Presentation for
MACHINE TOOLS AND METROLOGY
DEPARTMENT OF MECHANICAL ENGINEERING
B.Tech : V SEM

by

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BASIC MECHANISM OF METAL CUTTING

Definition of Manufacturing & Machine Tools

Manufacturing: The making of articles on a large scale using Machinery. Converting raw material, components or parts in to finished goods that meets a customer expectations.

- **Machine and Machine Tool**
- **Machine:** which will do only a particular work. It can't make its own parts
- example: Washing Machine
- **Machine Tool:** it is also a machine but it can produce its own parts.

Background of Machine Tools

Existence of some form of crude machine tool is recorded as early as 700 B.C. However, the most prominent beginning of the machine tool the **John Wilkinson's** horizontal boring machine towards 1775.

Henry Maudslay	engine lathe	1794
Roberts	Planer	1817

Maudslay combined a lead screw, a cross slide and change gears in a form, which is almost similar to the current day centre lathe.

Eli Whitney	Milling Machine	1818

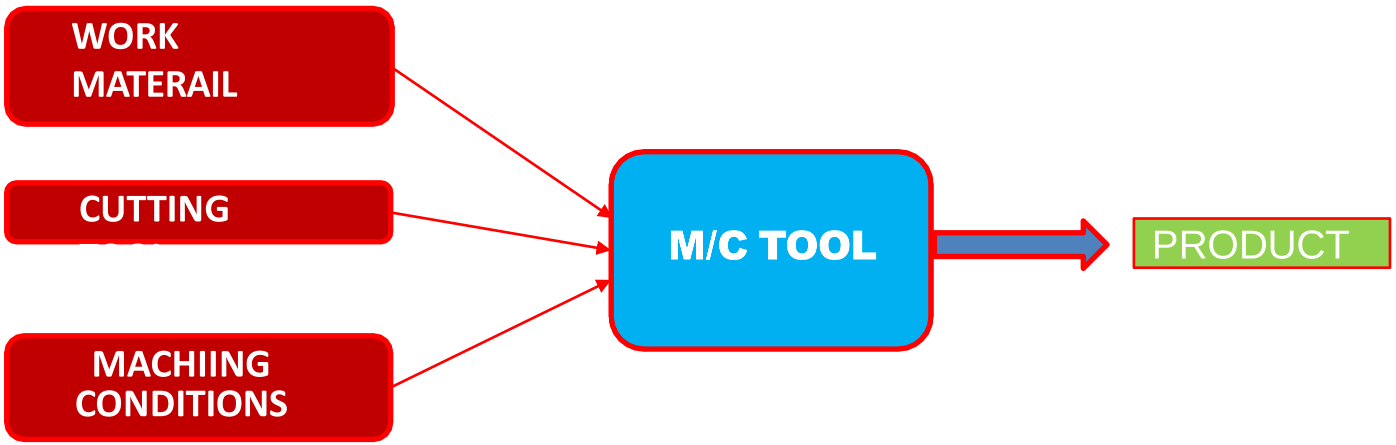
- **John Nasmyth** drilling machine 1840
- Stefen Fitch first Turret Lathe 1845
- Christoper Spencer automatic turret Lathe 1869
- NC lathe 1952

ORGANIZATION

NATURE OF RELATIVE MOTION BETWEEN THE TOOL AND WORKPIECE

1. FUNDAMENTALS OF METAL CUTTING
2. FACTORS INFLUENCING CUTTING PROCESS
3. MECHANICS OF CHIP FORMATIO
4. TYPES OF CHIPS
5. CHIP BREAKERS
6. CUTTING TOOL
7. TYPES OF CUTTING
8. TEMPERATURE DISTRIBUTION
9. TOOL WEAR

INEFFICIENT BUT MOST IMPORTANT MANUFACTURING PROCESS



Metal Cutting Plastic Deformation/Flow Process

Classification of Cutting
- **Orthogonal Cutting**
- **Oblique Cutting**

MANUFACTURING PROCESS

- Components are made of metals in different shapes, sizes and dimensions.
- Metals are shaped to the required forms by various processes.

Non-cutting shaping process	Cutting shaping process
Metal is shaped under action of heat, Pressure or both. No ship formation	Required shape is obtained by removing the unwanted material from the work piece in the form of chips
Ex: Forging, drawing, spinning, rolling, extruding etc.	Ex: Turning, boring, milling, drilling, shaping, broaching are called metal cutting operations....

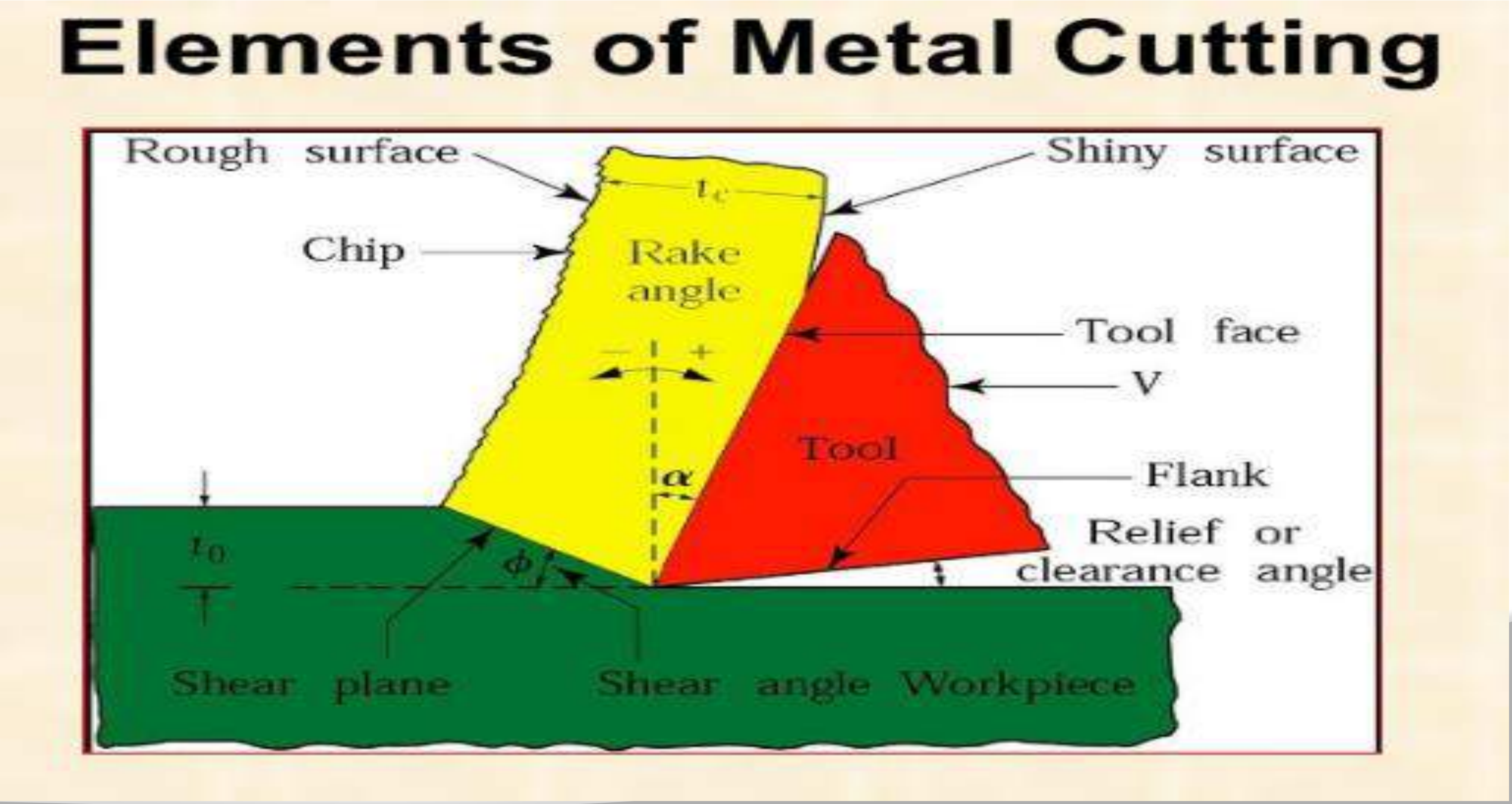
Metal cutting is done by a relative motion b/w the work piece and the hard edge of a cutting tool. It is obtained by

- Rotation of the work against the tool (Turning)
- Rotation of the tool against the work (Milling and Drilling)
- Linear movement of the work against the tool (Planing)
- Linear movement of the tool against the work (Shaping)

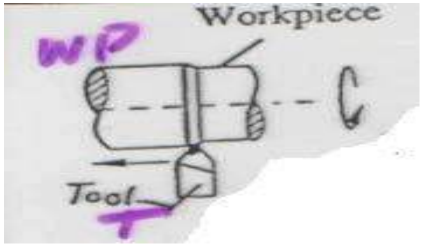
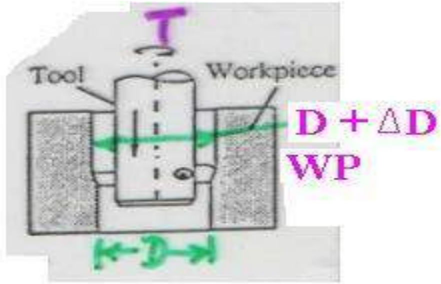
Metal Cutting can be done either by Single Point cutting tool or Multi point cutting tools

Basic elements of cutting process:

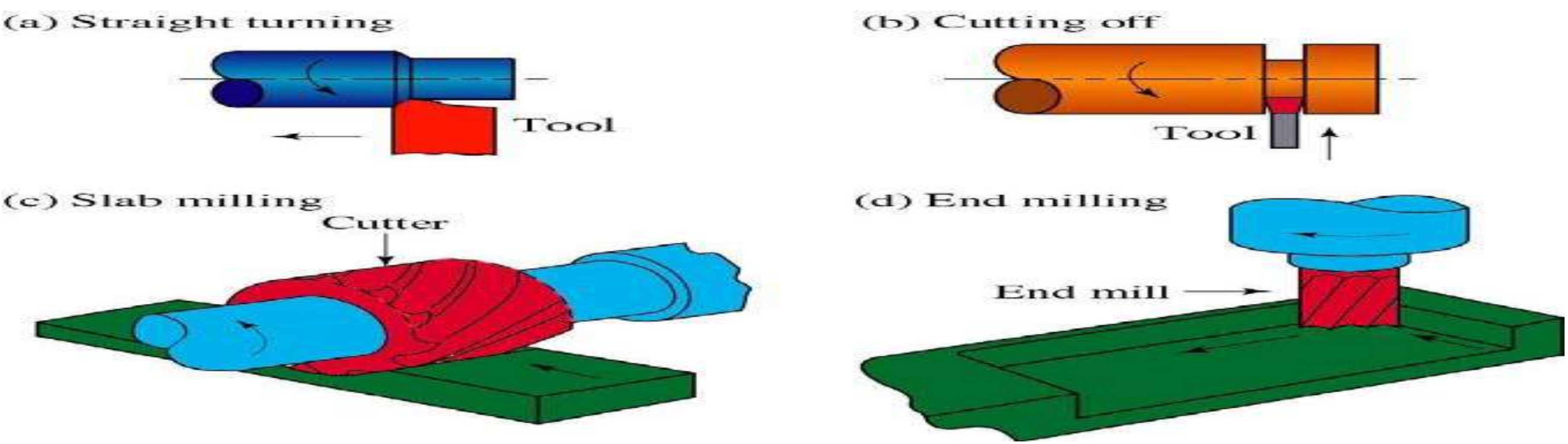
Work piece, Tool, Chip

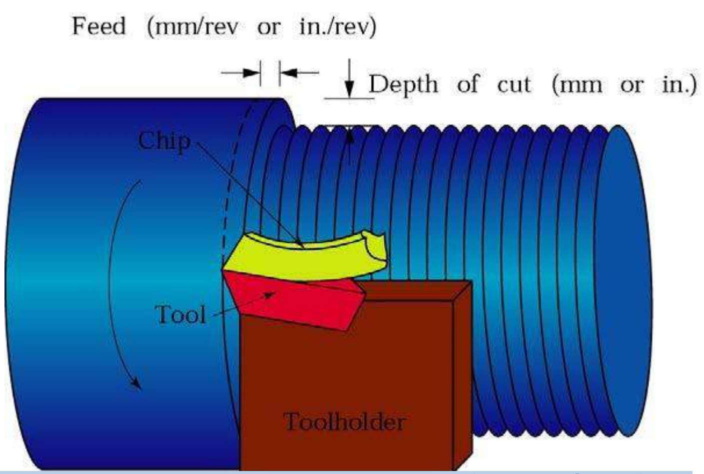


NATURE OF RELATIVE MOTION BETWEEN THE TOOL AND WORKPIECE

OPERATION	MOTION OF JOB	MOTION OF CUTTING TOOL	FIGURE OF OPEARTION
TURNING	ROTARY	TRANSLATORY (FORWARD)	
BORING	ROTATION	TRANSLATION (FORWARD)	
DRILLING	FIXED (NO MOTION)	ROTATION AS WELL AS TRANSLATORY FEED	

Fundamentals of Cutting





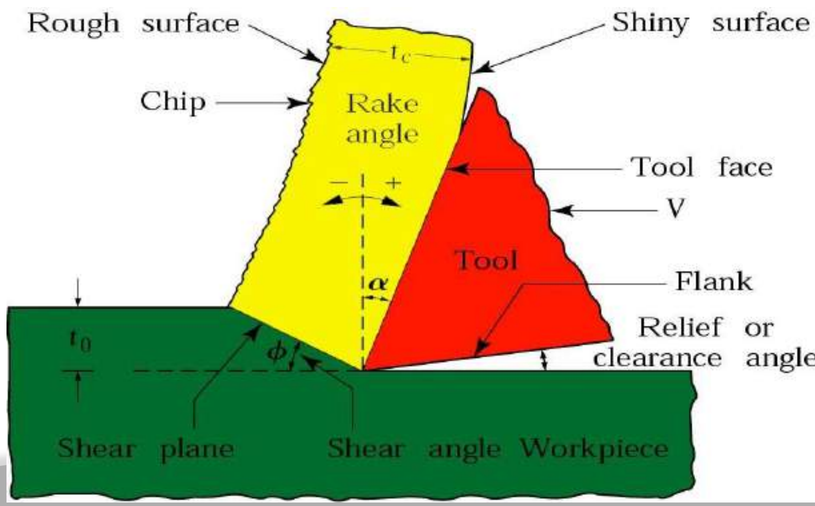


Figure: Basic principle of the turning operations.

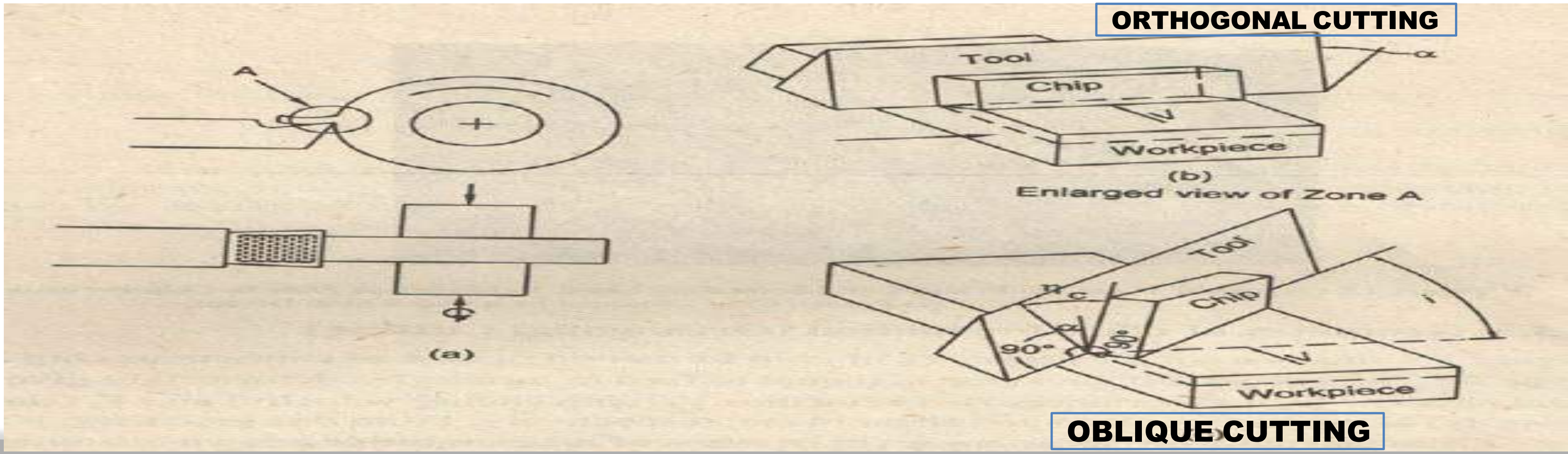
Types of Cutting

Orthogonal Cutting (2-D Cutting):

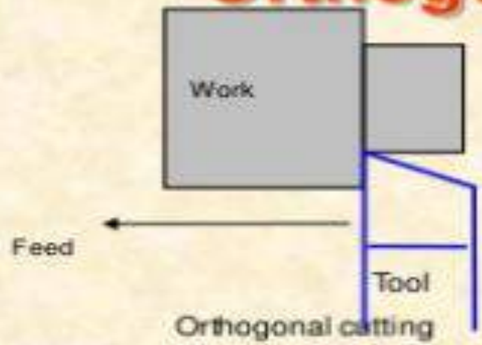
Cutting edge is (1) straight, (2)parallel to the original plane surface on the work piece and (3)perpendicular to the direction of cutting. For example: Operations:Lathe cut-off operation, Straight milling, etc.

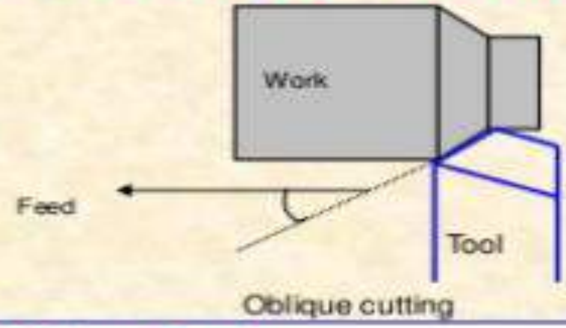
Oblique Cutting (3-D Cutting):

Cutting edge of the tool is inclined to the line normal to the cutting direction. In actual machining, Turning, Milling etc. / cutting operations are oblique cutting(3-D)



Orthogonal and Oblique Cutting





Orthogonal Cutting:

- The cutting edge of the tool remains normal to the direction of tool feed or work feed.
- The direction of the chip flow velocity is normal to the cutting edge of the tool.
- Here only two components of forces are acting: Cutting Force and Thrust Force. So the metal cutting may be considered as a two dimensional cutting.
- Examples are: Parting off operation, Broaching, Sawing, straight milling
- **Shear force acts on smaller area.**

Oblique Cutting:

- The cutting edge of the tool remains inclined at an acute angle to the direction of tool feed or work feed.
- The direction of the chip flow velocity is at an angle with the normal to the cutting edge of the tool. The angle is known as chip flow angle.
- Here three components of forces are acting: Cutting Force, Radial force and Thrust Force or feed force. So the metal cutting may be considered as a three dimensional cutting.
- The cutting edge being oblique, the shear force acts on a larger area and thus tool life is increased.
- Examples are: lathe turning, drilling etc.,
- **Shear force acts on larger area**

Chip Formation Mechanism

- When the tool advances in to the work piece, metal in front of the tool is severely stressed.

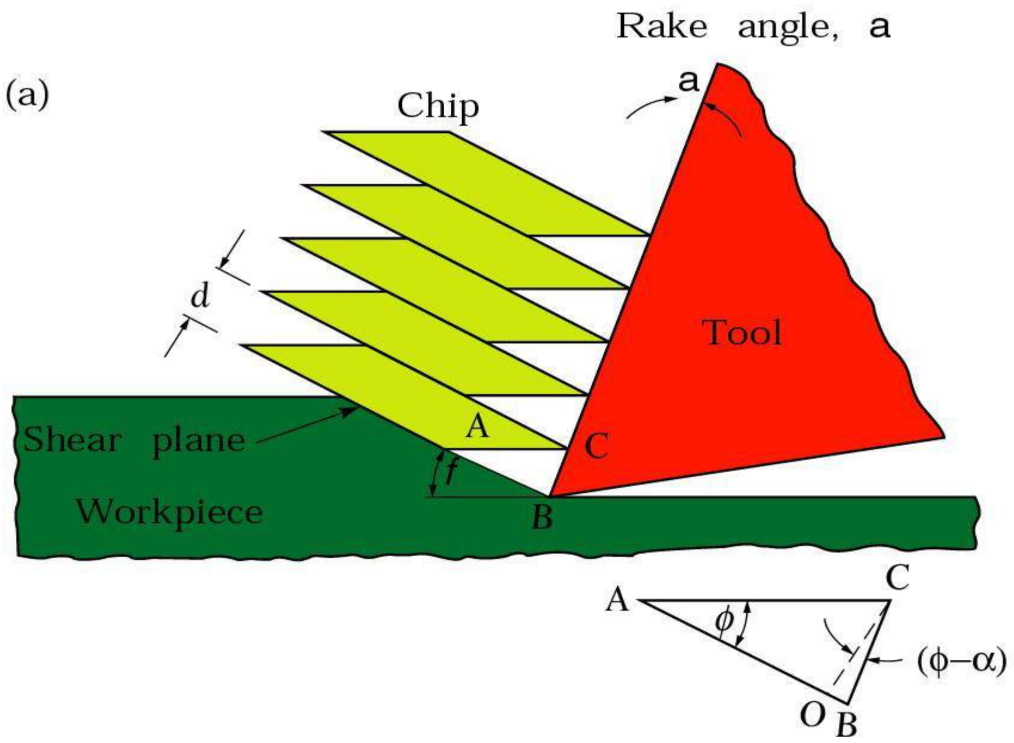
- This cutting tool produces internal shearing action in the metal, so metal yields and flows plastically in the form of chips.

- Compression of the metal under the tool takes place. When the ultimate stress of the metal is exceeded, separation of metal takes place in a localized area called shear plane and the chip moves upward on the face of the tool.

- This process is continued and a continuous chip formation takes place.

- The grains of the metal in front of the Tool cutting edge start elongating along line AB.
- This elongation continues until the grains are completely deformed along the line CD.
- The region b/w the lines AB and CD is called shear zone.
- After passing the shear zone, the deformed metal slides along the tool face due to the velocity of cutting tool.

Mechanics of Chip Formation

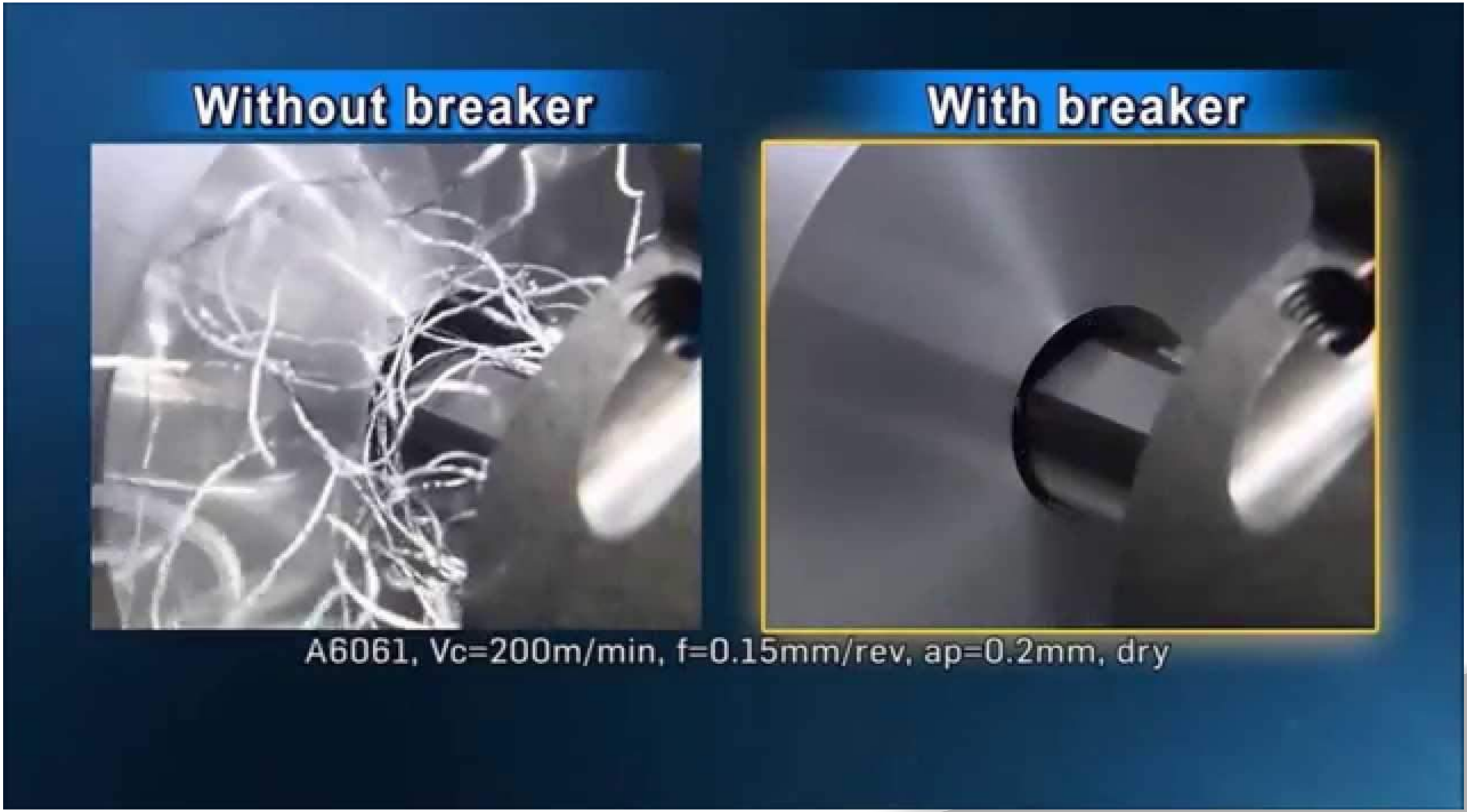


(a) Basic mechanism of chip formation in metal cutting.

(b) Velocity diagram in the cutting zone.

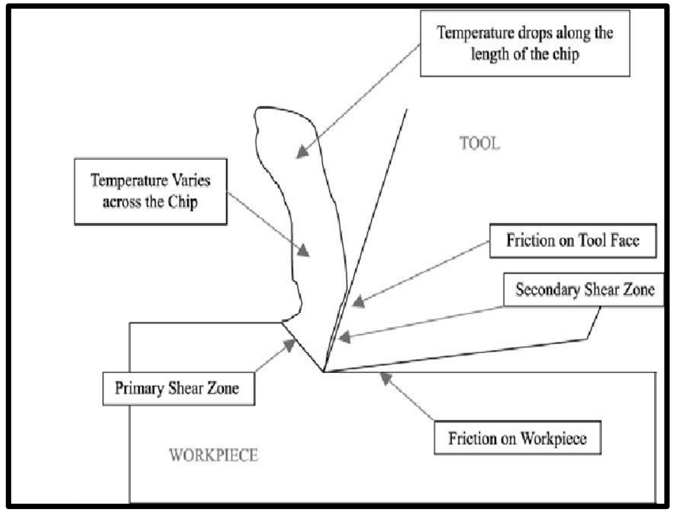
V= Cutting velocity, V_s= Shear velocity, V_c=Chip velocity

Φ= Shear angle, α=Rake angle


Without breaker
With breaker
A6061, Vc=200m/min, f=0.15mm/rev, ap=0.2mm, dry

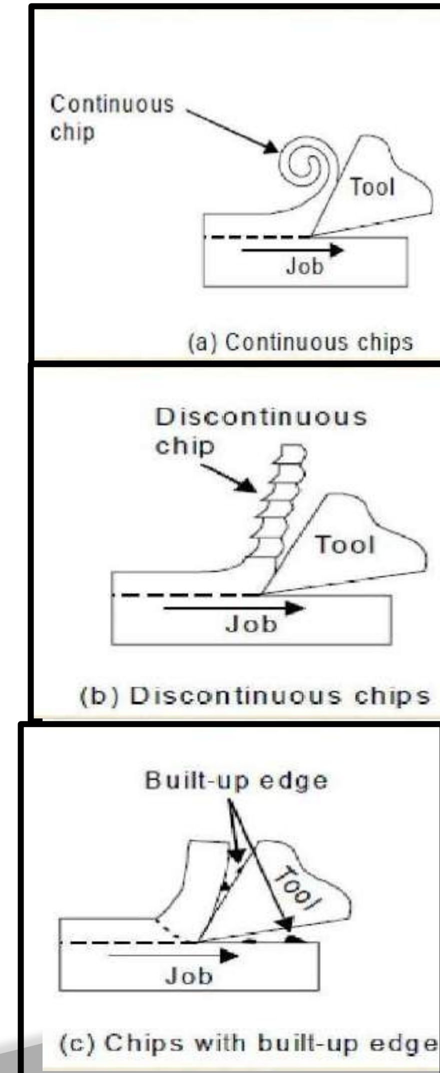
CHIP FORMATION

- **Types of Chips**
  - ✓ Continues Chips
  - ✓ Discontinues Chips
  - ✓ Continuous Chips with Built up Edge (BUE)



Conditions for Continuous Chips:

- Sharp cutting edges
- Low feed rate (f)
- Large rake angle (α)
- Ductile work material
- High cutting speed (v=)
- Low friction at Chip-Tool interface

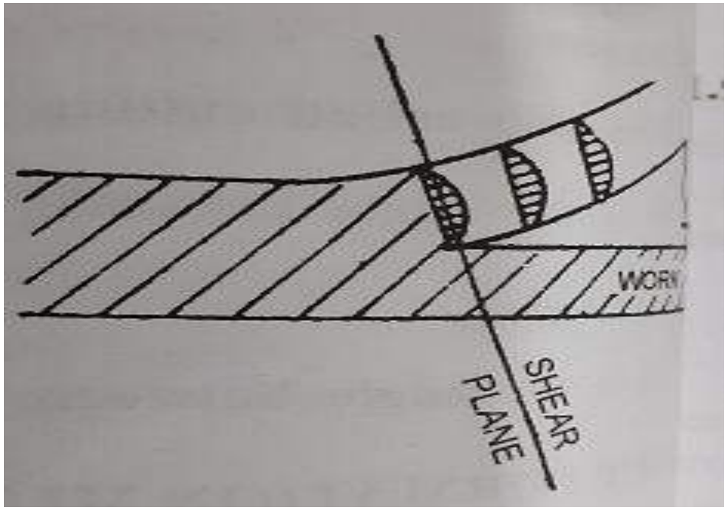


Fig; Schematic of different types of chip

Types of chips

Discontinuous chips:

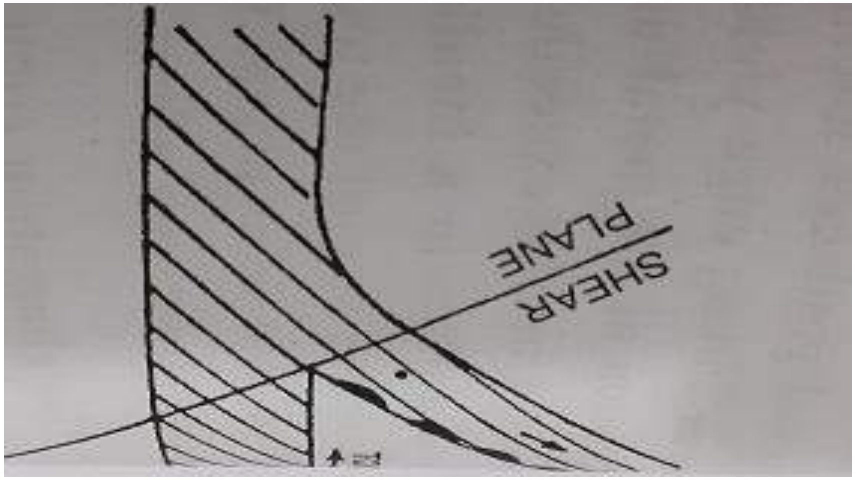
- Also be called as segmental chips.
- Mostly occurs while cutting brittle material (Cat Iron) or low ductile materials.
- Instead of shearing the metal as it happens in previous process, the metal is being fractured like segments of the fragments and they pass over the tool faces.
- Tool life more.
- Power consumption as in the previous case also low.



Types of chips

Continuous Chips:

- When cutting a ductile material, the compression of the metal is followed by the high heat at tool face.
- This in turns enables the part of the removed metal to be welded into the tool. This produces rough surface finish and the tool life may be reduced.



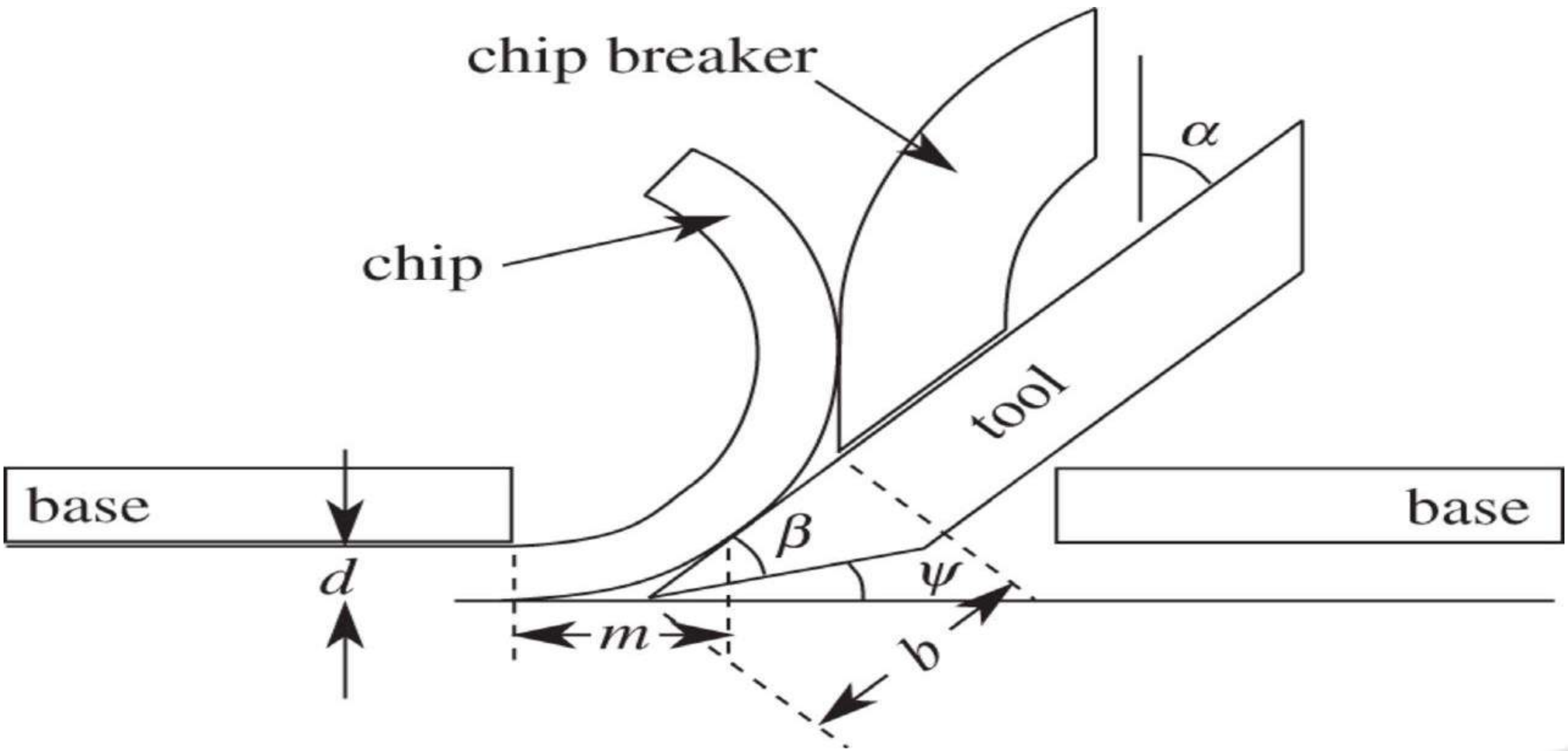
Types of chips

In operation at high cutting speeds, when a large quantity of inconvenient and hazardous steel chips Is produced in a short time, the problem of curling or breaking the chips into small pieces becomes one of primary importance

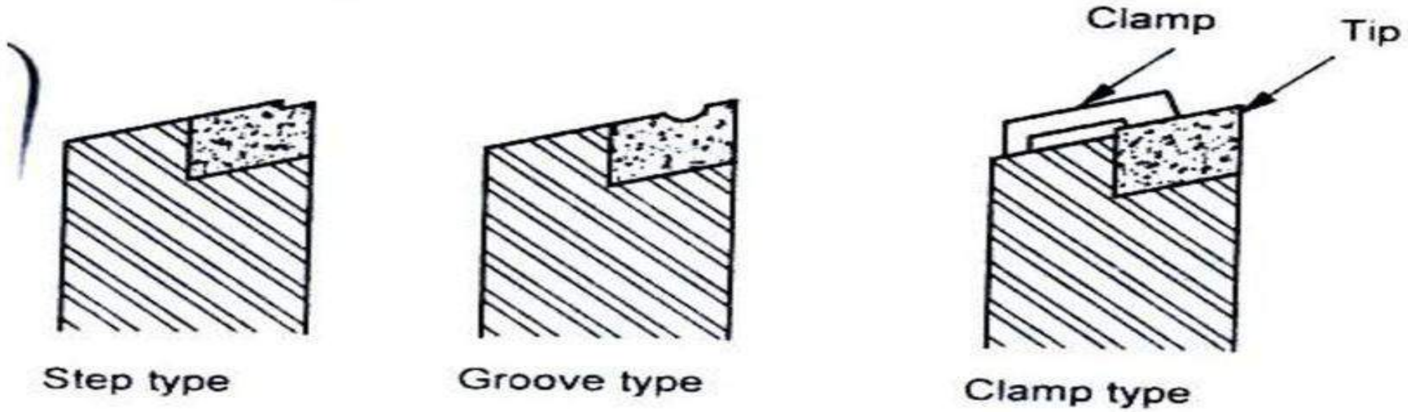
Chip Breakers

- Long continuous chips are undesirable
- Chip breaker is a piece of metal clamped to the rake surface of the tool which bends the chip and breaks it
- Chip can also be broken by changing the tool geometry, thereby controlling the chip flow

Chip Breakers



TYPES OF CHIP BREAKERS



In the step type, a step is ground on the tool face behind the cutting edge. This step will break the chip.

In groove type, a groove on the tool face behind the cutting edge will break the chip.

In the clamp type, a thin chip breaker is clamped or screwed on the face of the tool.

Chip- Breaking

- The chip breaker break the produced chips into small pieces.
- The work hardening of the chip makes the work of the chip breakers easy. When a strict chip control is desired, some sort of chip breaker has to be employed. The following types of chip breakers
  - Groove type
  - Step type
  - Secondary Rake type
  - Clamp type

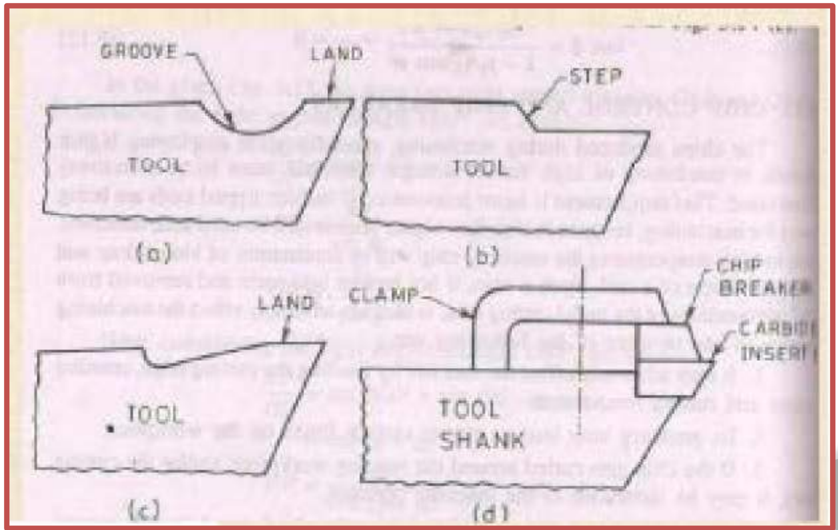


Fig: Schematics of different types of chip barkers

Classification of cutting tools

(1) Single Point Cutting Tool

(2) Multi point Cutting Tool

Single Point Cutting Tool: It has effective cutting edge and removes excess material along cutting edge

Types: (a) Ground Type, (b) Forged Type
(c) Tipped Type, (d) Bit Type

(a) Ground Type: Cutting edge is formed by grinding the end of a piece of tool steel stock

(b) Forged Type: Cutting edge is formed by rough forging before hardening and grinding

Classification of cutting tools

(c) Tipped Type: Cutting edge is in the form of a small tip made of high grade material which is welded to shank made up of low grade material.

(d) Bit Type: A high grade material of square, rectangular or some other shape is held mechanically in a tool holder.

Single point cutting tools are commonly used in Lathe, shapers, planers, boring M/C and Slotters.

Classification of cutting tools

Multi point cutting tool : Having more than a cutting edge Milling cutters, drills, broaches, grinding wheel

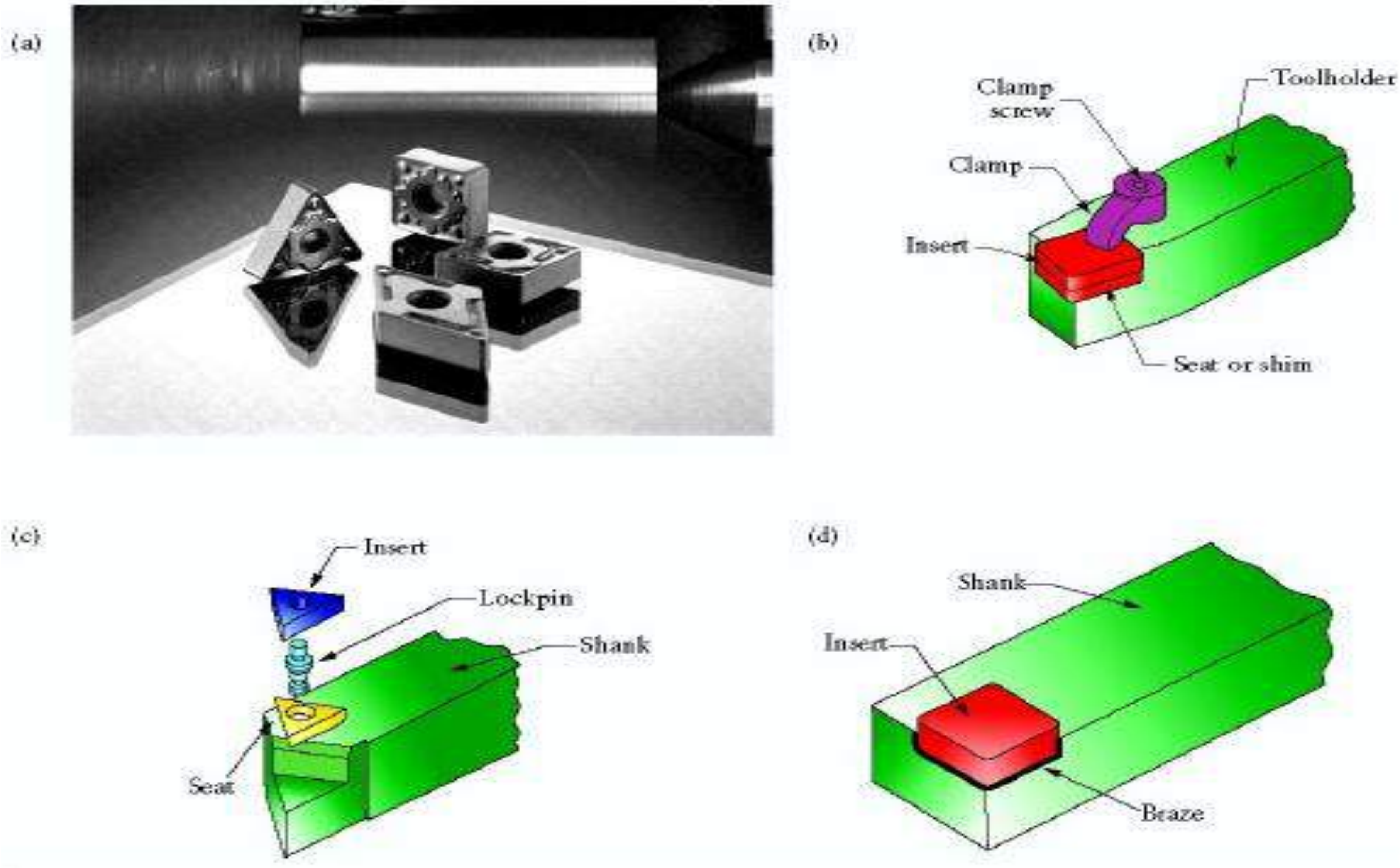
Cutting tools also classified according to the motion as

(1) Linear Motion: Lathe, boring, broaching, planning, shaping tools etc.

(2) Rotary Motion Tools: Milling Cutters, grinding wheels etc.

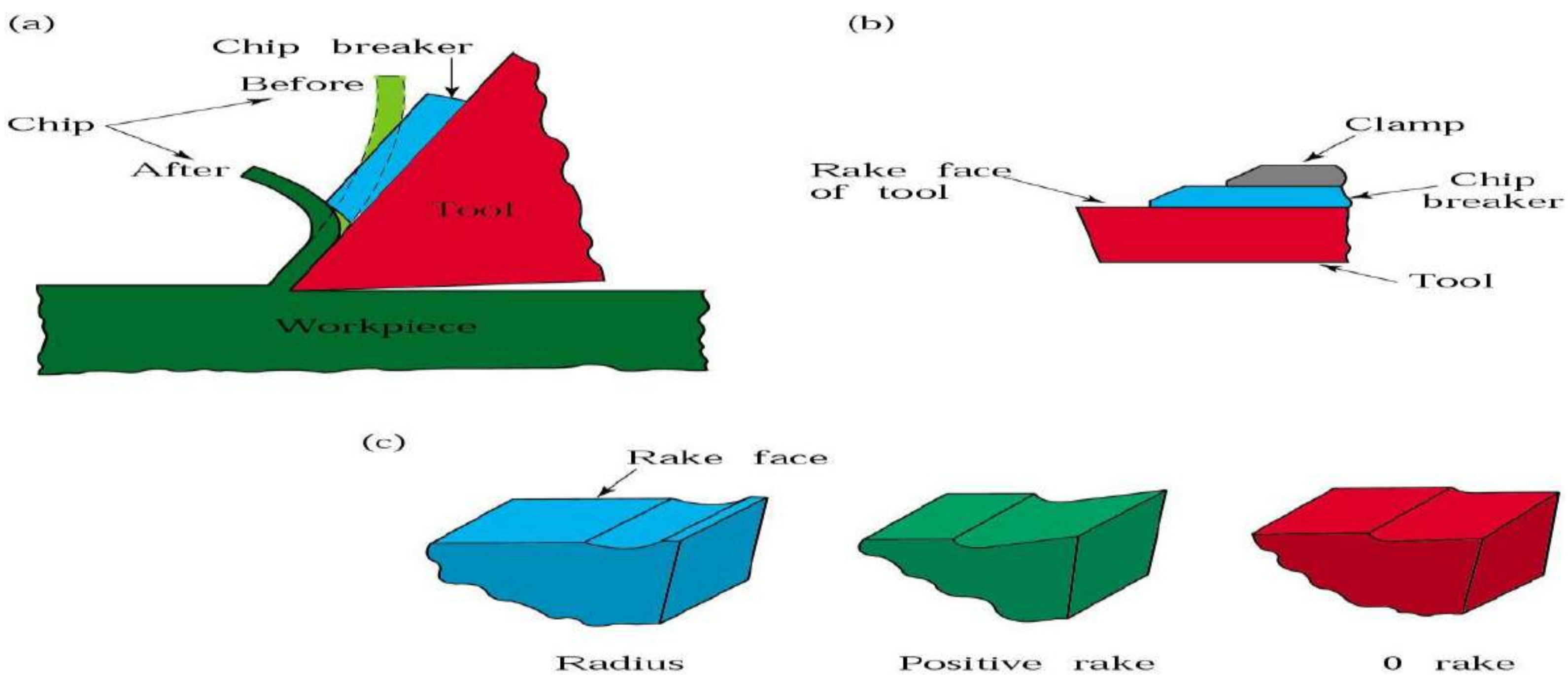
(3) Linear and rotary tools: Drills, honing tool, boring heads etc.

Bit Type



(a)
(b)
Clamp screw
Toolholder
Clamp
Insert
Seat or shim
(c)
Insert
Lockpin
Shank
Seat
(d)
Shank
Insert
Braze

Chip Breakers



(a) Schematic illustration of the action of a chip breaker. Note that the chip breaker decreases the radius of curvature of the chip. (b) Chip breaker clamped on the rake face of a cutting tool. (c) Grooves in cutting tools acting as chip breakers.

fig: a

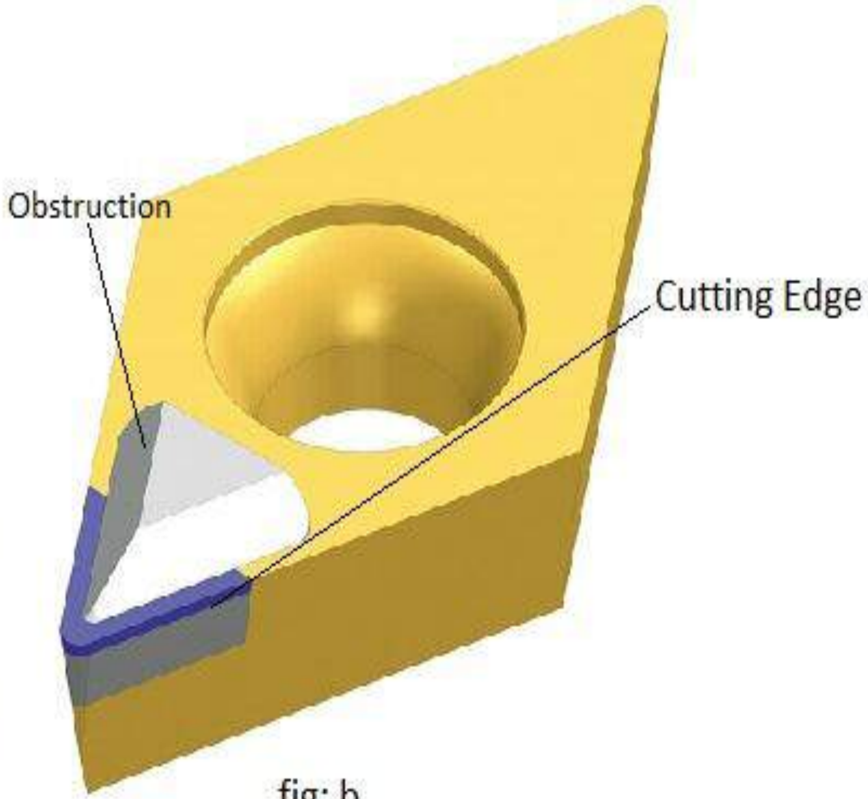
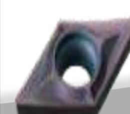
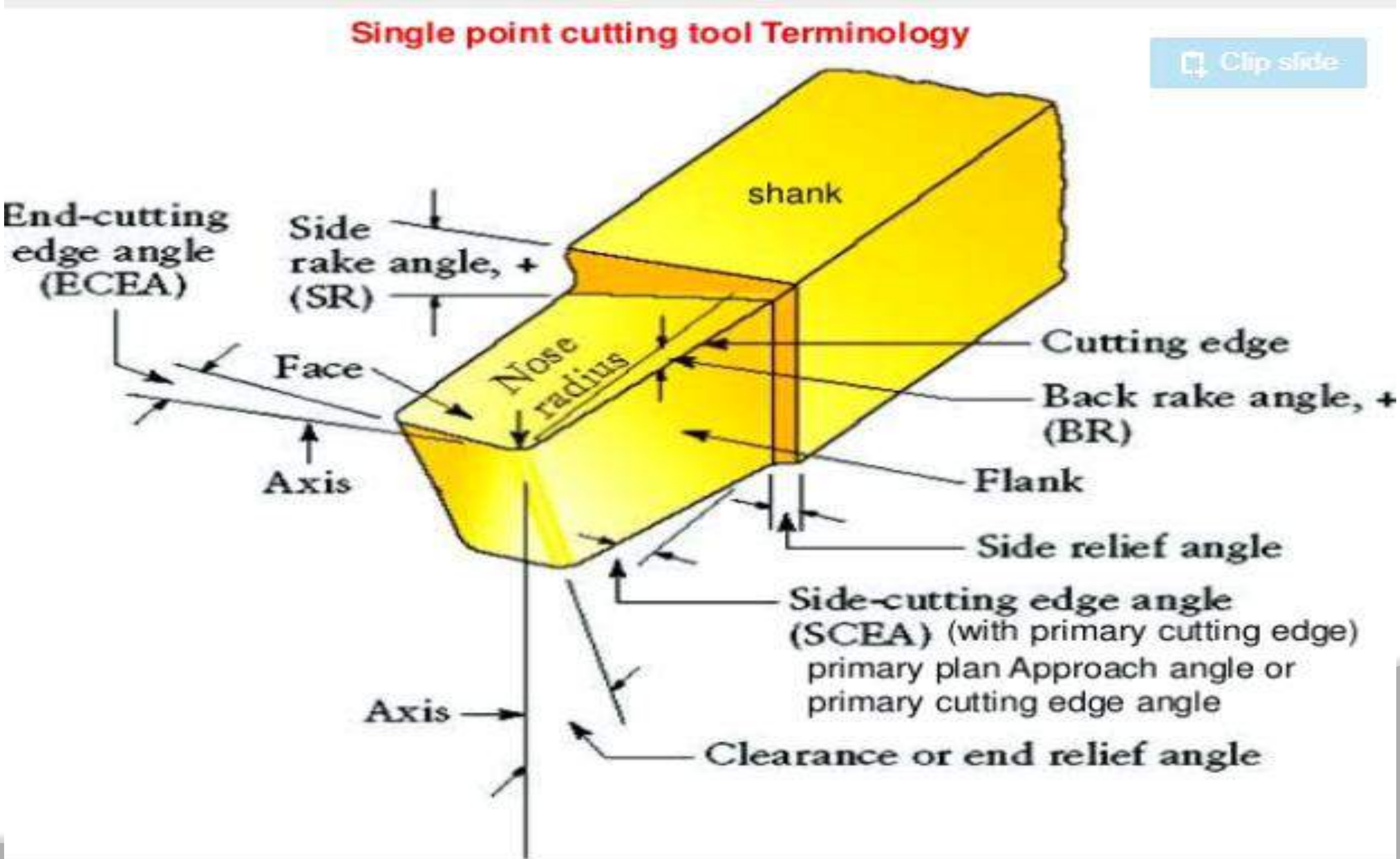


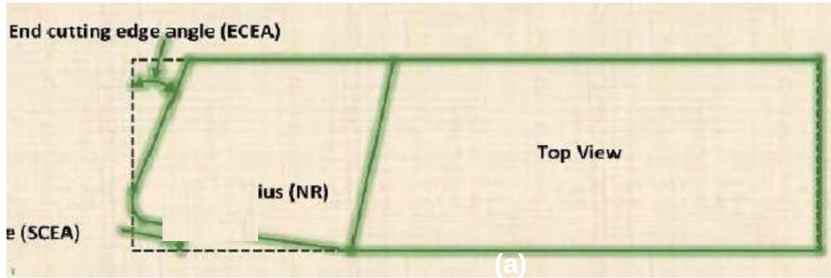
fig: b

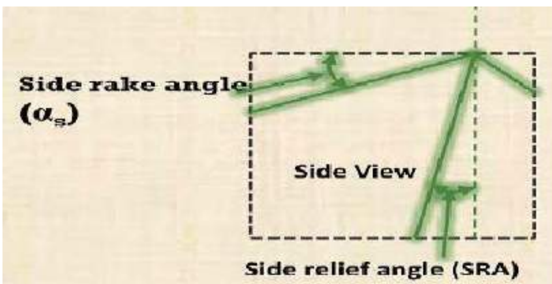
Breaker	Features	CCGH/CCGT Type	CCMH/CCMT CPMH/CPMT Type	DCMT Type	DCGT Type	TCGT/TCMT Type	TPMH Type	VBGT/VBMT Type	VCMT Type	WBMT/WCGT Type
SMG (G class)	● For medium cutting. ● 3D moulded chipbreaker provides good chip control. ● G class insert gives sharp cutting action, allowing high precision machining.		–	–		–	–	–	–	–
FV (M class)	● Sharp cutting edge and low resistance design achieves excellent cutting performance. ● Suitable for low depths of cut and low feed rates.	–			–					–
SV (M class)	● For light cutting. ● A peninsular dot ensures chip control at depths of cut under 1mm.	–			–	–				–
MV (M class)	● A positive insert and the large rake angle achieve sharp cutting edge performance. ● The double breakers and round-shaped dots in the rake face achieve a wide range of chip discharge.	–			–	–				
Standard (M class)	● For medium cutting. ● Balance of edge strength and sharpness due to a combination of a flat land and large rake angle.	–			–		–			–
FJ	● The curved edge allows smooth chip discharge. ● The large rake angle highly suitable for finishing difficult-to-cut materials.		–	–			–	–	–	
MJ	● The curved edge allows smooth chip discharge. ● Large rake angle highly suitable for finish-light cutting difficult-to-cut materials.		–	–			–	–	–	

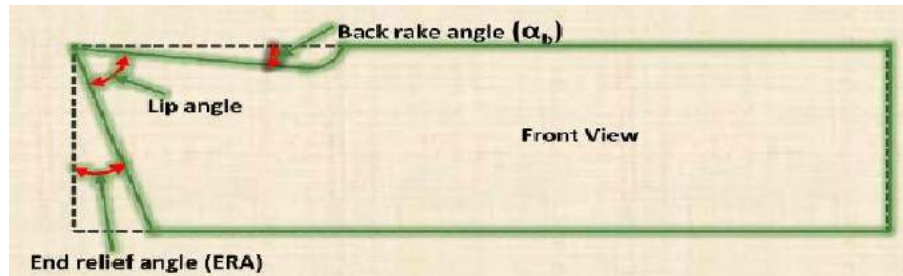
GEOMETRY OF S P C TOOL/ NOMENCLATURE

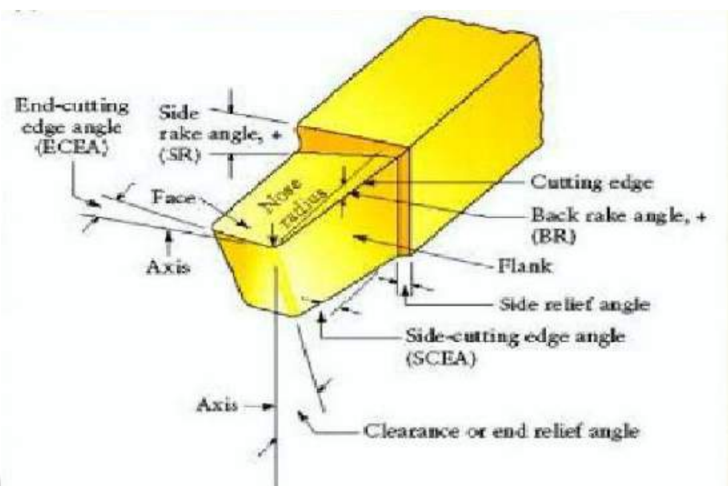


Tool Nomenclature/Angles









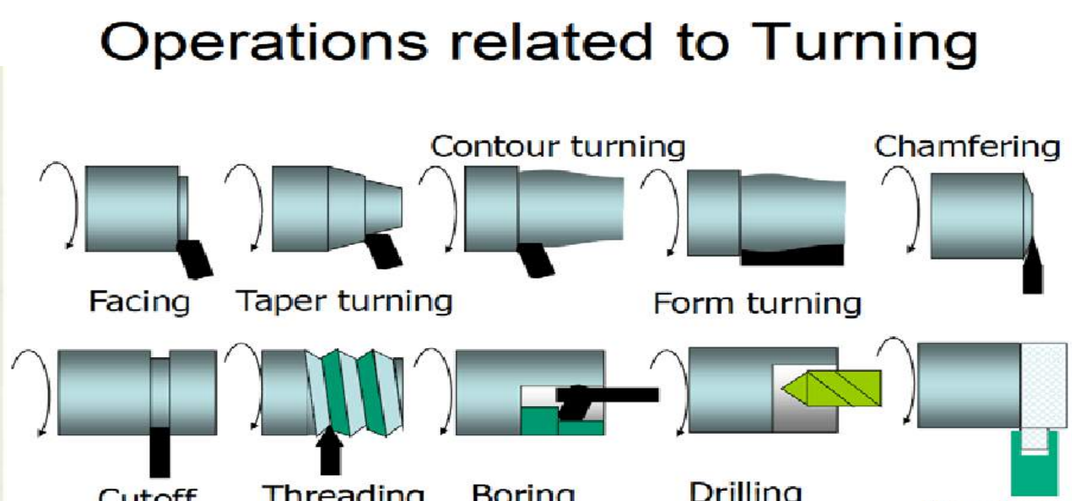


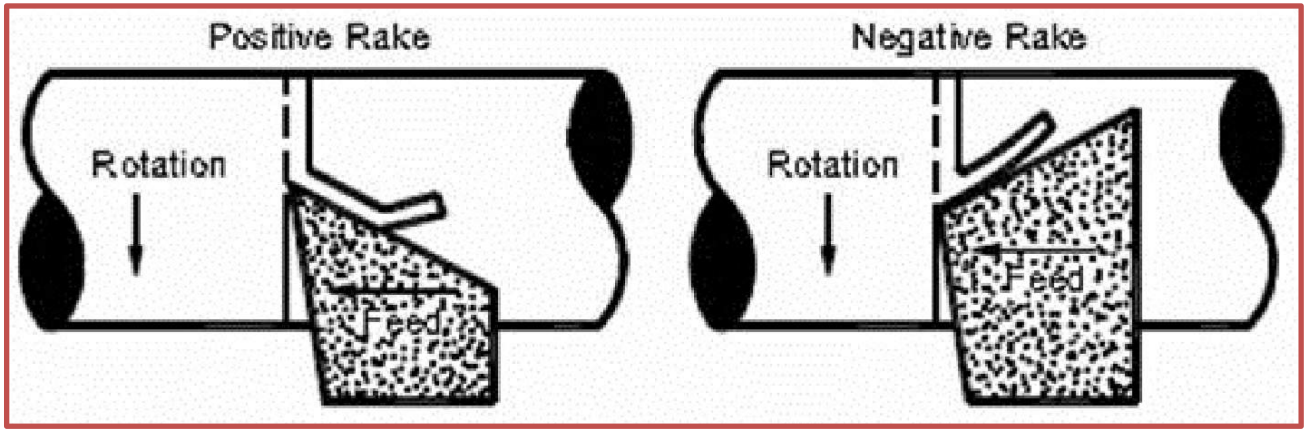
Fig: Turning Operations

Important parts of a single point cutting tool

Important parts of a single point cutting tool are

1. **Shank:** body of the tool which is unground.
2. **Face:** surface over which the chip slides.
3. **Flank:** surface of the tool facing work piece. Two flanks end flanks and side flanks
4. **Base:** bottom surface of the shank.
5. **Cutting edge**: junction of the face and the flank. Two types side cutting edge and end cutting edge.
6. **Nose:** Junction of side and end cutting edges

Tool Nomenclature/Angles



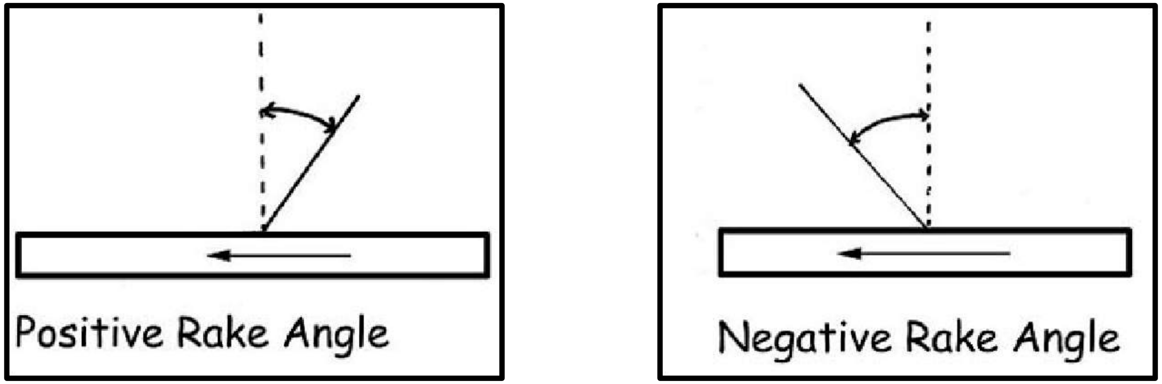
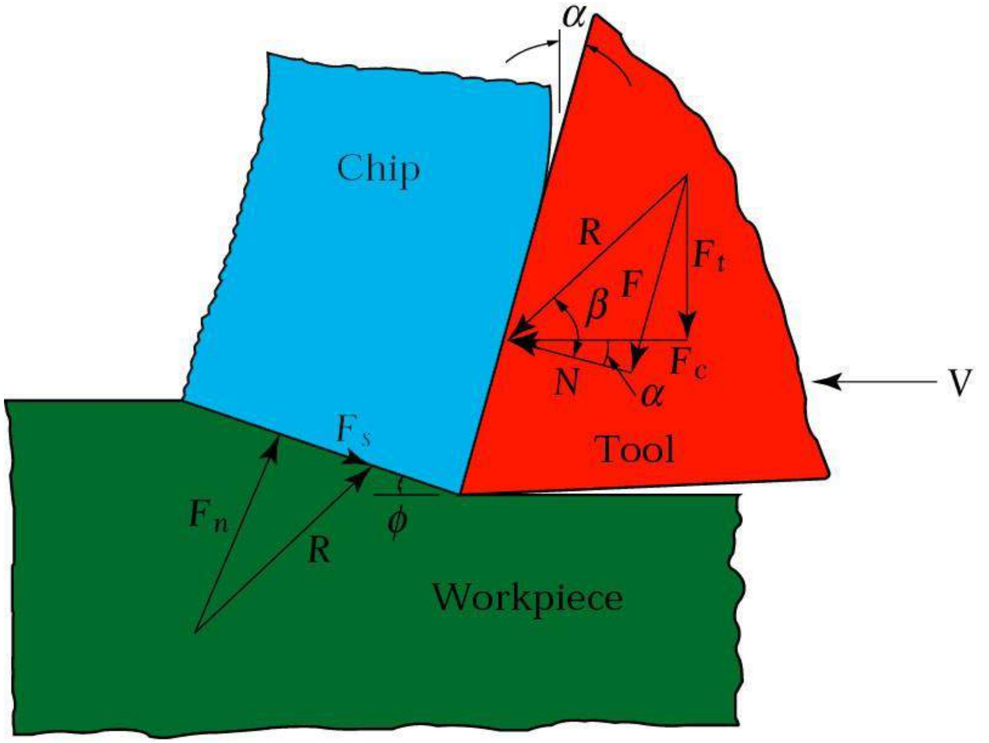


Fig: Terms used in metal cutting (a) Positive rake; (b) Negative rake

Forces in Two-Dimensional Cutting / Orthogonal Cutting



Forces acting on a cutting tool in two-dimensional cutting.

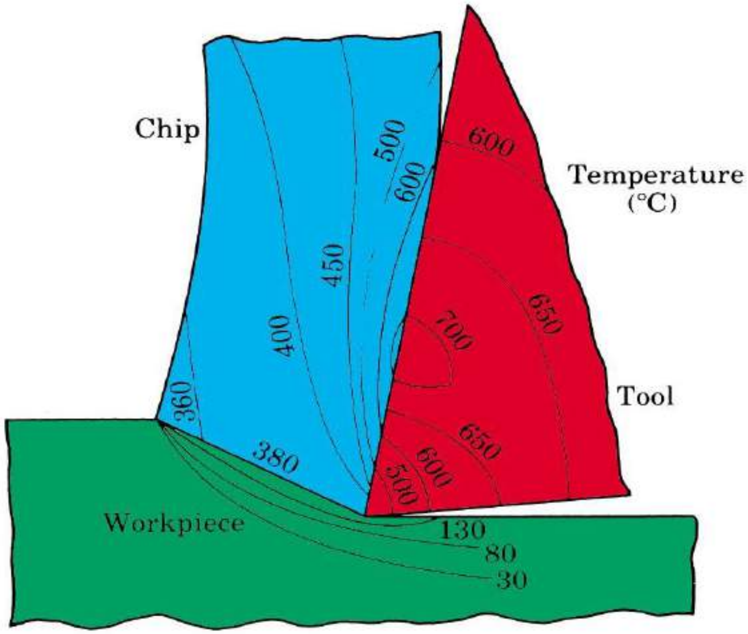
Note that the resultant force, R, must be collinear to balance the forces.

Approximate Energy Requirements in Cutting Operations

Approximate Energy Requirements in Cutting Operations (at drive motor, corrected for 80% efficiency; multiply by 1.25 for dull tools).

Material	Specific energy	
	W-s/mm3	hp-min/in.3
Aluminum alloys	0.4–1.1	0.15–0.4
Cast irons	1.6–5.5	0.6–2.0
Copper alloys	1.4–3.3	0.5–1.2
High-temperature alloys	3.3–8.5	1.2–3.1
Nickel alloys	0.4–0.6	0.15–0.2
Refractory alloys	4.9–6.8	1.8–2.5
Stainless steels	3.8–9.6	1.1–3.5
Steels	3.0–5.2	1.1–1.9
Titanium alloys	2.7–9.3	1.0–3.4
	3.0–4.1	1.1–1.5

Temperature Distribution and Heat Generated

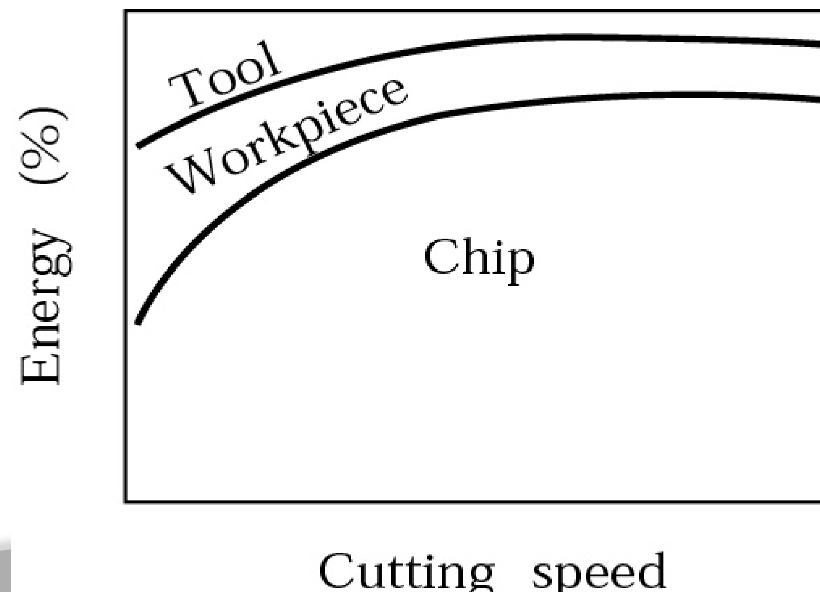


Typical temperature distribution in the cutting zone. Note the steep temperature gradients within the tool and the chip. :

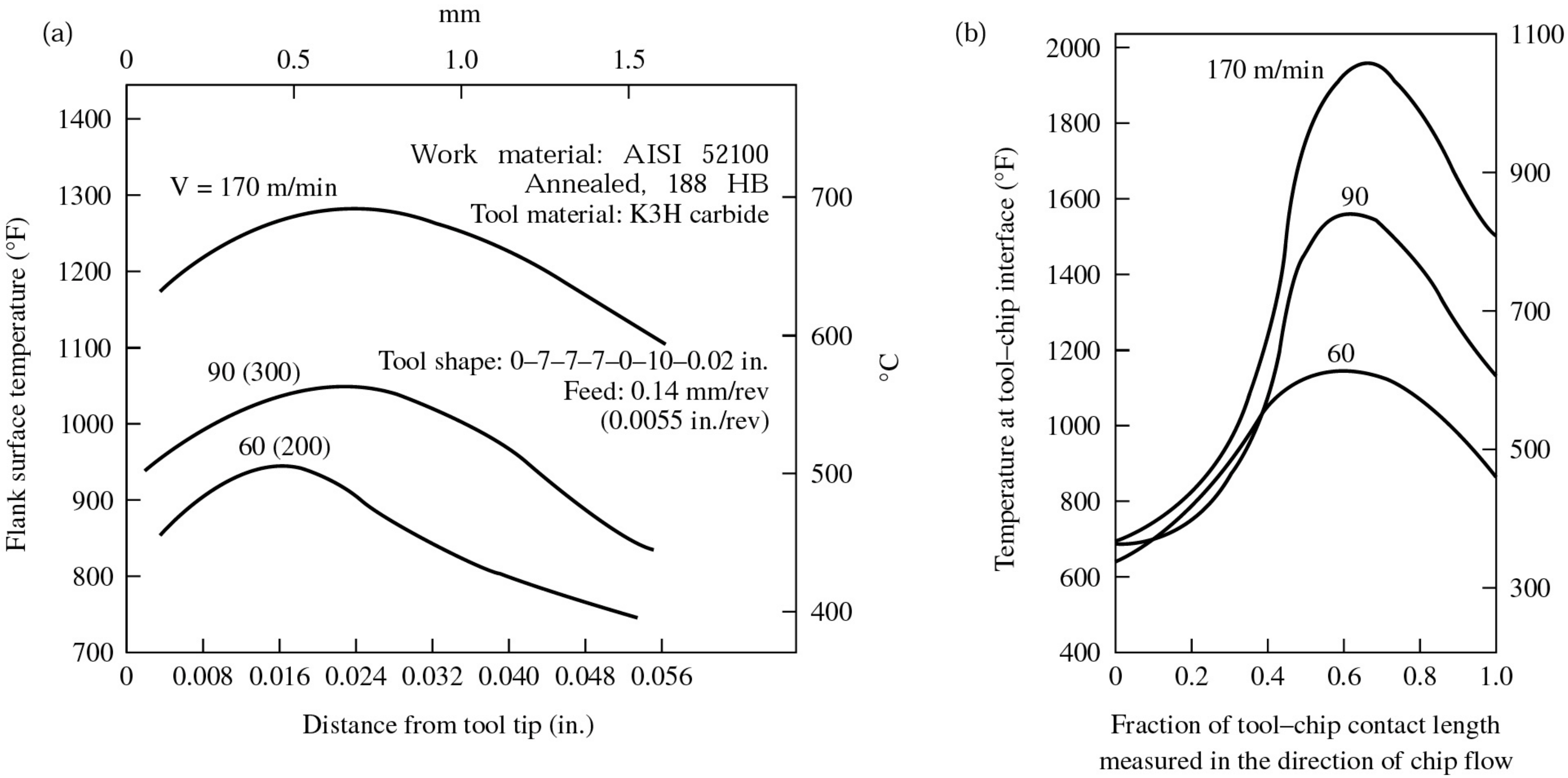
G. Vieregge. *Source*

Percentage of the heat generated in cutting going into the work piece, tool, and chip, as a function of cutting speed.

Note: Chip carries away most of the heat.



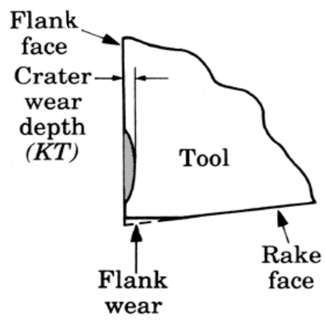
Temperature Distributions

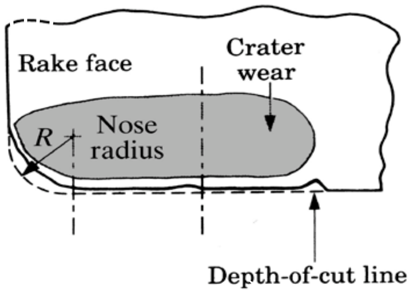


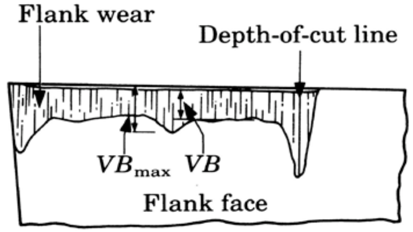
Temperatures developed in turning 52100 steel:

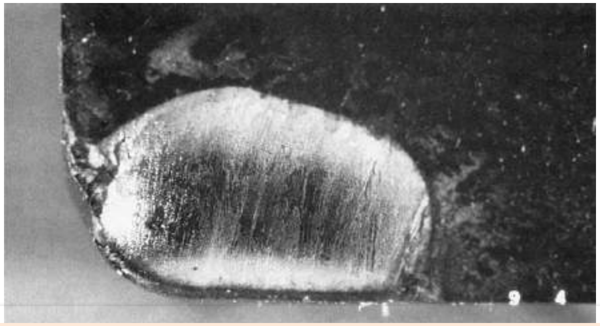
(a)flank temperature distribution; and (b) tool-chip interface temperature distribution.

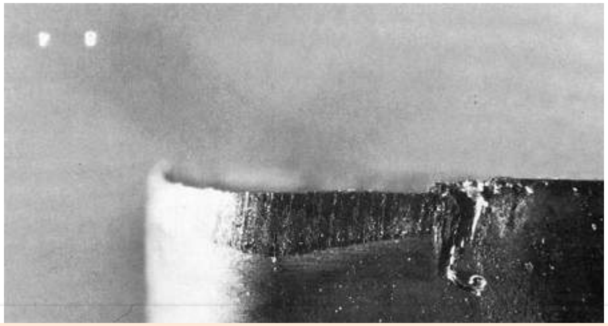
Flank and Crater Wear











(a) Flank and crater wear in a cutting tool. Tool moves to the left.

(b) View of the rake face of a turning tool, showing nose radius R and crater wear pattern on the rake face of the tool.

(c) View of the flank face of a turning tool, showing the average flank wear land VB and the depth-of-cut line (wear notch).

(d) Crater and (e) flank wear on a carbide tool. ***Source*: J.C. Keefe, Lehigh University.**

Surfaces Produced by Cutting

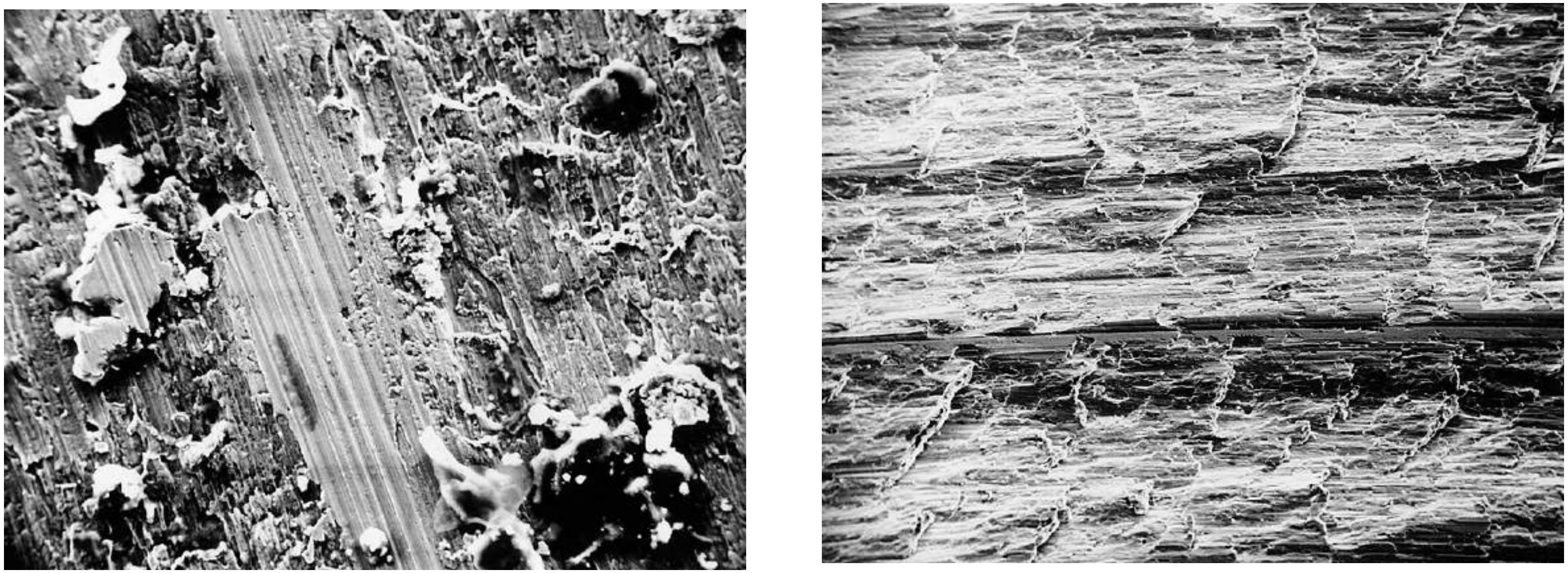
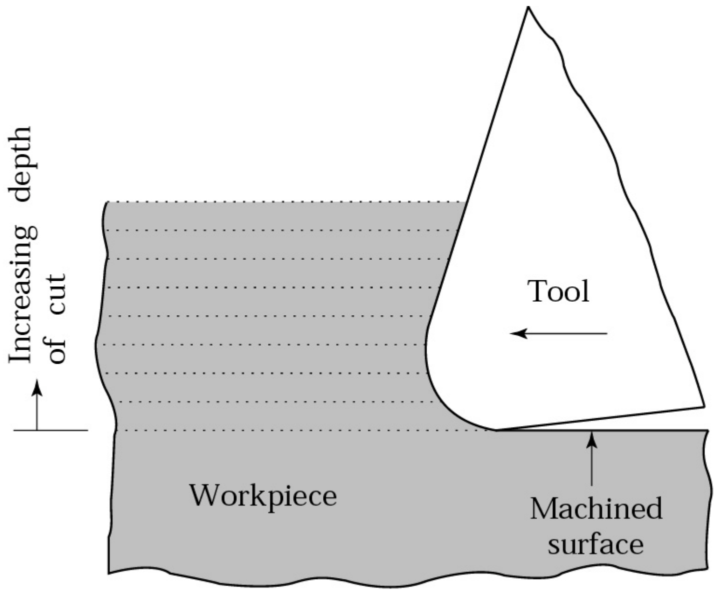


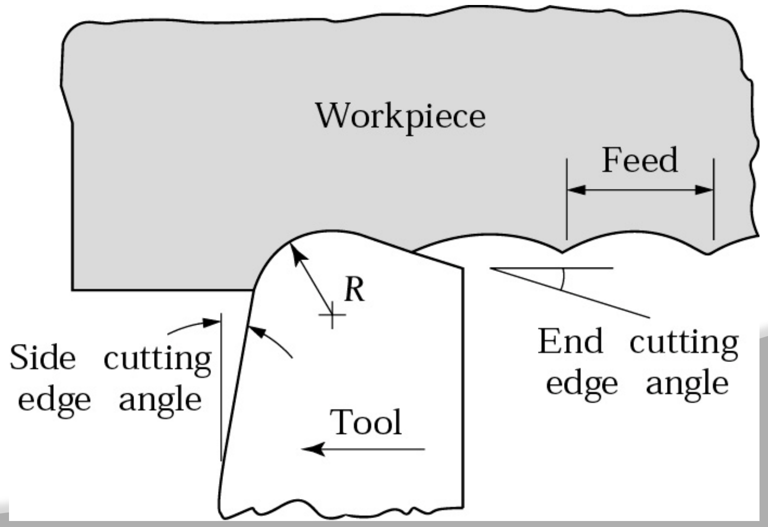
Figure 20.21 Surfaces produced on steel by cutting, as observed with a scanning electron microscope: (a) turned surface and (b) surface produced by shaping. Source: J. T. Black and S. Ramalingam.

Dull Tool in Orthogonal Cutting and Feed Marks



Schematic illustration of a dull tool in orthogonal cutting (exaggerated). Note that at small depths of cut, the positive rake angle can effectively become negative, and the tool may simply ride over and burnish the work piece surface.

Schematic illustration of feed marks in turning (highly exaggerated)



Problem 9: A seamless tubing 35mm outside diameter is turned orthogonally on a lathe. The following data available; rake angle 35°, cutting speed 15m/min, feed 0.10 mm/rev, length of continuous chip in one revolution is 50mm, cutting force 200 kg, feed force 80 kg. Calculate the coefficient of friction, shear plane angle, velocity of chip along tool face and chip thickness.

Solution:

(i) Coefficient of friction (μ)

$$= \frac{F_t + F_C \tan\gamma}{F_C - F_t \tan\gamma}$$

$\mu = 1.458$

$r = 64/(\pi \times 35) = 0.582$

$\Phi = 45$

$V_c = V \times r = 15 \times 0.582 = 8.73$ m/min

$T_2 = t_1/r = 0.171$ mm

Tool Life

Tool Life: It represents the use full life of the tool

Time from the start of cut to some end point defined by failure criterion

Factors influencing the tool life

1. Cutting Speed
2. Feed and Depth of Cut
3. Tool geometry
4. Tool Material
5. Cutting Fluid
6. Work Materials
7. Rigidity of work, tool and machine

Factors influencing the tool life

1. Cutting Speed
   - It has the greater influence on the tool life.
   - When cutting speed increase , cutting Temperature increases.
   - Hardness of the tool deceases
   - Hence, tool flank wear and crater wear occurs easily.
   - Due to these reasons tool life decreases.
   - The relation b/w the tool life and cutting speed is expressed by Taylor's formula

$$VT^n = C$$

T : Tool life

N : exponent (depends on tool and work)

for HSS and MS ...... $n = 0.1$

Factors influencing the tool life

2. Feed and Depth of cut
   - Tool life is depends up on the amount of material removed by the tool per minute.
   - For a given cutting speed, if the feed or depth of cut is increased, the rate of metal removal will reduce the tool life.

3. Tool geometry
   - Large rake angle reduces the tool cross section, so area of tool which will absorb heat is reduced.
   - If the cutting angle increases, more power will be required cutting.
   - Clearance angle will improve tool life at first, then TL decreases because of decreased strength. So correct clearance angle is 10^0 to 15^0.

Factors influencing the tool life

4. Tool material

   TL depend up on the tool material HSS has more life than carbon steel tool. Carbide tools have more life than HSS.

5. Cutting fluid

   Application of correct cutting fluid increases the tool. Carries away the heat and keeps the tool cool.

6. Cutting fluid

   Physical and chemical properties of work piece affect the tool life. Tool will be more when machining soft material than hard material like cast iron and bronze.

7. Rigidity of work, tool and machine

   A strongly supported tool on a rigid machine will have more life

Tool life equations

Constant C mainly depends upon the tool , work piece, feed, depth of cut, type of coolant and tool geometry etc.

$$VT^n = C \qquad \dots (1)$$

V = Cutting speed

T = Life

n = exponent

C = constant

Equation (1) can be rewritten as

$$\log r + n \log T = \log c \qquad \dots (2)$$

or $$\log T = \left(\frac{1}{n}\right) \log c - \left(\frac{1}{n}\right) \log r$$

As a log-log graph: The Taylor's tool life equation represents a straight line (3). Equation (1) can be generated to include the effects of feed and depth of cut. One such relationship is of the form.

$$VT^n f^{n1} \cdot d^{n2} = C_1 \qquad \dots (3)$$

Where the exponents n, n_1 and n_2 and the constant C_1 depend upon tool and work material, tool geometry, and type of coolant.

Problem 19: The useful tool life of a H.S.S. tool machining M.S at 18 m/min is 3 hours. Calculate the tool life when the tool operates at 24 m/min,

Solution:

$VT^n = C$

$V = 18$ m/min

$T = 3 \times 60 = 180$ min

$C = 18 \times (180)^n$

Let n = 0.180

$C = 18 \times (180)^{0.125} = 34.45$

Now V = 24 m/min

$VT^n = C$

Problem 20: The Taylor's tool life equation for machining C - 40 steel with a 18-4-1 H.S.S. cutting tool at a feed of 0.2 mm/min and a depth of cut of 2 mm is given by $VT^n = C$, where n and C are constants. The following V and T observations have been noted.

V, m/min	25	35
T, min	90	20

Calculate (i) n and C, (ii) Hence recommended the cutting speed for a desire tool life of 60 min.

Solution:

i) $VT^n = C$

$\therefore 25 \times 90^n = C$ and $35 \times 20^n = C$

$\therefore 25 \times 90^n = 35 \times 20^n$

$$\left\{\frac{90}{20}\right\}^n = \frac{35}{25} = 1.4$$

$\therefore n = 0.225$

$C = 25 \times 90^{0.225} = 68.8$

ii) $V \times 60^{0.225} = 68.8$

$\therefore V \times 2.512 = 68.8$

$V = 27.39$ m/min

Cutting Tool Material

(1) Carbon Steels: Oldest Cutting Tool

Constituents :

Composition	Weight percentage
C	0.7 to 1 %
Si	0.5 % (Max)
Mn	0.5 % (Max)

- It cannot have more hardness
- Hence this cannot be used at higher cutting speed
- Wear resistance is more because of higher carbon percentage.

(2) Medium Alloy Steels

- Similar to carbon steel
- With the addition of other elements like Cr, Molybdenum, and Tungsten properties are increased.
- Addition of Cr and Mb leads good hardness
- Tungsten leads improve in wear resistance.

Constituents :

Composition	Weight percentage
C	up to 3%
Si	up to 0.4 %
Mn	0.25 to 0.75 %
Cr	0.4 to 0.8%
Tungsten	1.5%
Steel	Balance

(3) High Speed Steels

- Mostly used in industries
- Major difference is permits higher cutting speed
- Also it has good hardness, wear resistance and retention of sharpness at the cutting edge.
- Added elements mainly Cr, Vanadium, Molybdenum and cobalt

Constituents :

Composition	Weight percentage
Tungsten	13 %
Chromium	4%
Vanadium	1%
Cobalt	1%

Simply it is called as 13-4-1 grade steel.

(4) Cemented Carbide tools

- Cemented carbide tool material is prepared by Powder metallurgy process
- Final powder mixture consisting of varies elements is pressed in order to get required shape
- And sintered in to cemented carbide.

(5) Ceramic tools

- Aluminium oxide is known as ceramic tool. Al_2O_3 powder is prepared in a mould and pressed of about 300 kg/cm^2 is applied and then sintered.

- The tool tip is prepared by this process and is fitted with the tool shank

- It can operate at high cutting speed
- They have high compressive strength
- They are brittle in nature
- They have low bending strength.

(6) Abrasives

- Abrasive grains such as Al_2O_3 and SiC . They are used in grinding wheels
- They are used to remove a very small portion of material in the work piece for final operations

Cutting fluids

Either liquid of gas that is used on the tool chip interface during machining is called cutting fluid

Properties and purposes of cutting fluids

(1) To reduce friction:

- Cutting fluid reduces the friction at tool interface and also at the tool work piece interface
- Since friction coefficient is reduced at the tool chip interface so flow of chip increases.
- Otherwise μ and power consumption increases.

(2) To improve surface finish

(3) To cool the tool and work piece

(4) To move the chip quickly ex: drilling

Cutting fluids

Important properties

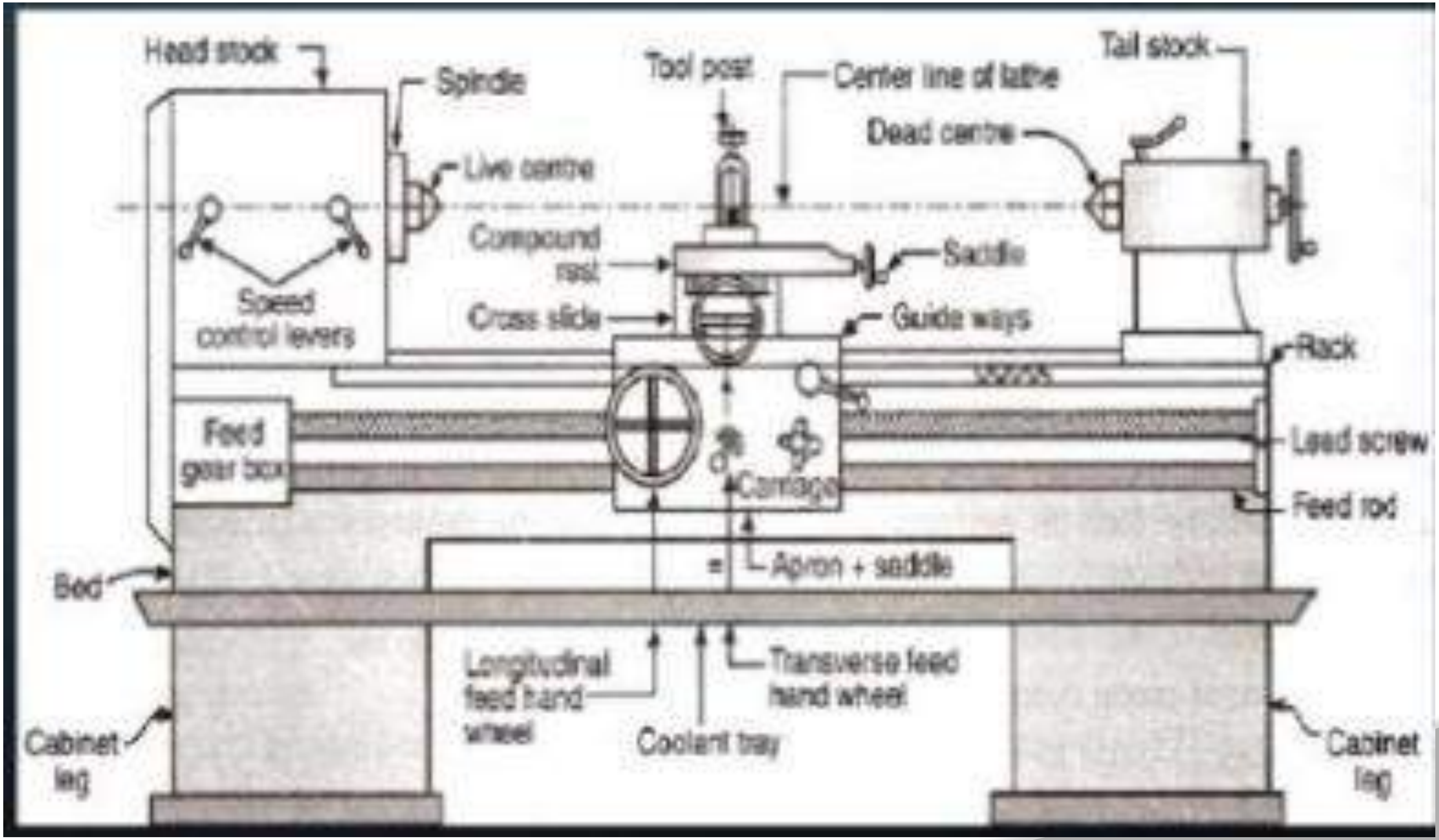
- It should absorb more heat
- It should reduce friction
- Should not be corrosive in nature
- Should have low viscosity
- Should be economical

Important cutting fluids

- Carbon Tetrachloride
- Acetic acid
- Turpentine
- Kerosene
- Paraffin oil
- Soluble oil
- Water

MACHINE TOOLS - I

Lathe

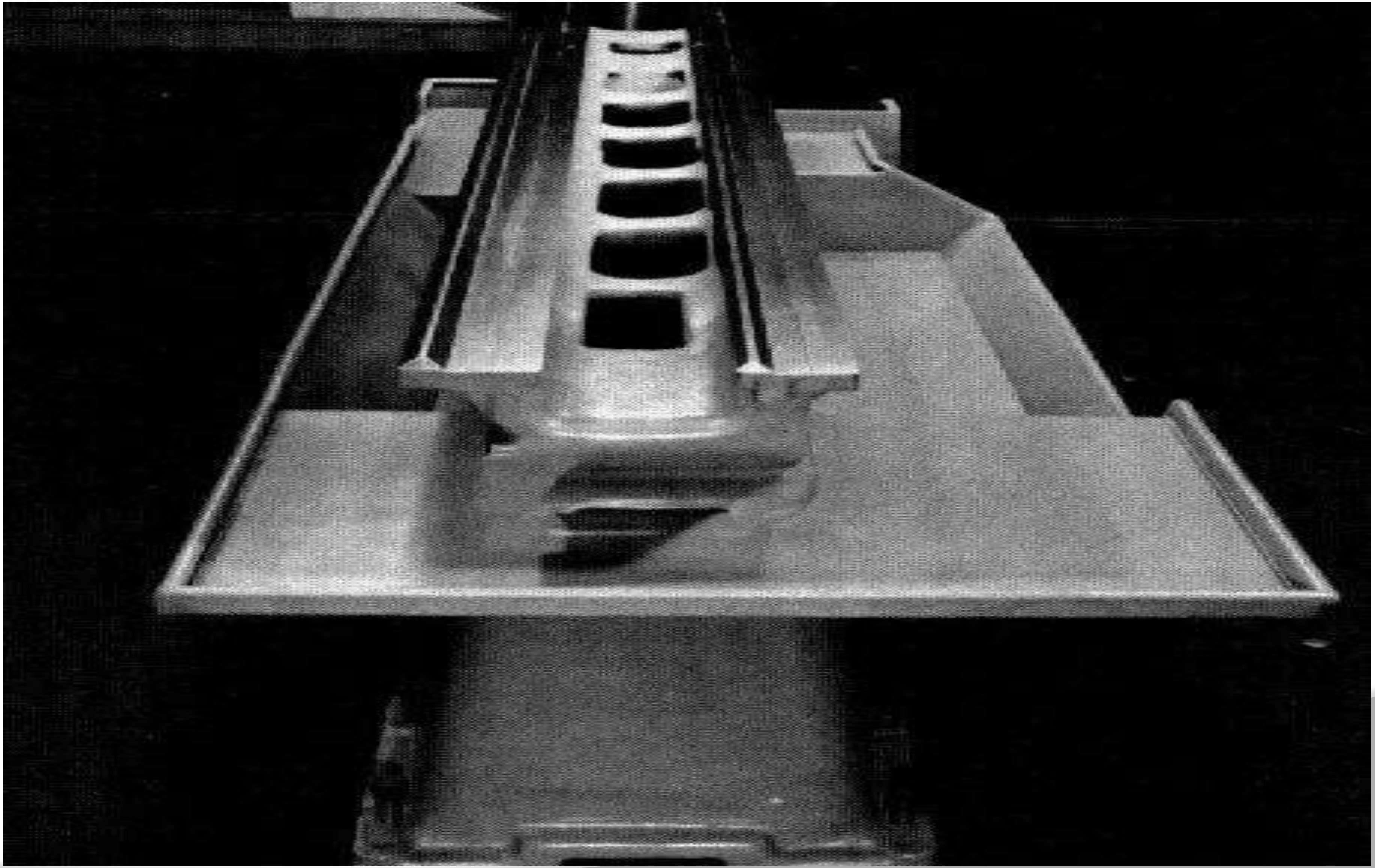


Head stock
Spindle
Tool post
Center line of lathe
Tail stock
Dead centre
Live centre
Compound rest
Saddle
Speed control levers
Cross slide
Guide ways
Rack
Feed gear box
Lead screw
Carriage
Feed rod
Apron + saddle
Bed
Longitudinal feed hand wheel
Transverse feed hand wheel
Coolant tray
Cabinet leg
Cabinet leg

Introduction

- A lathe is one of the oldest & most important machine tools ever developed. The job to be machined is rotated & the cutting tool is moved relative to the job. That is why, It's also called as *" Turning Machine".*
- A Lathe was basically developed to machine cylindrical surfaces. But many other operations can also be performed on lathes. e.g.- facing, parting, necking, knurling, taper turning & forming. We also can perform operations of other machine tools on a lathe, e.g. drilling, reaming, milling & drilling operation etc.
- A lathe is called the mother of the entire machine tool family.
- The lathe can be defined as a machine tool which holds the work between two rigid & strong centers, or in a chuck or face plate while the latter revolves. The cutting tool is rigidly held & supported in a tool post & feed against the revolving work.

Lathe Bed



Lathe parts

Lathe Bed

- Base of Machine
- Made to support working parts of lathe
- Head stock , carriage and tail stock are mounted on bed
- carriage and tail stock are move over the bed
- It has guide ways
- it is very strong to resist the cutting forces and vibrations
- Guide ways are very accurate for getting accuracy in jobs
- Made of Cast iron with nickel chromium, alloying additions.
- Heavy, rugged casting

Headstock

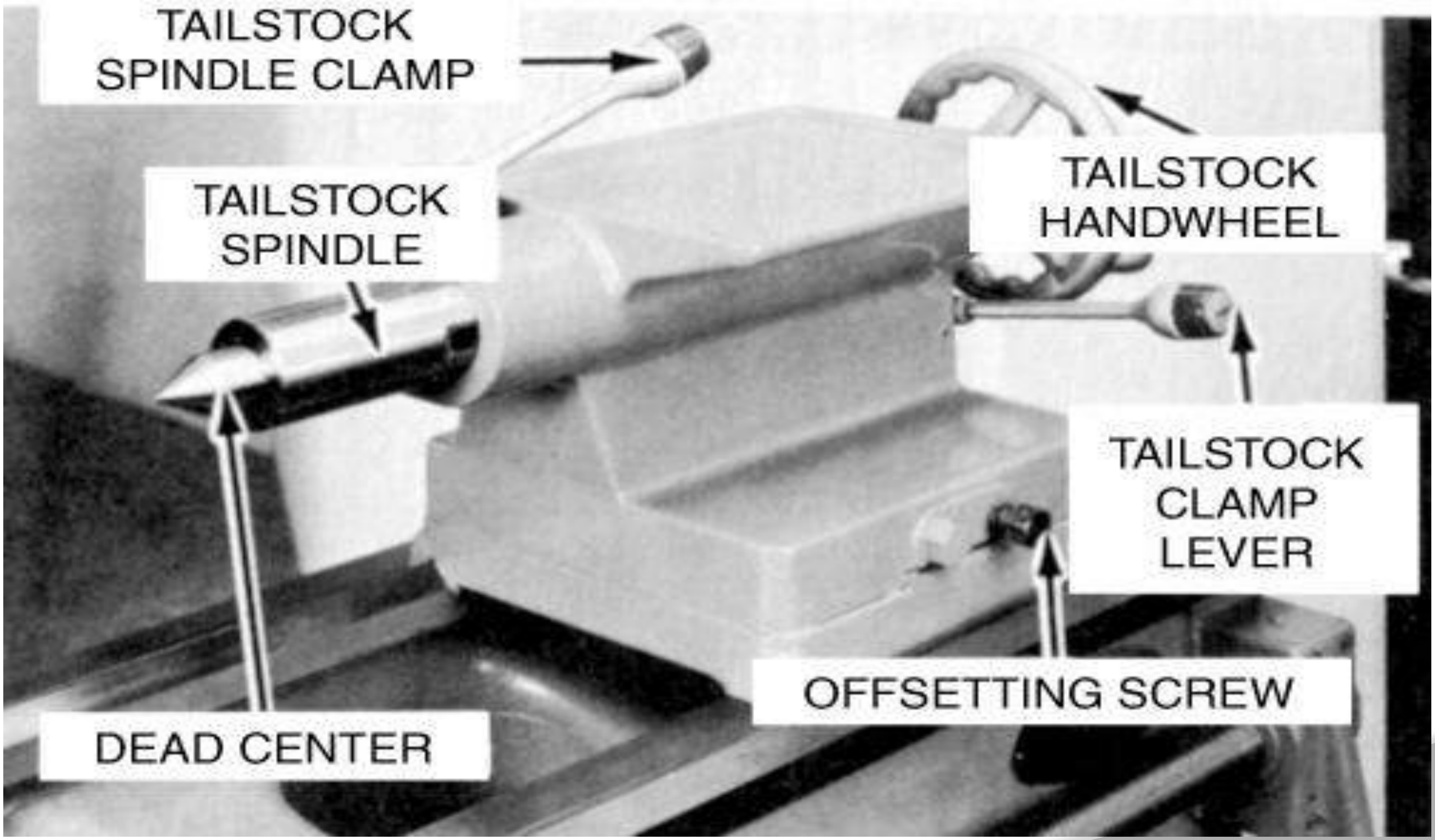
Head stock

- Mounted on the bed at left side
- It carries a hollow spindle
- A large bar can pass through the hole of the spindle
- The front end of the hole is tapered for holding tapered shanks
- Chucks and face plates can be attached to the nose of the spindle
- It has driving and speed changing mechanism
- Speed changing and feed changing levers are attached to the head stock

Tail stock

- Mounted on the right side of bed
- Used for the supporting of right end of work
- Also used for holding drilling, reamer or tap for drilling operation
- Can be moved and clamped at any position to support different lengths of work
- Tail stock body is bored and tail stock spindle moves through is a dead centre can be fixed in to the taper hole of the spindle for supporting

Tail stock


TAILSTOCK SPINDLE CLAMP
TAILSTOCK SPINDLE
TAILSTOCK HANDWHEEL
TAILSTOCK CLAMP LEVER
OFFSETTING SCREW
DEAD CENTER

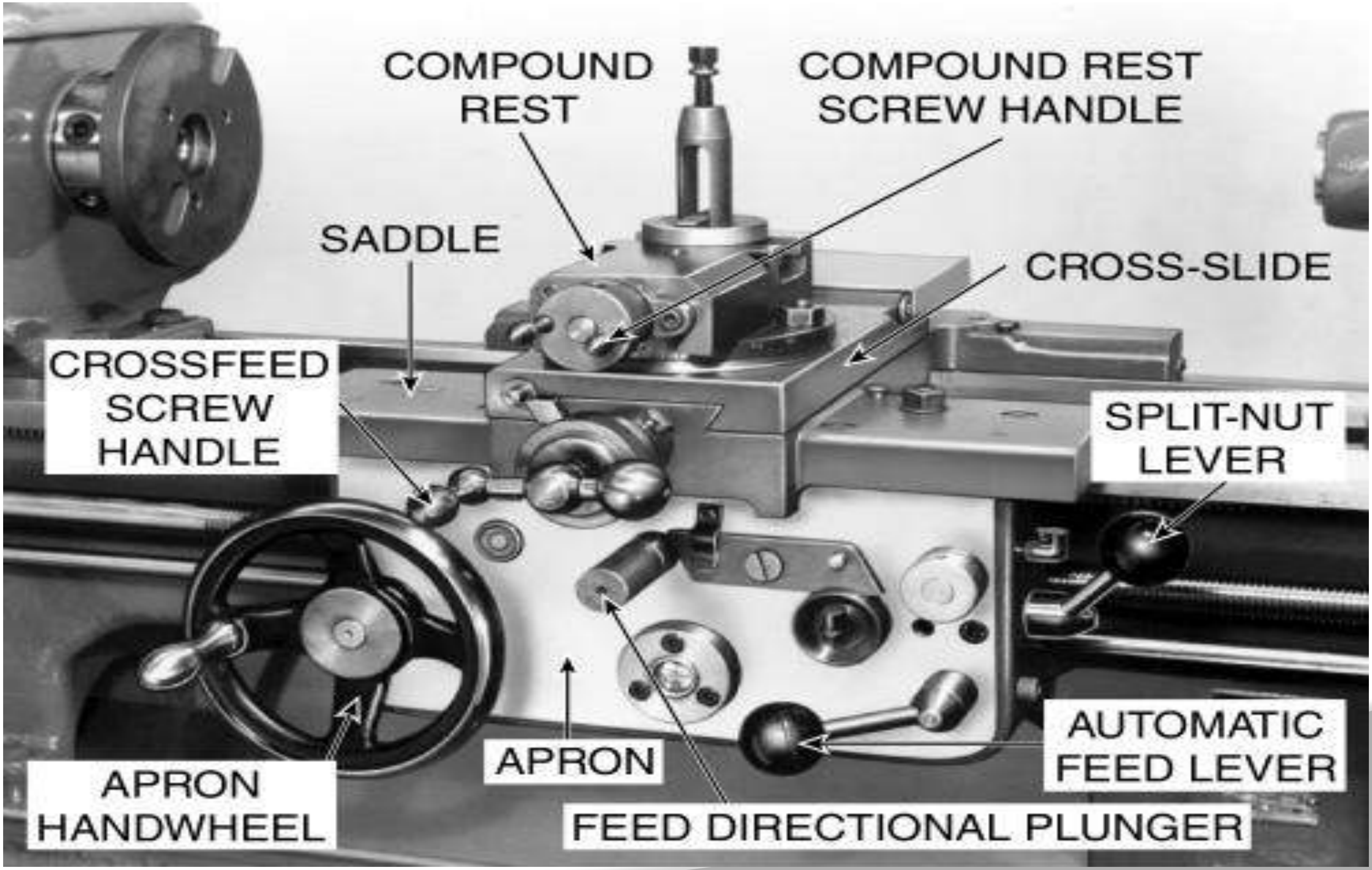
Saddle

- H shaped casting fitted over the bed
- Moves along the guide way
- It carries the cross slide and tool post
- It can be moved to the required position and locked to the bed.

Cross Slide

- Attached to the saddle
- Carries the compound rest and tool post
- Can be moved by power or by hand
- There is micrometer dial on the cross slide hand wheel with an accuracy of 0.05mm.

Saddle


COMPOUND REST
COMPOUND REST SCREW HANDLE
SADDLE
CROSS-SLIDE
CROSSFEED SCREW HANDLE
SPLIT-NUT LEVER
AUTOMATIC FEED LEVER
APRON
APRON HANDWHEEL
FEED DIRECTIONAL PLUNGER

Compound rest

- It marked in degrees
- Used during taper turning to set tool for angular cut
- No power feed only hand feed
- The is micrometer dial for showing depth of cut
- Should be locked strongly

Tool Post

Tool is clamped in the tool post

4 types of tool posts

(1) Single crew tool post

(2) Open side tool post

(3) Four bolt tool post

(4) Four way tool post.

Single crew tool post

- It can hold only one tool
- Tool is clamped by clamping screw
- Tool rests on the top flat surface of the convex rocker
- The convex rocker rests on a concave ring
- This arrangement is used to adjust the height of the tool

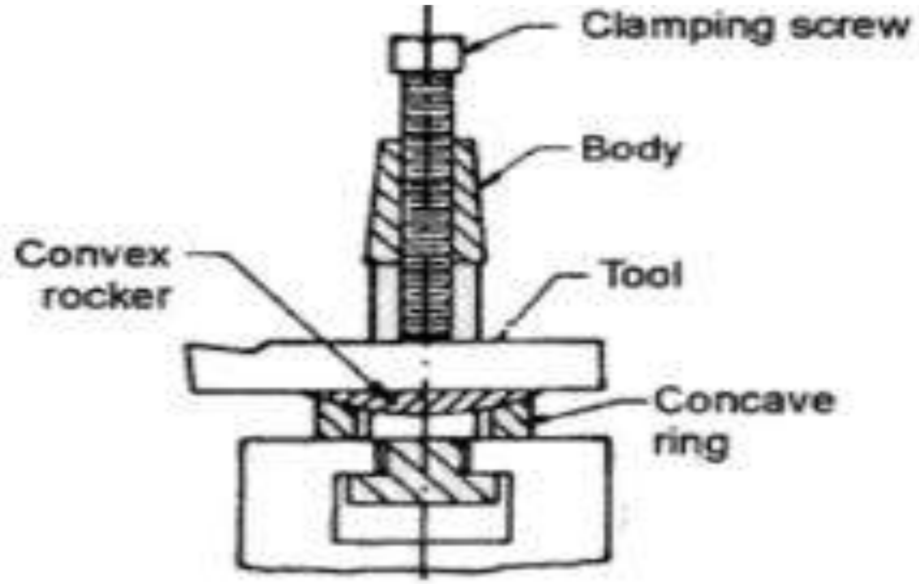


Figure 2.3. Single screw tool post

(2) Open side tool post

- The tool is held in position by two set screws
- parallel packing strips are used to adjust the height of the cutting tool
- The tool post can be tilted to any required position by loosening the clamp bolt.
- The clamping bolt is fitted in a T – slot ; so the tool can be changed quickly.

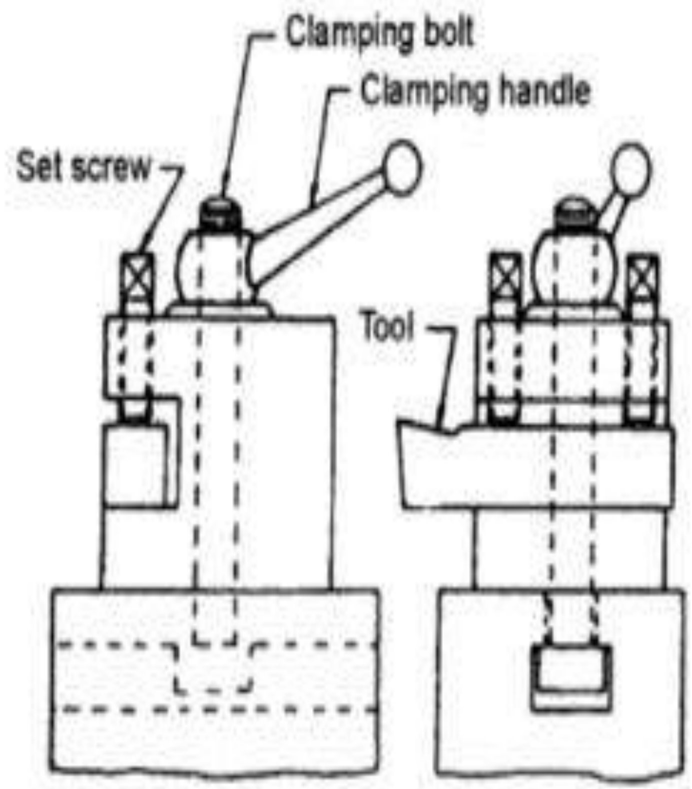


Figure 2.4. Openside Tool Post

Apron

- The apron is attached to the saddle and hangs in front of the bed
- It has gears, levers and clutches for moving the carriage with the lead screw for thread cutting.
- The apron hand wheel is used to move the carriage parallel to the lathe axis.

Feed Mechanism

- The movement of the tool relative to the work piece termed as "feed"
- There are 3 types of feeds namely longitudinal, cross and angular.
- If tool moves parallel to the axis of the lathe is called longitudinal feed, it is achieved by moving carriage
- When the tool moves perpendicular to the axis of the lathe that is cross feed, it is achieved by moving cross slide

- When the tool moves at an angle to the axis of the lathe that is called angular feed.

- angular feed is achieved by moving compound slide, after swiveling it at an angle to the lathe axis.

Feed Rod:

- It is a long shaft, used to move carriage or cross slide for turning, facing, boring and all operations except thread cutting

- Power is transmitted from the lathe spindle to the apron gears through the feed rod via large number of gears

Specifications of Lathe

Size of lathe is specified as follows

1. *The length between the centers*

   maximum length of job that can be mounted between the centers

2. *The length of the bed*

   this gives approximate floor area that the lathe can occupy

3. *Height of the centers*

   it is measured from the lathe bed.

4. *Maximum diameter over carriage*

   this is the diameter of the work or bar that may pass through the hole of the head stock spindle.

5. *The swing diameter of the bed*

   maximum dia of the work that may revolve revolve over the bed ways

6. *The swing diameter over carriage :* max dia of work that may rotate over the saddle

Types of Lathe Machine

- Speed Lathe
- Engine Lathe
- Bench Lathe
- Tool Room Lathe
- Capstan & Turret Lathe
- Automatic Lathe
- Special-Purpose Lathe.

Types of Lathe

1. Speed lathe
   (a) Wood working lathe.
   (b) Centering lathe.
   (c) Metal spinning lathe.
   (d) Polishing lathe.
2. Engine lathe
   (a) Belt drive.
   (b) Gear head drive
   (c) Individual motor drive.
3. Bench lathe.
4. Tool room lathe
5. Semi Automatic lathe.
   (a) Capstan lathe.
   (b) Turret lathe.
6. Automatic lathe.
7. Special purpose lathe.
   (a) Wheel lathe.
   (b) Gap bed lathe.

Specifications of Lathe

1. Speed Lathe

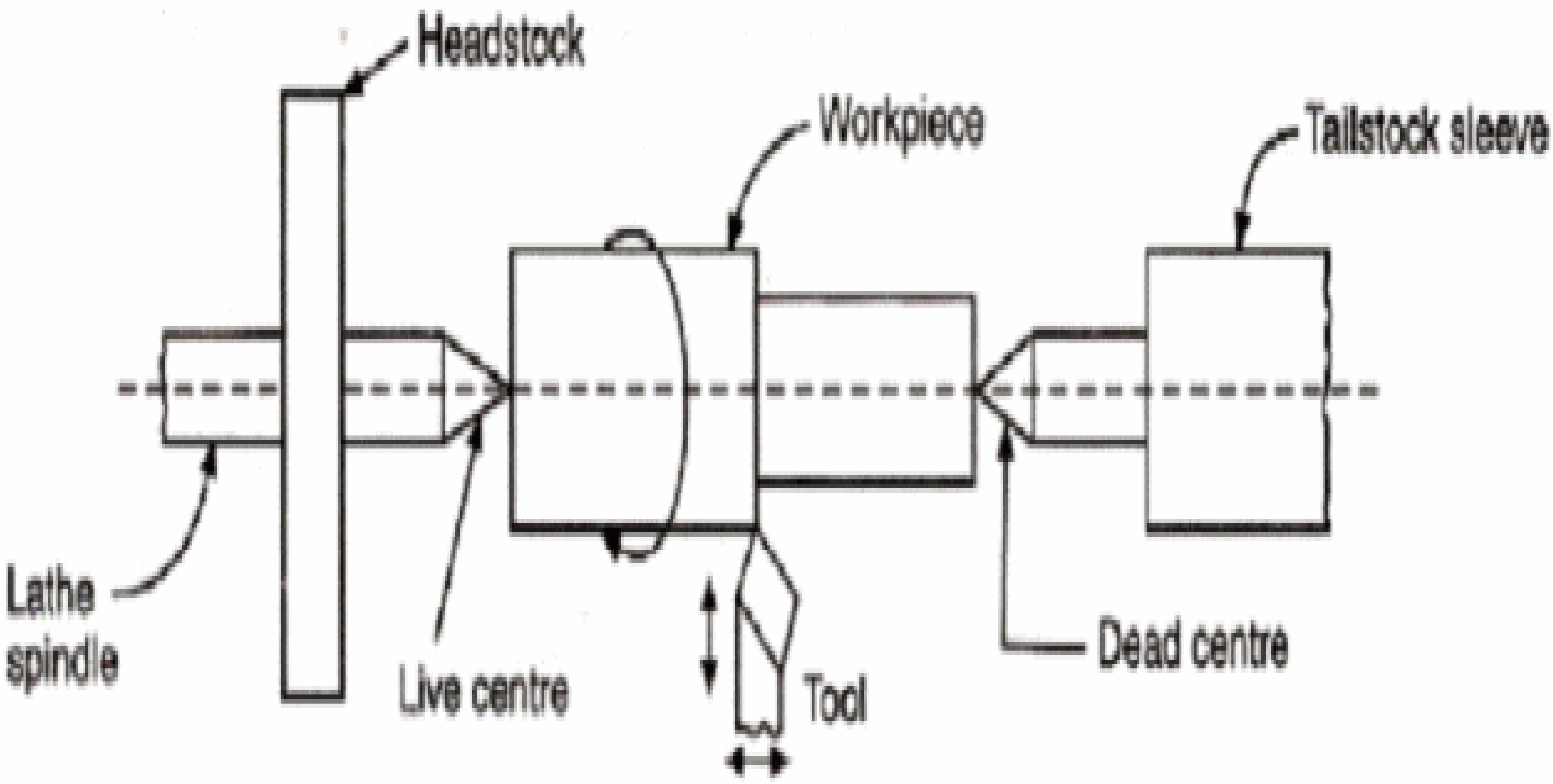
- It consist of a bed, a head stock , a tail stock and an adjustable tool post.
- As the speed of the spindle is very high, it is called as speed lathe
- Spindle is driven by a high speed motor through belts
- Two or three range of spindle speeds are obtained by step cone pulleys
- The work is mounted between centers or in a face plate screwed in the main spindle
- Mainly it is used for wood turning or polishing a work and for metal spinning.

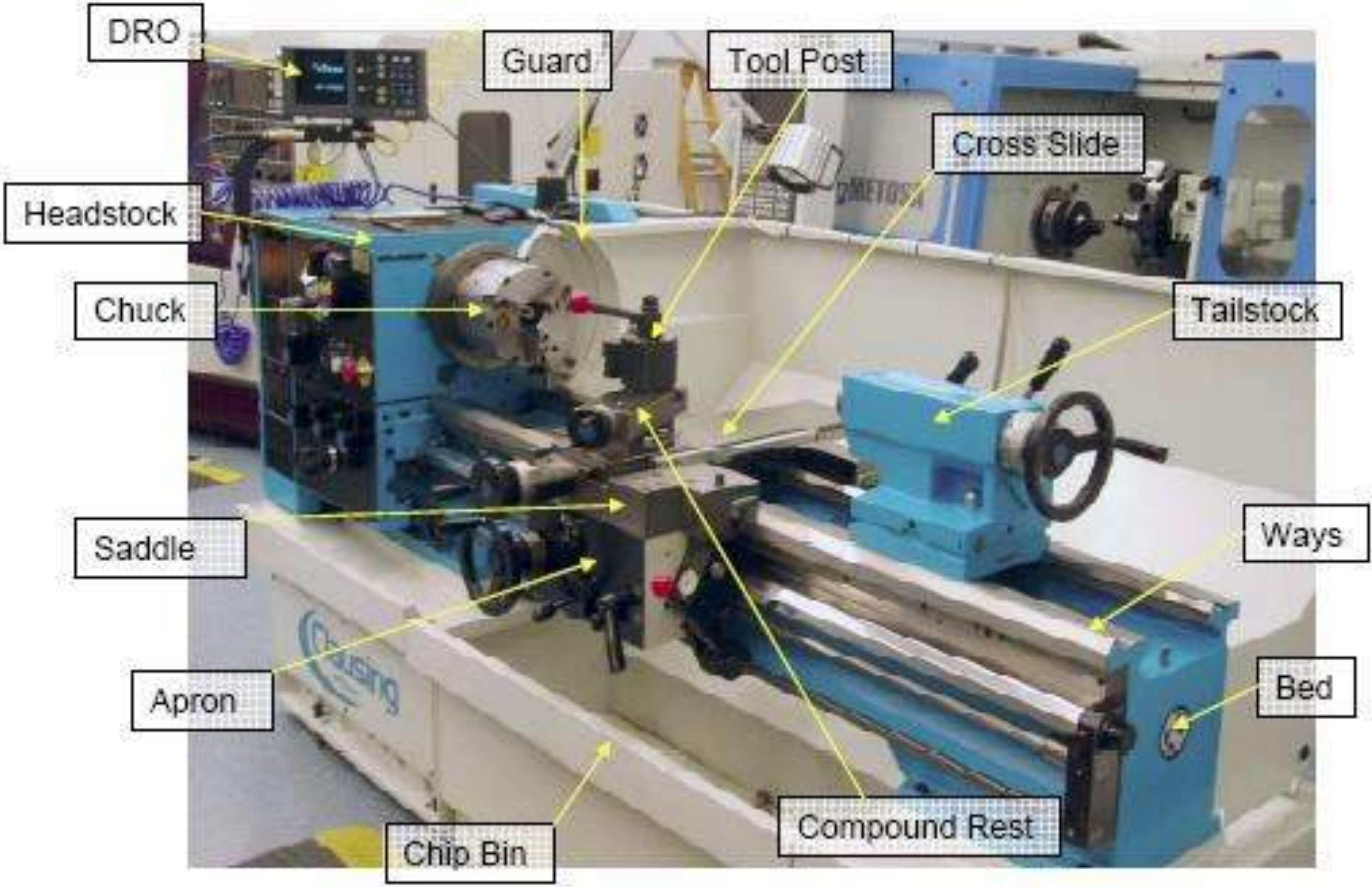
Types of Lathe

1. Engine Lathe

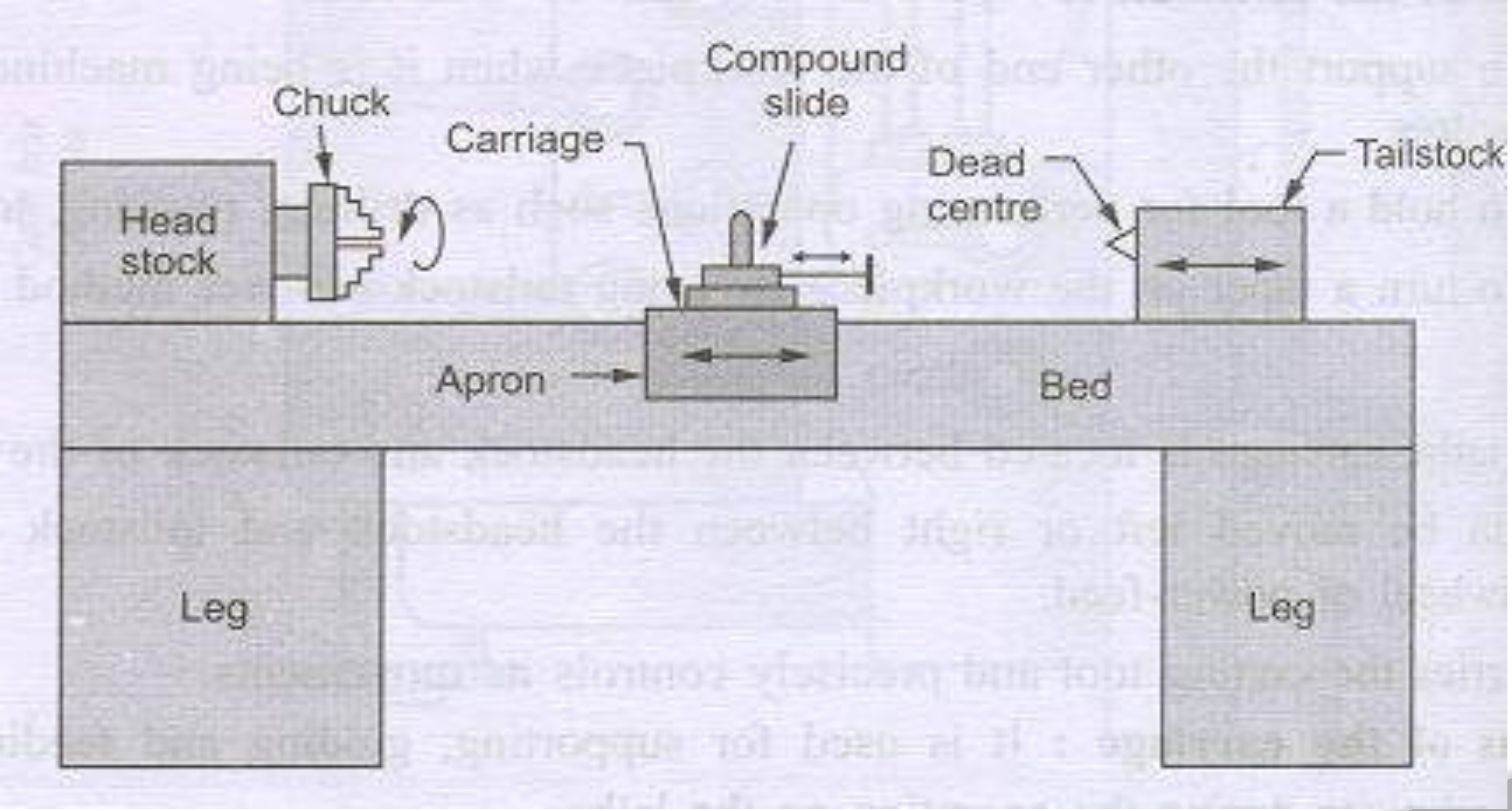
- important and widely used type of lathe
- Early day, it was driven by steam engine so it is called as engine lathe some times called as centre lathe
- It consists of a bed, a head stock, feed shaft and lead screw mechanism and carriage
- Work is mounted on the head stock. Tool is mounted on the carriage
- the tool may be fed cross wise or in longitudinal direction by hand or automatically.
- More than six range of spindle speeds can be obtained by change gears

Lathe Principle

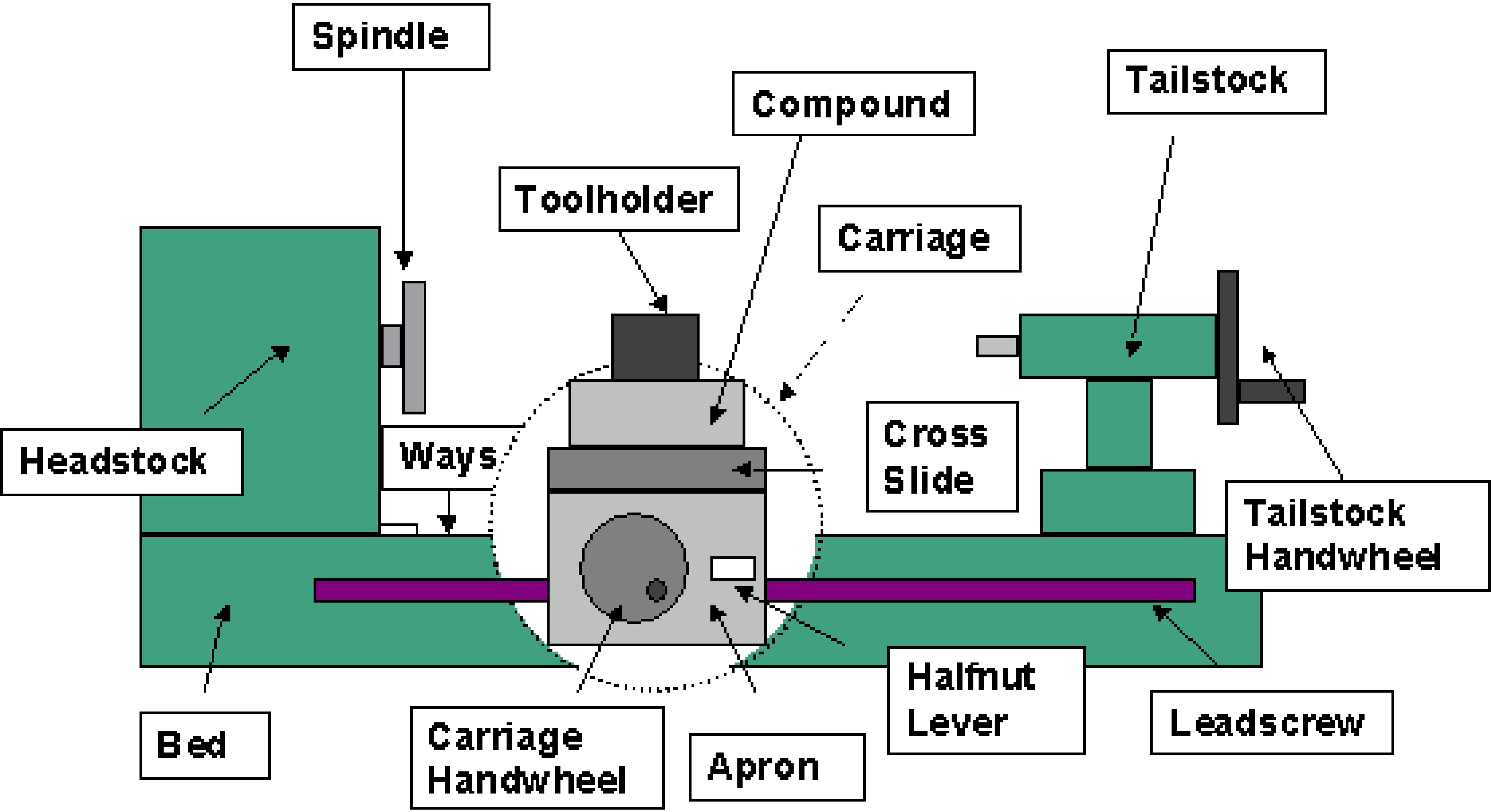



DRO
Guard
Tool Post
Cross Slide
Headstock
Chuck
Tailstock
Saddle
Ways
Apron
Bed
Chip Bin
Compound Rest

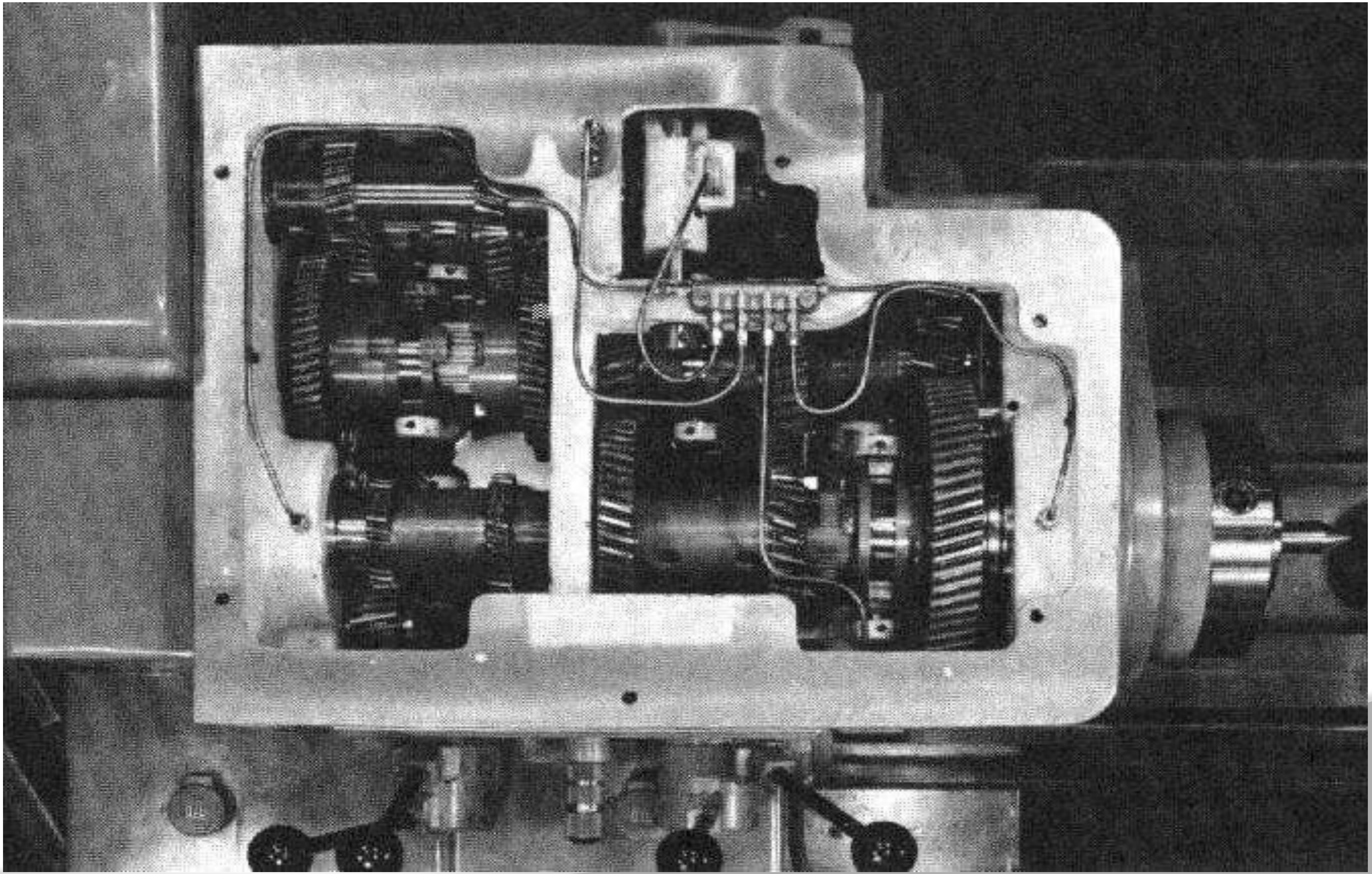
Block diagram of center lathe

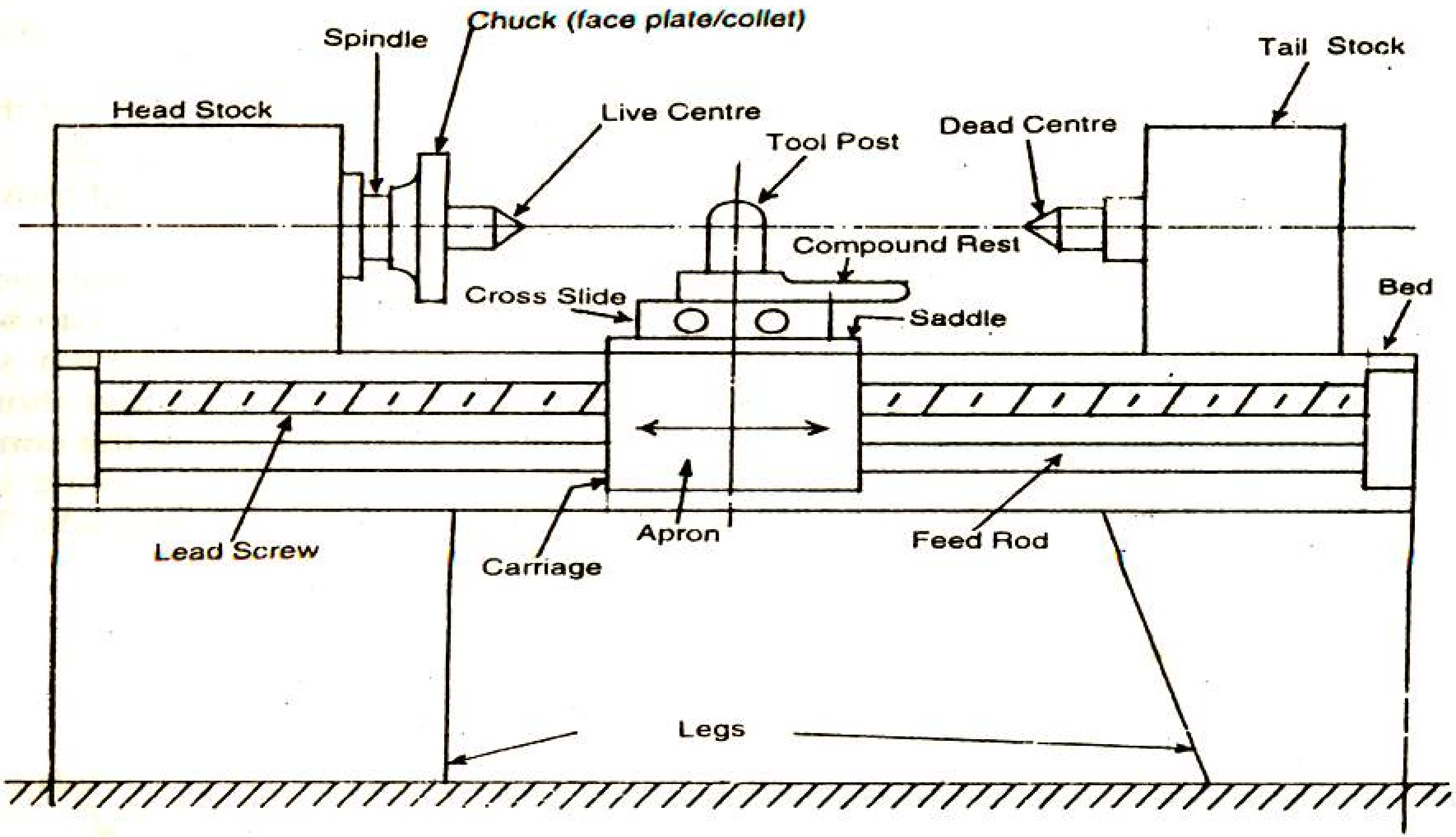


Lathe


Spindle
Compound
Tailstock
Toolholder
Carriage
Headstock
Ways
Cross Slide
Tailstock Handwheel
Halfnut Lever
Leadscrew
Bed
Carriage Handwheel
Apron

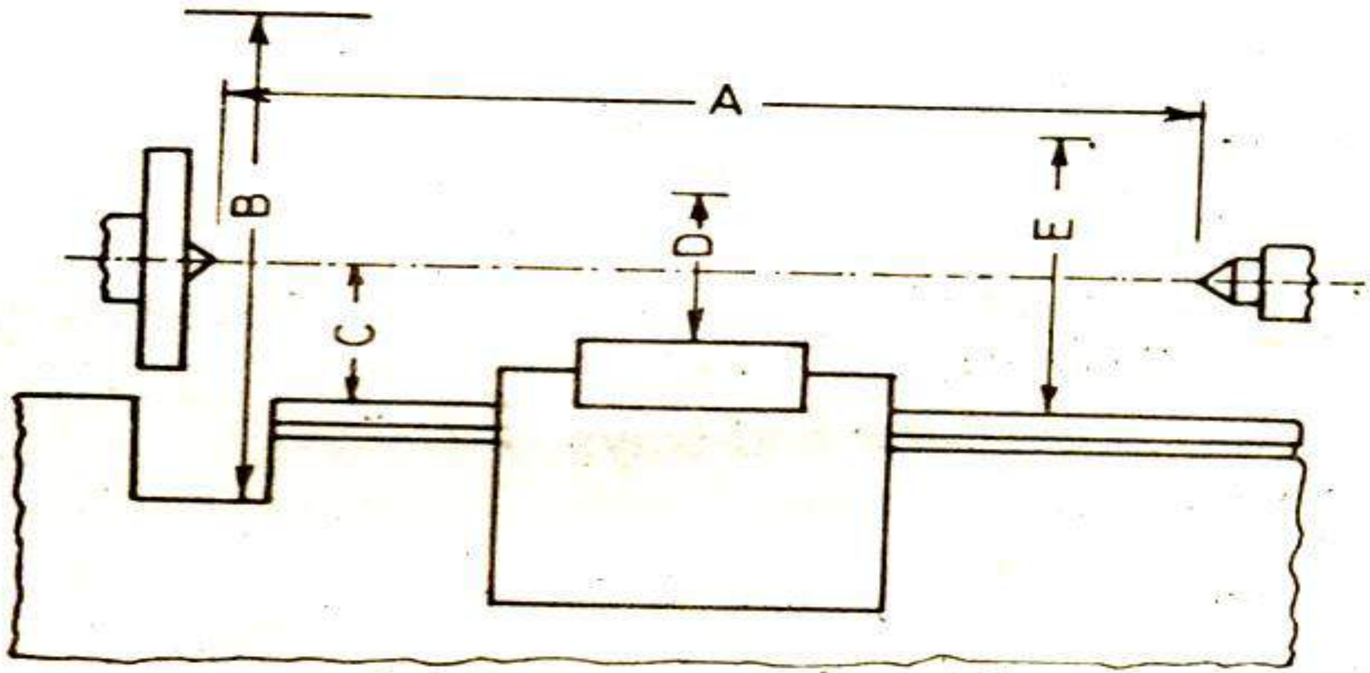
Quick-Change Gearbox





Block Diagram of an Engine Lathe

Specifications of Lathe machine

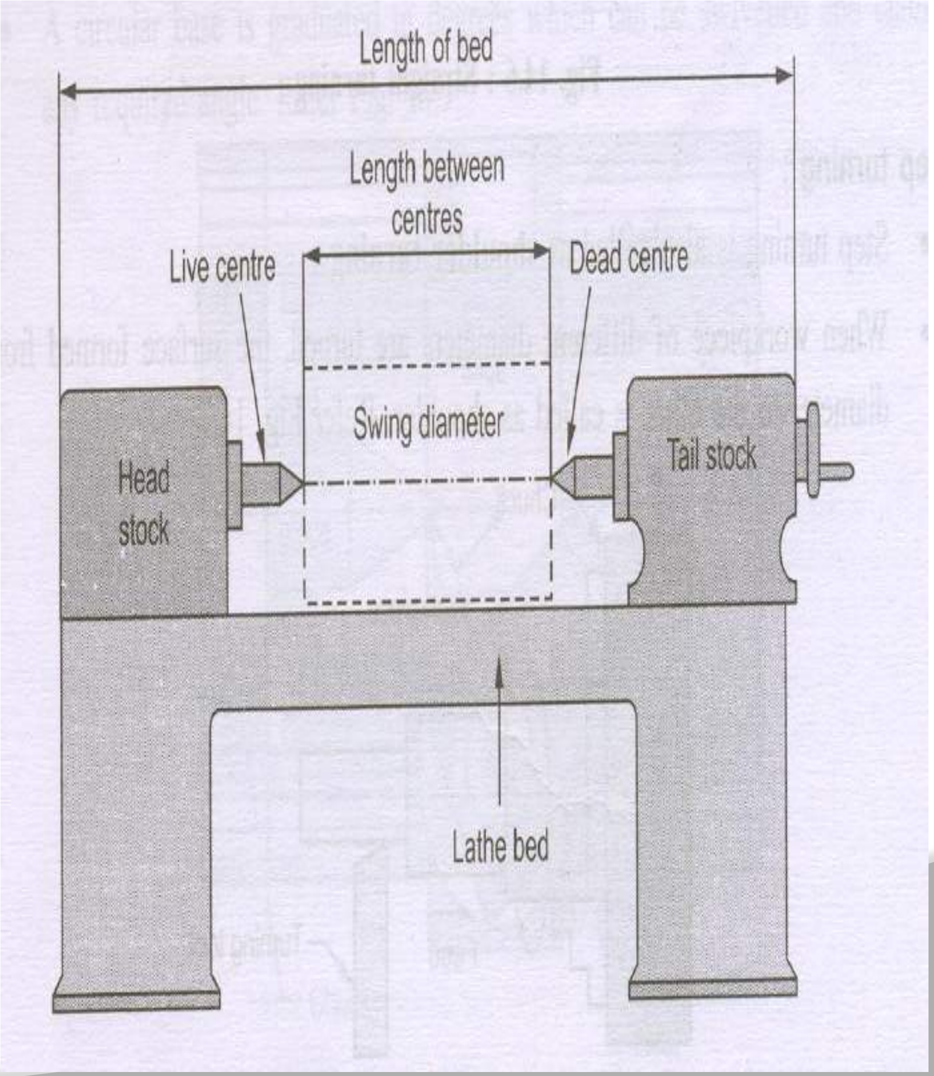


Lathe sizes

A—Maximum length that can be accommodated between centres. B—Swing in gap. C—Height of centres. D—Swing over carriage. E—Swing over bed.

Specification

- Height of center
- Length between the centers
- Length of bed
- The swing diameter over bed
- The swing diameter over carriage
- Maximum diameter of bar
- Spindle speed, motor hp

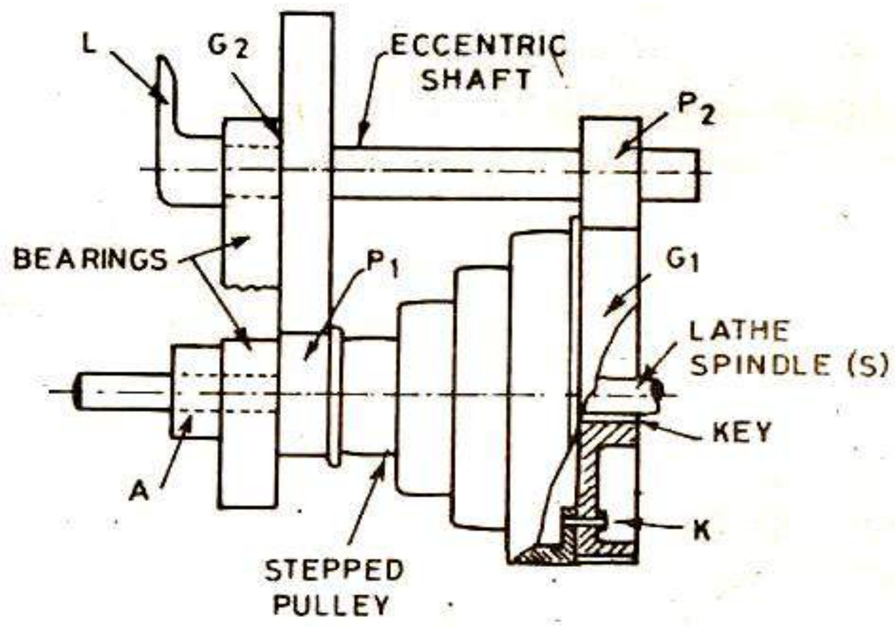


Headstock

- It is permanently fastened to the left hand end of the lathe. It serves to support the first operative unit of the lathe, i.e. spindle. It's also called as live centre because it turns with the work.
- The headstock is that part of the lathe which serves as a housing for the driving pulleys, back gears & spindle.

It consist of main parts:

1) Cone pulley,
2) Back gears & lever,
3) Main spindle,
4) Live centre, &
5) Feed reverse lever.



Geared Head Stock

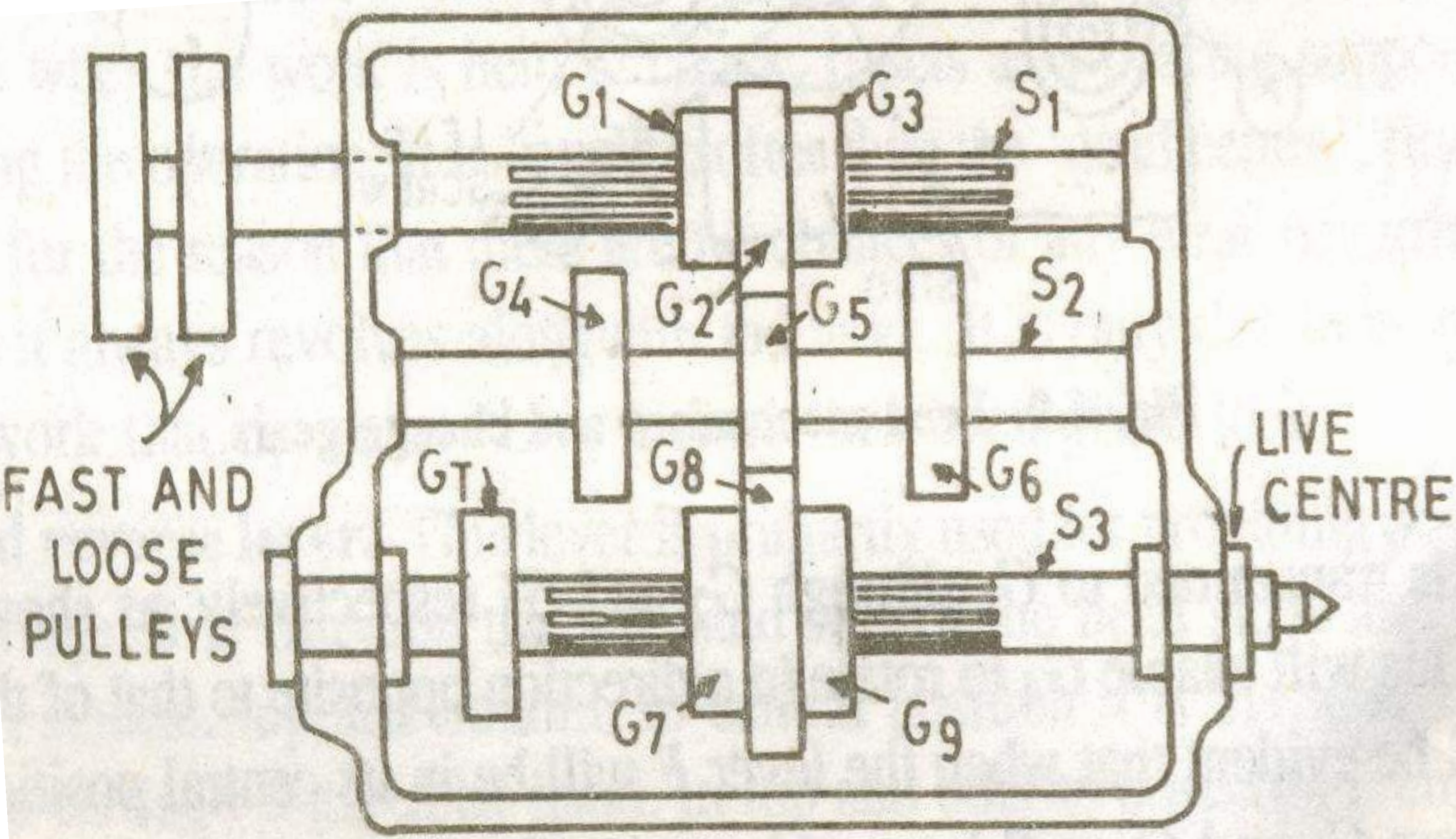


Fig. 6.10. A Geared head stock.

Tailstock -

It’s on the other end of the bed from the headstock. It’s chief function is to hold the dead centre so that long work pieces can be supported between centres.

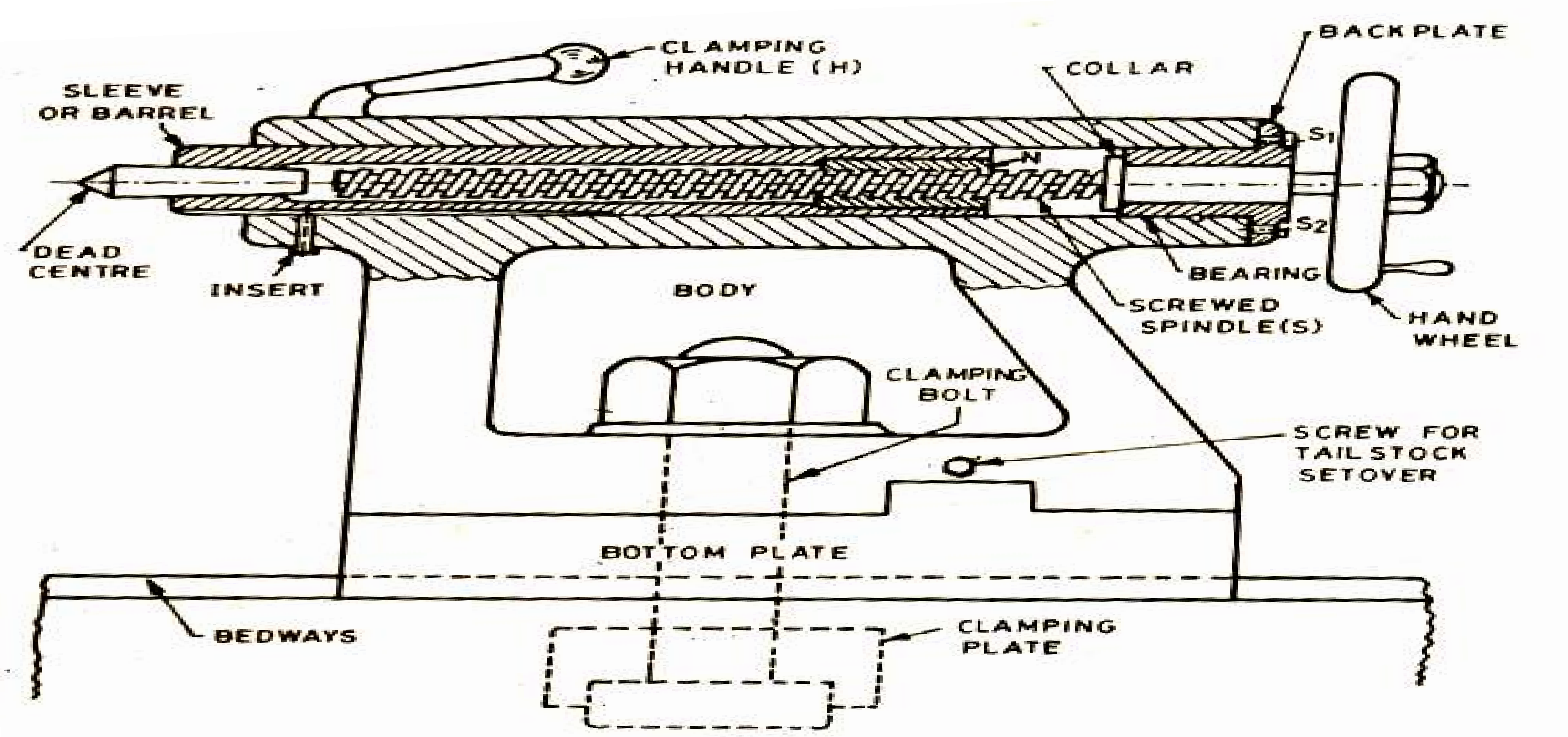


Fig. 6.11. Tail stock of a lathe.

Lathe Spindle

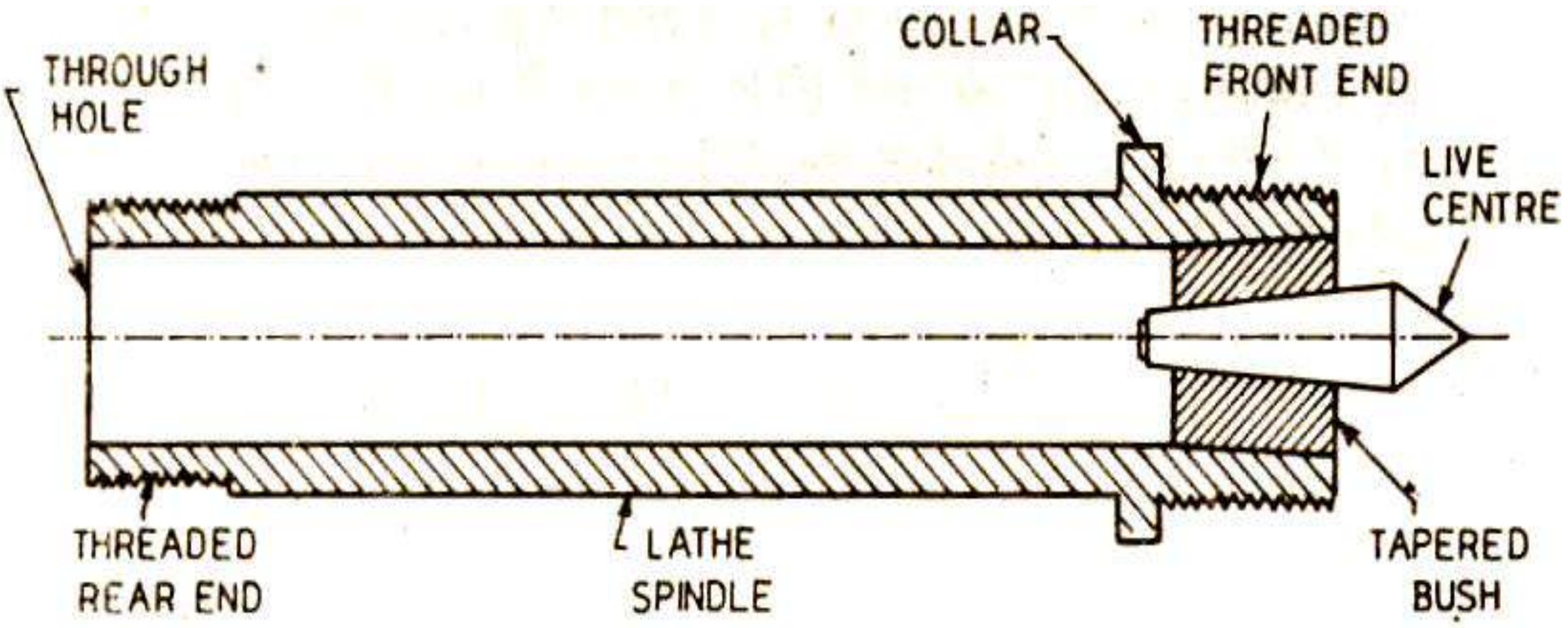


Fig. 6.8. A Lathe spindle.

Carriage

In between the headstock & tailstock is the carriage. It's movable on the bed ways and it's purpose is to hold the cutting tool & to impart to it either longitudinal or cross feed. It has five major parts:

a) **Saddle**
b) **Cross slide**
c) **Compound rest**
d) **Tool post**
e) **Apron**

Lathe Carriage

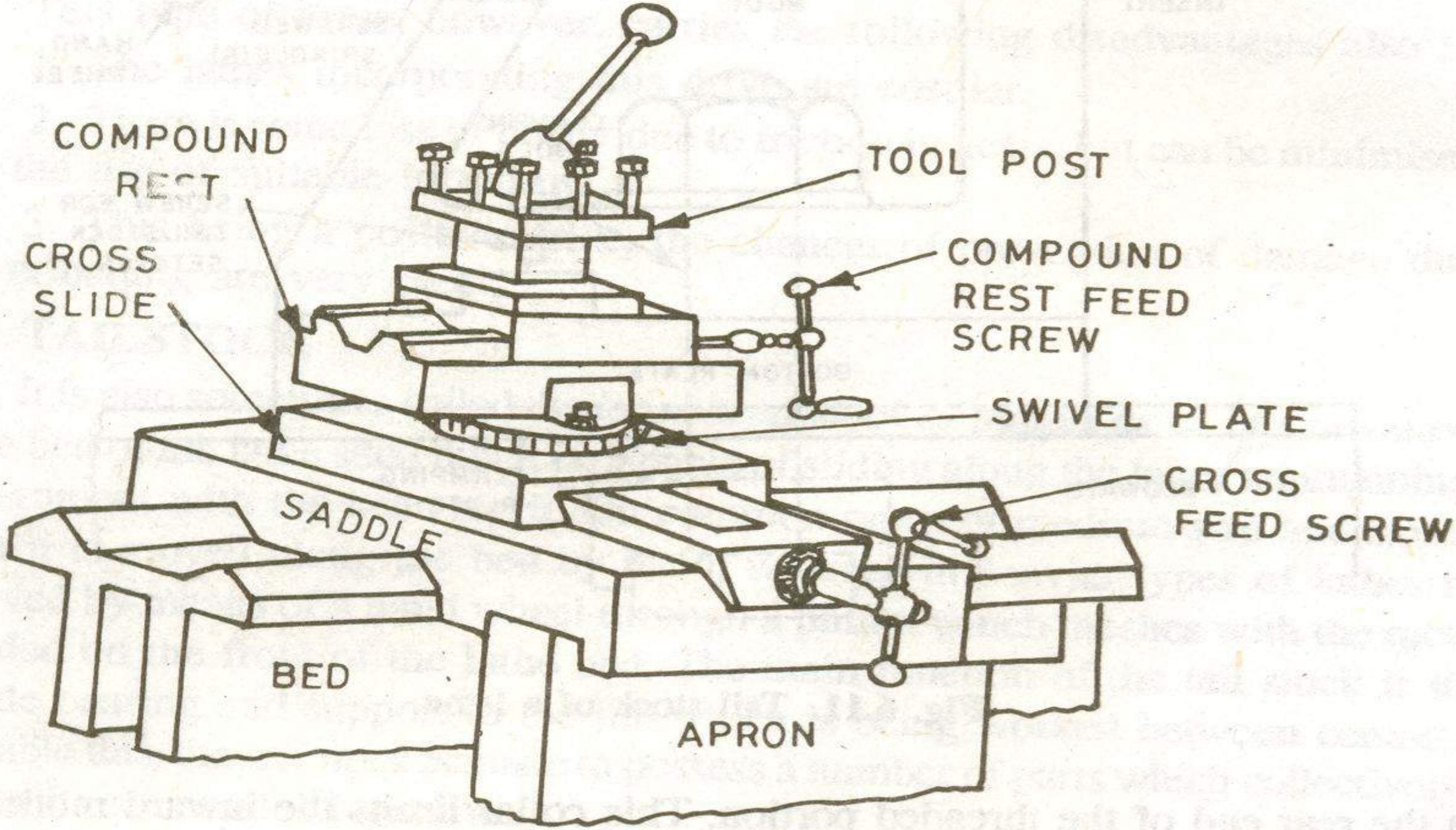


Fig. 6.12. The carriage.

Carriage

a) ***Saddle*** **–** The base of the carriage is the saddle which slides along the ways of the lathe bed and supports the cross-slide, compound rest & tool post.

b) ***Cross slide*** **–** It's mounted on top of saddle. It provides cutting tool motion which is perpendicular to the centre line of the lathe itself. The cross feed movement may be controlled by manual or by power feed.

c) ***Compound rest***– It's also known as tool rest. It's mounted on top of the cross-slide. It has a graduated circular base & can be swiveled around a vertical axis. It can be clamped to remain at any angular setting.

d) ***Tool post-*** It is mounted on the compound rest & slides in a T-slot. Cutting tool/ tool holder is firmly held in it.

e) ***Apron*** It's the hanging part in front of the carriage. It is secured underneath the saddle & hangs over the front of the bed.

Lead Screw

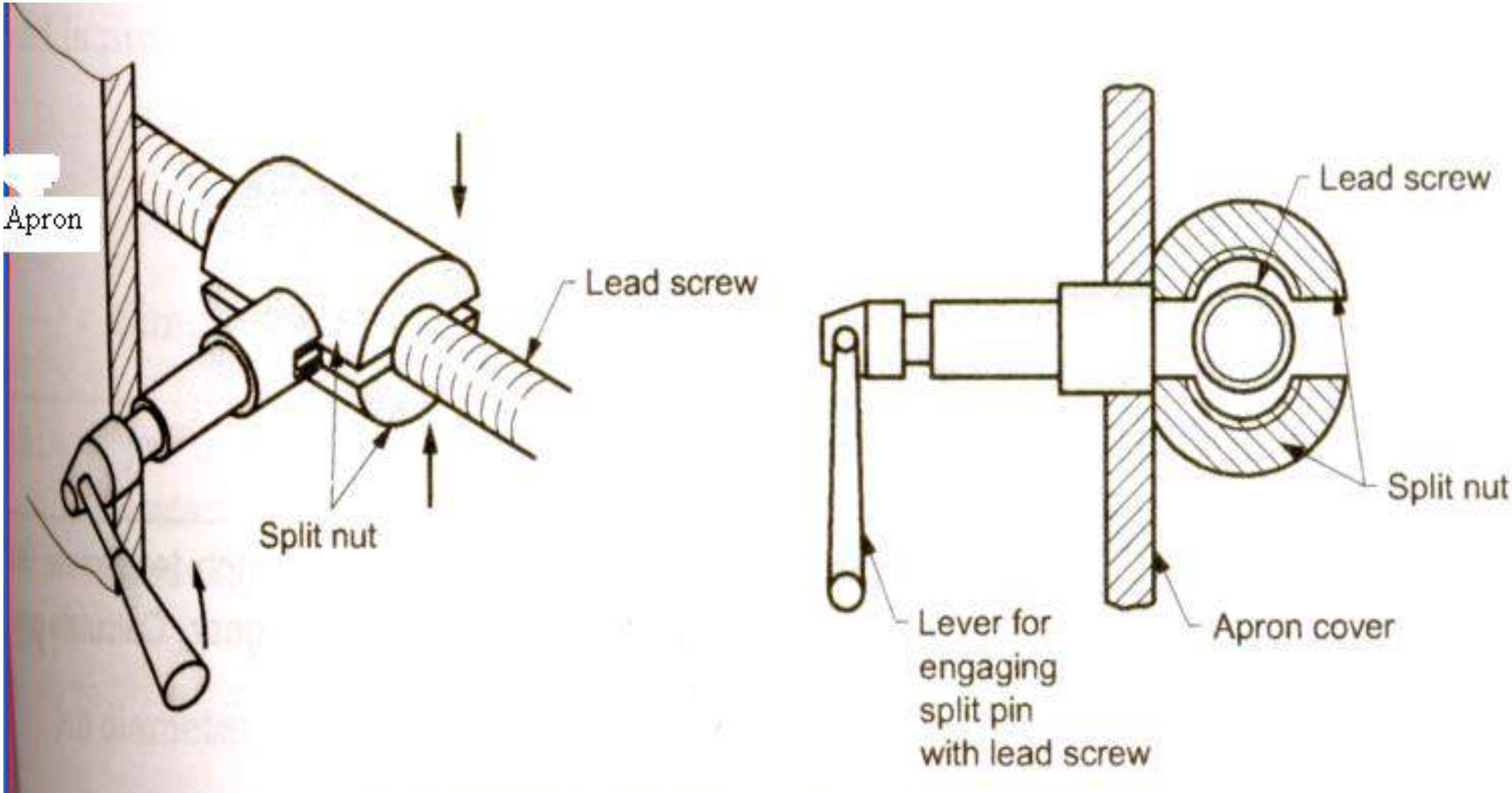


Fig. 4.9.13(b) : Split nut for screw cutting

Lathe Operations : Turning

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

Machine tool is called a ***lathe***

Types of cuts:

- Facing
- Contour turning
- Chamfering
- Parting (Cut-off) / Grooving
- Threading

Turning Parameters Illustrated

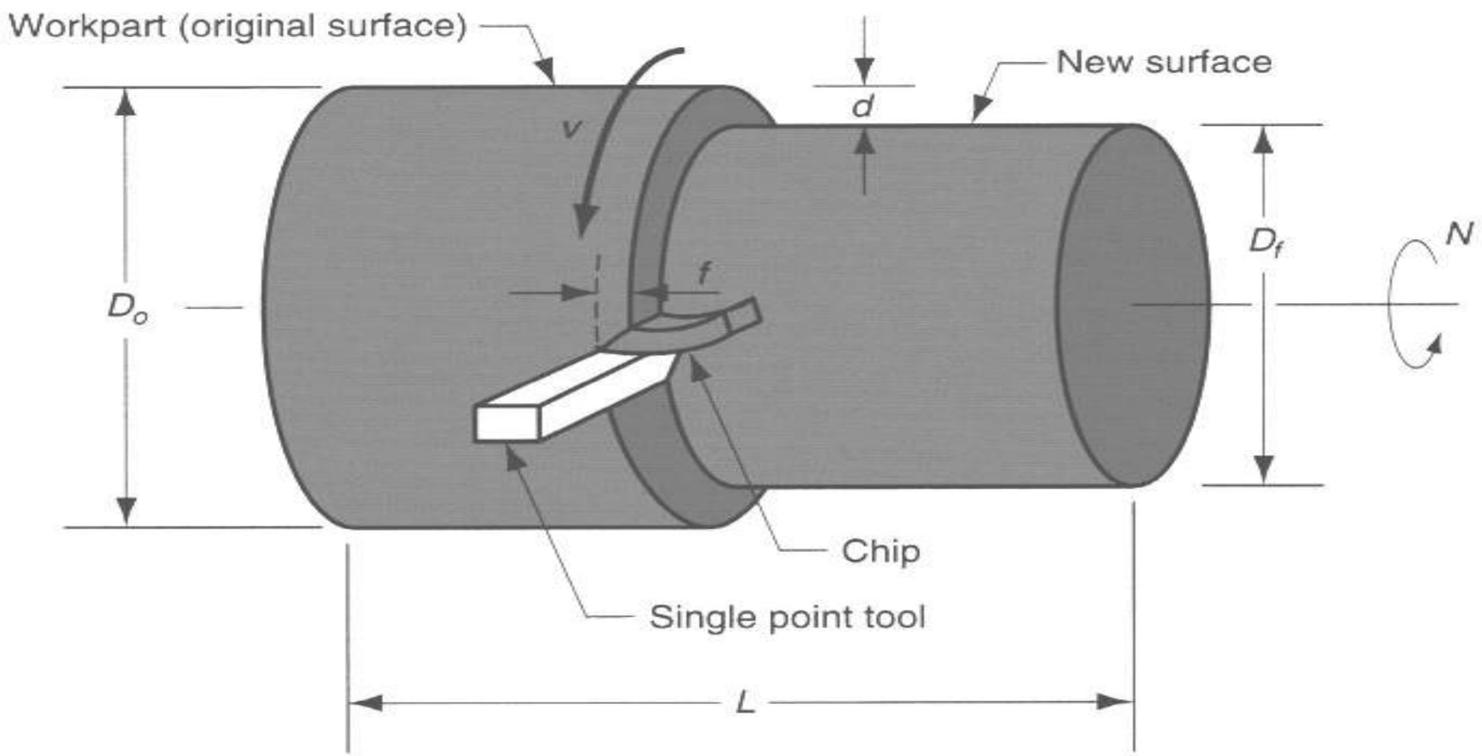


Figure 22.5 - Turning operation **[Groover (2004), p.503]**

Facing

Tool is fed radially inward

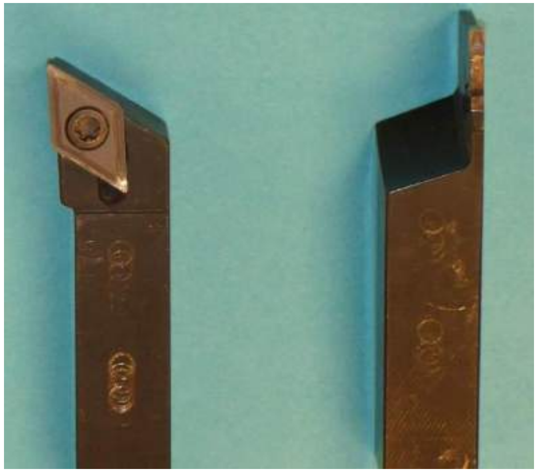
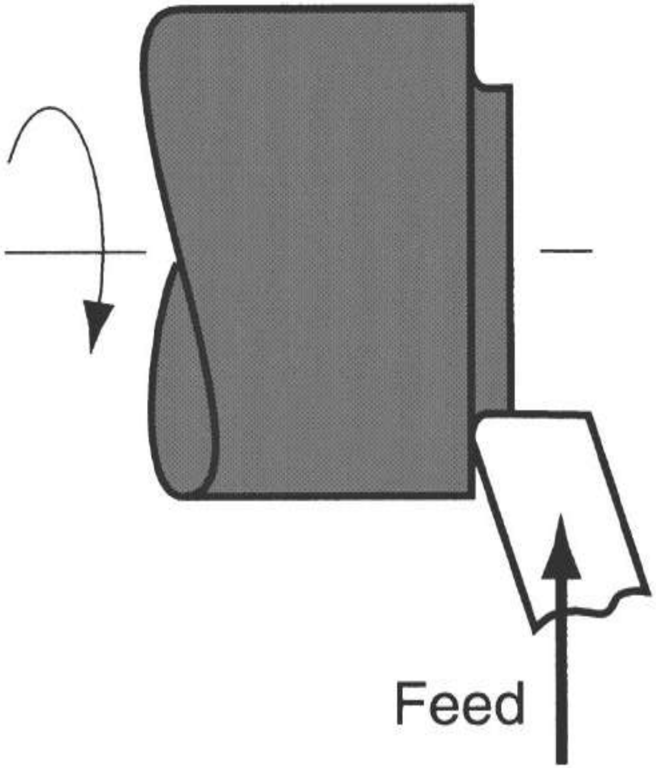


Figure 22.6 (a) facing



Contour Turning

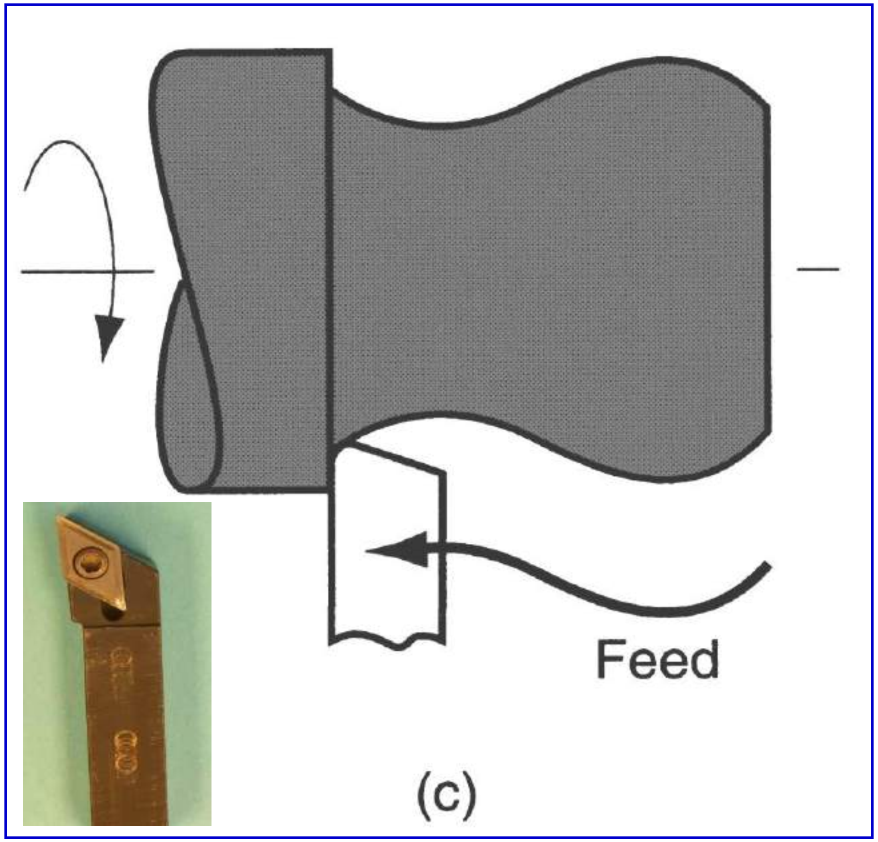


Figure 22.6 (c) contour turning

Instead of feeding the tool parallel to the axis of rotation, tool follows a contour that is not necessarily straight (thus creating a contoured form).

Right & Left Hand Tools

- Right Hand Tool:
  - Cuts from right to left

- Left Hand Tool:
  - Cuts from left to right

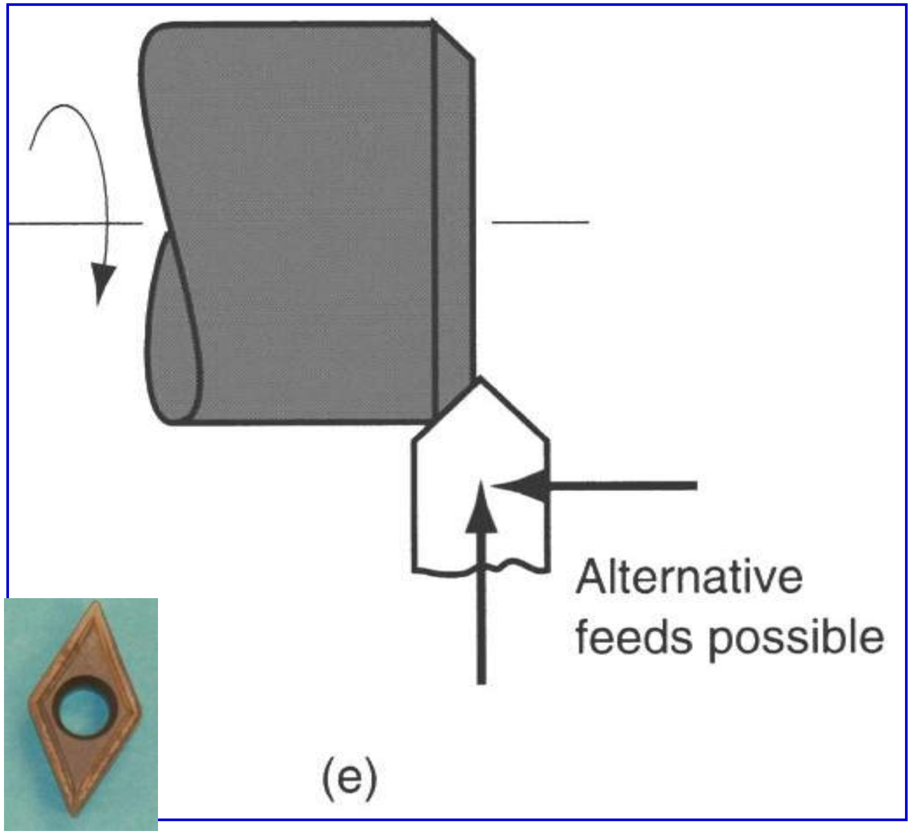
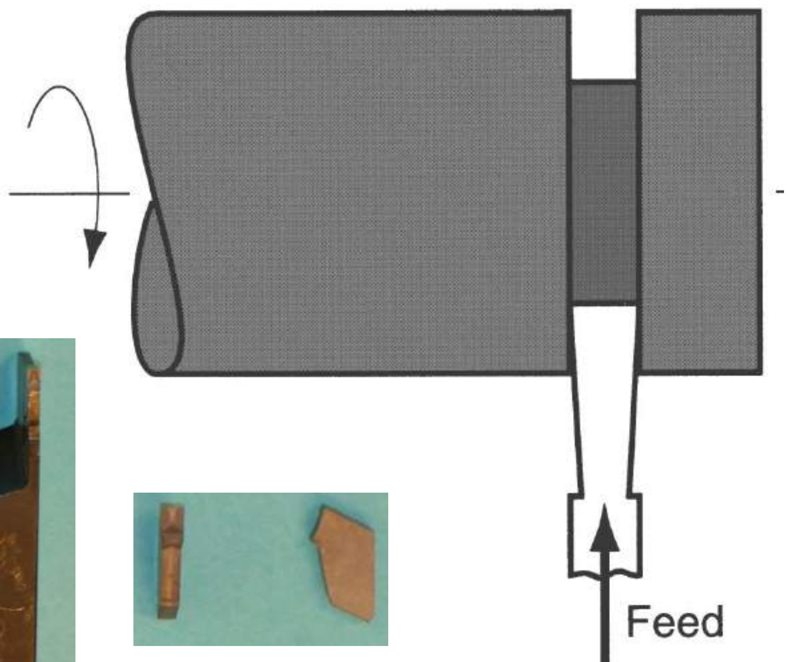


Figure 22.6 (e) chamfering

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

Parting (Cutoff) / Grooving

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



(f)

Figure 22.6 (f) cutoff

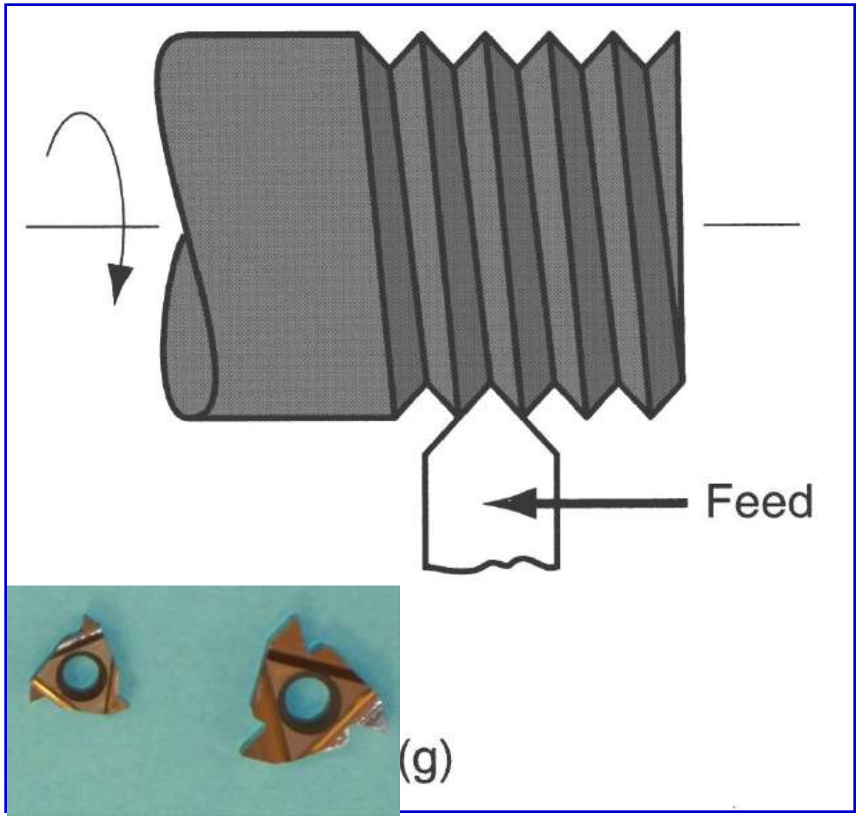


Figure 22.6 (g) threading

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

Machining Calculations: Turning

- Spindle Speed - N
  - **v = cutting speed**
  - **D_o = outer diameter**

$$N = \frac{v}{\pi D_o}$$ (rpm)

- Feed Rate - f_r
  - **f = feed per rev**

$$f_r = N f$$ (mm/min -or- in/min)

- Depth of Cut - d
  - **D_o = outer diameter**
  - **D_f = final diameter**

$$d = \frac{D_o - D_f}{2L}$$ (mm/rev -or- in/rev)

- Machining Time - T_m
  - **L = length of cut**

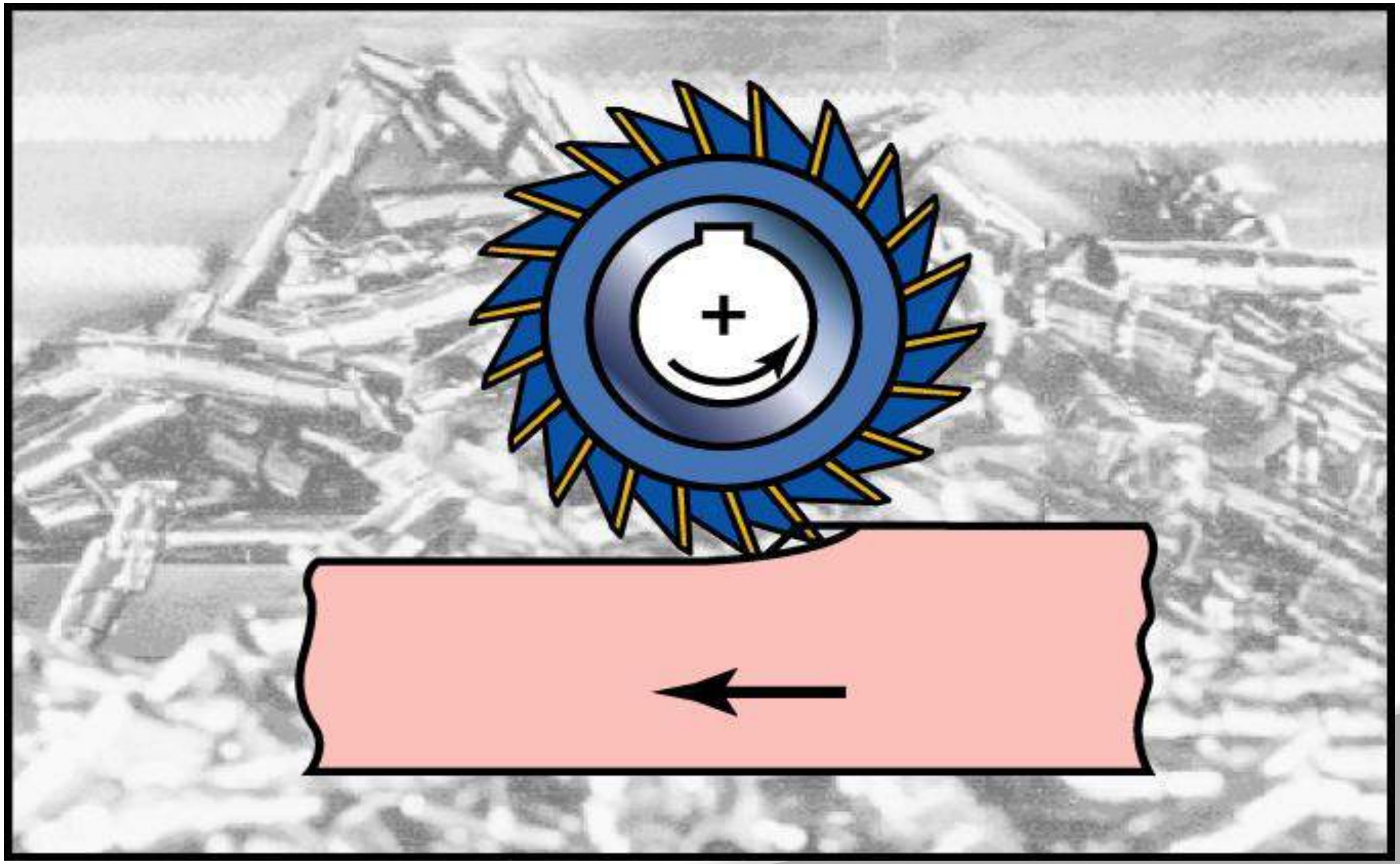
$$T_m = \frac{L}{f_r}$$ (min)

- Mat'l Removal Rate - MRR

$$MRR = v f d$$ (mm^3/min -or- in^3/min)

MACHINE TOOL-II

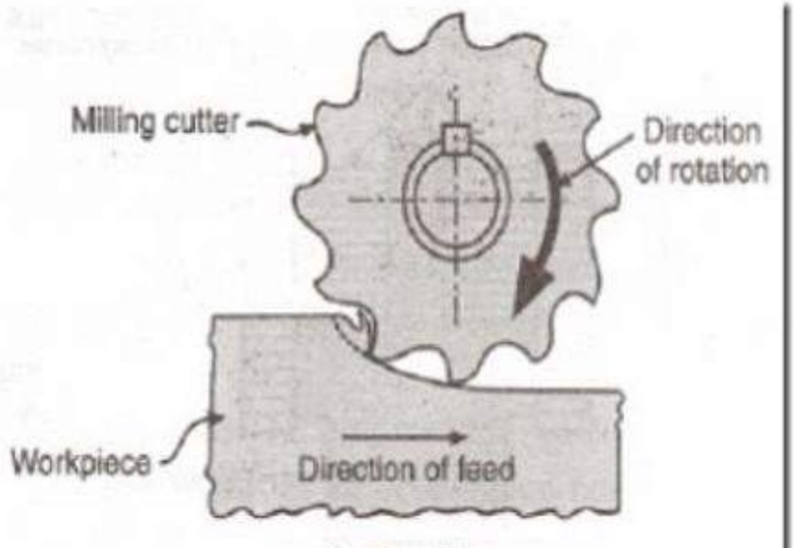
Machining Processes Used to Produce Various Shapes: Milling



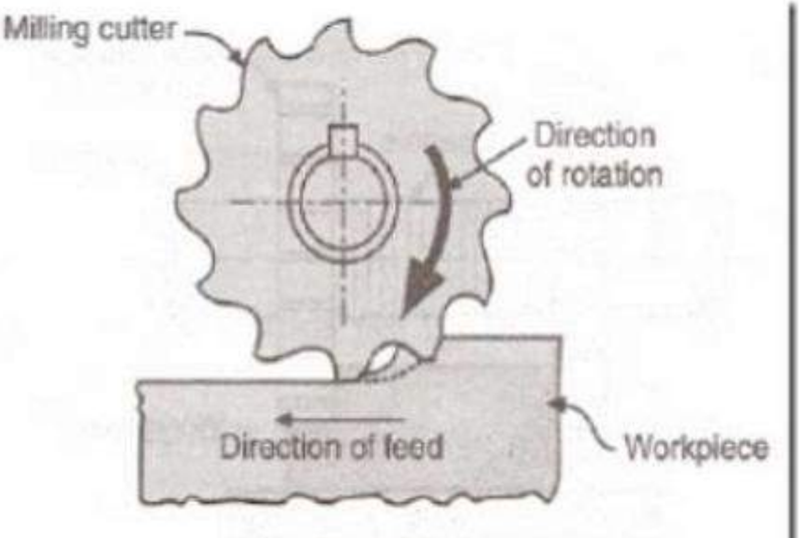
Milling:

- a process in which a rotating multi-tooth cutter removes material while traveling along various axes with respect to the work-piece.
- Figure shows basic types of milling cutters & milling operations
- In peripheral milling (also called plain milling), the axis of cutter rotation is parallel to the work-piece surface.
- When the cutter is longer than the width of the cut, the process is called slab milling

PRINCIPLE OF MILLING



(a) Up milling



(b) Down milling

Classifications of Milling Machines

CLASSIFICATION OF MILLING MACHINES

1. Column and knee milling machines
   a. Plain column & knee type milling machine
      - Horizontal spindle type
      - Vertical spindle type

2. Bed type milling machine

3. Planer type milling machine

4. Special purpose milling machine
   a. Tracer controlled milling machine
   b. Thread milling machine
   c. CNC milling machine

Horizontal Milling Machines

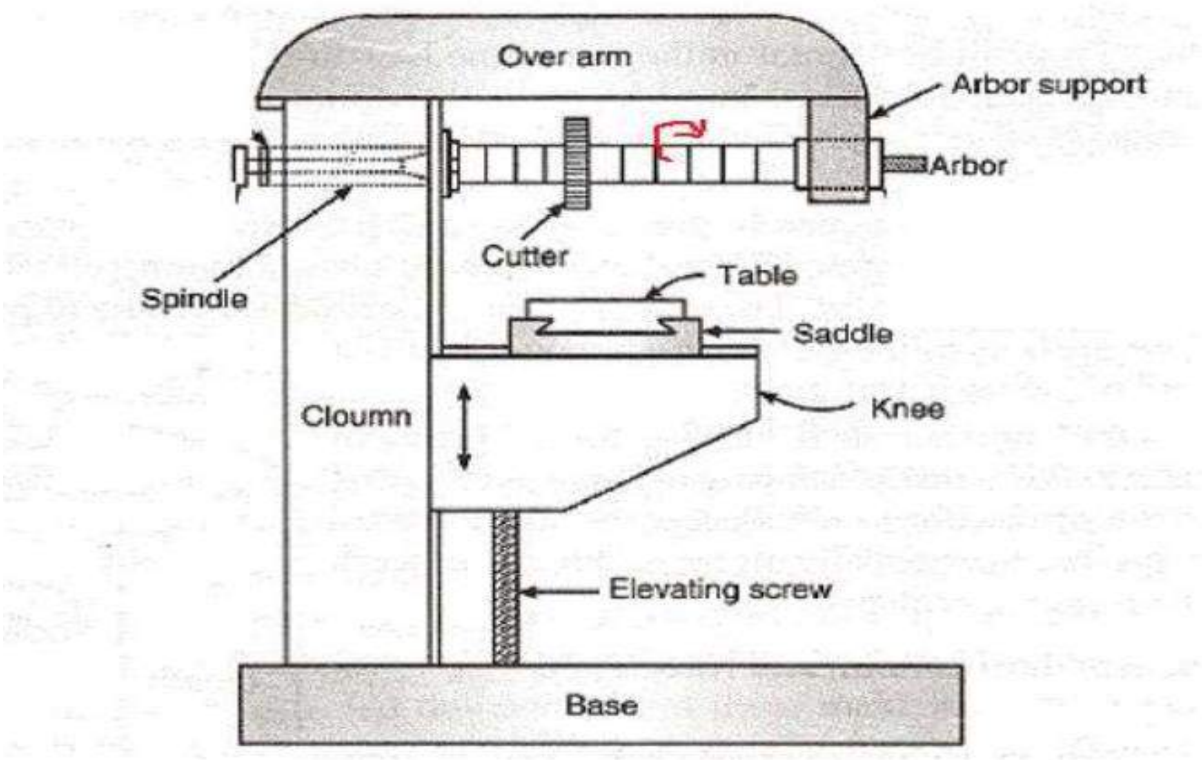
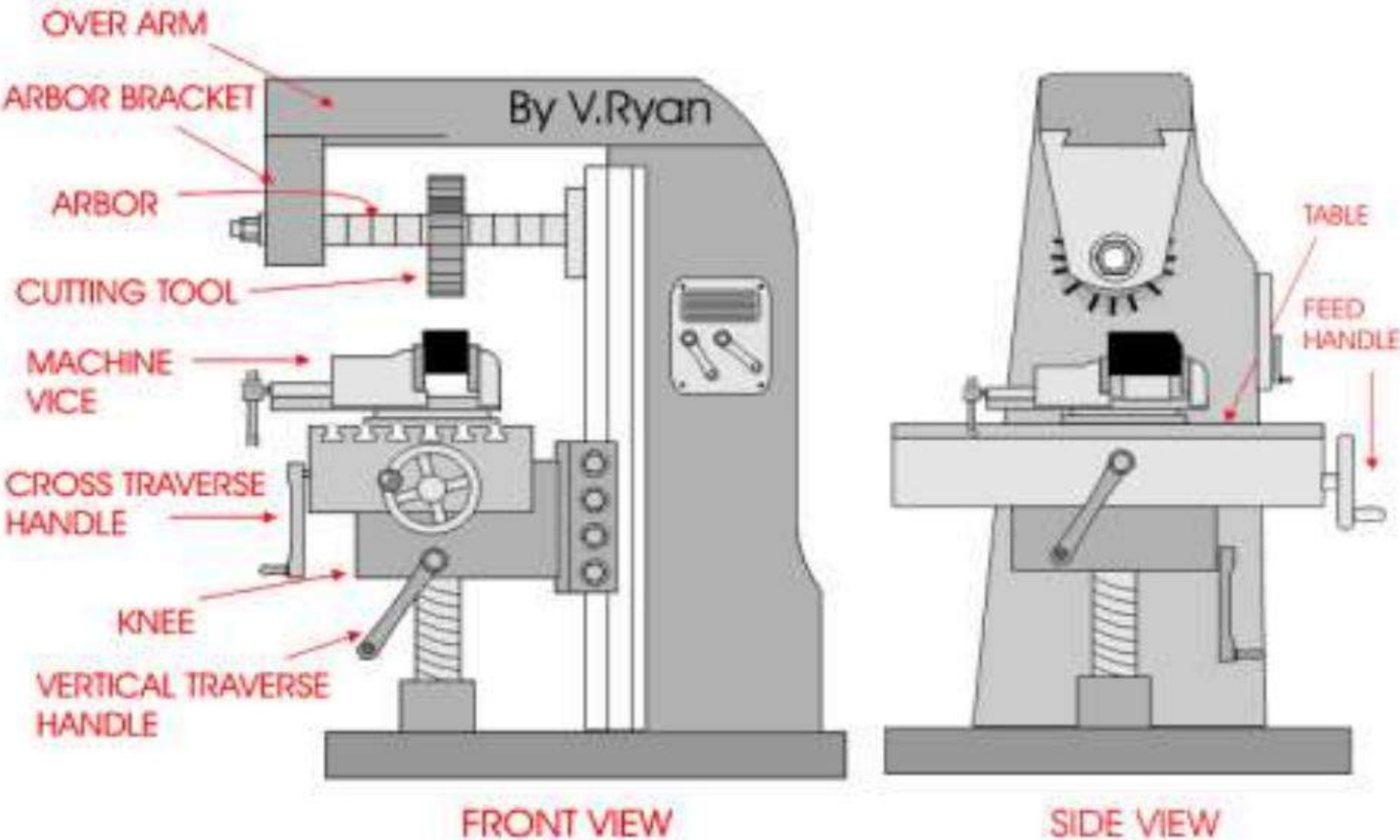


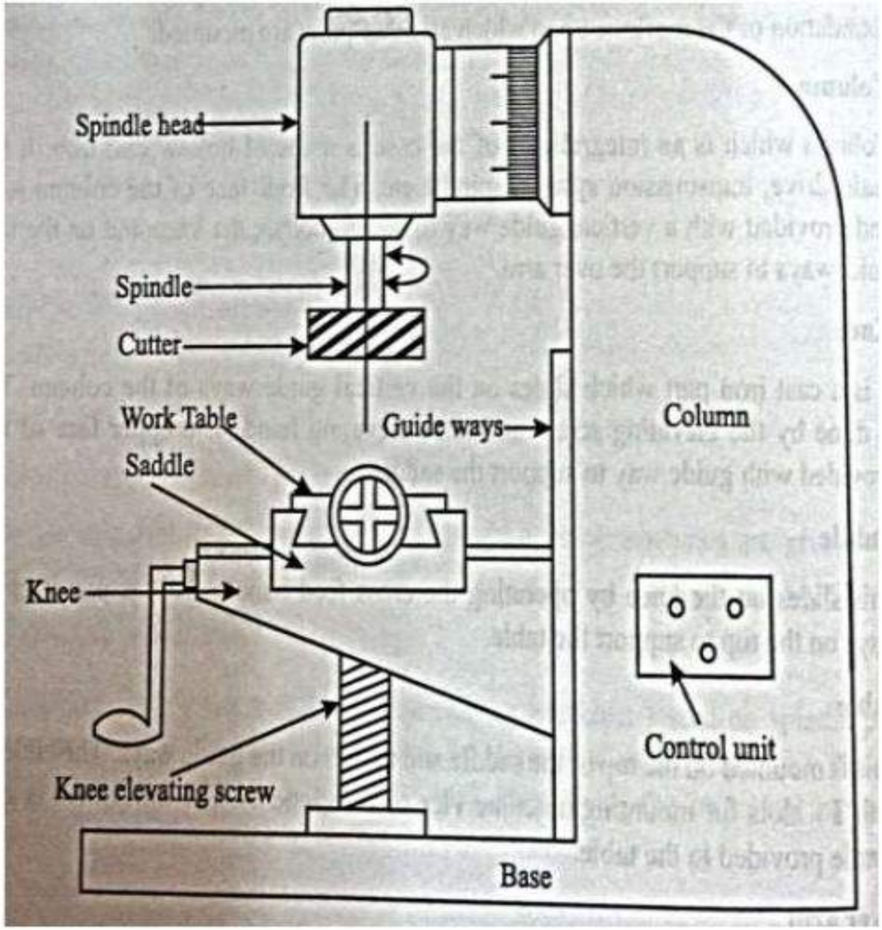
FIG. HORIZONTAL MILLING MACHINE

MAJOR PARTS :

1. BASE
2. COLUMN
3. SPINDLE
4. OVERARM
5. KNEE
6. SADDLE
7. WORKTABLE


OVER ARM
ARBOR BRACKET
By V.Ryan
ARBOR
CUTTING TOOL
MACHINE
VICE
CROSS TRAVERSE
HANDLE
KNEE
VERTICAL TRAVERSE
HANDLE
TABLE
FEED
HANDLE
FRONT VIEW
SIDE VIEW

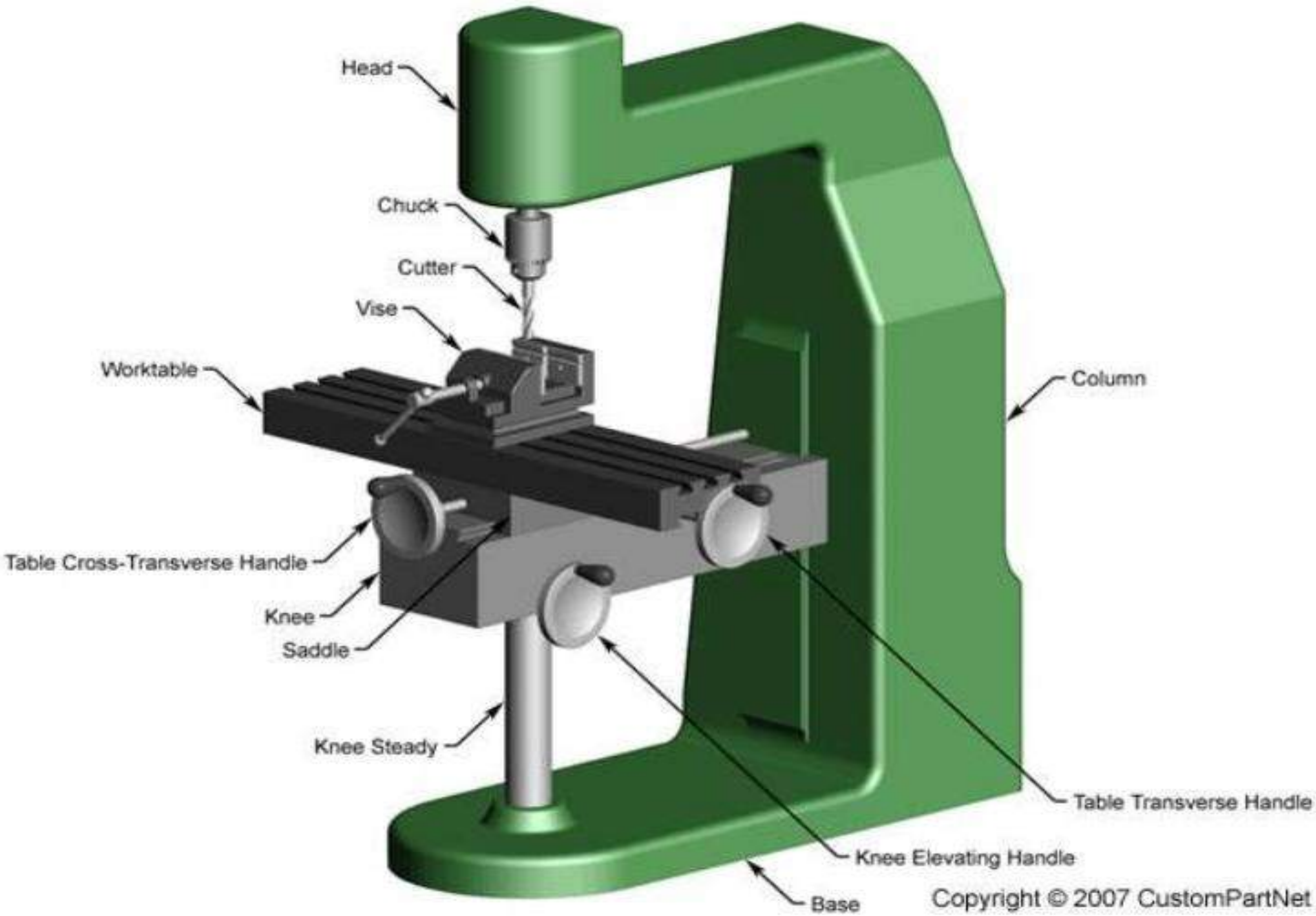
VERTICAL MILLING MACHINE



MAJOR PARTS :

1. BASE
2. COLUMN
3. SPINDLE
4. SPINDLE HEAD
5. KNEE
6. SADDLE
7. WORKTABLE

FIG. VERTICAL MILLING MACHINE


Head
Chuck
Cutter
Vise
Worktable
Column
Table Cross-Transverse Handle
Knee
Saddle
Knee Steady
Table Transverse Handle
Knee Elevating Handle
Base
Copyright © 2007 CustomPartNet

DIFFERENCES BETWEEN HORIZONTAL & VERTICAL MILLING MACHINES

SL. NO.	HORIZONTAL MILLING MACHINE	VERTICAL MILLING MACHINE
01	Spindle is horizontal & parallel to the worktable.	Spindle is vertical & perpendicular to the worktable.
02	Cutter cannot be moved up & down.	Cutter can be moved up & down.
03	Cutter is mounted on the arbor.	Cutter is directly mounted on the spindle.
04	Spindle cannot be tilted.	Spindle can be tilted for angular cutting.
05	Operations such as plain milling, gear cutting, form milling, straddle milling, gang milling etc., can be performed.	Operations such as slot milling, T-slot milling, angular milling, flat milling etc., can be performed and also drilling, boring and reaming can be carried out.

MILLING OPERATIONS

- Plain or slab milling
- Face milling
- End milling
- Slot milling
- Angular milling
- Form milling
- Straddle milling
- Gang milling
- Slitting or saw milling
- Gear cutting

Milling Cutters and Milling Operations

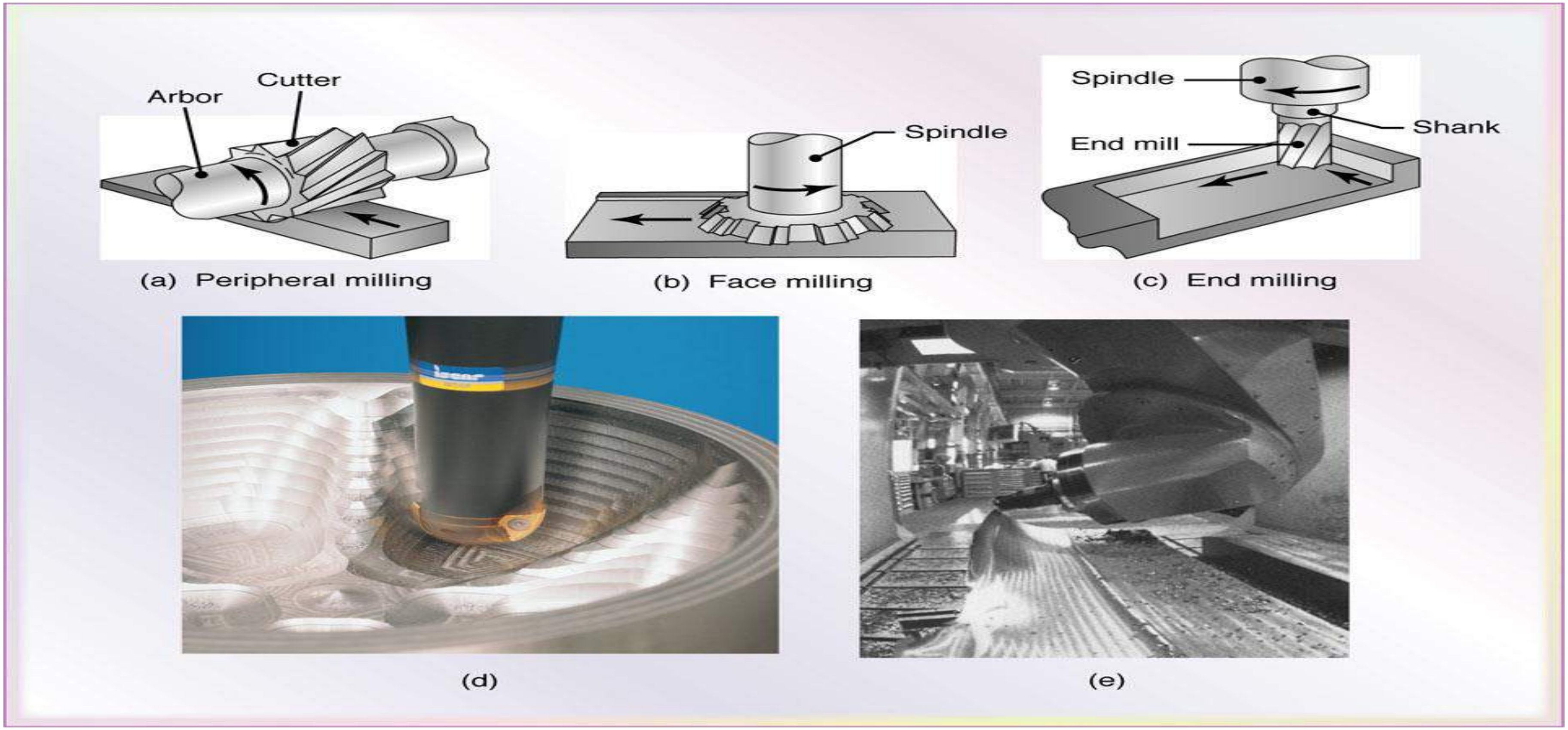


Figure 24.2 Some basic types of milling cutters and milling operations. (a) Peripheral milling. (b) Face milling. (c) End milling. (d) Ball-end mill with indexable coated-carbide inserts machining a cavity in a die block. (e) Milling a sculptured surface with an end mill, using a five-axis numerical control machine. *Source*: (d) Courtesy of Iscar. (e) Courtesy of The Ingersoll Milling Machine Co.

Milling Operations

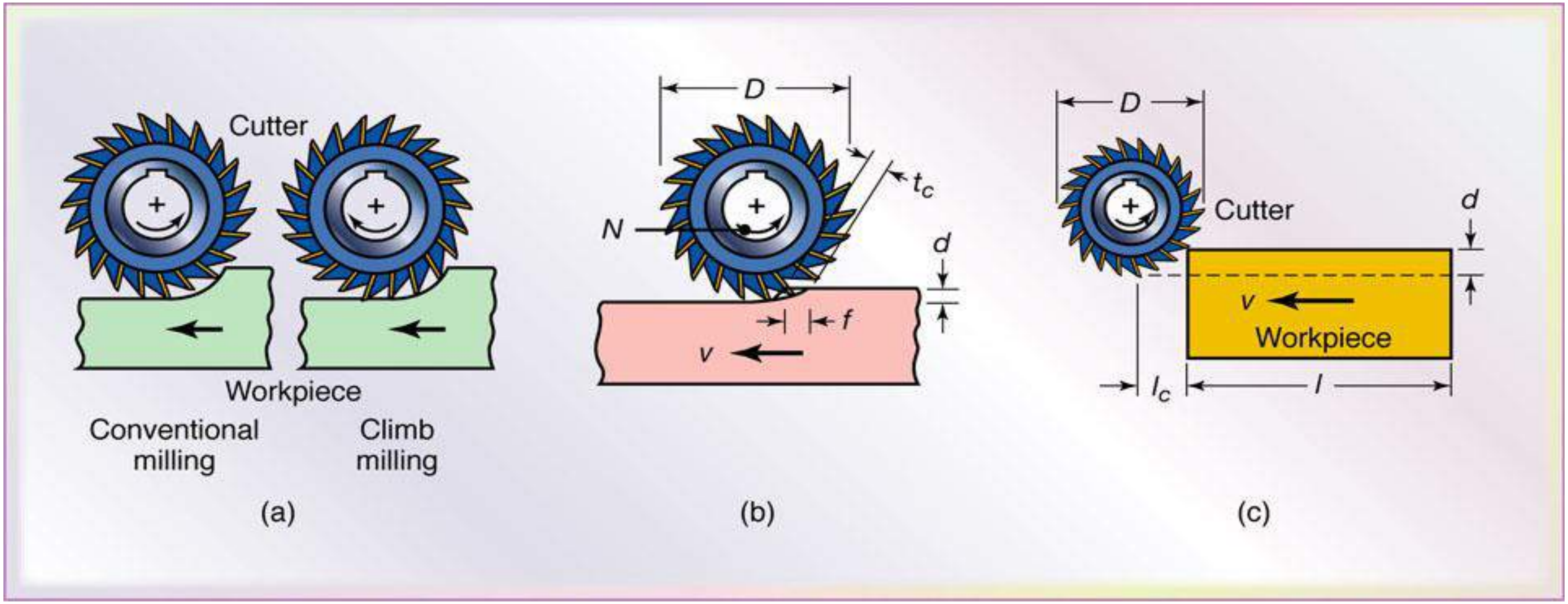


Figure 24.3 (a) Schematic illustration of conventional milling and climb milling. (b) lab-milling operation showing depth-of-cut, *d*; feed per tooth, *f*; chip depth-of-cut, t_c; and workpiece speed, *v*. (c) Schematic illustration of cutter travel distance, l_c, to reach full depth-of-cut.

Milling operations: up milling

Conventional Milling (Up Milling)

- Max chip thickness is at the end of the cut
- Advantage: tooth engagement is not a function of work piece surface characteristics, and contamination or scale on the surface does not affect tool life.
- Cutting process is smooth
- Tendency for the tool to chatter
- The work piece has a tendency to be pulled upward, necessitating proper clamping.

Climb Milling (Down Milling)

- Cutting starts at the surface of the work piece.
- Downward compression of cutting forces hold work piece in place
- Because of the resulting high impact forces when the teeth engage the work piece, this operation must have a rigid setup, and backlash must be eliminated in the table feed mechanism
- Not suitable for machining work piece having surface scale.

Milling Parameters

- N = Rotational speed of the milling cutter, rpm
- f = Feed per tooth, mm/tooth (in/tooth) = υ /N n
- D = Cutter diameter, mm (in)
- n = Number of teeth on cutter
- υ = Linear speed of the workpiece or feed rate, mm/min (in/min)
- V = Surface speed of cutter, m/min (ft/min) = π D N
- l = Length of cut, mm (in)
- t = Cutting time, s or min=(l+lc) / υ
- lc =extent of the cutter's first contact with workpiece lc=$\sqrt{Dd}$
- MRR = mm3/min or in3/min = w d υ , where w is the width of cut
- Torque = N.m (lb.ft) =(Fc) (D/2)
- Power = kW (hp) = (Torque) (ω), where ω = 2π N radians/min

Numericals

- EXAMPLE 24.1 Material-removal Rate, Power, Torque, and Cutting Time in Slab Milling
- A slab-milling operation is being carried out on a 300-mm-long, 100-mm-wide annealed mild-steel block at a feed f = 0.25 mrn/tooth and a depth of cut d = 3.0 mm. The cutter is D = 50 mm in diameter, has 20 straight teeth, rotates at N = 100 rpm, and, by definition, is wider than the block to be machined, Calculate the material-removal rate, estimate the power and torque required for this operation, and calculate the cutting time.
- Solution:

$$v = fNn = (0.25)(100)(20) = 500 \text{ mm/min.}$$

$$\text{MRR} = \frac{lwd}{t} = wdv, \quad \text{MRR} = (100)(3)(500) = 150{,}000 \text{ mm}^3\text{/min.}$$

From table 21.2 U=3 W.S/mm^3

$$\text{Power} = (3)(150{,}000)\left(\frac{1}{60}\right) = 7.5 \text{ kW}$$

$$\text{Torque} = \frac{\text{Power}}{\text{Rotational speed}}$$

$$= \frac{(7500)(60 \text{ N·m/min} \cdot \text{W})}{(100 \text{ rpm})(2\pi)}$$

$$= 716 \text{ N·m}$$

$$l_c = \sqrt{Dd} = \sqrt{(50)(3)} = 12.2 \text{ mm.}$$

Thus, the cutting time is

$$t = \frac{300 + 12.2}{500} = 0.62 \text{ min} = 37.2 \text{ s.}$$

Face-Milling Operation

The cutter is mounted on a spindle whose axis of rotation is perpendicular to work piece surface.

Lc= D/2

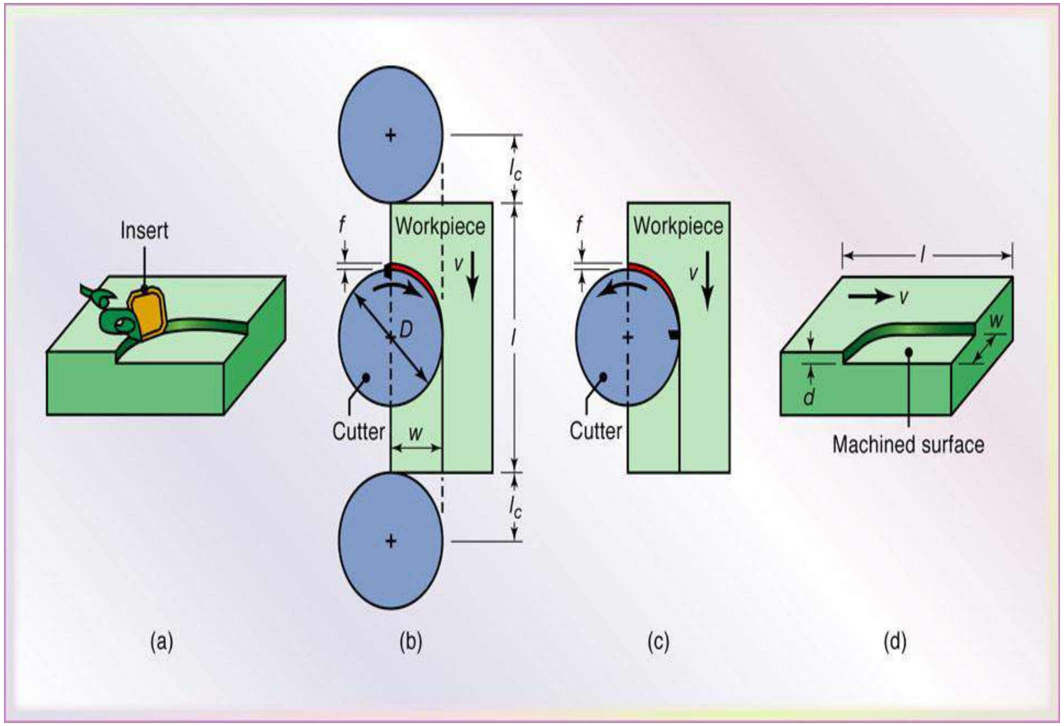


Figure 24.4 Face-milling operation showing (a) action of an insert in face milling; (b) climb milling; (c) conventional milling; (d) dimensions in face milling. The width of cut, *w*, is not necessarily the same as the cutter radius.

Face-Milling Cutter with Indexable Inserts

Figure 24.5 A face-milling cutter with index able inserts.
Source: Courtesy of Ingersoll Cutting Tool Company.

Effect of Insert Shape on Feed Marks on a Face-Milled Surface

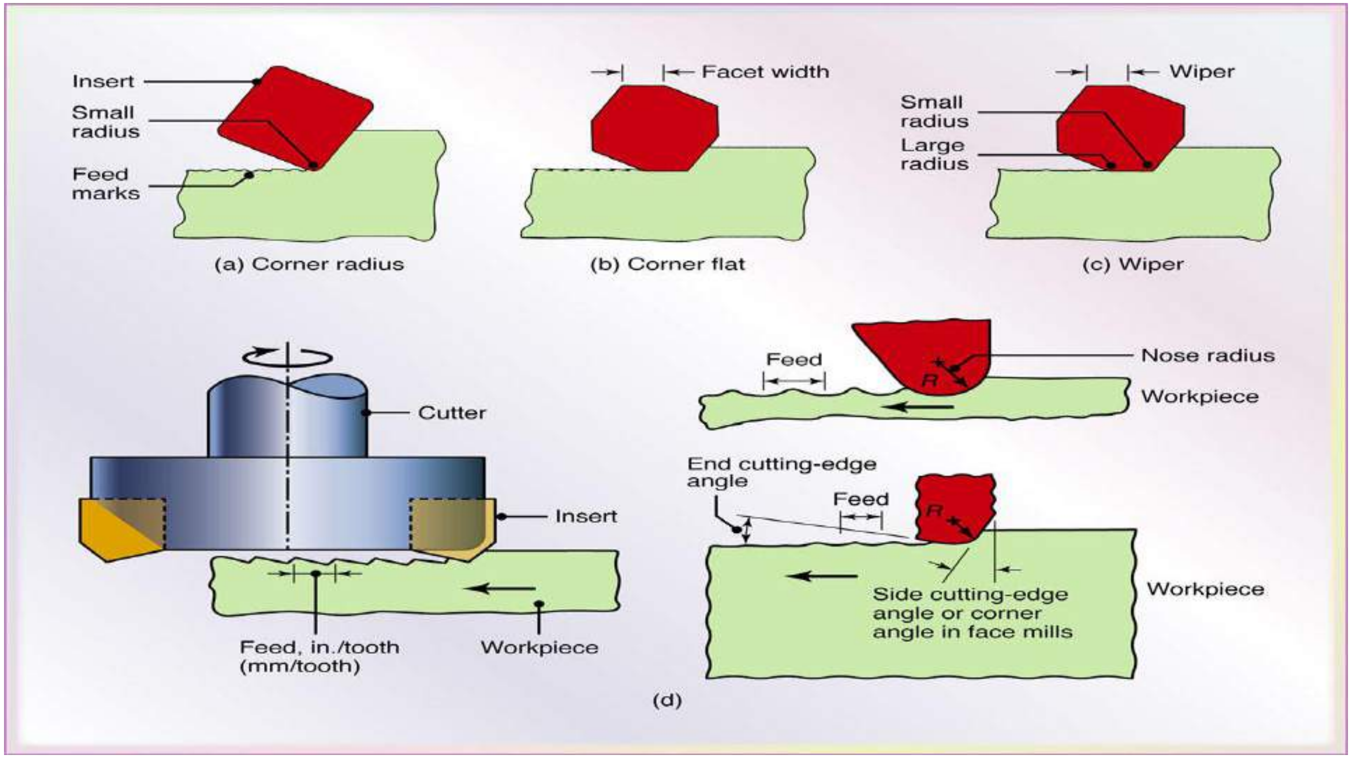


Figure 24.6 Schematic illustration of the effect of insert shape on feed marks on a face-milled surface: (a) small corner radius, (b) corner flat on insert, and (c) wiper, consisting of small radius followed by a large radius which leaves smoother feed marks. (d) Feed marks due to various insert shapes.

Face-Milling Cutter

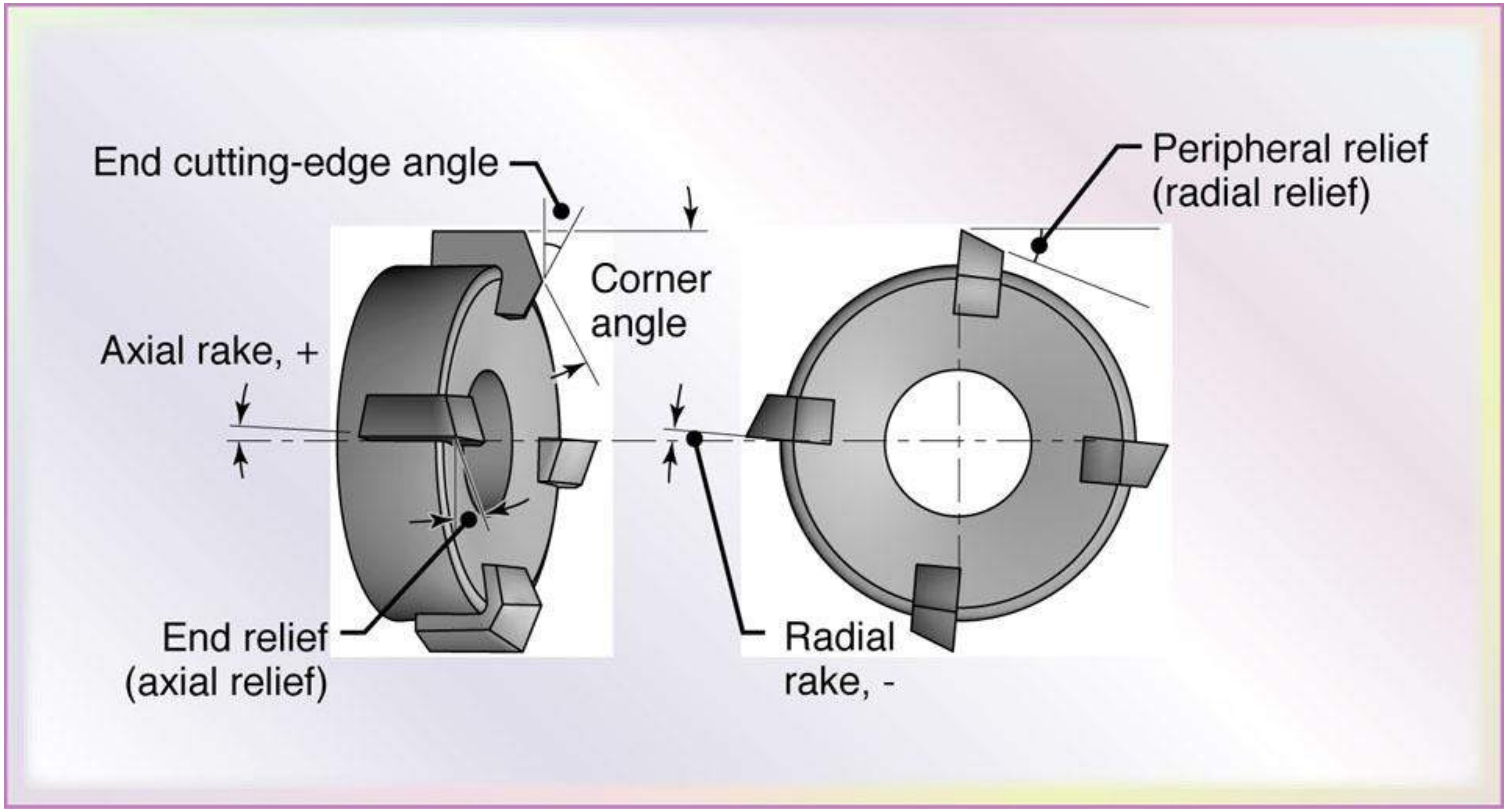


Figure 24.7 Terminology for a face-milling cutter.

Effect of Lead Angle on Un deformed Chip Thickness in Face Milling

- Lead angle of insert has a direct influence on un deformed chip thickness
- As the lead angle increases, un deformed chip thickness decreases, length of contact increases
- Range of lead angles = 0-45
- X-sectional area of un deformed chip remains constant
- As lead angle decreases, there is a smaller vertical force comp (axial force)
- Ratio of cutter diameter, D, to width of cut should be no less than 3:2

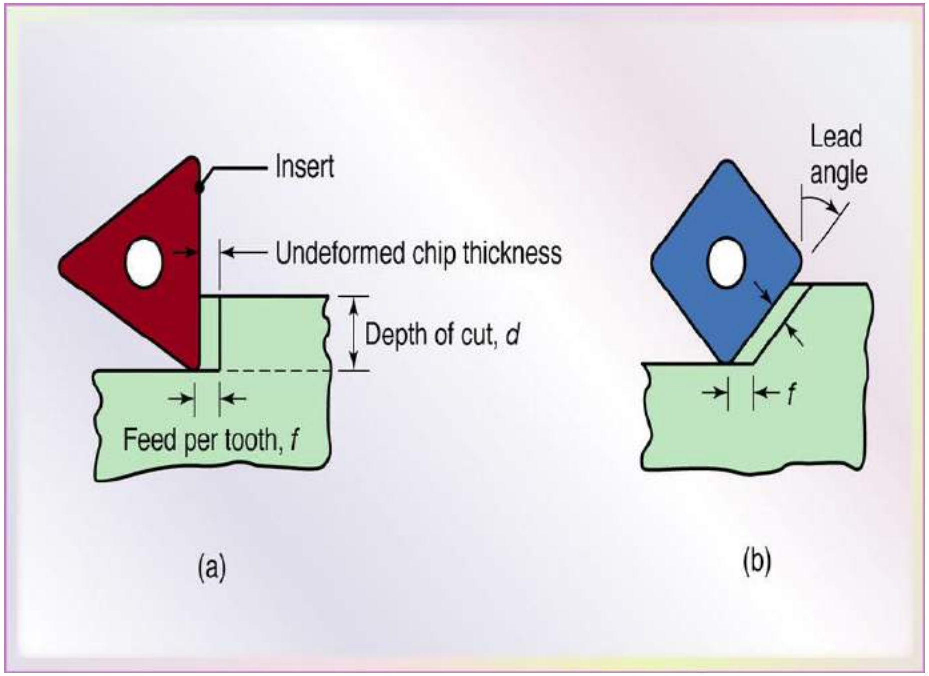


Figure 24.8 The effect of the lead angle on the un deformed chip thickness in face milling. Note that as the lead angle increases, the chip thickness decreases, but the length of contact (i.e., chip width) increases. The edges of the insert must be sufficiently large to accommodate the contact length increase.

Position of Cutter and Insert in Face Milling

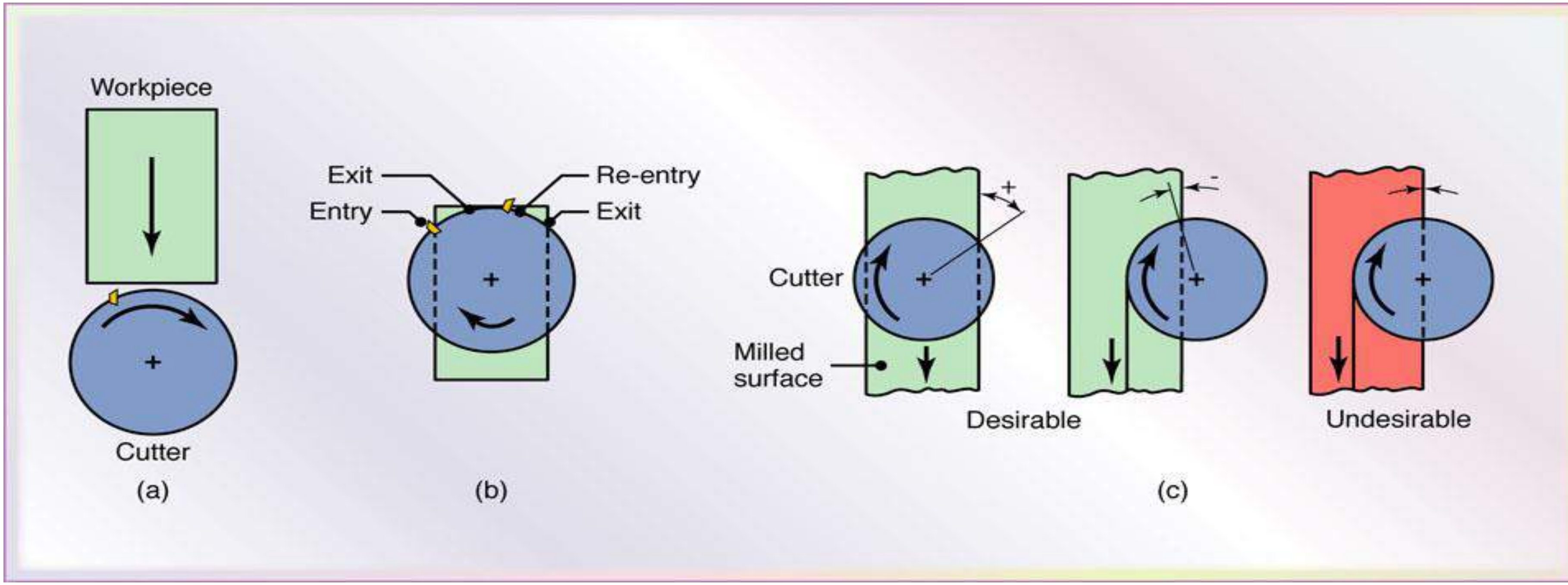


Figure 24.9 (a) Relative position of the cutter and insert as it first engages the work piece in face milling. (b) Insert positions towards the end of cut. (c) Examples of exit angles of insert, showing desirable (positive or negative angle) and undesirable (zero angle) positions. In all figures, the cutter spindle is perpendicular to the page and rotates clockwise.

EXAMPLE 24.2 Material-removl Rate, Power Required, and Cutting Time in Face Milling

T-Slot Cutting and Shell Mill

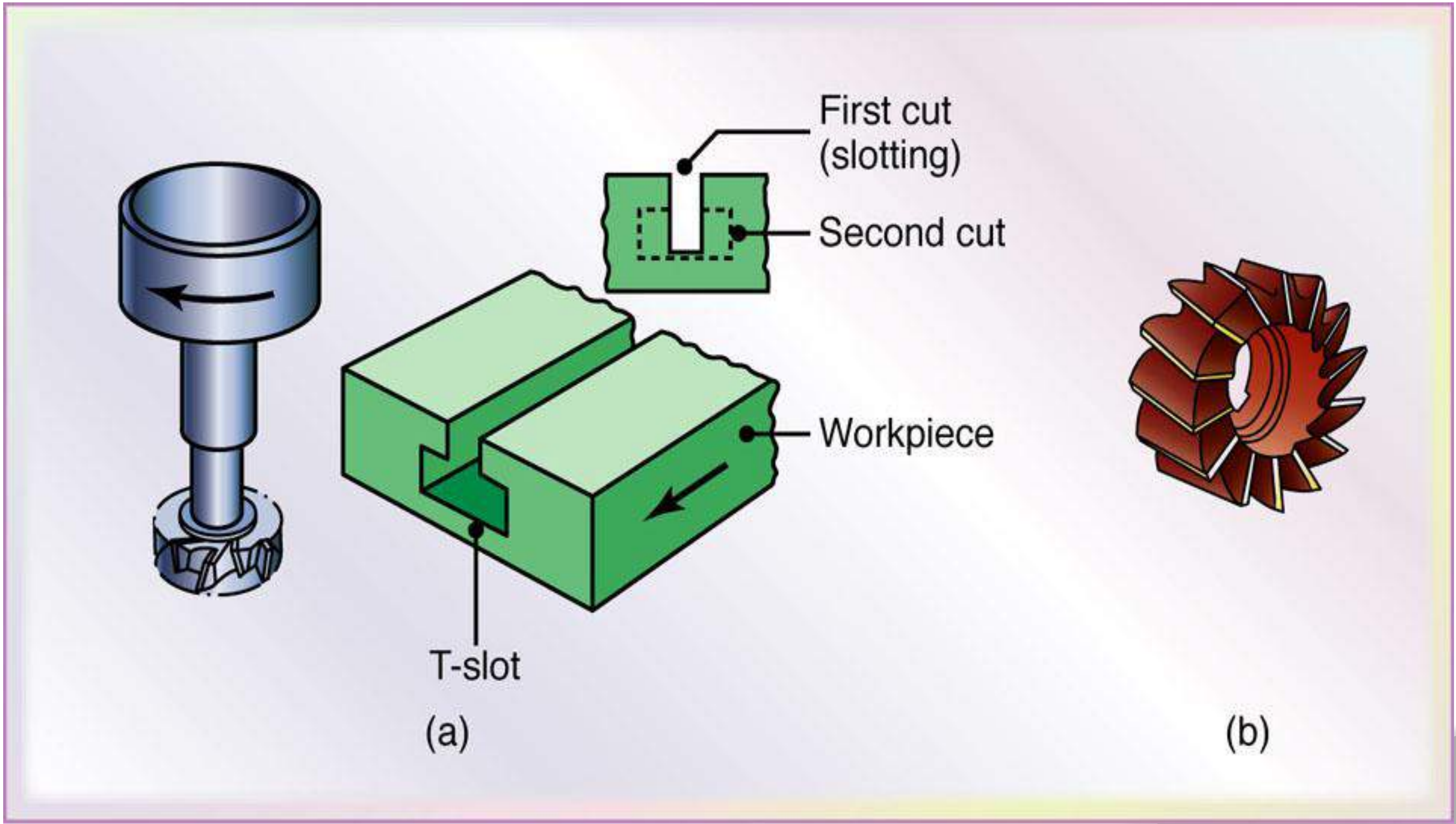
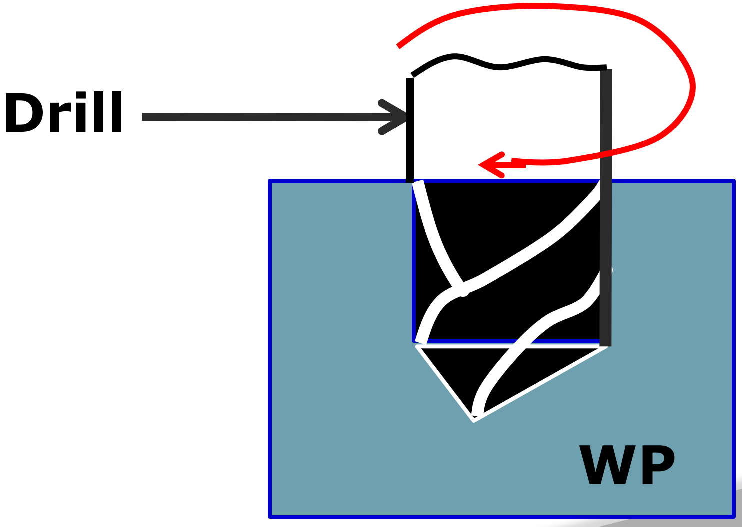


Figure (a) T-slot cutting with a milling cutter. (b) A shell mill.

- Drilling is the operation of originating a cylindrical hole
- Hole is generated by rotating cutting edges of drill, which exerts large force on the WP to originate a hole.



Principle of Drilling Machine

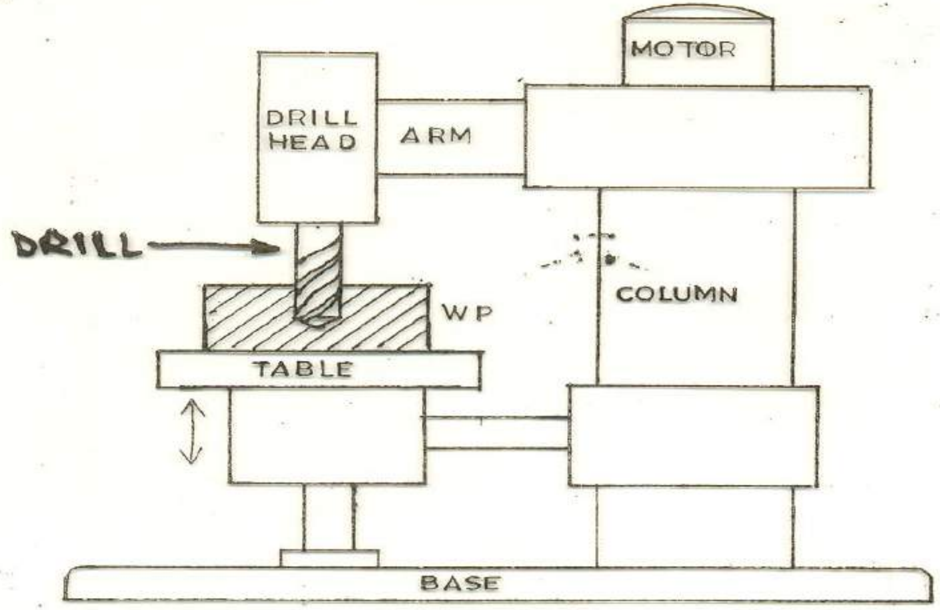
- Drilling is an operation of generating a hole of different diameters by means of rotating cutting tools of different diameters. The tool used for drilling hole is called as drill.

- Similar operations like boring, reaming, counter boring, counter sinking, tapping etc. are also performed with the drilling machine.

- This is done by holding the tools rigidly in the tool holding device know as Chuck. Thus in this machining operation the tool is rotating one while the work piece is stationary one, which rests on the working table.

Types of Drilling Machines

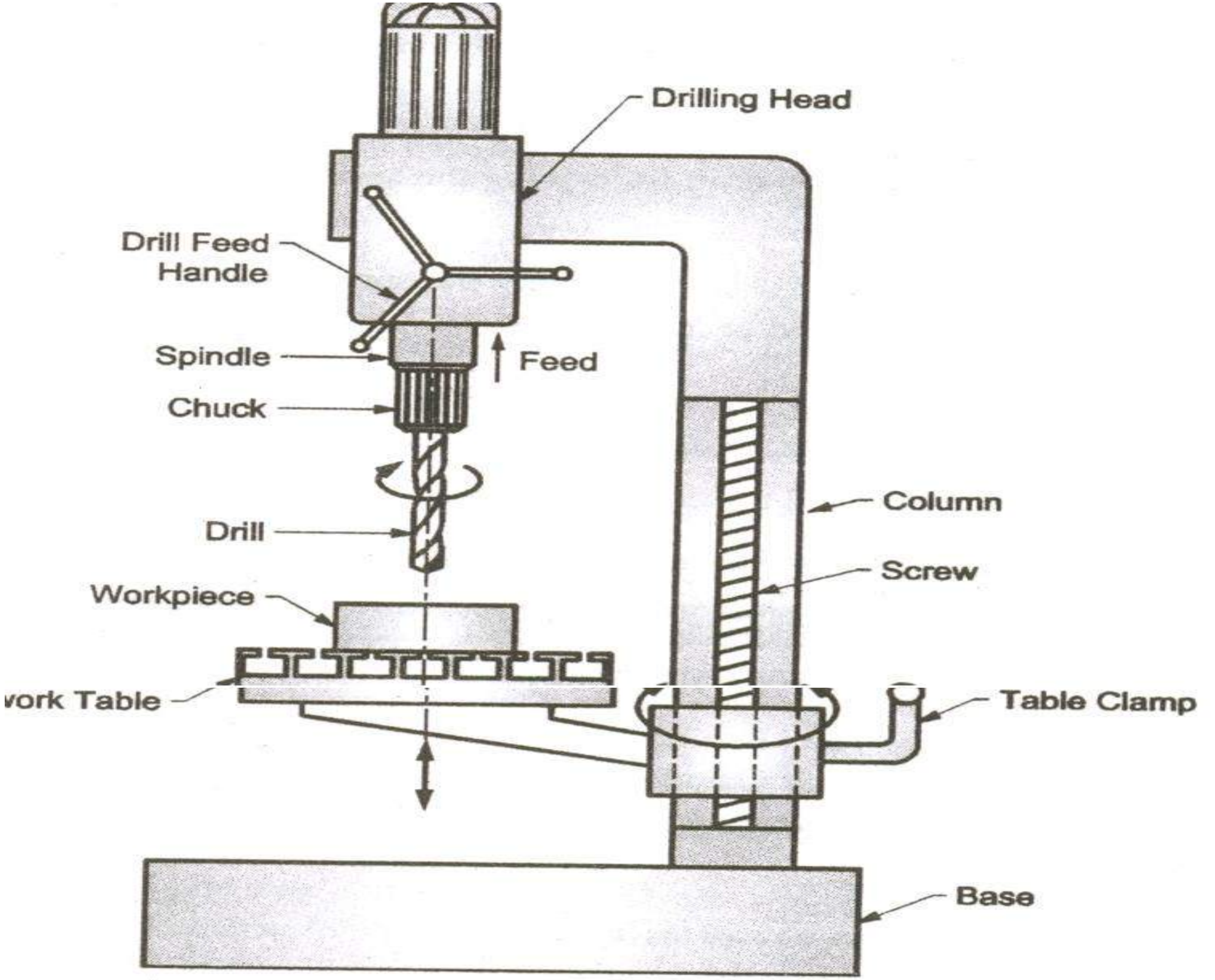
- Portable Drilling Machine
- Sensitive Drilling Machine
- Pillar/Upright Drilling Machine
- Radial Drilling Machine
- Gang Drilling Machine
- Multiple Spindle Drilling Machine
- Automatic Drilling Machine
- Deep Hole Drilling Machine
- Portable Drilling machine



Drill Machine

Twist Drill

Block Diagram of Drilling Machine



Major Components of Drill Machine

1. **Base –** It is a part of the machine on which the vertical column is mounted.
2. **Column –** It is the vertical member of the drilling machine. It supports table and the head including driving mechanism.
3. **Table –** It is mounted on the column. 'T' slots are provided on it to clamp the work piece on it.
4. **Head –** It is mounted on the top of the column. It consists of driving and feeding mechanism for the spindle.
5. **Spindle –**vertical shaft which holds the chuck and drill. Rotary motion of the spindle is given directly to the tool to cut the material from the work piece.
6. **Spindle drive and feed mechanism –** Multiple speeds may be obtained by a step cone pulley drive or by gear. Feed mechanism provided in drilling machine is either by quick reverse hand feed or by sensitive hand feed. The feed movement may be controlled by hand or power.

Sensitive Drilling Machine

- Drill holes from 1.5 to 15mm

- Operator senses the cutting action so sensitive drilling machine

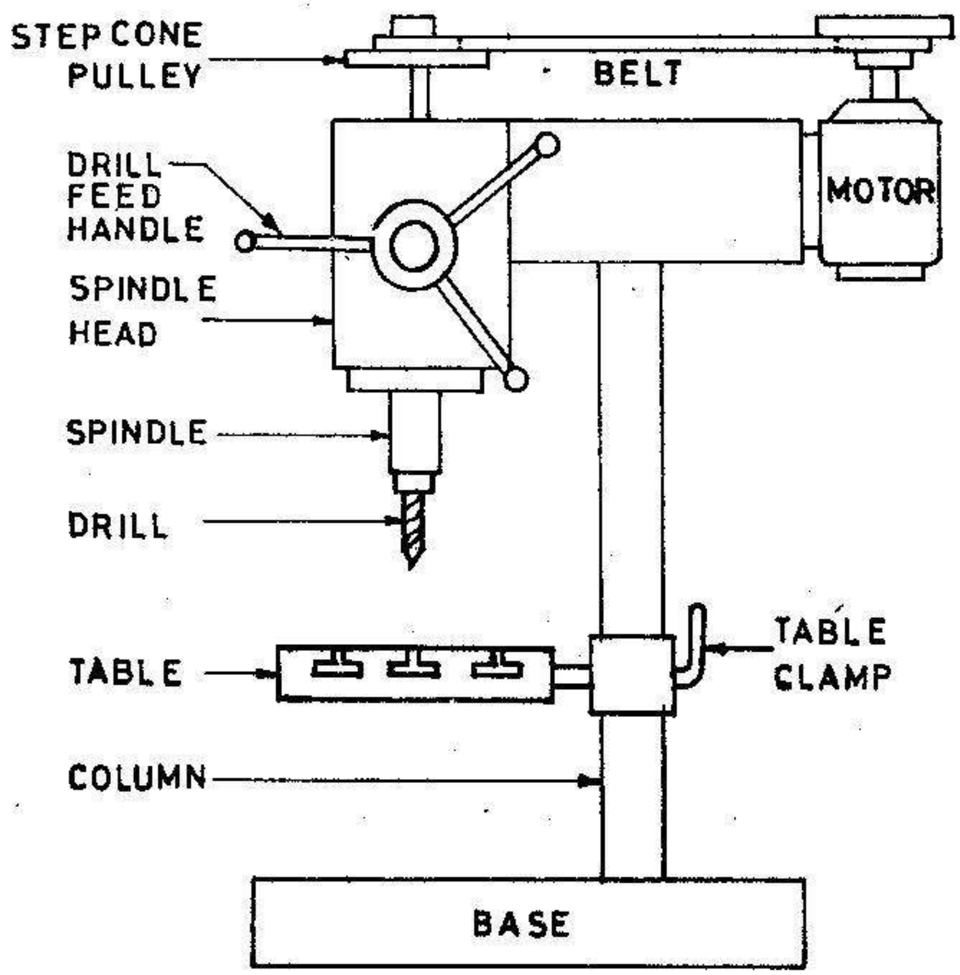
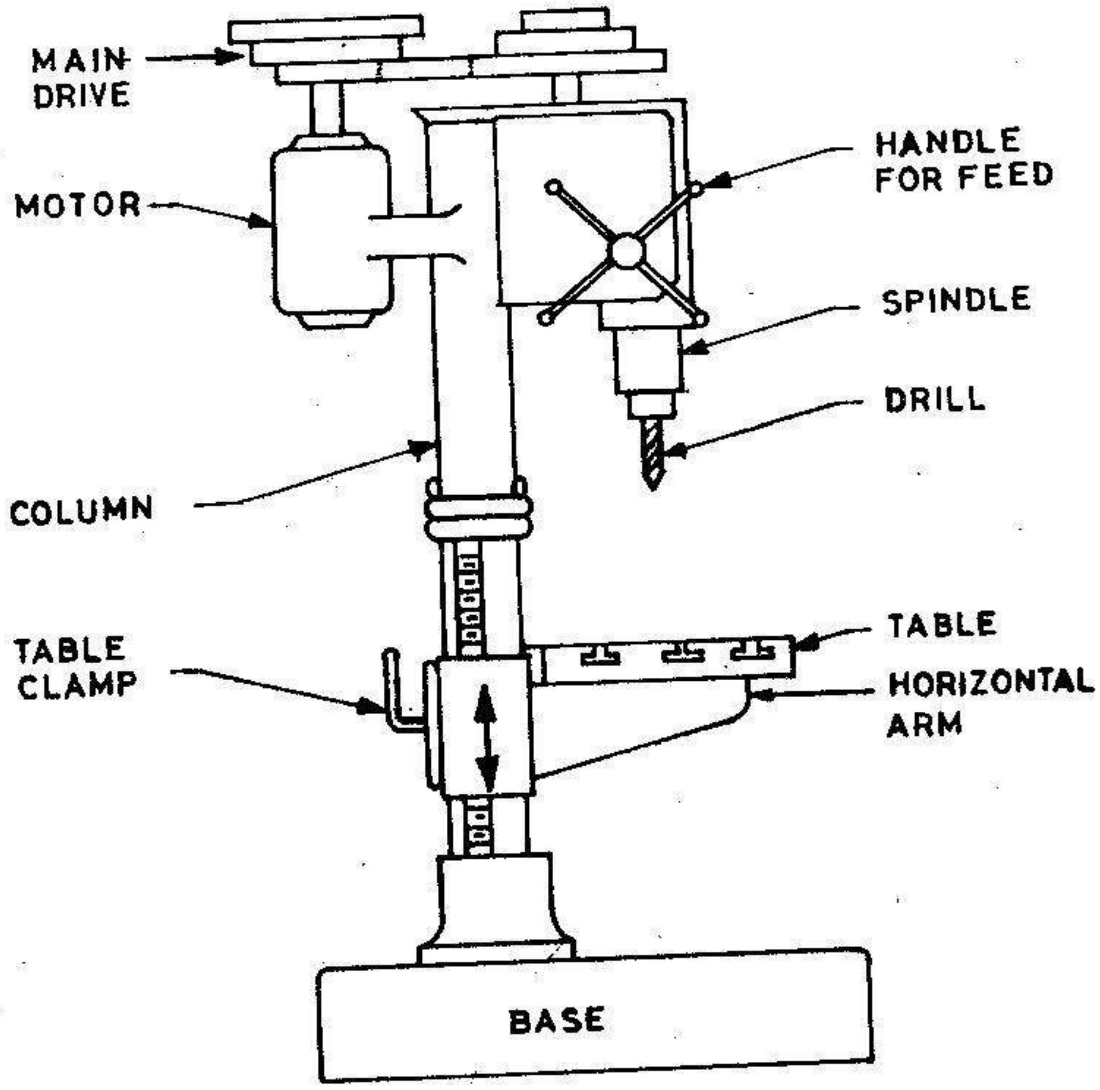


Fig.

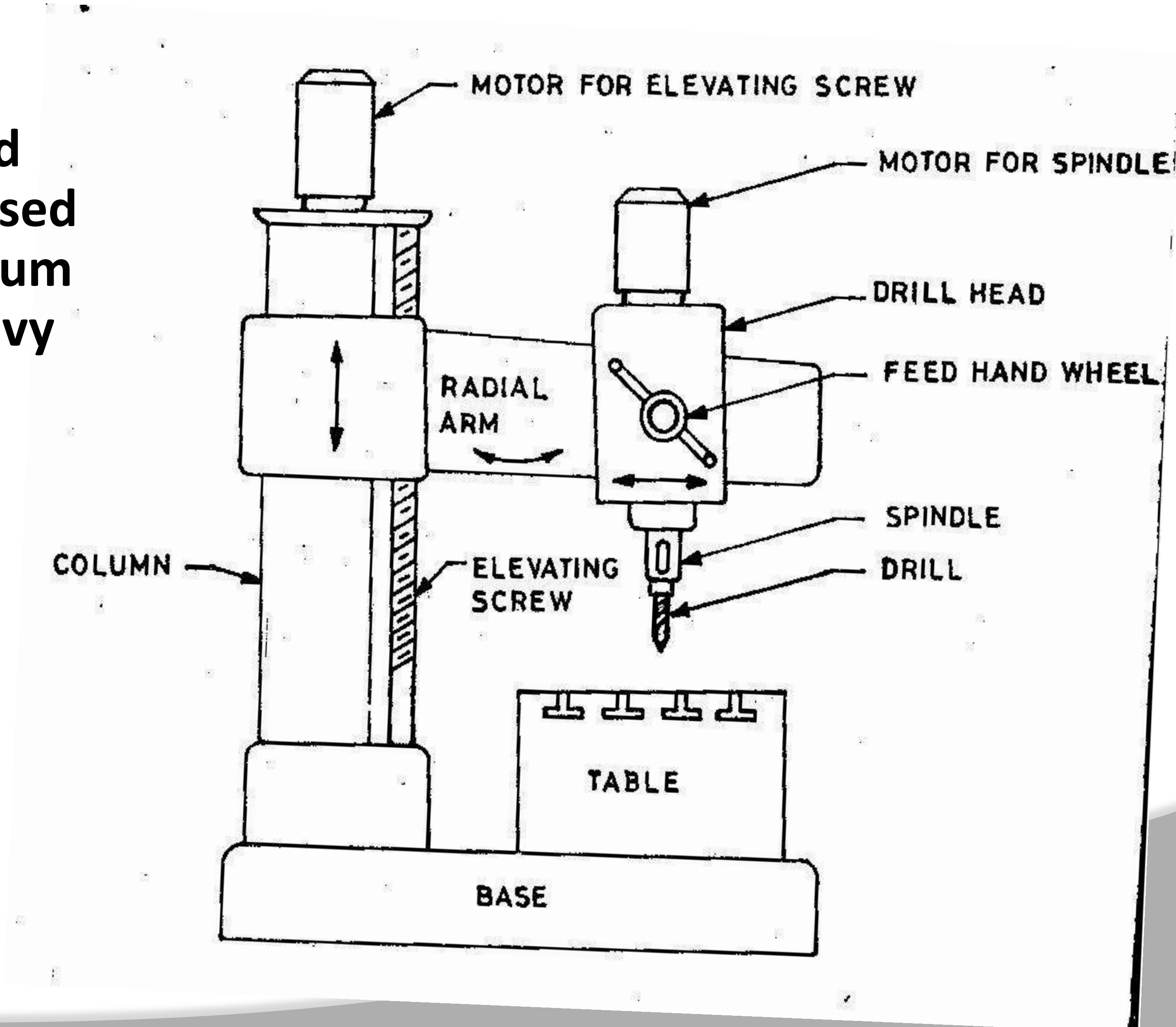
Up-Right Drilling Machine



- Drill holes upto 50mm
- Table can move vertically and radially

Radial Drilling Machine

- **It the largest and most versatile used for drilling medium to large and heavy work pieces.**



GEOMETRICAL DIMENSIONING AND TOLERANCES

Metrology

- Metrology is the science of measurement

- Dimensional metrology is that branch of Metrology which deals with measurement of “dimensions” of a part or workpiece (lengths, angles, etc.)

- Dimensional measurements at the required level of accuracy are the essential link between the designers intent and a delivered product.

Definitions

- **Normal size:** Normal size of part by which it is referred to as a matter of convenience

- **Basic size:** The size with reference to which the limits of size are fixed.

- **Zero line:** It is a straight line corresponding to the basic size.

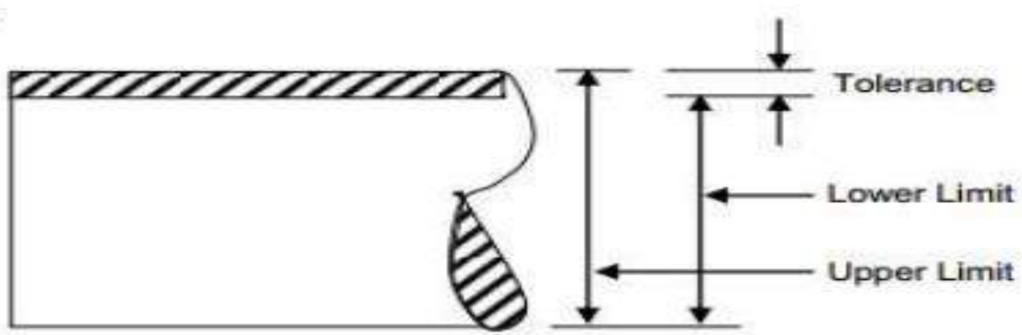
- **Actual size:** Actual measured dimension of the part

- **The two extreme permissible sizes of a part between which the actual size should lie.**

  (upper limit and lower limit)

  Upper limit: **The greater of the two limits of size.**

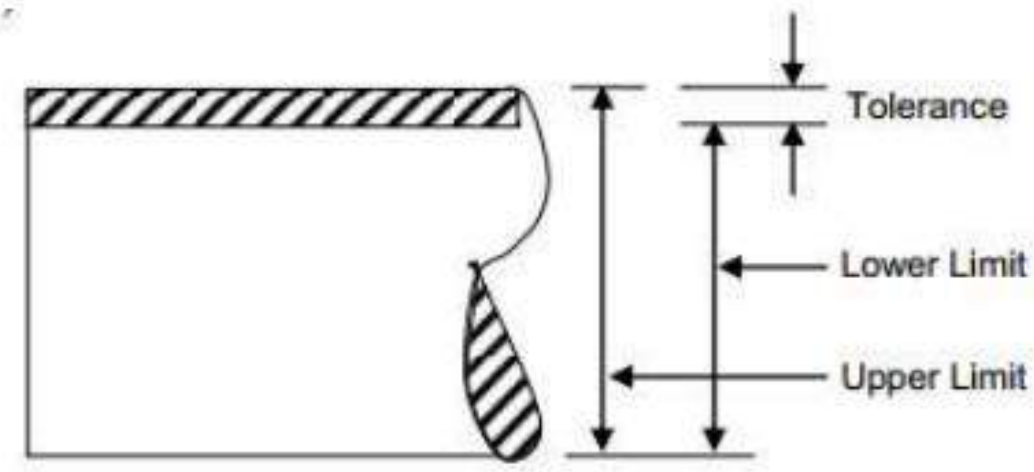
  Lower limit: **The smaller of the two limits of size.**



TOLERANCES

- **It is the difference between the upper and lower limits**

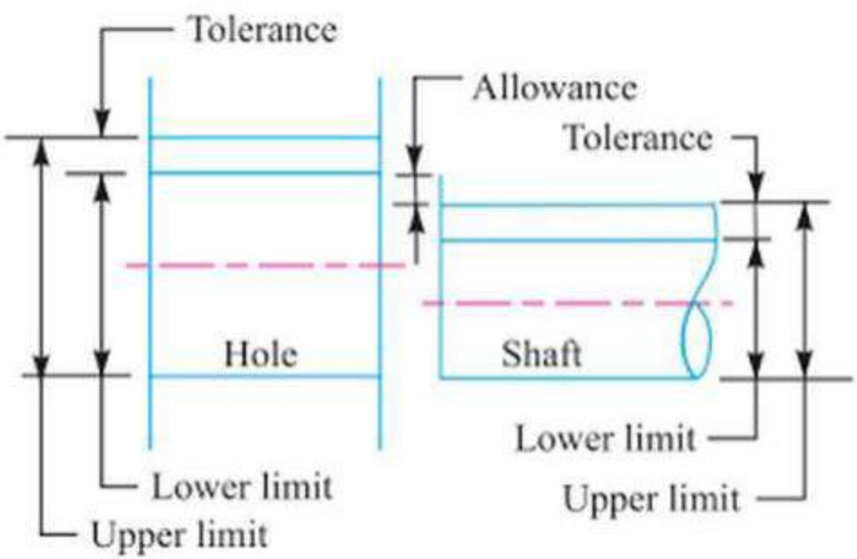
  tolerance = upper limit – lower limit



Why it is necessary?

- It is impossible to manufacture a part or component to an exact size or geometry.
- Since variation from the drawing is inevitable, acceptable degree of variation must be applied.
- Large variation may affect the functionality of the part.
- Small variation may effect the economy of the part.

- It is the difference between the basic dimensions of the mating parts
- When the shaft size is less than the hole size, then the allowance is positive and when the shaft size is greater than the hole size, then the allowance is negative.

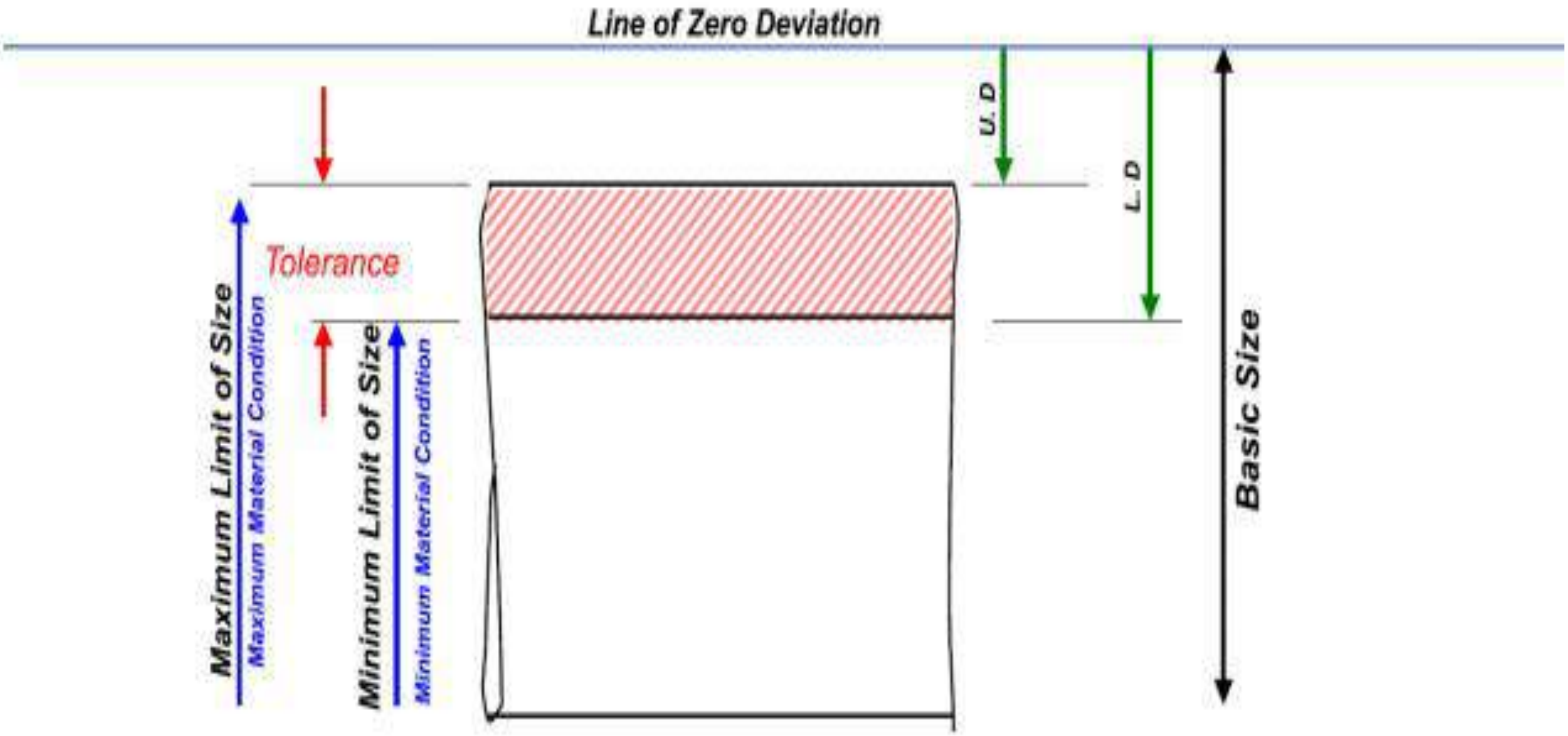


Definitions

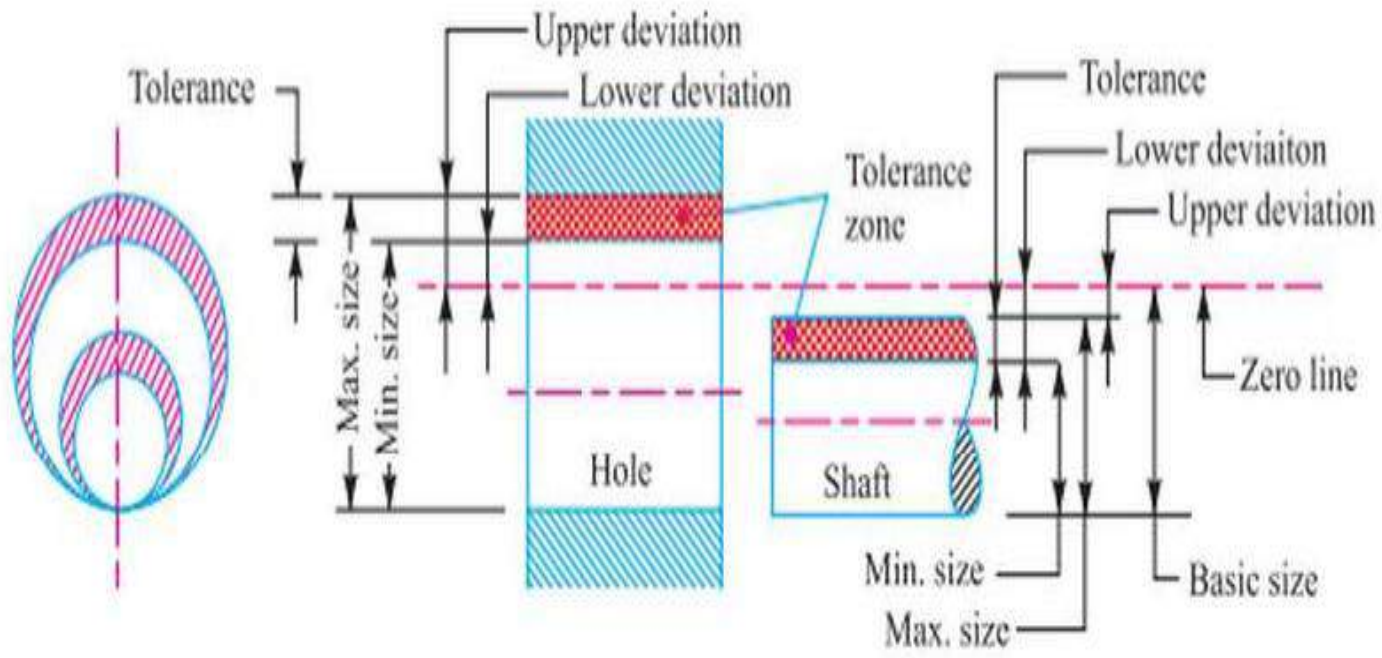
- **Tolerance Zone:** It is the zone between the maximum and minimum limit size.

- **Upper Deviation:** It is the algebraic difference between the maximum size and the basic size.

- **Lower Deviation:** It is the algebraic difference between the minimum size and the basic size.



Line of Zero Deviation
U. D
L. D
Tolerance
Maximum Limit of Size
Maximum Material Condition
Minimum Limit of Size
Minimum Material Condition
Basic Size

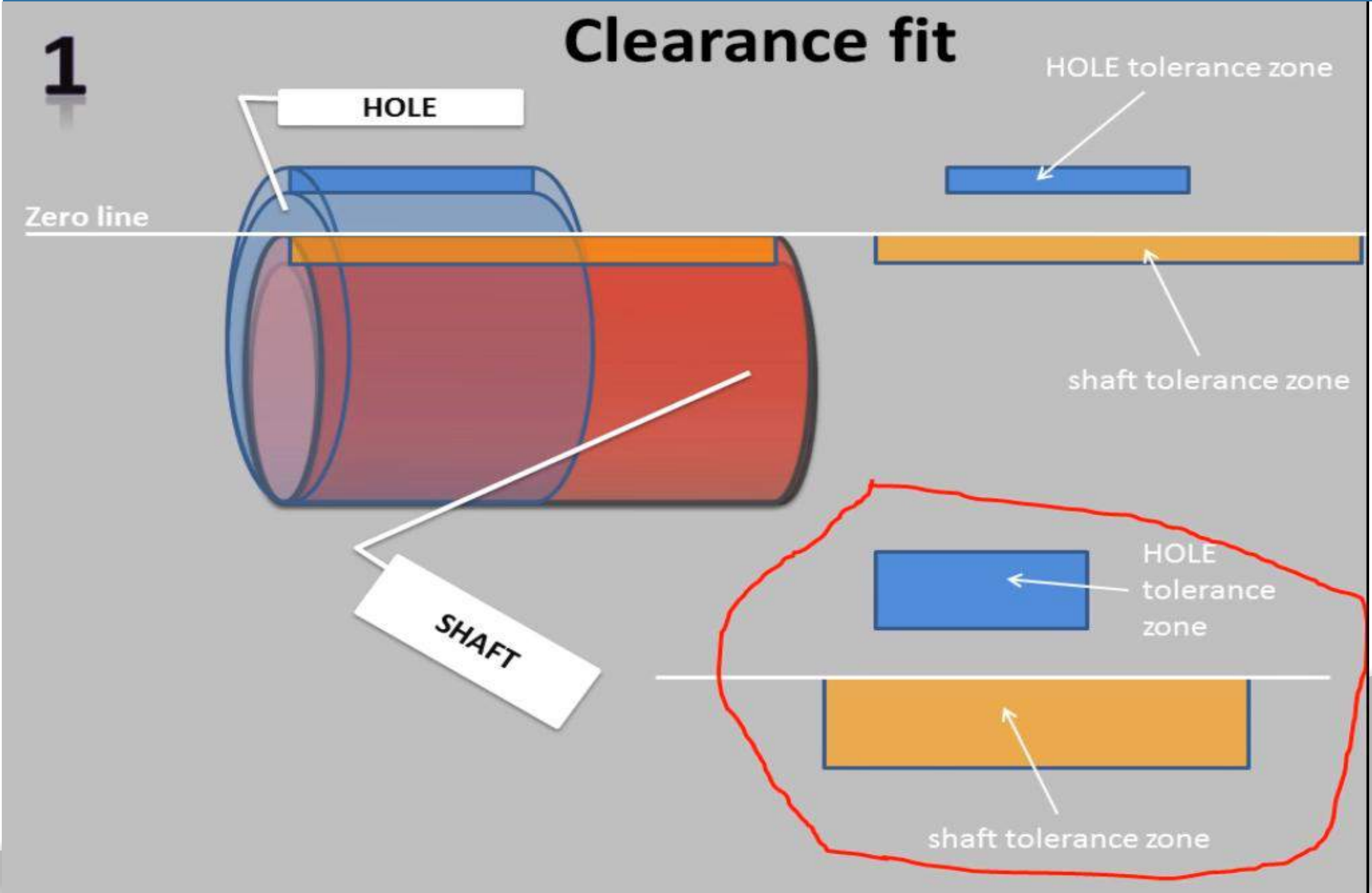

Upper deviation
Tolerance
Lower deviation
Tolerance zone
Tolerance
Lower deviaiton
Upper deviation
Max. size
Min. size
Zero line
Hole
Shaft
Min. size
Max. size
Basic size

FIT

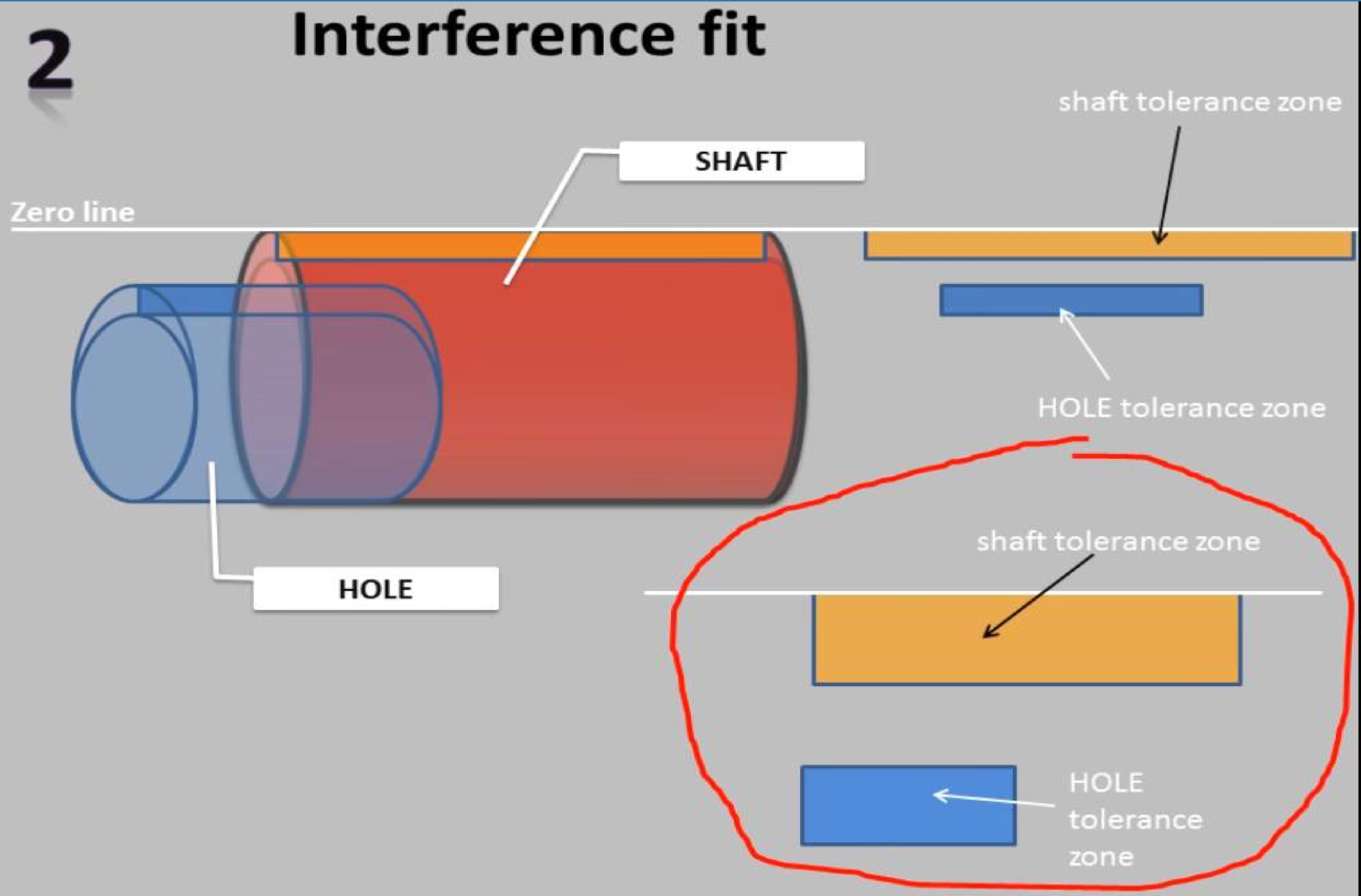
If it is the degree of looseness or tightness between two mating parts to perform a definite function.

1. **Clearance fit**
2. **Transition fit**
3. **Interference fit**

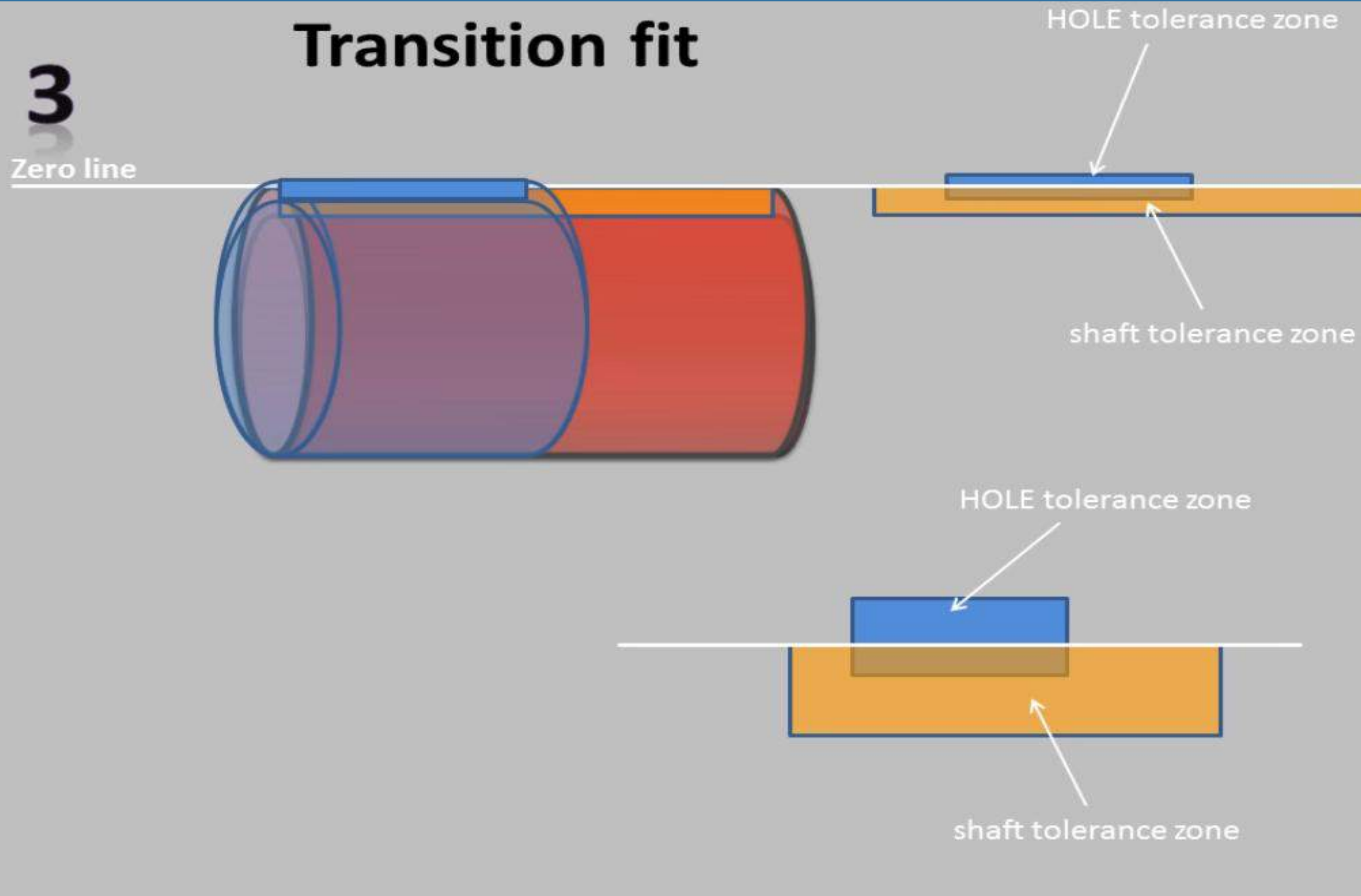
Clearance fit



Interference fit

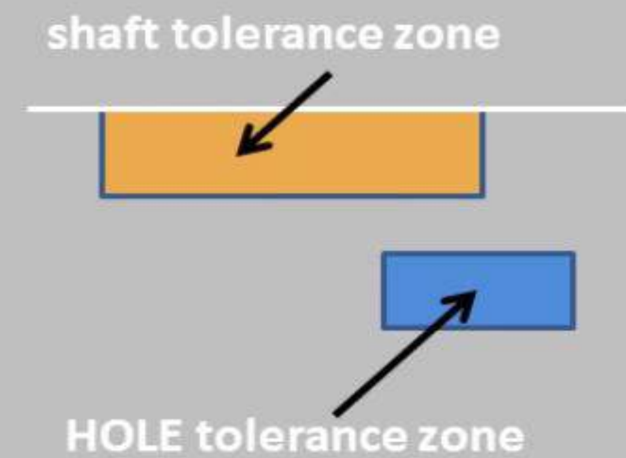


Transition fit



SHAFT BASIS SYSTEM

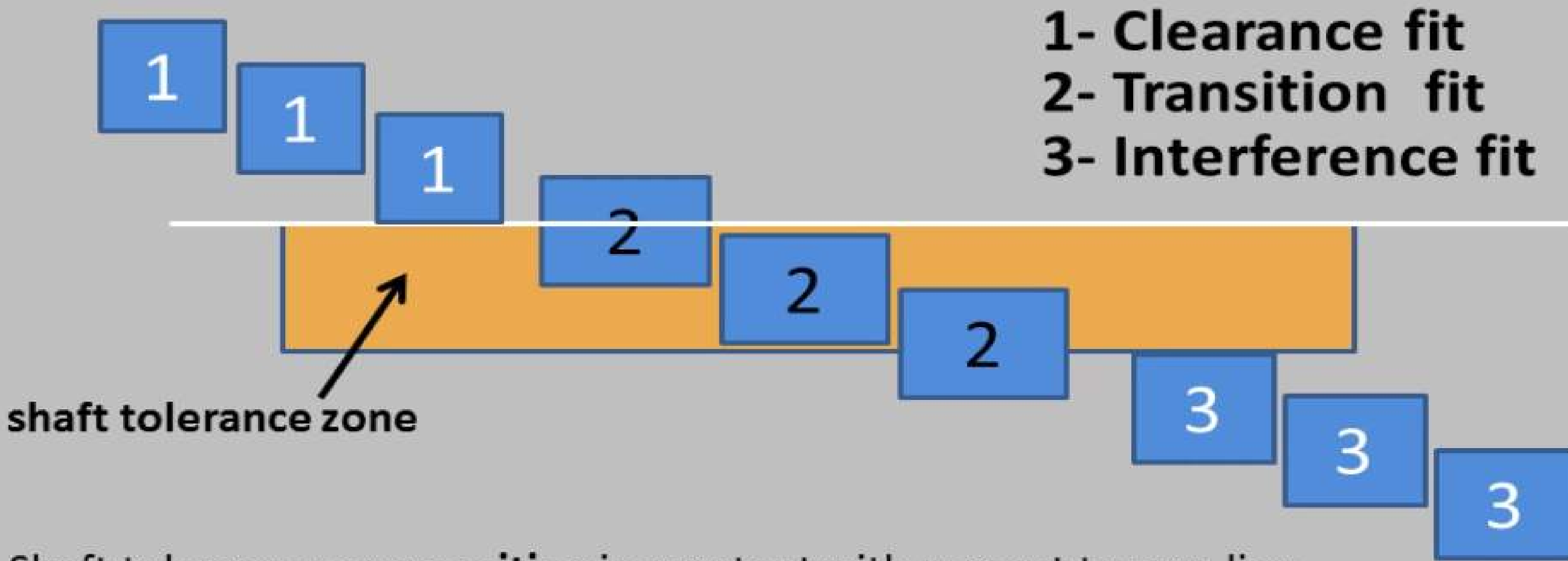
1	3	2
Clearance Fit	**Transition Fit**	**Interference Fit**



If you observe, HOLE tolerance zone changing its position to get required fit.

But **shaft tolerance zone is not moving its position with respect to zero line.**

It is **shaft basis system** of limits and fits.



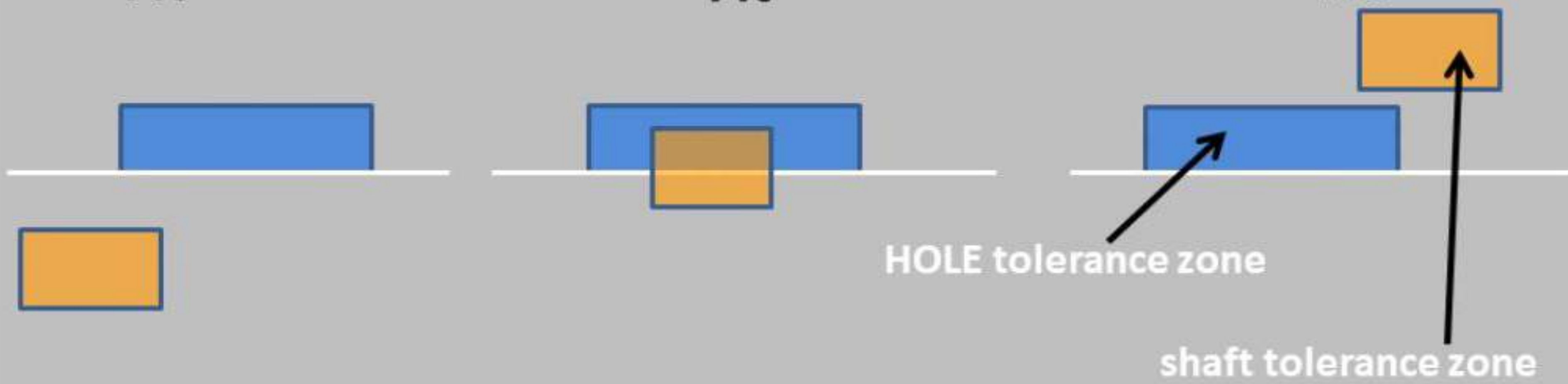
Shaft tolerance zone **position** is constant with respect to zero line.

Here **the upper deviation** is **zero** which is chosen as fundamental deviation.
Fundamental deviation of shaft matching zero line is denoted by "h"

In shaft basis system of limits and fits Fundamental deviation of shaft always will be "h"

HOLE BASIS SYSTEM

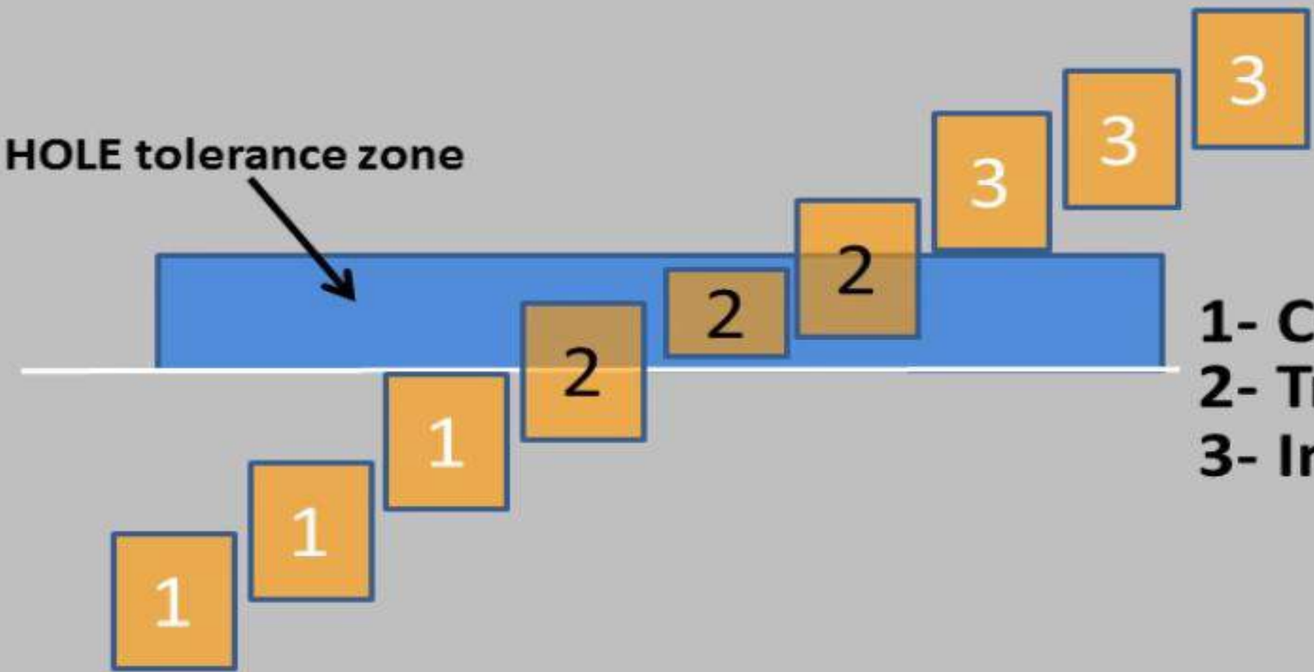
1	2	3
Clearance Fit	**Transition Fit**	**Interference Fit**



If you observe, shaft tolerance zone changing its position to get required fit.

But **HOLE tolerance zone is not moving its position with respect to zero line.**

It is **HOLE basis system** of limits and fits.

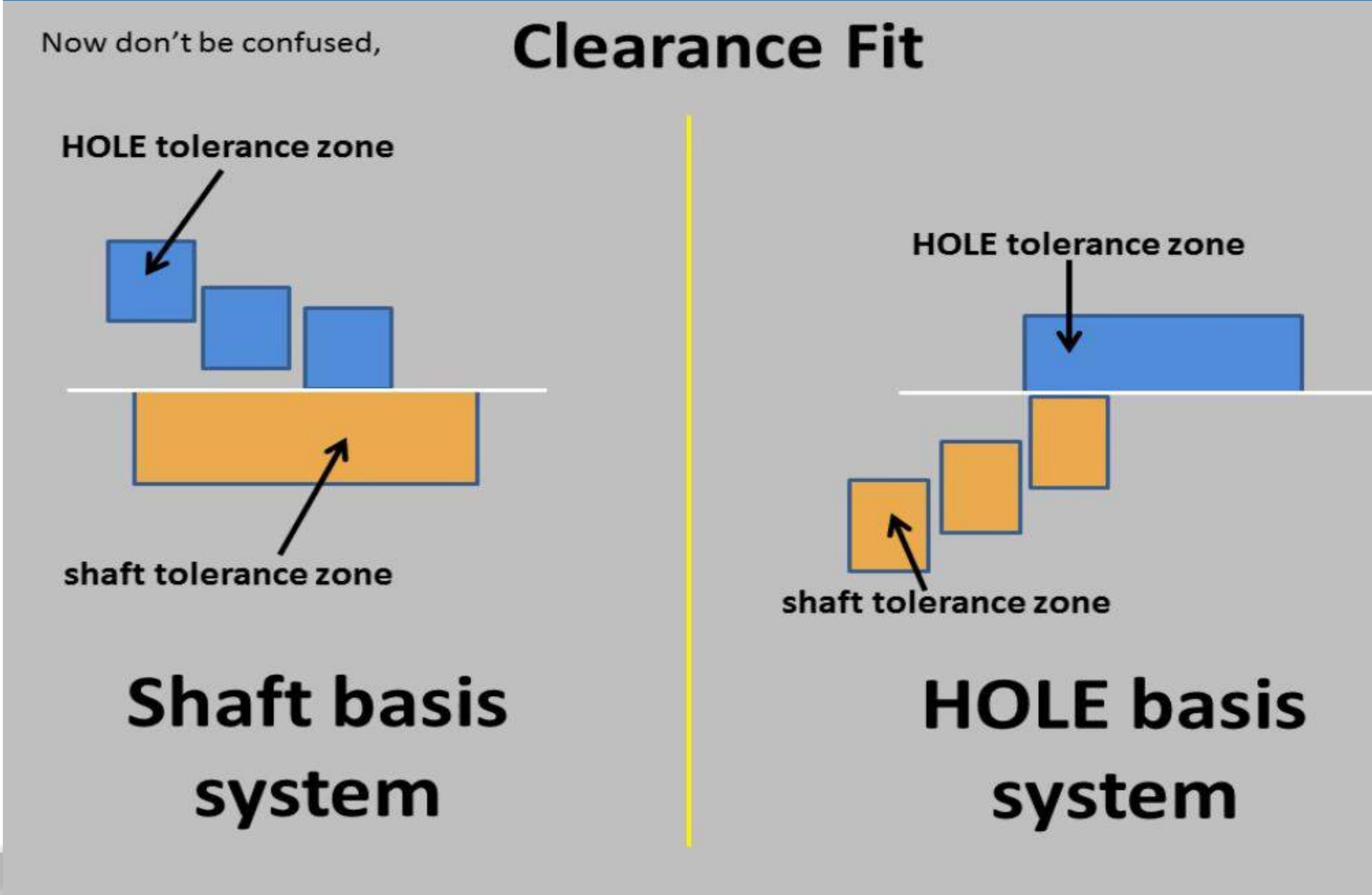


1- Clearance fit
2- Transition fit
3- Interference fit

HOLE tolerance zone **position** is constant with respect to zero line.
Note that **the LOWER deviation** is **zero** which is chosen as fundamental deviation.
Fundamental deviation of HOLE matching zero line is denoted by "H"

In HOLE basis system of limits and fits Fundamental deviation of HOLE always will be "H"

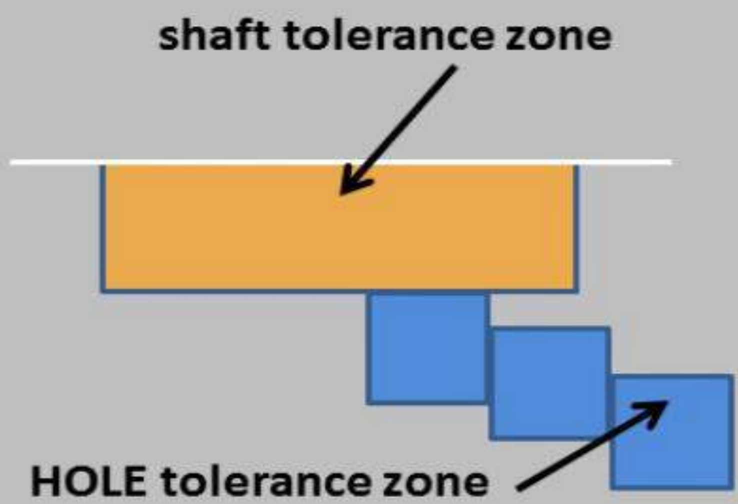
Clearance fit



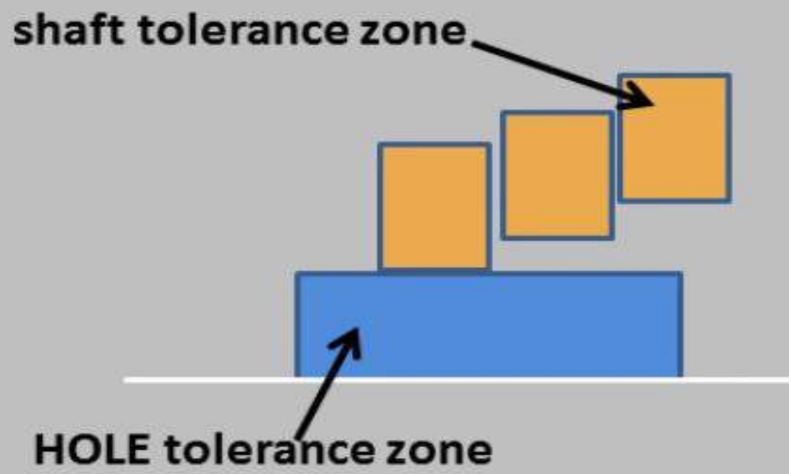
Interference fit

Now don't be confused,

Interference Fit



Shaft basis system



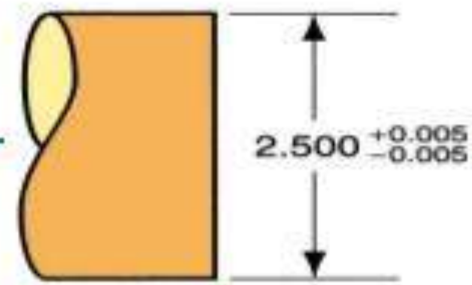
HOLE basis system

Tolerances

Bilateral Tolerance

Variation is permitted in both positive and negative directions from the nominal dimension

- Possible for a bilateral tolerance to be unbalanced; for example, 2.500 +0.010, -0.005



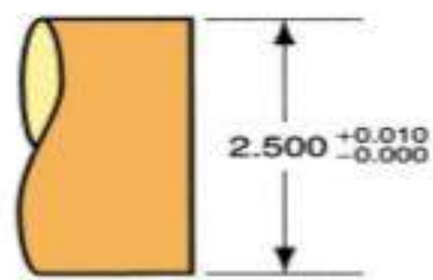
(a)

Fig: Ways to specify tolerance limits for a nominal dimension of 2.500

Unilateral Tolerance

Variation from the specified dimension is permitted in only one direction

- Either positive or negative, but not both



(b)

Fig: Ways to specify tolerance limits for a nominal dimension of 2.500

Bilateral Tolerance

Variation is permitted in both positive and negative directions from the nominal dimension

- Possible for a bilateral tolerance to be unbalanced; for example, 2.500 +0.010, -0.005

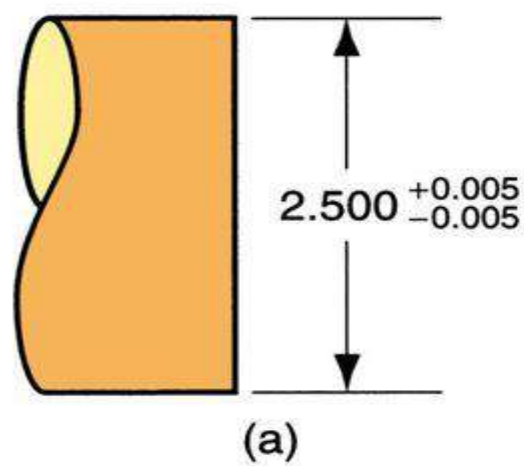


Figure 5.1 Ways to specify tolerance limits for a nominal dimension of 2.500: (a) bilateral

Unilateral Tolerance

Variation from the specified dimension is permitted in only one direction

- Either positive or negative, but not both

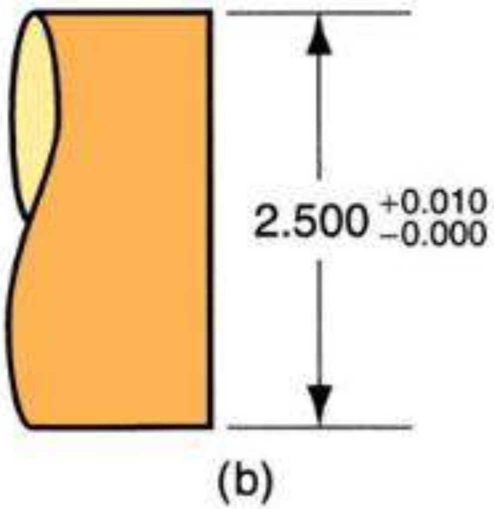


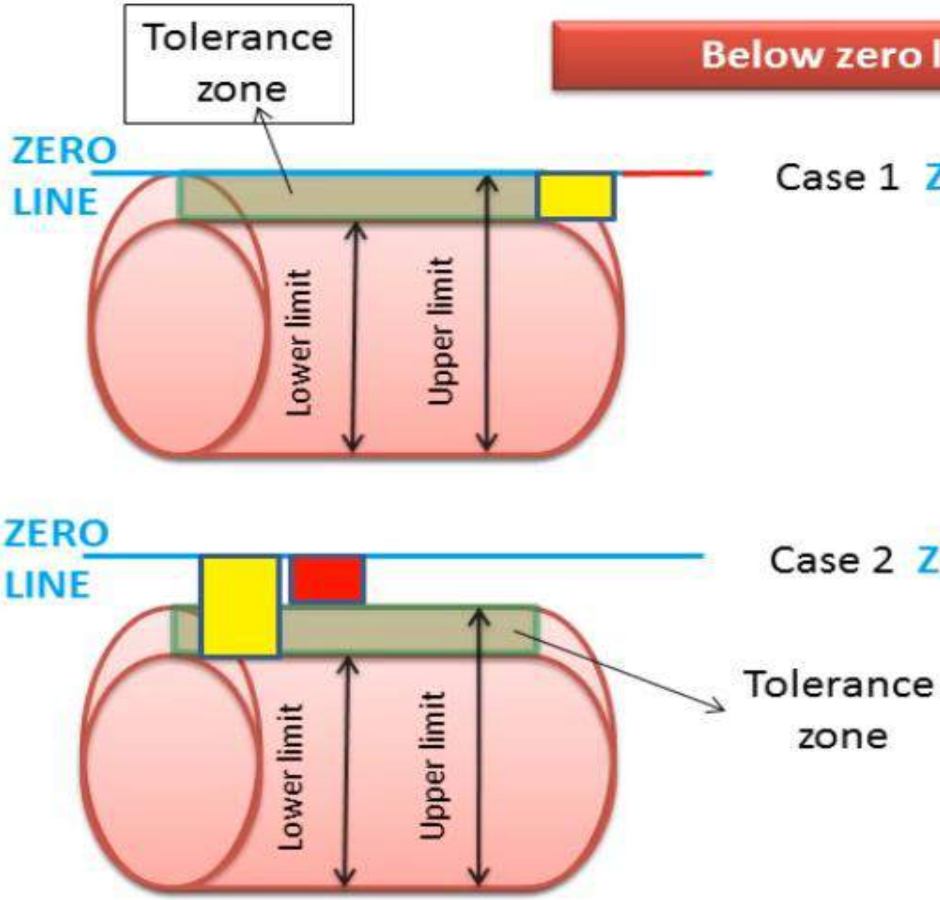
Figure 5.1 Ways to specify tolerance limits for a nominal dimension of 2.500: (b) unilateral

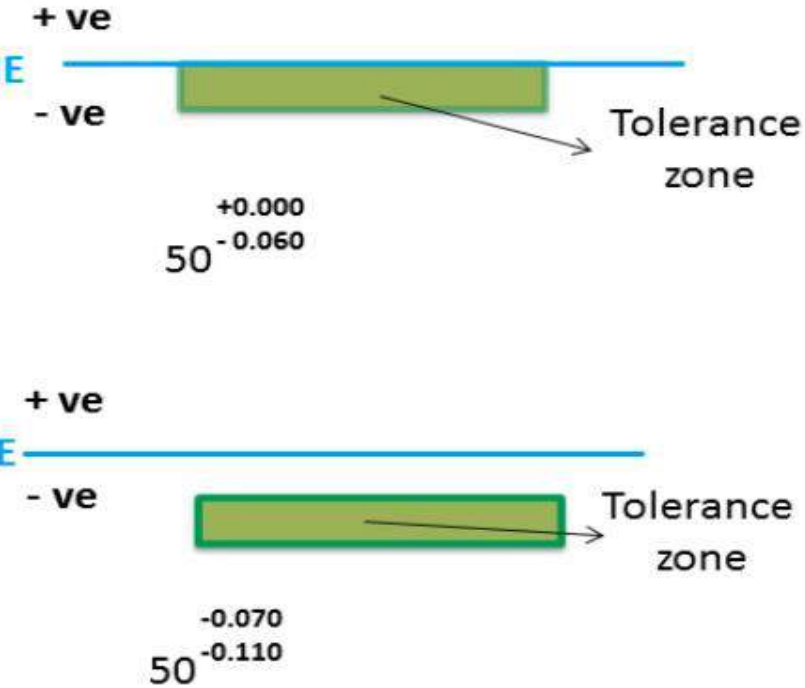
Unilateral Tolerances

UNILATERAL tolerance **(Uni – one, lateral – side)**

The tolerance zone always lie above zero line **or** below zero line in case of **Unilateral Tolerance. i.e. one side tolerance.**

Below zero line examples

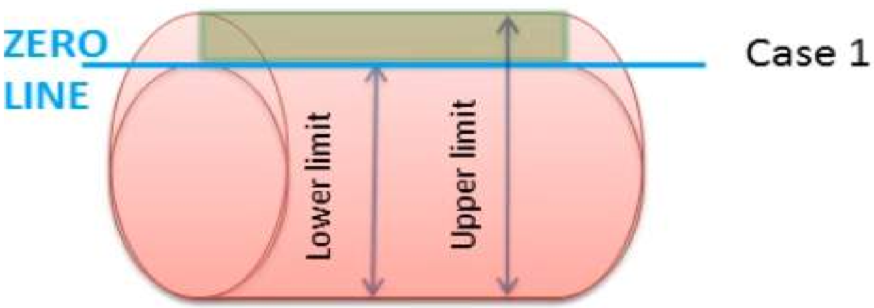


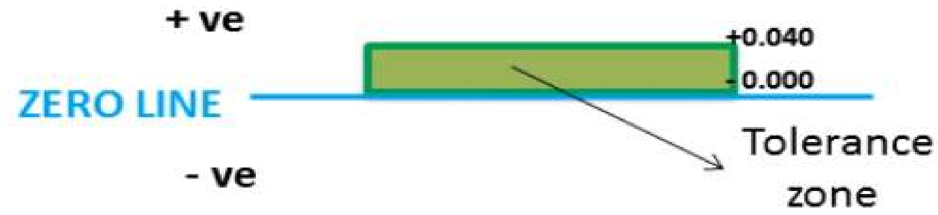


In both the cases tolerance zone lies **below zero line.** It means –ve deviation only.

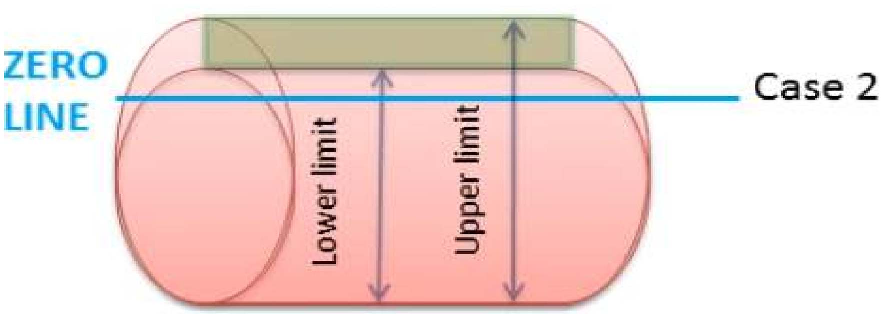
UNILATERAL tolerance

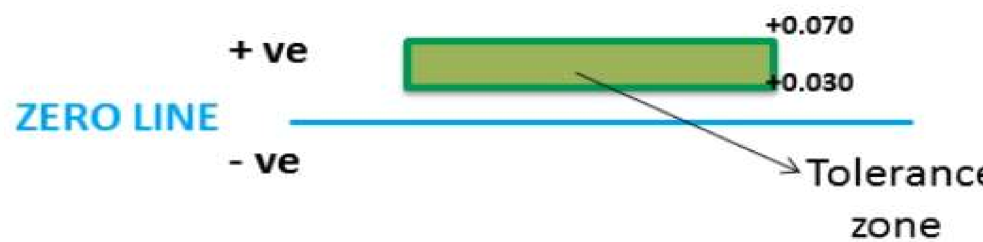
Above zero line examples





eg. $50^{+0.040}_{-0.000}$



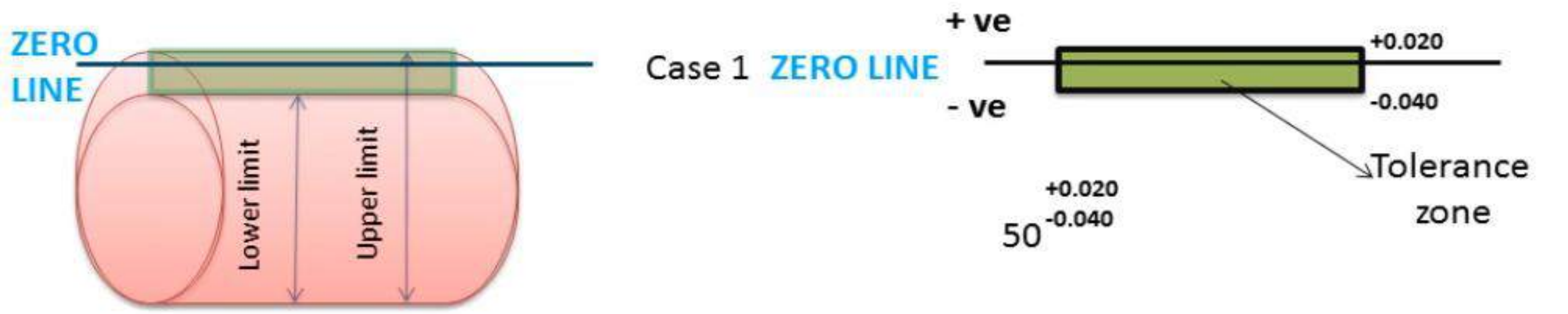


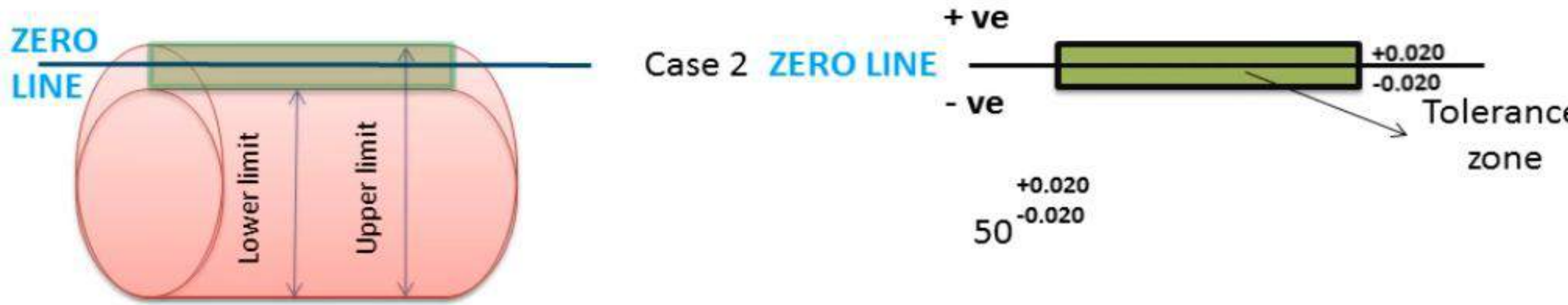
eg. $50^{+0.070}_{+0.030}$

In both the cases tolerance zone lies **above zero line.** It means +ve deviation only.

Bilateral Tolerances

BILATERAL tolerance (Bi – Two, lateral – side)





In both the cases upper deviation or lower deviation **will not** be **zero value**. And always will be combination of +ve &-ve deviations.

BILATERAL TOLERANCE

(Bi-Two, lateral-side)

The tolerance zone always lie on both sides of aero line.

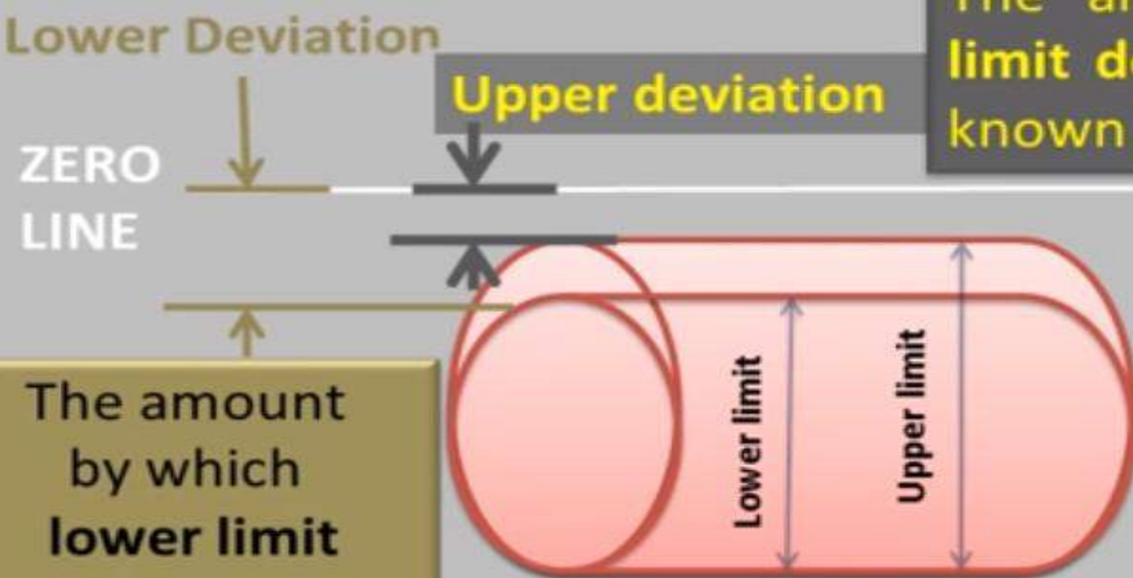
(above zero line & below zero line)

It is not necessary that zero line will divide tolerance zone equally on both sides, it may be equal or unequal.

- **Deviation:** It is the algebraic difference between a size and its corresponding basic size. It may be positive, negative, or zero.
- **Upper deviation:** It is the algebraic difference between the maximum limit of size and its corresponding basic size. This is designated as ‘ES’ for a hole and as ‘es’ for a shaft.
- **Lower deviation:** It is the algebraic difference between the minimum limit of size and its corresponding basic size. This is designated as ‘EI’ for a hole and as ‘ei’ for a shaft. Actual deviation: It is the algebraic difference between the actual size and its corresponding basic size.
- **Fundamental deviation:** It is the minimum difference between the size of a component and its basic size. This is identical to the upper deviation for shafts and lower deviation for holes.

LOWER DEVIATION & UPPER DEVIATION

Deviation means the amount by which the dimension differs (goes away) from zero line.



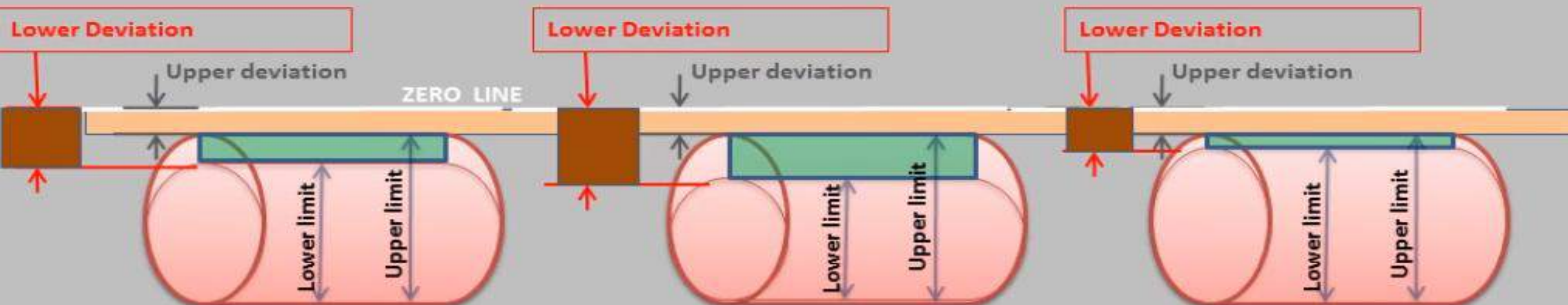
The amount by which **upper limit deviates** from zero line is known as **"Upper Deviation"**.

The amount by which **lower limit deviates** from zero line is known as **"Lower Deviation"**.

Fundamental deviation

It is either upper deviation or lower deviation which is conventionally chosen to define the position of tolerance zone in relation to the zero line.

It defines location of tolerance zone with respect to the zero line.



Suppose as shown in fig. **upper deviation chosen** as **fundamental** deviation. Then its position will not change with respect to zero line.

Case 1

to **increase** the tolerance zone.

Only lower deviation will be allowed to **move** down in order to increase tolerance zone.

Case 2

to **decrease** the tolerance zone.

Only lower deviation will be allowed to **move** up in order to decrease tolerance zone.

Position of Fundamental deviation is fixed with respect to zero line. In both the case.

How to interpret Fit

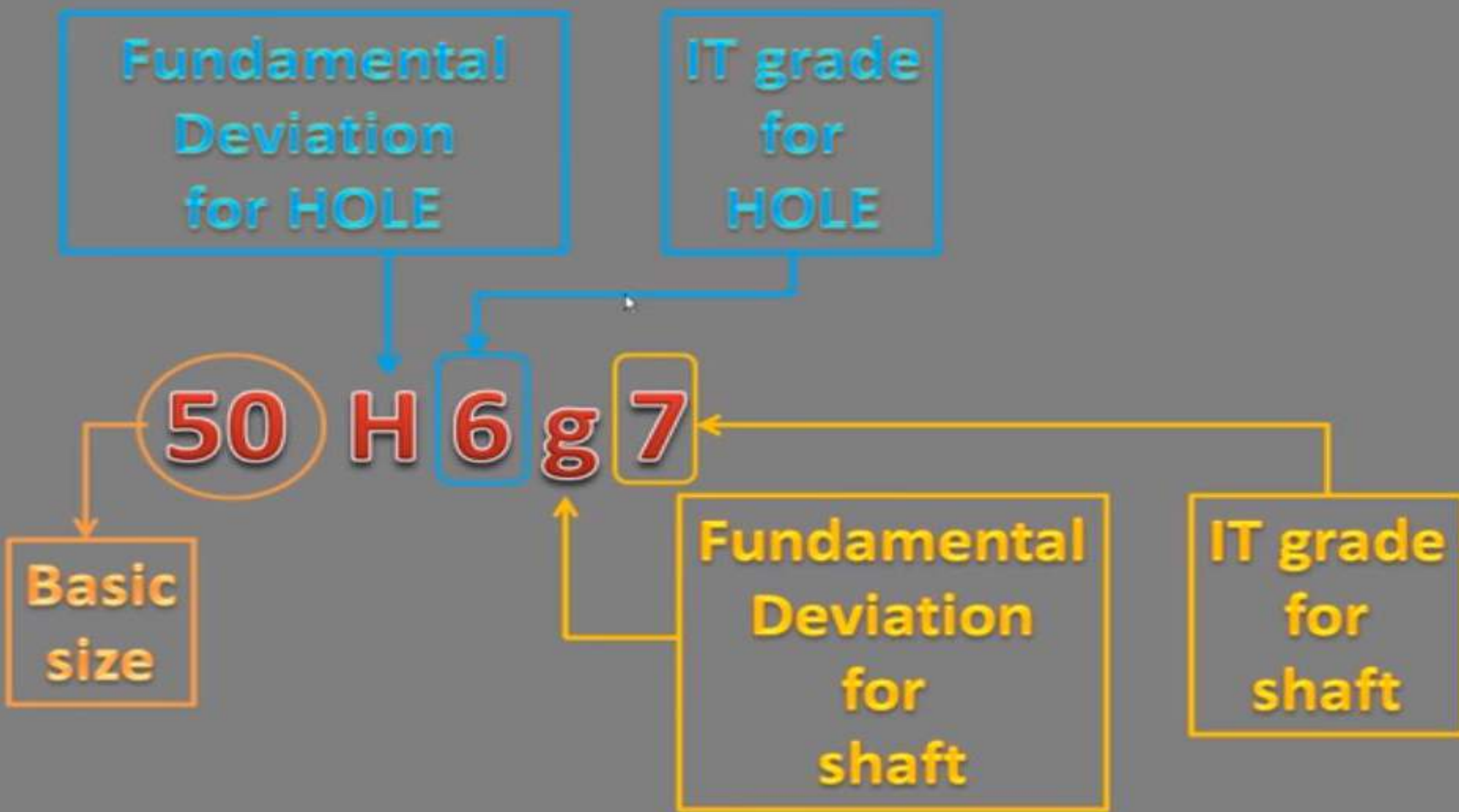
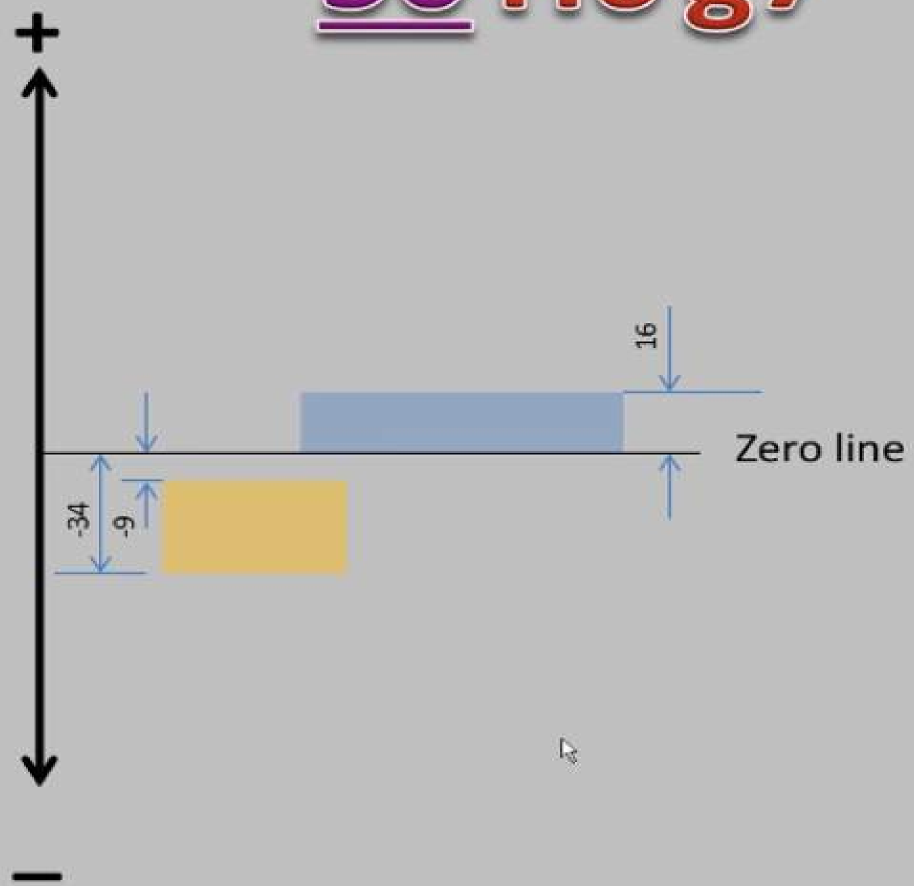


TABLE 6-10 TOLERANCE ZONES - INTERNAL DIMENSIONS (HOLES) (H16 ... H1) (ANSI B4.2)

mm

SIZE		H16	H15	H14	H13	H12	H11	H10	H9	H8	H7	H6	H5	H4	H3	H2	H1
OVER	0	0.600	0.400	0.250	0.140	0.100	0.060	0.040	0.025	0.014	0.010	0.006	0.004	0.003	0.002	0.001	0.0008
TO	3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
OVER	3	0.750	0.480	0.300	0.180	0.120	0.075	0.048	0.030	0.018	0.012	0.008	0.005	0.004	0.003	0.002	0.0010
TO	6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
OVER	6	0.900	0.580	0.360	0.220	0.150	0.090	0.058	0.036	0.022	0.015	0.009	0.006	0.004	0.003	0.002	0.0010
TO	10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
OVER	10	1.100	0.700	0.430	0.270	0.180	0.110	0.070	0.043	0.027	0.018	0.011	0.008	0.005	0.003	0.002	0.0012
TO	14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
OVER	14	1.100	0.700	0.430	0.270	0.180	0.110	0.070	0.043	0.027	0.018	0.011	0.008	0.005	0.003	0.002	0.0012
TO	18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
OVER	18	1.300	0.840	0.520	0.330	0.210	0.130	0.084	0.052	0.033	0.021	0.013	0.009	0.006	0.004	0.003	0.0015
TO	24	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
OVER	24	1.300	0.840	0.520	0.330	0.210	0.130	0.084	0.052	0.033	0.021	0.013	0.009	0.006	0.004	0.003	0.0015
TO	30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
OVER	30	1.600	1.000	0.620	0.390	0.250	0.160	0.100	0.062	0.039	0.025	0.016	0.011	0.007	0.004	0.003	0.0015
TO	40	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
OVER	40	1.600	1.000	0.620	0.390	0.250	0.160	0.100	0.062	0.039	0.025	0.016	0.011	0.007	0.004	0.003	0.0015
TO	50	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
OVER	50	1.900	1.200	0.740	0.460	0.300	0.190	0.120	0.074	0.046	0.030	0.019	0.013	0.008	0.005	0.003	0.0020
TO	65	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
OVER	65	1.900	1.200	0.740	0.460	0.300	0.190	0.120	0.074	0.046	0.030	0.019	0.013	0.008	0.005	0.003	0.0020
TO	80	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
OVER	80	2.200	1.400	0.870	0.540	0.350	0.220	0.140	0.087	0.054	0.035	0.022	0.015	0.010	0.006	0.004	0.0025
TO	100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000
OVER	100	2.200	1.400	0.870	0.540	0.350	0.220	0.140	0.087	0.054	0.035	0.022	0.015	0.010	0.006	0.004	0.0025
TO	120	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0000

50 H6 g7



If **hole** has fundamental deviation **"H"** means it is hole basis system of fits

If **shaft** has fundamental deviation **"h"** means it is shaft basis system of fits

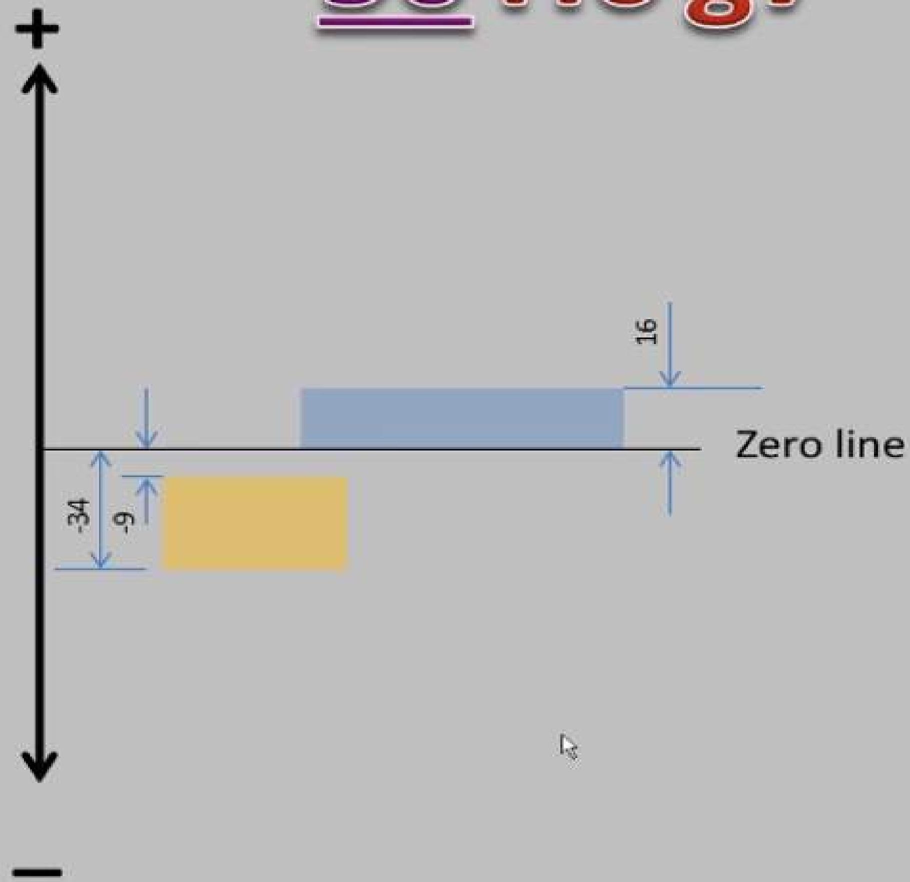
Here
Fundamental deviation for
Hole – H
Shaft – g
Means hole basis system and we know IT grades define tolerance zone.

TABLE 6-21 TOLERANCE ZONES - EXTERNAL DIMENSIONS (SHAFTS) (g9 ... g4, j7 ... j5) (ANSI

mm

SIZE		g9	g8	g7	g6	g5	g4	j7	j6	j5
OVER	0	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	0.006	0.004	0.002
TO	3	-0.027	-0.016	-0.012	-0.008	-0.006	-0.005	-0.004	-0.002	-0.002
OVER	3	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	0.008	0.006	0.003
TO	6	-0.034	-0.022	-0.016	-0.012	-0.009	-0.008	-0.004	-0.002	-0.002
OVER	6	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	0.010	0.007	0.004
TO	10	-0.041	-0.027	-0.020	-0.014	-0.011	-0.009	-0.005	-0.002	-0.002
OVER	10	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	0.012	0.008	0.005
TO	14	-0.049	-0.033	-0.024	-0.017	-0.014	-0.011	-0.006	-0.003	-0.003
OVER	14	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	0.012	0.008	0.005
TO	18	-0.049	-0.033	-0.024	-0.017	-0.014	-0.011	-0.006	-0.003	-0.003
OVER	18	-0.007	-0.007	-0.007	-0.007	-0.007	-0.007	0.013	0.009	0.005
TO	24	-0.059	-0.040	-0.028	-0.020	-0.016	-0.013	-0.008	-0.004	-0.004
OVER	24	-0.007	-0.007	-0.007	-0.007	-0.007	-0.007	0.013	0.009	0.005
TO	30	-0.059	-0.040	-0.028	-0.020	-0.016	-0.013	-0.008	-0.004	-0.004
OVER	30	-0.009	-0.009	-0.009	-0.009	-0.009	-0.009	0.015	0.011	0.006
TO	40	-0.071	-0.048	-0.034	-0.025	-0.020	-0.016	-0.010	-0.005	-0.005
OVER	40	-0.009	-0.009	-0.009	-0.009	-0.009	-0.009	0.015	0.011	0.006
TO	50	-0.071	-0.048	-0.034	-0.025	-0.020	-0.016	-0.010	-0.005	-0.005
OVER	50	-0.010	-0.010	-0.010	-0.010	-0.010	-0.010	0.018	0.012	0.006
TO	65	-0.084	-0.056	-0.040	-0.029	-0.023	-0.018	-0.012	-0.007	-0.007
OVER	65	-0.010	-0.010	-0.010	-0.010	-0.010	-0.010	0.018	0.012	0.006
TO	80	-0.084	-0.056	-0.040	-0.029	-0.023	-0.018	-0.012	-0.007	-0.007
OVER	80	-0.012	-0.012	-0.012	-0.012	-0.012	-0.012	0.020	0.013	0.006
TO	100	-0.099	-0.066	-0.047	-0.034	-0.027	-0.022	-0.015	-0.009	-0.009

50 H6 g7

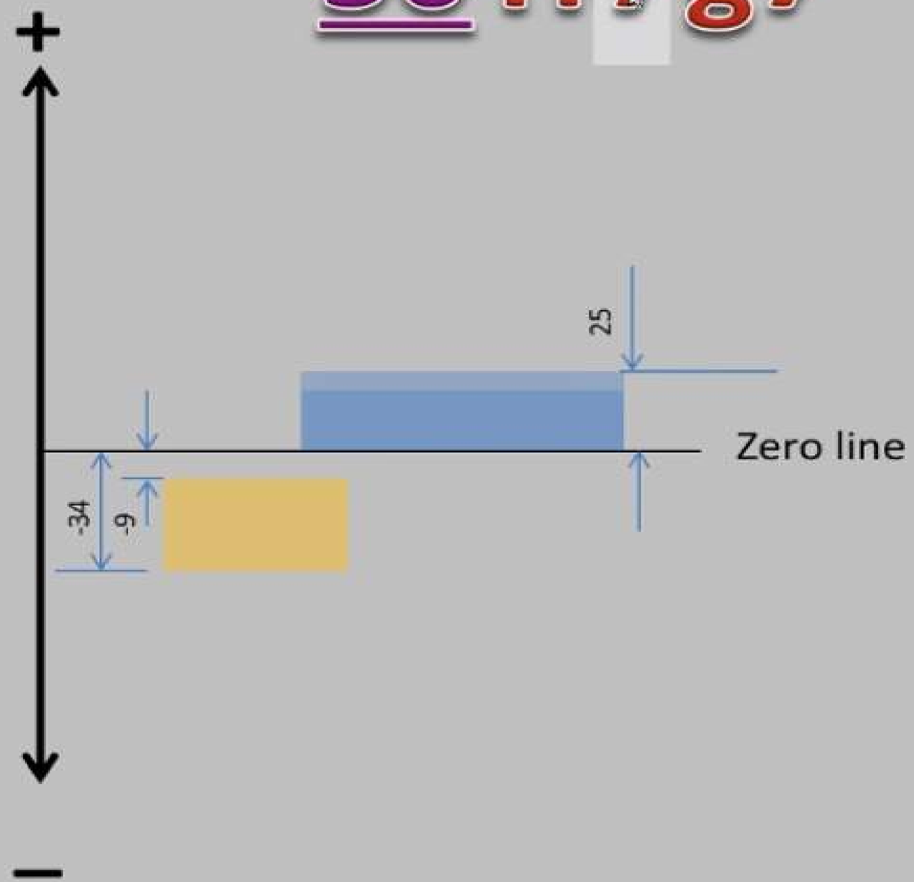


If **hole** has fundamental deviation **"H"** means it is hole basis system of fits

If **shaft** has fundamental deviation **"h"** means it is shaft basis system of fits

Here
Fundamental deviation for
Hole – H
Shaft – g
Means hole basis system and we know IT grades define tolerance zone.

50 H7g7

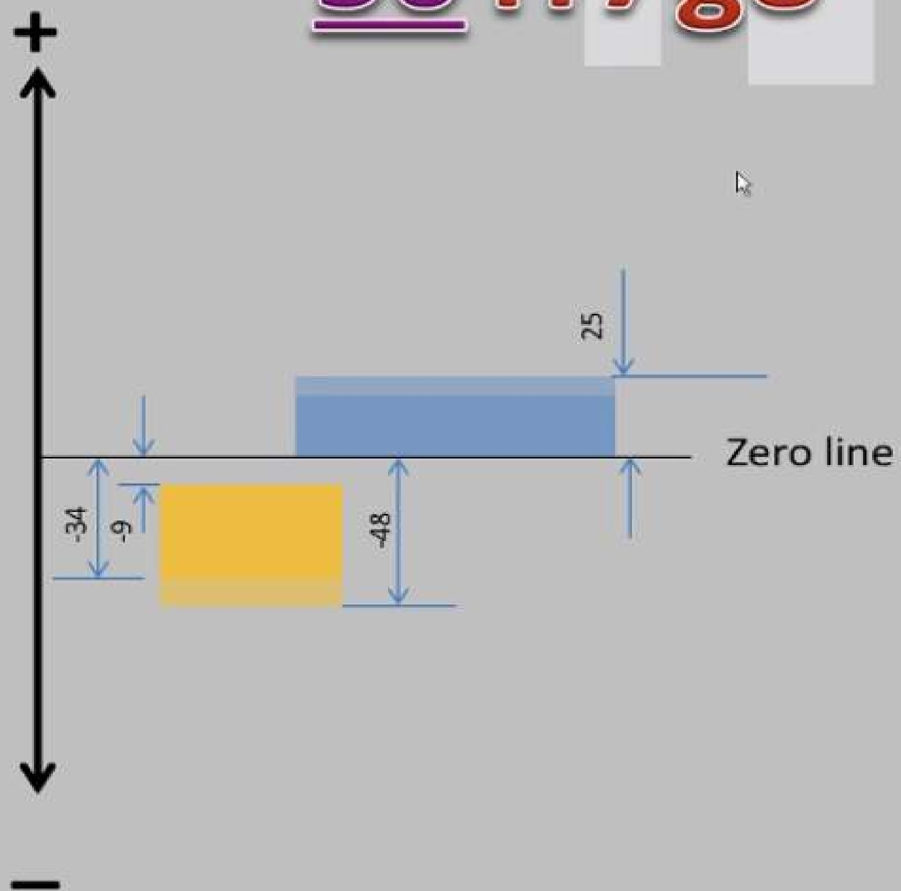


If **hole** has fundamental deviation **"H"** means it is hole basis system of fits

If **shaft** has fundamental deviation **"h"** means it is shaft basis system of fits

Here
Fundamental deviation for
Hole – H
Shaft – g
Means hole basis system and we know IT grades define tolerance zone.

50 H7g8



If **hole** has fundamental deviation **“H”** means it is hole basis system of fits

If **shaft** has fundamental deviation **“h”** means it is shaft basis system of fits

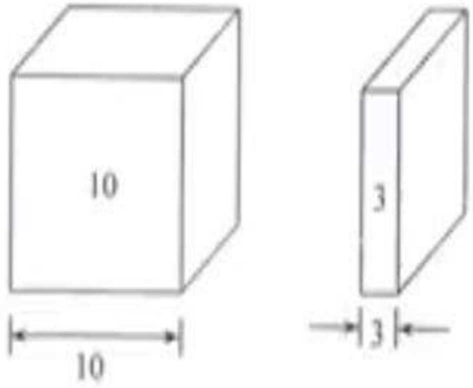
Here
Fundamental deviation for
Hole – H
Shaft – g
Means hole basis system and we know IT grades define tolerance zone.

TABLE 6-20 TOLERANCE ZONES - EXTERNAL DIMENSIONS (SHAFTS) (e11 ... e6, f10 ... f5) (ANSI B4.2)

mm

SIZE		e11	e10	e9	e8	e7	e6	f10	f9	f8	f7	f6	f5
OVER	0	-0.014	-0.014	-0.014	-0.014	-0.014	-0.014	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006
TO	3	-0.074	-0.054	-0.039	-0.028	-0.024	-0.020	-0.046	-0.031	-0.020	-0.016	-0.012	-0.010
OVER	3	-0.020	-0.020	-0.020	-0.020	-0.020	-0.020	-0.010	-0.010	-0.010	-0.010	-0.010	-0.010
TO	6	-0.095	-0.068	-0.050	-0.038	-0.032	-0.028	-0.058	-0.040	-0.028	-0.022	-0.018	-0.015
OVER	6	-0.025	-0.025	-0.025	-0.025	-0.025	-0.025	-0.013	-0.013	-0.013	-0.013	-0.013	-0.013
TO	10	-0.115	-0.083	-0.061	-0.047	-0.040	-0.034	-0.071	-0.049	-0.035	-0.028	-0.022	-0.019
OVER	10	-0.032	-0.032	-0.032	-0.032	-0.032	-0.032	-0.016	-0.016	-0.016	-0.016	-0.016	-0.016
TO	14	-0.142	-0.102	-0.075	-0.059	-0.050	-0.043	-0.086	-0.059	-0.043	-0.034	-0.027	-0.024
OVER	14	-0.032	-0.032	-0.032	-0.032	-0.032	-0.032	-0.016	-0.016	-0.016	-0.016	-0.016	-0.016
TO	18	-0.142	-0.102	-0.075	-0.059	-0.050	-0.043	-0.086	-0.059	-0.043	-0.034	-0.027	-0.024
OVER	18	-0.040	-0.040	-0.040	-0.040	-0.040	-0.040	-0.020	-0.020	-0.020	-0.020	-0.020	-0.020
TO	24	-0.170	-0.124	-0.092	-0.073	-0.061	-0.053	-0.104	-0.072	-0.053	-0.041	-0.033	-0.029
OVER	24	-0.040	-0.040	-0.040	-0.040	-0.040	-0.040	-0.020	-0.020	-0.020	-0.020	-0.020	-0.020
TO	30	-0.170	-0.124	-0.092	-0.073	-0.061	-0.053	-0.104	-0.072	-0.053	-0.041	-0.033	-0.029
OVER	30	-0.050	-0.050	-0.050	-0.050	-0.050	-0.050	-0.025	-0.025	-0.025	-0.025	-0.025	-0.025
TO	40	-0.210	-0.150	-0.112	-0.089	-0.075	-0.066	-0.125	-0.087	-0.064	-0.050	-0.041	-0.036
OVER	40	-0.050	-0.050	-0.050	-0.050	-0.050	-0.050	-0.025	-0.025	-0.025	-0.025	-0.025	-0.025
TO	50	-0.210	-0.150	-0.112	-0.089	-0.075	-0.066	-0.125	-0.087	-0.064	-0.050	-0.041	-0.036
OVER	50	-0.060	-0.060	-0.060	-0.060	-0.060	-0.060	-0.030	-0.030	-0.030	-0.030	-0.030	-0.030
TO	65	-0.250	-0.180	-0.134	-0.106	-0.090	-0.079	-0.150	-0.104	-0.076	-0.060	-0.049	-0.043
OVER	65	-0.060	-0.060	-0.060	-0.060	-0.060	-0.060	-0.030	-0.030	-0.030	-0.030	-0.030	-0.030
TO	80	-0.250	-0.180	-0.134	-0.106	-0.090	-0.079	-0.150	-0.104	-0.076	-0.060	-0.049	-0.043
OVER	80	-0.072	-0.072	-0.072	-0.072	-0.072	-0.072	-0.036	-0.036	-0.036	-0.036	-0.036	-0.036
TO	100	-0.292	-0.212	-0.159	-0.126	-0.107	-0.094	-0.176	-0.123	-0.090	-0.071	-0.058	-0.051
OVER	100	-0.072	-0.072	-0.072	-0.072	-0.072	-0.072	-0.036	-0.036	-0.036	-0.036	-0.036	-0.036
TO	120	-0.292	-0.212	-0.159	-0.126	-0.107	-0.094	-0.176	-0.123	-0.090	-0.071	-0.058	-0.051
OVER	120	-0.085	-0.085	-0.085	-0.085	-0.085	-0.085	-0.043	-0.043	-0.043	-0.043	-0.043	-0.043
TO	140	-0.335	-0.245	-0.185	-0.148	-0.125	-0.110	-0.203	-0.143	-0.106	-0.083	-0.068	-0.061

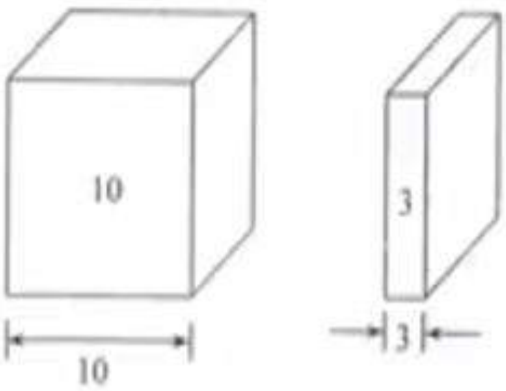
SLIP GAUGES

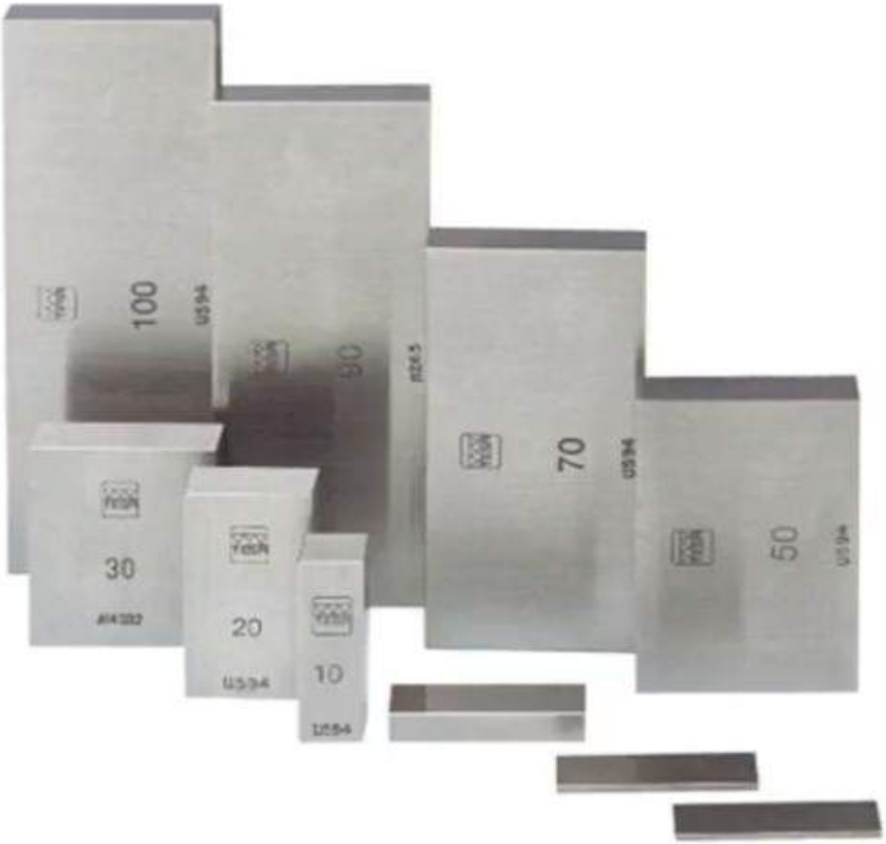


- Also called precision gauge blocks or *Johannsen gauges.*
- Used as *measuring blocks.*
- Made of *hardened alloy steel* of rectangular cross section.
- These rectangular bock of steel will have cross section *30 mm X 10 mm.*
- Standard sets of slip gauges 32 pieces, 45 pieces, 88 pieces, etc.

SLIP GUAGES

- Slip gauges are rectangular block of high grade steel with close tolerance
- Also called precision gauge blocks or Johannsen gauges
- Used as measuring blocks
- Made of hardened alloy of rectangular cross section
- These rectangular bock of steel will have cross section 30mm x 10mm
- Standard sets of slip gauges 32 pieces, 45 pieces, 88 pieces, etc



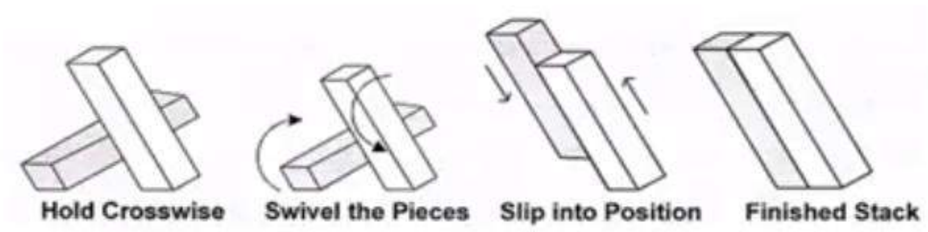


The cross section of the gauges are
(i)9mmx30mm for sizes up to 10mm
(ii)9mmx35mm for larger sizes.

Range (mm)	Step (mm)	Total Nos. of Pcs.
1.0005	-	1
1.001 – 1.009	0.001	9
1.01 – 1.49	0.01	49
0.5 - 25	0.5	50
50 - 100	25	3

Wringing of slip gauges

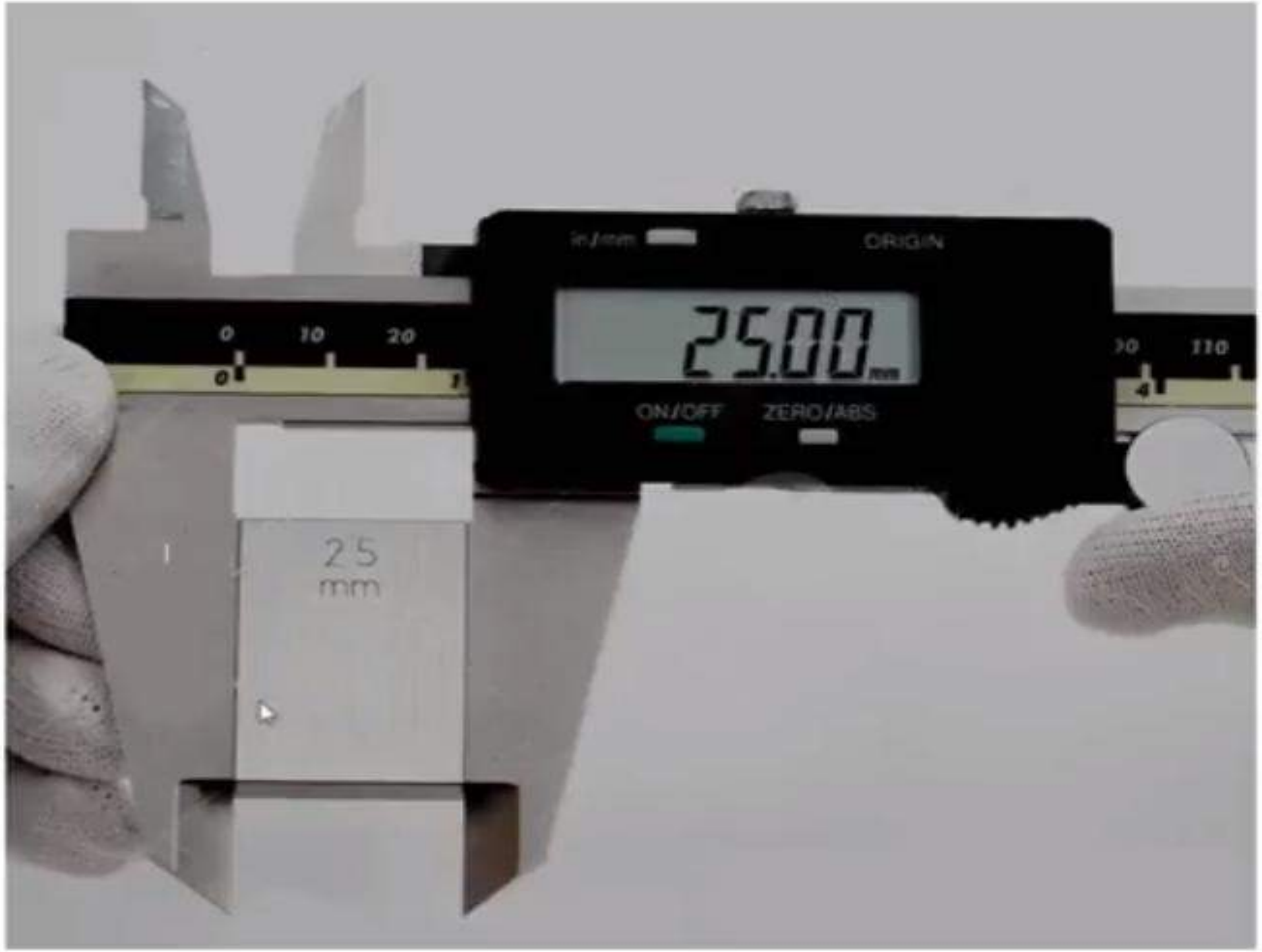
The accuracy of measurement depends on the phenomenon of wringing. The slip gauges are wrung together by hand through a combined sliding and rising motion.



Uses of Gauge block

- Direct precise measurement where accuracy is required
- For calibration of Vernier callipers, micrometer etc
- Setting up a comparator to a specific dimension
- It is used for angle measurement with sine bar
- To check gap between parallel locations such as in gap gauges or between 2 mating parts
- Some other uses also in manufacturing sector.

Checking the width of a job



Calibration of Digital vernier caliper with slip gauge

Calibration of Micrometer with slip gauge

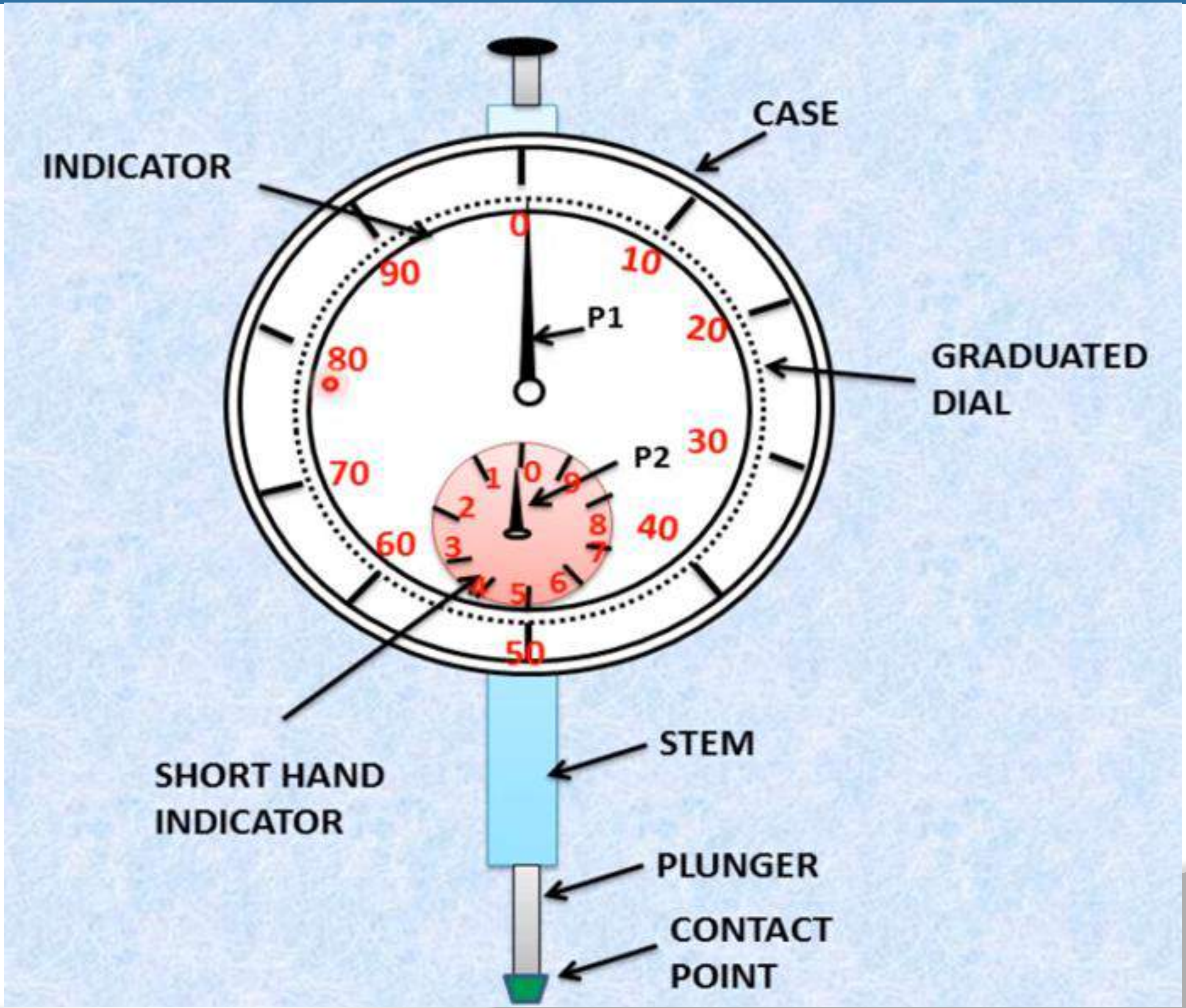
Measurement of angle of a job with sine bar and slip gauge

DIAL GAUGE INDICATOR

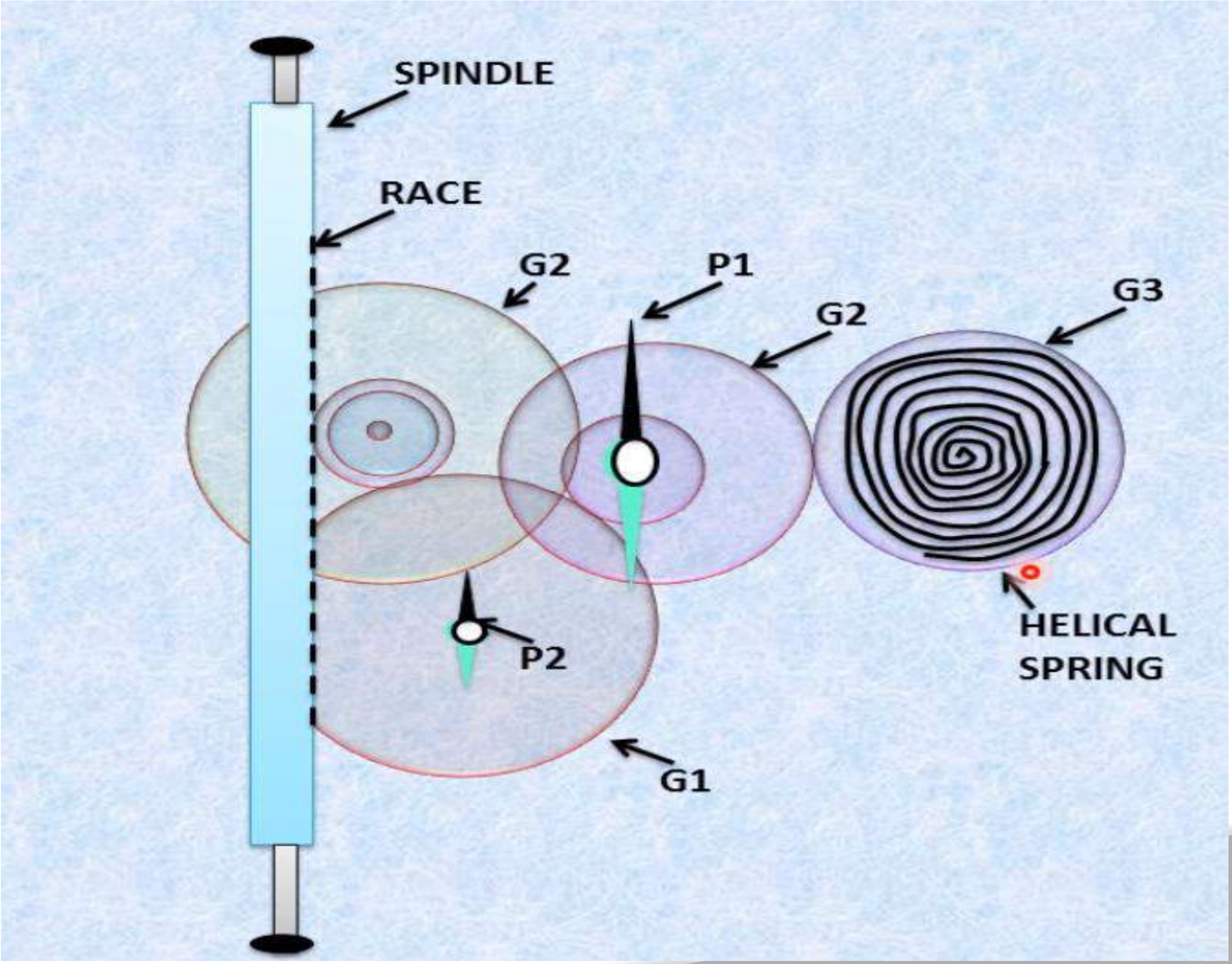
- **It is used for measuring flatness and inclination of objects**

Based on the principle of “Rack and Pinion”

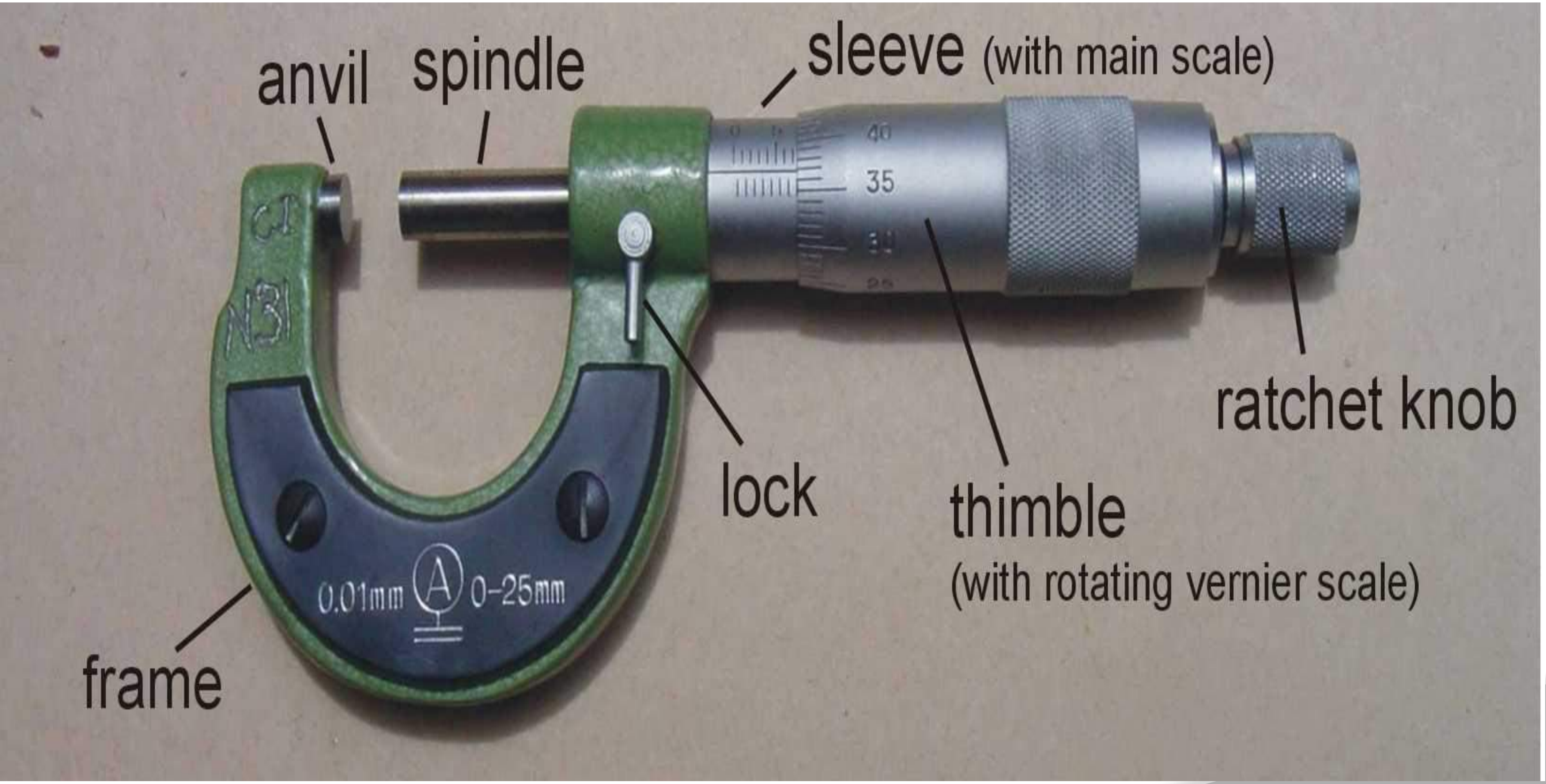
It can measure up to 0.01mm-Least count


CASE
INDICATOR
GRADUATED DIAL
P1
P2
0
10
20
30
40
50
60
70
80
90
STEM
SHORT HAND INDICATOR
PLUNGER
CONTACT POINT

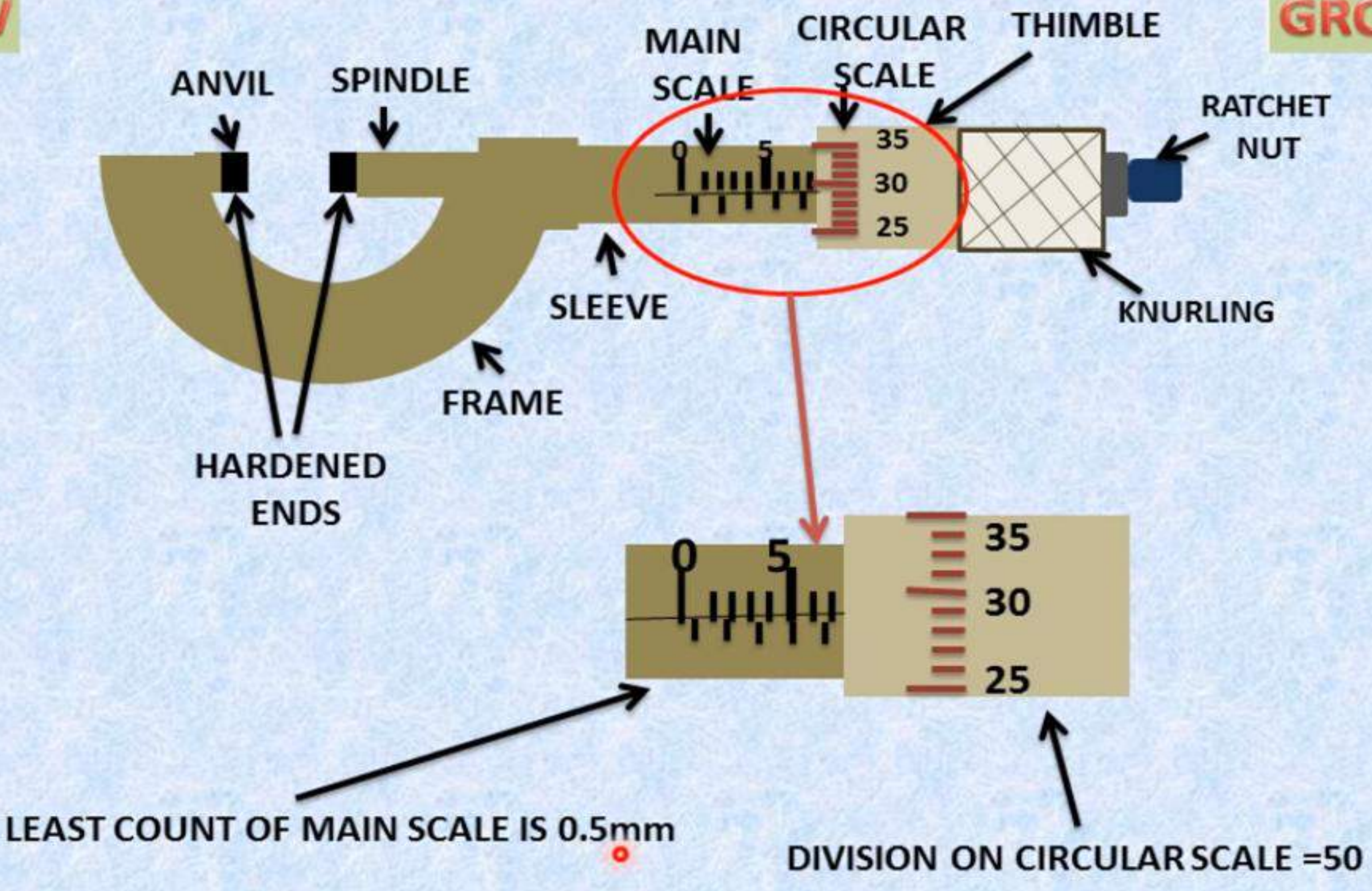
Internal Arrangement of Dial Gauge Indicator

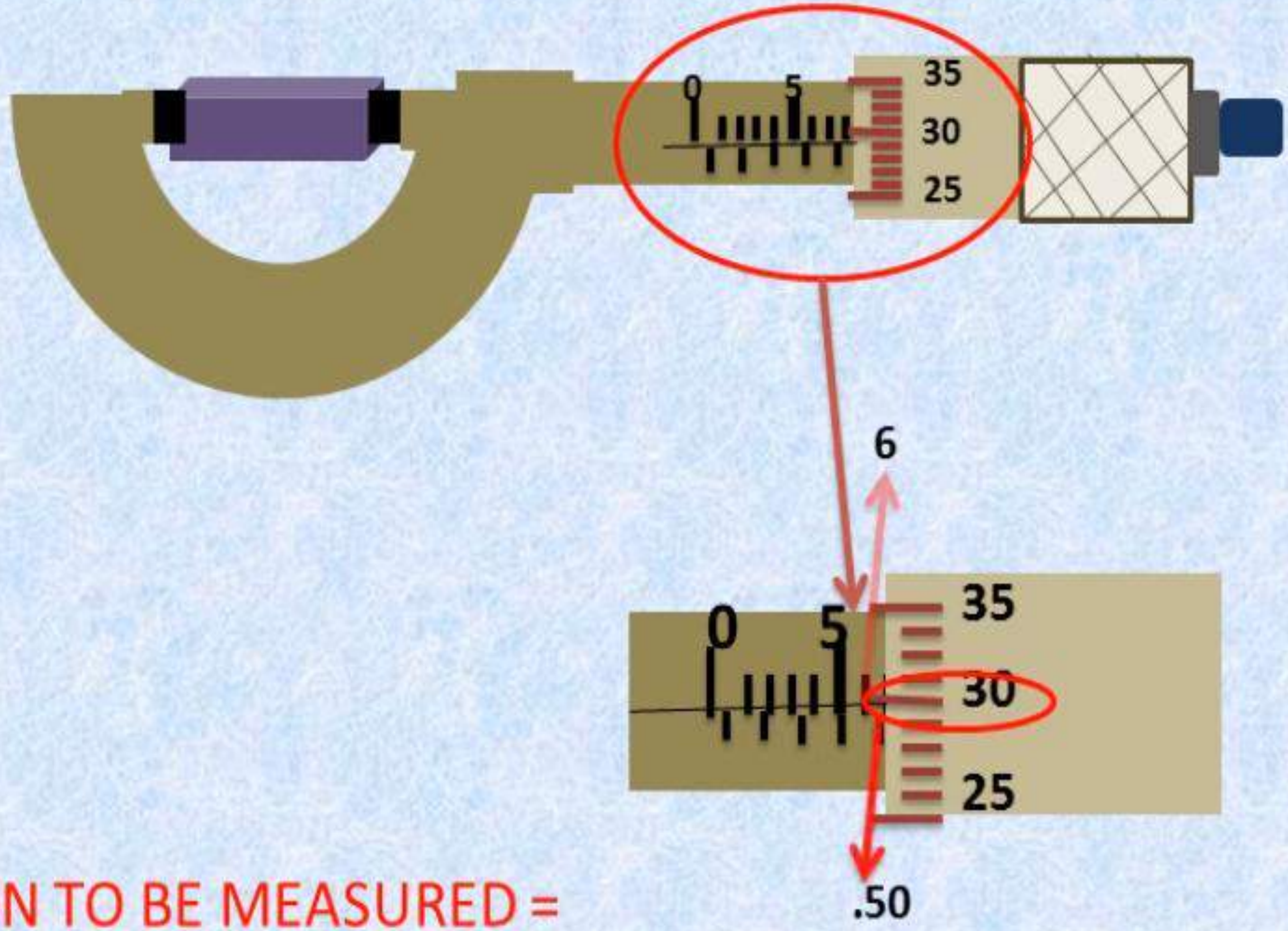


MICROMETRE



anvil
spindle
sleeve (with main scale)
40
35
ratchet knob
lock
thimble
(with rotating vernier scale)
0.01mm
0-25mm
frame


ANVIL
SPINDLE
MAIN SCALE
CIRCULAR SCALE
THIMBLE
RATCHET NUT
0
5
35
30
25
SLEEVE
KNURLING
FRAME
HARDENED ENDS
LEAST COUNT OF MAIN SCALE IS 0.5mm
DIVISION ON CIRCULAR SCALE =50

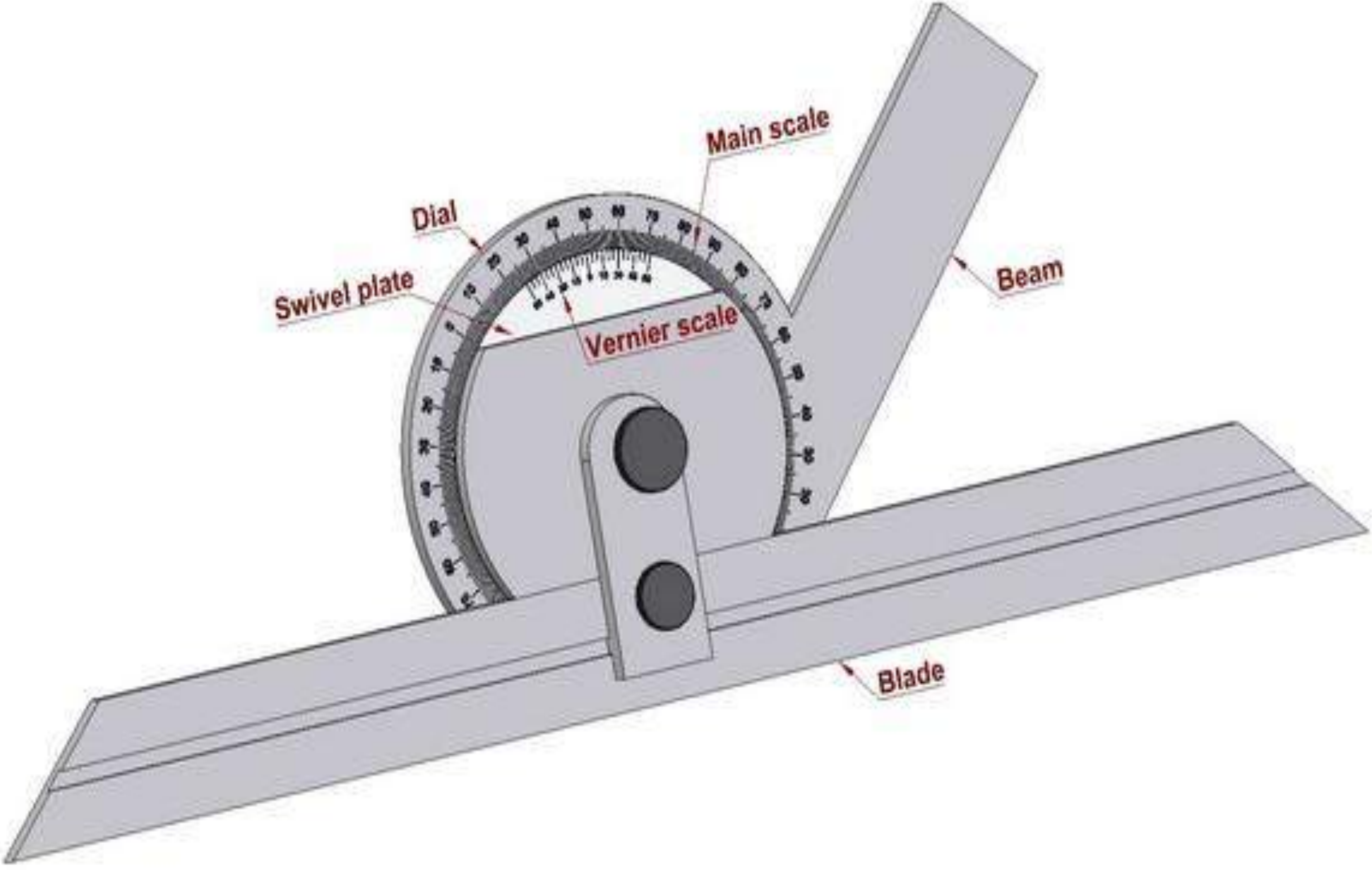


DIMENTION TO BE MEASURED =

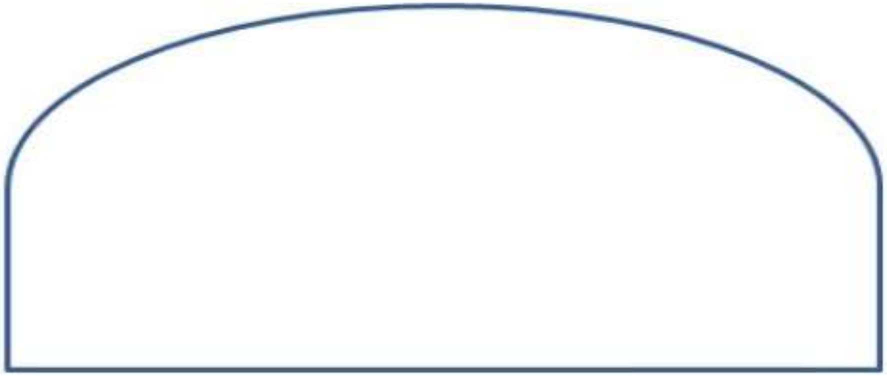
MAIN SCALE READING + (THIMBLE SCALE READING x LEAST COUNT)

$$(6 + 0.50) + (30 \times 0.01) = 6.50 + 0.3 = 6.8 \text{ mm}$$

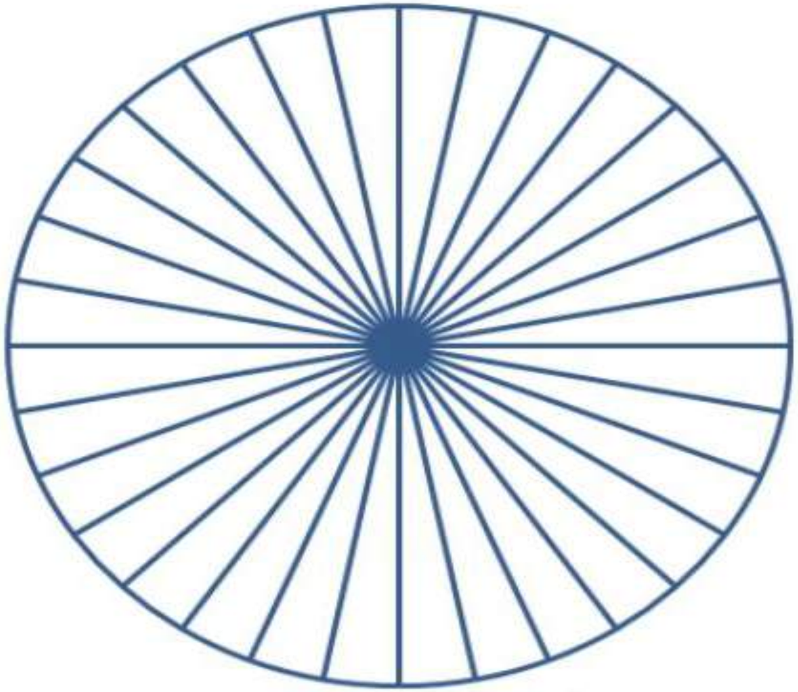
BEVEL PROTRACTOR



BEVEL PROTRACTOR



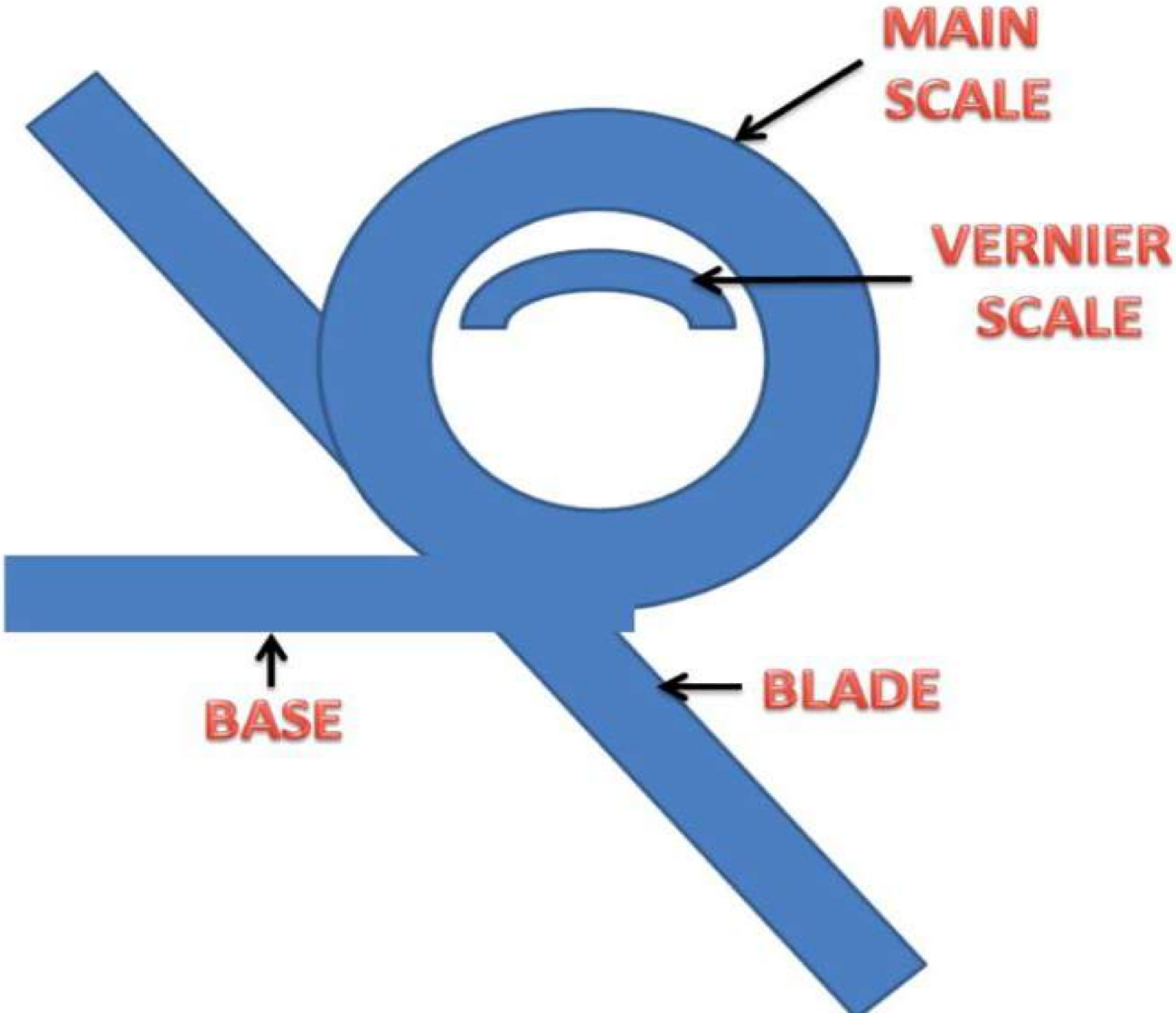
D-PROTRACTOR (180^0)

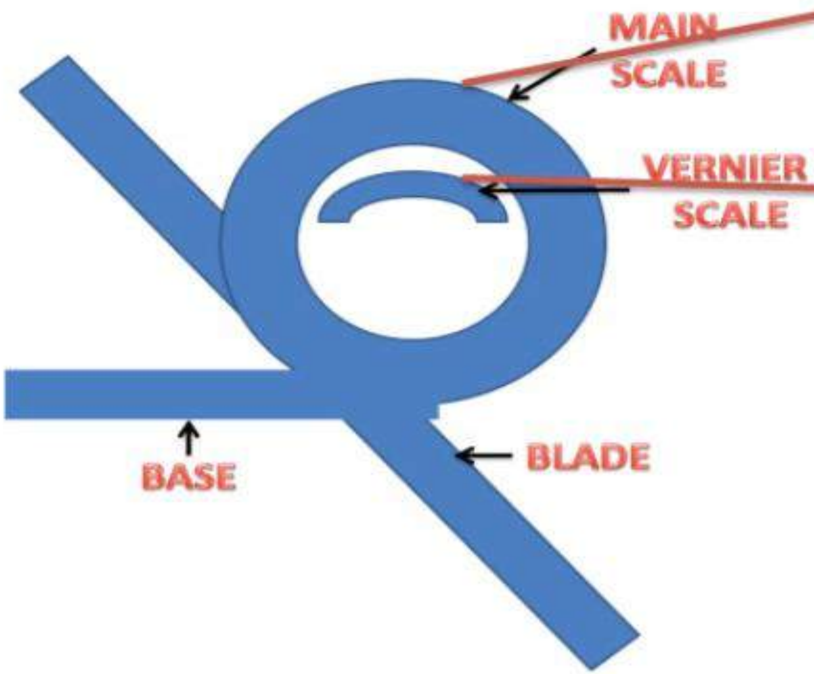


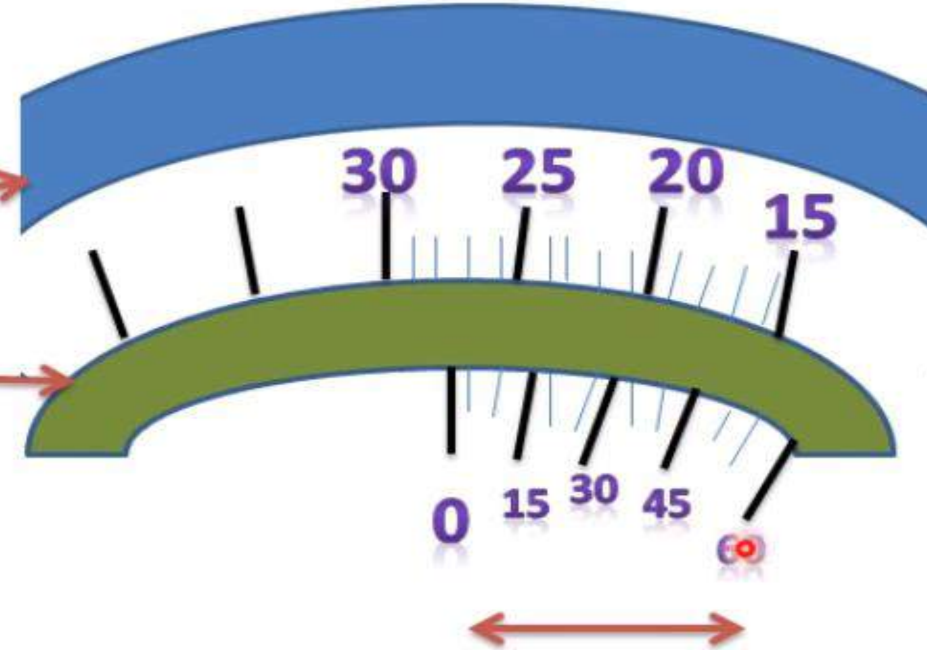
CIRCLE(360^0)

CIRCLE IS DIVIDED IN TO 360 PARTS EACH PART IS CALLED A DEGREE.

PARTS OF BEVEL PROTRACTOR



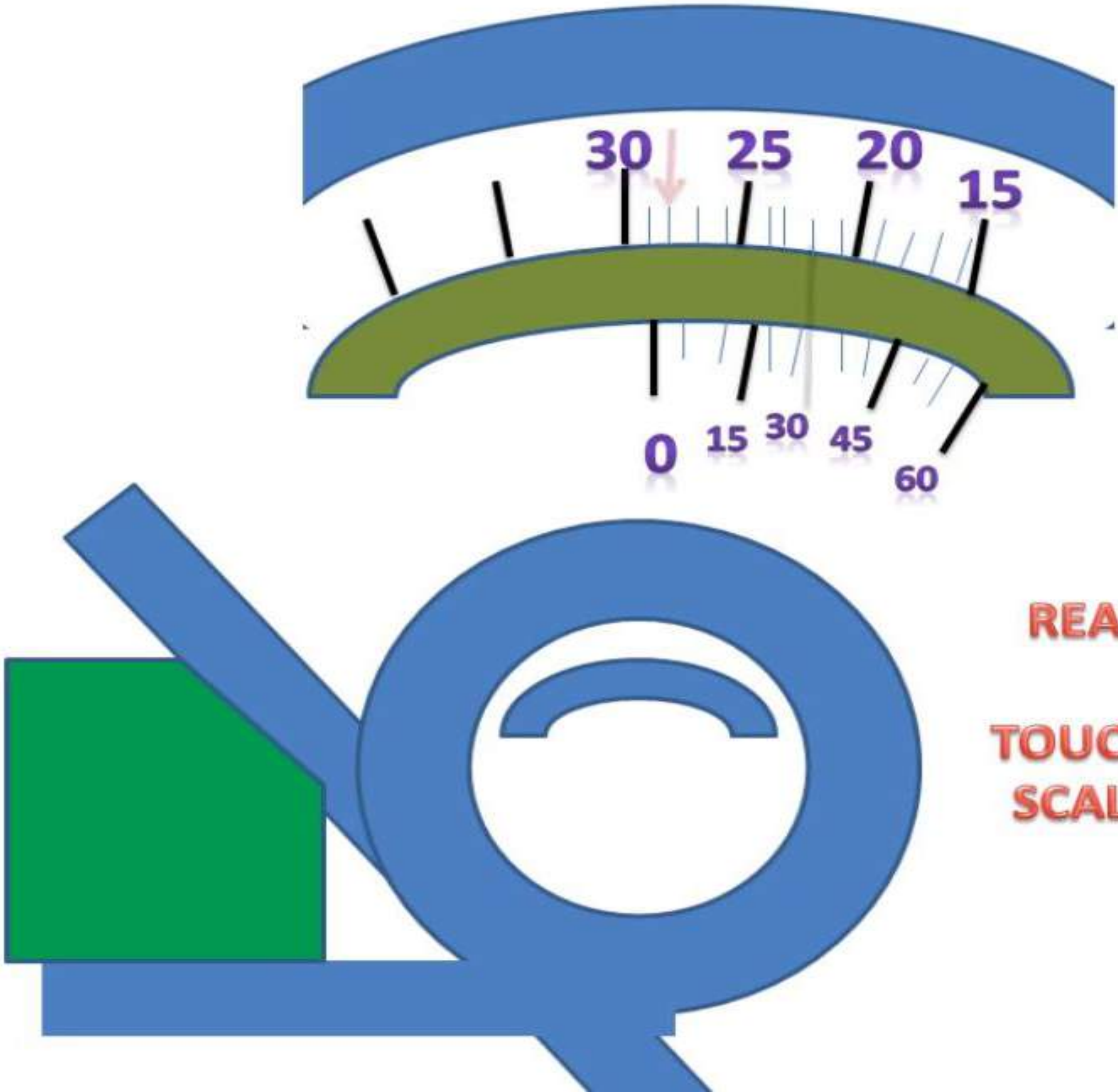




12 DIVISION

EACH DIVISION IS OF 5 MINUTES

12 X 5 = 60 MINUTES



READING OF MAIN SCALE

+

TOUCHING LINE OF VERNIER SCALE TO THE MAIN SCALE

28 DEGREE

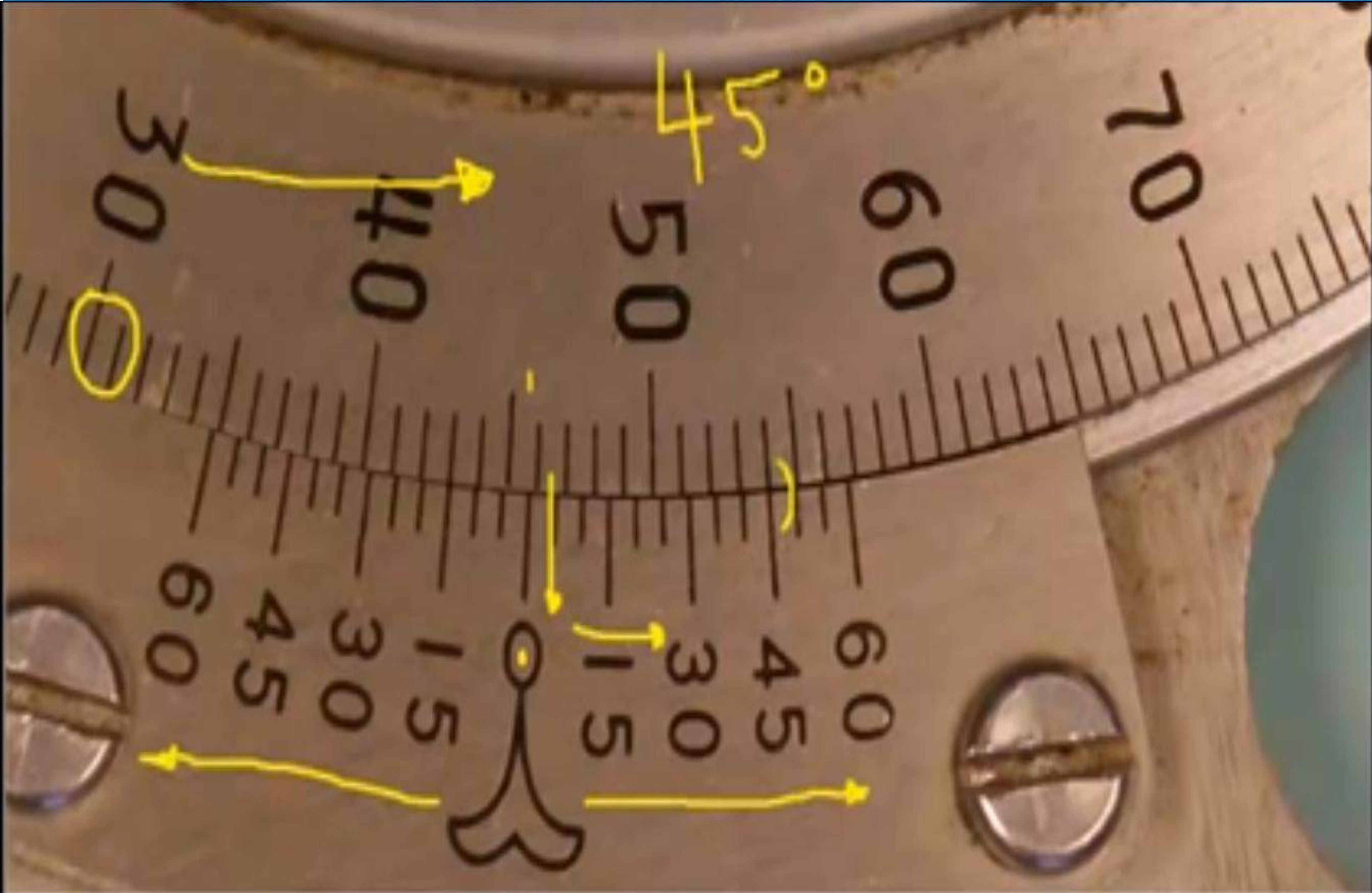
+

30 MINUTE

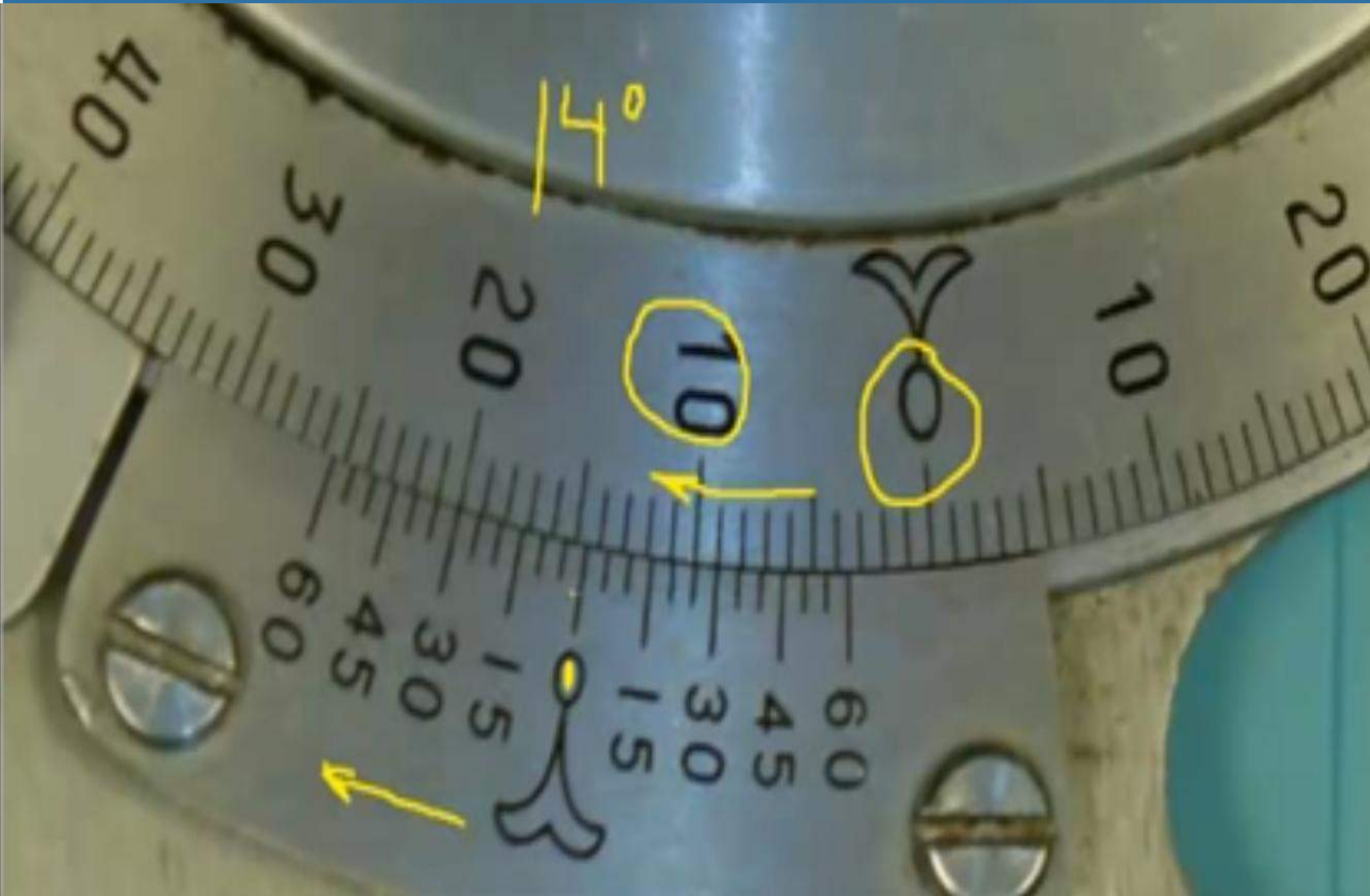
- **Bevel protractors are nothing but angular measuring instruments.**
- **Types of bevel protractors:**

The different types of bevel protractors used are:

1) **Vernier bevel protractor**
2) **Universal protractor**
3) **Optical protractor**

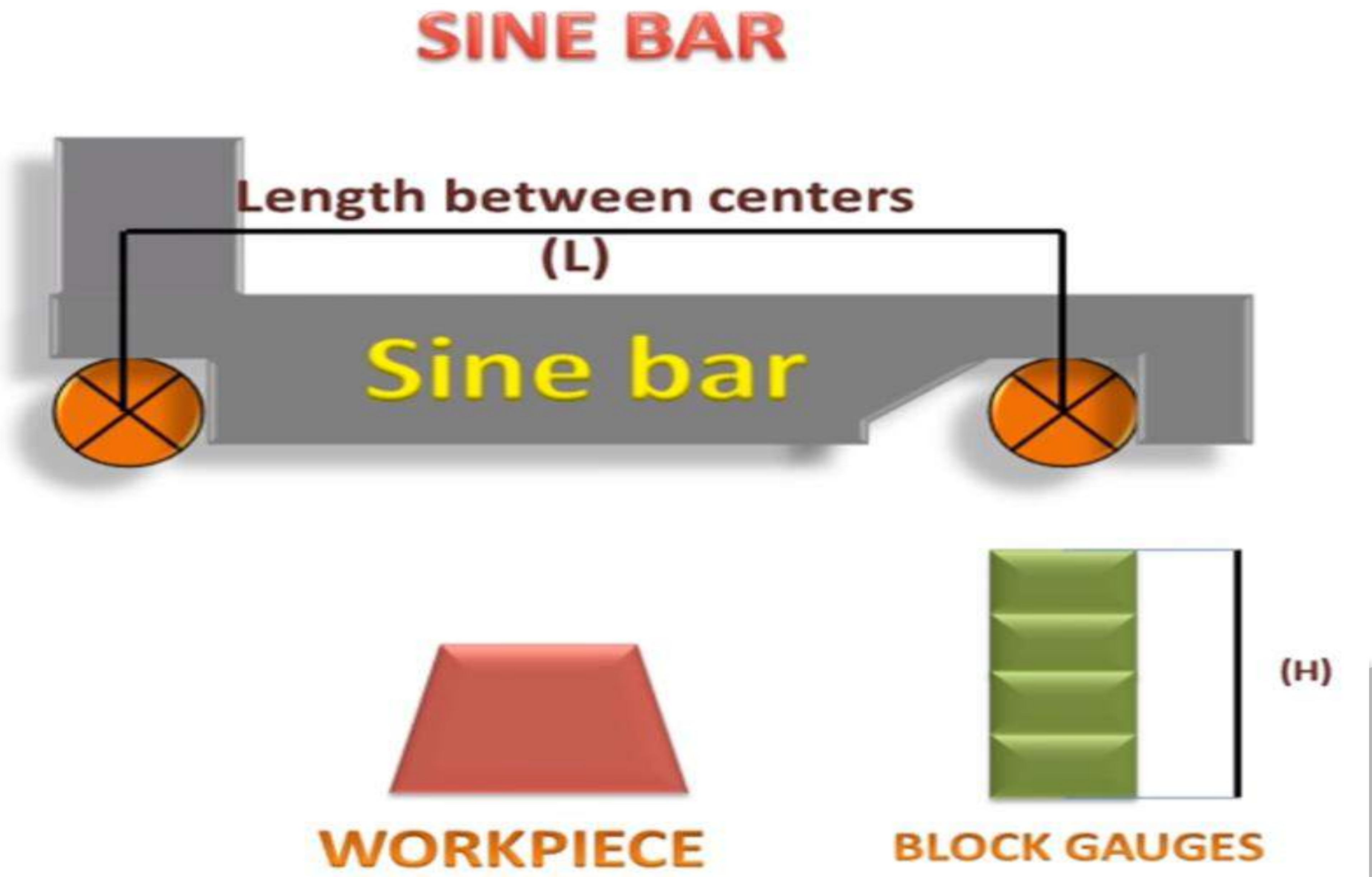


45°
30
40
50
60
70
60 45 30 15 0 15 30 45 60

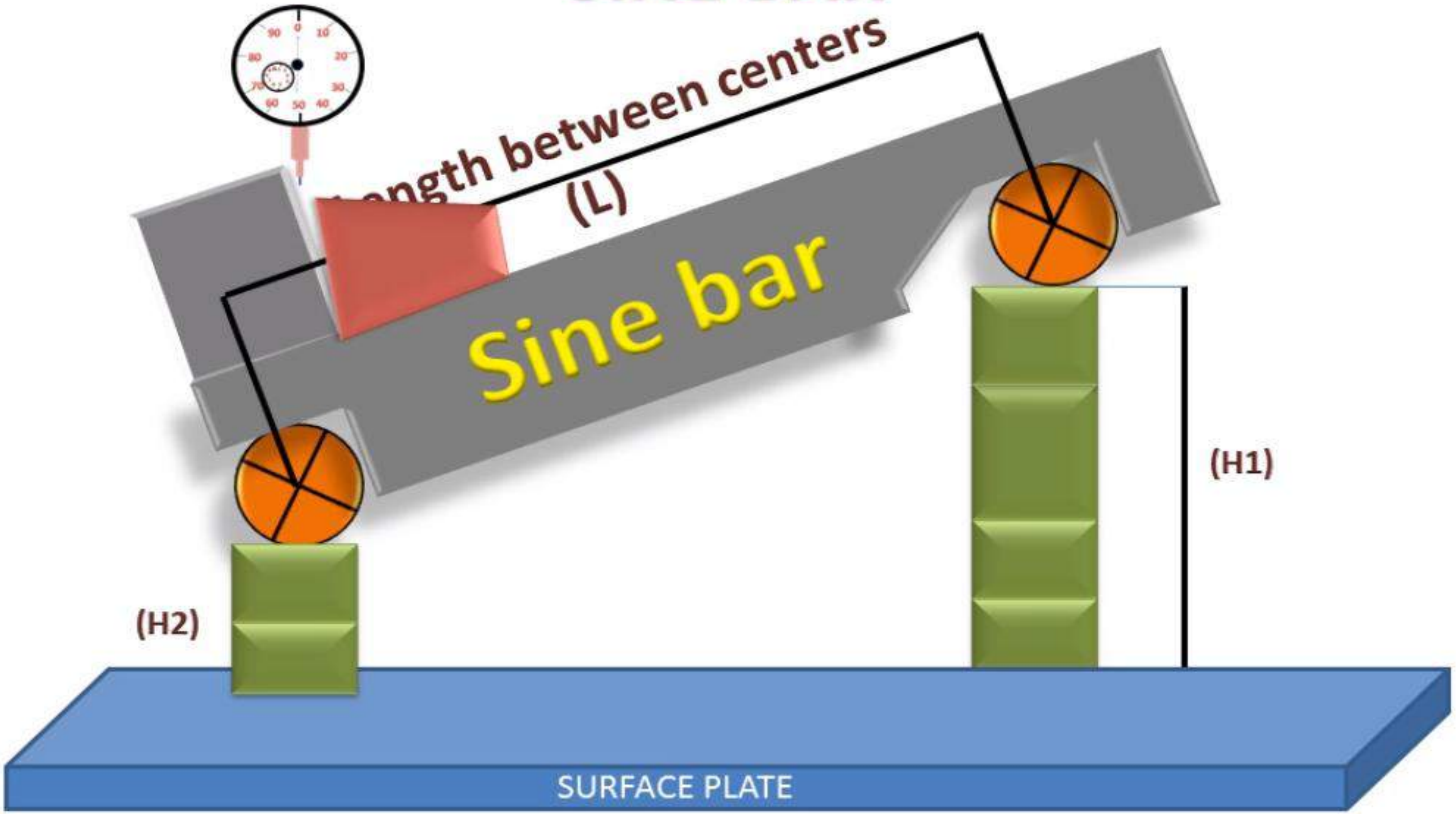


14°
40
30
20
10
0
10
20
60
45
30
15
15
30
45
60

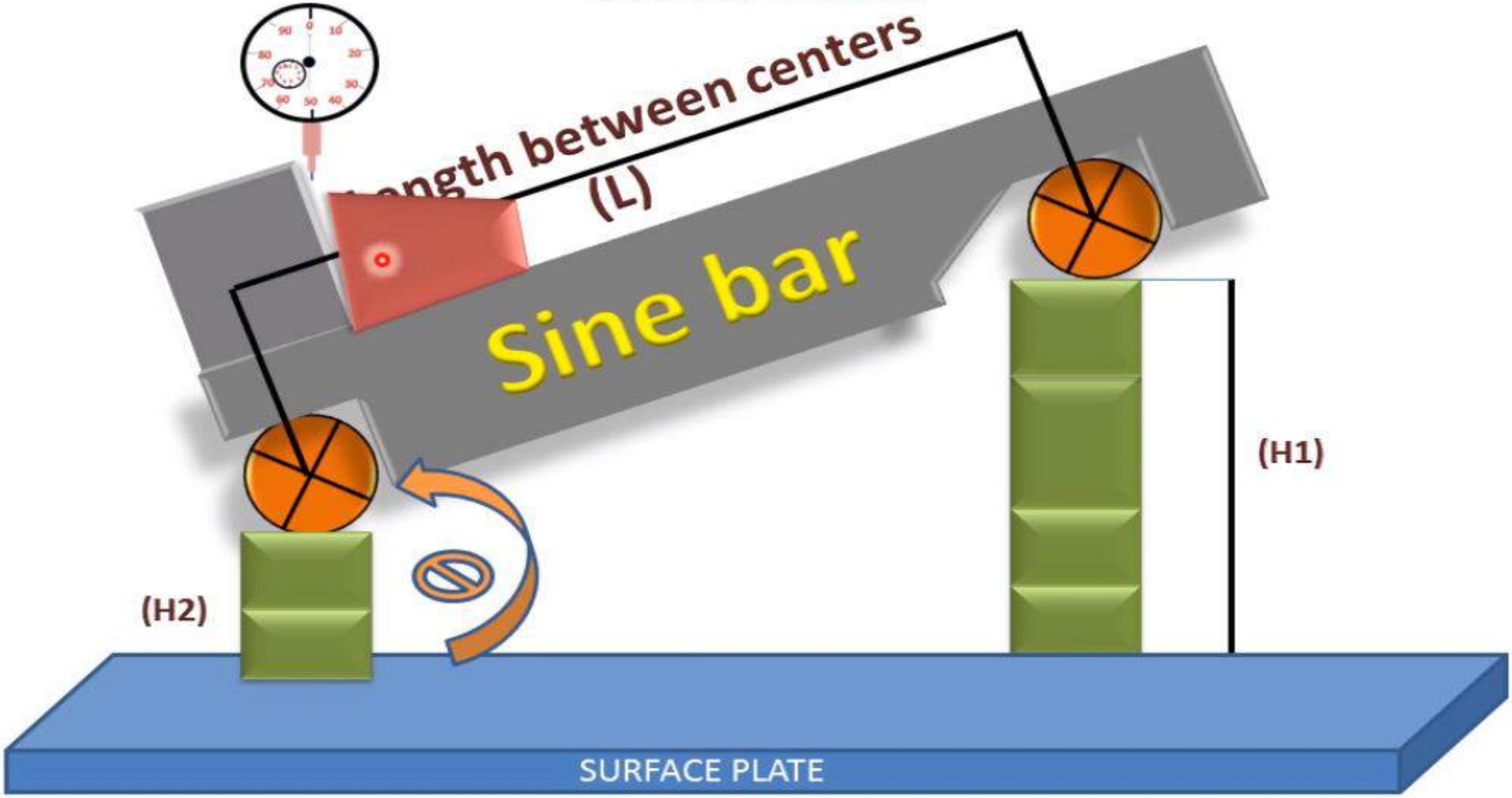
SINE BAR


SINE BAR
Length between centers
(L)
Sine bar
(H)
WORKPIECE
BLOCK GAUGES

SINE BAR

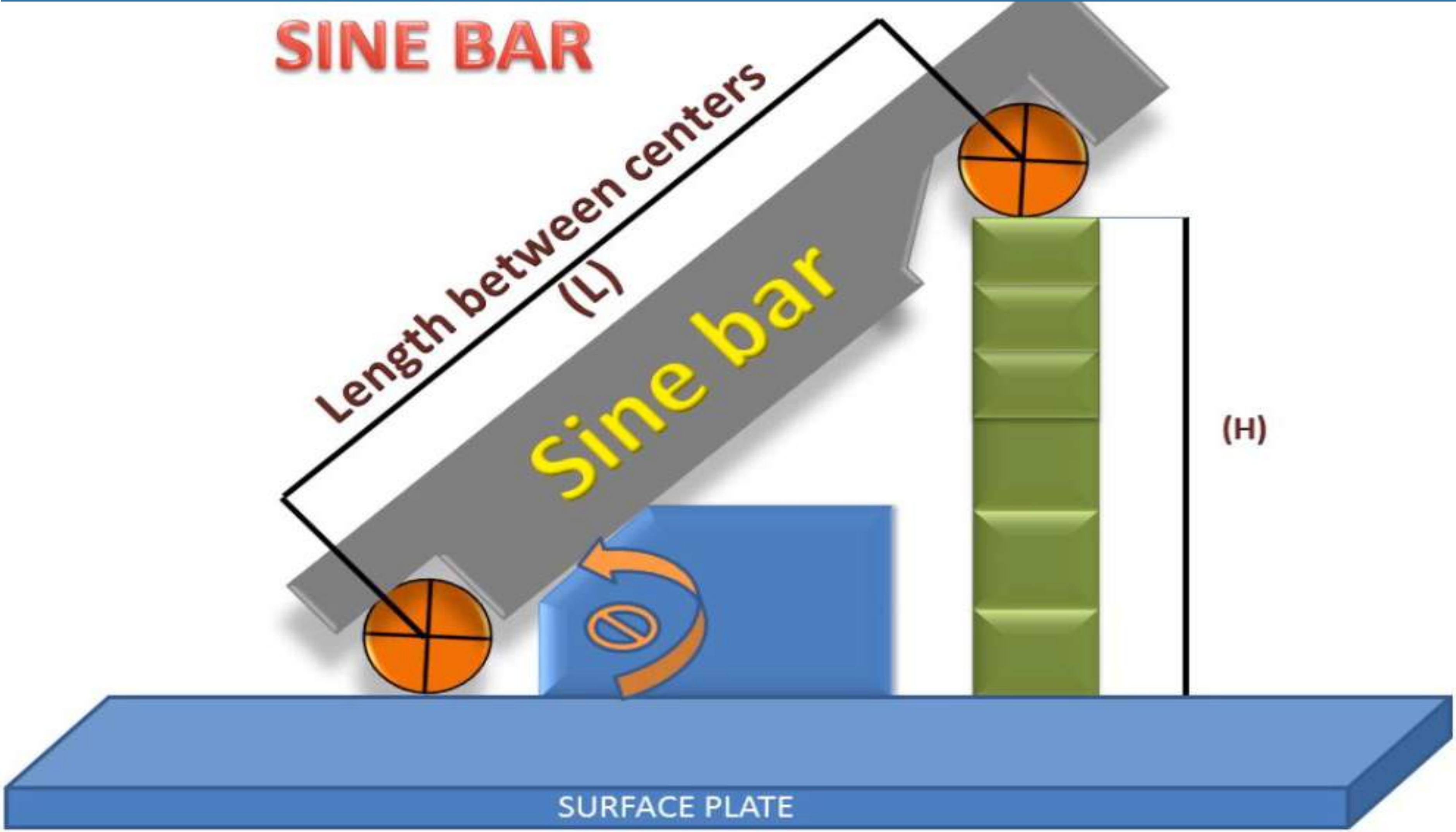


SINE BAR



SIN⊘ = H1-H2/L

SINE BAR



$\sin \theta = H/L \qquad \theta = \sin^{-1} H/L$

SPIRIT LEVEL


60cm

MEASURING INSTRUMENTS

Screw Thread Terminology

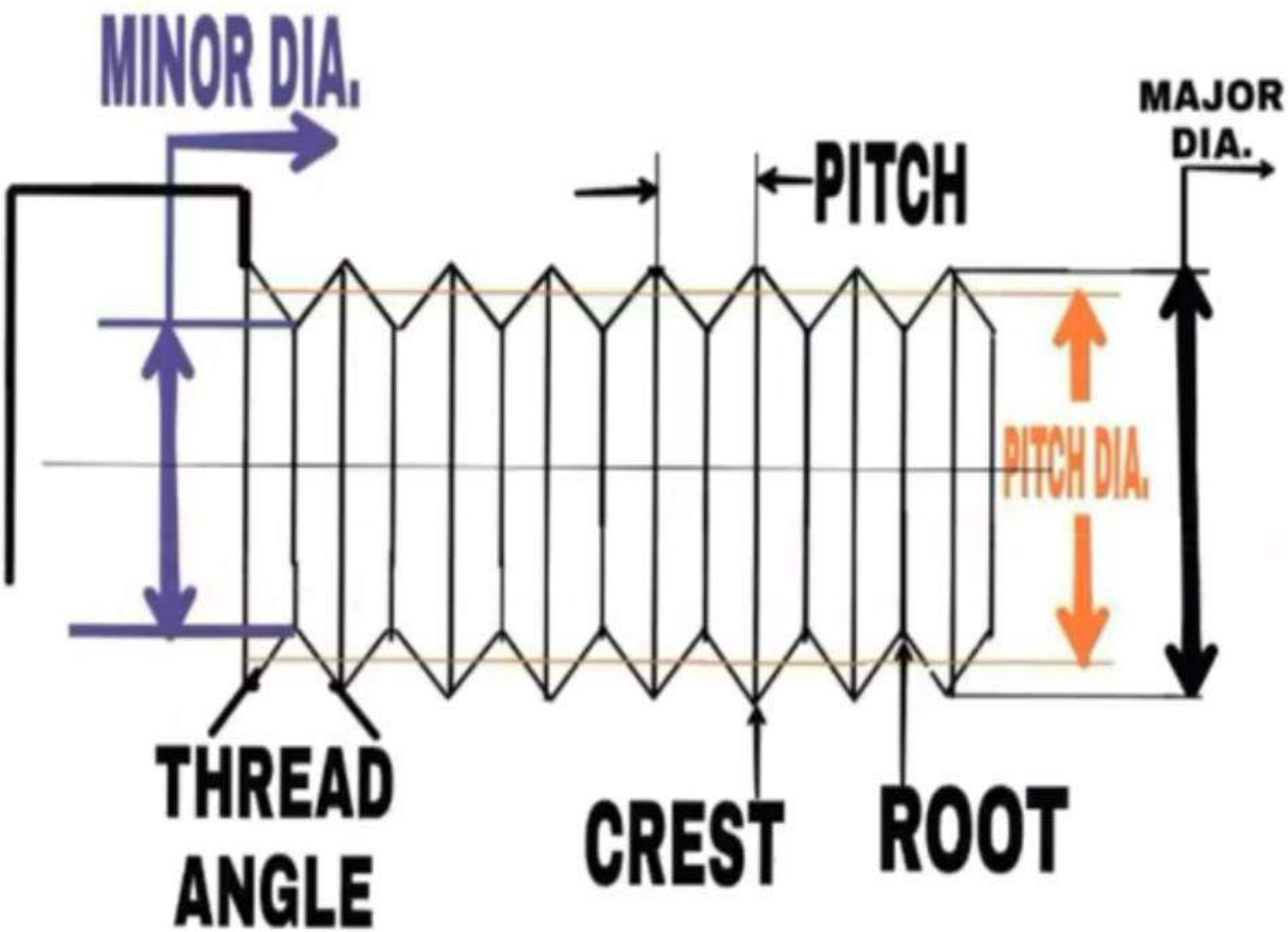


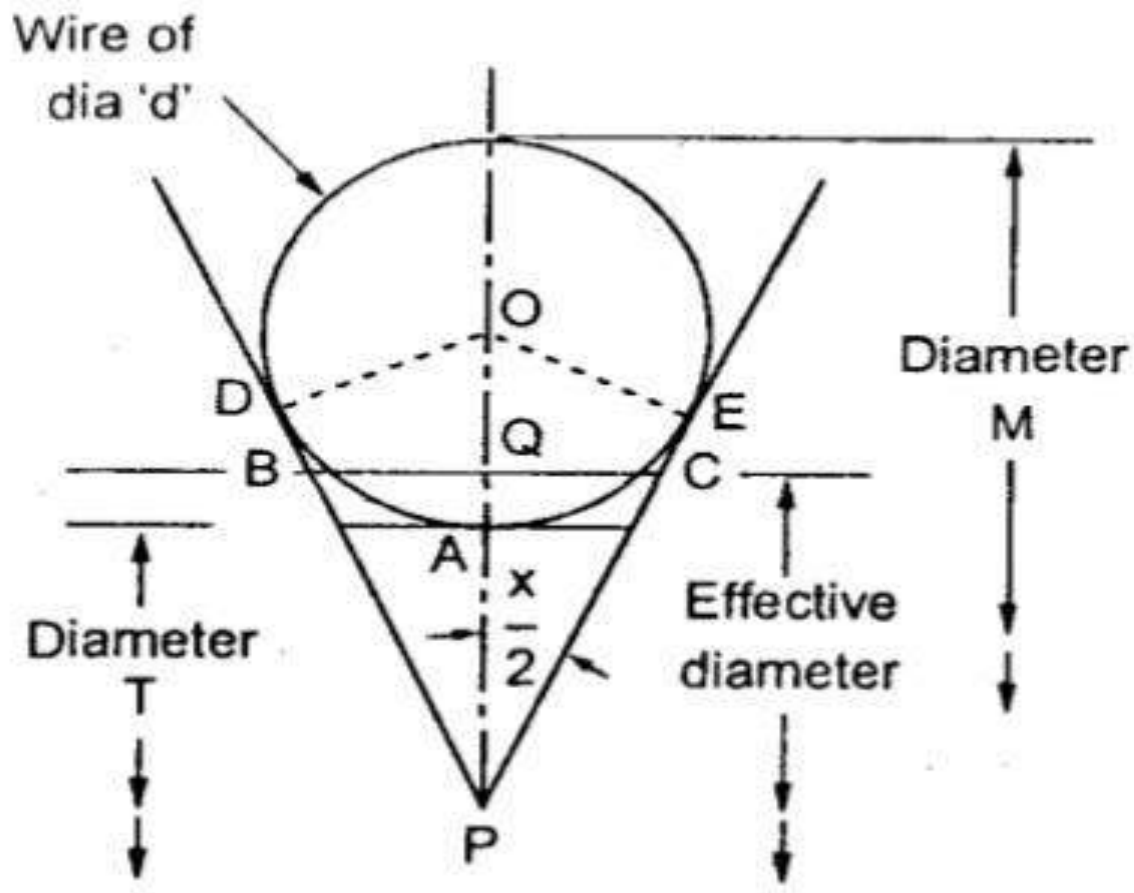
Fig-Screw Thread Terminology

Measurement of Effective Diameter

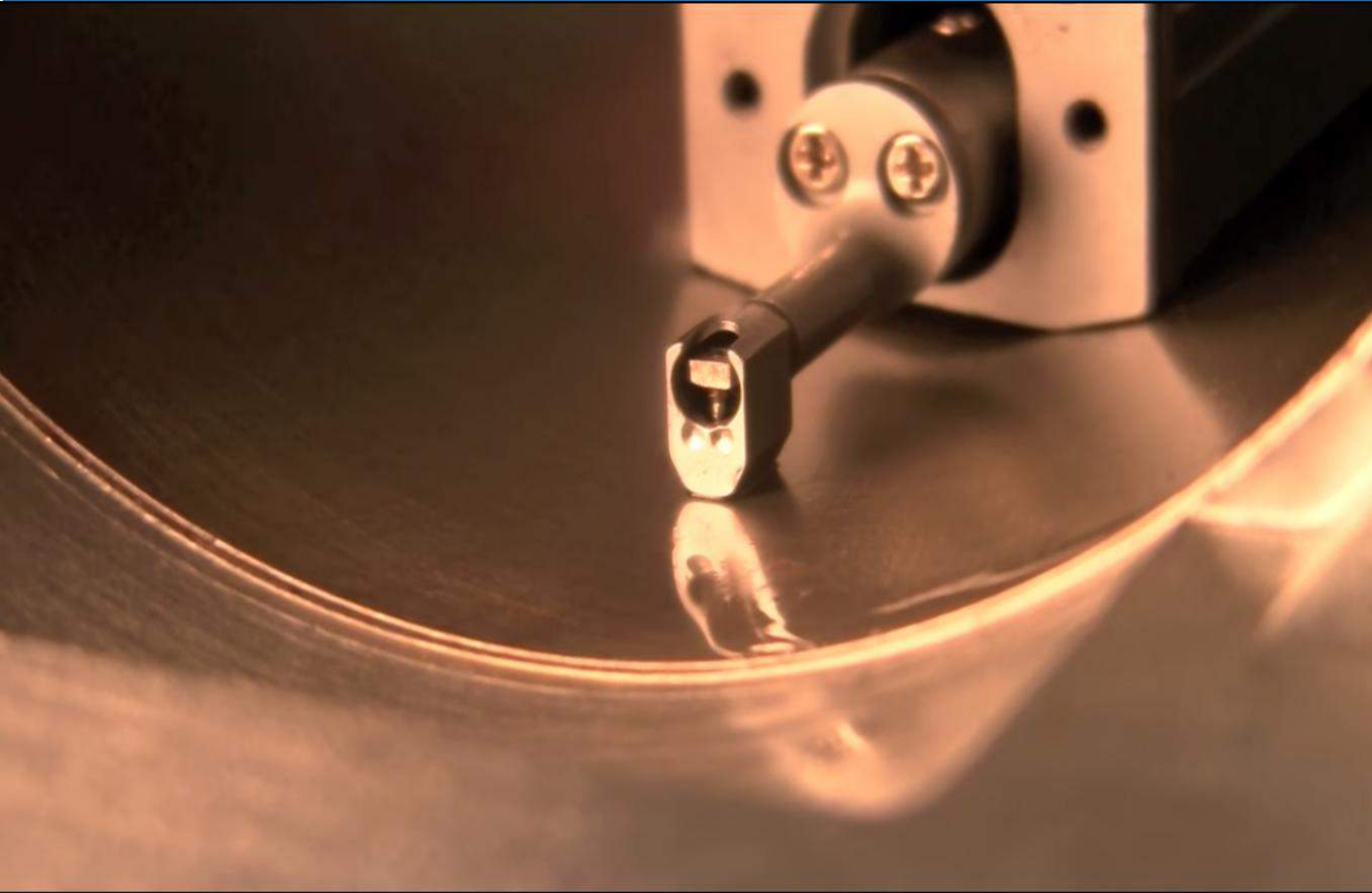
1. Thread micrometre method

2. one wire, two wire and three wire method

Two wire method:



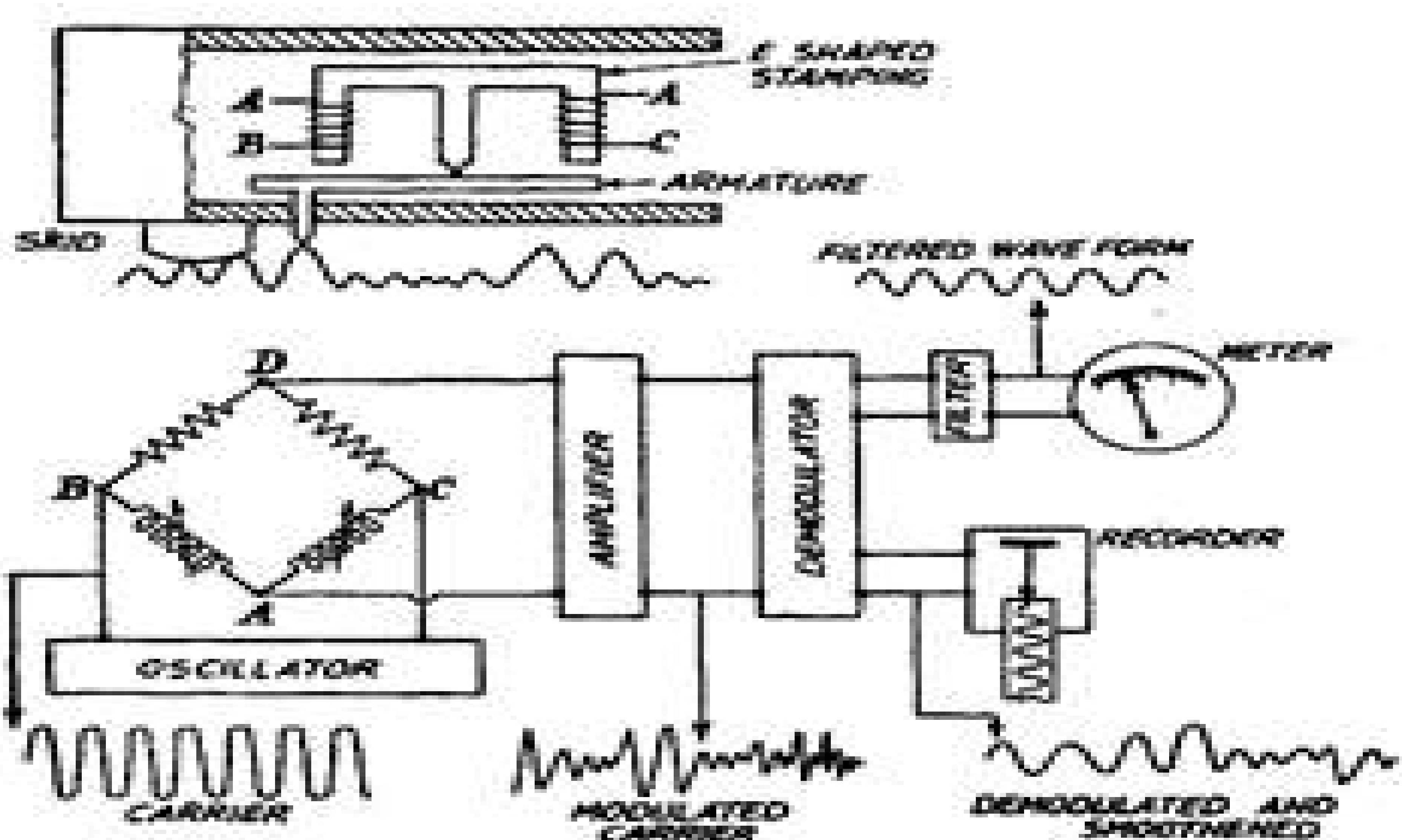
PROFILOMETER



PROFILOMETER

- A fine pointed stylus mounted in the pick-up unit is traversed across the surface either by hand or by motor drive.
- Instruments records the rectified output from the pick-up which is amplified further and operates an indicating device.
- Thus this records the average height of the surface roughness.
- Roughness together with waviness and flaws comprises the irregularities found on the surface
- Instrument is best in surface finish of deep bores.

TAYLOR HOBSON TALYSURF



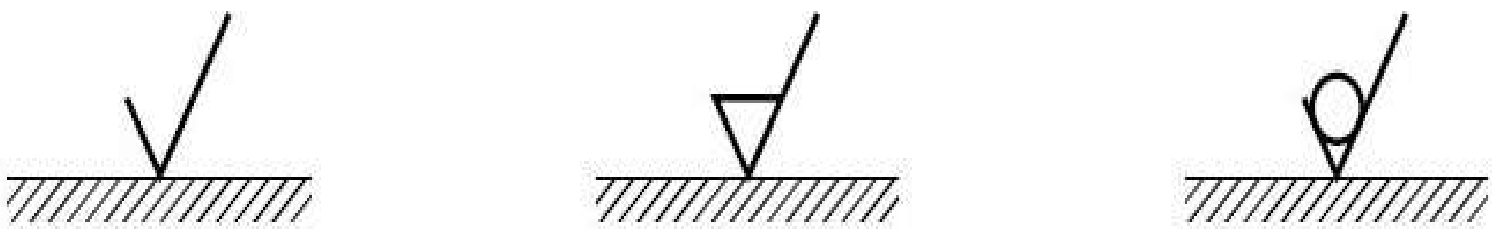
ISI symbol for indication of surface finish

Equivalent Surface Roughness Symbols

Roughness values R_a μm	*Roughness grade number*	*Roughness grade symbol*
50	N12	~
25	N11	▽
12.5	N10	
6.3	N9	▽▽
3.2	N8	
1.6	N7	
0.8	N6	▽▽▽
0.4	N5	
0.2	N4	
0.1	N3	▽▽▽▽
0.05	N2	
0.025	N1	

Symbols indicating target surface and the position of these symbols

When pictorially representing the surface texture, the symbol that indicates the target surface is expressed with two lines having different lengths with an angle of 60° between them.

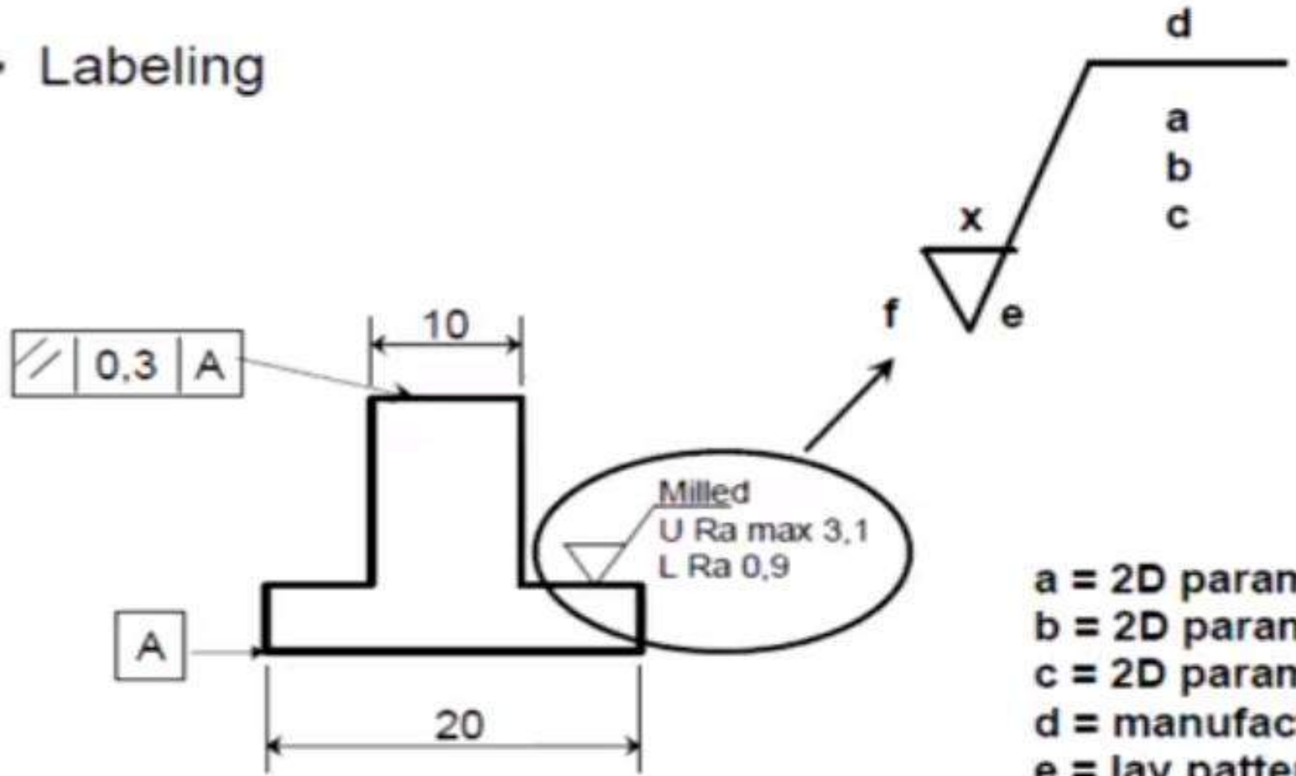


Symbol indicating the surface | Symbol indicating a surface that requires material removal | Symbol indicating a surface that does not require material removal

This surface roughness indication method pictorially displays information such as the surface roughness value, cutoff value, sampling length, machining method, crease direction symbol, and surface waviness on the surface indication symbol as shown below.

Indication of Surface Roughness

- Labeling

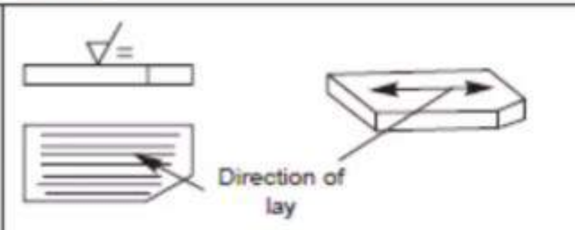
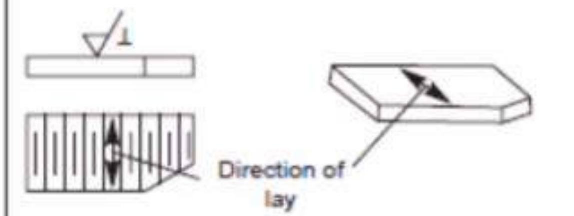
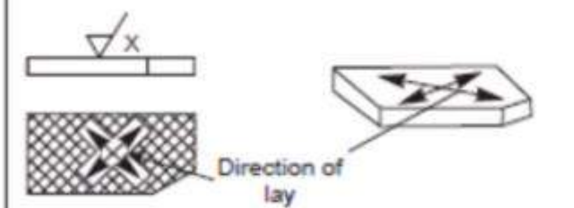
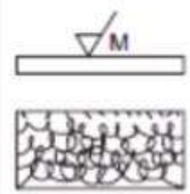
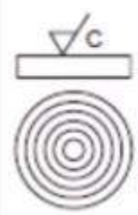


a = 2D parameter 1
b = 2D parameter 2
c = 2D parameter 3
d = manufacturing method
e = lay pattern
f = allowance
x = not allowed

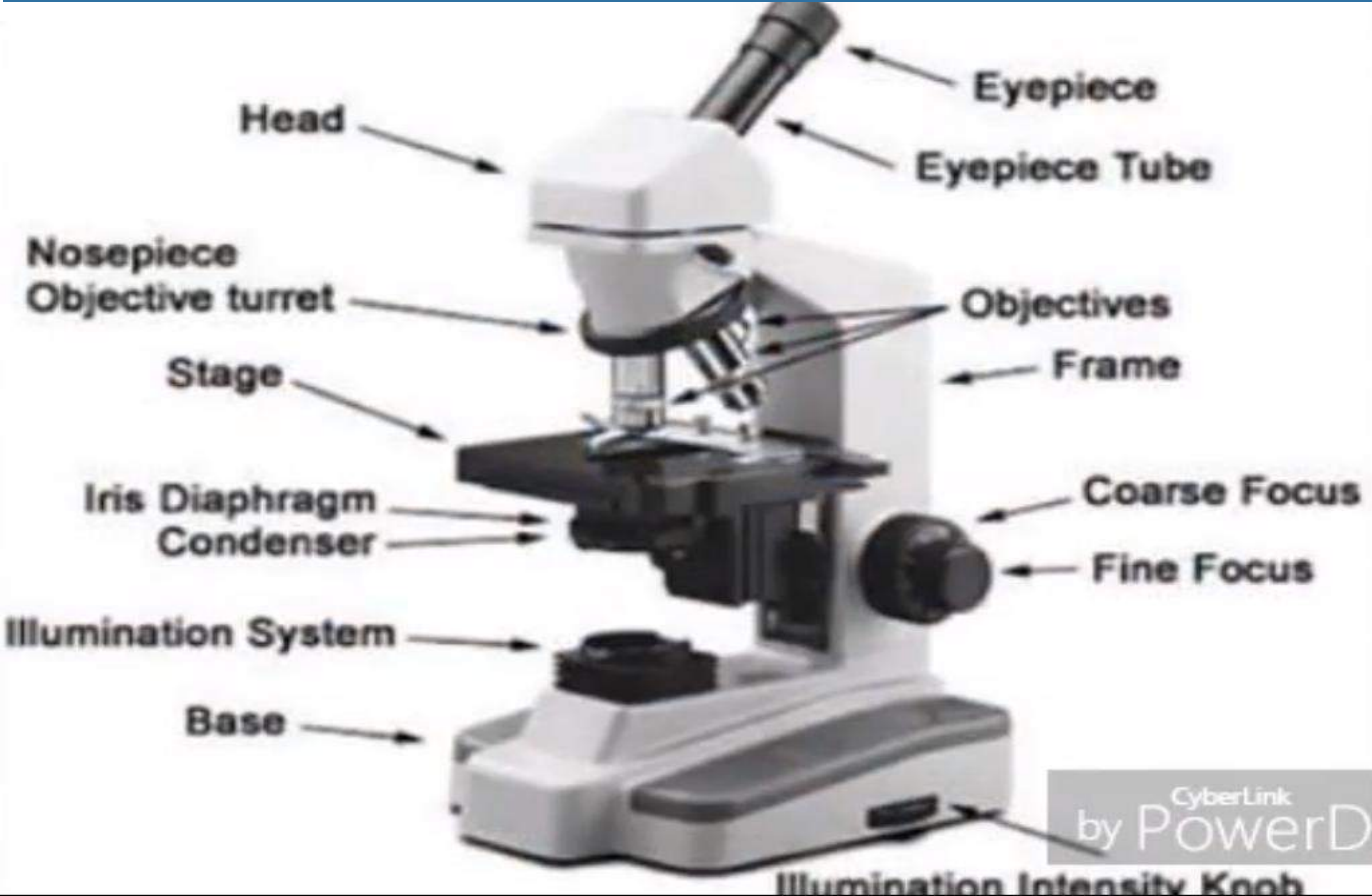
Surface roughness expected from various manufacturing processes

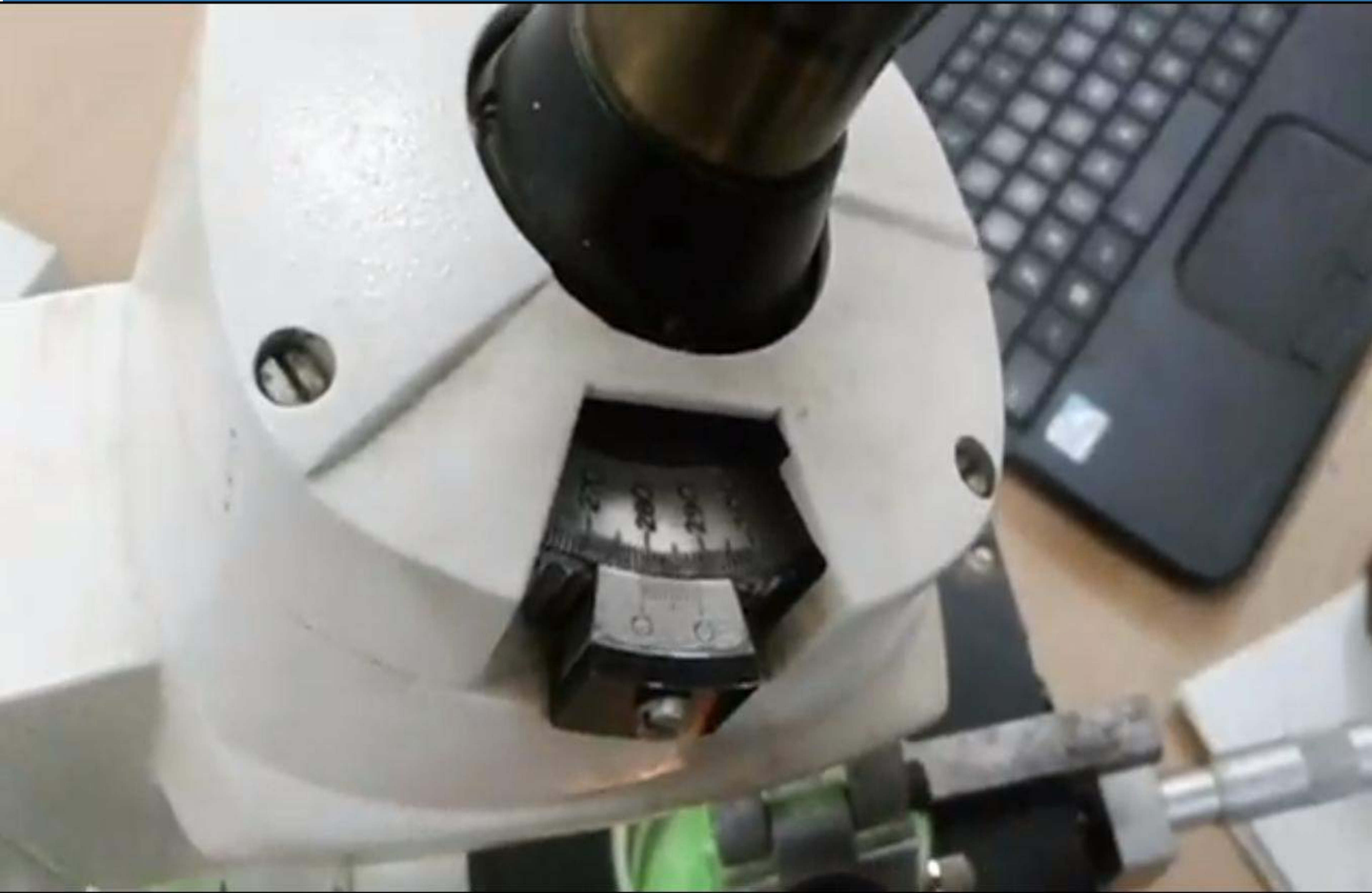
Sl. No.	Manufacturing Process	R_a in µm (from)	R_a in µm (to)
1	Sand casting	5	50
2	Permanent mould casting	0.8	6.3
3	Die casting	0.8	3.2
4	High pressure casting	0.32	2
5	Hot rolling	2.5	50
6	Forging	1.6	28
7	Extrusion	0.16	5
8	Flame cutting, sawing & Chipping	6.3	100
9	Radial cut-off sawing	1	6.3
10	Hand grinding	6.3	25
11	Disc grinding	1.6	25

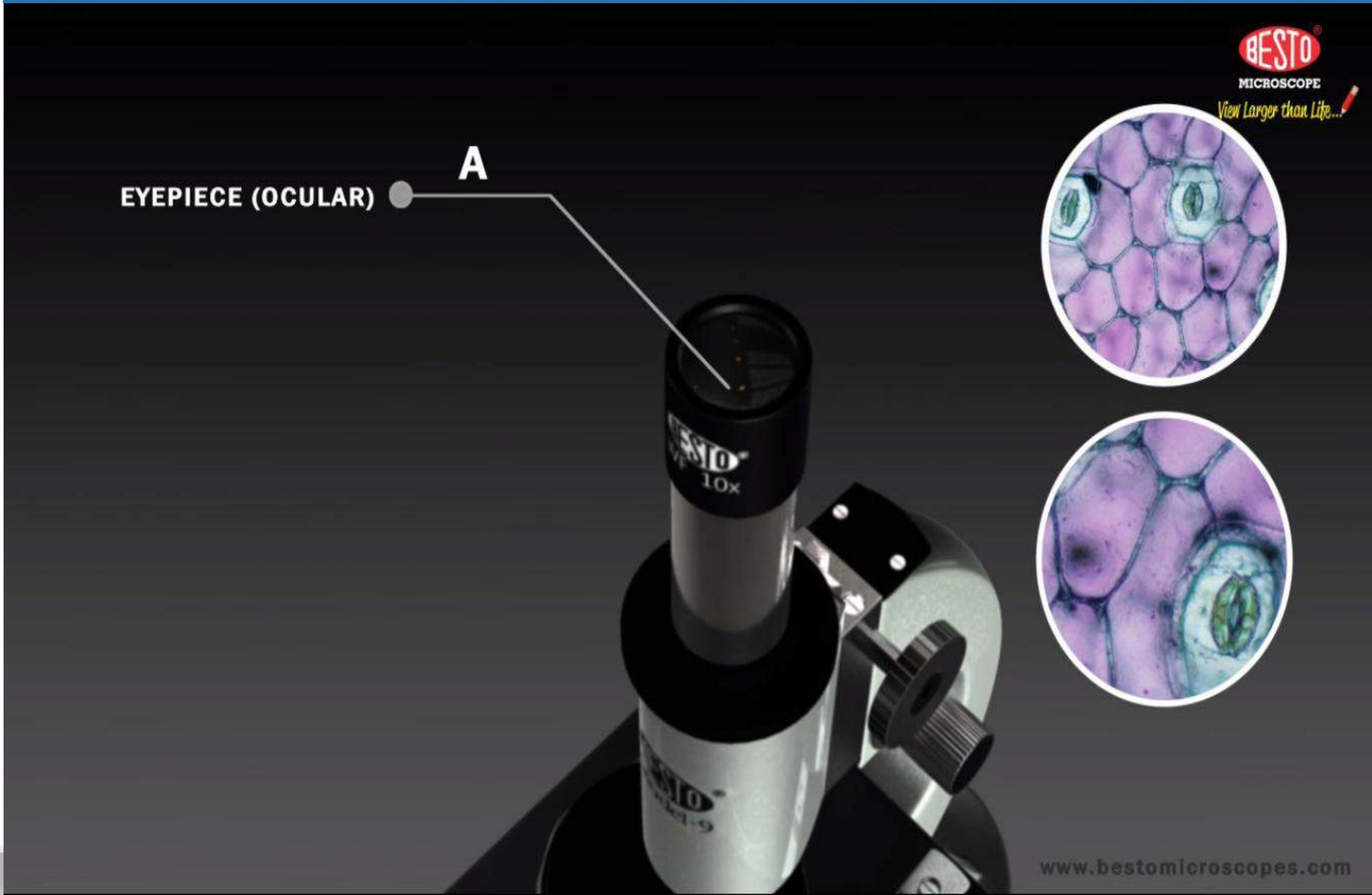
12	Filing	0.25	25
13	Planing	1.6	50
14	Shaping	1.6	25
15	Drilling	1.6	20
16	Turning & Milling	0.32	25
17	Boring	0.4	6.3
18	Reaming	0.4	3.2
19	Broaching	0.4	3.2
20	Hobbing	0.4	3.2
21	Surface grinding	0.063	5
22	Cylindrical grinding	0.063	5
23	Honing	0.025	0.4
24	Lapping	0.012	0.16
25	Polishing	0.04	0.16
26	Burnishing	0.04	0.8
27	Super finishing	0.016	0.32

Symbol	Interpretation	
=	Parallel to the plane of projection of the view in which the symbol is used	
⊥	Perpendicular to the plane of projection of the view in which the symbol is used	
X	Crossed in two slant directions relative to the plane of projection of the view in which the symbol is used	
M	Multi-directional	
C	Approximately circular, relative to the centre of the surface to which the symbol is applied	

Tools Makers Microscope







A
EYEPIECE (OCULAR)
BESTO
10x
BESTO
MICROSCOPE
View Larger than Life...
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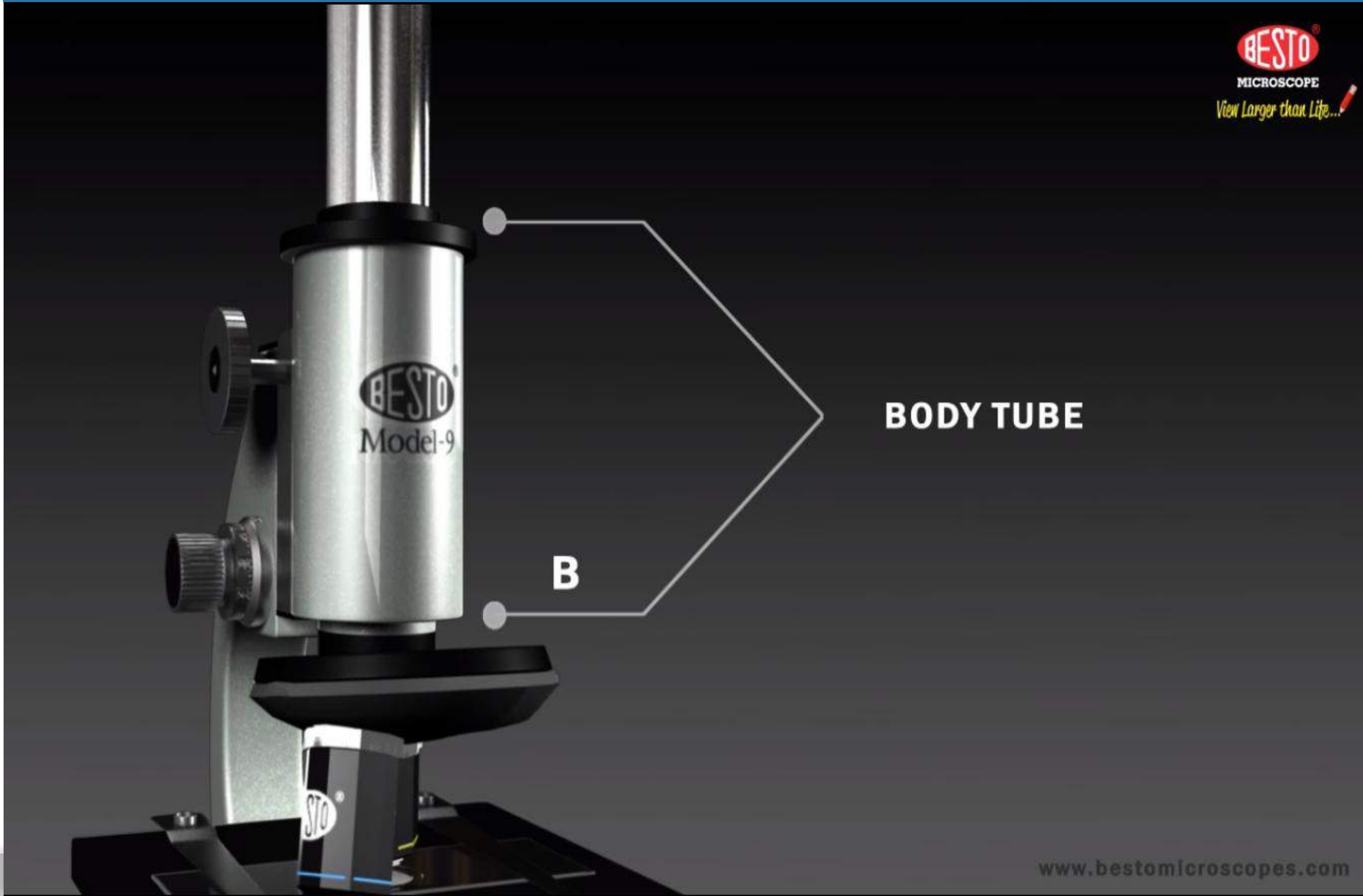
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MICROSCOPE
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BODY TUBE
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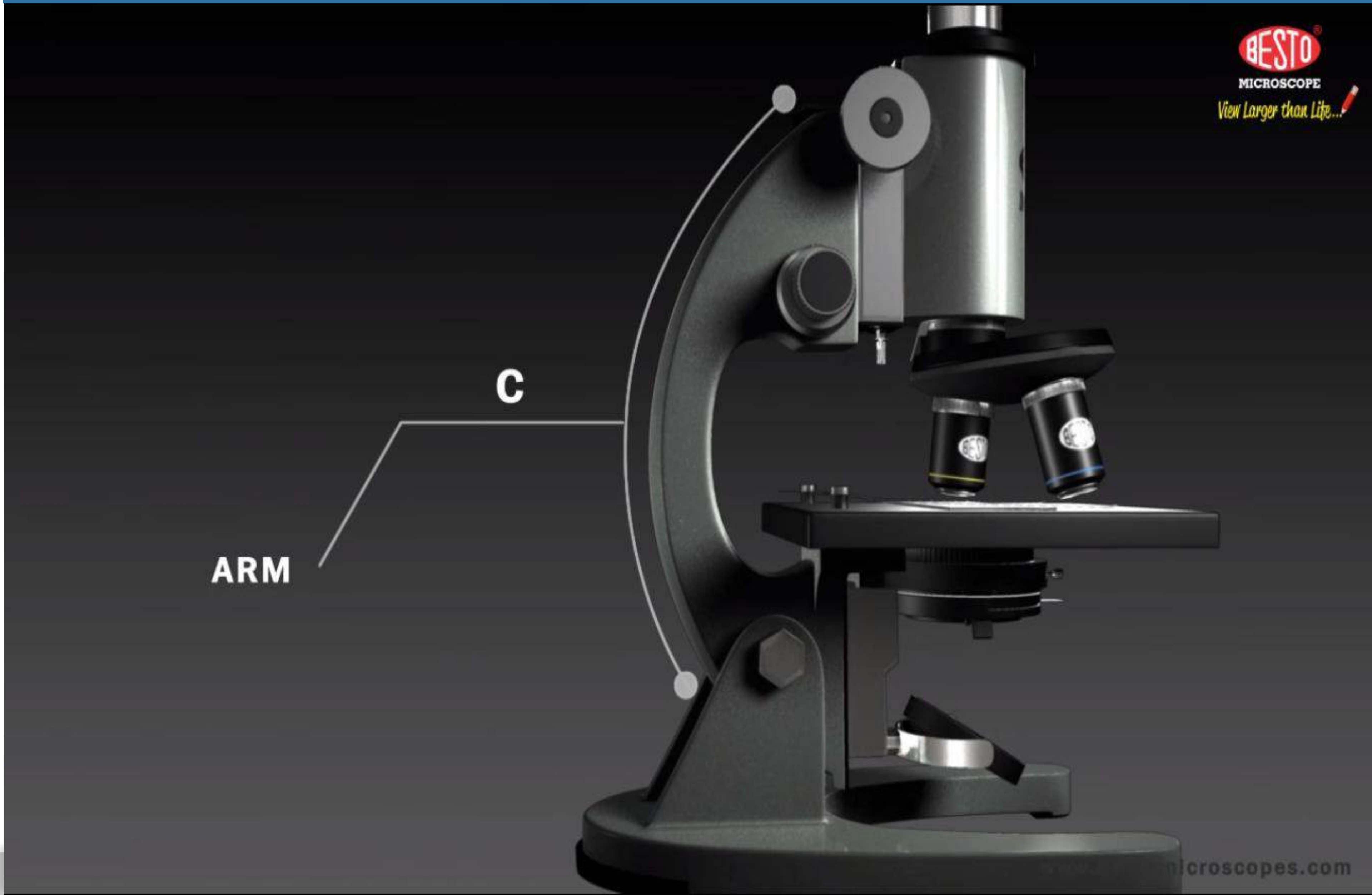
C
ARM


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D
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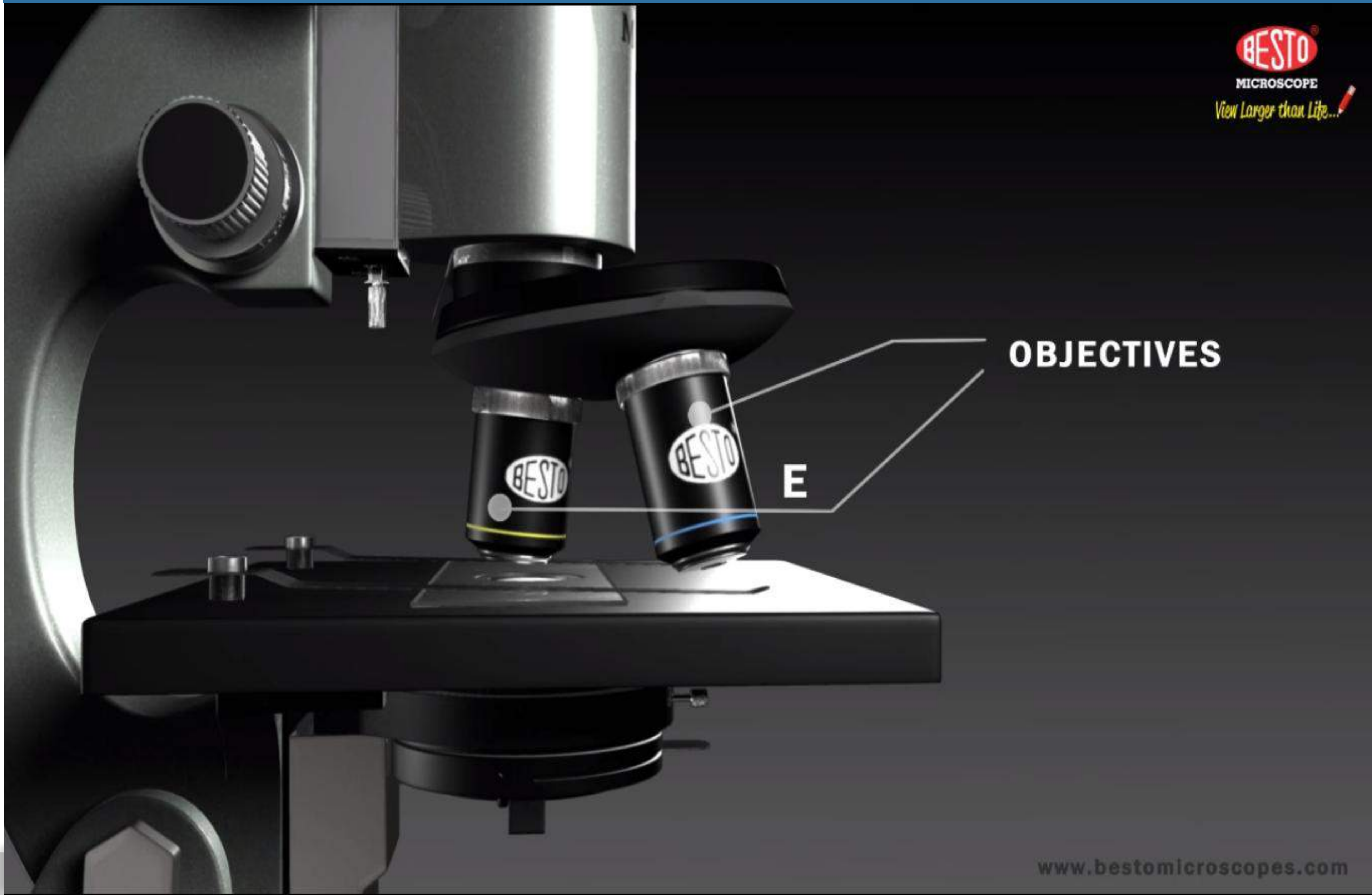
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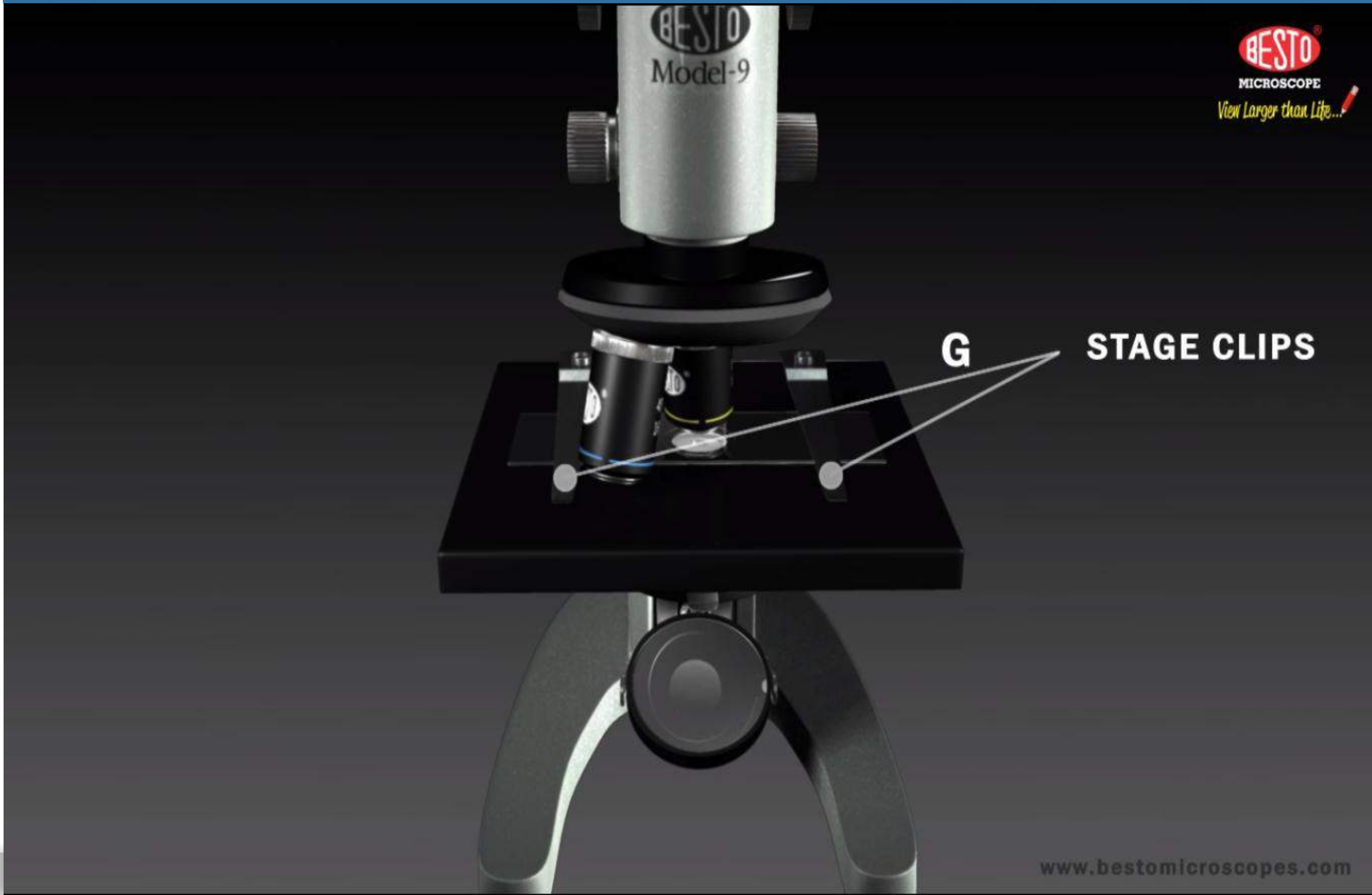
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View Larger than Life...
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KNOB
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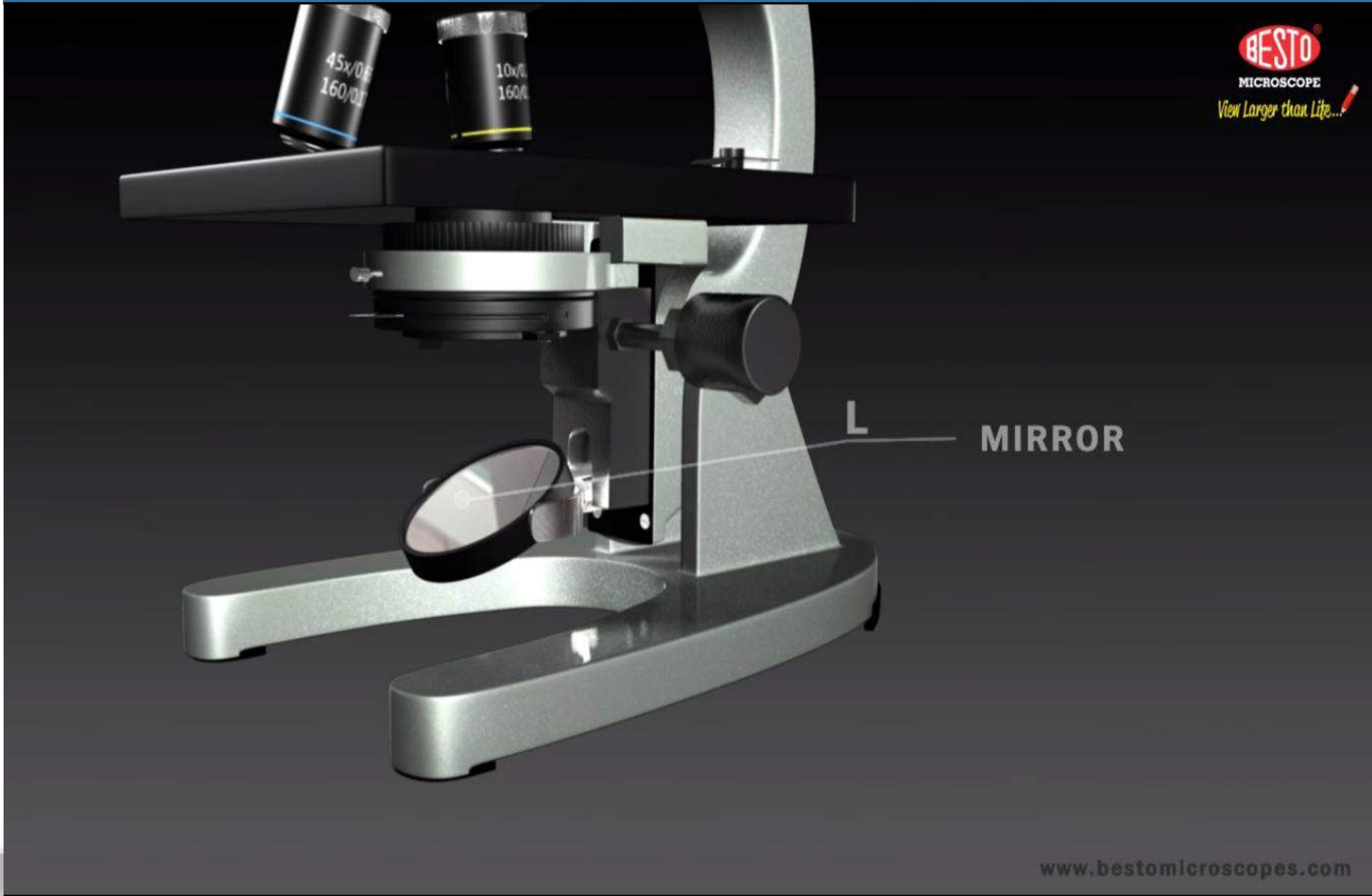
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L
MIRROR
BESTO
MICROSCOPE
View Larger than Life...
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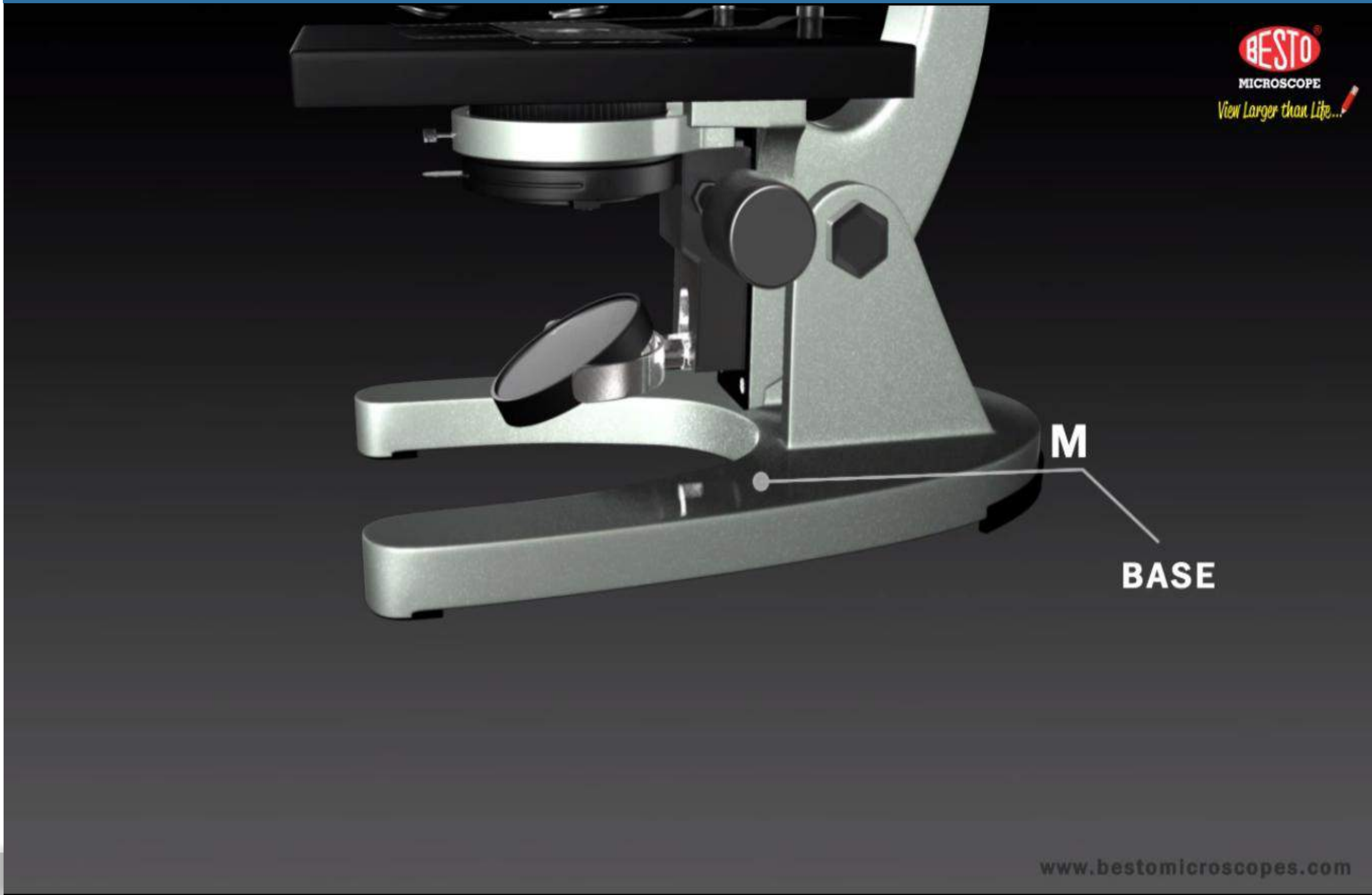
M
BASE
BESTO
MICROSCOPE
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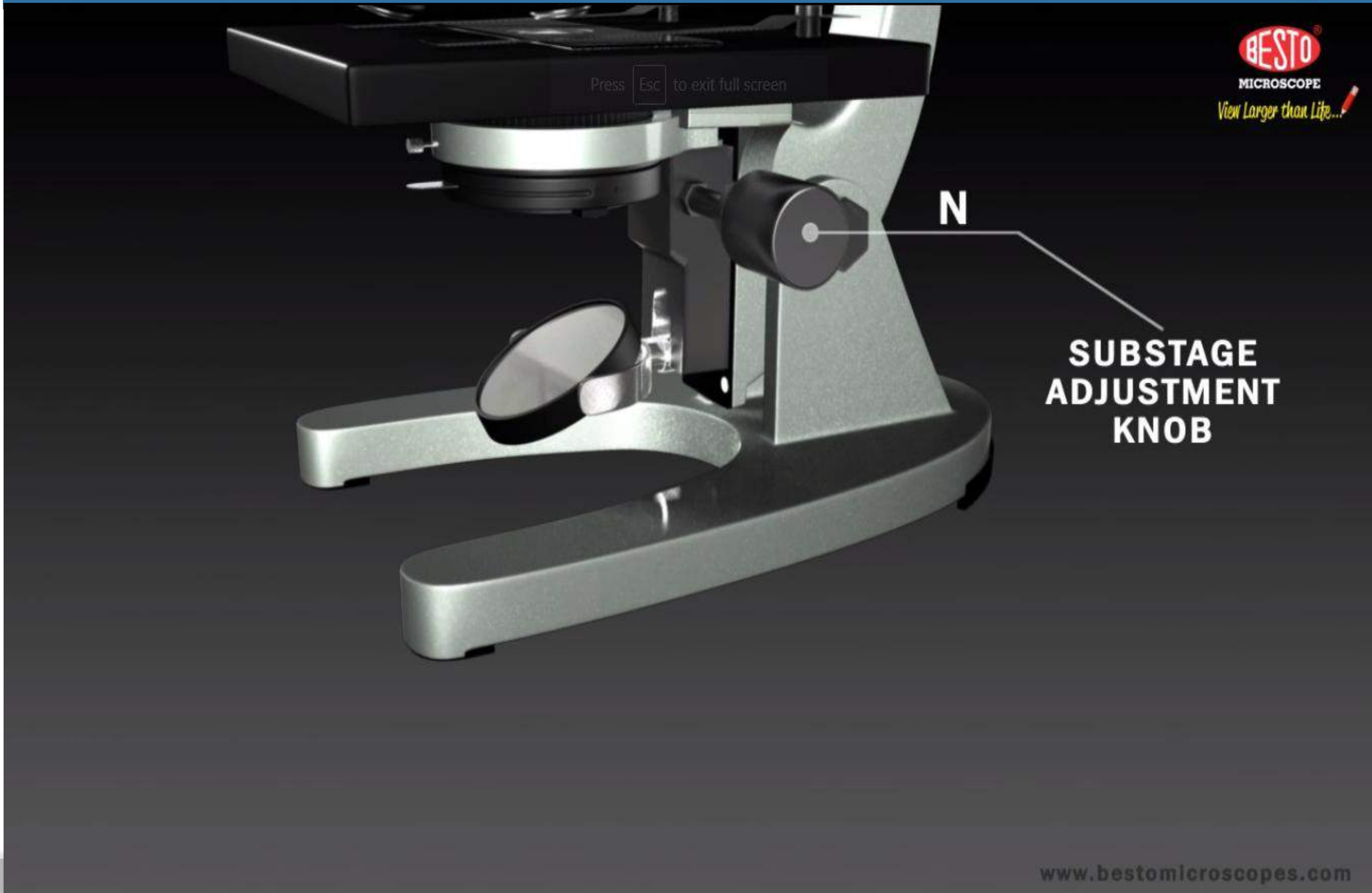
Press Esc to exit full screen
N
SUBSTAGE
ADJUSTMENT
KNOB
BESTO
MICROSCOPE
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Collimator

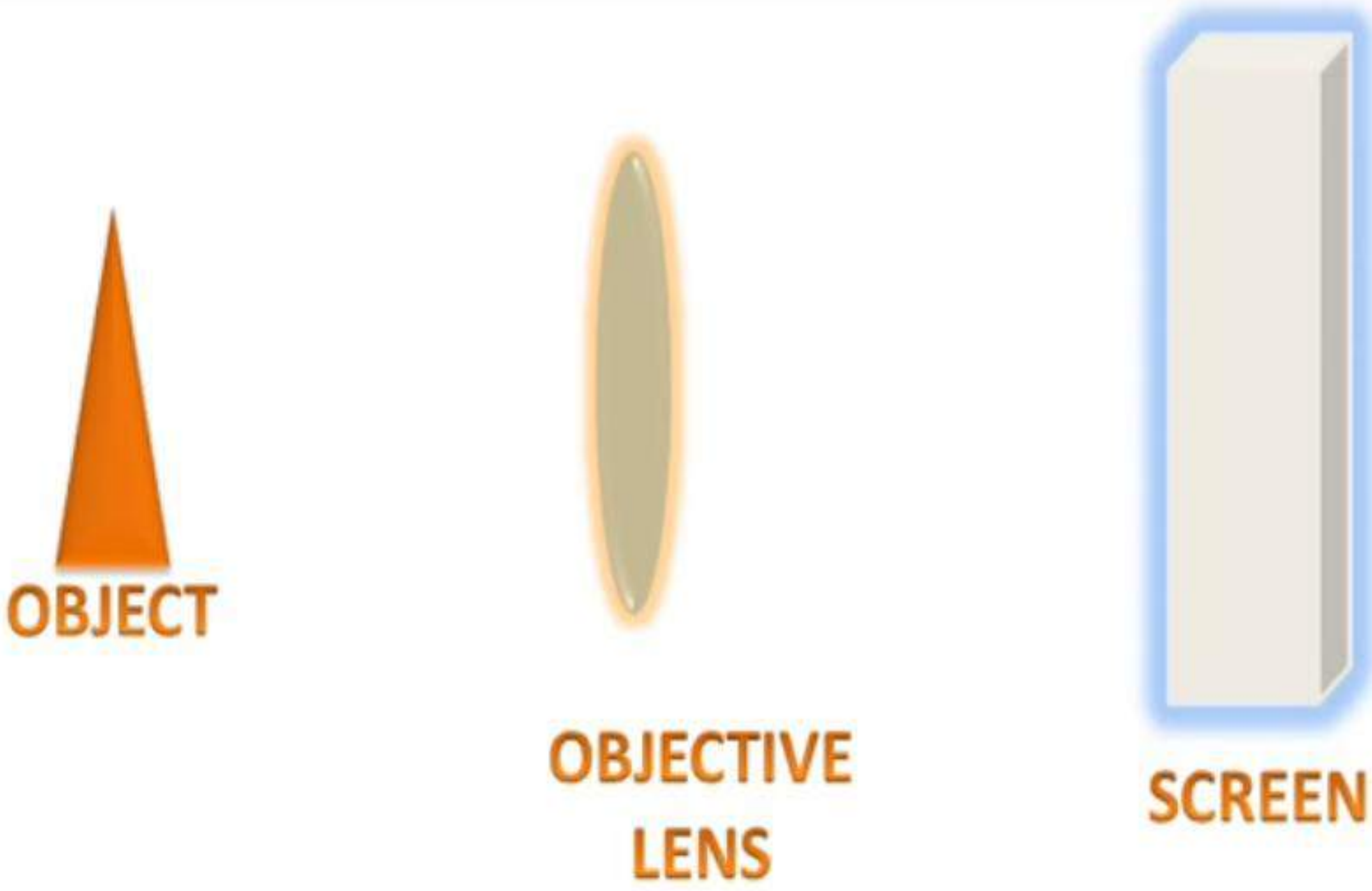
- An optical device that generates a parallel beam of light. Often used to compensate for laser beam divergence.

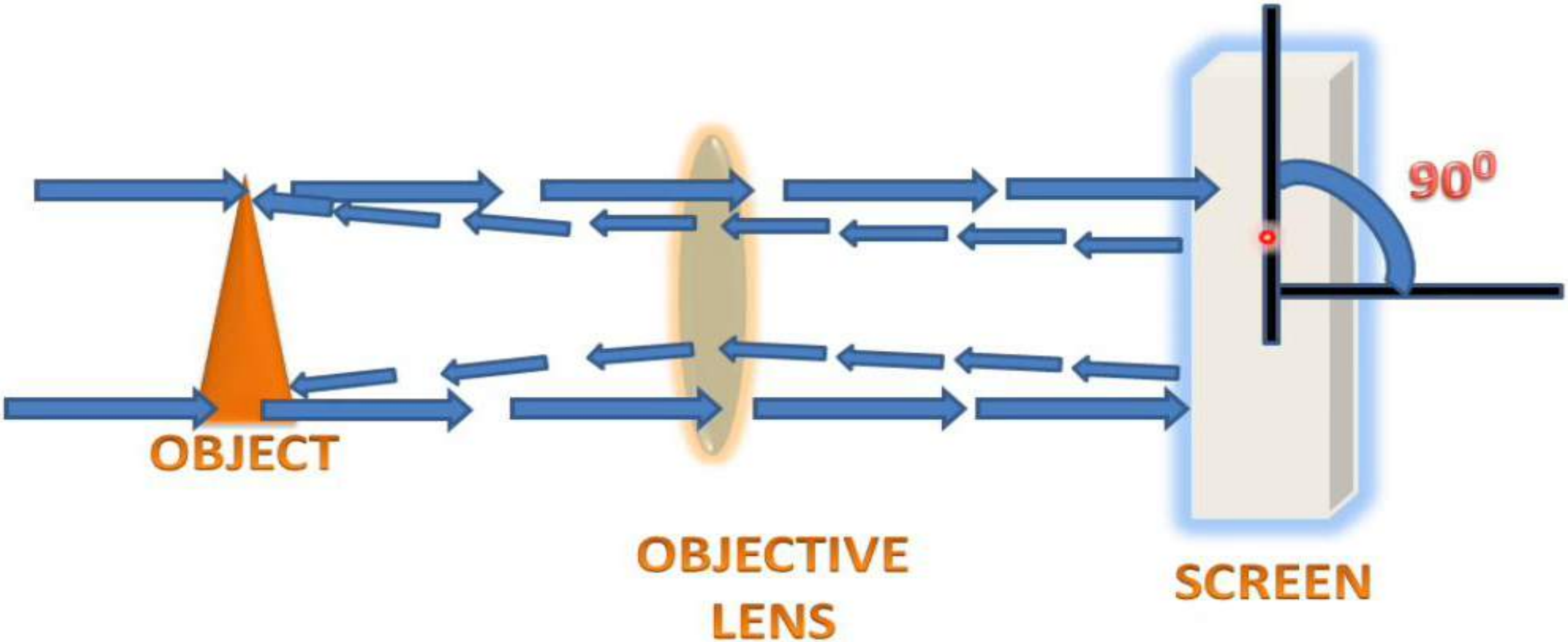
- A similar device that produces a parallel beam of particles such as neutrons.

- A small telescope attached to a larger one, used to point it in the correct general direction.

Autocollimator

- **It is an optical angular measuring instruments**
- **Used for non contact measurement of small angles with very high sensitivity**
- **It has high accuracy**


OBJECT
OBJECTIVE
LENS
SCREEN



90⁰
OBJECT
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LENS
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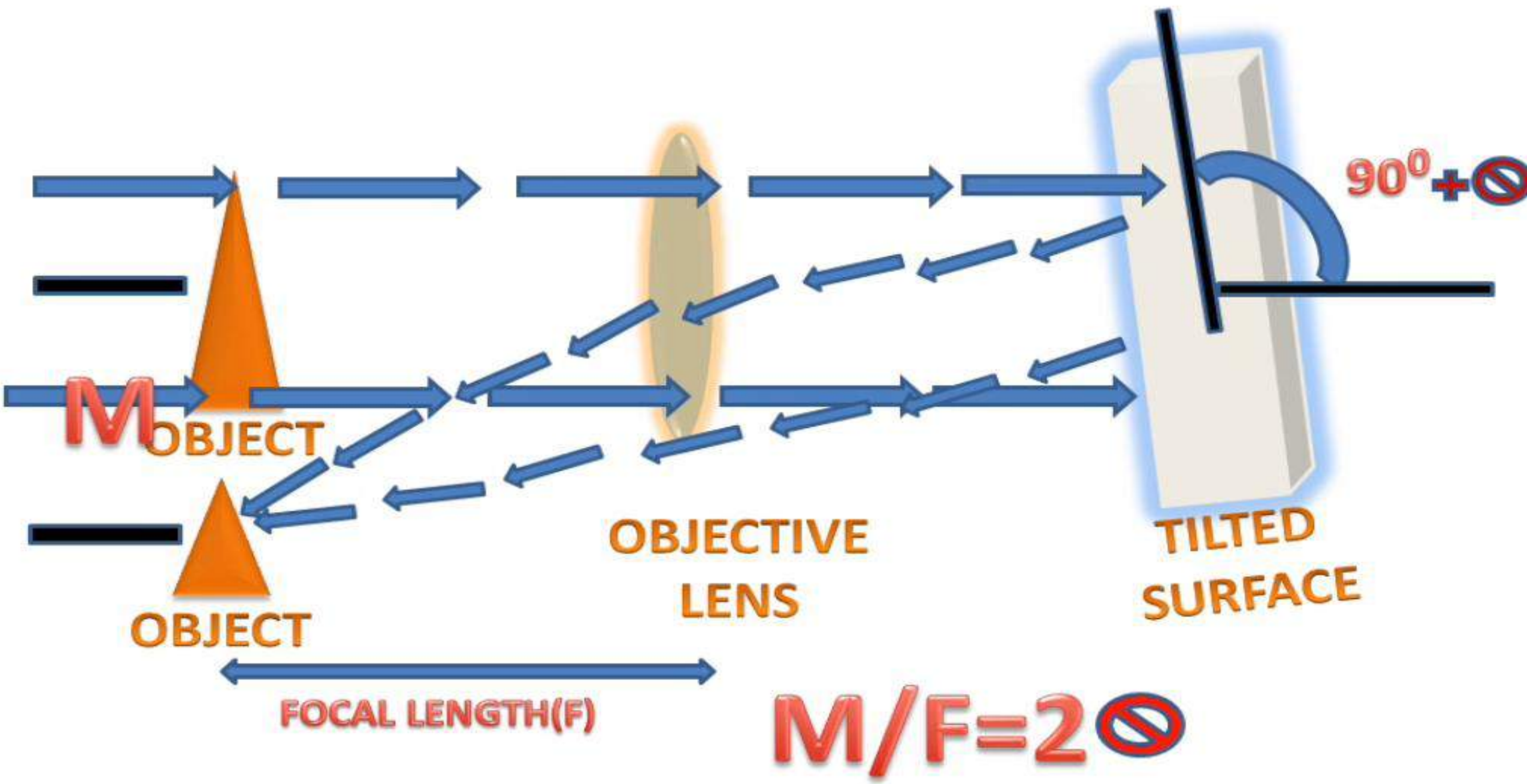
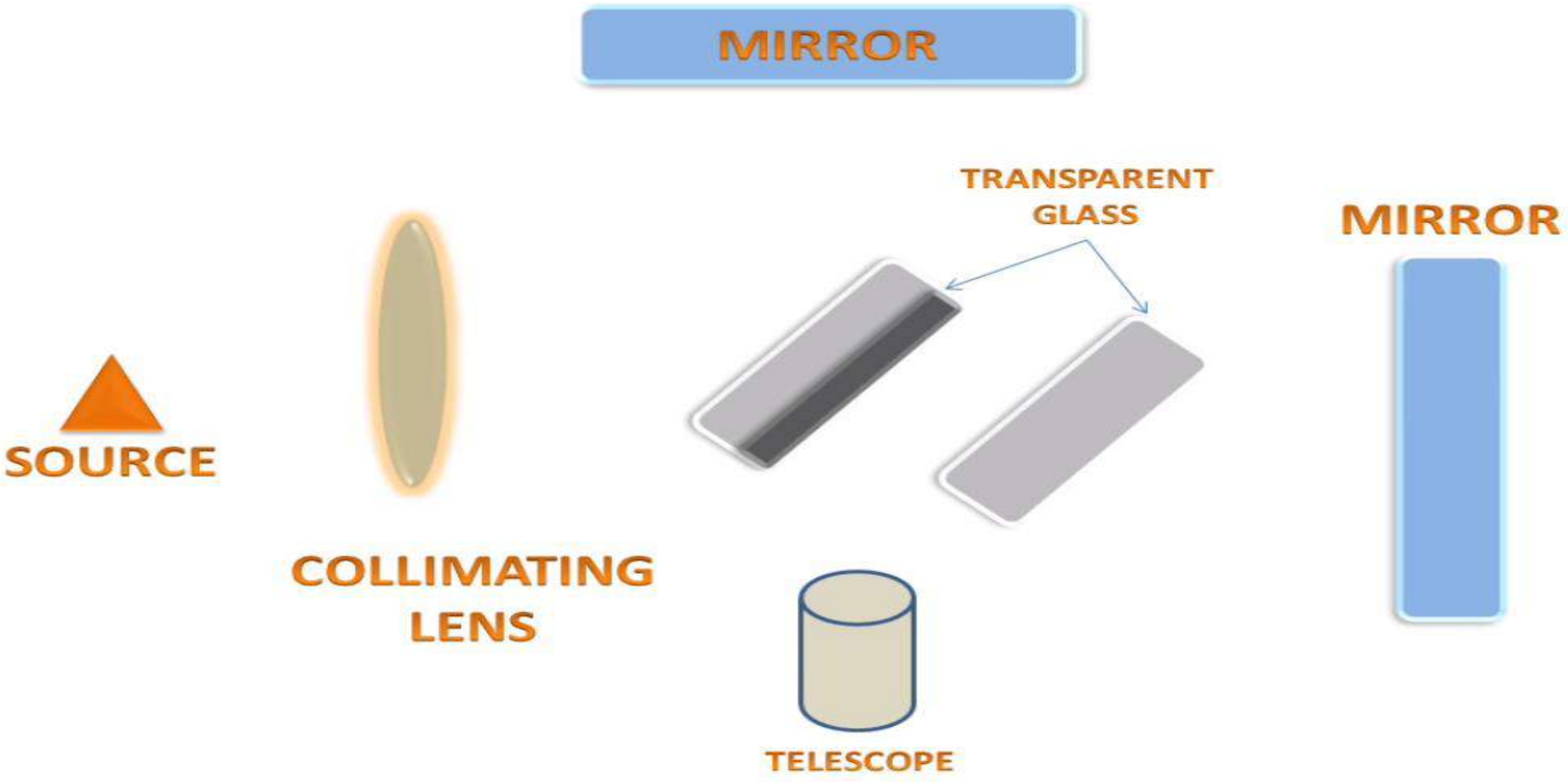
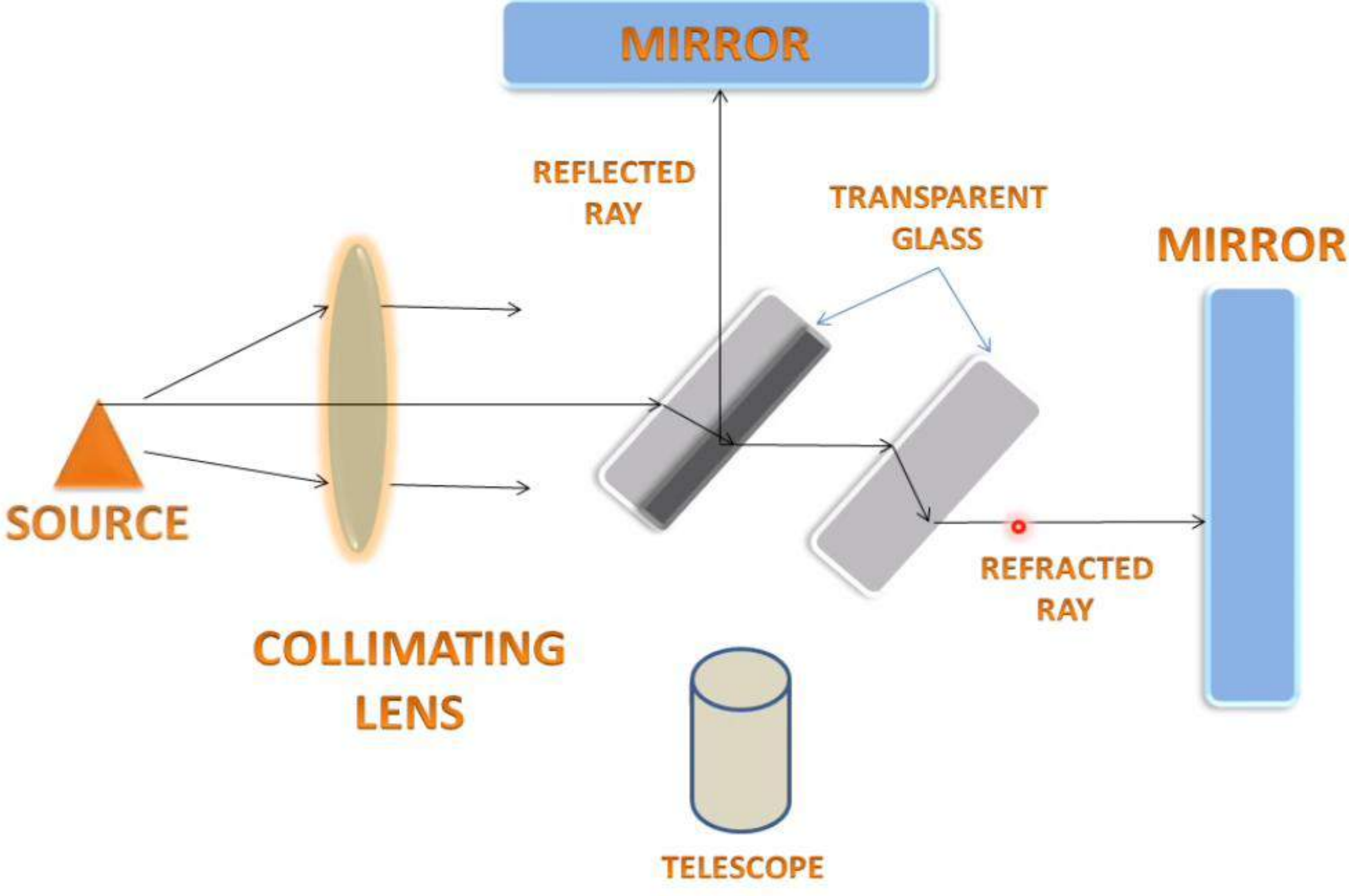


M
OBJECT
OBJECT
OBJECTIVE
LENS
TILTED
SURFACE
FOCAL LENGTH(F)
M/F=2⊘

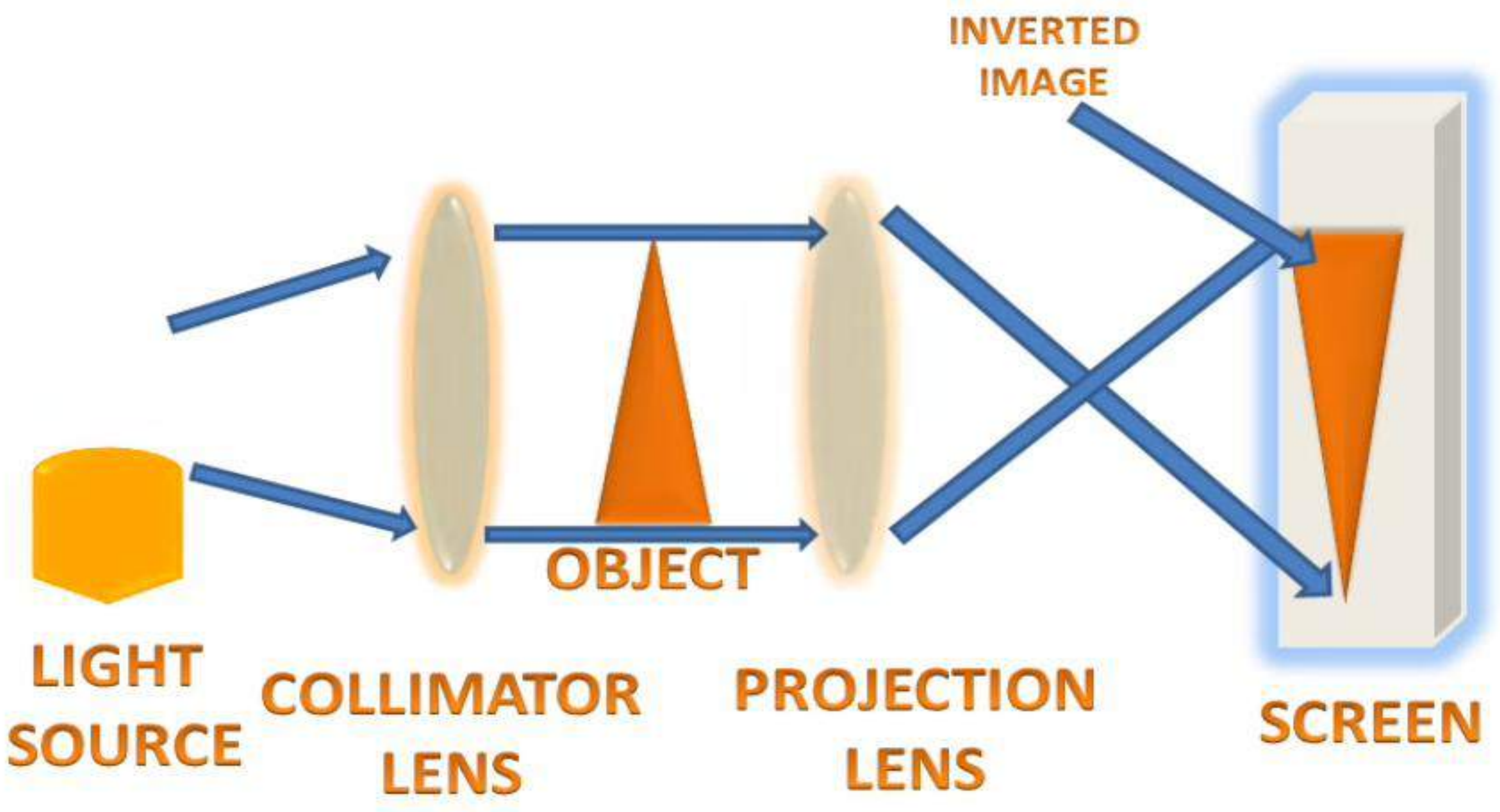
Interferometer

Used to study fine structure of spectral lines to determine wavelength of monochromatic light




MIRROR
REFLECTED
RAY
TRANSPARENT
GLASS
MIRROR
SOURCE
REFRACTED
RAY
COLLIMATING
LENS
TELESCOPE

OPTICAL PROJECTOR




Thank You!