MODULE – 1

LESSON CONTENTS:

Introduction to Metal cutting: Orthogonal and oblique cutting. Classification of cutting tools: single, and multipoint; tool signature for single point cutting tool. Mechanics of orthogonal cutting; chip formation, shear angle and its significance, Merchant circle diagram. Numerical problems. Cutting tool materials and applications.

Introduction to basic metal cutting machine tools: Lathe- Parts of lathe machine, accessories of lathe Machine and various operations carried out on lathe. Kinematics of lathe. Turret and Capstan lathe.

1.1 INTRODUCTION TO METAL CUTTING

- Metal Cutting is a process of removing (cutting) a layer of material from a metal blank by means of a tool, which is harder than the metal being cut.
- This process is most important because almost all products get their final shape and size directly or indirectly by machining.
- Its major drawback is that in this process there is a lot of material lost in the form of chips.

1.2 MECHANICS OF CHIP FORMATION

- A wedge-shaped tool is made to move relative to the workpiece.
- As the tool makes contact with the workpiece it exerts pressure on it resulting in compression of the metal near the tool tip.
- This induces shear − type deformation within the metal and it starts moving upward along the face of the tool.
- As the tool advances this process of shearing goes on increasing and material is removed.

1.3 Orthogonal Cutting and Oblique Cutting

The Process of Metal Cutting is classified into two types,

a) Orthogonal Cutting
b) Oblique Cutting

Orthogonal Cutting

- It is a type of cutting operation in which the cutting edge of the tool is straight and perpendicular to the direction of work or tool travel.
- It is also referred as 2-D cutting operation. Only two components of cutting force acts on the tool and both are perpendicular to each other.
- The chip does not flow to either side, but flows over the tool face.
- The drawback of this type of cutting is shorter tool life.

- This is because, for the same feed and depth of cut, the force which shears the metal acts on a smaller area thereby reducing the life of cutting tool.

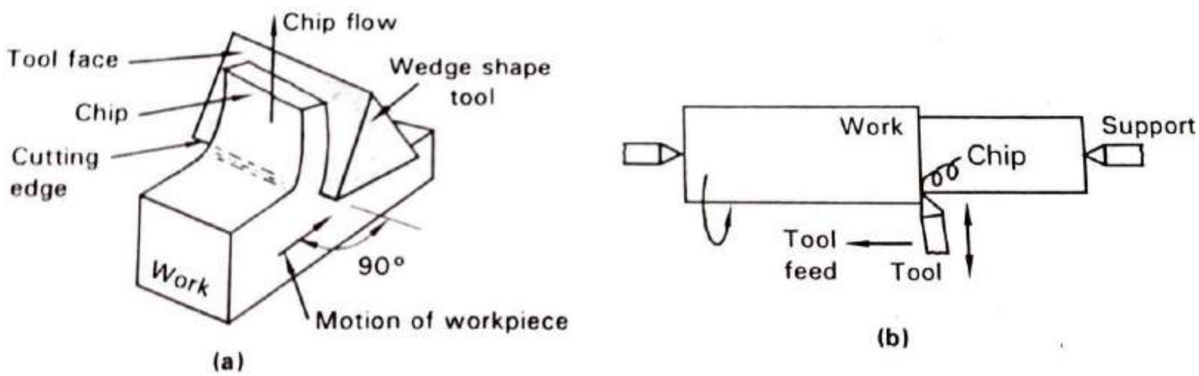

Fig. Orthogonal cutting

Oblique Cutting

- It is a type of cutting operation in which the cutting edge of the tool is straight and inclined to the direction of work or tool travel.
- It is also referred as 3-D cutting operation. Three components of cutting force acts at the cutting edge and they are mutually perpendicular to each other.
- The chip flow across the tool face with a side-ways movement producing a helical form of chip.
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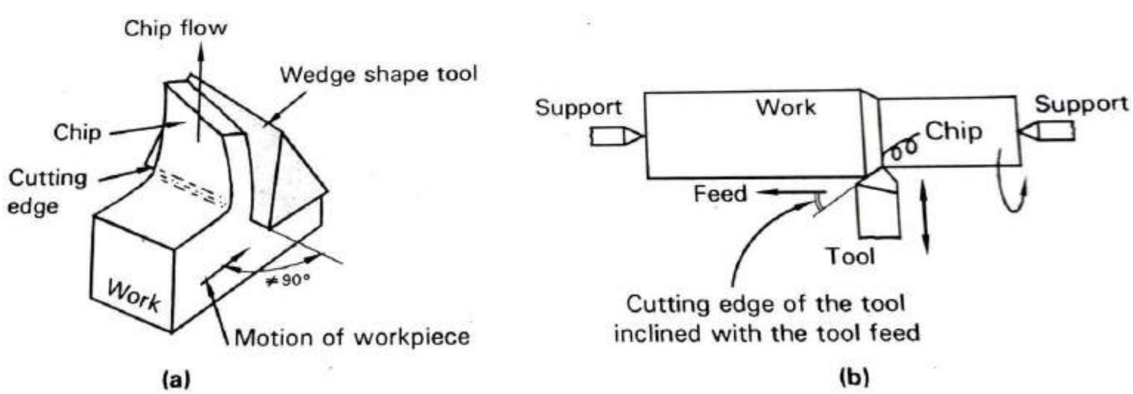


Fig. Oblique cutting

1.3.1 Comparison between Orthogonal and oblique cutting

Sl. No.	Orthogonal metal cutting	Oblique metal cutting
1	Cutting edge of the tool is perpendicular to the direction of tool travel.	The cutting edge is inclined at an angle less than 90^o to the direction of tool travel.
2	The direction of chip flow is perpendicular to the cutting edge.	The chip flows on the tool face making an angle.
3	The chip coils in a tight flat spiral	The chip flows sideways in a long curl.
4	For same feed and depth of cut the force which shears the metal acts on a smaller area. So, the life of the tool is less.	The cutting force acts on larger area and so tool life is more.
5	Produces sharp corners.	Produces a chamfer at the end of the cut
6	Smaller length of cutting edge is in contact with the work.	For the same depth of cut greater length of cutting edge is in contact with the work.
7	Generally parting off in lathe, broaching and slotting operations are done in this method.	This method of cutting is used in almost all machining operations.

1.4 Classification of cutting tools

Cutting tools are classified into two types based on the number of cutting edges they possess.

- **Single point cutting tool** is the simple type consisting of a single effective cutting edge that removes the excess material from the workpiece. Example: Lathe Tools (chamfering tool, parting tool, facing tool etc), Shaper Tools, Planar Tools, Boring Tools etc., are single point cutting tools.
- **Multi point cutting tool** has more than one cutting edge and includes milling cutters, drill bit, reamers, broaches, grinding wheel.

1.4.1 SINGLE POINT CUTTING TOOL NOMENCLATURE

The important nomenclature for a single point turning tool is illustrated in figure., and listed below.

- **Tool Shank** is the main body of cutting tool, and is also the part of the tool that gripped in the tool holder.
- **Face** is the top surface of the tool over which the chip (cut material) flows during cutting.

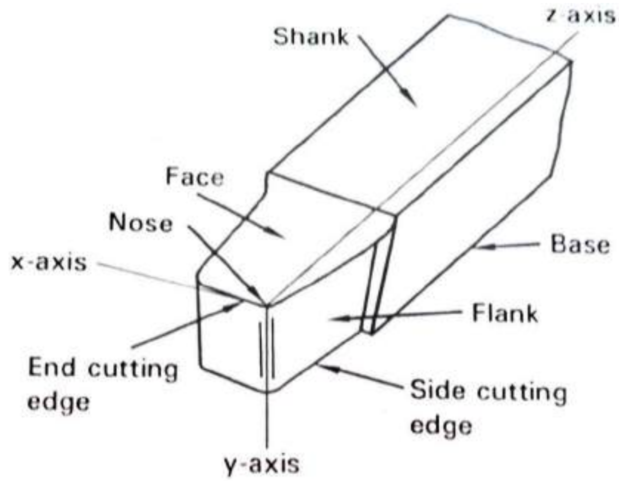


Fig. Single point cutting tool Nomenclature.

- **Cutting edge** is the portion of the face edge that separates the chip from the workpiece. The total cutting edge of the tool includes,
  - ✓ **Side cutting edge** is the primary or major cutting edge formed on the side face of the tool.
  - ✓ **End cutting edge** is the minor cutting edge formed at the end face of the tool
- **Flank** is the surface adjacent to, and below the cutting edge when the tool lies in a horizontal position.
- **Nose** is the tip of the cutting tool and is formed by the intersection of the side cutting edge and the end cutting edge.
- **Nose radius** is the radius of the nose of the cutting tool. It is a very important parameter, since it gives strength to the cutting tip, increases tool life, and gives a fine surface finish on the workpiece.

Cutting Tool Geometry

The cutting tool can perform its function efficiently, when it is ground to the correct shape and with correct angles. Tool geometry refers to the various angles provided on the cutting tool. Figure., below shows a single point cutting tool with various geometric elements marked on it.

- **Side cutting edge angle:** Side cutting edge angle is the angle between straight cutting edge on the side of tool and the side of the shank (longitudinal axis {z-axis}). It is responsible for turning the chip away from the finished surface.
- **Side relief angle** is the angle that prevents the interference as the tool enters the material. It is incorporated on the tool to provide relief between its flank and the workpiece surface.

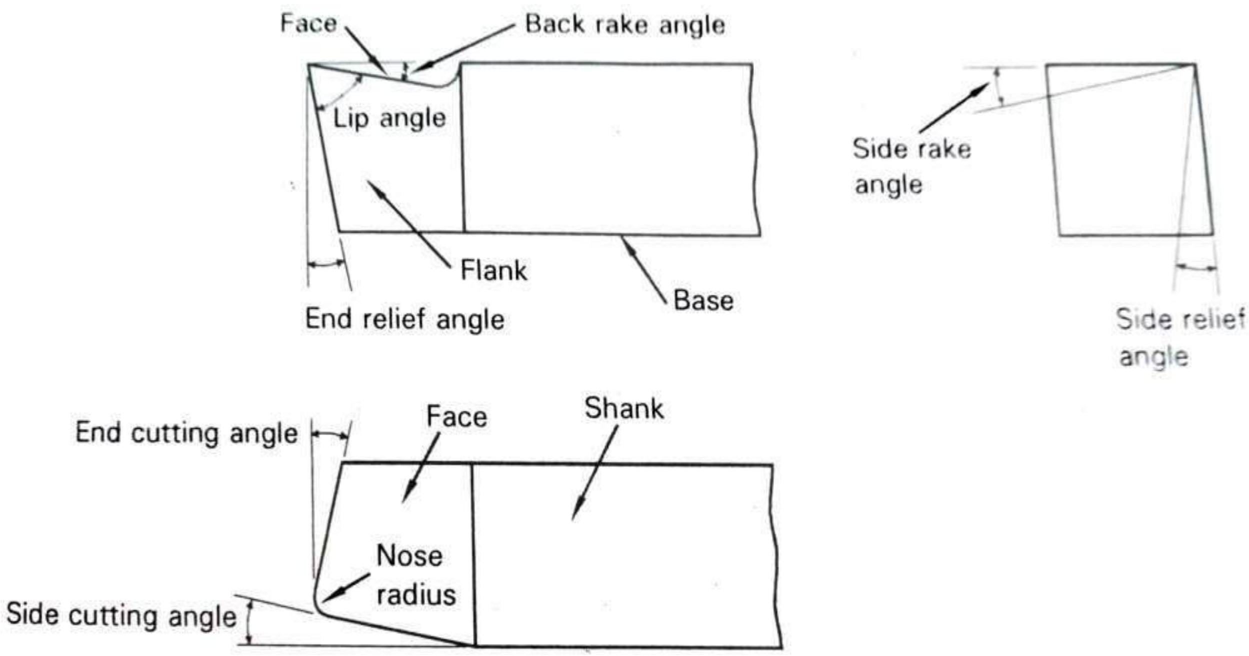


Fig. Geometry of single point cutting tool (3-Principal views)

- **End cutting edge angle**: End cutting edge angle is the angle between the end cutting edge and a line perpendicular to the shank of the tool. It provides clearance between tool cutting edge and workpiece.
- **End relief angle**: End relief angle is defined as the angle between the portion of the end flank immediately below the cutting edge and a line perpendicular to the base of the tool, measured at right angles to the flank. End relief angle allows the tool to cut without rubbing on the workpiece.
- **Lip angle**: It is the angle between the tool face and the ground end surface of the flank. Lip angle is maximum when clearance and rake angle are minimum.
- **Rake angle** is the inclination of the face (top surface) of the tool with respect to the horizontal reference surface. Rake angle can be zero (neutral), positive or negative as shown in figure., below.

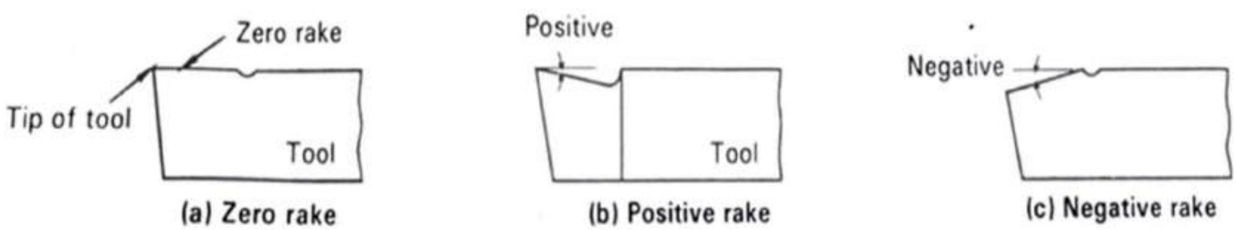


Fig. Types of rake angle

- ✓ **Back Rake angle**: Back rake angle is the angle between the face of the single point cutting tool and a line parallel with base of the tool measured in a perpendicular plane through the side cutting edge. If the slope face is downward toward the nose, it is negative back rake angle and if it is upward toward nose, it is positive back rake angle. Back rake angle helps in removing the chips away from the workpiece.
- ✓ **Side rake angle**: Side rake angle is the angle by which the face of tool is inclined sideways. Side rake angle is the angle between the surface the flank immediately below the point and the line down from the point perpendicular to the base. Side rake angle of cutting tool determines the thickness of the tool behind the cutting edge. It is provided on tool to provide clearance between workpiece and tool so as to prevent the rubbing of workpiece with end flake of tool.
- ✓ **Zero (neutral) rake angle:** When the of the cutting tool is flat or horizontal as shown in fig. (a) above, the tool is said to contain a zero rake.
- ✓ **Positive rake angle:** When the factor of the tool is so ground that it slopes downwards from the tip of the tool as shown in fig. (b) above, the tool said to contain a positive rake. Positive rake angle helps in the formation of continuous chip in ductile materials and contributes in avoiding the formation of built-up-edge chip.
- ✓ **Negative rake angle:** When the face of the cutting tool slopes upwards from the tip of the tool as shown in fig. (c) above, the tool said to contain a negative rake. Cutting tools with negative rake angle are stronger making them suitable for machining high strength materials; for taking interrupted cuts, and machining with high feeds.

1.4.2 Designation of Cutting Tools (Tool Signature)

The tool is designated to denote a standardized system of specifying the principal tool angles of a single point cutting tool. This designation is termed as tool signature.

There are two systems used to designate the cutting tool:

i). ASA- (American Standard Association) System or ANSI (American National Standard Institute)

ii). ORS - (Orthogonal Rake Angle) System

i) ASA- (American Standard Association) System

In the ASA System, the various tool angles are specified independently of the position of the cutting edge. The three planes of reference and the coordinates are chosen based on the configuration and axis of the machine tool concerned.

Tool signature of a tool as ***10,9,6,5,8,7,2mm*** represents:

a) Back rake angle = 10°
b) Side rake angle = 9°
c) End relief angle = 6°
d) Side relief angle = 5°
e) End cutting edge angle = 8°
f) Side cutting edge angle = 7°
g) Nose radius = 2mm

ii) ORS - (Orthogonal Rake Angle) System

In the ORS System, the various tool angles are specified with reference to position of the cutting edge. The planes of reference and the coordinates are chosen based on the configuration of cutting tool.

Tool signature of a tool as ***5, 10,6,6,5,90,1mm*** represents:

a) Angle of inclination = 5°
b) Normal rake angle = 10°
c) Side relief angle = 6°
d) End relief angle = 6°
e) End cutting edge angle = 5°
f) Approach angle = 90°
g) Nose radius = 1mm

1.5 Mechanics of Orthogonal Cutting

- When the cutting tool is forced to move against the work piece, the tool exerts a compressive force on the work piece.
- The material of the work piece is stressed beyond its yield point causing it to deform plastically and shear off.

- The sheared portion of the metal begins to flow along the cutting tool face in the form of small pieces called chips.
- Work is done by the tool on the work piece, and more than 90% of the energy is transformed into heat.
- The heat is concentrated near the tip of the tool, and as a result, in some cases causes the chips to weld to the cutting tool.
- Hence, the cutting force, heat and wear of the tool form the basic features of the metal cutting.

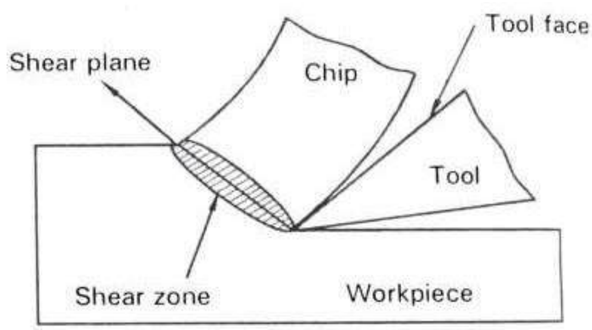


Fig. Mechanics of machining

1.6 Mechanics of chip formation (Chip formation process)

In the process of metal cutting, as the cutting tool moves forward, the tool removes the work piece metal along the shear plane in the form of chips.

Three different types of chips are formed:

a) Continuous chips
b) Continuous chips with built-up-edges (BUE)
c) Discontinuous chips

a) Continuous chips:

- When the work piece material is ductile fracture will not occur in the shear plane, and the chip comes off in the form of a long string or ribbon like shining surface. These are called continuous chips. Shown in Fig. **a1**
- Continuous chips are desirable, as it creates smooth finish on the work piece, absorb less energy/power, create less machining noise and enhances tool life.
- To solve these problems, turning tools are often equipped with chip breakers. Shown in Fig. **a2**

The various cutting conditions resulting in the formation of Continuous chip includes:

- ✓ Work piece material is ductile.
- ✓ Large rake angle is provided on the tool.
- ✓ Fine feed and high cutting speeds are selected during cutting.
- ✓ Efficient coolants are used.

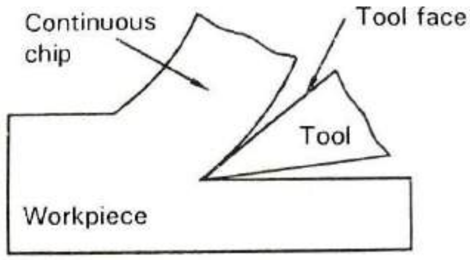


Fig.a1) Continuous Chip

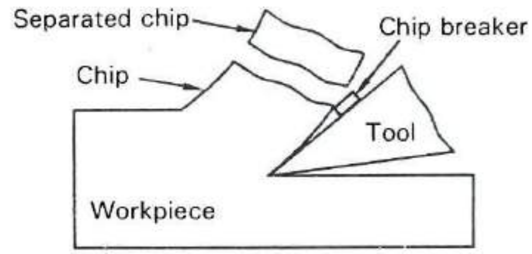


Fig.a2) Use of chip breaker

b) Continuous chips with built-up-edges (BUE)

- During machining tough steels such as alloy steels, tool steels etc., larger cutting forces are required.
- This produces a lot of heat at the tool-work interface.
- The high heat generated causes the compressed metal adjacent to the tool nose to get welded to it in the form of metal lumps.
- The extra metal welded to the nose or point of the tool is called built- up-edge.
- As the chip slides up the tool, the built-up-edge is broken and carried away with the chip, while rest of it adheres to the surface of the work piece making it rough. Shown in Fig. **b.**
- Thus, the formation of BUE must be reduced and this is achieved by circulating a proper cutting fluid at the cutting zone during machining.

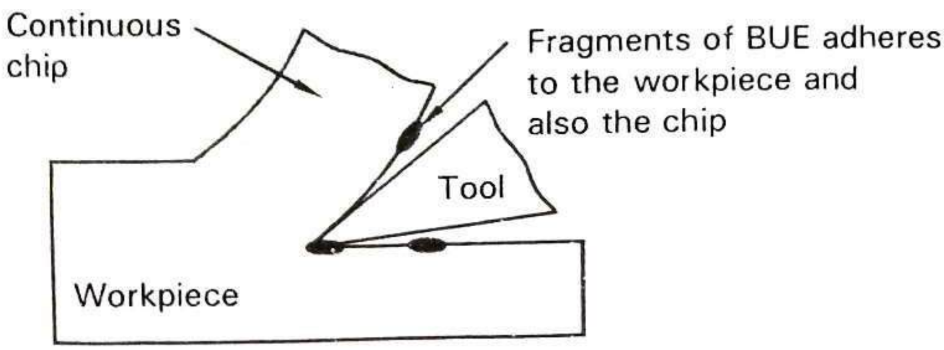


Fig. b) Continuous chip with BUE

The various cutting conditions resulting in the formation of built-up-edge includes:

- ✓ Cutting tool provided with low rake angle.
- ✓ Low cutting speeds imparted during cutting.
- ✓ Imparting high depth of cuts
- ✓ Rough surface of cutting tool
- ✓ Insufficient circulation of cutting fluid.

c) Discontinuous chips

- When cutting brittle materials like Cast iron, bronze etc., the work piece material along the shear plane will periodically fracture producing a segment of the chip. This type of chip is called Discontinuous chips. Shown in Fig. c.
- The primary reason for the formation of such chips in brittle materials is the fact that, the binding strengths for metal grains are not very strong, and as such, the metal easily shears before it elongates.

The various cutting conditions resulting in the formation of discontinuous chips includes:

- ✓ The work piece material is brittle.
- ✓ Small rake angle is provided on the tool.
- ✓ Coarse feeds and low speeds are selected during cutting.

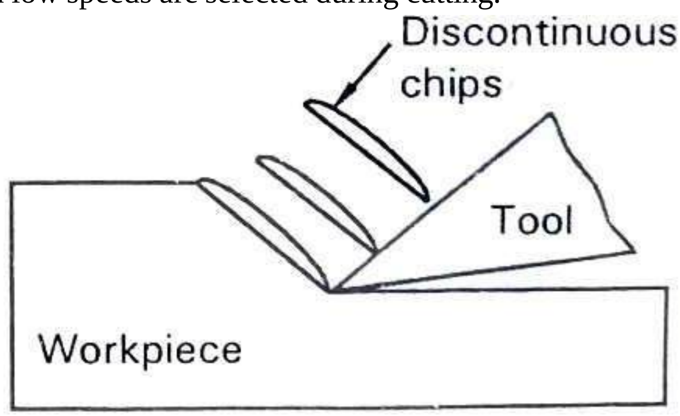


Fig. c) Discontinuous chips

1.7 MERCHANT'S MODEL FOR ORTHOGONAL CUTTING

- During metal cutting process, various forces act on the cutting tool and flowing chip.
- It is desirable to know the value of these forces, since it helps to calculate the power required for operating the machine tool; design and stiffness, etc.; for machine tolerances; whether the workpiece is capable of withstanding the cutting pressure, and other relevant information.
- Merchant circle diagram is used to analyse the forces acting in metal cutting.

- The analysis of three forces system, which balance each other for cutting to occur. Each system is a triangle of forces.

The relationship among the various forces was established by Merchant with the following assumptions:

- ✓ The tool is perfectly sharp and there is no contact between the workpiece and tool flank.
- ✓ The width of the cutting tool is greater than that of the workpiece.
- ✓ Only continuous type of chip is produced.
- ✓ There is no sideways flow of chip.
- ✓ Cutting velocity remains constant.
- ✓ The depth of cut is constant.
- ✓ Inertial forces of the chip are neglected.

MERCHANT’S CIRCLE DIAGRAM & ANALYSIS

- Merchant suggested a compact and a convenient way of representing the forces inside a circle, whose diameter represents the resultant F_R of all the various forces acting on the chip. The resultant diagram is called *Merchant’s circle diagram* and is shown in figure. below.
- The relationship between the various forces acting on the cutting tool is derived as follows:
  - Let α = Rake angle and ϕ = Shear angle
  - β = Friction angle
  - F_f = Frictional force along tool face
  - F_n = Normal force to the tool face
  - Therefore, $F_f = \mu F_n$ where μ = co-efficient of friction between the tool-chip interface
  - F_s = Shear force
  - F_{ns}= Force normal to the shear force.
  - F_c = Horizontal cutting force exerted by the tool on the workpiece.
  - F_t = Thrust force, or vertical force.
  - F_R = Resultant force acting at the tool cutting edge.
  - t_1 = chip thickness before cutting
  - t_2 = chip thickness after cutting

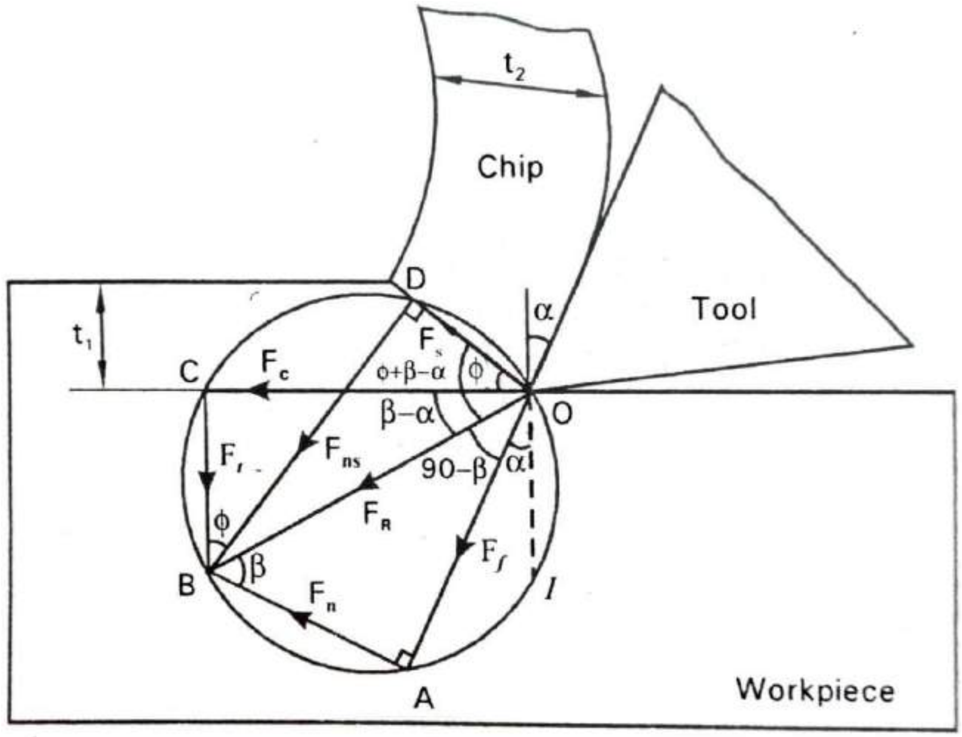


Fig. a) Merchant's circle diagram showing various angles

To draw Merchant's Circle diagram formula for finding angle are given below

<u>To find</u>

Angle AOB =?

Angle ABO = β

Angle BAO = 90^o

From triangle ABO,

Total angle of triangle ABO = Angle AOB + Angle BAO+ Angle ABO

$$180^o = \text{Angle AOB} + 90^o + \beta$$

$$180^o - 90^o - \beta = \text{Angle AOB}$$

$$\text{Angle AOB} = 90^o - \beta$$

<u>To find</u>

Angle BOC = ?

Angle BOD = ?

From Triangle BOC

Angle BOC =?

From the figure above

Angle IOC = 90^o

Angle IOA = α

Angle AOB = $90^o - \beta$

From the figure above

Angle IOC = Angle IOA + Angle AOB + Angle BOC

∴ Angle BOC = Angle IOC – (Angle IOA + Angle AOB)

∴ Angle BOC = $90^o - [\alpha + (90^o - \beta))$

∴ Angle BOC = $90^o - \alpha - 90^o + \beta$

∴ Angle BOC = $\beta - \alpha$

<u>To find</u>

Angle BOD = ?

From Triangle BOD

∴ Angle BOD = Angle COD + Angle BOC

∴ Angle BOD = $\phi + (\beta - \alpha)$

∴ Angle BOD = $\phi + \beta - \alpha$

From Figure above
Angle COD = ϕ
Angle BOC = $\beta - \alpha$

To find F_c and F_t :

From triangle BOC,

$$\cos(\beta - \alpha) = \frac{F_c}{F_R} \qquad \therefore F_c = F_R \cos(\beta - \alpha) \text{ ----------------------------- [1]}$$

Also,

$$\sin(\beta - \alpha) = \frac{F_t}{F_R} \qquad \therefore F_t = F_R \sin(\beta - \alpha) \text{ -------------------------------- [2]}$$

To find F_s and F_{ns} :

From triangle OBD,

$$\cos(\phi + \beta - \alpha) = \frac{F_s}{F_R} \qquad \therefore F_s = F_R \cos(\phi + \beta - \alpha) \text{ ---------------- [3]}$$

Also,

$$\sin(\phi + \beta - \alpha) = \frac{F_{ns}}{F_R} \qquad \therefore F_{ns} = F_R \sin(\phi + \beta - \alpha) \text{ --------------- [4]}$$

To find F_f and F_n :

Note: F_f and F_n must be expressed in terms of cutting force (F_c) and thrust force (F_t).
The Merchants circle diagram is re-constructed as shown in **Fig. b)**

- Extend the line AB to a short distance.
- From O, draw a line OR parallel to AB. Extend OR to a short distance.
- From point C, draw a line parallel to OA to cut the extended lines at M & N.

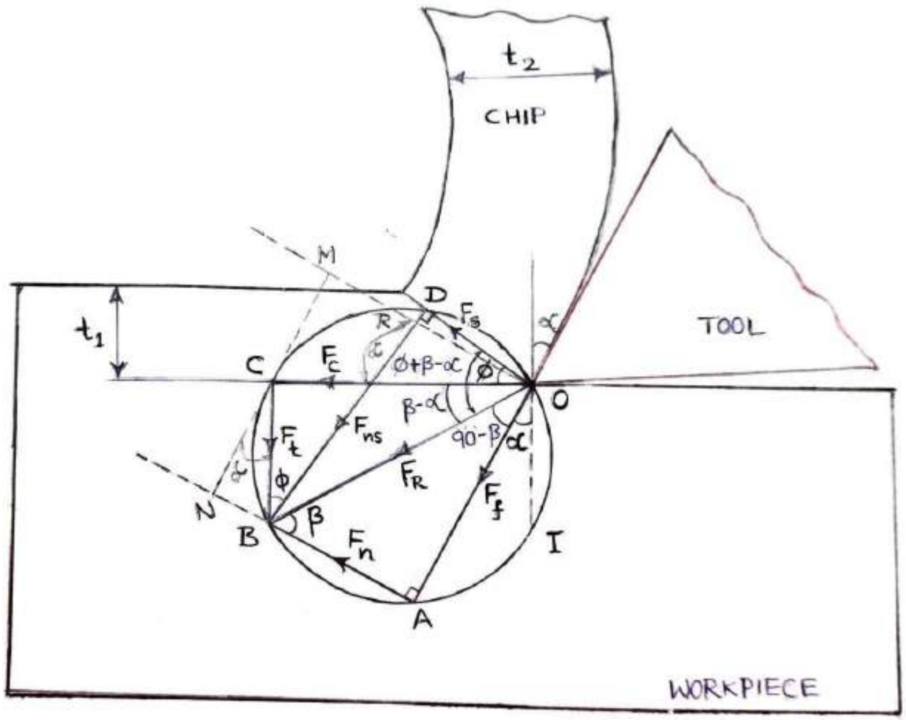


Fig. b) Reconstructed Merchant's circle diagram

To find F_f :

From the diagram

$F_f = OA = MN$ $\therefore F_f = MN = MC + CN$ ---------------- [5]

But $MC = ?$ & $CN = ?$

To find *MC* :

From triangle MCO, $\sin \alpha = \frac{MC}{OC} = \frac{MC}{F_c}$

$\therefore MC = F_c \sin \alpha$ ---[6]

To find *CN* :

From triangle CNB, $\cos \alpha = \frac{CN}{CB} = \frac{CN}{F_t}$

$\therefore CN = F_t \cos \alpha$ ---[7]

Equation [6] and [7] in [5] gives,

$$F_f = F_c \sin \alpha + F_t \cos \alpha \text{ --[8]}$$

To find F_n :

Now, from the diagram

$$F_n = AB = OR \qquad \text{or} \qquad \therefore\ F_n = OR = OM - MR \text{ --------------- [9]}$$

But $OM = ?$ & $MR = ?$

From triangle OMC, $\cos\alpha = \frac{OM}{OC} = \frac{OM}{F_c}$

$$\therefore\ OM = F_c \cos\alpha \text{ --- [10]}$$

To find *MR* : From figure *MR* =*NB*

From triangle CNB, $\sin\alpha = \frac{NB}{CB} = \frac{NB}{F_t}$

$$\therefore\ NB = F_t \sin\alpha \qquad [MR = NB]$$

$$\therefore\ MR = F_t \sin\alpha \text{ -- [11]}$$

Equation [11] and [10] in [9] gives,

$$F_n = F_c \cos\alpha - F_t \sin\alpha \text{ ---[12]}$$

To calculate co-efficient of friction (μ)

w.k.t $F_f = \mu\ F_n \qquad \therefore\ \mu = \frac{F_f}{F_n}$ -----------[13]

Substituting [12] and [8] in [13], we get

$$\mu = \frac{F_c \sin\alpha + F_t \cos\alpha}{F_c \cos\alpha - {}_t \sin\alpha}$$

Thus the Merchant's diagram helps to calculate all the forces involved in metal cutting. Summarizing the results, we have the following.

$F_c = F_R \cos(\beta - \alpha)$

$F_t = F_R \sin(\beta - \alpha)$

$F_s = F_R \cos(\phi + \beta - \alpha)$

$F_{ns} = F_R \sin(\phi + \beta - \alpha)$

$F_f = F_c \sin\alpha + F_t \cos\alpha$

$F_n = F_c \cos\alpha - F_t \sin\alpha$

$$\mu = \frac{F_f}{F_n} = \frac{F_c \sin\alpha + F_t \cos\alpha}{F_c \cos\alpha - F_t \sin\alpha}$$

1.8 SHEAR ANGLE

- Shear angle is the inclination of the shear plane with respect to the direction of tool travel or from the direction of the cutting velocity as shown in figure below.
- A higher shear angle results in a smaller shear plane area.
- Since the shear strength is applied across this area, the shear force required to form the chip will decrease when the shear plane area is decreased.
- This tends to make machining easier to perform, and also lower cutting energy and cutting temperature.
- The shear angle can be increased by increasing the tool rake angle.
- However, the effects of increasing rake angle must be considered accordingly.
- Shear angle thus forms a complex parameter in metal cutting operations

<u>Shear angle (ϕ) relationship in terms of chip thickness ratio (r) and rake angle (α)</u>

Consider the chip formation process as shown in figure below. The various angles are marked thereon.

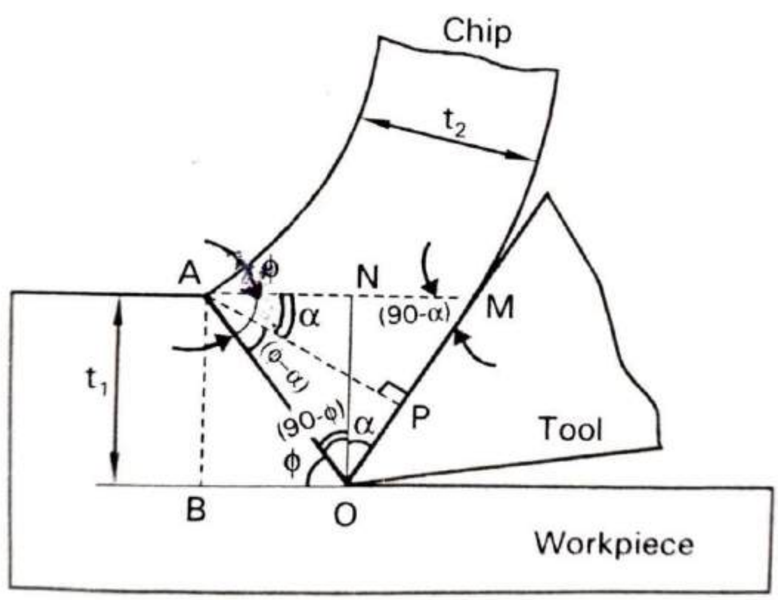


Fig. Chip formation processes

In figure above to find Angle OMN =?

<u>From Triangle OMN</u>

Angle ONM = 90^o

Angle NOM = α

Total angle of Triangle OMN = Angle OMN + 90^o + α

180^o = Angle OMN + 90^o + α

Angle OMN = $\mathbf{90^o - \alpha}$

From Triangle AOB;   Angle AOB = ϕ ;   **∴ Angle OAM = ϕ**

In figure above to find Angle PAM=?
From Triangle PAM

Angle APM = 90^o

Angle AMP = $90^o - \alpha$

Total angle Triangle PAM = Angle PAM + 90^o + ($90^o - \alpha$)

180^o = Angle PAM + 90^o + $90^o - \alpha$

Angle PAM = α

Let

- t_1 = chip thickness before cutting
- t_2 = chip thickness after cutting

The initial feed given during machining is taken as chip thickness before cutting)

- α = Rake angle
- ϕ = Shear angle

$$r = \text{Chip thickness ratio} = \frac{t_1}{t_2} < 1 \text{ --------------------- [1]}$$

From triangle OAB,

$$\sin\phi = \frac{AB}{A0} \qquad \therefore AO = \frac{AB}{\sin\phi} = \frac{t_1}{\sin\phi} \qquad \text{------[2]}$$

From triangle PAO,

$$\cos(\phi - \alpha) = \frac{AP}{A0} = \frac{t_2}{A0} \qquad \therefore AO = \frac{t_2}{\cos(\phi - a)} \qquad \text{------[3]}$$

From equation [2] and [3], we have

$$AO = \frac{t_1}{\sin\phi} = \frac{t_2}{\cos(\phi - \alpha)}$$

$$\frac{t_1}{t_2} = \frac{\sin\phi}{\cos(\phi - a)} \qquad \text{-------- [4]}$$

But from equation[1]

$$\frac{t_1}{t_2} = r = Chip\ thickness\ ratio$$

$\therefore$ equation [4] becomes, $r = \dfrac{\sin \phi}{\cos (\phi - a)}$

w.k.t. $\cos (A - B) = \cos A . \cos B + \sin A . \sin B$

$$\therefore r = \frac{\sin \phi}{\cos \phi . \cos \alpha + \sin\phi . \sin a} \quad \text{--------- [5]}$$

Divide both sides of equation [5] by r, we have,

$$\frac{r}{r} = \frac{\sin \phi}{r . (\cos \phi . \cos \alpha + \sin\phi . \sin\alpha)}$$

$$1 = \frac{\sin \phi}{r . \cos \phi . (\cos \alpha + \frac{\sin\phi . \sin\alpha}{\cos \phi .})}$$

$$1 = \frac{\sin \phi}{r . \cos \phi . (\cos \alpha + \sin\alpha . \tan\phi)}$$

$$1 = \frac{\tan \phi}{r . (\cos \alpha + \sin\alpha . \tan\phi)}$$

$$\tan\phi = r . \cos \alpha + r . \sin\alpha . \tan \phi$$

$$\tan\phi \, (1 - r . \sin\alpha) = r . \cos \alpha$$

$$\tan\phi = \frac{r . \cos a}{(1 - r . \sin a)} \quad \text{-------- [6]}$$

Equation [6] gives the relationship between shear angle (ϕ), rake angle (α) and chip thickness ratio (r)

1.9 IMPORTANT RELATIONS

Following are a few important parameters in metal cutting

a) Chip thickness ratio (r)

The ratio of uncut chip thickness (chip thickness before cutting t_1) to chip thickness after cutting (t_2)

$$Chip\ thickness\ ratio = r = \frac{t_1}{t_2}$$

In orthogonal cutting, the width of chip equals the width of cut. Assuming specific gravityof metal to be constant, the volume of chip produced will be equal to the volume of metal cut.

$$[\textbf{width} \cdot t_1 \cdot L_1 = \textbf{width} \cdot t_2 \cdot L_2]$$

$$\text{i.e., } t_1 L_1 = t_2 L_2$$

$$\frac{t_1}{t_2} = \frac{L_2}{L_1}$$

$$Chip\ thickness\ ratio = r = \frac{t_1}{t_2} = \frac{L_2}{L_1}$$

Where L_1 = length of metal cut (uncut chip length before cutting)
L_2 = length of chip (chip length after cutting)

b) Chip reduction coefficient (k)

Chip reduction coefficient is the inverse of chip thickness ratio.

$$\text{i.e., } k = \frac{1}{r}$$

c) Power consumed (P) in turning

The power consumed by a single point cutting tool to remove excess material from the workpiece depends on the cutting force (F_c) and cutting velocity (V_C)

$$Power = P = \frac{(F_c * V_C)}{60 * 1000} \qquad (units: kW)$$

d) Specific cutting energy (P_S)

Specific energy is the power consumption per unit volume of material removed. This parameter is essential to determine the size of the driving motor in the machine tool.

$$P_s = \frac{F_c}{b \cdot f}$$

Where, b = depth of cut ($\boldsymbol{d_c}$) or width of cut(mm), f = tool feed (mm/rev) and cutting force (F_c)

INTRODUCTION TO CUTTING TOOL MATERIALS

The cutting tool is subjected to

(a) high temperatures,

(b) high contact stresses, and

(c) rubbing along the tool-chip interface and along the machined surface.

PROPERTIES / CHARACTERISTICS / REQUIREMENTS OF CUTTING TOOL MATERIALS

The material selected for cutting tool should possess the following basic properties:

- Hot or Red hardness
- Wear resistance
- Toughness
- Thermal conductivity and specific heat
- Chemical stability and inertness
- Availability and cost

- **Hot or Red hardness**: The ability of the material to resist softening at elevated temperatures is known as hot or red hardness. A cutting tool material should have high value of hardness to resist temperature generated during metal cutting.
- **Wear resistance**: The material selected for the tool should have high resistance to wear to ensure longer tool life.
- **Toughness**: Toughness describes a material's resistance to fracture. Hence, the material selected for the tool should be tough enough to withstand the external sudden shocks or impact forces without fracture.
- **Thermal conductivity and specific heat**: A tool material should have a high thermal conductivity and specific heats, because it can readily absorb the heat generated at the cutting zone and conduct it away.
- **Chemical stability and inertness**: The chemical stability and inertness with respect to the workpiece material should be high, so that any adverse reactions contributing to tool wear are avoided.
- **Availability and cost**: The material selected for the manufacture of cutting tool should be easily available and with low cost.

TYPES OF CUTTING TOOL MATERIALS

There are various cutting tool materials, each having their own characteristics and applications. A few commonly used tool materials are discussed briefly as follows:

- High Speed Steel (HSS)

- Carbides
- Coated Carbides
- Ceramics
- Cubic Boron Nitride (CBN)

HIGH SPEED STEEL (HSS):

- High speed steel is an alloyed steel with 14–22% tungsten, as well as cobalt, molybdenum, chromium, and vanadium.
- It is so called because tools manufactured from HSS materials cut about four times faster than the carbon steel tools.
- With proper heat treatment, the alloying elements play a significant role in developing high hardness, strength, and other properties necessary for the tool.

<u>There are two basic types of high-speed steels:</u>

(1) Tungsten-type HSS, designated T-type by the American Iron and Steel Institute (AISI); and

(2) Molybdenum-type HSS, designated M – type by AISI.

- T-type Category, **18-4-1** HSS in common use, containing 18% tungsten as its principal alloying ingredient. Additional alloying elements are 4% chromium, and 1% vanadium, in addition to a carbon content of 0.7%
- M-type Category, 6-6-4-2 HSS is in common use, containing 6% molybdenum, 6% tungsten, 4% chromium and 2% vanadium, in addition to a carbon content of 0.6%
- HSS have excellent hardenability and can retain their hardness up to 600 ^{0}C, but softens rapidly at higher temperatures.
- They are relatively rough and moderately priced. They can be shaped easily. As such HSS are commonly used for manufacturing drill bits, reamers, counter bore, milling cutters and many single/multiple point cutting tools and rotary tools.

CARBIDES

- Cemented tungsten carbide, often called simple carbide is the most common material used for manufacturing cutting tools. It is produced by powder metallurgy technique by sintering a combination of tungsten carbide powder with powdered cobalt.
- The material so obtained possesses high strength, toughness and hardness compared to HSS materials.
- The chief advantage of carbide versus HSS is the ability to cut at higher speeds.
- Carbide tools cut 3 to 5 times faster than HSS and hence, have replaced HSS in many applications.

COATED CARBIDES

- Cutting with carbide tools is slightly difficult because carbide is more brittle than other tool materials thereby making it susceptible to chipping and breaking.
- To increase the life of the carbide tools, they are coated with certain materials like titanium carbide, titanium nitride, ceramics, diamonds etc., and hence are called coated carbides.
- Coating provides longer wear resistance and helps to decrease the temperature associated with the cutting process thereby increasing the life of the tool.

CERAMICS

- Ceramic tools are made by powder metallurgy technique from aluminium oxide or silica nitride compounds mixed with additives like titanium oxide and magnesium oxide to improve cutting properties.
- The primary benefit of ceramic materials for manufacturing tools includes high hardness, ability to maintain their properties at extremely high temperatures, high electrical and wear resistance, and chemical inertness. However, they are extremely brittle in nature and this makes them to be used as inserts in cutting tool applications.

CEMENTED OXIDE TOOLS: They are made primarily from aluminium oxide (alumina) with certain additions of titanium, magnesium, chromium or zirconium oxides or silicon carbide grains that are distributed homogeneously throughout the alumina matrix are called cemented oxide tools.
SIALON TOOLS: Sialon *(Si-Al-O-N)* is a ceramic tool material having silicon-aluminum oxynitride isostructural with beta-silicon nitride (Si_3N_4). Cutting tools made with sialon material possess high fracture toughness, high strength, and a low co-efficient of thermal expansion that results in a very good thermal shock resistance.

CUBIC BORON NITRIDE (CBN)

- Boron Nitride, in its natural form has hexagonal, graphite like structure.
- When this hexagonal boron nitride is subjected to high temperature and pressures, the hexagonal structure can be converted to cubic form, and hence is known as cubic boron nitride.
- This material in the powder form is sintered at high temperature and pressure with a metal or a ceramic binder phase to get polycrystalline mass to use as a insert in the tool holder.

The advantage of CBN is that, it is second in hardness only to diamond. Also, at high temperatures it remains chemically inert to ferrous metals and resists oxidation thereby making it particularly suited for machining hard and difficult to cut materials.

INTRODUCTION TO MACHINE TOOLS:

A machine tool is a power-driven machine, designed to hold and move a sharp cutting tool against a rigidly held workpiece material or vice versa, so as to remove excess material from the workpiece in order to produce the desired shape, size and finish.
A few commonly used machine tools include, Lathe, drilling machines, milling machines, and Grinding machines.

There are a variety of machine tools designed for various applications, however in general, most machine tools perform the following functions:

a) Hold the work material.
b) Hold the cutting tool in position.
c) Impart motion to the work material, or cutting tool, or both, in the desired direction.
d) Regulate the cutting speed and also the feeding movement between the cutting tool and work material.

LATHE

Lathe is the oldest of all machine tool and perhaps the most basic tool used in industries**.**

Working principle of Lathe

- **The lathe is a machine tool which holds the work piece between two rigid and strong supports called centers or in a chuck.**
- The cutting tool is rigidly held and supported in a tool post which is fed against the revolving work.
- The normal cutting operations are performed with the cutting tool fed either parallel or at right angles to the axis of the work.
- The cutting tool may also be fed at an angle relative to the axis of work for machining tapers and angles.
- **The below figure** shows the working principle of the Lathe.

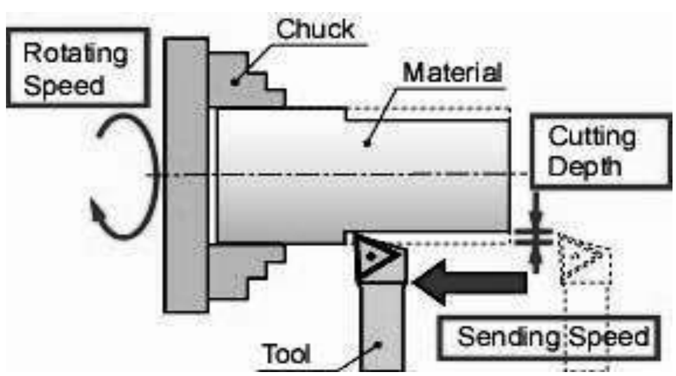


Fig. Principle of working of a lathe.

CONSTRUCTION OF CENTRE LATHE:

The main parts of the lathe are the bed, headstock, quick changing gear box, carriage and tailstock.

- **Bed:** Usually made of cast iron. Provides a heavy rigid frame on which all the main components are mounted. It is the foundation part of a lathe and supports the remaining parts.

The top of the bed is formed by precision-machined guide ways.

- **Guide Ways**: Inner and outer guide rails that are precision machined parallel to assure accuracy of movement.
- **Headstock:** mounted in a fixed position on the inner ways, usually at the left end. Using a chuck, it rotates the work. The housing comprising of the feed gearbox and the cone pulley called headstock of the lathe. The main spindle projects out from the headstock. The motor drives the cone pulley drives the main spindle through belting. Spindle speeds can be further varied using beck gear mechanism
- **Gearbox:** inside the headstock, providing multiple speeds with a geometric ratio by moving levers.
- **Spindle:** Hole through the headstock to which bar stock can be fed, which allows shafts that are up to 2 times the length between lathe centers to be worked on one end at a time.
- **Chuck:** allows the mounting of difficult work pieces that are not round, square or triangular. 3-jaw (self centering) or 4-jaw (independent) to clamp part being machined.
- **Tailstock:** Fits on the inner ways of the bed and can slide towards a headstock to fit the length of the work piece. Tail stock is the movable part of the lathe that carries the dead centre in it. The main function of the tailstock is to support the free end of the long work pieces. It is mounted loosely on the bed ways and can be moved in desired direction an optional taper turning attachment would be mounted to it.

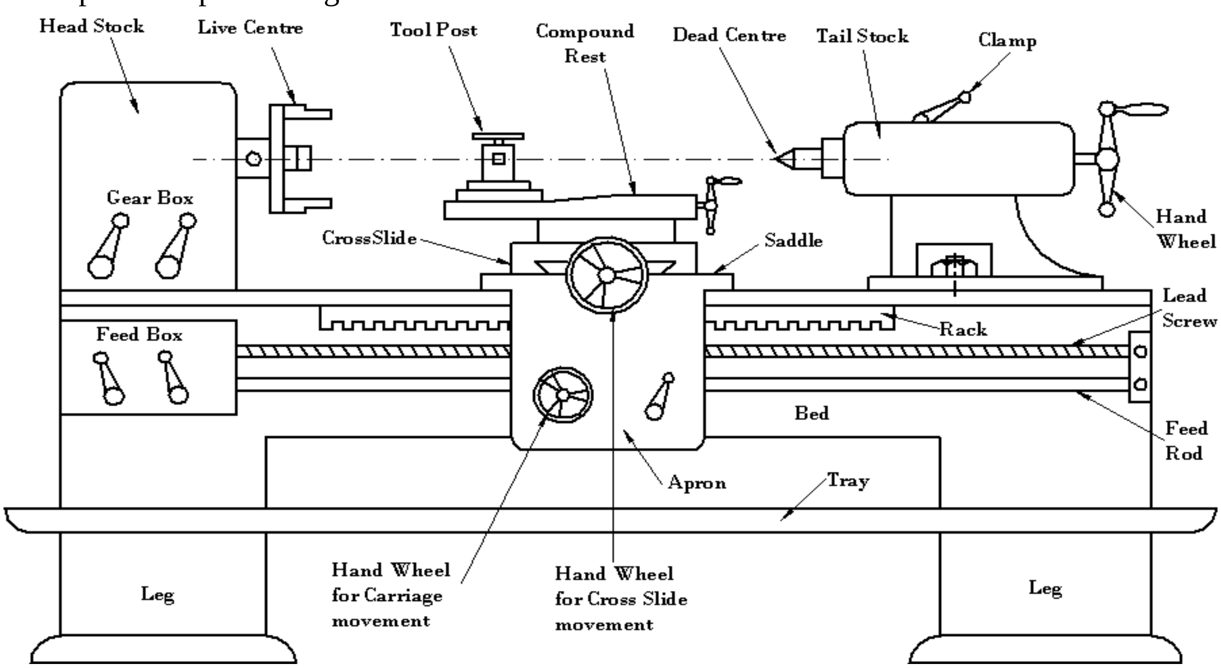


Fig. Parts of Lathe

- **Carriage Assembly:** Moves on the outer ways. Used for mounting and moving most the cutting tools. The carriage assembly consists of.
  - ✓ **Saddle:** is a H-shaped casting slides over the outer set of guide ways and serves as the base for the cross slide.
  - ✓ **Cross slide:** is mounted on the saddle and enables the movement of the cutting tool laterally across the lathe bed by means of cross-feed hand wheel.
  - ✓ **Compound Rest:** is mounted on the top of the cross slide and is swiveled to any angle in the horizontal plane to facilitate taper turning and thread cutting operations.
  - ✓ **Apron:** is mounted in front of the saddle beneath it and houses the carriage and cross slide mechanisms.
  - ✓ **Tool Post:** is mounted in the T-Slot of the compound rest and properly clamps the cutting tool.
  - ✓ **Feed Rod:** Has a keyway, with two reversing pinion gears, either of which can be meshed with the mating bevel gear to forward or reverse the carriage using a clutch. is a stationary rod mounted in front of lathe bed and facilitates longitudinal movement of the carriage
  - ✓ **Lead Screw**: is the screw rod that runs longitudinally in front of the lathe bed. The gyration of the lead screw moves the carriage to and fro longitudinally during thread cutting operations.

1.14.2 Specification of Center Lathe:

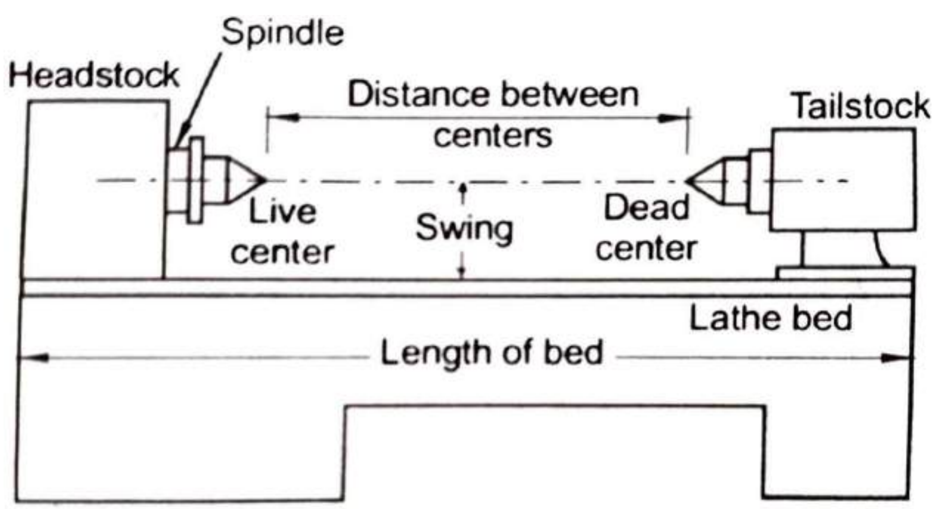


Fig. Specification of Center Lathe [2]

- **Distance between Centers:** The maximum length of the job that can be held between the live center and dead center.
- **Swing diameter:** It is the maximum diameter of the workpiece that can revolve without touching the guide ways.
  Some manufactures specify Height of centers instead of swing diameter.
  Height of centers: It is the height measured from the bed to the lathe center axis.
- **Length of bed:** Indicates the approximate floor space occupied by the lathe
- **Range of spindle speeds**

Important elements to work on LATHE

1. **Rotating Speed**: It expresses with the number of rotations (rpm) of the chuck of a lathe. When the rotating speed is high, processing speed becomes quick, and a processing surface is finely finished. However, since a little operation mistake may lead to the serious accident, it is better to set low rotating speed at the first stage.

2. **Cutting Depth**: The cutting depth of the tool affects to the processing speed and the roughness of surface. When the cutting depth is big, the processing speed becomes quick, but the surface temperature becomes high, and it has rough surface

3. **Sending Speed (Feed)**: The sending speed of the tool also affects to the processing speed and the roughness of surface. When the sending speed is high, the processing speed becomes quick. When the sending speed is low, the surface is finished beautiful.

Lathe operations or Machining process on LATHE

The operations that can be performed on a lathe are

a) By holding the job between centers or between chuck and dead center

1. Turning – plain, step, taper, etc.
2. Facing
3. Chamfering
4. Knurling
5. Thread cutting
6. Thread cutting
7. Polishing
8. Spinning

b) By holding the job by a chuck alone

1. Turning and Facing of short-length work piece.
2. Drilling
3. Reaming
4. Boring
5. Thread cutting, internal/external.

c) By using special attachments.

1. Grinding
2. Milling

I. Plain Turning or Cylindrical Turning

- The process of metal removal from the cylindrical jobs is called straight or plain turning. It is a machining process for producing a cylindrical surface on the workpiece as shown figure below.
- The work-piece is supported in-between the two centres which permit the rotation of the work-piece. A single point cutting tool is fed perpendicular to the axis of the work-piece to a known predetermined depth of cut, and is then moved parallel to the axis of the work-piece.
- Cross-slide and the carriage are used to perform turning operations and make the operation faster and economical. Plain turning operations are generally performed in two steps-rough and finish turning.
- Rough turning is usually done for rolled, cast, or forged parts to remove the uneven or sandy, or rough surface on the jobs. A roughing tool does roughing and used for excess stock removal. For finishing a tool with a slightly round cutting edge is used. The depth of cut rate is at the range of 0.2 to 1 mm and the feed rate between 0.1 to 0.3 mm.

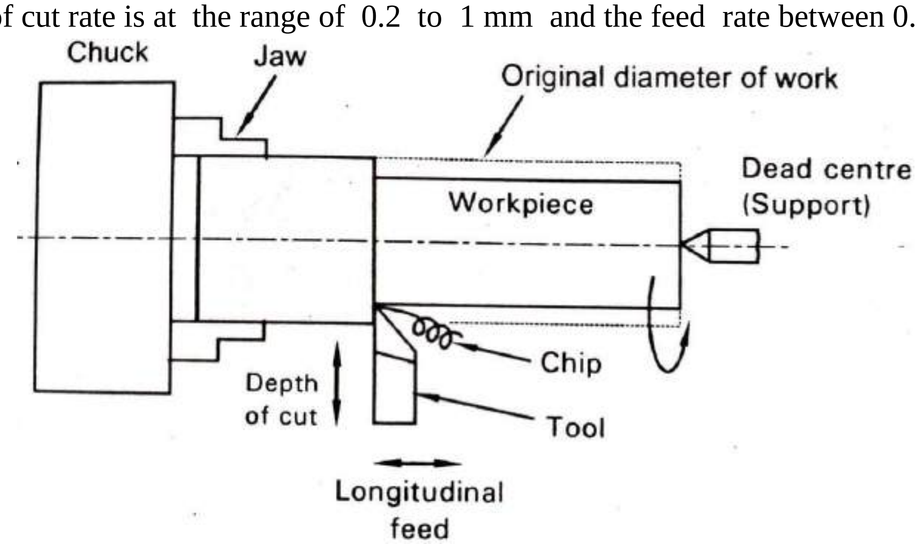


Fig. Cylindrical Turning

II. Facing

- Facing is a machining process for producing a flat surface at the end face of the workpiece as shown in figure below.
- Is the operation of machining the ends of a piece of the work to produce a flat surface square with the axis.
- This is used to cut the work to the required length. The operation involves feeding the tool perpendicular to the axis of rotation of the workpiece.
- A regular cutting tool may be used for facing a large workpiece. The cutting edge should be set at the same height as the center of the workpiece. A properly ground-facing tool is mounted in a tool holder in the tool post to accomplish facing operation.

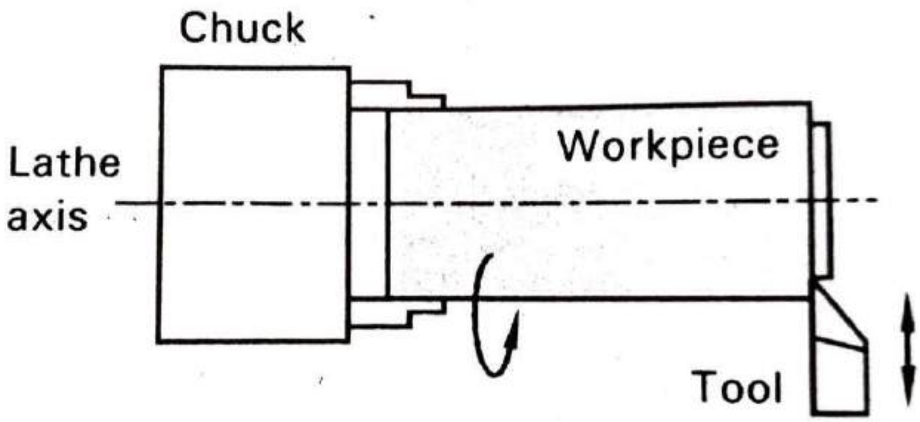


Fig. Facing

III. Taper Turning

- Taper turning is a machining process for producing conical surface on a cylinder workpiece as shown figure below.
- The work piece is held rigidly between the two supports of the machine and the cutting tool is fed against the revolving workpiece at an angle to the lathe axis. operation on a lathe to produce conical surface on the work pieces.

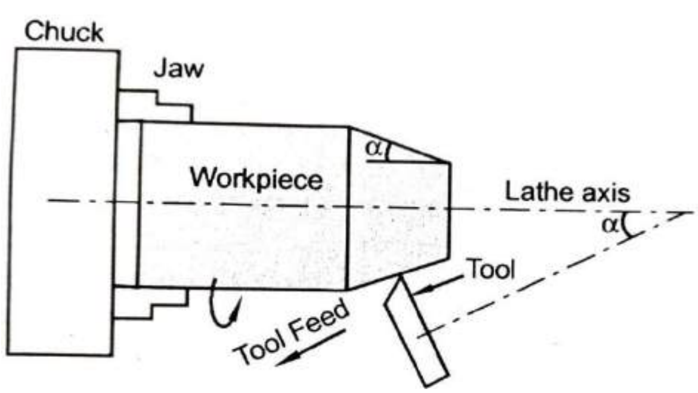
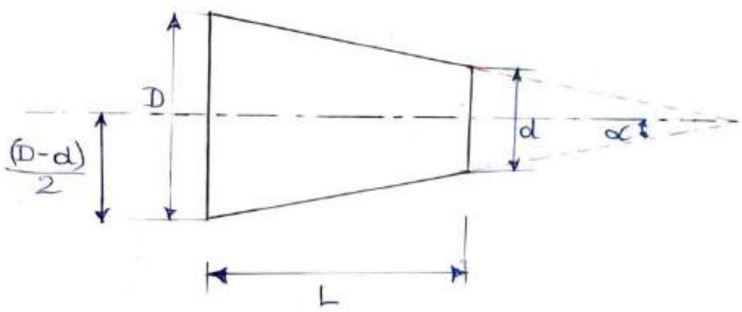


Fig. Taper Turning



Where, D = Bigger diameter of the taper (mm)
d = Smaller diameter of the taper (mm)
L = Length of the taper (mm)
α = Half – tapered angle

Half – tapered angle is calculated using the equation:

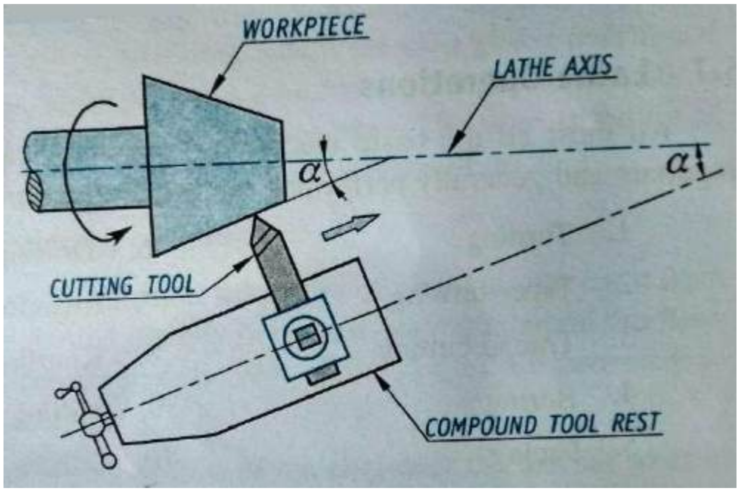
$$\tan \alpha = \left(\frac{\frac{D-d}{2}}{L}\right)$$

$$\text{Half – taper angle} = \alpha = \tan^{-1}\left(\frac{D-d}{2L}\right)$$

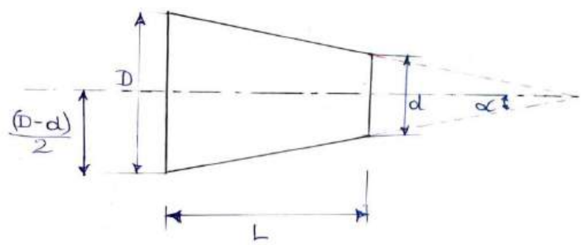
METHODS OF TAPER TURNING.

a) Swivelling the compound rest.
b) Offsetting the Tailstock
c) Taper turning attachment method.
d) By using form tool.

a) TAPER TURNING BY SWIVELLING THE COMPOUND REST.



- In this method compound rest is swiveled to the required taper angle and then locked in the angular position.
- The carriage is also locked in that position
- For taper turning the compound rest is moved linearly at an angle so that the cutting tool produces the tapered surface on the workpiece.
- This method is suitable for limited lengths due to the limited movement of compound rest



Where, D = Bigger diameter of the taper (mm)
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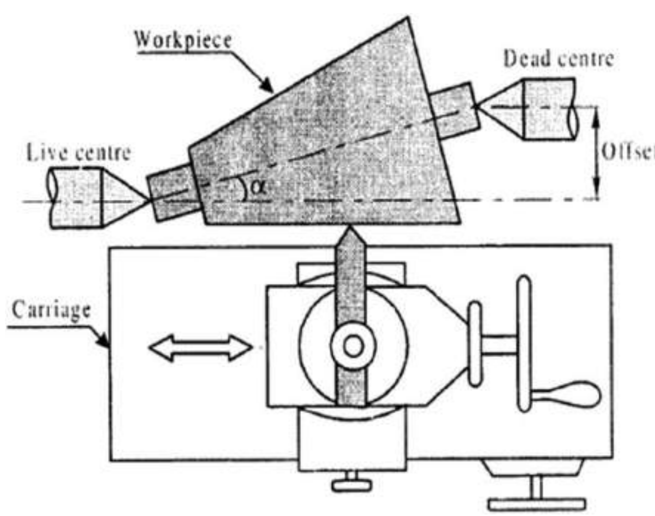
$$\tan \alpha = \left(\frac{\frac{D-d}{2}}{L}\right)$$

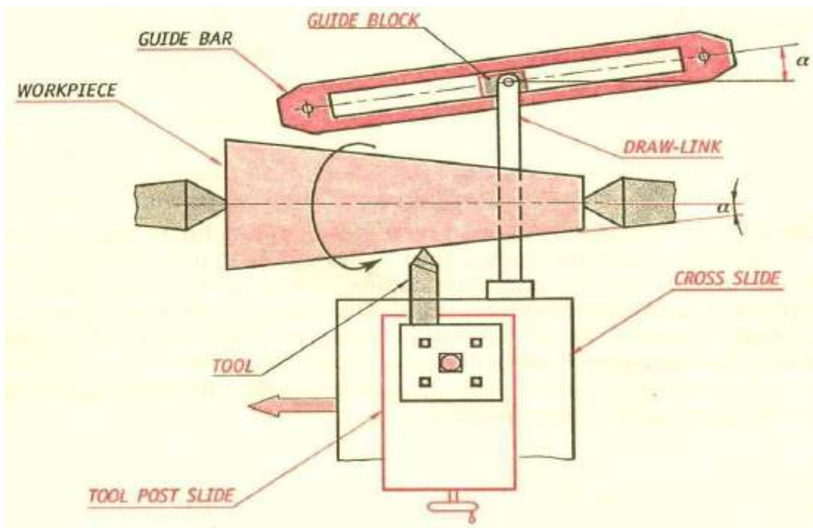
$$\text{Half – taper angle} = \alpha = \tan^{-1}\left(\frac{D-d}{2L}\right)$$

b) TAPER TURNING BY OFFSETTING THE TAILSTOCK



- This method is also known as setover tailstock method.
- In this method the tailstock center is set out of alignment, the workpiece gets taper because its axis will be inclined at an angle with the longitudinal movement of the tool which will be parallel to the lathe bed.
- The cutting tool is fed parallel to the lathe axis and the desired taper is produced.

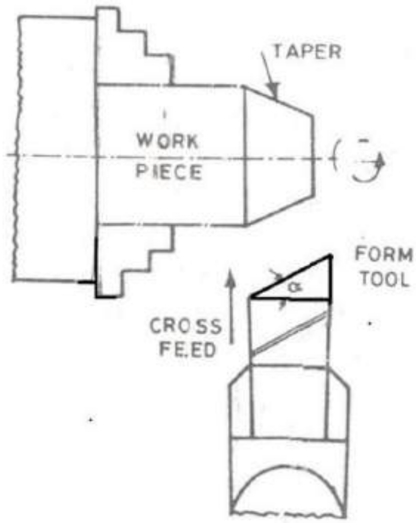
c) TAPER TURNING BY TAPER TURNING ATTACHMENT



Taper Turning Attachment

- A taper turning attachment is used to cut both internal and external tapers.
- The taper turning attachment shown in Fig. consists of a bracket (not shown in figure) which will be connected to the rear side of the lathe bed.
- A guide bar which can be swiveled in the horizontal plane and locked in position, is mounted over the bracket.
- A guide block pivoted to a draw-link will slide in the longitudinal slot in the guide bar. The draw-link is connected firmly to the cross slide.
- The tool is mounted on the tool post slide. The cross slide is allowed to move freely on its ways by loosening the cross feed screw and the engaging nut.
- When the carriage is moved, the guide slides inside the slot in the guide bar.
- The sliding of the guide inside the slot forces the cross slide to move in the traverse direction.
- The combined traverse motion of the cross slide and the longitudinal motion of the carriage moves the tool parallel to the inclined axis of the guide bar and produce the required taper on the workpiece.

d) TAPER TURNING BY A FORM TOOL



- The taper turning by using a broad nose form tool
- Method is suitable only for very short tapers (max. 20mm length)
- Form or broad-nose tool is used [cutting edge is ground to contain half taper angle]
- During operation, lot of vibrations are caused as full cutting edge is involved in cutting.

IV. THREAD CUTTING:

- Thread cutting or threading is a machining process for cutting screw threads on metallic parts as shown in the figure below.

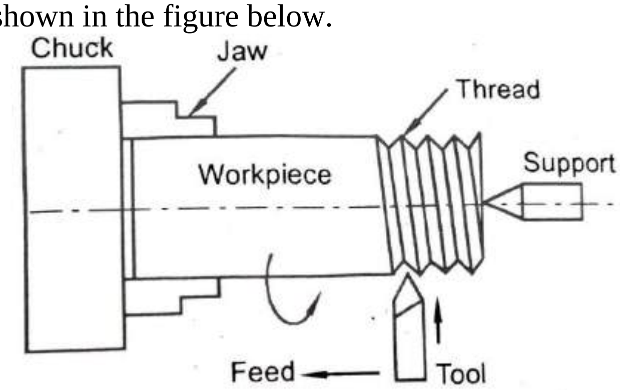


Fig. Thread cutting

- A thread is a helical ridge formed on the cylindrical rod surface. By employing a V-Shaped cutting tool it is possible to accomplish threads on the workpiece.
- In operation, a suitable tool which gives the required thread profile, say V-thread, square thread etc., is mounted on the tool post of the lathe.
- The workpiece is made to revolve at a very slow speed with uniform motion.
- The depth of cut is selected and the tool is made to move parallel to the lathe axis by

means of automatic arrangements. (An appropriate gear ratio is maintained between the spindle on which the work piece is mounted and the lead screw)

- Thread cutting is carried out in a number of passes. The final cut is a finishing cut with a very small depth of cut in order to obtain a good surface finish.

V. KNURLING:

- Knurling is an operation performed on the lathe to generate serrated surface on the work piece. This is used to produce a rough surface for griping like the barrel of the micrometer or screw gauge. This is done by a special tool called knurling tool which has a set of hardened roller with the desired serrations. As shown in figure (a) and figure (b)
- During knurling operation, the hardened rollers of the tool are pressed against the slowly rotating work pieces such that the impression of tool serrations are formed on the work pieces surface.
- Usually, there are three different pattern of knurling produced as per requirements and is as shown.

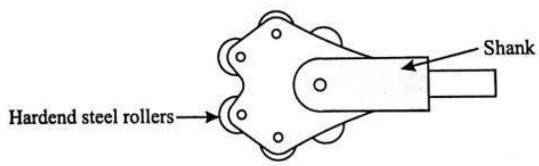


Figure (a): A typical knurling tool

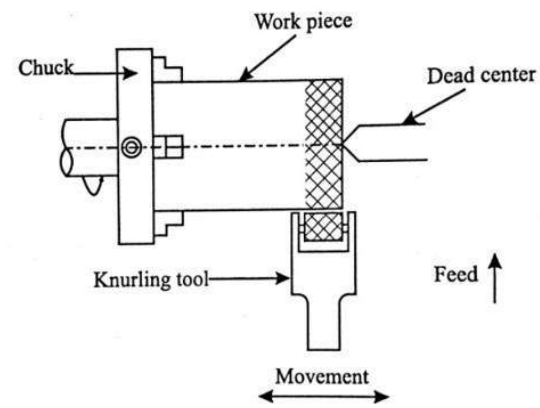


Figure (b): Knurling operation

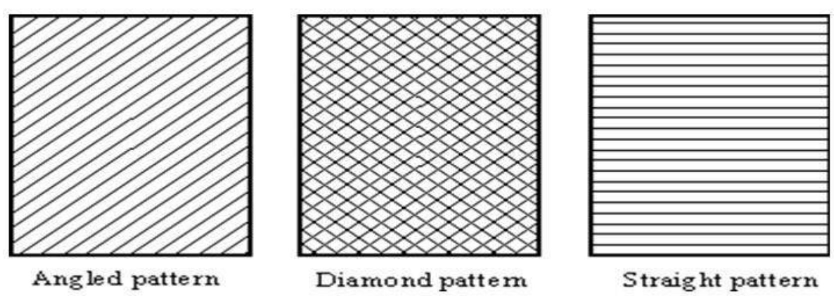


Fig. (c) different pattern of knurling produced

VI. DRILLING ON LATHE:

- Drilling is the operation of producing a cylindrical hole by means of a revolving tool called twist drill or drill bit.
- In operation, one end of the workpiece is held in chuck, The tool is held in the tapered hole of the tailstock sleeve and is fed into the rotating workpiece with the help of rotating hand wheel of the tailstock.
- Drilling on lathe is limited to holes through the axis of rotation of the workpiece and from any of the ends only.

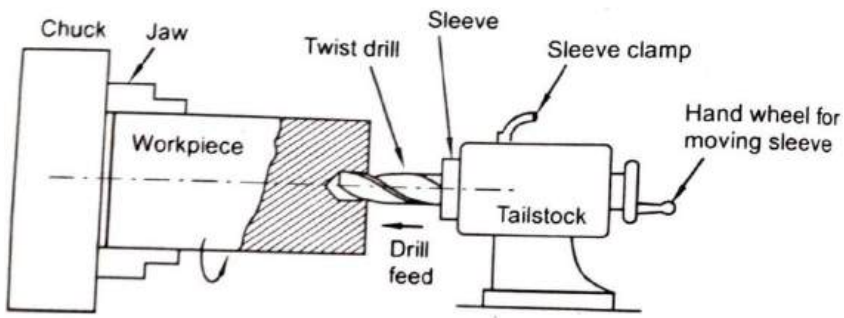


Fig. Drilling on lathe [2]

VII. BORING OR INTERNAL TURNING

- Boring is the operation of enlarging a previously drilled hole by means of an adjustable cutting tool having. only one cutting edge. Refer figure (a). In operation, the boring tool is held on the tool post of the lathe.
- The workpiece is made to rotate at suitable speeds while the **tool is fed parallel to the axis of the workpiece** and to the desired length in order to increase the diameter of the hole.

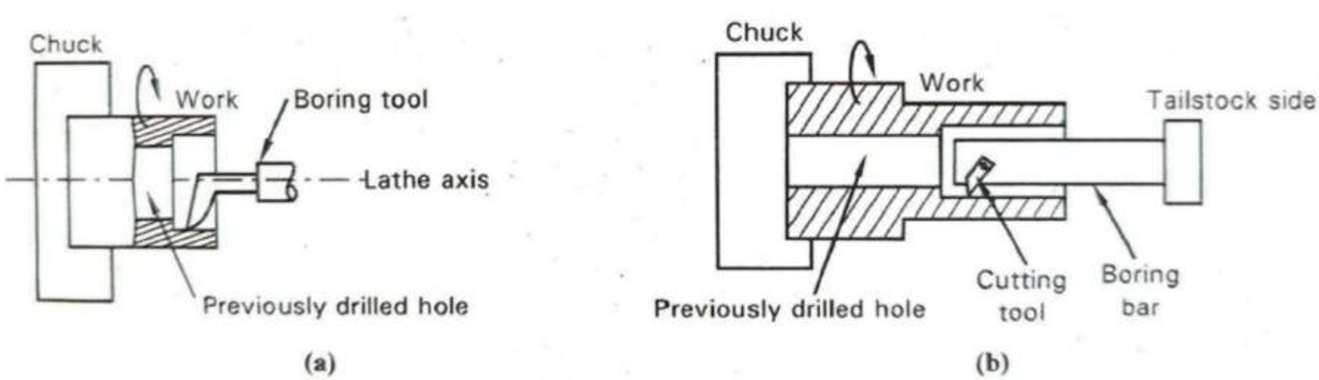


Fig. Boring

- For boring deep holes, a single point cutting tool is fastened and adjusted to a cylindrical shaped boring bar which is held in the sleeve or barrel of the tailstock as shown in figure (b).
- The tool is fed axially against the revolving workpiece to enlarge the hole.

- In addition to enlarging a previously drilled hole, boring operation corrects the hole location and out-of-roundness, if any, as the tool can be adjusted to re1nove more metal from one side of the hole than the other.

LATHE ACCESSORIES

Lathe accessories are tools and equipment's used for holding and supporting the workpiece., and also for holding the tool rigidly during machining.

The common lathe accessories used in lathe are illustrated in figure and briefed as below

- Lathe Centers
- Lathe chuck
- Lathe dog
- Drive plate
- Face plate
- Mandrel
- Steady rest
- Follower rest

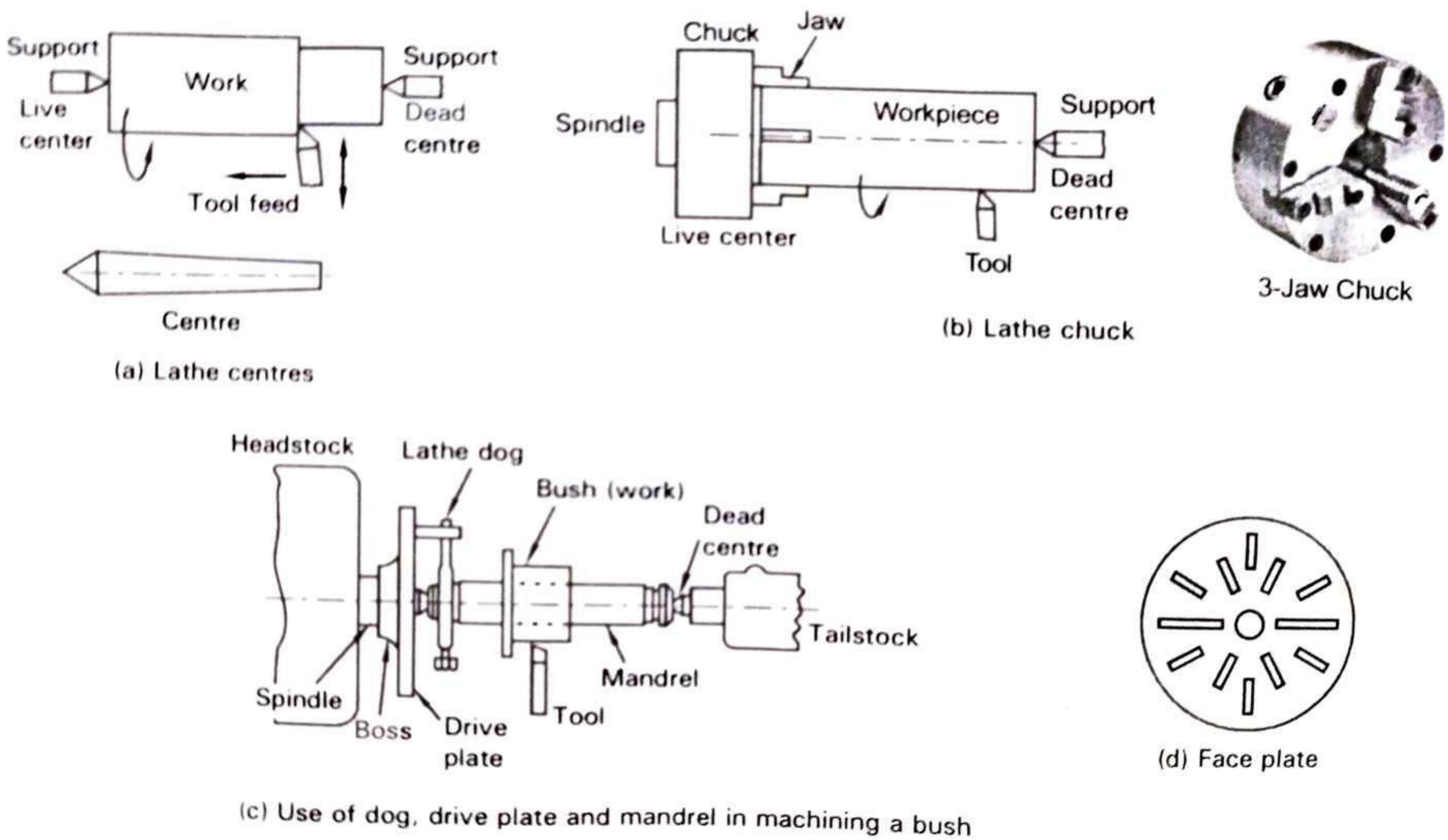


Fig. Lathe accessories

a) **Lathe centers:** Lathe centers are required to support the long workpiece in the tailstock and turn the workpiece between them. Refer figure (a). There are two types of centers, viz., live center and dead center. The center fitted in the headstock spindle and rotating with the spindle and the work is called the live revolving center, while the center fitted in the tailstock and remains stationary, supporting the workpiece is called the dead center.

b) **Lathe chuck:** A lathe chuck is a tool, which by means of its adjustable jaws, holds the work as well as rotates the workpiece so that the stationary cutting tool can perform machining operation. Refer figure (b). The chuck is used for workpieces of short length and large diameter or of irregular shape that cannot be supported between center. The Chuck attached to the headstock spindle and hence rotates with the spindle. Chucks in manual lathe can be a 3-jaw or self –centering chuck, 4-jaw independent chuck, collet chuck.

c) **Lathe dog:** A lathe dog is a tool which transmits motion to the workpiece from the spindle when the work is held between two centers. As shown in figure (c)

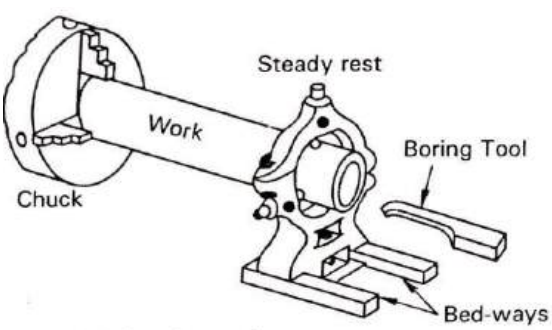
d) **Drive plate:** A drive plate is a flat disc that attaches to the spindle nose. It has grooves and pins to engage and turn a lathe dog, as shown in figure (c) above

e) **Face plate:** A faceplate is a large disc that may attach to the lathe spindle nose. It is similar to a drive plate, but is larger. Faceplates are used to hold oddly shaped workpieces that cannot be held in a chuck or between centres.

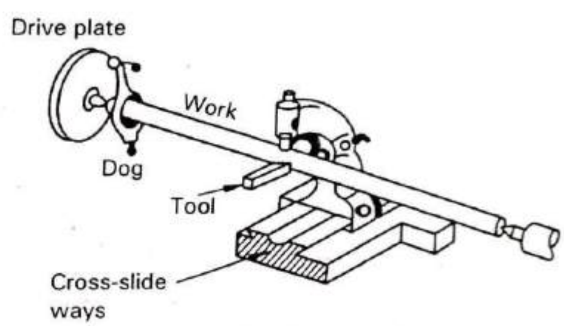
f) **Mandrel :** A mandrel is used to grip a workpiece by its bore. Several types of mandrels are available. They are used when gripping a workpiece with jaws could mar the surface. Workpieces are held in mandrels by a shallow solid taper, a tapered sleeve or a nut on the threaded portion, as shown in figure (c) above.

g) **Steady rest:** Long, thin workpieces present special problems for the lathe operator. A steady rest solves these problems by supporting the workpiece either at the end or in the middle. A steady rest is an optional piece of equipment supplied with most lathes.

h) **Follower rest:** A long, thin workpiece tends to deflect away from the cutting tool during a cut. The deflection is greater in the middle of the workpiece than at either end, which results in a diameter that is not uniform



(e) Steady rest in use



(f) Follower rest in use

1.16 KINEMATICS OF LATHE

- Kinematics is a branch of science which deals with relative motion of bodies without considering the forces causing the motion.
- In a turning operation carried on a manual lathe, the movement (rotation) of the workpiece forms the primary motion while the linear movement of the cutting tool forms the feed or secondary motion.
- The movement or rotation of the workpiece is controlled with the help of machine tool drives, i.e., the motion is transmitted from the power source to the workpiece in a controlled manner. The cutting tool is fed manually by the operator
- The work piece takes the rotational power from the electric motor through the belt-pully, clutch and then the speed gear box which splits the input speed into a number of speeds by operating the cluster gears.
- While cutting screw threads on workpiece, the half nut is engaged with the rotating lead-screw to positively cause travel of the carriage and hence the tool parallel to the lathe bed or axis of the workpiece.
- The feed rate for both turning and threading is varied as required by operating the Norton gear and the main drive systems existing in the feed gear box. The range of feeds can be increased by changing the gear ratio in the gear quadrant connecting the gear box with the spindle.

1.17 CAPSTAN & TURRET LATHE

Capstan and Turret lathes are semi-automatic machines, equipped with special tooling facilities capable of accommodating around 6 to 8 cutting tools that can be fed into the workpiece in a proper sequence. Also, the positive stops or feed trips located on the machine help the operator to carry out the machining operation independently without the necessity for making measurements on the workpiece length each time. Such a facility avoids re-setting of work or tools, thereby reducing time and labour. The details regarding the lathes are briefed as follows.

1.17.1 Saddle Type Turret Lathe

Saddle Type Turret Lathe as shown in figure below, is basically suited for heavy-duty jobs, particularly those requiring long and accurate cuts. The consists of the following parts.

a) **Bed:** The bed is a long, box-like casting with rectangular guideways upon which are mounted the carriage and turret saddle. It also supports the headstock and other parts of the machine. The bed provides strength and rigidity to all the parts of the machine during its operation.
b) **Headstock:** The headstock mounted on the left end of the bed houses the powerful motor and transmission mechanism like gears, which operates the spindle to rotate at various speeds

c) **Turret and turret saddle:** In a turret lathe, there is no tailstock; instead, a hexagonal indexable turret (turret head or tool holder) is mounted on saddle, which slides longitudinally on the bed. The turret is a hexagonal (six sided) block with a through hole machined on each face of the hexagon into which the shank of six different tools may be accommodated and clamped by means of screws provided on the top the turret. The turret may be indexed (rotated through fixed angle) automatically or manually to bring each tool in proper position for performing the operation on the work piece.

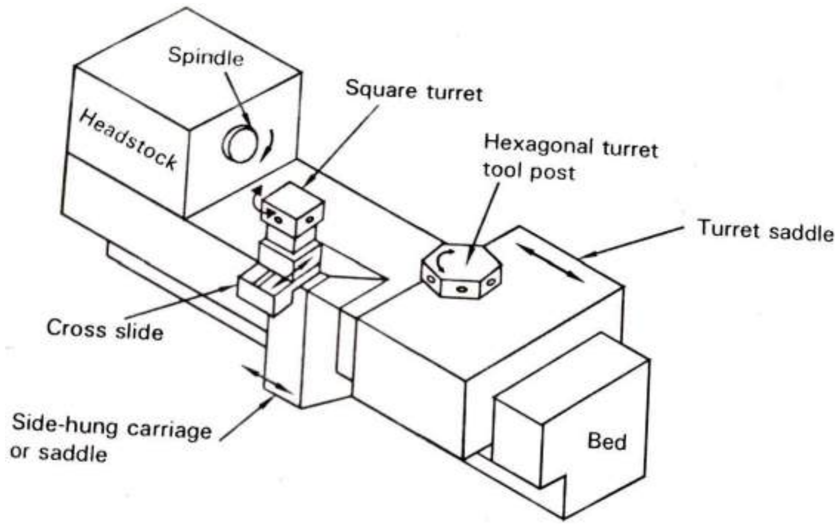


Fig. (a) Pictorial view of a saddle-type turret lathe [2]

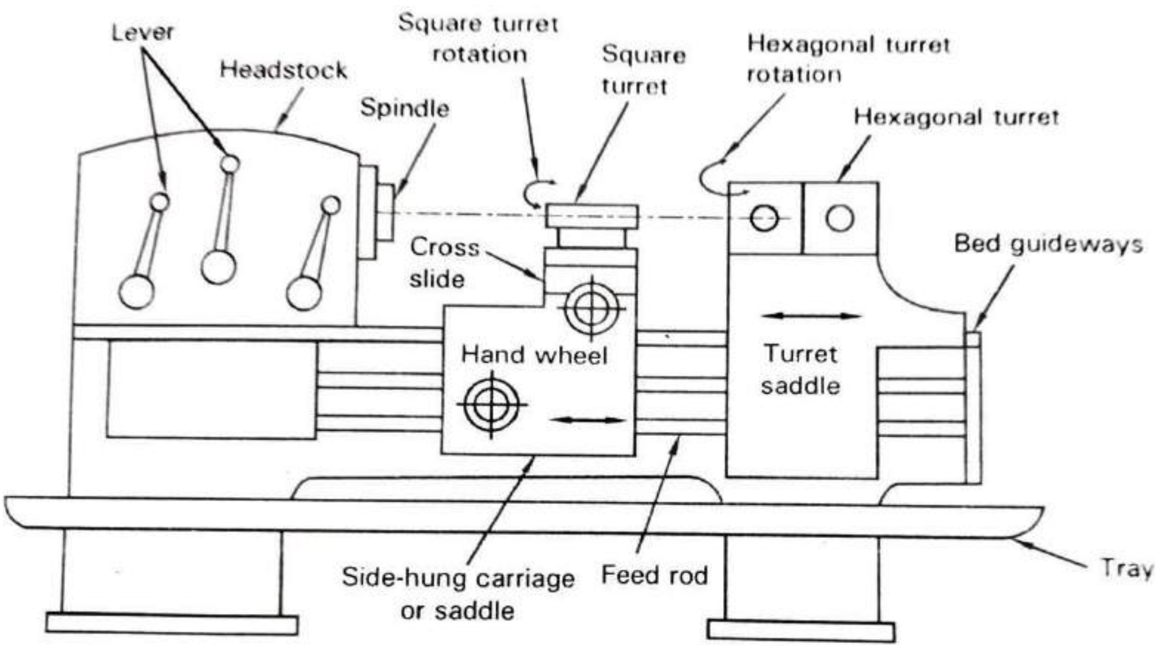


Fig. (b) Front view of saddle type Turret Lathe

d) **Cross-slide and square turret:** The cross-slide is mounted over the chaser saddle, which is of a side-hung type supported on the front bedways, and on an additional way provided on the front of the bed near its bottom. The chaser saddle can slide longitudinally on the bedways of the machine through power or manual operation. The cross-slide carries a square turret tool post capable of holding four different single point cutting tools. The square turret is indexed manually about a vertical axis to bring each of the four tools into operating position. It can also move in transverse direction (perpendicular to the spindle axis) on the cross-slide.

e) **Feed rod:** It controls the motion for the side-hung carriage during thread cutting and other related operations.

f) **Legs:** Legs are hollow castings, acting as supports, carrying the entire load of the machine over them. They are firmly secured to the floor by means of foundation bolts in order to prevent vibrations of the machine during operation. The left leg accommodates in it several mechanisms like electrical, drives, oil pump, etc.

1.17.2 Capstan Lathe or Ram Type Turret Lathe

The modern name for a capstan lathe used in industries is a ram type turret lathe. The capstan lathe is similar in appearance to the saddle type turret lathe, except regarding the features of the saddle and cross-slide, which forms the main basis of difference between the two types of lathes. The capstan lathe is so called, because of the tool head carrier, the turret being circular shaped instead of hexagon. However, in some machines, the tool head is designed to have a hexagonal shape also, Figure. shows the features of a capstan lathe. The machine consists of the following parts:

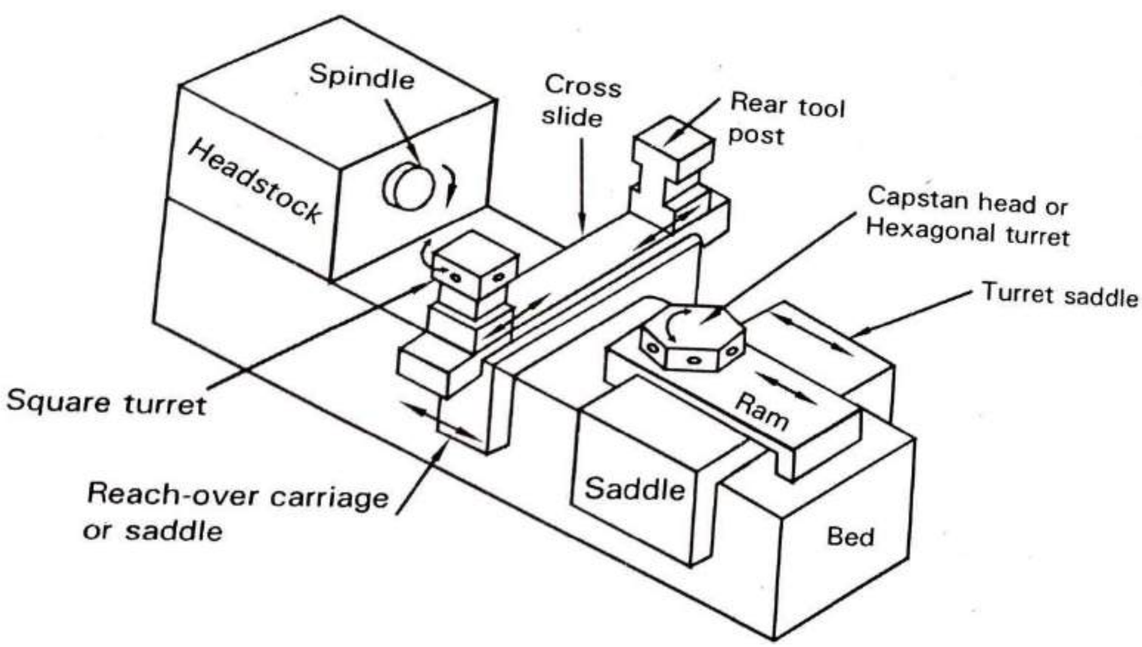


Fig. (a) Pictorial view of a ram-type turret lathe (capstan lathe)

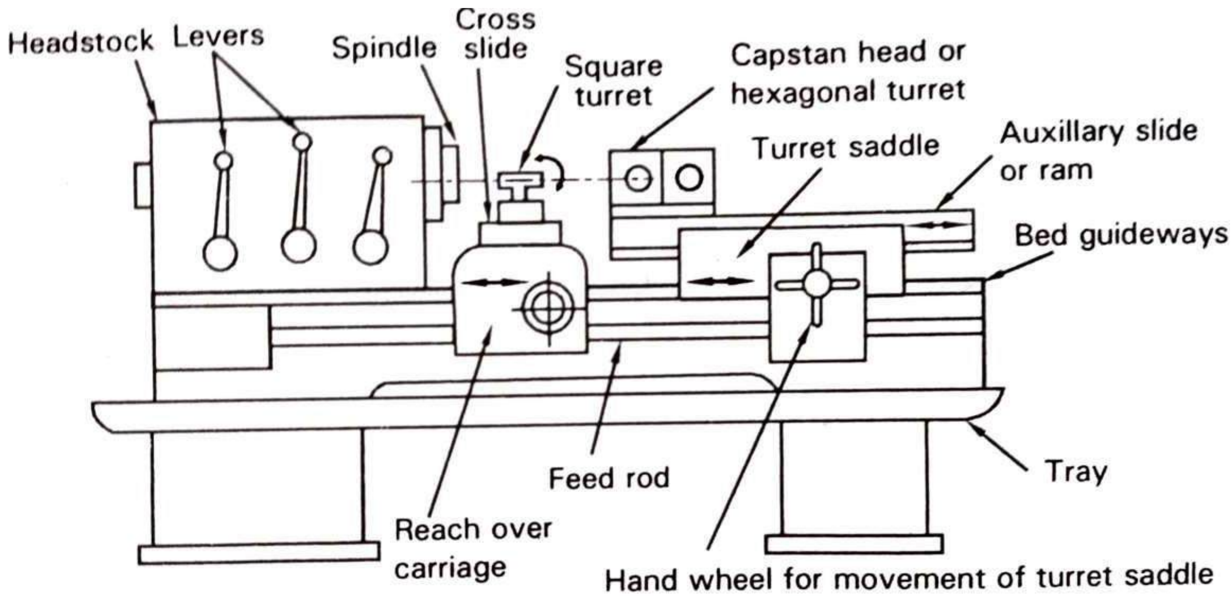


Fig. (b) Front view of capstan lathe or Ram-type turret lathe [2]

a) **Bed**: The bed is a long, box like casting with rectangular guideways upon which are mounted the carriage and turret saddle. It also supports the headstock. The bed provides strength and rigidity to other parts of the machine.

b) **Headstock**: It is a large casting mounted on the left end of the bed. Generally, an all-geared headstock is used for rapid change of the spindle speeds. This should be selected prior to an operation by changing the lever or pressing the speed changing button.

c) **Turret saddle**: The saddle in a capstan lathe supports an auxiliary slide called **ram**, which in turn supports the capstan head (turret) on a vertical spindle. The capstan head is a circular shaped block with through holes machined around its periphery to accommodate around six tools of different types. The carrying the capstan head slides longitudinally on the turret saddle feeding the tools against the workpiece.

   Further, the saddle in a capstan lathe can be moved along the bedways and secured at any desired position in order accommodate work piece of different lengths. The turret or capstan head can be moved manually by means of hand wheel or through power feed mechanism.

d) **Cross**-Slide: It is mounted over the chaser saddle, which is of a ***reach over type*** or bridge type that can slide longitudinally on the bedways between the headstock and the turret saddle. The cross-slide carries a square turret tool post capable of holding four different single point cutting tools. The advantage of ***reach over type saddle*** over the ***side-hung saddle*** as used in saddle type turret lies in the availability of an additional tool post at the rear end, which also can carry around four cutting tools for various operations. The square turret tool post at the front, and the tool post at the rear can be moved in the transverse direction on the cross-slide.

e) **Feed rod**: The feed rod controls the motion for the reach-over saddle during thread cutting and similar such operations.
f) **Legs**: Legs are hollow castings, acting as supports, carrying the entire load of the machine over them. They are firmly secured to the floor by means of foundation bolts in order to prevent vibrations of the machine during operation. The left leg accommodates in it several mechanisms like electrical, drives, oil pump, etc.

1.17.2 Specification of Capstan/Turret Lathe

The size of the Capstan/Turret lathe is specified by one or more of the following criteria.

- Maximum diameter of the workpiece that can be revolved
- Maximum diameter of the workpiece that can be passed through the headstock spindle.
- Power of main drive motor.
- Range of spindle speeds
- Range of longitudinal and cross-feed rates.

1.17.2 Difference Between Capstan and Turret Lathe [2]

Sl. No.	Turret Lathe	Capstan Lathe
1.	The turret head is mounted on a saddle, which slides directly on the bedways of the machine	The turret or capstan head is mounted on an auxiliary slide called ram, which slides on the guideways provided on the saddle
2.	The entire saddle unit is moved for feeding the tools against the rotating work.	The saddle is fixed at a convenient distance from the work and the tools are fed by moving the ram.
3.	Manual movement of the entire saddle for feeding the tools is a tedious process.	The capstan head can be moved back and forth easily without having to move the entire saddle unit.
4.	The cutting forces of the hexagonal turret head are transferred to the rigid lathe bed. Hence, heavy jobs involving high cutting forces can be machined.	The cutting forces of the capstan head are transferred to the auxiliary slide – ram, which is not rigid as the lathe bed. Hence heavy cuts may result in deflection or vibrations of the ram. This makes the machine suitable only for small and light jobs.
5.	Turret lathe may carry either a reach-over type or side-hung type carriage/saddle.	A capstan lathe can carry only reach-over type saddle.
6.	Capable of turning workpieces up to 200 mm in diameter.	Capable of turning workpieces up to 60 mm in diameter.