75 and 1000 mm respectively and 1 piece extra of 1.005 mm.

Slip gauge set of 56 slips is made up as shown below :

9 slips 1.001 to 1.009 in steps of 0.001 mm

9 slips 1.01 to 1.09 in steps of 0.01 mm

9 slips 1.0 to 1.9 in steps of 0.1 mm

25 slips 1 to 25 in steps of 1.0 mm

3 slips 25 to 75 in steps of 25 mm and Slip of 1.0005 mm.

SELECTING SLIP GAUGES FOR REQUIRED DIMENSION

- Always start with the last decimal place.

- Eg:

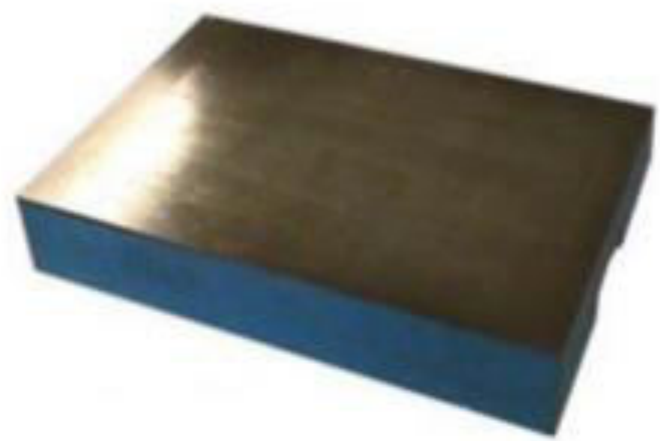
if the required dimension is 58.975 mm.

- 50.975—1.005 = 57.970 mm.
- Take second decimal place
- The remainder is 57.970 – 2.47 = 55.500 mm.
- Next for 55.500 mm, we choose 5.500 mm piece and finally 50.000 mm piece.
- 50.000 + 5.500 + 2.47 + 1.005 = 58.975 mm.
- All these four slip gauges are wrung properly to get required dimension.

Q 1. Building a size of 43.716 mm, 55.87mm, 30.87 mm and 23.258 mm with minimum number of slip gauges

Surface plate

- The surface plate has a high degree of flatness. The flat surface is being used as a datum surface for marking out and for measuring purposes. It is also called surface table if it can stand on the floor.



- Most surface plates are rectangular having 4:3(L:W) ratio.
- Surface plates must be calibrated on a regular basis to ensure that chipping, warping or wear has not occurred.
- A common problem with surface plates are specific areas or a section that is frequently used by another tool (such as a height gauge) that will cause wear to a specific point resulting in an uneven surface and reduced overall accuracy to the plate.

5.1 MAINTAINING THE SURFACE PLATE

♦ You should

1- Keep the surface in a good condition.

2- Keep the surface lightly oiled to prevent corrosion.

3- Take care when placing marking out tools on the surface.

♦ You should not

1- Place anything on the surface that would damage it.

2- Drop tools on the surface.

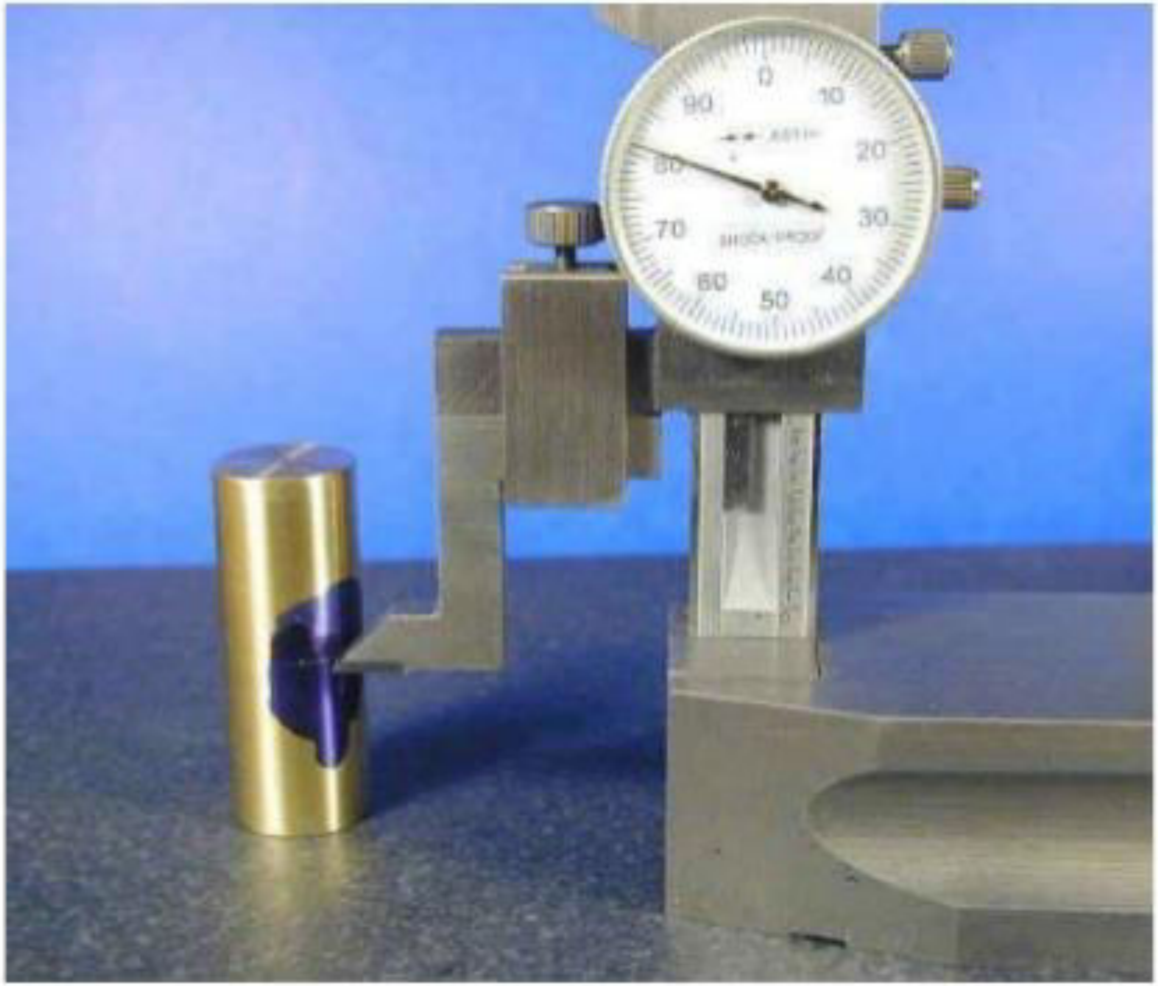
3- Hammer on the surface.

Height Gauge

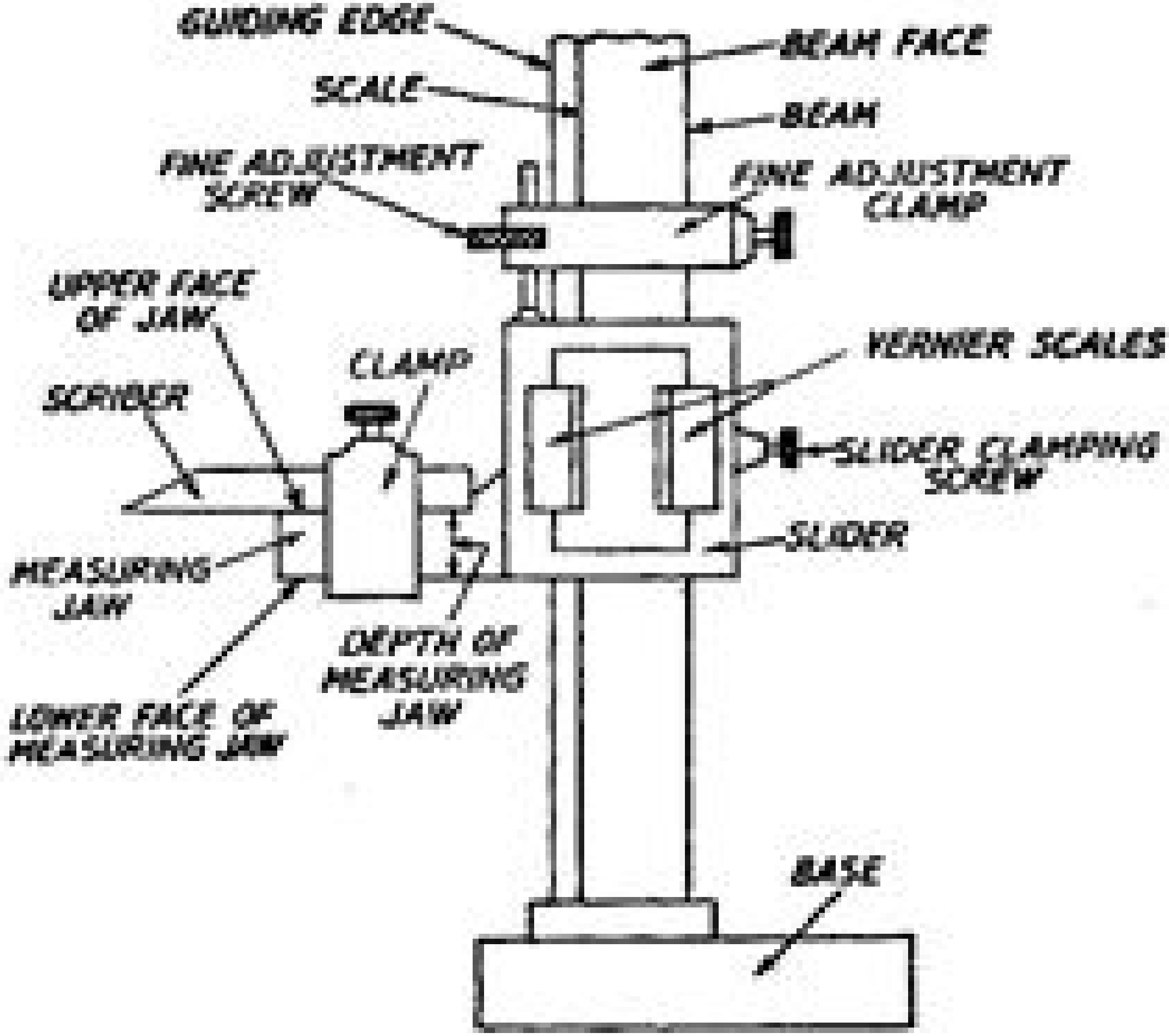
- A **height gauge** is a measuring device used either for determining the height of something, or for repetitious marking of items to be worked on.

- It used in metalworking or metrology to set or measure vertical distances and also it measures the height of an object.

SIMPLE DIAL HEIGHT GAUGE



SIMPLE VERNIER HEIGHT GAUGE


GUIDING EDGE
BEAM FACE
SCALE
BEAM
FINE ADJUSTMENT SCREW
FINE ADJUSTMENT CLAMP
UPPER FACE OF JAW
CLAMP
VERNIER SCALES
SCRIBER
SLIDER CLAMPING SCREW
SLIDER
MEASURING JAW
DEPTH OF MEASURING JAW
LOWER FACE OF MEASURING JAW
BASE

BASIC CONSTRUCTION

- A height gauge has a vertical column.
- A unit is attached to this column which slides up and down.
- An arm protrudes from the gauge coming into direct contact with the part being measured.
- Each height gauge features a solid base giving the vertical column enough stability that it remains at a right angle to the table's surface.
- The moving slide is engraved with vernier calibrations enabling setting to an accuracy of 0.02 mm
- The height of the scribe's point can be finely adjusted with a thumbscrew .

PREPATORY STEPS

- To use and read the digital height gauge correctly, follow these general steps below:
- Step1: Clean the working platform and put the digital height gauge on it.

PREPATORY STEPS contd. …

- Step 2: Dry the surface of the protective sticker of the digital height gauge.

PREPATORY STEPS contd. …

- Step3: Fix the measuring jaw of the digital height gauge

PREPATORY STEPS contd. …

- Step 4: Loosen the locking screw of the height gauge

PREPATORY STEPS contd. ...

- Step 5: Move the slider to check if the LCD displays and all the buttons work properly.

Applications

- These are used to mark out lines and widely used on surface plates and on machine tables.
- The height gauge with an indicator attachment is used for checking of surface holes.
- The height gauge with a scribe attachment is used to mark reference lines and locations on castings and forgings.

Vernier Caliper

Vernier calipers, an instrument for making very accurate linear measurements was introduced in 1631 by Pierre Vernier of France. Vernier calipers are widely used in scientific laboratories and in manufacturing for quality control measurements

Vernier calipers are used to measure

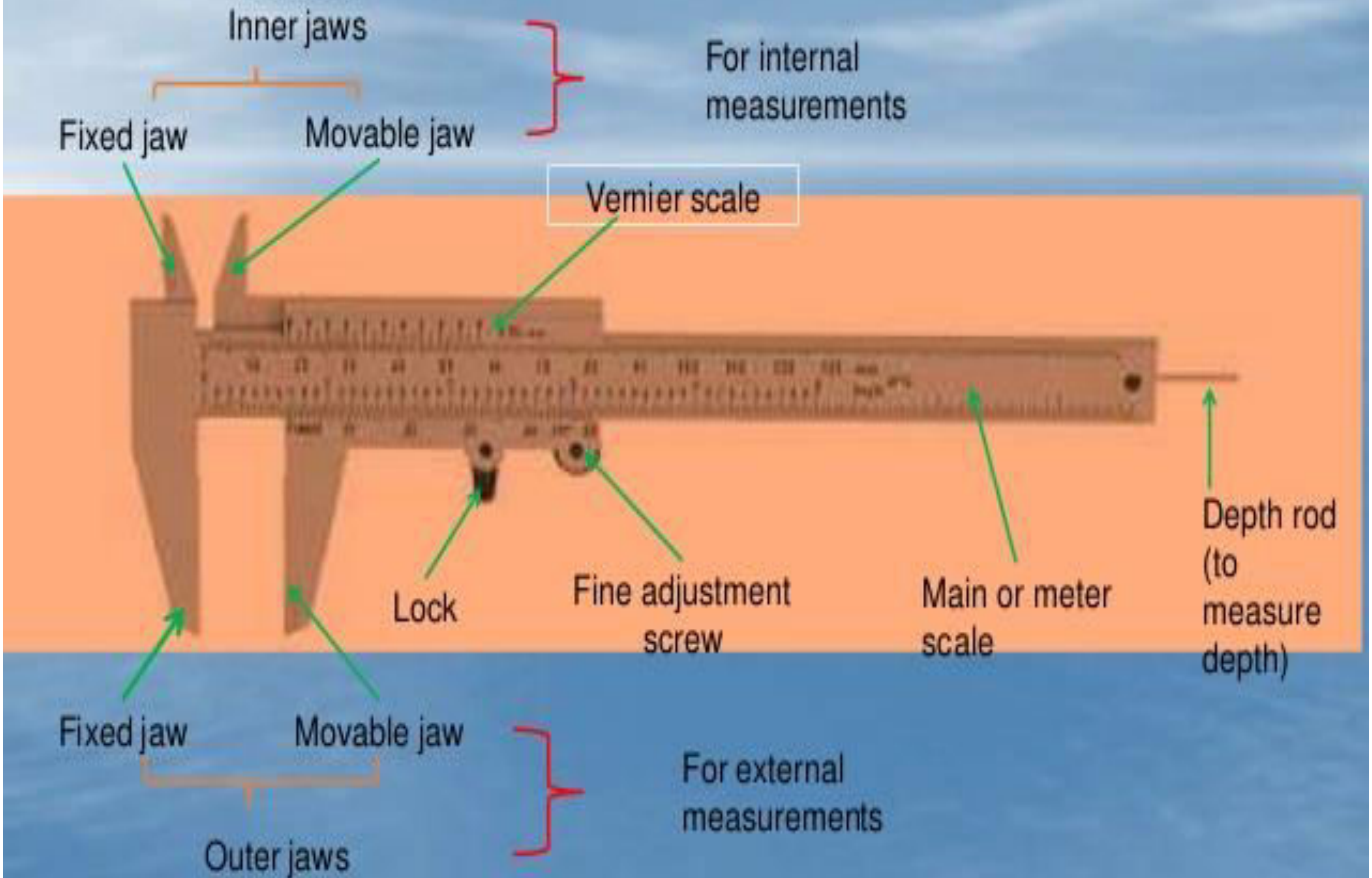
(i)The length of a rod or any object

(ii)The diameter of a sphere

(iii)The internal and external diameter of a hollow cylinder

(iv)The depth of a small beaker

PARTS OF A VERNIER CALIPER



1.Main Scale - The main scale is similar to that on a ruler, graduated in mm and cm on one side ; inches on the other side.

2.Vernier Scale – The Vernier scale is a sliding scale. It slides parallel to the main scale and enables readings to be made to a fraction of a division on the main scale.

3.Screw -The Vernier scale can be fixed at any position on the main scale with the help of a screw.

4.Jaws –It has two jaws. The lower jaws are called outside jaws and they are used to measure the length of a rod ,diameter of a sphere or the external diameter of a cylinder. The upper jaws are called the inside jaws which are used to measure the internal diameter of a hollow cylinder or pipe .

5.Strip - The thin strip is used to measure the depth of the objects like beakers .

Principle of Vernier

The graduations on the Vernier scale are such that the length of ‘ n’ divisions on the Vernier scale is equal to (n-1) divisions of the main scale.

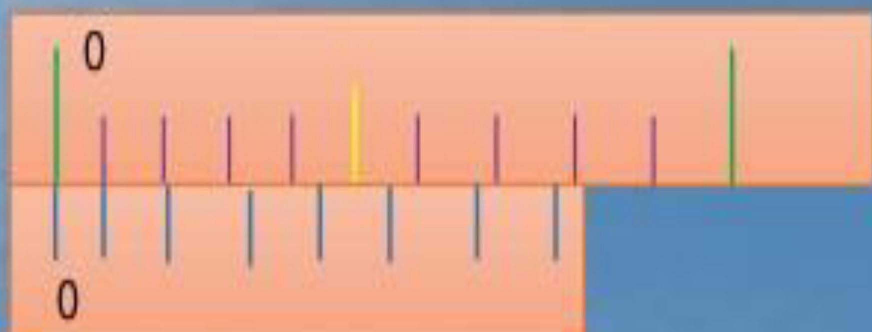
Generally, a Vernier has 10 divisions and the the length of these 10 divisions is equal to the length of 10 – 1 = 9 divisions of the main scale.

LENGTH FORMULA FOR A VERNIER CALIPER

Although the least count may vary between different calipers, the length formula for any caliper is as follows:

Length = MSR + (VSR * LC)

Where MSR, VSR and LC refer to Main Scale Reading, Vernier Scale Reading and Least Count respectively.



ERROR IN A VERNIER CALIPER

Any vertical caliper may have two types of errors:

1. Positive zero error
2. Negative zero error

Positive zero error –

Occurs when the zero of the vernier scale is to the right of the vernier scale when the two jaws are in contact.

To take the precise value for the measurement we are taking, we have to substract the value of the positive zero error from the obtained measurement.

Negative zero error –

Occurs when the zero of the vernier scale is to the left of the vernier scale when the two jaws are in contact.

To take the precise value for the measurement we are taking, we have to add the value of the negative zero error to the obtained measurement.

NO ZERO ERROR

No zero error is the precise arrangement of the meter scale and the vernier scale so that the zeros of both scales fit each other as follows:

To take precise measurements, we have to ensure that the caliper we are using is of no zero error.

COMPARATORS

Introduction:

- Comparator is an instrument used for comparing the dimensions of a component with a standard of length
- Purpose of a comparator, in general, is to detect & display the small differences b/w the unknown linear dimension & length of the standard

The **general principle** of comparator is to indicate the differences in size between the standard and the work being measured by means of some pointer on a scale with sufficient magnification

It thus does not measure the actual dimension but indicates how much it differs from the basic dimension

All comparators consist of three basic features

1)A **sensing device**

- which faithfully senses the input signal

2) A **Magnifying** or **amplifying system**

- to increase the signal to suitable magnitude. Mechanical, Optical, Pneumatic,hydraulic and electronic methods are used for this purpose.

3) A display system (usually a scale and pointer)

Which utilizes the amplified signal to provide a suitable readout.

Essential characteristics

1. Robust design and construction
2. Linear characteristics of scale
3. High magnification
4. Quick in results
5. Versatility
6. Minimum wear of contact point
7. Free from oscillation
8. Free from back lash
9. Quick insertion of workpiece
10. Adjustable table
11. Compensation from temperature effects
12. Means to prevent damage

Uses of Comparators:

1. To inspect newly purchased gauges
2. In mass production, where components are to be checked at a very fast rate
3. As laboratory standards from which working or inspection gauges are set & correlated
4. As working, to prevent work spoilage & to maintain required tolerance at all important stages of manufacture

Types of Comparators:

Most common commercially available comparators can be classified into the following types:

1. Mechanical comparators
2. Optical comparators
3. Electrical & Electronic comparators
4. Pneumatic comparators

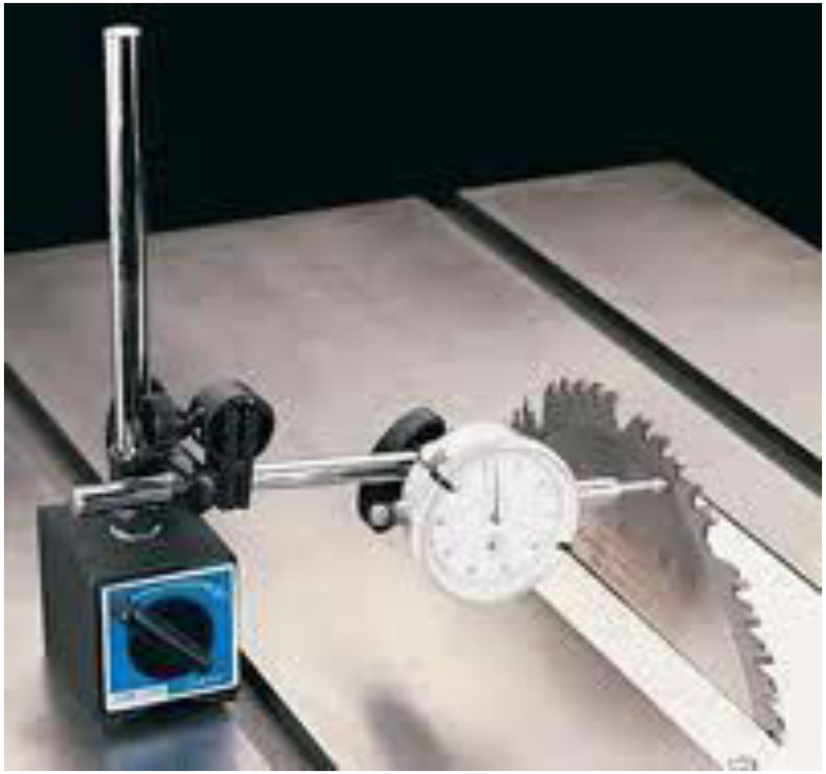
MECHANICAL COMPARATOR

- The mechanical comparators utilize mechanical methods of magnifying, the movement of the contact plunger; their manufacture requires a high degree of skill & accuracy.
- The usual magnifications of the mechanisms range from about 250 to 1000.
- The magnification of the small stylus movement is obtained by means of levers, gear trains, rack and pinion or a combination.

1. Dial Indicator:

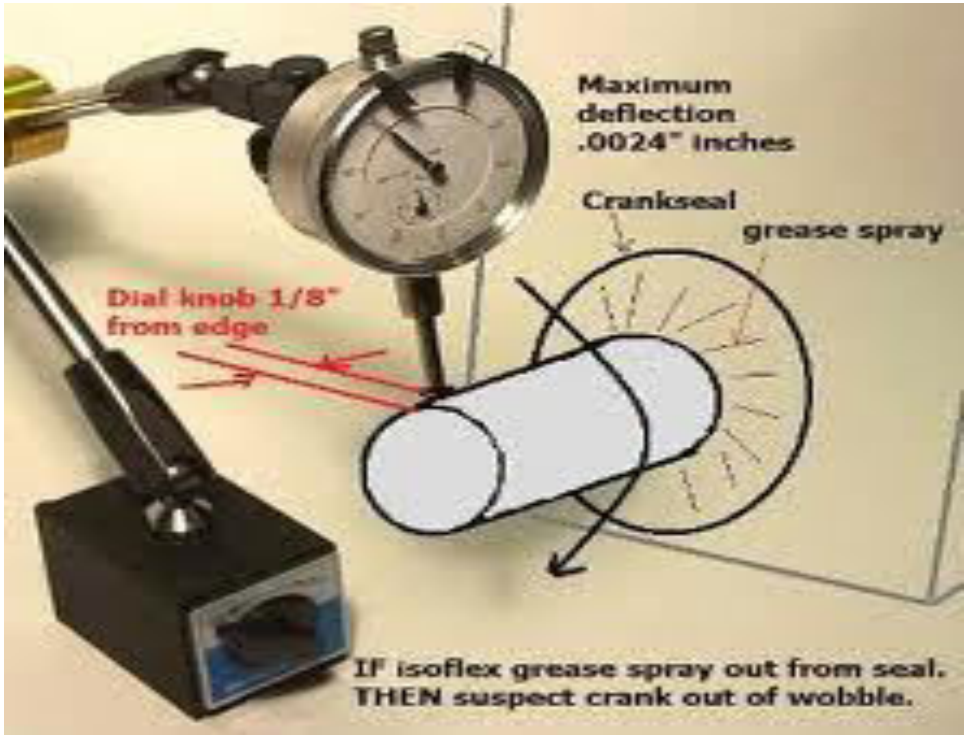
MECHANICAL COMPARATOR

1. Dial Indicator: (different uses)



MECHANICAL COMPARATOR

1. **Dial Indicator: (Various Uses)**



Dial Indicators

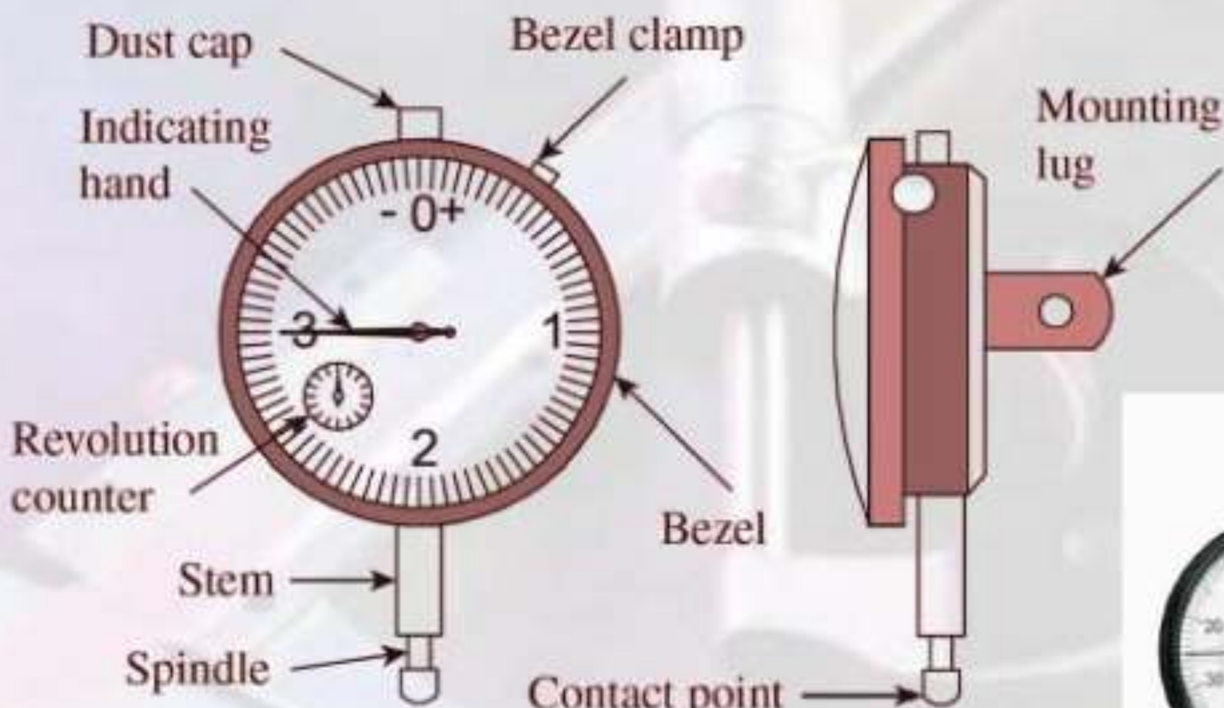
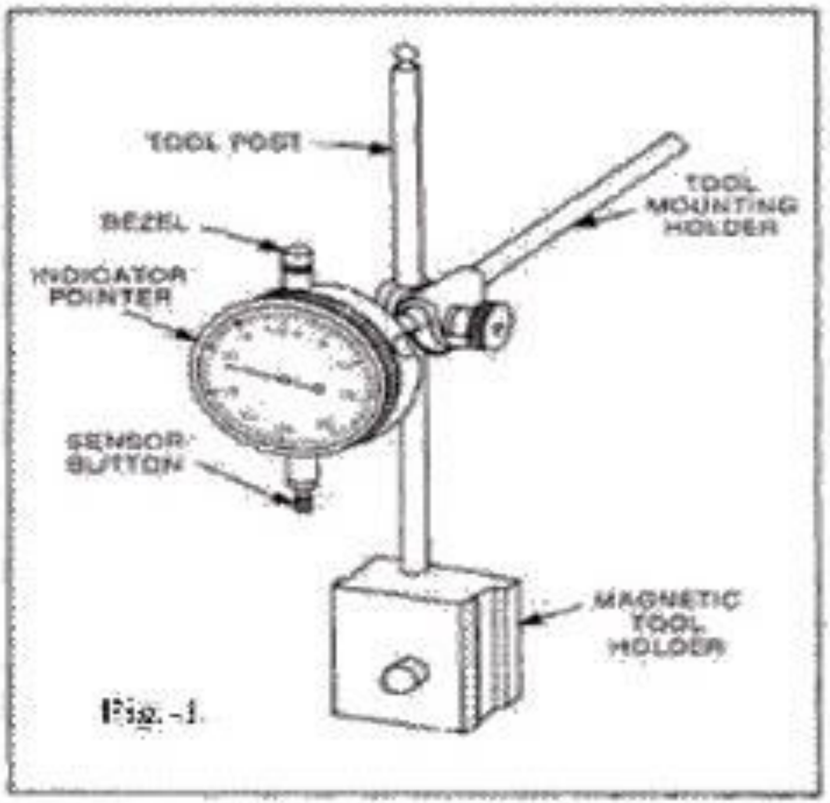
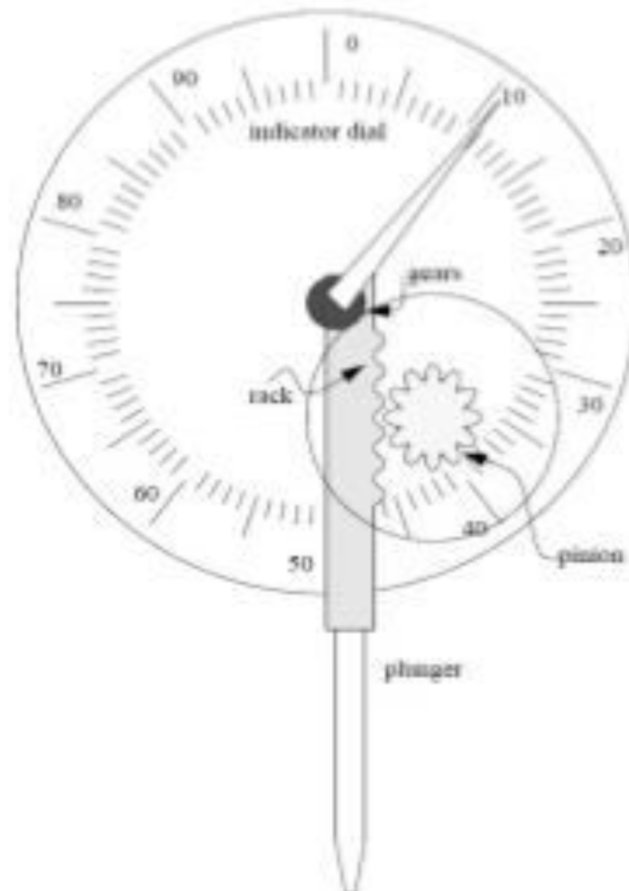


Fig. 6.2 Functional parts of a dial indicator

Dial indicator/ Dial Gauge





- The simplest type of mechanical comparator
- It consists of a base with a rigid column rising from its rear
- An arm mounted on this column and it carries a dial gauge at its outer end
- The indicator is set at zero by the use of slip gauges
- The part to be checked is placed below the plunger
- The linear movement of the plunger is magnified by means of mechanical means to a sizable rotation of the pointer

This type is generally used for inspection of small precision machined parts

The dial gauge with various attachments are commonly used

This comparator is ideal for the checking of components with a tolerance of $\pm$ 0.005 mm

Dial Indicators

With the plunger set to approximately mid-position, the face dial is set to read zero.

From this zero reference point, two rules apply:

- As the plunger moves out of the case, the needle travels **counter-clockwise**...giving a **NEGATIVE** reading.
- As the plunger moves into the case, the needle travels **clockwise.**..giving a **POSITIVE** reading.

Applications:

1. Comparing two heights or distances between narrow limits.
2. To determine the errors in geometrical form such as ovality, roundness and taper.
3. For taking accurate measurement of deformation such as intension and compression.
4. To determine positional errors of surfaces such as parallelism, squareness and alignment.
5. To check the alignment of lathe centers by using suitable accurate bar between the centers.
6. To check trueness of milling machine arbours and to check the parallelism of shaper arm with table surface or vice.

Johansson Mikrokator

This comparator was developed by C.F. Johansson.

Principle:

It works on the principle of a Button spring, spinning on a loop of string like in the case of Children’s toys.

Johansson Mikrokator

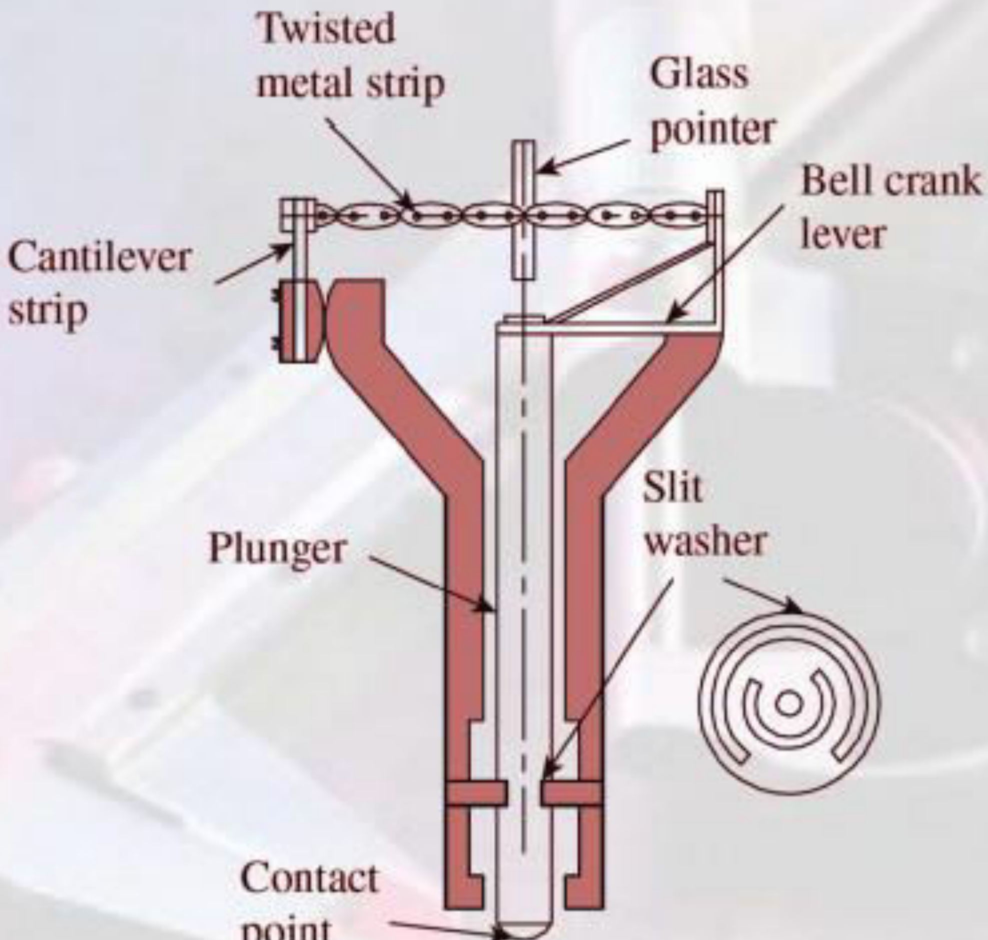


Fig. 6.7 Johansson mikrokator

Johansson Mikrokator

- ✓ A light pointer made of glass fixed to a thin twisted metal strip
- ✓ While one end of the strip is fixed to an adjustable cantilever link, the other end is anchored to a bell crank lever
- ✓ Any linear motion of the plunger will result in a movement of the bell crank lever, which exerts either a push or pull force on the metal strip.
- ✓ Accordingly the glass pointer will rotate either clockwise or anti-clockwise depending on the direction of plunger movement
- ✓ A calibrated scale is employed with the pointer, so that any axial movement of the plunger can be conveniently recorded.

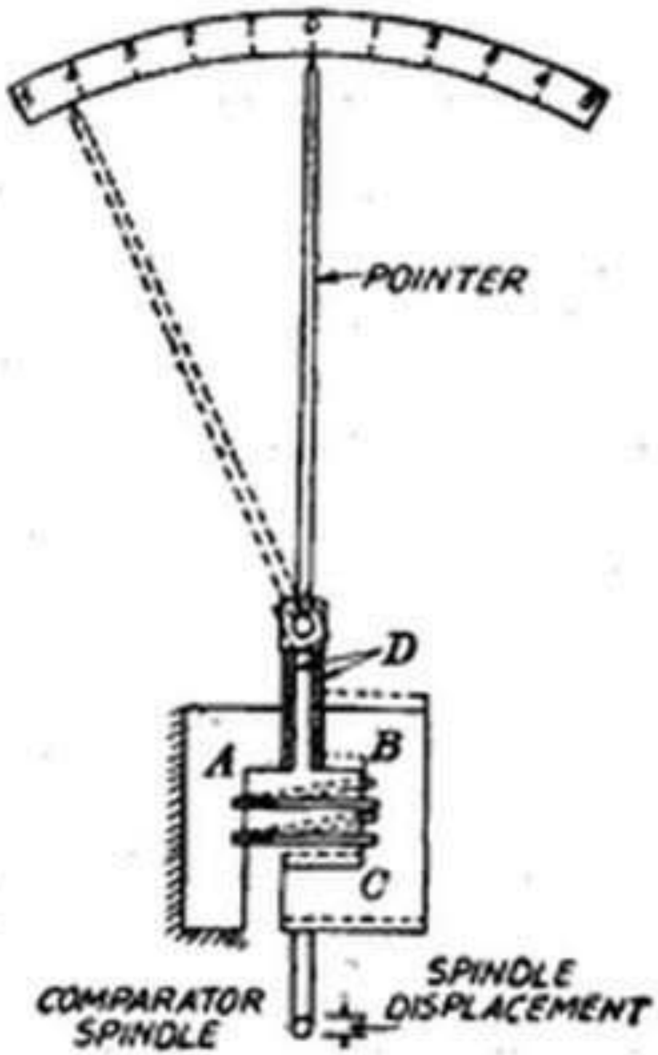
Advantages of Mechanical Comparator:

1. They do not require any external source of energy.
2. These are cheaper and portable.
3. These are of robust construction and compact design.
4. The simple linear scales are easy to read.
5. These are unaffected by variations due to external source of energy such air, electricity etc.

Disadvantages:

1. Range is limited as the pointer moves over a fixed scale.
2. Pointer scale system used can cause parallax error.
3. There are number of moving parts which create problems due to friction, and ultimately the accuracy is less.
4. The instrument may become sensitive to vibration due to high inertia.

Reed Type Comparator



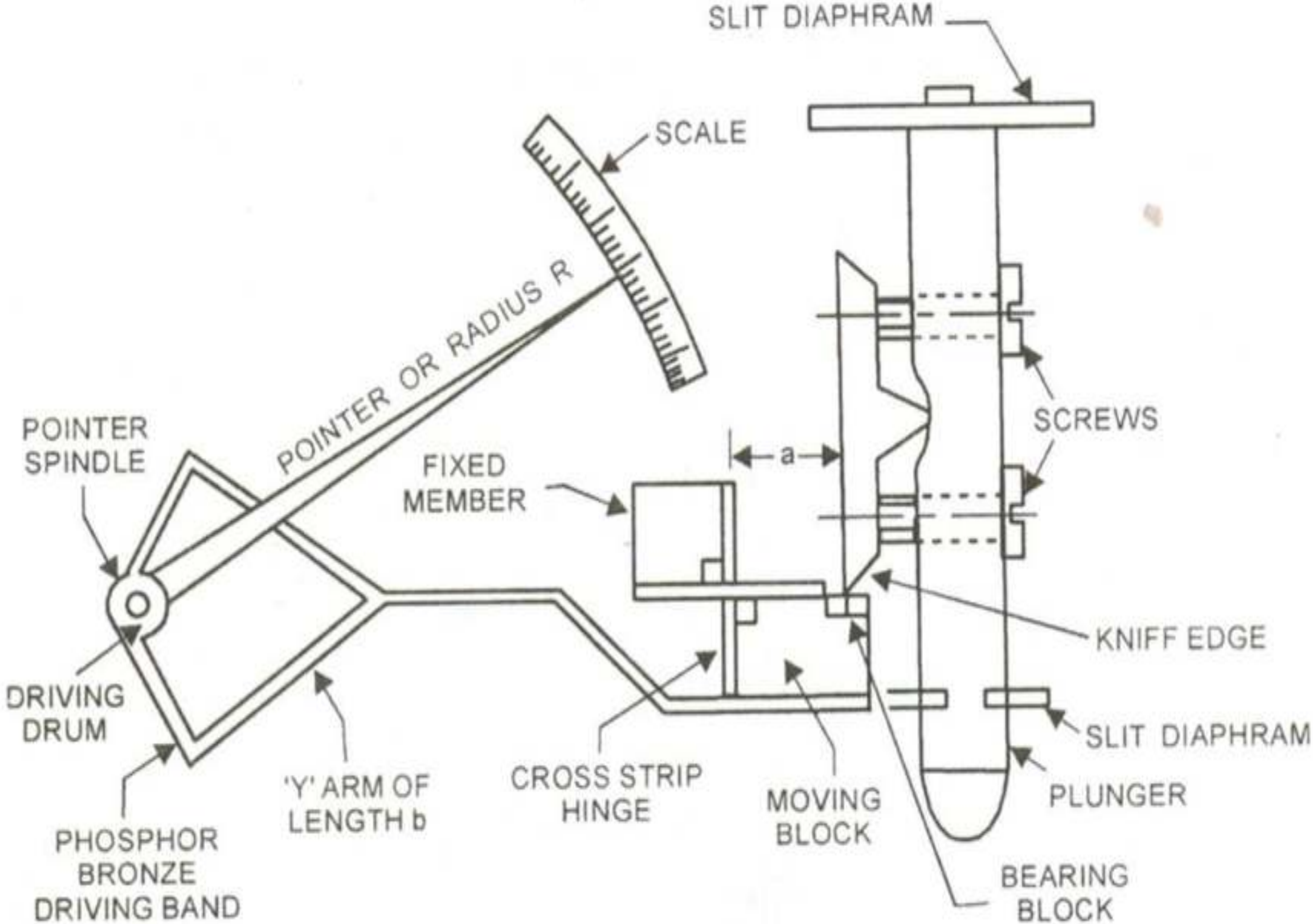
- A reed type comparator uses the frictionless reed mechanism for magnifying small motions of spindle

- In the following figure:

1. A - Fixed Block
2. B- Floating Block
3. C- Reeds

- This is a frictionless device for expanding small motions of the spindle.
- It comprises of a static block A, which is strictly attached to the gauge head case.
- The floating block B carries the gauging spindle & is connected horizontally to the static block by reeds C.
- A perpendicular reed is attached to every block with the higher ends combined together, as shown in the below figure.
- A linear motion of the spindle travels the free block perpendicularly causing the perpendicular reed to slide. This effort roots the target to swing through an arc over the scale related to the distance moved by the spindle.

Sigma Comparator



SLIT DIAPHRAM
SCALE
POINTER OR RADIUS R
POINTER SPINDLE
FIXED MEMBER
a
SCREWS
KNIFF EDGE
DRIVING DRUM
SLIT DIAPHRAM
PLUNGER
PHOSPHOR BRONZE DRIVING BAND
'Y' ARM OF LENGTH b
CROSS STRIP HINGE
MOVING BLOCK
BEARING BLOCK

Construction and working of Sigma comparator

1. The Plunger will hold the contact with the work piece, and it is positioned in place with the help of slit diaphragms.
2. The plunger will have a notch at its center as shown in the figure.
3. A knife Edge is attached to the plunger to magnify the linear movement of the plunger and which is connected to the Cross strip with the help of moving the block.
4. The Y-shaped metallic arm is connected to the cross strip to Driving drum. This arm rotated and make the drum to rotate and hence the pointer will move on the scale.
5. The first step of magnification take place at the knife edge and cross strip and the second step of magnification is done at the drum diameter and the pointer length.

Advantages of Sigma Comparator

1.If any shock loads forced on the plunger those will not affect the inside equipment, due to the knife edge will be dis-engage after some extent of movement.

2.constant measuring pressure can be achieved by using the magnetic plunger in sigma comparator.

Disadvantages of Sigma Comparator

1.Due to more number of moving parts, there will be wear in moving parts.

2.Less sensible due to friction in moving parts

If a = Distance from hinge pivot to the knife edge

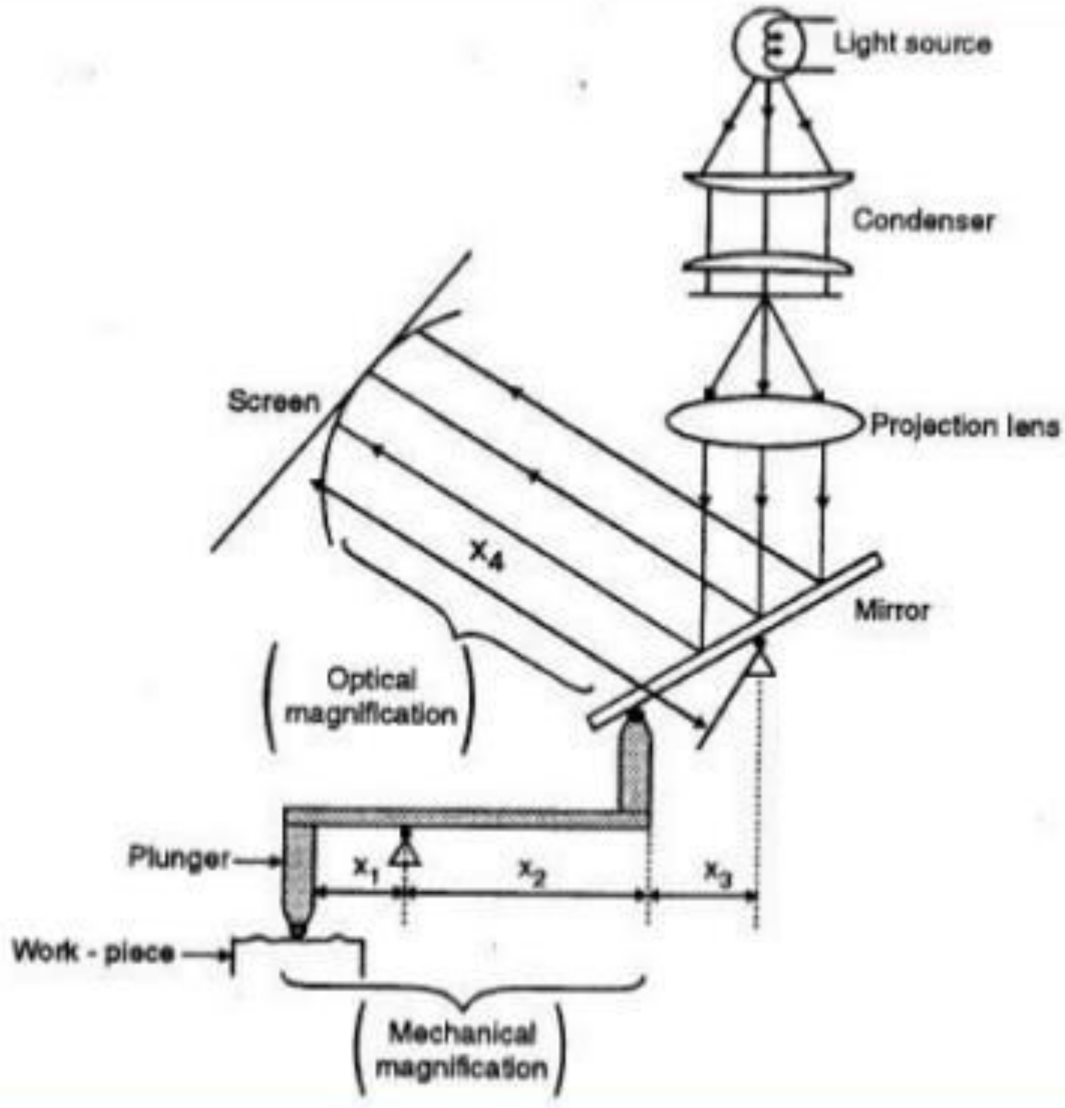
b = Length of y-arm

R = Driving drum radius

D Length of the pointer

Then the total magnification = $(b/a) * (D/R)$

Mechanical - Optical



Working Principle

- In mechanical optical comparator, small variation in the plunger movement is magnified: first by mechanical system and then by optical system.
- In mechanical optical comparators small displacements of the measuring plunger are amplified first by a mechanical system consisting of pivoted levers.
- The amplified mechanical movement is further amplified by a simple optical system involving the projection of an image.

Principle of Working:

The optical principle adopted in the optical comparators is 'optical lever' and is shown in Figure.

If a ray of light AC strikes a mirror, it is reflected as ray CO such that:

∠ACN =∠NCO

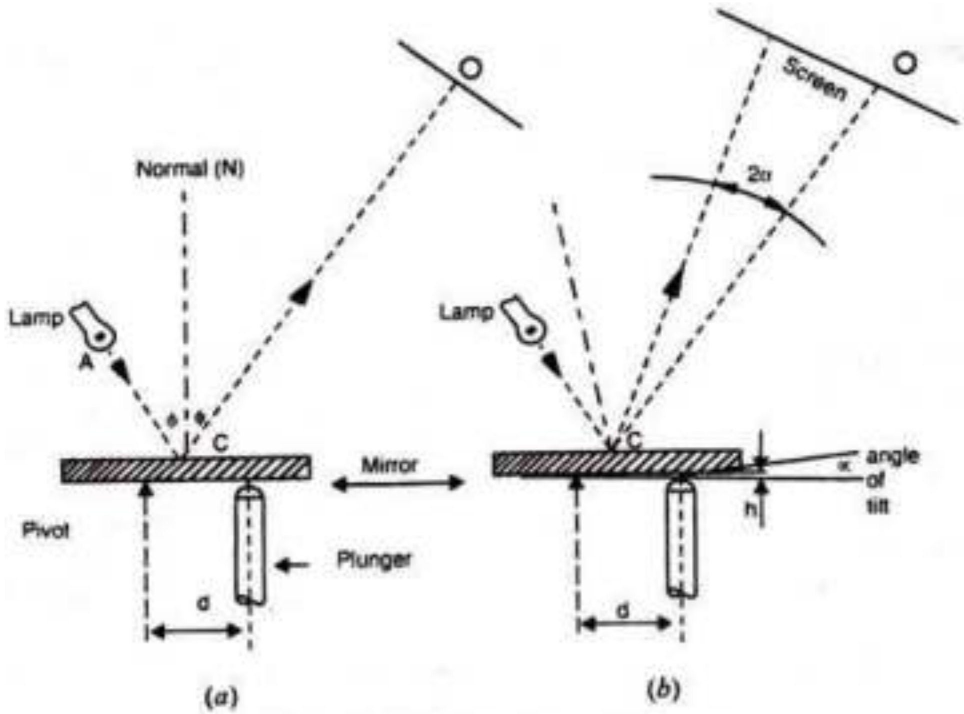


Fig. 1.14. Principle of the optical lever.

Now, if the mirror is tilted through an angle α, the reflected ray of light has moved through an angle of 2 α.

In optical comparators, the mirror is tilted by the measuring plunger movement and the movement of reflected light is recorded as an image on a screen.

Figure shows the working principle of an optical-mechanical comparator in which both mechanical and optical levers are used

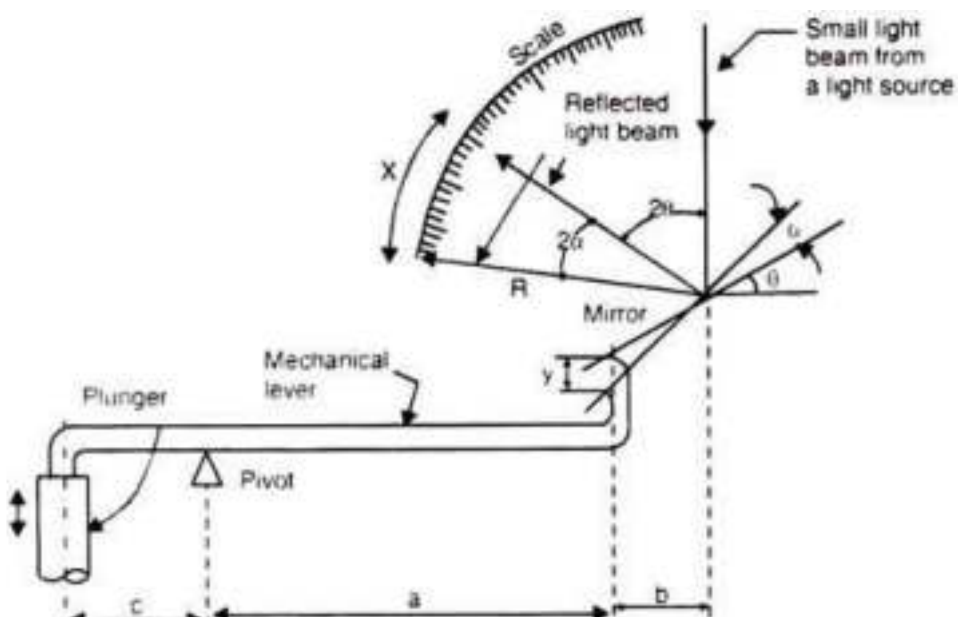


Fig. 1.15. An Optical Comparator.

Magnification:

The magnification of optical comparator is defined as "the ratio between distance moved by the indicating pointer (beam) and the displacement of plunger"

$$\text{Total Magnification} = \text{Mechanical Magnification} \times \text{Optical Magnification}$$

$$= \frac{a}{c} \times \frac{2R}{b}$$

$$= \frac{a}{c} \times \frac{X}{Y} \qquad \left(\because \frac{X}{Y} \simeq \frac{2R}{b}\right)$$

The Magnification of optical comparators is usually 1000:1, with measuring range of plus and minus 0.075 mm.

PROS

1. These Comparators are almost weightless and have less number of moving parts, due to this there is less wear and hence less friction.
2. Higher range even at high magnification is possible as the scale moves past the index.
3. The scale can be made to move past a datum line and without having any parallax errors.
4. They are used to magnify parts of very small size and of complex configuration such as intricate grooves, radii or steps.

Cons

1. The accuracy of measurement is limited to 0.001 mm
2. They have their own built in illuminating device which tends to heat the instrument.
3. Electrical supply is required.
4. Eyepiece type instrument may cause strain on the operator.
5. Projection type instruments occupy large space and they are expensive.
6. When the scale is projected on a screen, then it is essential to take the instrument to a dark room in order to take the readings easily.

Pneumatic Comparators

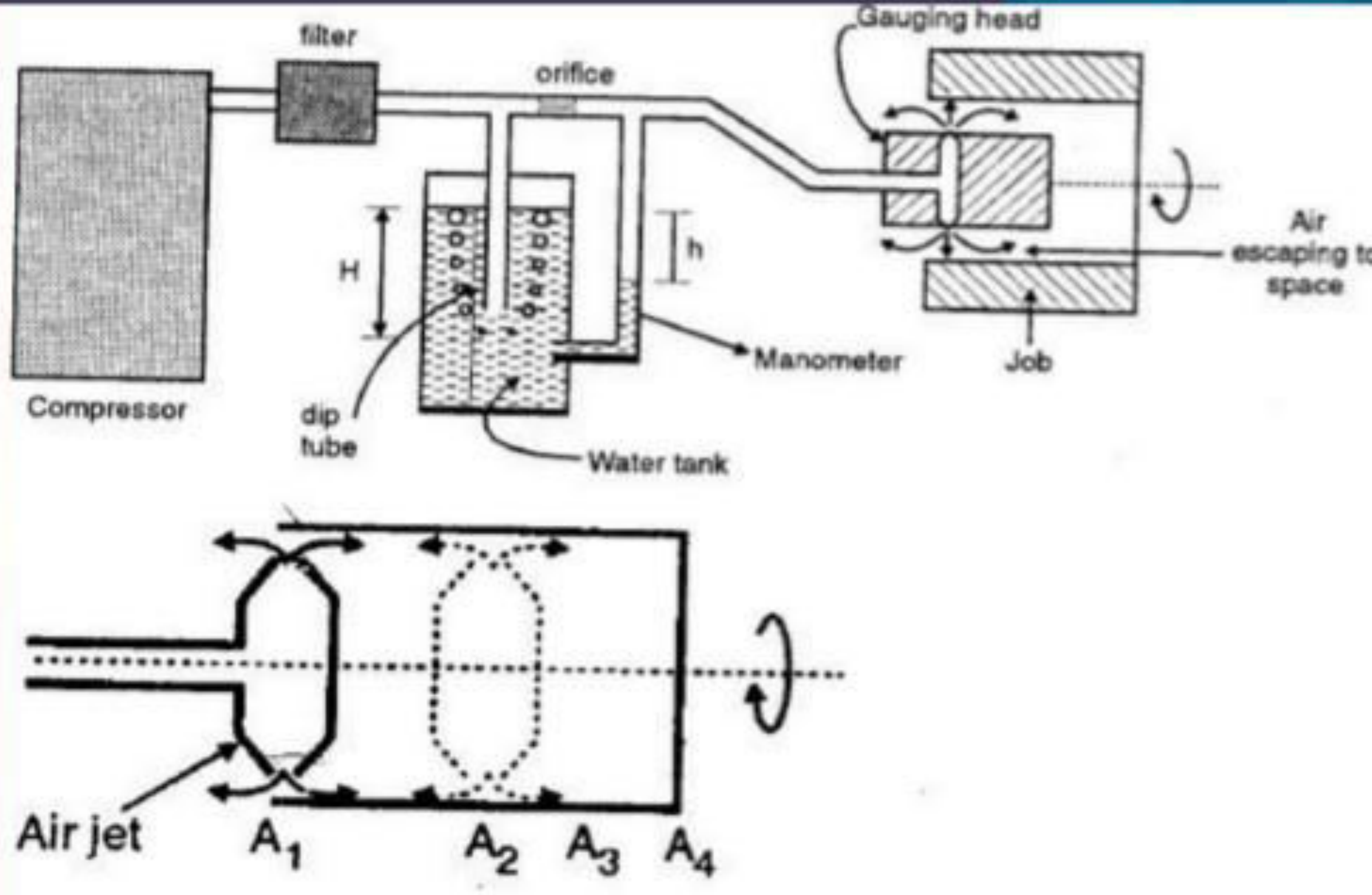


Figure (b)

Working Principle

- It works on the principle of pressure difference generated by the air flow.
- Air is supplied at constant pressure through the orifice and the air escapes in the form of jets through a restricted space which exerts a back pressure.
- The variation in the back pressure is then used to find the dimensions of a component.

The air is compressed in the compressor at high pressure which is equal to Water head H. The excess air escapes in the form of bubbles. Then the metric amount of air is passed through the orifice at the constant pressure. Due to restricted area, at A1 position, the back pressure is generated by the head of water displaced in the manometer tube. To determine the roundness of the job, the job is rotated along the jet axis, if no variation in the pressure reading is obtained then we can say that the job is perfectly circular at position A1. Then the same procedure is repeated at various positions A2, A3, A4, position and variation in the pressure reading is found out. Also the diameter is measured at position A1 corresponding to the portion against two jets and diameter is also measured at various position along the length of the bore

PROS

1. It is cheaper, simple to operate and the cost is low.
2. It is free from mechanical hysteresis and wear.
3. The magnification can be obtained as high as 10,000 X.
4. The gauging member is not in direct contact with the work.
5. Indicating and measuring is done at two different places.
6. Tapers and ovality can be easily detected.
7. The method is self cleaning due to continuous flow of air through the jets and this makes the method ideal to be used on shop floor for online controls.

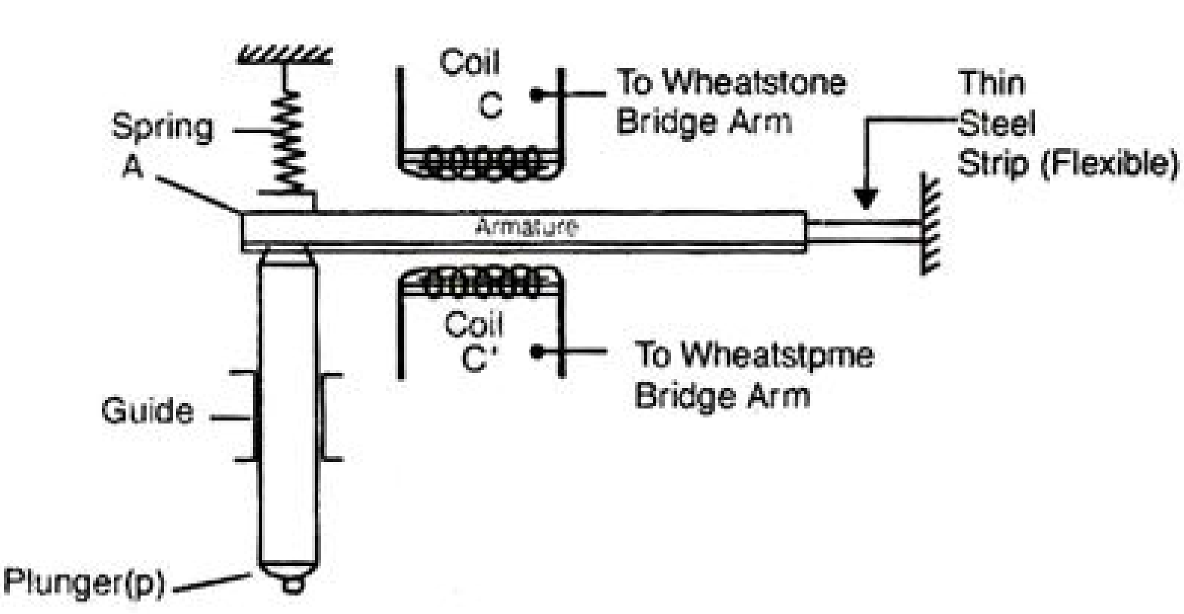
CONS

1. They are very sensitive to temperature and humidity changes.
2. The accuracy may be influenced by the surface roughness of the component being checked. 3.
3. Different gauging heads are needed for different jobs.
4. Auxiliary equipments such as air filters, pressure gauges and regulators are needed.
5. Non-uniformity of scale is a peculiar aspect of air gauging as the variation of back pressure is linear, over only a small range of the orifice size variation

Electrical Comparators:

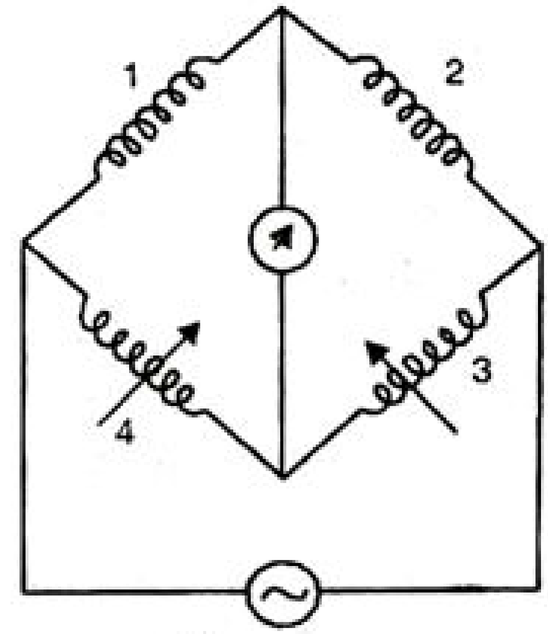
An Electrical comparator employs electrical means to get the magnification. In this comparator the movement of the measuring contact plunger is converted into an electrical signal.

The electrical signal is recorded by an instrument which can be calibrated in terms of plunger movement.



Coil
C
To Wheatstone
Bridge Arm
Thin
Steel
Strip (Flexible)
Spring
A
Armature
Coil
C'
To Wheatstpme
Bridge Arm
Guide
Plunger(p)

(*a*)



1
2
3
4

(*b*)

Construction

An electrical comparator consists of four basic units.

(i) Measuring Probe (Plunger):

This is in direct contact of the component being checked.

(ii) Amplifier and Indicating Unit:

Amplifier boost up the electrical signals obtained and gives to indicating unit. Indicating unit indicates the variation of dimensions if any by movement of pointer on a calibrated scale.

(iii) Power Unit:

Power unit gives the power to the wheat-stone bridge to balance it while setting the pointer to zero with respected to standard component.

(iv) Base and Standard Unit:

These provide hold and support to all the other units. Other than four basic units, a spring is provided to control the contact pressure. A thin flexible steel strip also provided as shown in Figure.

Working Principle:

The principle of operation of an electrical comparator is shown in Figure an armature supported on thin flexible steel strip is suspended between two coils C and C. When the distance of the armature from two coils is equal, the Wheatstone bridge is balanced and no current flows through the galvanometer.

Little movement of the measuring plunger unbalances the bridge resulting in the flow of current through the galvanometer. Galvanometer scale is calibrated to give the movements of the plunger.

Magnification:

Electrical comparators are available to read up to 0.0001mm with magnification ranging between 1100-18,000. Some most sensitive electrical comparators available with magnification of 40,000 or higher.

Special Features:

These comparators could also be supplied with indicators, which would give out a signal if the component being checked lies below or above the standard dimensions. The signal from the indicator may either be coloured lamps or a buzzer sound.

This principle is known as “Visual gauging Head”. Such, instruments do not provide any difference in dimension but gives only a Visual Indication

Relative advantages and disadvantages

Comparator	Advantages	Disadvantages
Mechanical	1. Cheaper 2. No need of electricity 3. Linear scale	1. More moving parts 2. More friction 3. Less accuracy
	4.Robustn and compact	4. Sensitive to vibration
	5. Easy to handle	5. Range is limited
	6.portable	6. Parallax error is possible
Electrical	1.Small moving parts	1.Needs Electric supply
	2. Very high magnification 3.High range 4. Not sensitive to vibration	2. Variation in supply affects accuracy 3. Heating coil may cause errors 4. expensive
Pneumatic	1. No contact with job 2. Small moving parts 3. More accuracy 4. High magnification 5. Instrument can be used placed at remote from job	1. Auxiliary equipment needed 2. Scale not uniform 3. Not portable 4. Different gauging head required
	6. Used to check ovality and temperature	

Angular measurements

Introduction

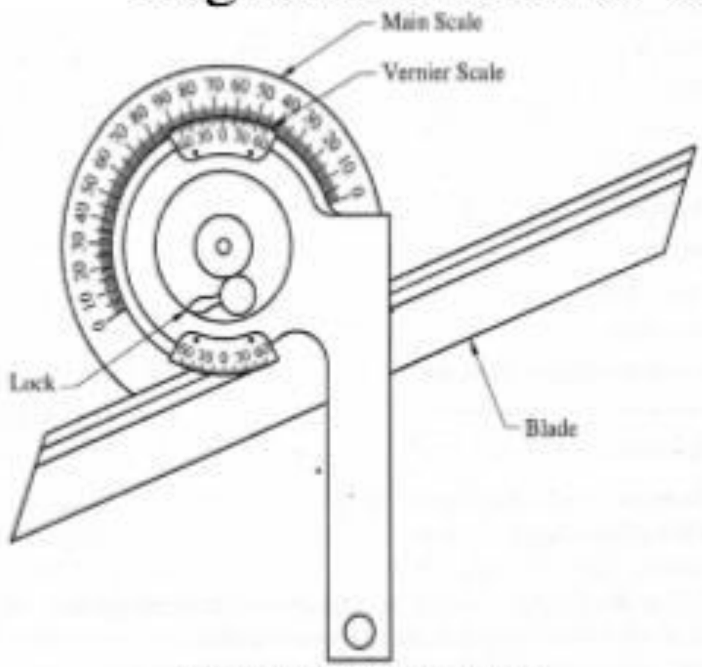
- The angle is defined as the opening between two lines which meet at a point.
- Circle is divided into 360 parts, each part is called a degree (º).
- Each degree is divided in 60 minutes (') and each minute into 60 Seconds (“)
- Unit of angle derived from theoretical considerations is the radian, defined as the angle subtended at the centre of a circle by an are length equal to radius of circle.

Angle Measurement Instrument

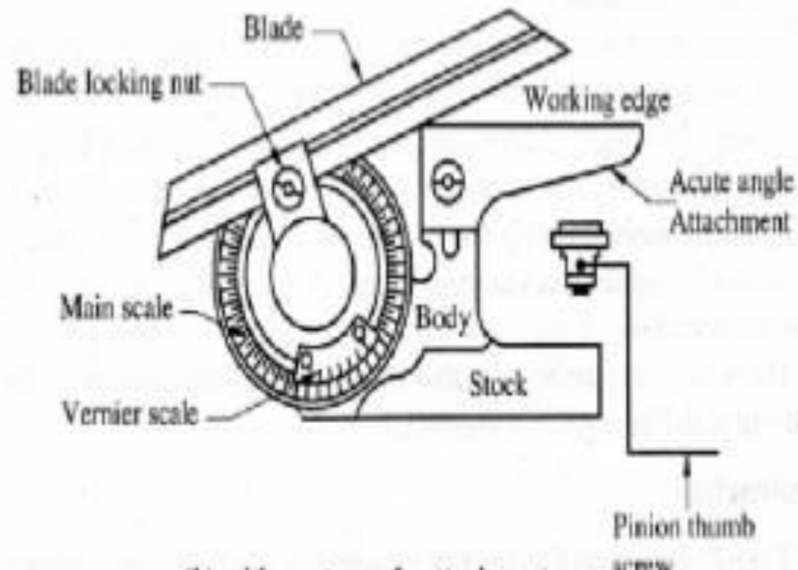
- Line Standard Angular Measuring Devices
  - Protractors
  - Universal Bevel Protractors
- Face Standard Angular Measuring Devices
  - Sine bar
  - Sine Center
- Measurement of Inclines
  - Spirit Level
  - Clinometer
- Angle Comparators
  - Autocollimators

Vernier Bevel protractor

- The simplest instrument for measuring the angle between two faces of component.
- Main scale on the protractor is divided into degrees from 0 to 90 each way.

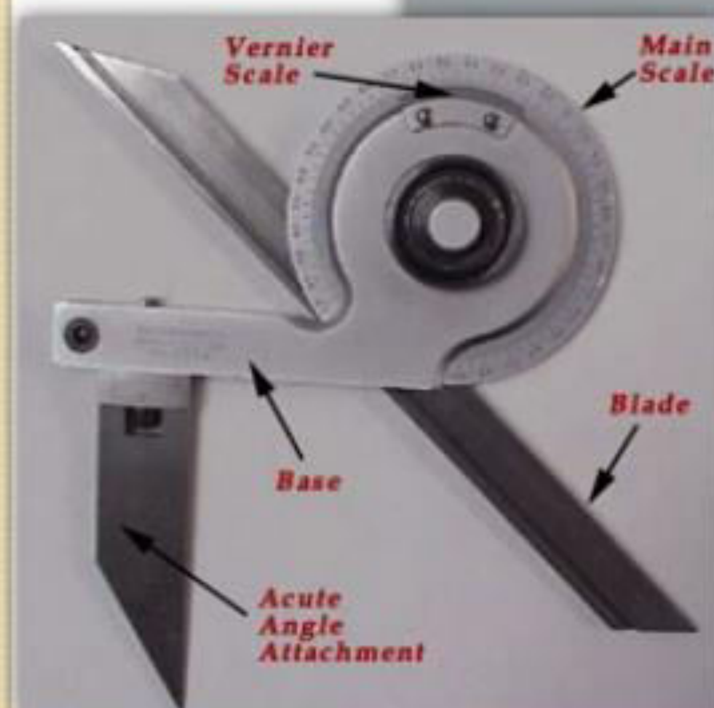


(a) Without acute angle attachment

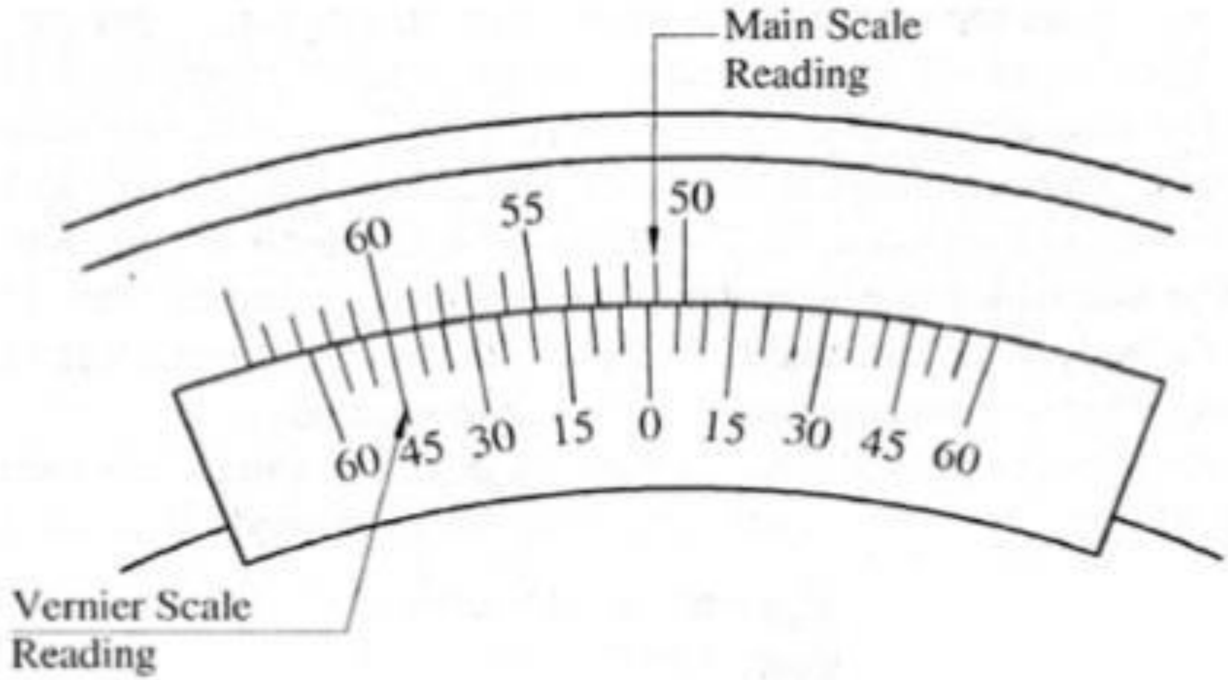


(b) with acute angle attachment

Vernier Bevel protractor



Vernier Bevel protractor



Thus the reading of the vernier bevel protractor equals :

The largest 'whole' degree on the main scale + the reading on the vernier scale in line with a main scale division.

= Main scale reading, 51° + Vernier 45 mark in line with main scale

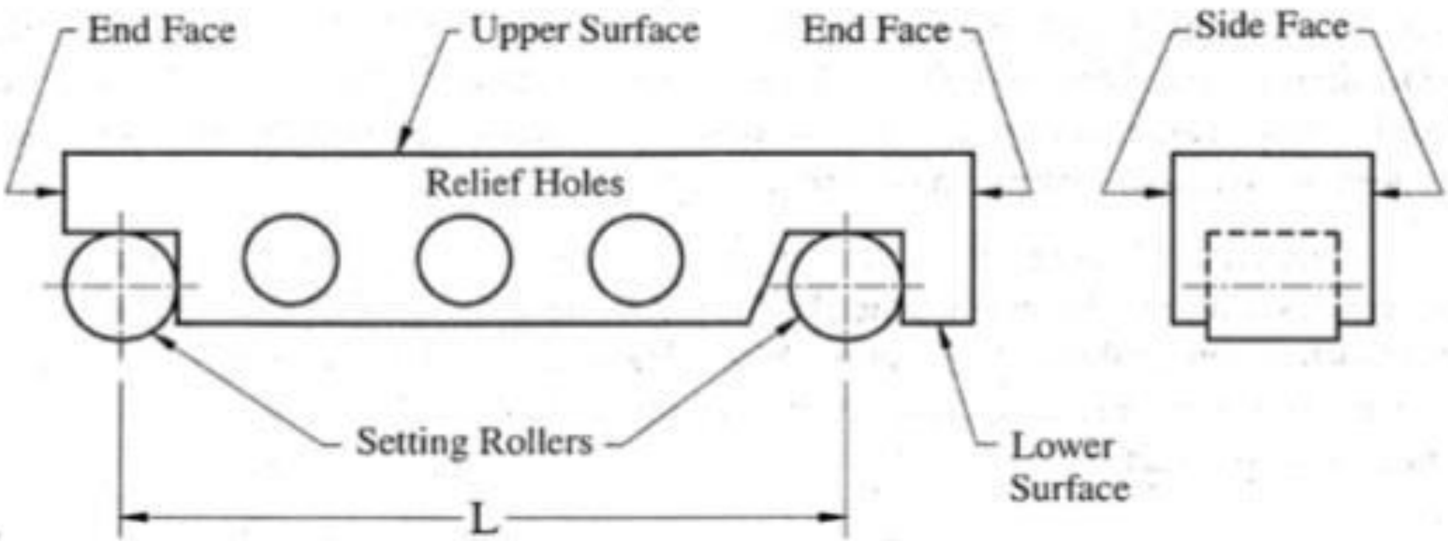
= $51^{\circ}45'$

SINE BAR

A sine bar is used in conjunction with slip gauge blocks for precise angular measurement. A sine bar is used either to measure an angle very accurately or face locate any work to a given angle. Sine bars are made from a high chromium corrosion resistant steel, and is hardened, precision ground, and stabilized.

Sine bars

- A precision angle measuring instrument used along with slip gauges



- Two cylinders of equal diameter are placed at the ends of the bar.
- The axes of these two cylinders are mutually parallel to each other, and are also parallel to, and at equal distance from, the upper surface of the sine bar.
- Accuracy up to 0.01mm/m of length of the sine bar can be obtained.
- A sine bar is generally used with slip gauge blocks.
- The sine bar forms the hypotenuse of a right triangle, while the slip gauge blocks form the opposite side.

Sine bars

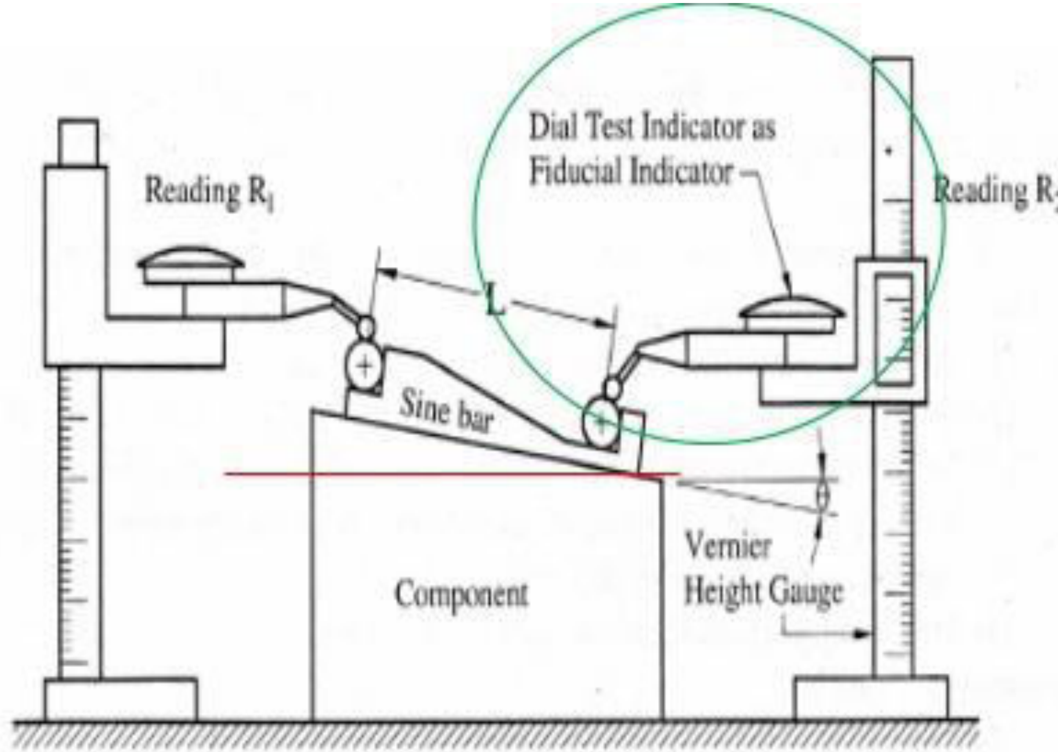


Fig. 3.10 Measuring angle of large size component.

- Height over the rollers can be measured by a vernier height gauge; using a dial test gauge mounted on the anvil of height gauge to ensure constant measuring pressure.
- This is achieved by adjusting the height gauge until the dial gauge shows the same zero reading each time

$$\sin\theta = \frac{R_1 - R_2}{L}.$$

Sine bars

- Advantages of sine bar

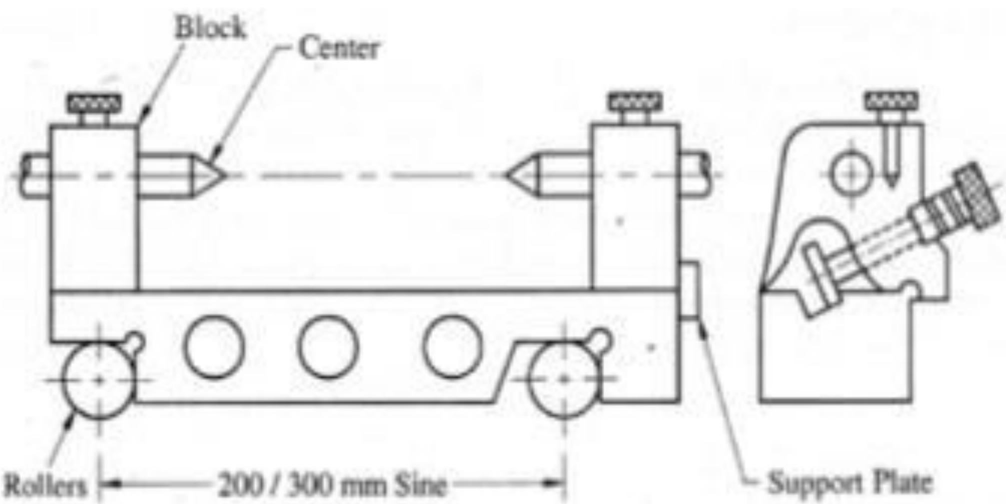
1. It is precise and accurate angle measuring device.
2. It is simple in design and construction.
3. It is easily available

- Disadvantages

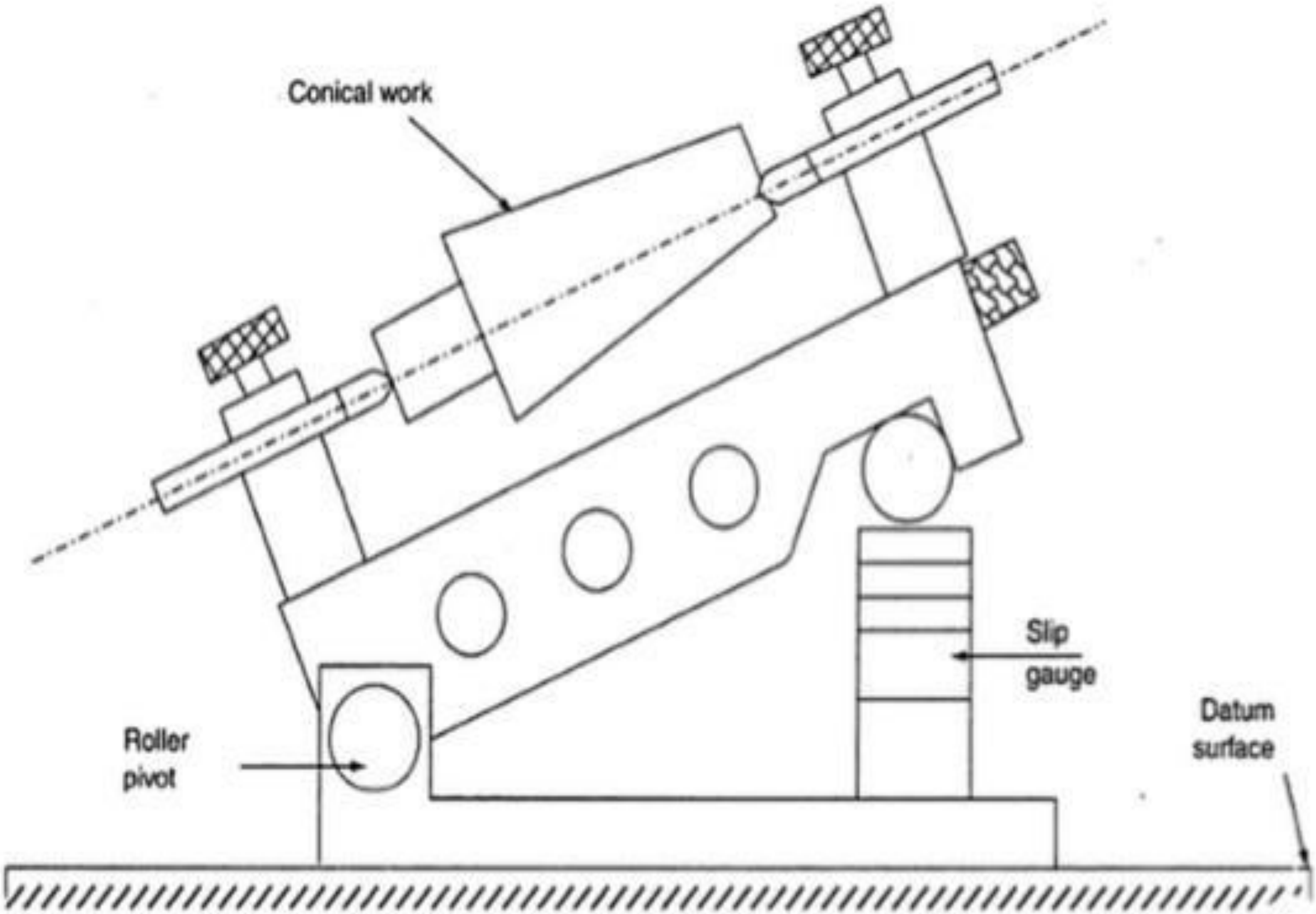
1. It is fairly reliable at angles less than 15 but become increasingly inaccurate as the angle increases. It is impractical to use sine bar for angle above 45 .
2. It is difficult to handle and position the slip gauges.
3. The sine bar is physically clumsy to hold in position.
4. The application is limited for a fixed center distance between two rollers.
5. Slight errors of the sine bar cause larger angular errors.

Sine Centre

- Sine center is basically a sine bar with block holding centers which can be adjusted and rigidly clamped in any position. used for the testing of conical work, centered at each end as shown.
- Extremely useful since the alignment accuracy of the centers ensures that the correct line of measurement is made along the workpiece.
- The centers can also be adjusted depending on the length of the conical work piece, to be hold between centers.



Sine Centre



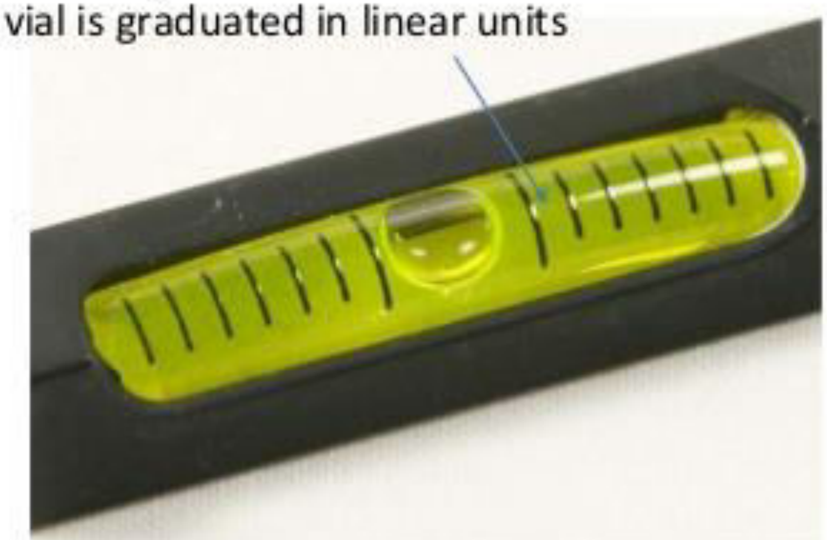
Measurement of included angle of taper plug gauge using sine cen

Angle Gauge

- Angle gauges are made of hardened steel and seasoned carefully to ensure permanence of angular accuracy, and the measuring faces are lapped and polished to a high degree of accuracy and flatness like slip gauges.

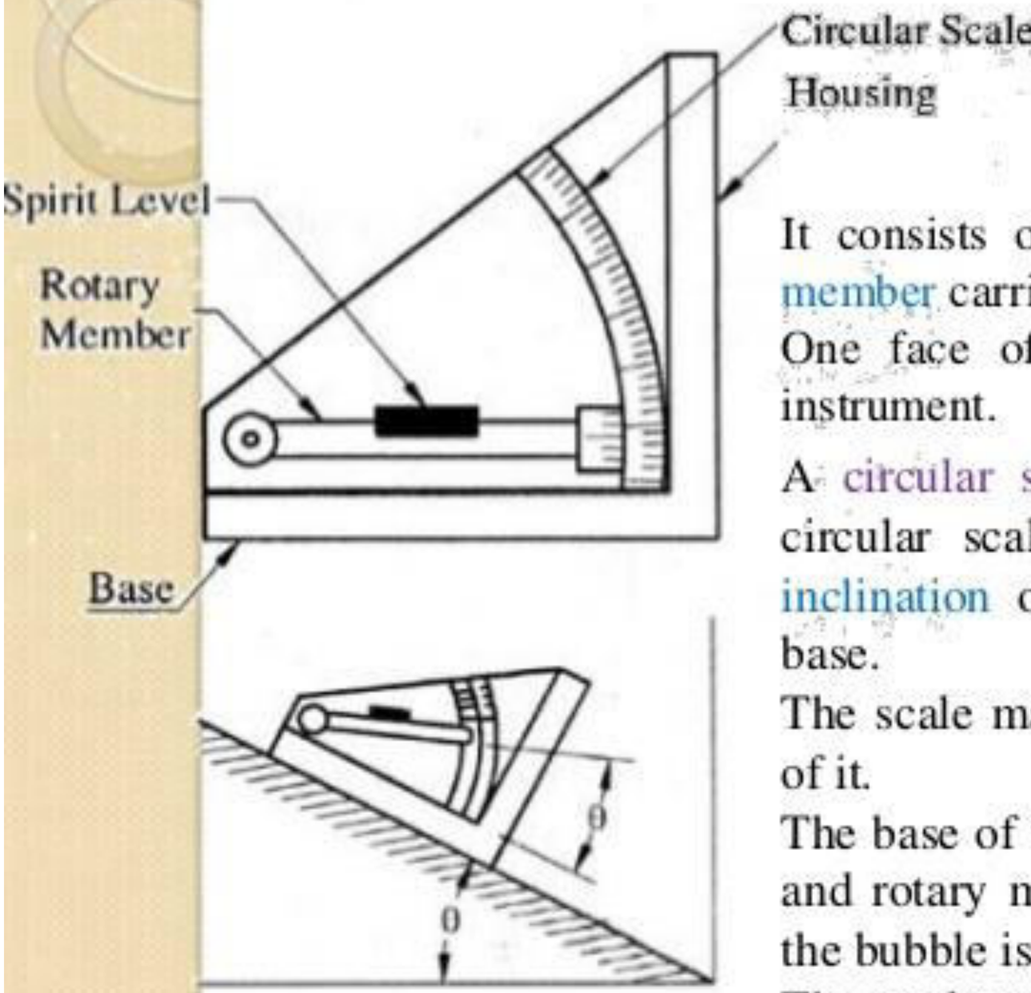
Spirit Level

low viscosity fluids
the vial is graduated in linear units



Clinometers

- The clinometers is a special case of the application of the spirit level. It is an instrument used for measuring angle relative to the horizontal plane.



It consists of a spirit level mounted on a rotary member carried in a housing.

One face of the housing forms the base of the instrument.

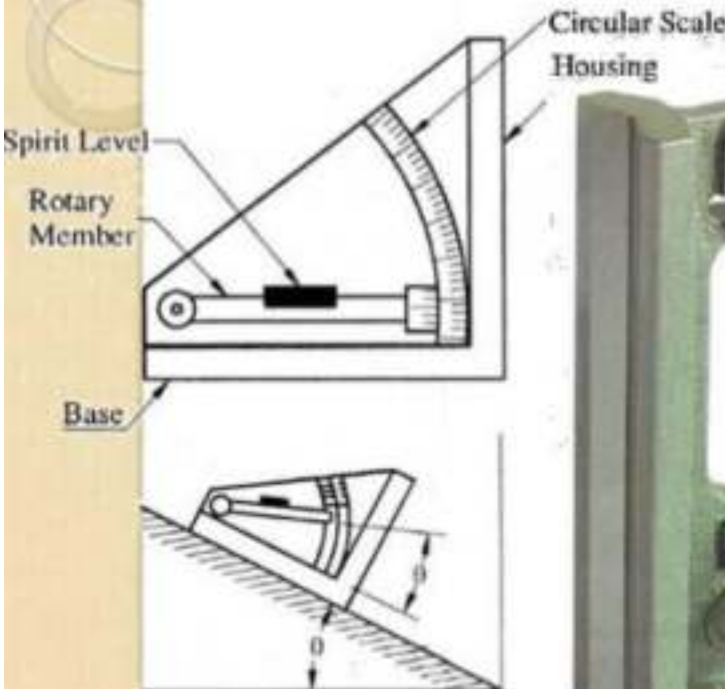
A circular scale is provided on the housing. A circular scale is used to measure the angle of inclination of the rotary member relative to the base.

The scale may cover the whole circle or only part of it.

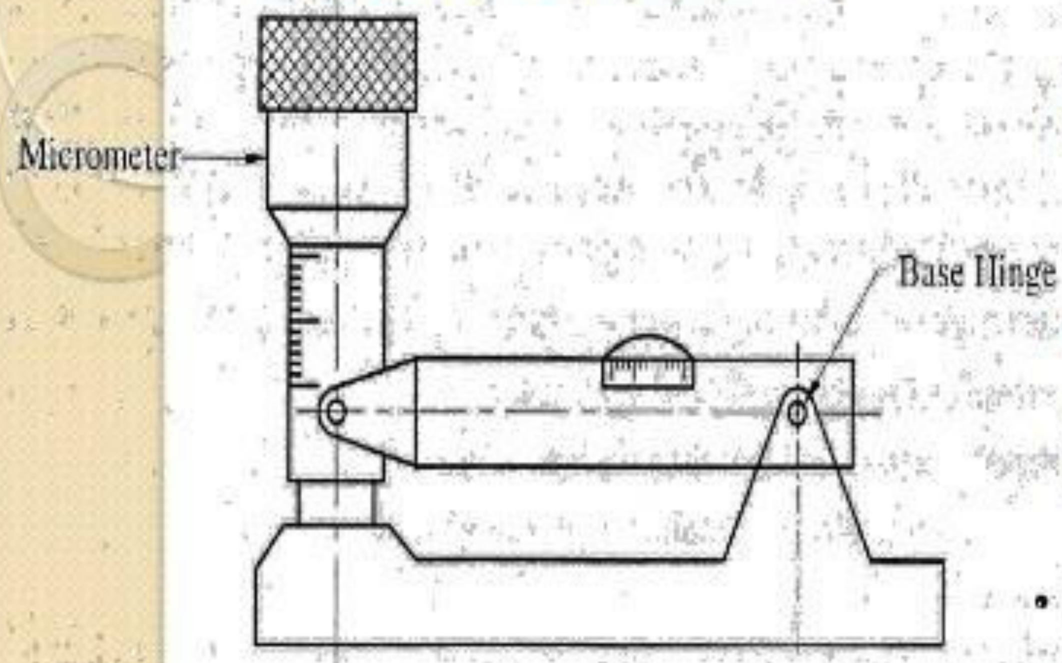
The base of the instrument is placed on the surface and rotary member is adjusted till zero reading of the bubble is obtained as shown in Fig.

The angle of rotation is then noted on the circular scale against an index.

Clinometers



Clinometers



- Micrometer clinometers is shown in Fig. In this type, one end of spirit level is attached at end of the barrel of a micrometer

The other end of the spirit level is hinged on the base. The base is placed on the surface whose inclination is to be measured.

- The micrometer is adjusted till the level is horizontal. This type of clinometers is suitable for measuring small angles.

- The most commonly used clinometers is of the Hilger and Walts type in which circular, scale is totally enclosed and is divided from 0 to 360 at l0' interval. For observation of 10'-subdivision optical micrometer is provided..