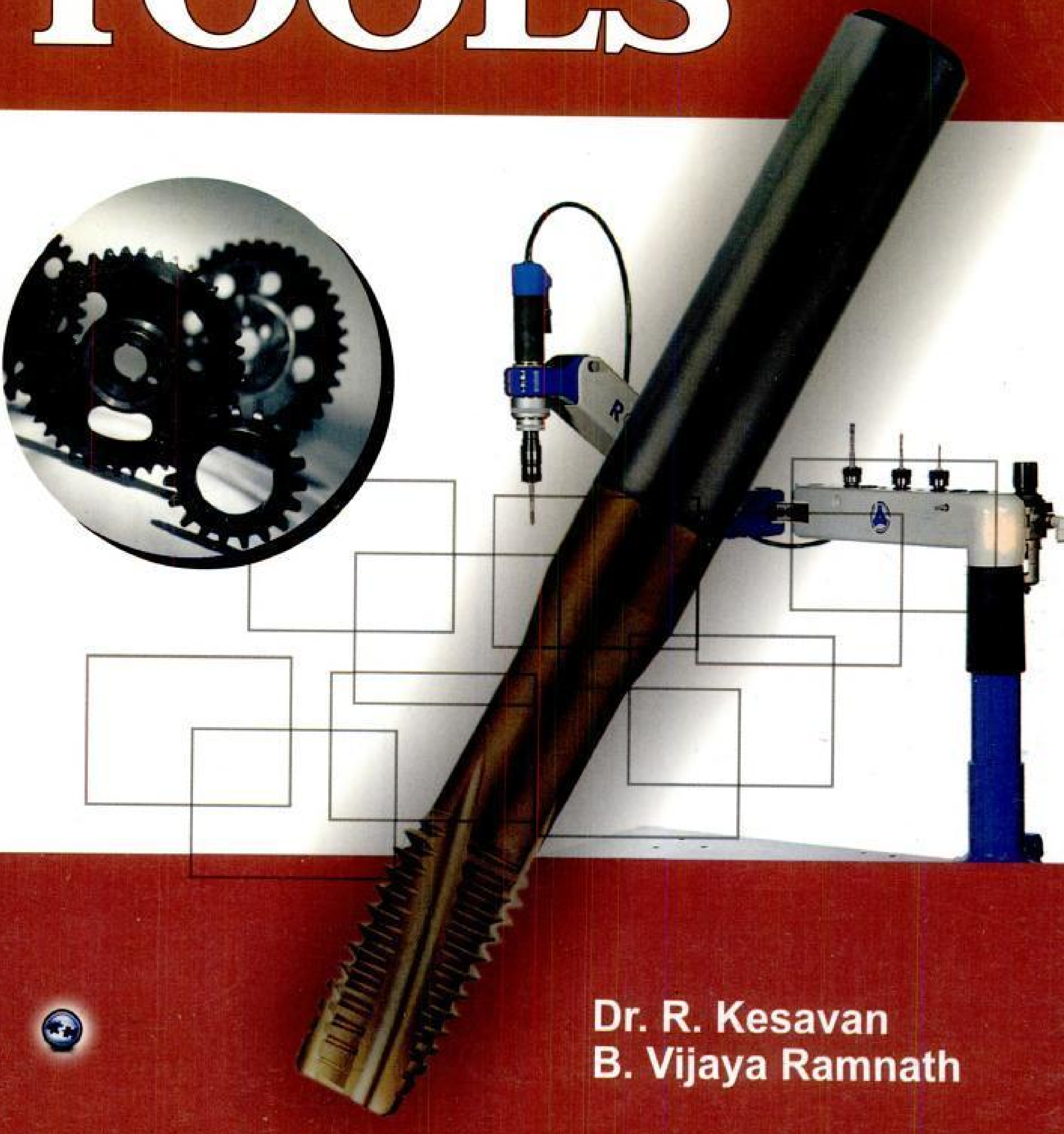
MACHINE TOOLS



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CONTENTS

PREFACE

The book "Machine Tools" based on the latest syllabus for B.E/B.Tech., Mechanical and Production Engineering for JNTU as well as other universities. It is a valuable asset for diploma students.

This book is an attempt to provide all the necessary information about Machining Processes. The subject matter has been presented in a simple and systematic way with numerous diagrams so as to enable the students to have thorough understanding of the topics.

We have endeavored out best effort to provide solved problems in theory of metal cutting chapter. Important review questions have been provided at the end of each chapter which help students in the examination.

Any suggestions for the improvement of this book are eagerly welcome and would be incorporated in the next edition.

—Authors

UNIT - 1

ELEMENTARY TREATMENT OF METAL CUTTING THEORY

1.1. INTRODUCTION

In Engineering industry, components are made of metals in different shapes, sizes and dimensions. Metals are shaped to the required forms by various processes. These processes can be generally divided into two groups. They are:

1. Non-cutting shaping process.
2. Cutting shaping process.

In non-cutting shaping, the metal is shaped under the action of heat, pressure or both. Here there is no chip formation. This group includes operations like forging, drawing, spinning, rolling, extruding etc.

In cutting shaping, the required shape of metal is obtained by removing the unwanted material from the workpiece in the form of chips. A few important processes are turning boring, milling, drilling, shaping, broaching etc. These operations are known as machining or metal cutting operations.

The metal cutting is done by a relative motion between the workpiece and the hard edge of a cutting tool. The relative motion between the workpiece and the cutting tool may be obtained by:

1. Rotation of the work against the tool (Turning)
2. Rotation of the tool against the work (Milling and drilling)
3. Linear movement of the work against the tool (Planing)
4. Linear movement of the tool against the work (Shaping).

Metal cutting can be done either by single point cutting tools or by multi point cutting, tools.

1.2. ELEMENTS OF CUTTING PROCESS

The basic elements of all machining operations are:

1. Workpiece
2. Tool
3. Chip

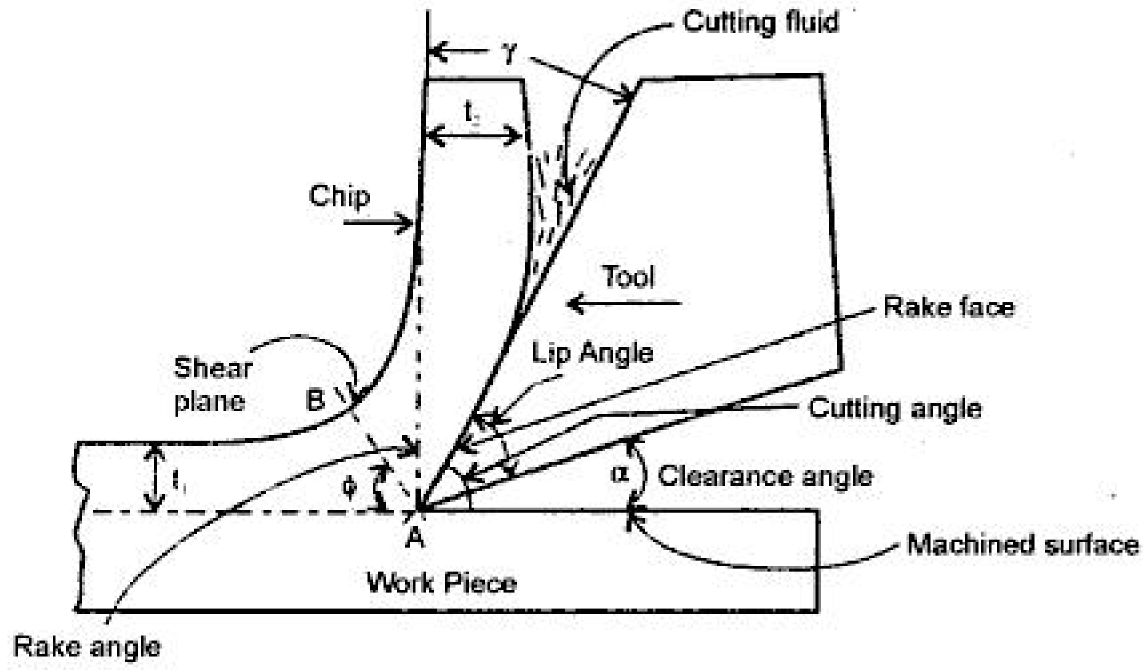


Figure 1.1

γ = rake angle, ϕ = shear angle,

α = clearance angle or relief angle,

t_1 = uncut chip thickness, t_2 = chip thickness after cut.

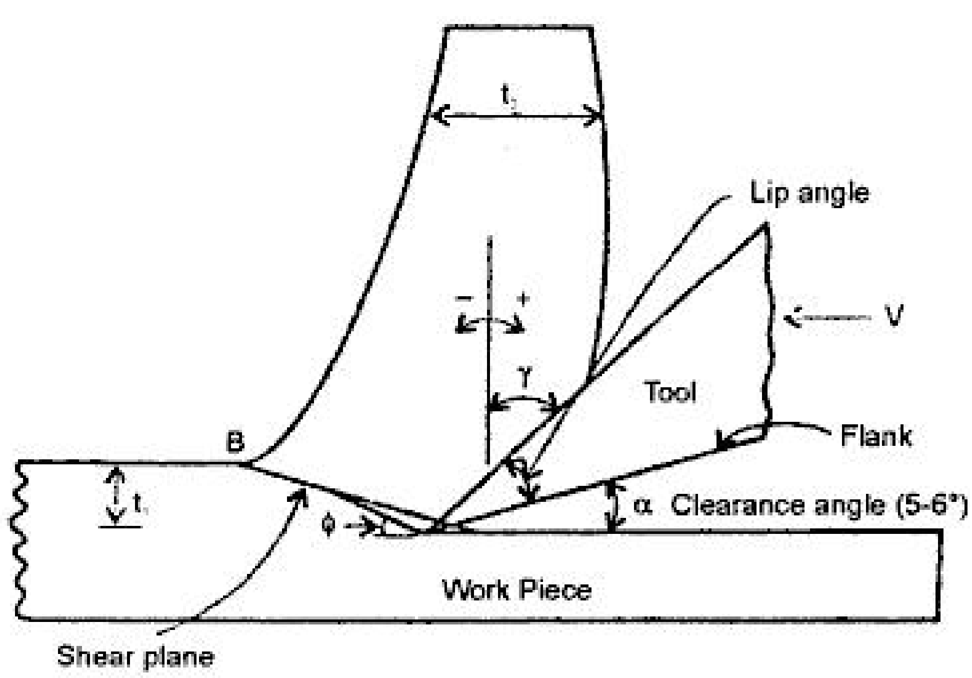


Figure 1.2

γ = Rake angle (15°), ϕ = Shear angle or slip angle,

α = relief angle,

t_1 = uncut chip thickness, t_2 = chip thickness after cut

These elements are displayed in figure (1.1) and (1.2). Which represents the cutting action of a list in two-dimensional or orthogonal cutting. For providing the cutting action, a relative motion between the tool and the work piece is necessary. This relative motion can be provided by either keeping the work piece stationary and moving the tool or, by keeping the tool stationary and moving the work or by moving both in relation to one another.

The work piece provides the parent metal from which the unwanted metal is removed by the cutting action of the tool to obtain the predetermined shape and size of the component. The chemical composition and the physical properties of the metal of the work piece have a significant effect on the machining operation. Similarly, the tool material and its geometry are equally significant for successful machining. The type and geometry of the chip formed are greatly effected by the metal of the work piece, geometry of cutting tool, and method of cutting etc., chemical composition and the rate of flow of the cutting fluid also provide considerable influence over the machining operation.

1.3. METHODS OF METAL CUTTING

The two basic methods of metal cutting using a single point cutting tool are:

1) Orthogonal cutting

2) Oblique cutting

1.3.1. Orthogonal cutting

If the cutting face of the tool is at 90° to the direction of the tool travel the cutting action is called *Orthogonal cutting*.

1.3.2. Oblique cutting

If the cutting face of the tool is inclined at less than 90° to the path of the tool, the cutting action is called *Oblique cutting* (Refer figure 1.3).

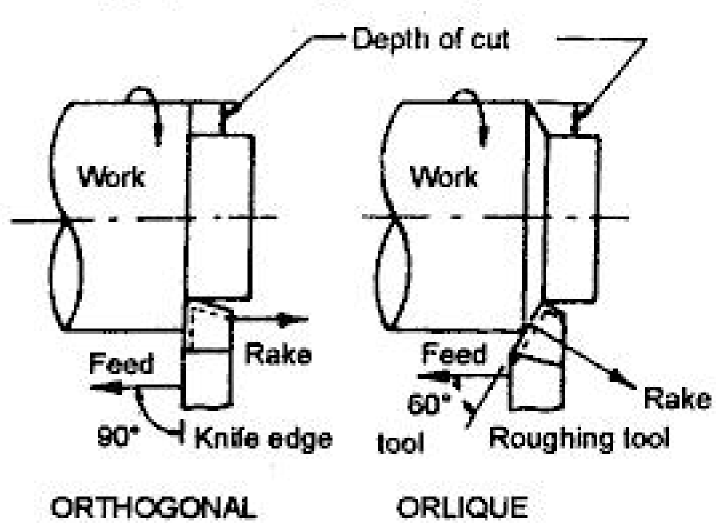


Figure 1.3

1.3.3. The Differences between orthogonal cutting and oblique cutting

	Orthogonal Cutting	Oblique Cutting
1.	Cutting edge of tool is perpendicular to the direction of tool travel	The cutting edge is inclined at an angle less than 90° 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 side ways 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 tool life 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 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

a) Depending upon the number of cutting edges the cutting tools used in metal cutting are classified as follows:

(i) Single point cutting tool

(ii) Multi point cutting tool

(i) Single Point Cutting Tool

This type of tool has a effective cutting edge and removes excess material from the work piece along the cutting edge. Single point cutting tool is of the following types.

(a) Ground type   (b) Forged type

(c) Tipped type   (d) Bit type

In ground type the cutting edge is formed by grinding the end of a piece of tool steel stock. Whereas in forged type the cutting edge is formed by rough forging before hardening and grinding. In tipped type cuttihg tool the cutting edge is in the form of a small tip made of high grade material which is welded to a shank made up of lower grade material. In bit type, a high grade material of a square, rectangular or some other shape is held mechanically in a tool holder. Single point tools are commonly used in lathes, shapers, planers, boring machines and slotters.

Single point cutting tool may be left handed or right handed type. A tool is said to be right/left hand type if the cutting edge is on the right or left side when viewing tool from the point end lathe tools, shaper tools, planner tool and boring tools are single point tools.

(ii) Multi Point Cutting Tool

Having more than a cutting edge. Milling cutters, drills, broaches, grinding wheel are multipoint cutting tools.

b) Cutting tools can also be classified according to the motions as:

i) Linear motion: Lathe, boring, broaching, planing, shaping tools etc.

ii) Rotory motion tools: Milling cutter, grinding wheels etc.

iii) Linear and rotory tool: Drills, honing tool, boring heads etc.

1.5. GEOMETRY OF SINGLE POINT CUTTING TOOL / NOMENCLATURE

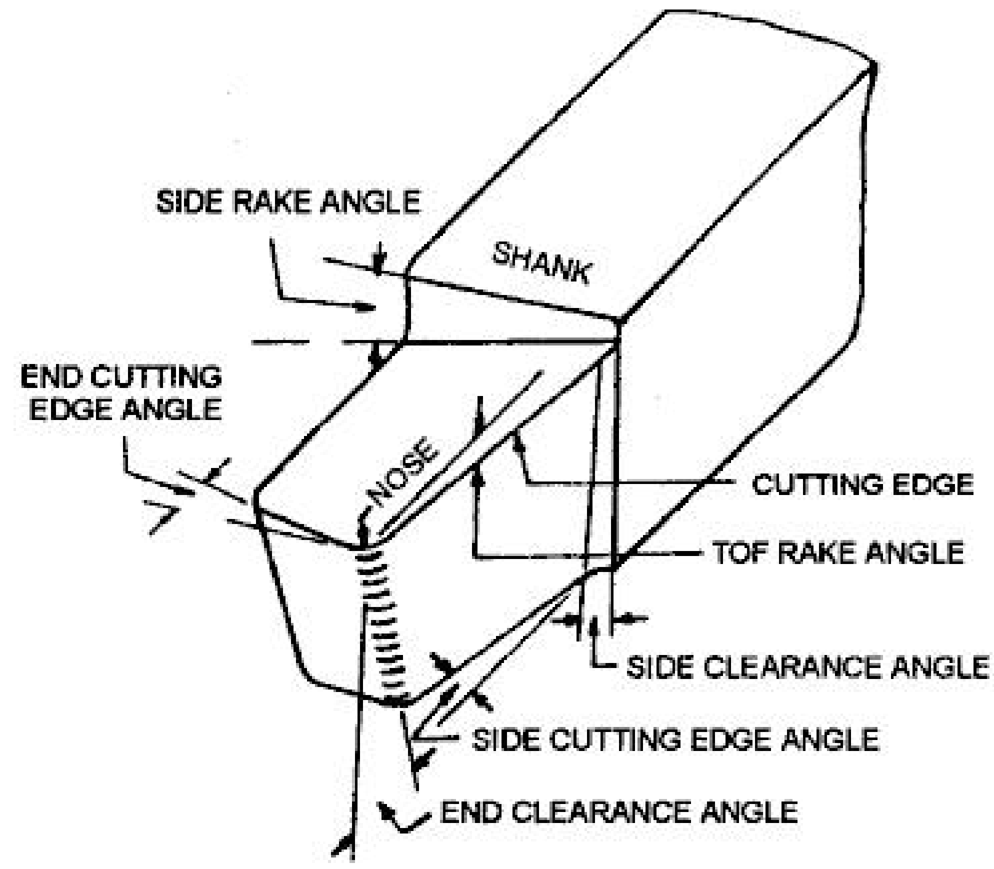


Figure 1.4

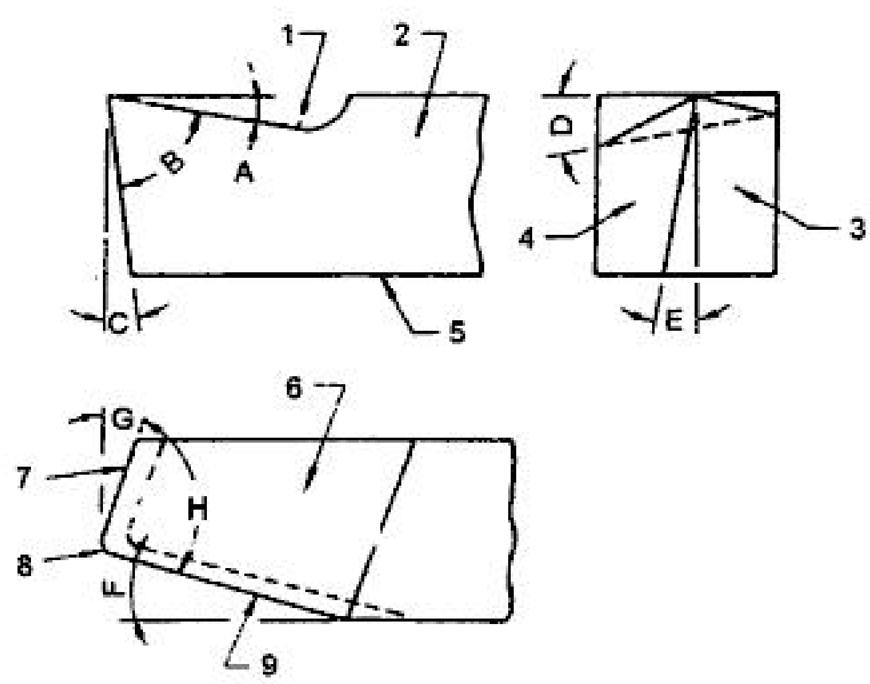


Figure 1.5

Naming the various parts and angles of a cutting tool is known as nomenclature of cutting tool.

The various parts and angles of a single point cutting tool are shown in figure 1.4 and 1.5.

1 & 6 - Face A - Top rake angle

2 - Shank B - Lip Angle

3 - Side flank
4 - End flank
5 - Base
6 - End cutting edge
7 - Nose
8 - Side cutting edge

C - Front clearance angle
D - Side rake angle
E - End clears nee angle
F - Side cutting edge angle
G - End cutting edge angle
H - Nose angle

The important parts of a single point cutting tool are:

1. Shank - It is the body of the tool which is unground.

2. Face - It is the surface over which the chip slides.

3. Flank - It is the surface of the tool facing the workpiece.

There are two Flanks namely end flank and side flank.

4. Base - It is the bottom surface of the shank.

5. Cutting edge - It is the junction of the face and the flanks. There are two cutting edges namely side cutting edge and end cutting edge.

6. Nose - It is the junction of side and end cutting edges.

The important angles of a single point cutting tool are:

1. Top rake angle

It is also called back rake angle. It is the slope given to the face or surface of the tool. This slope is given from the nose along the length of the tool.

2. Side rake angle

It is the slope given to the face or top of the tool. This slope is given from the nose along the width of the tool (side ways). The rake angles help easy flow of chip.

3. Clearance angle or relief angle

These are the slopes ground downwards from the cutting edges. Those are two clearance angles namely, side clearance angle and end clearance angle. This is given to the tool to prevent rubbing of the job on the tool.

4. Cutting edge angles

There are two cutting edge angles namely side cutting edge angle and end cutting edge angle.

Side cutting edge angle is the angle, the side cutting edge makes with the axis of the tool.

End cutting edge angle is the angle, the end cutting edge makes with the width of the tool.

5. Lip angle

It is also called cutting angle.

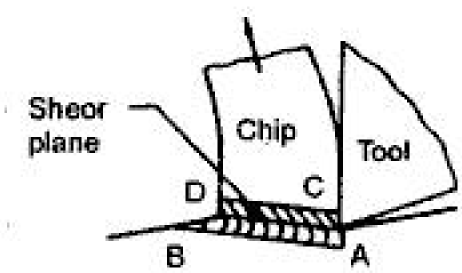
It is the angle between the face and end surface of the tool.

6. Nose angle.

It is the angle between the side cutting edge and end cutting edge.

1.6. CHIP FORMATION MECHANISM

The chip formation is shown in figure 1.6. When the tool advances into the workpiece, the metal in front of the tool is severely stressed. The cutting tool produces internal shearing action in the metal. The metal below the cutting edge yields and flows plastically in the form of chip. Compression of the metal under the tool takes place. When the ultimate stress of the metal is exceeded, separation of metal takes place. The plastic flow takes place in a localised area called shear plane the chip moves upward on the face of the tool. The process is continued and a continuous chip formation takes place. The grains of metal in front of the tool cutting edge start elongating along line AB.



SHEAR ZONE DURING METAL CUTTING

Figure 1.6

This elongation continues until the grains are completely deformed along the line CD. The region between 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.

1.7. TYPES OF CHIPS

The removed metal layer during the metal cutting operation is known as chips. The layer undergoes the following operations : elastic deformation, plastic deformation and the final removal from the parent metal. The type of chip depends on the material being cut and the Cutting conditions.

1.7.1. Continuous Chip (without built up edge)

When the cutting tool moves towards the workpiece, there occurs a plastic deformation of the work piece and the metal is separated without any discontinuity and it moves like a ribbon.

The chip moves along the face of the tool. This mostly occurs while cutting a ductile material. It is desirable to have smaller chip thickness and higher cutting speed in order to get continuous chips. Lesser power is consumed while continuous chips are produced. Total life is also mortised in this process. (Refer Fig. 1.7).

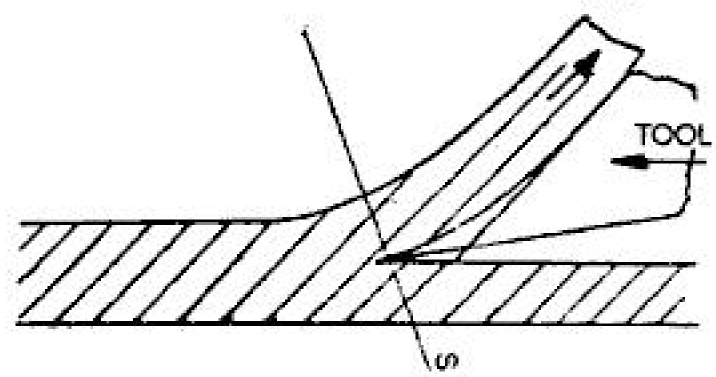


Figure 1.7

1.7.2. Discontinuous Chips

This can also be called as segmental chips. This mostly occurs while cutting brittle material such as cast iron or low ductile materials. Instead of shearing the metal as it happens in the previous process, the metal is being fractured like segments of fragments and they pass over the tool faces. Tool life can also be more in this process. Power consumption as in the previous case is also low. (Ref. Fig. 1.8.)

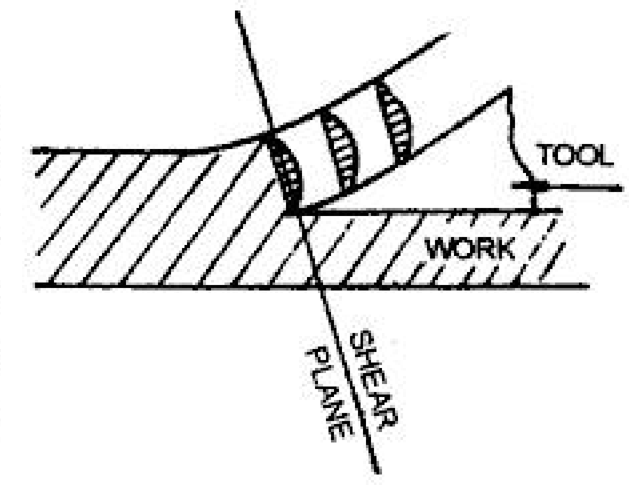


Figure 1.8

1.7.3. Continuous Chips (with built up edge)

When cutting a ductile metal, the compression of the metal is followed by the high heat at tool face. This in turns enables part of the removed metal to be welded into the tool. This is known as built up edge. The weld metal is work hardened or strain hardened. While the cutting process is continued, some of built up edge may be combined with the chip and pass along the tool face. Some of the built up edge may be permanently fixed on the tool face. This produces a rough surface finish and the tool life may be reduced. (Ref. Fig. 1.9.)

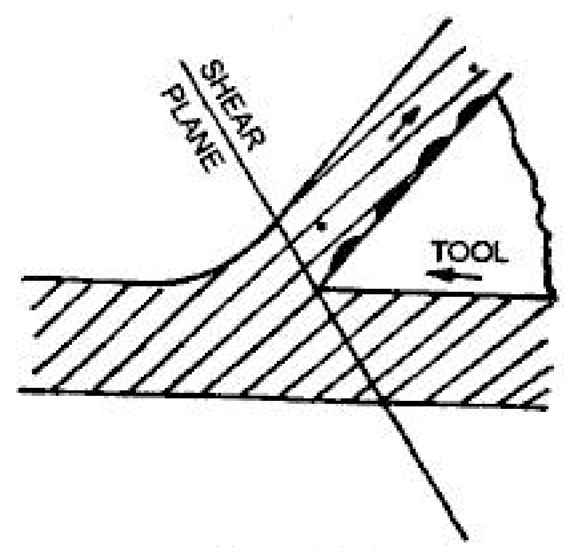


Figure 1.9

1.8. CHIP BREAKERS

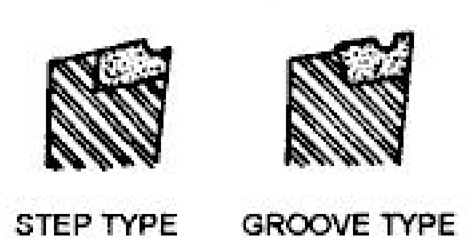


Figure 1.10. Chip Breakers

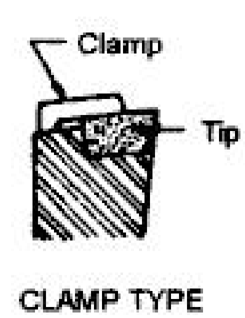


Figure 1.11. Clamp Type Breakers

During machining, long and continuous chip will affect machining. It will spoil tool, work and machine. It will be difficult to remove metal and also dangerous to safety. The chip should be broken into small pieces for easy removal, safety and to prevent damage to machine and work. This is very important in automatic machines and machines which run at high speeds. Chip breakers are used to break the long continuous chip into small pieces. The chip breaker is provided on the cutting tool. Different types of chip breakers used on a cutting tool are (1) Step type (2) Groove type and (3) Clamp type.

1.9. MEASUREMENT OF CUTTING FORCES

There are several important reasons for measuring forces which include:

1. To estimate the various power required in a machine tool.
2. To estimate the forces acting on the tool, that must be resisted by the machine tool components, bearings etc.,
3. To survey the characteristics of new work and tool material.

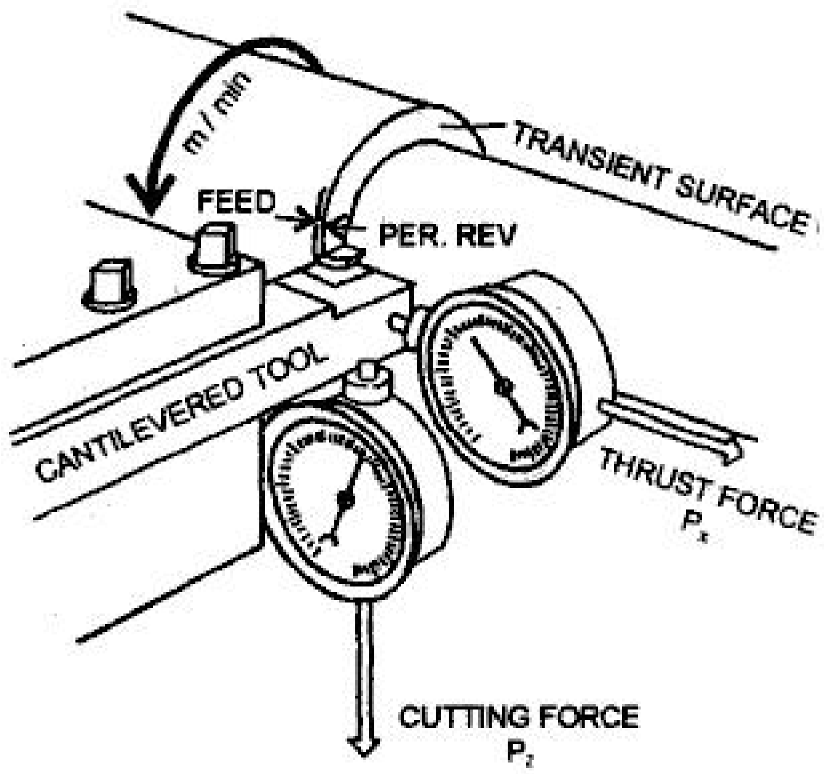


Figure 1.12 Mechanical tool force dynamometer

1.9.1. Measurement of cutting forces

Cutting forces or power at the cutting tool may be measured in various ways, such as:

1. Dynamometer 2. Ammeter 3. Wattmeter
4. Calorimeter 5. Thermocouple

1.9.1.1. Mechanical - Dynamo meter

Direct measurement by dynamometers have won generalacceptance. Mechanical and strain-gauge dynamometers are most commonly used for measuring forces in metal cutting. The common feature in all types of dynomometer is the measuring springs whose deflections are proportional to cutting forces. The major difference in the design of various dynamometer lies in the technique employed to measure spring deflection. A mechanical tool force dynamometer which is shown in figure (1.12) measures deflection on the tool holder by the use of sensitive dial indicators. Another way the sensitivity can be achieved by using a lever system that can magnify the deformation. Various researches utilized this methodology by combining a sensitive dial gauge and a lever, the end of which is connected with the tool using a roller and a screw.

For example, the cutting (or) tangential force P_Z (or) F_C will tend to deflect the tool and tool holder downwards, the axial force or thrust force (P_x) or (F_t) along the axis of the workpiece (opposite to the direction of feed) and the radial force (F_r) will tend to push the tool away from work which may cause chatter. A two dimensional dial indicator type mechanical dynamometer schematically shown in figure (1.12). With this arrangement the forces (P_x) or (F_t) and (P_z) or (F_C) can be directly measured. The above principle can be easily adapted for measuring torque and thrust force in a suitably designed drilling dynamometer.

1.9.1.2. Electrical Strain gauge Dynamo meter

The basic principle of a strain gauge dynamometer is illustrated in figure (1.13) with respect to a turning dynamometer designed by shaw. The unbalance of the wheatstone bridge indicates the cutting forces. Each of the two sets of four gauges are connected into two bridge circuits to enable the determination of (P_x) or (F_t) and (P_y) or (F_r). The strain gauge dynamometer is more accurate and is in common use.

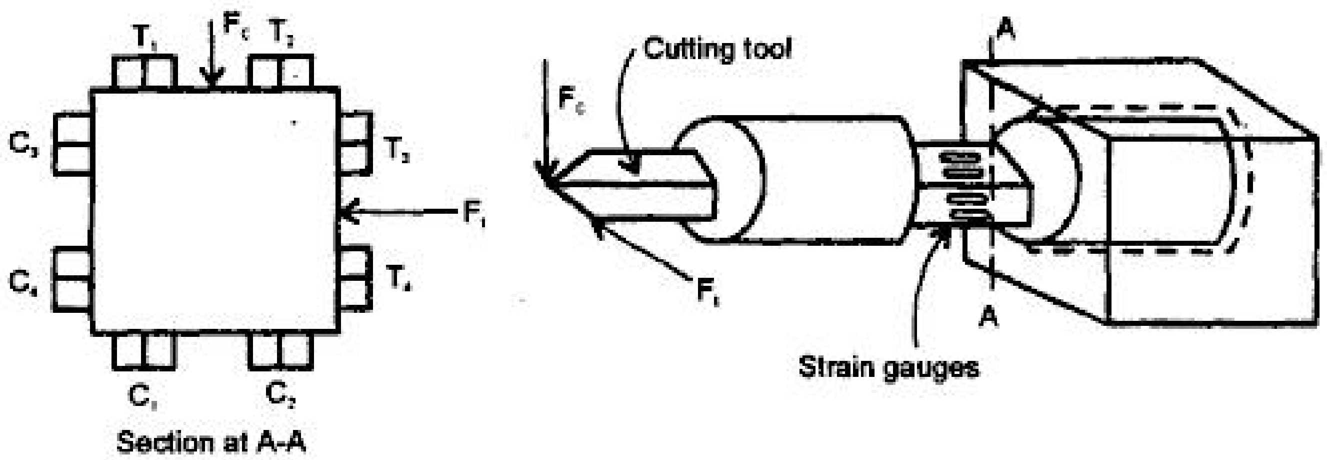


Figure 1.13 Use of strain gauges in a set up for two dimensional force measurement in turning on a lathe.

P_X (or) F_t = The feed force or thrust force acting in horizontal plane parallel to the axis work

P_Y (or) F_r = Radial force, also acting in the horizontal plane but along a radius of the work piece, i.e., along the axis of the tool.

P_z (or) F_C = The cutting force, acting in vertical plane and is tangential to the work surface. Also called the tangential force.

1.10. CUTTING FORCES IN ORTHOGONAL CUTTING

The forces acting on a single point cutting tool are of fundamental importance in the design and of cutting and machine tools. For a conventional turning process the force system is shown in figure (1.14).

The resultant cutting force P represented by OA acting on the tool is considered to be as vector sum of three component cutting forces mutually at right angles.

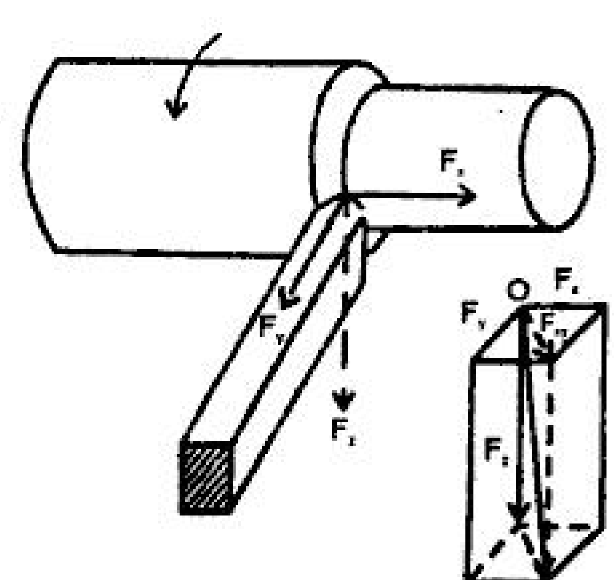


Figure 1.14

i) Feed force F_x acts in a horizontal plane but in the direction opposite to the feed,

ii) Thrust force F_y acting in the direction perpendicular to the generated surface,

iii) Cutting forces F_z in the direction of the main cutting motion.

The relationships between forces, F_x, F_y, and F_z depend upon the cutting variables, geometry of the tool point, the work material, tool wear etc.

$$R = \text{Resultant force} = \sqrt{F_x^2 + F_y^2 + F_z^2}$$

This three dimensional force system can be reduced to a two dimensional force system if in the orthogonal plane M the forces are considered in such a way that the entire force system is contained in the considered state, when

$$R = \sqrt{F_z^2 + F_{xy}^2}$$

$$F_{xy} = \sqrt{F_x^2 + F_y^2}$$

For this $\alpha_i = 0$ and F_{xy} is contained in orthogonal plane M. This system is then known as orthogonal system of first kind for which the conditions are as follows.

i) $\alpha_i = 0$

ii) $0 < \phi < 90$

iii) Chip flow deviations are small

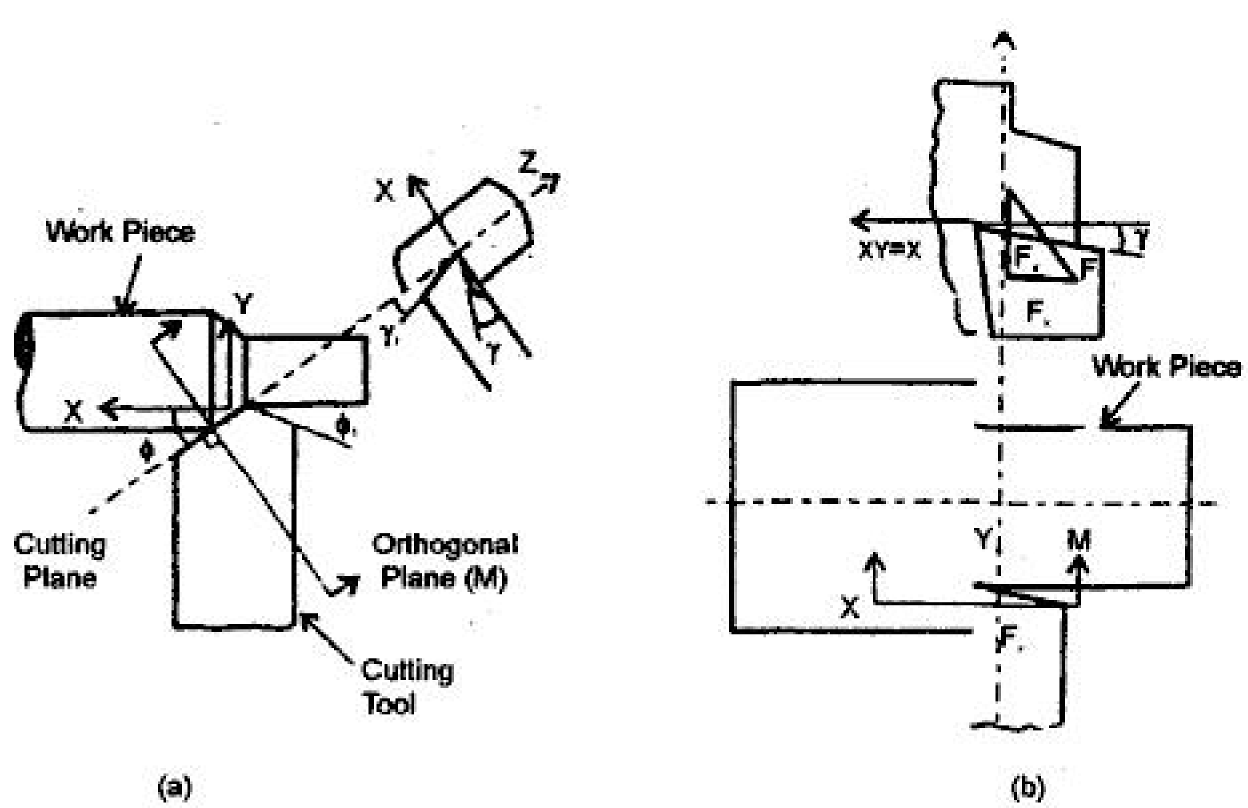


Figure 1.15

The various forces for the orthogonal system of first kind is shown in figure 1.15 (a).

Where ϕ = principal cutting edge angle

α_i = inclination angle

In orthogonal system of first kind

$$F_x = F_{xy} \sin \phi$$

$$F_y = F_{xy} \cos \phi$$

There is either orthogonal system known as orthogonal system of second kind in which F_y is made zero by having $\alpha_i = 0$ and $\phi = 90°$ when two dimensional force system is

$$R = \sqrt{F_z^2 + F_x^2}$$

$$F_{xy} = \sqrt{F_x^2 + F_y^2}$$

$$= \sqrt{F_x^2 + 0}$$

$$F_{xy} = F_x$$

$$F_{xy} = F_y$$

When $\phi = 0$ and $\alpha_i = 0$

Figure 1.15(b) shows two dimensional force system in plane M for orthogonal system of second kind.

In orthogonal system the tool shape is specified by the following terms stated in order.

i) Inclination angle

ii) Orthogonal rake angle

iii) Orthogonal clearance angle

iv) Auxillary orthogonal clearance angle.

v) Auxillary cutting edge angle

vi) Principal cutting edge angle

vii) Nose radius in millimeters

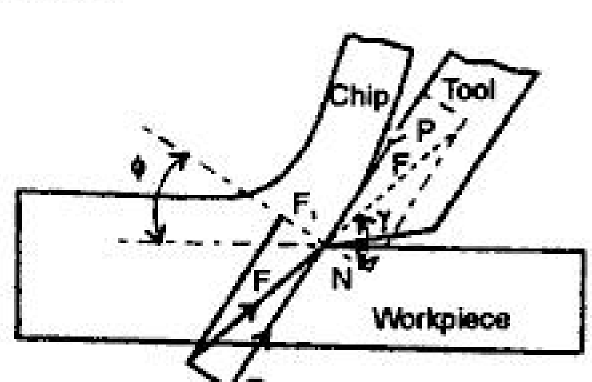


Figure 1.16

The chip may be considered as a separate body held in equilibrium by the various forces shown in figure (1.16).

Force F_s acts along the shear plane and is the resistance to shear of the metal in forming the chip. Force F_n is normal to shear plane. This is a backing up force on the chip provided by the work piece. F is the resultant of F_S and F_n. Force P is the frictional resistance of the tool acting downward against the motion of chip as it moves along the tool face. The normal force N is normal to the tool face and is provided by the tool. The resultant of these two forces is F' and is the force exerted by the tool on the workpiece the force F and F' are equal in magnitude. Opposite in direction and collinear.

$$\vec{F} = \vec{F_s} + \vec{F_n}$$

$$F' = \vec{P} + \vec{N}$$

The relation between various forces have been worked out by Merchant with a large number of assumtions as follows.

i) The chip behaves as a free body in stable equilibrium under the action of two equal opposite and collinear resultant forces.

ii) Continuous chip without built up edge is produced.

iii) The cutting velocity remains constant.

iv) The cutting tool has a sharp cutting edge and it does not make any flank contact with the work piece.

Merchant suggested a compact and easiest way of representing the various forces inside a circle having the vector F as diameter. Figure (1.17) shows merchant circle diagram which is convenient to determine the relation between the various forces and angles. The circle has a diameter equal to F or f ' passing through the tool point.

γ = Rake angle of Tool

ϕ = Shear angle

β = Friction (wedge) angle of the tool face

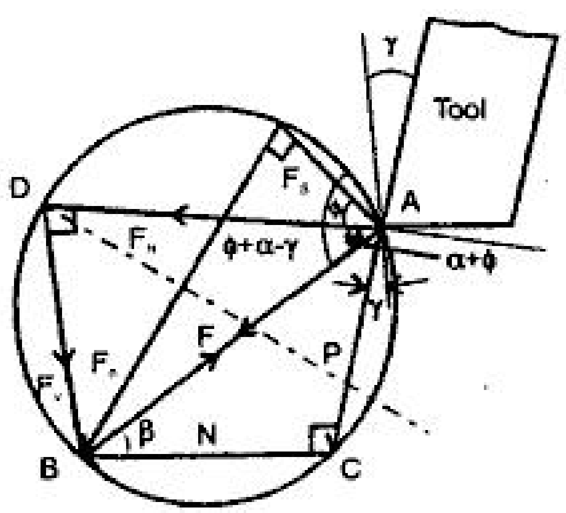
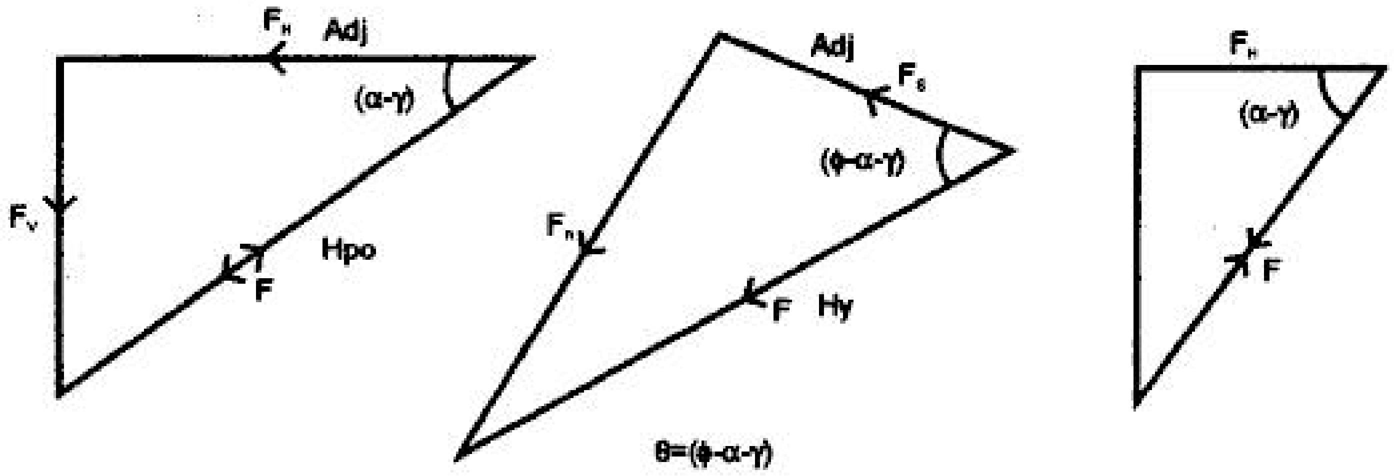
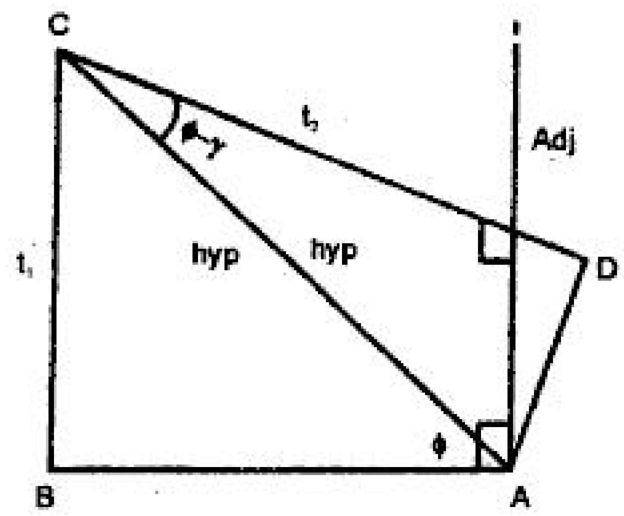


Figure 1.17 Merchant circle diagram



Shear angle ϕ



As the chip slides over the tool face under pressure therefore the kinetic coefficient of friction (m) may be expressed as

$$\mu = \frac{P}{N} = \tan\alpha$$

The cutting force F_H and feed force F_v can be measured with a cutting tool dynamometer and then the other forces can be determined in terms of F_H and F_v. Shear angle ϕ can be obtained from the equation.

$$\tan\phi = \frac{r\cos\gamma}{1 - r\sin\gamma}$$

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

where

t_1 = chip thickness before cutting

t_2 = chip thickness after cutting

P = friction resistance

$= F_H \sin\gamma + F_v \cos\gamma$

N = normal force

$= F_H \cos\gamma + F_v \sin\gamma$

$$F = \sqrt{F_H^2 + F_v^2}$$

F = Cutting force

$= F \cos(\alpha - y)$

Also, $F_S = F \cos\theta$

$$\therefore F = \frac{F_s}{\cos\theta}$$

where

$$\theta = \phi + \alpha - \gamma$$

$$F_H = \frac{F_s \cdot \cos(\alpha - \gamma)}{\cos\theta}$$

$$= \frac{F_s \cdot \cos(\alpha - \gamma)}{\cos(\phi + \alpha - \gamma)}$$

μ = coefficient of friction

$$= \tan\alpha = \frac{P}{N}$$

$$= \frac{F_H \sin\gamma + F_v \cos\gamma}{F_H \cos\gamma - F_v \sin\gamma}$$

$$= \frac{F_H \cdot \tan\gamma + F_v}{F_H - F_v \tan\gamma}$$

The relationships for F_s and F_n are as follows:

Cutting forces depends on the following:

i) Material to be cut.

a) Hardness of material

b) Strength of material

ii) Depth of cut

iii) Feed

iv) Tool geometry

1.10.1. Construction of Merchants Circle Diagram (or) Merchant Force Diagram

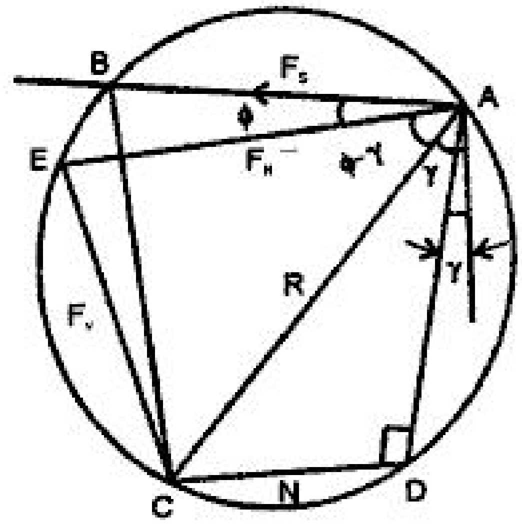


Figure 1.18 Merchant's circle diagram

where

ϕ = Shear angle

F_S = Shear force

F_C = Cutting force

F_v = Vertical component

γ = Back rake angle

Draw a horizontal line and choose a point 'A' conveniently. At 'A' draw the vector "F_s" to suitable scale at angle "q". From the merchant's theory: 20 + ϕ = 90°. Knowing "θ" and "γ" can be evaluated. Draw the vector R at angle (ϕ - γ) from the horizontal. Choose the centre of the Merchant's circle on the vector "R" and draw a circle such that it passes through the points "A" and "B". The circle cuts the vector "R" extended at "C". Produce "A" to meet the other end of the circle at E, which measures the vertical component of the cutting force "F_v" to the scale. Join "E_C" which is the horizontal component "F_C" to the same scale. At "A" draw a vertical and vector "F" at an angle "α" which meets the circle at "D". Join "CD" which is equal to "N" and "CB" measures "FN". Thus all the force components can be readily obtained from the Merchant's circle (Fig. 1.18).

1.11. STRESS AND STRAINS DURING THE CHIP FORMATION

During, machining the chips are produced due to the plastic deformation of the metal and are subjected to stress and strain.

Let F_S = Shearing force

f_S = Shear stress in the shear plane

or σ_{na} = Average or Shear stress on the shear plane

A_1 = Cross sectional area of chip before cutting

A_2 = Area of Shear Plane

Now $f_s = \dfrac{F_S}{A_3}$

$$A_2 = \frac{A_1}{\sin\phi}$$

$$\therefore f_s = \frac{F_S}{A_1}\sin\phi$$

$$= \frac{(F_H\cos\phi - F_v\sin\phi)\sin\phi}{A_1}$$

$$= \frac{F_H\cos\phi\sin\phi - F_v\sin\phi}{A_1}$$

F_H or F_C = Cutting Force

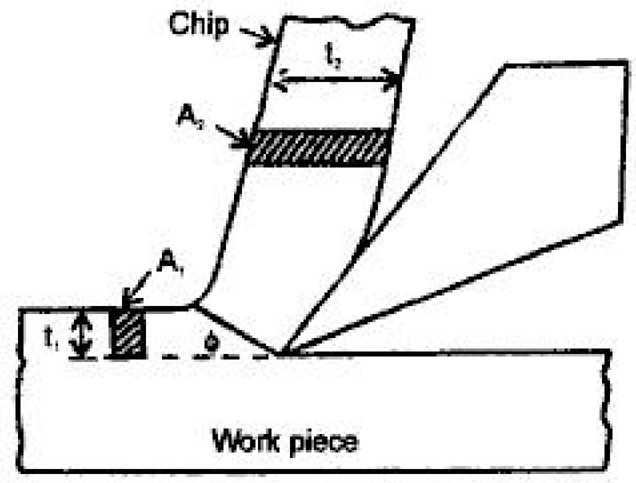


Figure 1.19

where $A_1 = b_1 \cdot t_1$

b_1 = width of the chip
t_1 = thickness of chip

1.12. SHEAR STRAIN

The chip is considered to the considering of stress of plate like element of thickness "Δ_y" and displaced through a distance "Δ_S" relative to each other as shown in figure (1.20). Strain is defined as the deformation per unit length.

$$e = \text{Shear strain} = \frac{\Delta S}{\Delta Y}$$

Now $$e = \frac{\Delta S}{\Delta Y} = \frac{AB}{CD}$$

$$= \frac{BD}{CD} + \frac{AD}{CD}$$

$$= \cot\phi + \tan(\phi + \gamma)$$

$$= \frac{1}{\tan\phi} + \frac{\tan\phi - \tan\gamma}{1 + \tan\phi\tan\gamma}$$

$$= \frac{1 + \tan^2\phi}{\tan\phi + \tan^2\phi\tan\gamma}$$

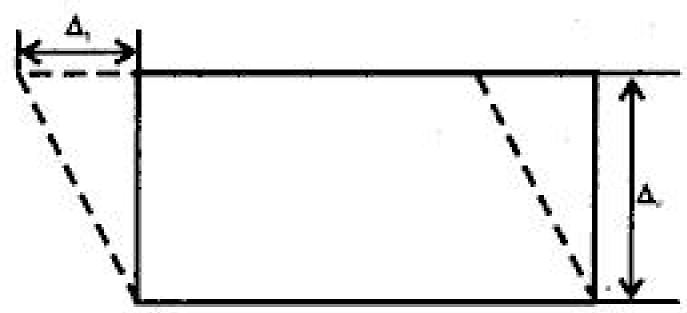


Figure 1.20

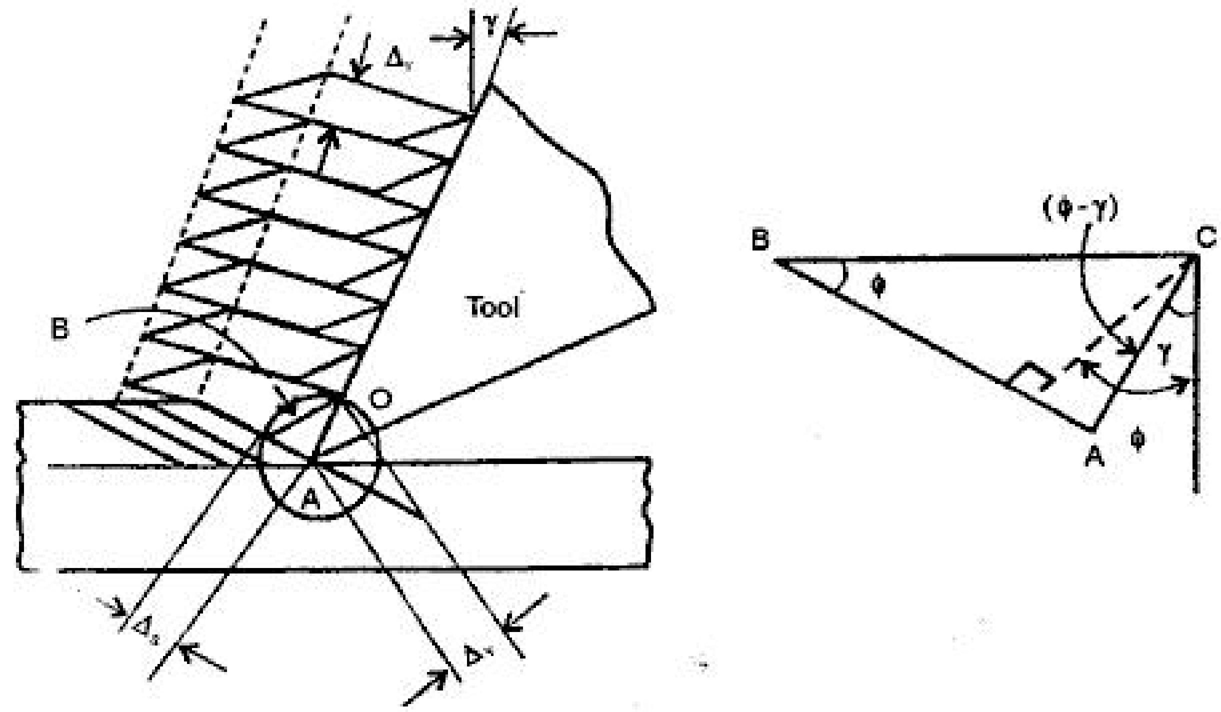


Figure 1.21

$$\frac{c^2 \phi}{\text{in}\, \phi \tan \gamma)}$$

$$= \frac{}{\sin \phi} \quad \overline{(\phi - \gamma)}$$

To prove that,

$$e = \frac{K^2 - 2K \sin \gamma + 1}{K \cos \gamma}$$

we know from equation (1)

$$e = \cot \phi + \tan(\phi - \gamma)$$

$$\tan \phi = \frac{r \cos \gamma}{1 - r \sin \gamma} = \frac{\cos \gamma}{\frac{1}{r} - \sin \gamma}$$

$$= \frac{\cos \gamma}{K - \sin \gamma}$$

Now $\quad e = \cot \phi + \tan(\phi - \gamma)$

$$e = \frac{\cot \phi + \tan \phi - \tan \gamma}{1 + \tan \phi \cdot \tan \gamma}$$

substitute the values of tan β,

$$e = \frac{K - \sin\gamma}{\cos\gamma} + \frac{\dfrac{\cos\gamma}{K - \sin\gamma} - \tan\gamma}{1 + \dfrac{\cos\gamma}{K - \sin\gamma} \times \tan\gamma}$$

$$= \frac{K - \sin\gamma}{\cos\gamma} + \frac{\cos\gamma - \tan\gamma \times (K - \sin\gamma)}{K - \sin\gamma + \cos\gamma \cdot \tan\gamma}$$

$$K = \frac{K - \sin\gamma}{\cos\gamma} + \frac{\cos^2\gamma - k\sin\gamma\sin^2\theta}{K\sin\gamma}$$

$$e = \frac{K - \sin\gamma}{\cos\gamma} + \frac{1 - \sin\gamma \times K}{K\cos\gamma}$$

$$= \frac{K^2 - K\sin\gamma + 1 - K\sin\gamma}{K\cos\gamma}$$

$$= \frac{K^2 - 2K\sin\gamma + 1}{K\cos\gamma}$$

where K = Chip reduction co-efficient

1.13. WORK DONE IN CUTTING

The total workdone is cutting is equal to the sum of the workdone in shearing the metal and the workdone in overcoming the friction.

Now, if W = Total workdone

W_s = Workdone in shear

W_f = Workdone against friction

$$W = W_S + W_f \qquad \text{... (1)}$$

If no work is lost, the total work done must be equal to the work supplied by the motor.

i.e., work supplied by the motor should be = $W_S = W_f$

Now, the work supplied by the motor is partly used in cutting and partly in feeding the tool. If W_m be the work supplied by the motor, then;

W_m = Work consumed in cutting + work spend in feeding

$= F_C \times V_C + F_t \times$ feed velocity.

In comparison to the cutting velocity the feed velocity is very normal. Similarly, F_t is very small as compared to F_C. So, the work spent in feeding can be considered as negligible.

Therefore $\quad W_m = F_C \times V_C$ ... (2)

Also, under ideal conditions, i.e., when there is no loss of work

$$W_m = W$$

Therefore, $\quad F_C \times V_C = W_S + W_f$ ... (3)

Now $\quad W_S = F_S \times V_S$ (Shearforce × shear velocity)

and $\quad W_f = F \times V_f$ (Frictional force x velocity of chip flow)

or $\quad F_C \times V_C = F_S \times V_S + F \times V_f$ ... (4)

If the forces are taken in kg and velocities in meters per minute, the workdone will be in kgfm/min

Total workdone per unit volume of the metal removed in unit time.

$$= \frac{\text{Total work done in cutting per unit time}}{\text{Volume of the metal removed in unit time}}$$

$$= \frac{F_C \times V_C}{A_0 \times V_C}$$

where A_0 = Cross sectional area of chip before removal.

$$= \frac{F_C}{A_0}$$

Horse power calculation

$$\text{H.P. required in cutting} = \frac{\text{Work done in cutting / min}}{4500}$$

$$= \frac{F_C \times V_C}{4500} \text{ h.p}$$

$$= \frac{F_C \times V_C}{4500 \times 1.36} \text{ K.W}$$

where F_C is in kg.

V_C in m/min

1.14. METAL CUTTING THEORIES

1. Ernst-Merchant theory
2. Lee and Shaffer's theory

1.14.1. Ernst-Merchant Theory

This theory, first propagated by Ernst and Merchant in 1941, is based on the principle of minimum energy consumption. It implies that during cutting the metal shear should occur in that direction in which the energy requirement for shearing is minimum the other assumptions made by them include:

a) The behaviour of the metal being machined is like that of an ideal plastic.

b) At the shear plane the shear stress is maximum is constant and independent of shear angle (ϕ).

They deduced the following relationship:

$$\phi = \frac{\pi}{4} - \frac{\beta}{2} + \frac{\gamma}{2}$$

where

ϕ = Shear angle

γ = rake angle

β = friction angle

1.14.2. Lee and Shaffer's Theory

This theory analysis the process of orthogonal metal cutting by applying the theory of plasticity for an ideal rigid plastic material. The principal assumptions are.

a) The workpiece material ahead of the cutting tool behaves like an ideal plastic material.

b) The deformation of the metal occurs on a single shear plane.

c) This is a stress field within the produced chip which transmits the cutting force from the shear plane to the tool face and therefore, the chip does not get hardened.

d) The chip separates from the parent material at the shear plane.

Based on these, they developed a slip line field for stress zone, in which no deformation would occur even if it is stressed to its yield point. From this, they derived the following relationship.

$$\phi = \frac{\pi}{4} + \gamma - \alpha$$

$$= 45° + \gamma - \alpha$$

$$= \phi + \alpha - \gamma = 45°$$

This was further modified as,

$$\phi = \frac{\pi}{4} + \gamma - \theta - \alpha$$

$$= 45° + \gamma + \theta - \alpha$$

$$= \phi + \alpha - (\gamma - \theta) = 45°$$

The term 'θ' was introduced to cover the changes in different parameter on account of the formation of built up edge.

A large number of investigators have been working on 'Metal Cutting' over the years assuming different cutting conditions and parameters and have derived many different relationships. Some of the prominent researchers, apart from the above, in this include stabler, show-cork and Finnie, Hucks, Kronenberg, Hitomi and Okushima, Zorev, Albrecht and Loladze. However it is not possible to discuss the works of all of them in this small chapter. Some standard book on metal cutting needs to be referred for this purpose.

1.14.3. Modified-Merchant Theory

According to this theory the relation between rake angle γ, shear angle ϕ and friction angle β is as follows

$$\phi = \frac{\pi}{4} - \frac{\beta}{2} + \frac{\gamma}{2}$$

i) Shear will take place in a direction in which energy required for shearing is minimum.

ii) Shear stress is maximum at the shear plane and it remains constant.

we have proved that

$$F_H = \frac{F_S \cdot \cos(\alpha - \gamma)}{\cos(\phi + \alpha - \gamma)}$$

Now $F_S = f_S \cdot A_2$

where

f_S = Shear stress

A_2 = Area of shear plane

$$= \frac{b_1 t_1}{\sin\phi}$$

$$\therefore F_H = \frac{b_1 t_1}{\sin\phi} \frac{\cos(\alpha - \gamma)}{\cos(\phi + \alpha - \gamma)}$$

Differentiating w.r.t. to β

$$\frac{dF_H}{d\beta} = -f_S \cdot b_1 t_1 \cos(\alpha - \gamma) \times \frac{\cos\phi \cdot \cos(\phi + \alpha - \gamma) - \sin\phi \cdot \sin(\phi + \alpha - \gamma)}{\sin^2\phi \cos^2(\alpha + \alpha - \gamma)}$$

= 0 in order that ϕ will assume that value which required a minimum force to cut the material.

$$\therefore \cos\phi \cos(\phi + \alpha - \gamma) - \sin\phi \sin(\phi + \alpha - \gamma) = 0$$

$$\cos(\phi + \phi + \alpha - \gamma) = 0$$

$$\cos(2\phi + \alpha - \gamma) = 0$$

$$2\phi + \alpha - \gamma = \frac{\pi}{2}$$

$$\phi = \frac{\pi}{4} - \frac{\alpha}{2} + \frac{\gamma}{2}$$

1.14.4. Chip Thickness Ratio

The outward flow of the metal causes the chip to be thicker after separation from the parent metal. Metal prior to being cut is much longer than the chip which is removed.

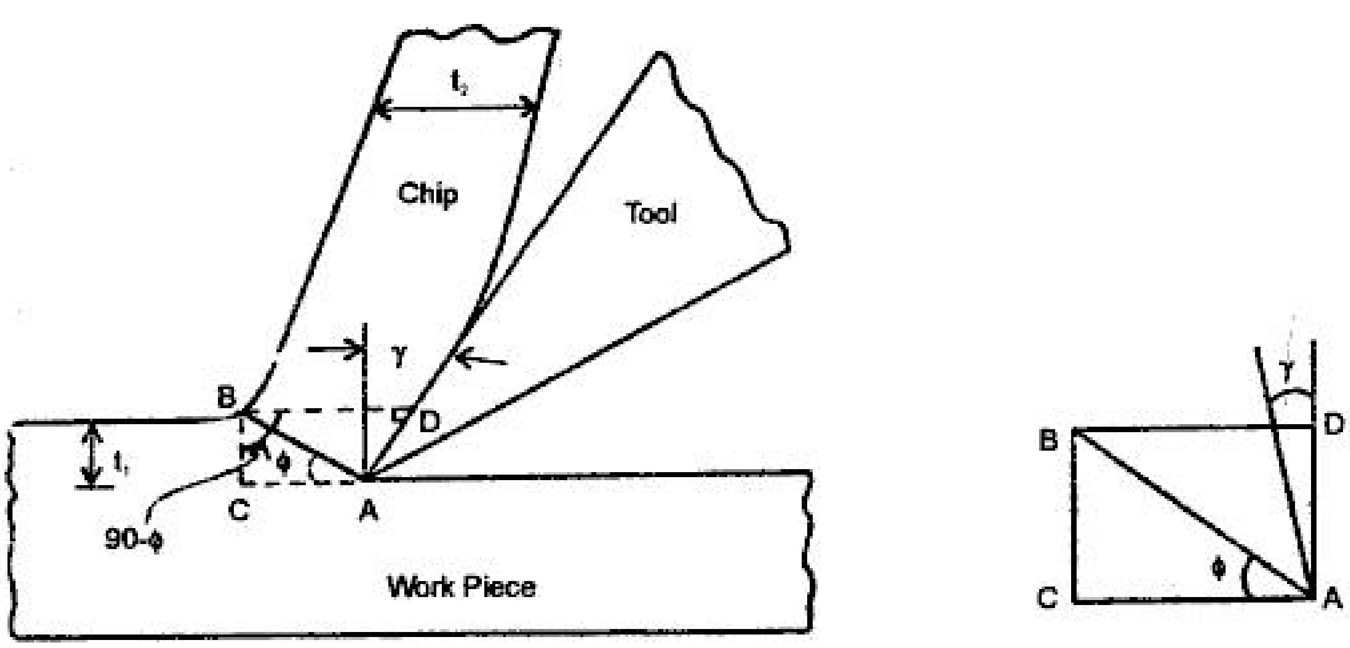


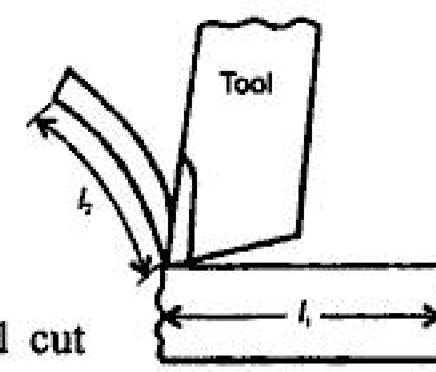
Figure 1.22 An orthogonal cutting operation

Let t_1 = Chip thickness before cutting

t_2 = Chip thickness after cutting

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

The chip thickness ratio or cutting ratio is always less than unity. If the ratio 'r' is large, the cutting action is good. A ratio of 1:2 yields good results.



K = Chip reduction coefficient.

$= \frac{1}{r}$

when metal is cut there is no change in the volume of the metal cut

$$t_1 \cdot b_1 \cdot l_1 = t_2 \cdot b_2 \cdot l_1$$

where t_1 = Chip thickness before cutting (depth of cut)

b_1 = width of cut

l_1 = length of chip before cutting

Figure (1.23) shows the effect of cutting speed (v) an chip reduction coefficient 'K' with an increase in cutting speed contraction is first reduced, reaching a minimum and then increase reaching a maximum after which it drops again figure (1.24) shows variation of chip reduction coefficient with feed upon an increase in feed coefficient of chip reduction is usually reduced. The effect of surface active cutting fluids is clearly manifested in the reduction of chip contraction figure (1.25).

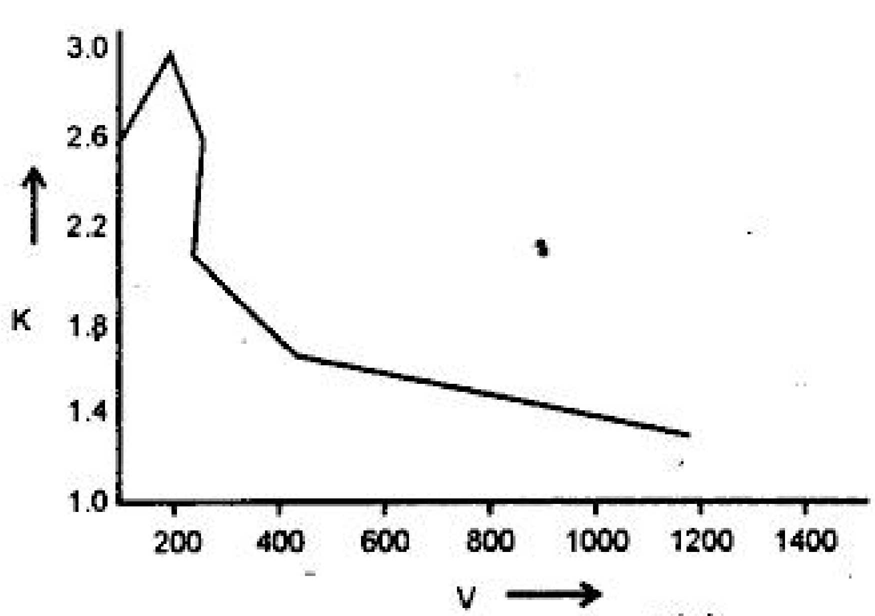


Figure 1.23

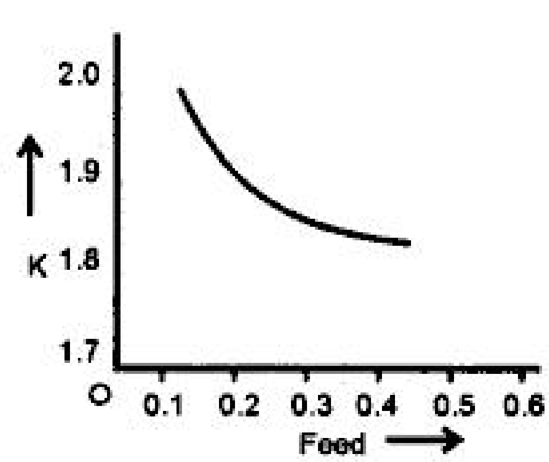


Figure 1.24

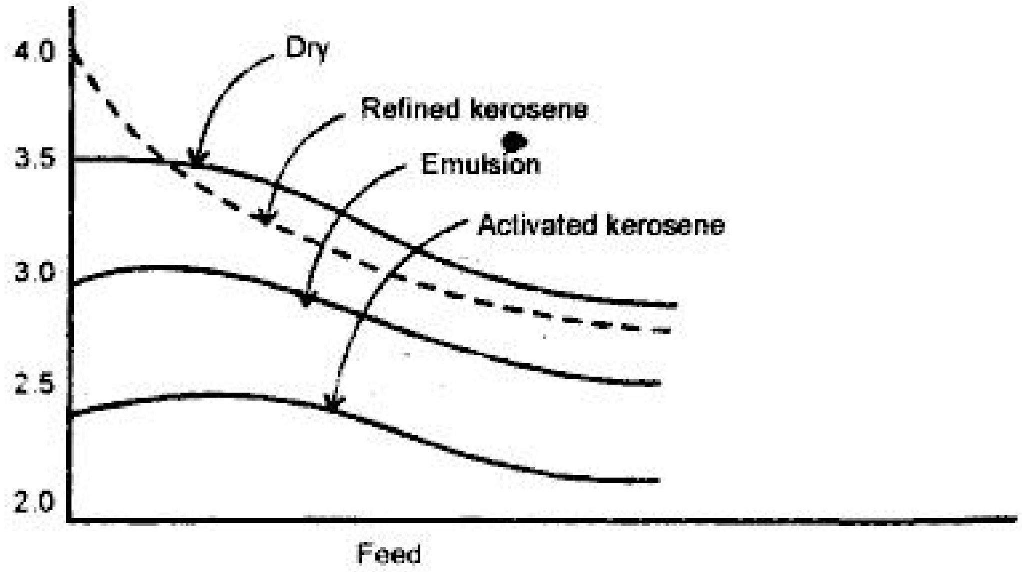


Figure 1.25

1.14.5. Velocity Relationships

The relationship of different velocities for orthogonal cutting is shown in figure (1.26). Let the velocities depicted in the diagram be as follows:

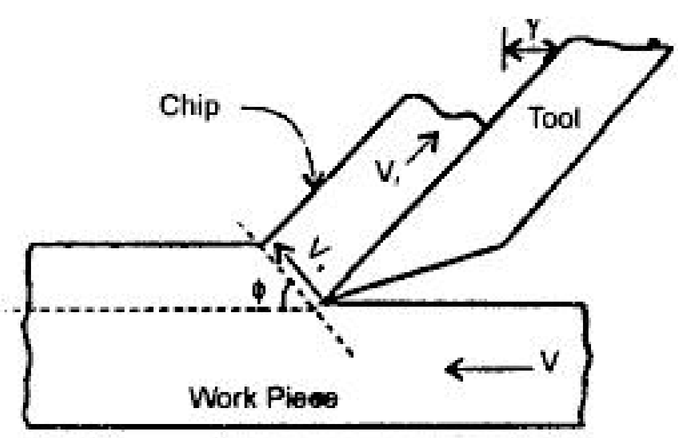


Figure 1.26 Velocity relationship

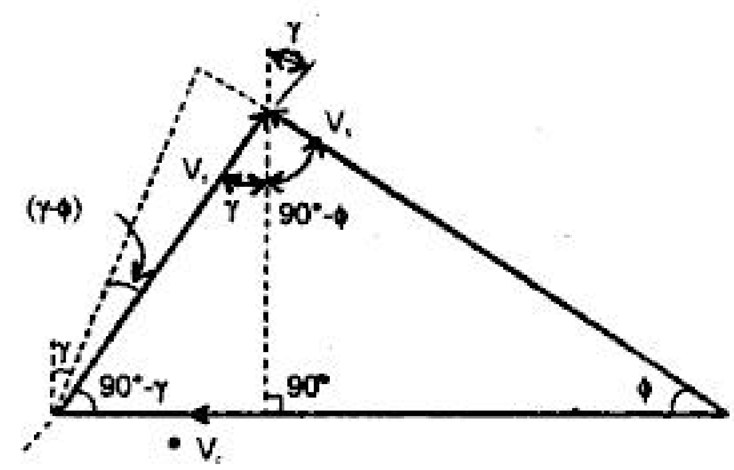


Figure 1.27 Velocity diagram

V_c = Velocity of tool relative to work, or the cutting velocity.

V_f = Velocity of chip flow relative to tool, or the chip flow velocity.

V_s = Velocity of displacement of the chip along the shear plane relative to work, or the velocity of shear.

Of the above three velocities the cutting velocity V_c is always known. The other two can be computed with its help of the following relations. Which refer to the velocity diagram shown in the right side in figure (1.27).

From standard trignometrical ratios, we get.

$$\frac{V_C}{\sin(90-\phi+\gamma)} = \frac{V_f}{\sin\phi} = \frac{V_S}{\sin(90-\gamma)}$$

or

$$\frac{V_C}{\sin[90-(\phi-\gamma)]} = \frac{V_f}{\sin\phi} = \frac{V_S}{\cos\gamma}$$

or $$\frac{V_C}{\cos(\phi-\gamma)} = \frac{V_f}{\sin\phi} = \frac{V_S}{\cos\gamma}.$$

From these relations the values of V_f and V_S can be derived in terms of the known velocity 'V_C' as follows:

$$V_S = V_C \cdot \frac{\cos\gamma}{\cos(\phi-\gamma)} \qquad \text{... (1)}$$

and $$V_f = V_C \cdot \frac{\sin\gamma}{\cos(\phi-\gamma)} \qquad \text{... (2)}$$

But, it has already been shown in equation (3) in chip thickness ratio,

that, $$r = \frac{\sin\phi}{\cos(\phi-\gamma)}$$

therefore, by substituting this value in equation (2)

we get, $V_f = V_C \times r$. ... (3)

the same relationship can also be derived by equating the two volumes of material, which are equal to in orthogonal cutting, such as:

volume of material cut per unit of time = Volume of the material flowing up as chip

i.e., $V_C \cdot t_1 \cdot w = V_f \cdot t_2 \cdot w$ [w = width of cut]

or $$\frac{V_C \cdot t_1}{t_2} = V_f$$

or $$V_f = V_C \cdot \frac{t_1}{t_2} \qquad \left[\text{But } \frac{t_1}{t_2} = r\right]$$

$$\therefore \quad V_f = V_C \cdot r$$

1.15. MACHINING PARAMETERS

1.15.1. Cutting Speed (V)

It is the travel of a point on the cutting edge relative to the surface of cut in unit time in the process of accomplishing the primary cutting motion.

For example in lathe work when a work piece of diameter (D) rotates at a speed (N) revolutions per minute the cutting speed (V) is given by the relation.

$$V = \frac{\pi DN}{1000} \text{m per min}$$

where D = Diameter of workpiece in mm.

1.15.2. Feed

The feed or more precisely rate of feed is the amount of tool advancement per revolution of job parallel to the surface being machined. Feed is expressed either as the distance moved by the tool in one minute. It is expressed is mm per revolution on a shaper, feed is the distance the work is moved relative to the tool for each cutting stroke. Feed is expressed in mm per tooth for milling cutters and broaches. Feed depends on the depth of cut, rigidity of cutting tool and type of cutting tool material. Higher feeds are used in rough cuts, rigid set-ups, soft materials, rugged cutters and heavy machine tools. Lower feeds are used for finish cuts, frail set ups hard work materials and weak cutters. Normally feed various from 0.1 to 1.5mm.

In milling a good commercial surface finish can be obtained by using a feed rate of 0.75 mm to 1.25 mm per revolution of the cutter. Finer feeds such as 0.4 mm per revolution of cutter will result in an excellent surface finish.

Table (1.1) show cutting speed and feed for H.S.S. turning tools for machining some of the materials.

Table (1.1)

Material to be machined	Cutting speed m/min	Feed (mm/rev)
Aluminium	70 - 100	0.2 - 1.00
Brass (free catting)	70 - 100	0.2 - 1.5
Copper	35 - 70	0.2 - 1.00
Grey C.I	25 - 40	0.2 - 1.7
Mild steel	35 - 50	0.2 - 1.00

In lathe work distinction is made between longitudinal feed when the tool travels in a direction to the work axis and cross feed when the tool travels in a direction perpendicular to the work axis.

Feed of a lathe and similar machine tool is the distance the cutting tool is fed for each revolution of work. The feed of drilling machine is the rate at which drill is advanced into the workpiece per revolution of drill. The feeds for reaming operation is usually higher than that used for drilling because reamers have more teeth and a reaming operation is used for finishing the holes.

P_X (or) F_t = The feed force or thrust force acting in horizontal plane parallel to the axis work

P_Y (or) F_r = Radial force, also acting in the horizontal plane but along a radius of the work piece, i.e., along the axis of the tool.

P_Z (or) F_C = The cutting force, acting in vertical plane and is tangential to the work surface. Also called the tangential force.

Important Formulae in Metal Cutting

1. Chip thickness ratio (r) $= \dfrac{t_1}{t_2}$

$t_1 \rightarrow$ chip thickness before cutting = Feed

$t_2 \rightarrow$ chip thickness after cutting

2. Shear angle (f)

$$\tan\phi = \frac{r\cos\gamma}{1 - r\sin\gamma} \;;\; \gamma \rightarrow \text{rake angle}$$

3. Cutting force $\quad (F_H) = \dfrac{F_S \cdot \cos(\alpha - \gamma)}{\cos(\phi + \alpha - \gamma)}$

4. Shear force $\quad (F_S) = \dfrac{\text{Shear Strength} \times \text{Area of chip}}{\sin\phi}$

or $\quad F_S = F_H \cos\phi - F_V \sin\phi$

5. Shear strain $\quad = \cot\phi + \tan(\phi - \gamma)$

6. Compressive force $(F_n) = F_V\cos\phi + F_H\sin\phi$; F_V - Feed force

7. Work done in shear $= F_S \cdot V_S \;;\; V_S = \dfrac{V\cos\gamma}{\cos(\phi - \gamma)}$

8. Horse power $\quad = \dfrac{F_H \times V}{75}$

9. Time required for Turning $(T) = \dfrac{L}{f \cdot N}$

where L → Length of work, mm

N → Spindle speed, m/min

f → feed, mm/rev

10. Coefficient of friction $(\mu) = \dfrac{F_H \tan\gamma + F_V}{F_H - F_v \tan\gamma}$

11. Length of chip removed $(l_2) = r \cdot l_1$

$$l_2 = \pi \cdot D \cdot N$$

12. Velocity of chip along tool face $(V_C) = V \cdot r$

13. Maximum metal removal rate $(\omega) = t \times f \times V$

14. Coefficient of friction $(\mu) = \tan\beta$; β - friction angle

1.16. SOLVED PROBLEMS ON CUTTING FORCES

Problem 1: In orthogonal cutting of a mildsteel component if the rake angle of tool is 10° and shear angle is 30°, find the chip thickness ratio.

Data:

- Rake angle $(\gamma) = 10°$
- Shear angle $(\phi) = 30°$

To find:

1. Chip thickness ratio (r)

Solution :

1. Shear angle $\tan\phi = \dfrac{r\cos\gamma}{1 - r\sin\gamma}$

$$\tan 30° = \frac{r\cos 10°}{1 - r\sin 10°}$$

$$0.577 = \frac{0.985r}{1 - 0.174r}$$

$$0.985\,r = 0.577(1 - 0.174r)$$

$$= 0.577 - 0.1\,r$$

$$0.985\,r + 0.1\,r = 0.577$$

$$r = \frac{0.577}{1.085}$$

$$\therefore r = 0.53$$

Problem 2: Determine the cutting speed and machining time per cut when the work having 35 mm diameter is rotated at 200 rpm. The feed given is 0.2mm/rev and length of cut is 60 mm.

Data:

D = 35mm = 0.035m

N = 200 rpm

f = 0.2mm/rev = 0.0002 m/rev

L = 60mm = 0.06m

To find:

1. Cutting speed (V)
2. Machining time (T)

Solution:

1. Cutting speed

$$V = \frac{\pi DN}{60}$$

$$V = \frac{\pi \times 0.035 \times 200}{60}$$

$$V = 0.366 \text{ m /s}$$

2. Machining time

$$T = \frac{L}{f \cdot N}$$

$$= \frac{0.06}{0.0002 \times 200}$$

$$T = 1.5 \text{ min}$$

Problem 3: In an Orthogonal turning operation, cutting speed is 80m/min, cutting force 20kg, feed force 8 kg, Back rake angle 15°, feed 0.2 mm/rev and chip thickness 0.4mm.

Determine the following:

a. Shear angle b. Workdone in shear c. Shear strain.

Data:

V = 80m/min=1.33m/sec

F_H = 20kg

F_V = 8 Kg

γ = 15°

f = 0.2mm/rev = t_1

t_2 = 0.4mm

To find:

a. Shear angle (ϕ)

b. Workdone in shear

c. Shear strain

Solution:

a. Shear angle

$$\tan\phi = \frac{r\cos\gamma}{1 - r\sin\gamma}$$

But, $$r = \frac{t_1}{t_2} = \frac{0.2}{0.4} = 0.5$$

$$\therefore\ \tan\phi = \frac{0.5\cos 15°}{1 - 0.5\sin 15°}$$

$$= 0.55$$

$$\phi = \tan^{-1}(0.55)$$

$$\phi = 28°$$

b. Workdone in shear:

$$W = F_S \cdot V_S$$

But, $$F_S = F_H\cos\phi - F_V\sin\phi$$

$$= 20\cos 28° - 8\sin 28°$$

$$F_S = 13.9\ \text{kg}$$

Also $$V_S = \frac{V\cos\gamma}{\cos(\phi - \gamma)}$$

$$= \frac{1.33 \times \cos 15°}{\cos(28° - 15°)}$$

$$V_s = 1.32\ \text{m/sec}$$

$$\therefore\ W = 13.9 \times 1.32$$

$$W = 18.34\ \text{kg-m/sec}$$

c. Shear strain

$$= \cot\phi + \tan(\phi - \gamma)$$

$$= \cot 28° + \tan(28° - 15°)$$

Shear strain = 2.11

Problem 4: Calculate the power required during cutting of a low carbon steel bar 40 mm diameter of cutting force is 150 kg at 200 rpm.

Data:

$D = 40mm = 0.04m$

$F_H = 150kg$

$N = 200$ rpm

To find:

1. Power

Solution:

$$\text{Horse power} = \frac{F_H \times V}{75}$$

$$\text{But} \quad V = \frac{\pi DN}{60} = \frac{\pi \times 0.04 \times 200}{60} = 0.42m/sec$$

$$H.P = \frac{150 \times 0.49}{75}$$

H.P 0.98

Problem 5: In Orthogonal cutting if the feed is 1.25 mm/rev, and chip thickness after cutting is 2mm; find the following i) chip thickness ratio ii) shear angle.

The tool bit has a rake angle of 10°, width of cut is 10 mm, cutting speed 30 m/min, coefficient of friction 0.9.

Determine the following:

1. Shearing force
2. Friction angle
3. Cutting force
4. Horse power

Data:

$f = 1.25$ mm/rev $= t_1 = 0.125$ cm

$t_2 = 2$ mm

rake angle $\gamma = 10°$

Shear strength $= 6000$ kg/cm^2

width $= 10$ mm $= 1$ cm

Cutting speed $V = 30$ m/min

$\mu = 0.9$

To find:

1. Chip thickness ratio (r)
2. Shear angle (ϕ)
3. Shearing force (F_S)
4. Friction angle (β)
5. Cutting force (F_H)
6. Horse power (HP)

Solution:

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

$$= \frac{1.25}{2}$$

$$r = 0.625$$

2. Shear angle:

$$\tan\phi = \frac{r\cos\gamma}{1-\sin\gamma}$$

$$= \frac{0.65\cos 10^\circ}{1-0.625\sin 10^\circ}$$

$$\phi = \tan^{-1}(0.72)$$

$$\phi = 35^\circ 4'$$

3. Shearing force

$$(F_S) = \frac{\text{shear Strength} \times \text{Area of chip}}{\sin\phi}$$

$$= \frac{6000 \times (1 \times 0.125)}{\sin 34^\circ}$$

$$F_S = 1341 / \text{kg}$$

4. Friction angle:

$$\tan\beta = \mu$$

$$\beta = \tan^{-1}(0.9)$$

$$\beta = 42^\circ$$

5. Cutting force

$$(F_H) = \frac{F_S \cdot \cos(\alpha-\gamma)}{\cos(\phi+\alpha-\gamma)}$$

$$= \frac{1341\cos(42^\circ - 10^\circ)}{\cos(34^\circ + 42 - 10^\circ)}$$

$$F_H = 2796 \text{ kg}$$

6. Horse Power

$$= \frac{F_H \times V}{75}$$

$V = 30$ m/min $= 0.5$ m/sec

$$\therefore \text{HP} = \frac{2796 \times 0.5}{75}$$

HP = 18.64

Problem 6: In orthogonal cutting of a material the feed force is 80 kg and cutting force is 150 kg. Calculate the following:

1. Compression and shear forces on shear plane
2. Coefficient of friction

Take chip thickness ration 0.3 and rake angle 8°.

Data:

$F_V = 80$ kg

$F_H = 150$ kg

$r = 0.3$

$\gamma = 8°$

To find:

1. Compressive force (F_n)
2. Shear force (F_S)
3. Coefficient of friction (μ)

Solution:

1. Compressive force $(F_n) = F_V \cos\phi + F_H \sin\phi$

But $\tan\phi = \dfrac{r\cos\gamma}{1 - r\sin\gamma}$

$$\phi = \tan^{-1}\left(\frac{0.3\cos 8°}{1 - 0.3\sin 8°}\right)$$

$\phi = 17°$

$\therefore F_n = 80 \cos 17° + 150 \sin 17°$

$F_n = 120$ kg

2. Shear force:

$F_S = F_H \cos\phi - F_V \sin\phi$

$= 150 \cos 17° - 80 \sin 17°$

$F_S = 120$ kg

3. Coefficient of friction:

$$(\mu) = \frac{F_H \tan\gamma + F_V}{F_H - F_V \tan\gamma}$$

$$= \frac{150 \tan 8° + 80°}{150 - 80° \tan 8°}$$

μ = 0.73

Problem 7: A steel tube 42 mm outside diameter is turned on a lathe. The following data was obtained.

Rake angle = 32°, cutting speed 18m / min, feed 0.12 mm/rev, length of continuous chip in one revolution = 52 mm, Cutting force = 180 kg, feed force 60 kg.

Determine,

1. Chip thickness ration
2. Chip thickness
3. Shear plane angle
4. Velocity of chip along tool face
5. Coefficient of friction

Data:	**To find:**
D = 42 mm	1. Chip thickness ration r
γ = 32°	2. Chip thickness
V = 18 m/min = 0.3 m/sec	3. Shear plane angle
f = 0.12 mm/rev = t_1	4. Velocity of chip face
l_1 = 52 mm	5. μ
F_H = 180 kg	
F_V = 60 kg	

Solution:

1. Chip thickness ratio:

$$r = \frac{l_1}{l_2} = \frac{52}{\pi \times 42} = 0.394$$

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(ii) Shear strain $= \tan(\phi - \gamma) + \cot\phi$

$$= \tan(31.5° + 10) + \cot 31.5°$$

$$= 0.884 + 1.631 = 2.515$$

(iii) Strain energy per unit volume

= Shear stress × Shear strain

Shear Stress $= \dfrac{F_S}{A_S} = \dfrac{F_C \cos\phi - F_t \sin\phi}{A_0} \times \sin\phi$

$$= \frac{125 \times 0.852 - 30 \times 0.522}{0.2 \times 2.1} \times 0.522$$

$$= \frac{106.5 - 15.660}{0.441} \times 0.522$$

= 90.740 × 1.185 = 107.52 kg/mm^2

Shear-energy = 107.52 × 2.515 = 270 kg/mm^2

Problem 11: During orthogonal cutting of a M.S. tube at 15m/min. Using a 15° rake H.S.S. tool, the following data were recorded.

Chip thickness ratio = 0.35

Coefficient of friction = 0.60

The friction force, on the tool chip interface was measured by means of a special set up, as 48 kgf. Determine the components of the cutting force, shear angle, shear strain and work done in deformation.

Solution:

$$\tan\phi = \frac{r\cos\gamma}{1 - r\sin\gamma} = \frac{0.35\cos 15}{1 - 0.35\sin 15} = 1$$

or ϕ = 45°

Coefficient of friction, (μ) = tan β

Friction angle = β = $\tan^{-1}(\mu)$ = $\tan^{-1}$ (0.60) = 31°

Friction force = F = $F_C \sin\gamma + F_t \cos\gamma$ = 48 kg (given)

Also F/N = 0.6

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Problem 14: During machining C20 steel with a carbide cutting tool having a tool geometer given by 0-5-6-6-8-75-1 mm ORS, the following forces have been recorded by a two dimensional dynamometer.

Cutting force $F_Z = 1300$ N

Feed Force $F_X = 800$ N

Determine the following:

a) Radial component of force, F_y

b) Frictional force P

c) Normal force N.

d) Kinetic coefficient of friction (μ)

Given

$F_Z = F_H = 1300$ N

$F_X = F_V = 800$ N

$\gamma_b = 0°$

$\gamma_S = 5°$

$\alpha_e = 6°$

$\alpha_S = 6°$

$\phi_e = 8°$

$\phi_S = 75°$

$R = 1$ mm

Solution:

a) F_X = Feed force = 800 N

ϕ = Principal cutting edge angle =75°

$F_X = F_{XY} \sin \phi$

$800 = F_{XY} \cdot \sin 75$

$$\therefore F_{XY} = \frac{800}{\sin 75} = 828.22 \text{ N}$$

$F_{XY} = F_{XY} \cos \phi$

$= 828.22 \times \cos 75$

$F_Y = 214.3$ N

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$$\therefore T^{0.13} = \frac{28.38}{0.396 \times 1.403 \times 36} = 1.419$$

$$\therefore T = (1.419)^{\frac{1}{0.13}} = (1.419)^{7.09} = 14.75 \text{ min}$$

ii) Now f = 0.3 × 1.2 = 0.36 mm/rev.

$$\therefore T^{0.13} = \frac{28.38}{(0.39)^{0.77} \times 1.403 \times 30} = 1.48$$

$$\therefore T = (1.48)^{7.69} = 20.39 \text{ min}$$

iii) Now d = 2.5 × 1.2 = 3 mm

$$\therefore T^{0.13} = \frac{28.38}{30 \times 0.396 \times (3)^{0.27}} = 1.591$$

$$\therefore T = (1.591)^{7.69} = 35.55$$

The maximum effect on tool life is of cutting speed, and the least effect is of depth of cut.

iv) Now V = 36 m/min, f = 0.36 mm/rev, d = 3 mm

$$\therefore T = \frac{28.38}{38 \times 0.455 \times 150} = 1.154$$

$$\therefore T = (1.154)^{7.69} = 3.011 \text{ min}$$

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 × 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

$VT^n = C$

Crater wear usually occurs due to:

1. Severe abrasion between the chip and tool face.
2. High temperatures in the tool-chip interface reaching the softening or melting temperature of tool resulting in increased rate of wear. The sharp increase in wear rate after the interface temperature reaches a certain temperature is attributed to 'diffusion'. Diffusion is the movement of atoms between tool and chip materials resulting in loss of material from the face of the tool. It depends upon the work piece materials, in addition to temperature. So, unless these conditions are favourable, crater wear due to diffusion may be absent.

Crater wear is more common in cutting ductile materials, which produce continuous chips. Also, it is more common in H.S.S. tools than ceramic or carbide tools, which have much higher hot hardness.

The reason for "Nose wear" may be one more of the reasons discussed above. Chipping of the tool may occur due to the following factors:

1. Tool material is too brittle.
2. As a result of crack that is already in the tool.
3. Excessive static or shock loading of the tool.
4. Weak design of the tool, such as a high +ve rake angle.

Wear Mechanisms

Some of the important tool wear mechanism of a hard metal (tool) which is in contact with a softer but deforming metal sliding past the former at a fairly high speed are described below.

(e) Diffusion Wear

When a metal is in sliding contact with another metal and the temperature at their interface is high, conditions may become right for atoms from the harder metal to diffuse into the softer matrix, thereby increasing the latter's hardness and abrasiveness. On the contracty atoms from the softer metal may also diffuse into the harder medium weakening the surface layer of the latter to such an extent that particles on it are dislodged, torn (or sheared off) and are carried away by the flowing medium figure 1.28(b). Diffusion is a phenomeon strongly dependent upon temperature. For example, diffusion rate is approximately doubled for an increment of the order of 20° C in the case of machining steel with HSS tools.

Shearing at High Temperature

The hard metal softens at high temperature. Therefore, its shear yield stress becomes several times smaller than what it is at room temperature. Though the metal sliding over it has lower yield stress, it may get so much work hardened as to be able to exert frictional stress sufficient to

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1.20. CUTTING FLUIDS

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

a) Properties and Purpose of Cutting Fluids

The following are the essential purposes of cutting fluids :

1. To reduce friction. The cutting fluid reduces the friction at the tool-chip interface and also at the tool work interface. Since the coefficient of friction is reduced at the tool chip interface the chip flow is increased. If on the other hand, if the coefficient of friction is more not only the chip finds difficult to flow, but also it increases the power consumption.
2. To improve surface finish. Since there is a smooth flow of chip and lesser coefficient of friction, surface finish is improved.
3. To cool the tool and the workpiece. The cutting action produces more heat to be generated at the zone of chip, tool and workpiece. The cutting fluid reduces the heat. Since heat is reduced, it enables the hot hardness of the tool to be retained and at the same time tool life is also increased.
4. To move the chips quickly. The flow of fluid enables the quick disposal of the chips. For example, in drilling, the chip flows through the flutes.

b) Important Properties of Fluids

1. It should absorb more heat.
2. It should reduce friction.
3. It should not be corrosive in nature.
4. It should have low viscosity.
5. It should be economical.

c) Cutting fluids

The following are the fluids normally used :

1. Carbon Tetrachloride.
2. Acetic acid.
3. Turpentine
4. Kerosene
5. Paraffin oil.
6. Soluable oil.
7. Water

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SUMMARY

- Non-cutting shaping, the metal is shaped under the action of heat, pressure or both. Here there is no chip formation. This group includes operations like forging, drawing, spinning, rolling, extruding etc.
- Cutting shaping, the required shape of metal is obtained by removing the unwanted material from the workpiece in the form of chips. A few important processes are turning boring, milling, drilling, shaping, broaching etc.
- The cutting face of the tool is at 90° to the direction of the tool travel the cutting action is called Orthogonal cutting.
- The cutting face of the tool is inclined at less than 90° to the path of the tool, the cutting action is called Oblique cutting
- ***Top rake angle :*** It is also called back rake angle. It is the slope given to the face or surface of the tool. This slope is given from the nose along the length of the tool.
- ***Side rake angle:*** It is the slope given to the face or top of the tool. This slope is given from the nose along the width of the tool (side ways). The rake angles help easy flow of chip.
- ***Clearance angle or relief angle:*** These are the slopes ground downwards from the cutting edges. Those are two clearance angles namely, side clearance angle and end clearance angle. This is given to the tool to prevent rubbing of the job on the tool.
- ***Cutting edge angles:*** There are two cutting edge angles namely side cutting edge angle and end cutting edge angle.

  Side cutting edge angle is the angle, the side cutting edge makes with the axis of the tool.

  End cutting edge angle is the angle, the end cutting edge makes with the width of the tool.
- ***Lip angle:*** It is also called cutting angle. It is the angle between the face and end surface of the tool.
- ***Nose angle:*** It is the angle between the side cutting edge and end cutting edge.
- ***Chip formation mechanism:*** When the tool advances into the workpiece, the metal in front of the tool is severely stressed. The cutting tool produces internal shearing action in the metal. The metal below the cutting edge yields and flows plastically in the form of chip. Compression of the metal under the tool takes place. When the ultimate stress of the metal is exceeded, separation of metal takes place. The plastic flow takes place in a localised area called shear plane the chip moves upward on the face of the tool. The process is continued and a continuous chip formation takes place.

Unit - 2

ENGINE LATHE AND SPECIAL PURPOSE LATHE

2.1. ENGINE LATHE

2.1.1. Introduction

LATHE is the father of machine tools. The main function of a lathe is to remove metal from a piece of work to give it the required shape: and size. The lathe is used to machine cylindrical shapes. In a lathe, workpiece is held and rotated about its axis. Generally single point cutting tool is used as the cutting tool. The tool is moved parallel to the axis of rotation of workpiece to produce a cylindrical surface.

2.1.2. Parts of Lathe

A simple sketch of a centre lathe is shown in figure 2.1. The various parts and their functions are given below:-

2.1.2.1. Bed

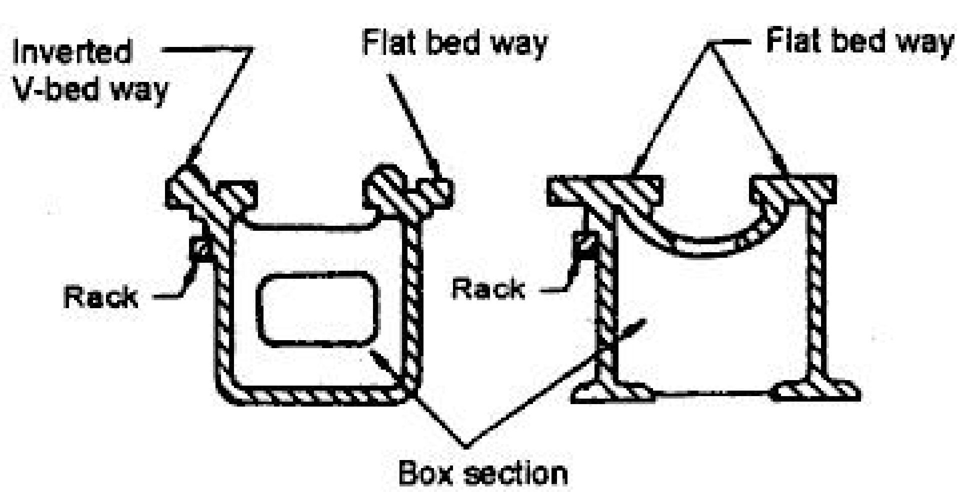

Figure 2.1. Lathe Bed ways

It is the base of the machine. The headstock is mounted on the left end, the carriage in the middle and the tailstock at the right end of bed. The carriage and the tailstock move over the bed. The bed has guide ways. The bed is very strong to resist the cutting forces and vibrations. The bed has ribbed construction. The guide ways are very accurate for getting accuracy in jobs.

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2. *The length of bed*

   This gives the approximate floor area that the lathe can occupy.

3. *The height of the centres*

   This is measured from the lathe bed.

4. *The maximum diameter*

   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*

   This indicates the maximum diameter of the work that may revolve over the bed ways.

6. *The swing diameter over carriage*

   This indicates the maximum diameter of the work that may rotate over the saddle. This is normally less than swing diameter over the bed.

2.3. TYPES OF LATHE

Lathes are classified as follows:

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.

2.4.1.2. Four Jaw Independent Chuck:

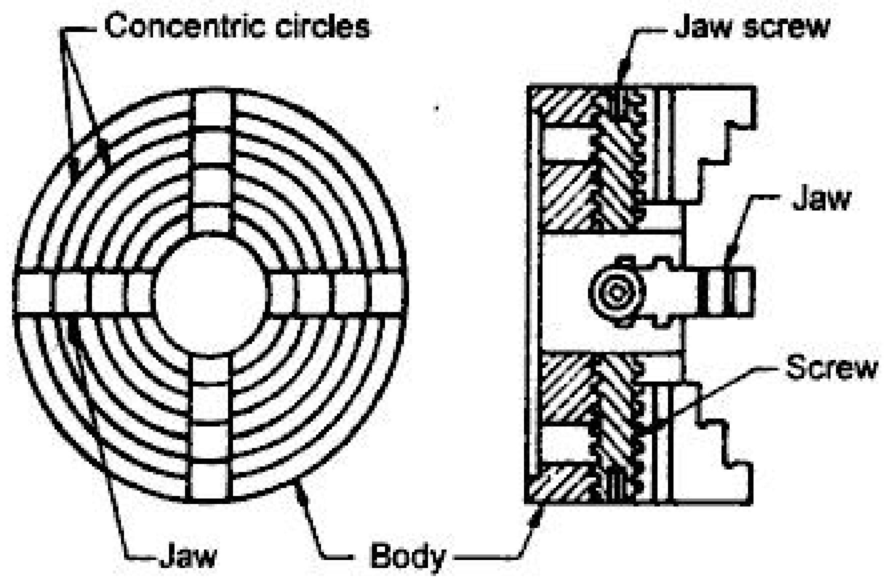

Figure 2.7

It has four jaws. These jaws may be made to slide within the slots in the body of the chuck. Each jaw can be moved independently. When the chuck key is turned in the slot, that particular jaw to the required amount. The jaw can be reversed for holding the job of larger sizes. Concentric circles are inscribed on the face of the chuck for quick centering. Four jaw chuck is used for holding large jobs and irregular jobs.

2.4.1.3. Magnetic Chuck

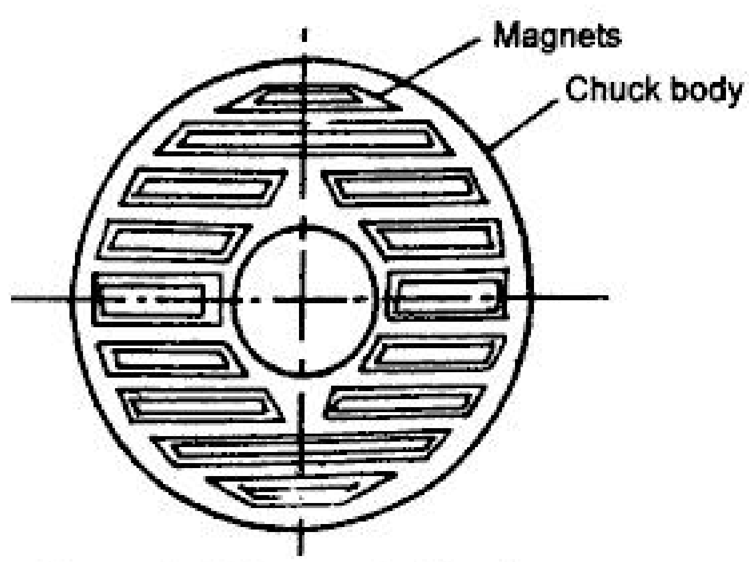

Figure 2.8 Magnetic Chuck

This is used for holding thin jobs. When the pressure of jaws is to be prevented, this chuck is used. The chuck gets magnetic power from an electro-magnet. Only magnetic materials can be held on this chuck.

2.4.1.4. Collet Chuck

It is mostly used for holding bars of small sizes, below 63mm. It is normally used where mass production work is required such as in capstan lather and automatic lathe. The front portion the collet is splitted which provides a springy action and hence the grip.

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is rotated. Live centre rotate with the work and the dead centre support the right end of the work, as shown in fig. 2.17.

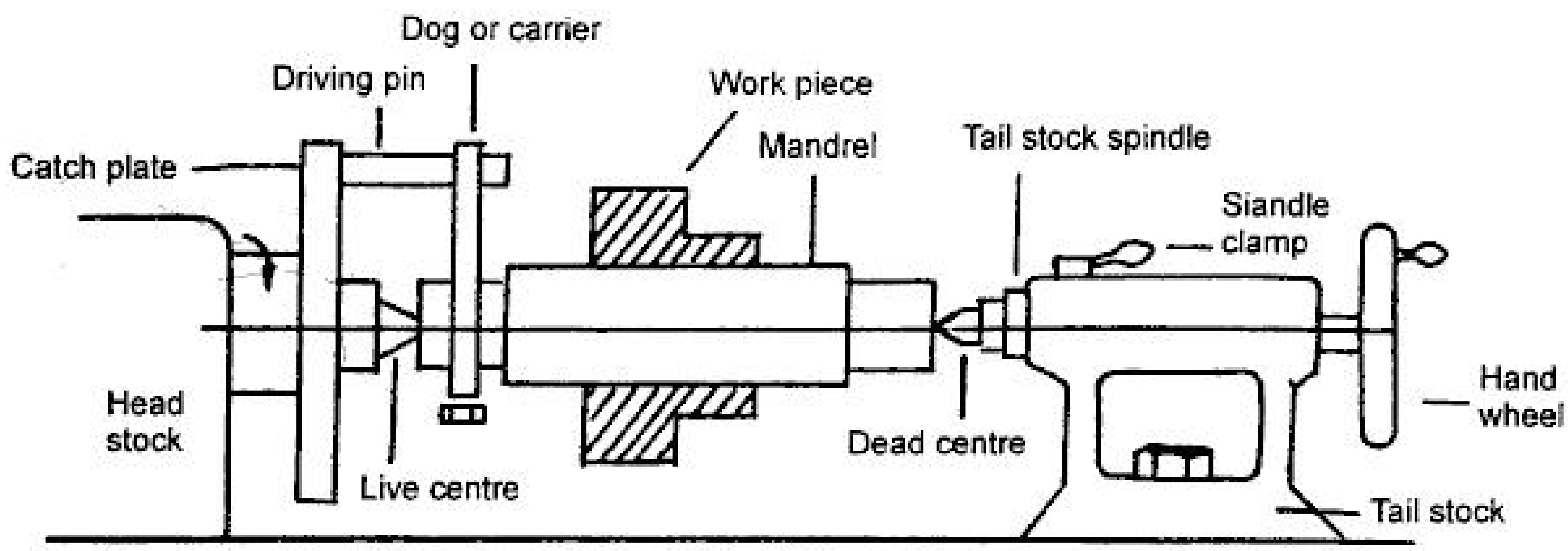

Figure 2.17. Lathe centres supporting a workpiece

The various lathe centers are shown in fig. 2.18

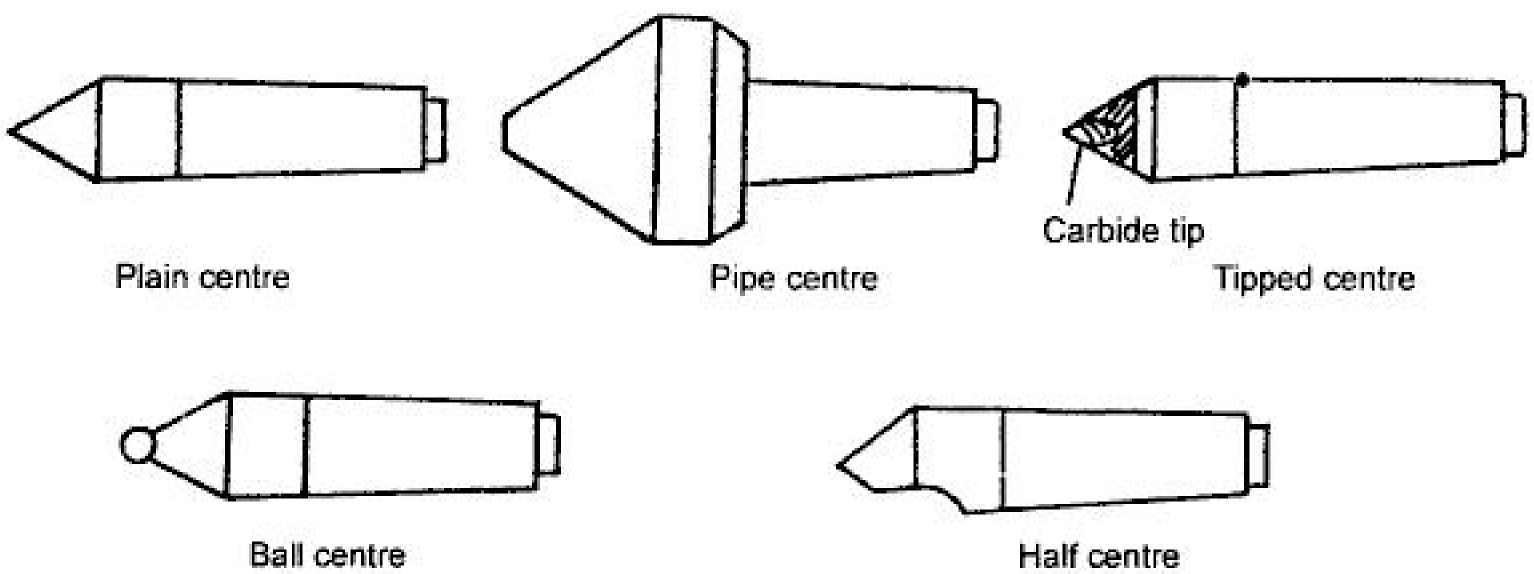

Figure 2.18. Lathe centres

2.5.2. Catch plate or Driving plate

It is a circular plate having a projected boss at its rear. The boss has a threaded hole and it can be mounted on the lathe spindle. A driving pin is fitted to the plate. In transfers motion to the dog fitted with the workpiece. Here, the workplace is held between the catch plate centre and tail stock centre. Refer fig. 2.19.

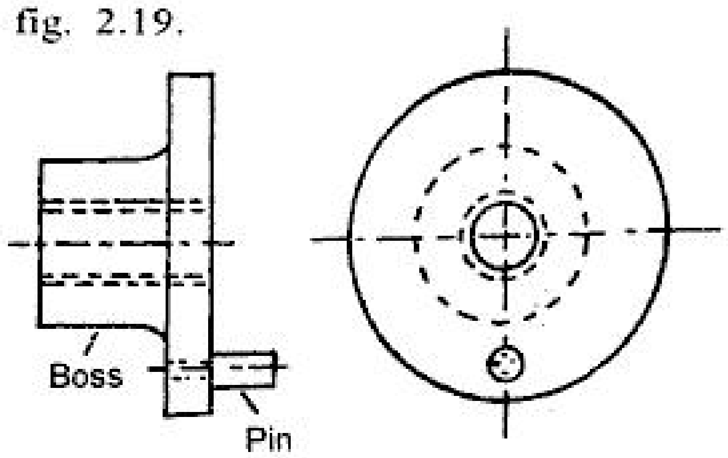

Figure 2.19. Catch Plate

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2.5.8. Steady rest

For machining long workpieces, steady or follower rests are used to support the workpieces. A steady rest supports the workpieces at convenient points in between headstock and tailstock. The three jaws are adjustable. A steady rest can be used to give support to the work thereby avoiding vibration and bending of the workpieces. If one end of the work is supported by the live centre, drilling and boring may be done on the either end when the steady rest is used as a support. It is illustrated in fig. 2.30.

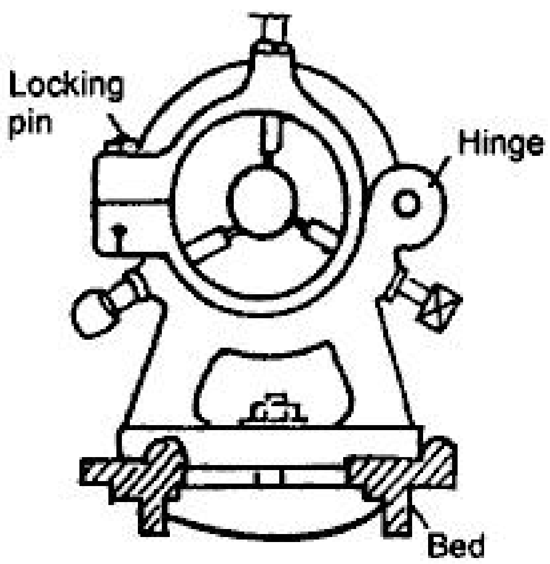

Figure 2.30. Steady Rest

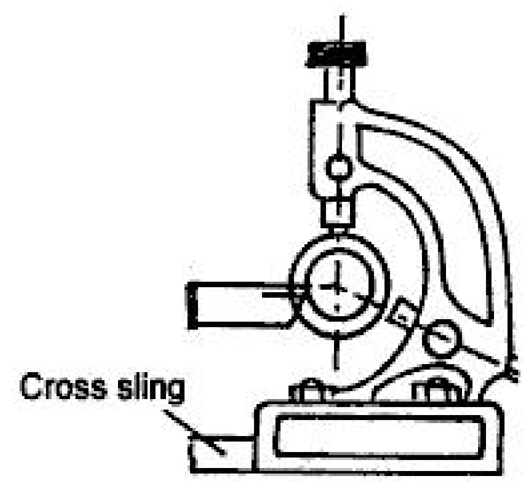

Figure 2.31. Follower Rest

Follower Rest:

A follower rest performs the same function as steady rest but it is mounted on the saddle and moves together with the tool. It has two jaws which support the work opposite the tool. When the entire length of the workpiece is to be turned in one setting without any disturbance, the flower rest has to be used. If the steady rest is used atleast two settings are required. A follower rest in shown in fig. 2.31.

2.6. LATHE TOOLS

2.6.1. Classification of Tools

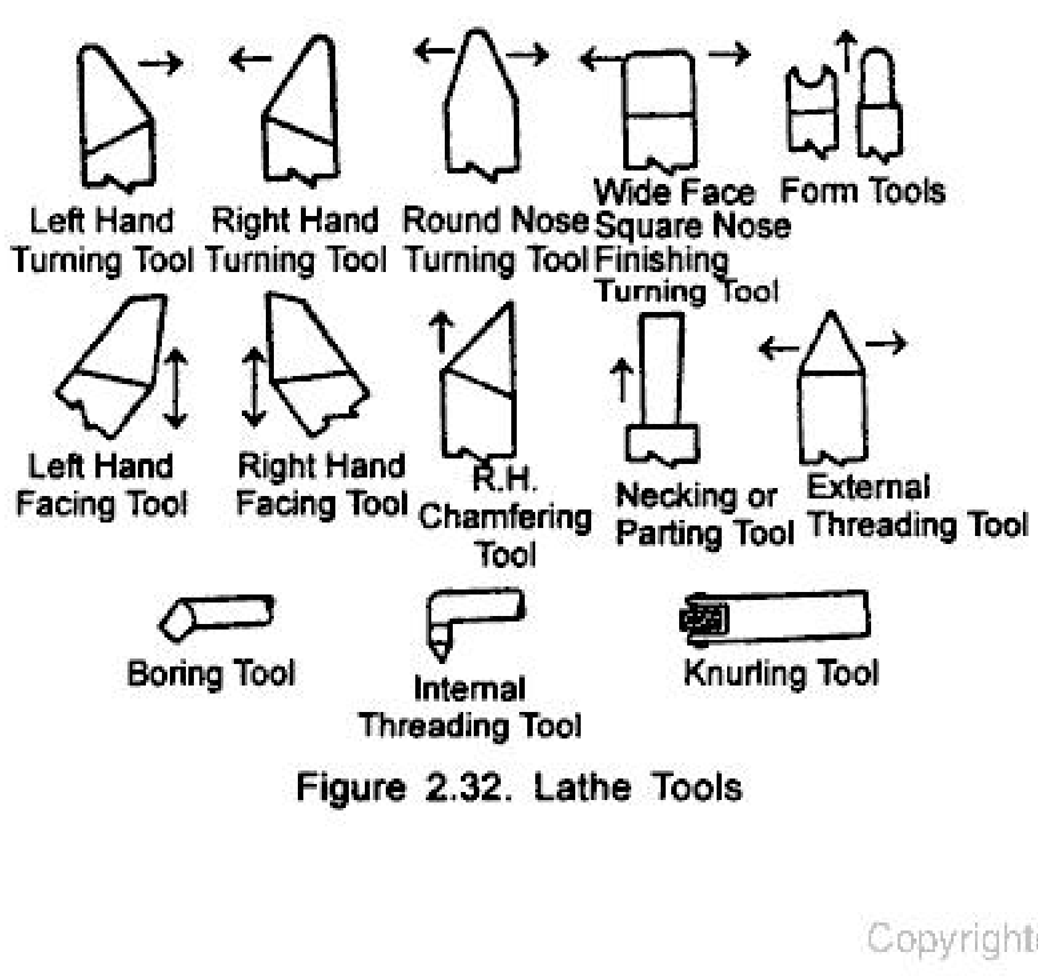

Figure 2.32. Lathe Tools

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the rear end of the lathe bed. While turning taper using this attachment, cross slide of the lathe is disengaged from the lathe feed screw and fastened to the guide bar set at an angle to the lathe axis. When the longitudinal feed is engaged, the tool mounted on the cross slide and the cross slide is caused to move transversely to provide the proper taper angles. This is shown in fig. 2.48.

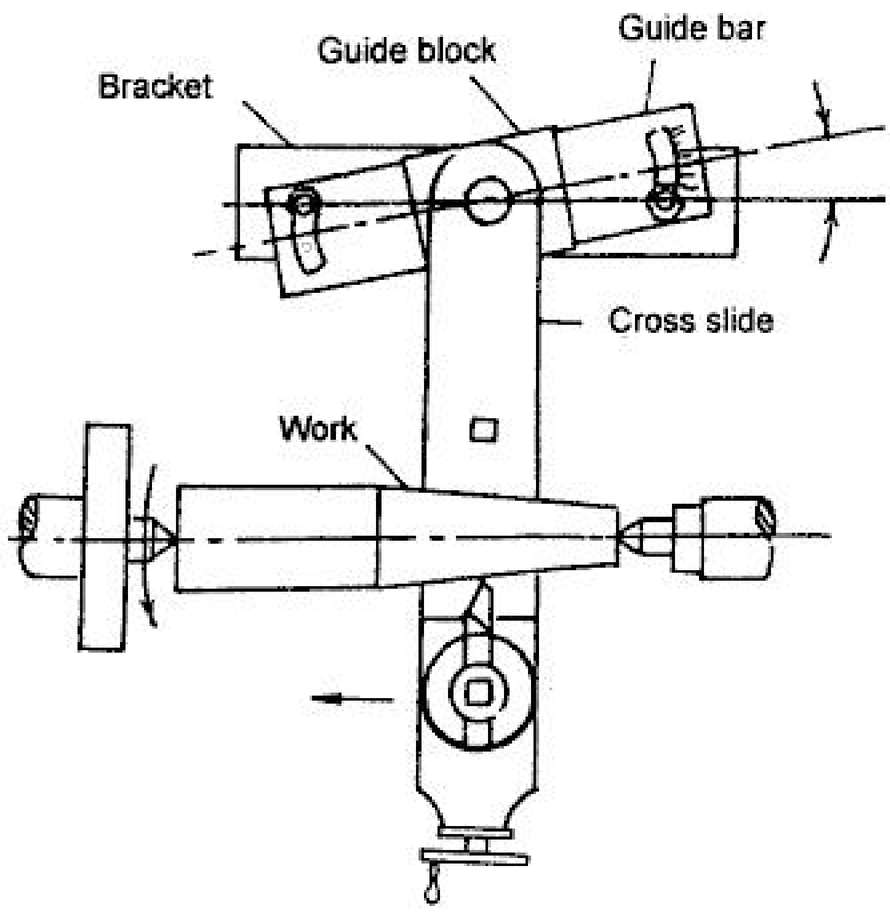

Figure 2.48. Taper turning attachment

2.8.5. Taper turning by combination feed method

A taper can be turned, by combining both the longitudinal and cross feeds at the same time. But it is not an accurate method. The longitudinal feed movement is given by moving the carriage and the cross feed movement is given by moving the cross slide.

2.9. DRIVING ARRANGEMENTS IN HEAD STOCK

The two types of headstock driving arrangements are explained below:

2.9.1. All geared headstock

The all geared headstock is shown in figure 2.49. A constant speed motor at the base of the lathe drives the lathe spindle through gears. Speed changes are made by levers. When the levers are shifted into different positions, different gear combinations are made and the spindle rotates at different speeds.

Gears Z_4, Z_5, Z_6, are mounted on a splined shaft and receive power from the fast and loose pulley. Gears Z_7, Z_8, and Z_9 are mounted on an intermediate shaft and cannot move axially. Gears Z_{11}, Z_{12}, and Z_{13} are mounted on the headstock spindle and can be moved axially by levers. The gear combinations for nine different speeds are:

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screw (or feed rod) rotates in the same direction of the spindle rotation. The carriage will move towards headstock. This arrangement is used for cutting right hand threads. In position 2, the shift lever is in the horizontal position. Now E is connected to gear B, B to A and A to D. So the lead screw rotates in anti-clockwise direction. That is the lead screw (or feed rod) rotates in opposite direction to the spindle rotation. The carriage will move towards tail stock. This arrangement is used for cutting left hand threads. When the lever M is in the middle position (i.e.,) neutral position, tumbler gears are not engaged. So automatic-feed is not possible. Only hand feed is given to the carriage.

2.10.2. Quick change gear Box

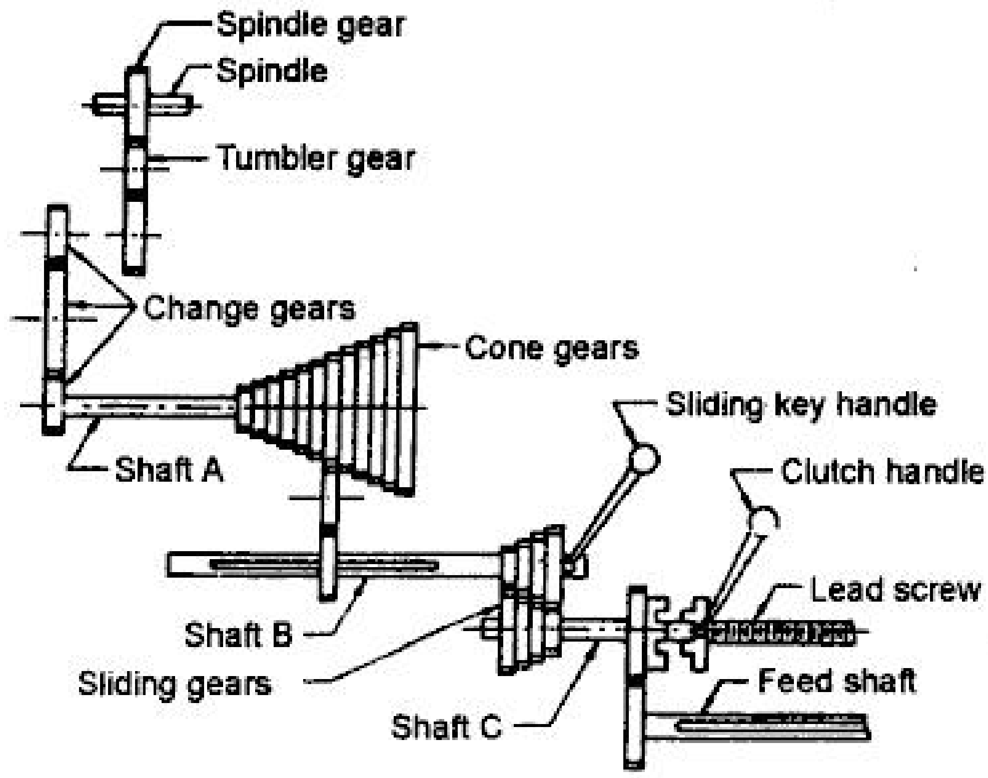

Figure 2.53. Quick Change gear box

Quick change gear box is shown in figure.2.53. The motion is transmitted from the spindle gear to the shaft A through the tumbler gear and change gears. Shaft A has got 12 cone gears keyed to it. So shaft B can get 12 different speeds from A by the use of sliding gear. Shaft B is connected to shaft C through 4 cone gears.

With the four additional gears, shaft C can have $12 \times 4 = 48$ speeds. The driver shaft C is connected to lead screw by a clutch. In some lathes the lead screw will be used for thread cutting and also for automatic feeds. In some lathes, both lead screw and feed rod are available. In these lathes, the lead screw will be used for thread cutting only. Feed rod is used for automatic feeds. The figure shows a lathe having lead screw and feed rod to receive 48 different speeds and feeds from the quick change gear box.

2.10.3. Apron mechanism

The inner details of apron mechanism is shown in figure 2.54. When the spindle gear rotates, the lead screw and feed rod will rotate through tumbler gears. Splined shaft K will be rotating

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Or, the gearing ratio $= \left|\frac{1}{2}\right| = \frac{3}{1.5} = \frac{2}{4}$

(ii) Suppose the pitch on the lead screw = 2 mm.

The pitch of the thread on workpiece = 1 mm.

The speed of the spindle should be half the speed of the lead screw.

or, the gearing ratio = ½

Therefore, the gearing ratio, can be written as :

$$= \frac{\text{Pitch of the screw be cut on the work}}{\text{Pitch of the lead screw}}$$

or $$= \frac{\text{Lead of the screw be cut on the work}}{\text{Lead of the lead screw}}$$

This can also be given as,

$$= \frac{\text{Number of teeth of stud gear (driver)}}{\text{Number of teeth of driven gear (gear keyed on the lead screw)}}$$

In short $= \frac{\text{Driver}}{\text{Driven}}$

These relations are true for both threads cut in metric units or inch units. All the lathes are provided with a set of change gears, usually having teeth from 20 to 120, with a variation of 5 teeth. Thus, the set has gears with following teeth :

20, 25, 80, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100, 105, 110, 115, 120.

In addition the set has a gear with 127 teeth. The particular gear is called translating gear. (We shall see its uses later on).

To cut Metric Threads on British (or English) Standard Lead Screw-

Sometimes it becomes necessary to cut, metric threads (i.e. the threads expressed in metric units) on a lathe having British standard lead screw (whose pitch is expressed in inches). One can argue that we can replace the British Standard Lead Screw with Metric Lead Screw and cut the desired threads. But this proposition is not practical. Instead with the help of an additional gear with 127 teeth, we can cut the desired threads. Let us see how

$$\frac{\text{Driver}\dfrac{1}{10}}{\text{Driven}\dfrac{1}{6}}=\frac{6}{10}$$

$$=\frac{3}{5}\times\frac{10}{10}$$

$$=\frac{30}{50}\text{ (simple train with one idles)}$$

or $$=\frac{3}{5}\times\frac{15}{15}$$

$$=\frac{45}{75}\text{ (simple train with one idler)}$$

and also on.

Proplem 3: Calculate the gear train to cut L. H. threads of 2 mm pitch. The pitch of lead screw is 5 mm.

Solution:

$$\frac{\text{Driver}}{\text{Driven}}=\frac{2}{5}$$

$$=\frac{2}{5}\times\frac{15}{15}$$

$$=\frac{30}{75}\ \textbf{Ans.}$$

(Simple gear train which 2 idlers, since the threads to be cut are of left hand type).

$$=\frac{2}{5}\times\frac{20}{20}$$

$$=\frac{40}{100}\ \textbf{Ans.}$$

(Simple gear train which 2 idlers, since the threads to be cut are left hand type).

2.12. LATHE ATTACHMENTS

2.12.1. Grinding Attachment

It has a bracket. It is mounted on the cross slide. A grinding wheel attached to the bracket is driven by a separate motor. The job may be held between centres or in a chuck. The wheel is fed against it. In grinding operation both the job and grinding wheel rotate. The metal is removed

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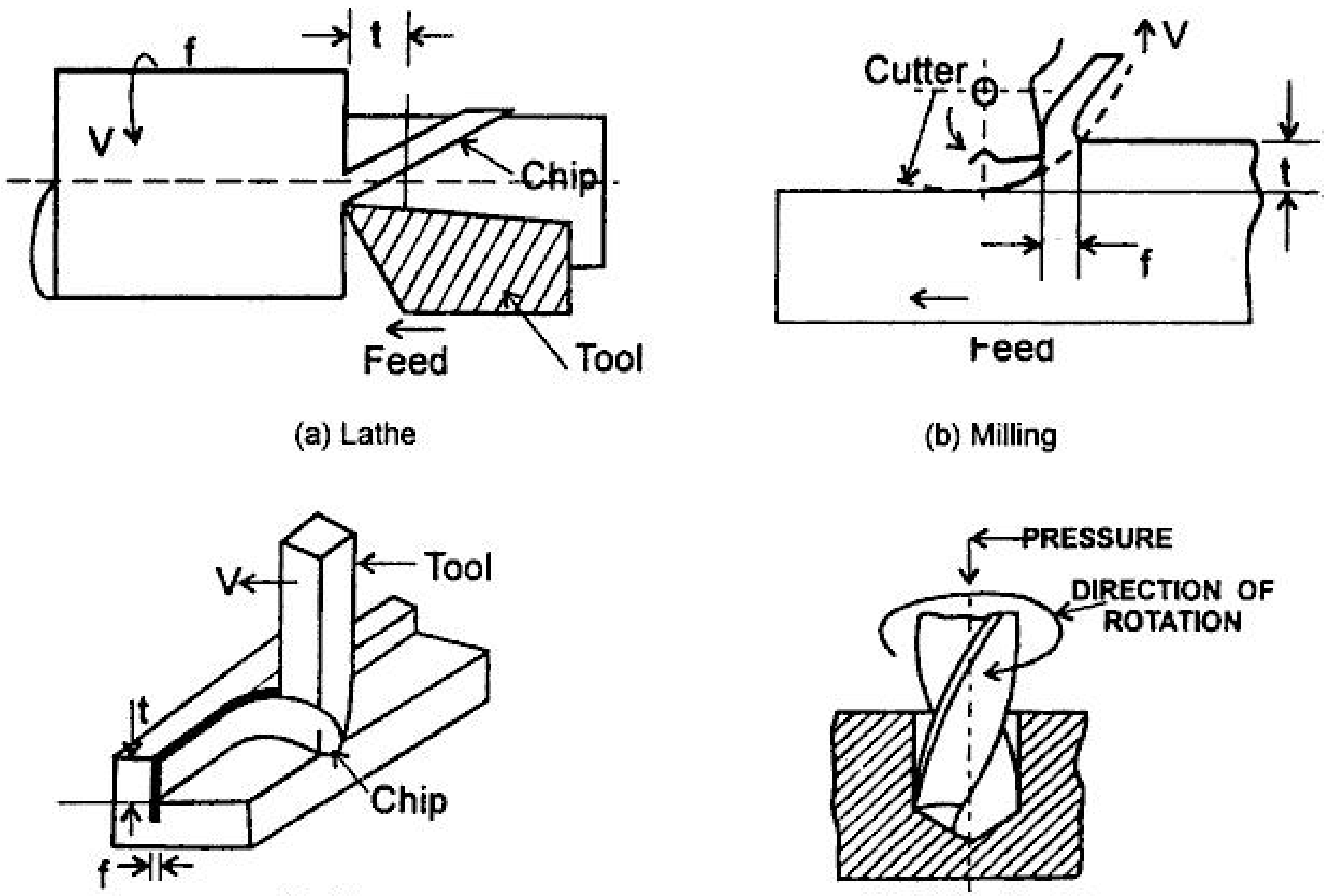
(iii) Depth of cut:



(a) Lathe (b) Milling (c) Shaper (d) Drilling Machine

Figure 2.61

It is the thickness of the layer of metal removed in one cut or pass measured in a direction perpendicular to the machined surface. The depth of cuts always perpendicular to the direction of the feed motion. In external longitudinal turning it is half the difference between the work diameter (D_1) and the diameter of the machined surface (D_2) obtained after one pass.

$$t = \text{Depth of cut} = \frac{D_1 - D_2}{2} \text{ mm}$$

Figure (2.61) shows cutting speed (V), depth of cut (t), and feed (f) for lathe, milling machine, drilling machine and shaper.

In general speed and feed depend upon the following factors:

i) Type of material of work piece.

ii) Type of material of cutting tool

iii) Quality of finish desired

iv) Type of coolant used

v) Rigidity of the machine tool

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2.15.3. Turret head and saddle

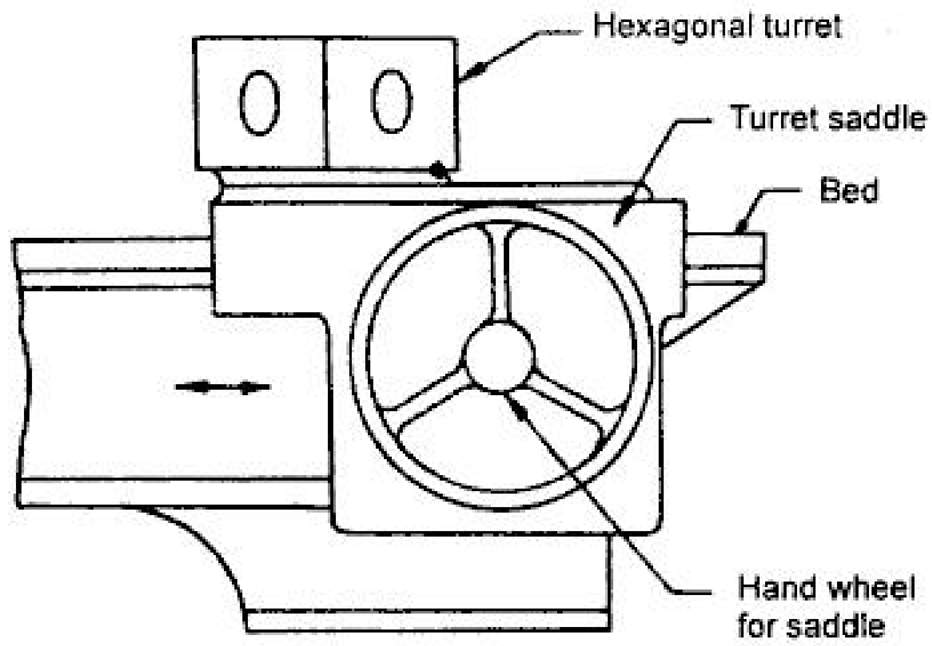

Figure 2.64. Saddle of Turret Lathe

A turret is a block which can hold a number of tools at a time. The turret can be indexed (rotated through fixed angle) about a vertical axis. By indexing, different tools are brought to position for machining.

Generally, a hexagonal turret is used. It has six faces. On each face, there is a bore to receive the shank of a tool. Four tapped holes (threaded holes) are available on each face of the turret for clamping tool holders.

On smaller capstan lathes, the turret is circular. Six holes are equally spaced around the circumference of the circular turret.

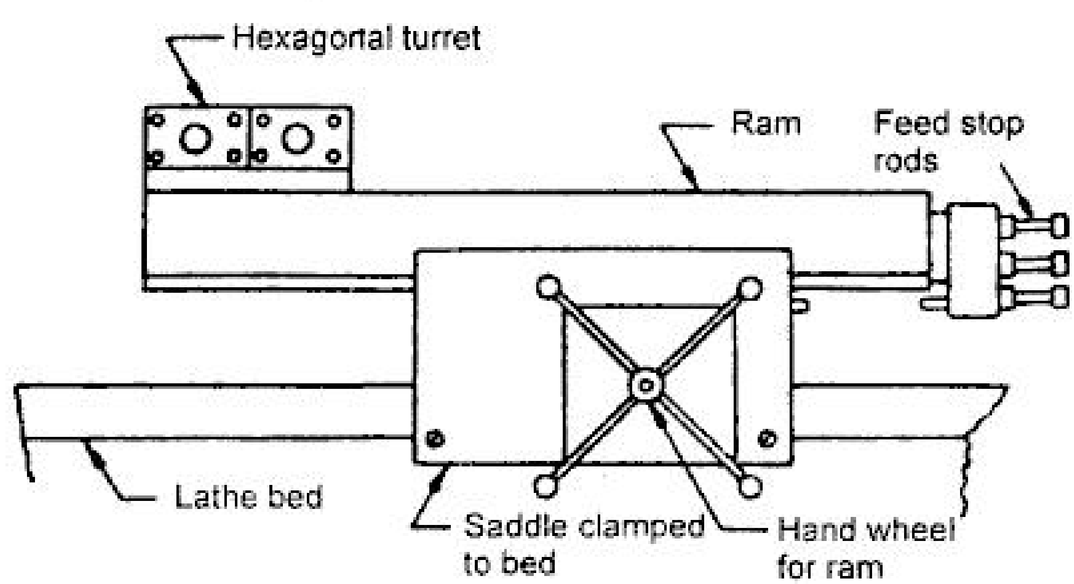

Figure 2.65. Ram of Capstan Lathe

A large star wheel is fitted at the front of the machine. It is used for moving the turret forward for each tool position. The forward movement is controlled by a pre-set stop. When the turret returns to the starting position, it is automatically indexed by 1/6 of a revolution. The next tool comes into the cutting position. This is done by a mechanism known as Geneva mechanism.

When the bar is released by the collet, the force due to suspended weight will feed the bar towards right. This feeding takes place till the end of the bar butts against the bar stop held in the turret. Then the collet is closed.

In this way the bar is fed without stopping the machine. After a number of such feedings, the bar chuck will approach the rear end of the head stock. Now the bar chuck is released from the bar and brought to the left extreme position. Then it is screwed on to the bar.

2.18. HOLDING DEVICES

In capstan and turret lathes, work is not held between centres and there is no tail stock to support the work. The work is held in chucks or fixtures only. Usually collet chucks are used in capstan lathes.

2.18.1. Collet Chucks

Small components are produced in large number in capstan lathe. Generally these components are produced from work pieces in the form of bar stock. These bar stocks have circular or hexagonal cross section.

Collet chucks are used for holding the bar stock. Quick setting and accurate centering is done using collet chucks. A collet is a cylindrical steel bush having three or four equally spaced-slits along its length. These slits give spring action. The collet nose is made thicker to form the jaws. The outside surface of the nose fits in the taper hole of the hood. The bore of the collet may be circular, hexagonal etc. depending on the shape of the work. A collet can be used only for one size and shape of the bar stock. The different types of collets used in capstan lathes are:

1. Draw back collet
2. Push out collet.
3. Dead length collet.

2.18.1.1. Draw Back collet

This is also known as draw-in type collet. Here the taper of the collet nose and sleeve converge towards the left. To grip the work, the collet is pulled back by the collet tube into the tapper bore of the hood or sleeve. The taper surface of the nose fits into the taper hole of the sleeve or hood. This makes the collet to close in and grip the bar. The collet tube is placed behind the collet in the spindle. It can be moved axially a short distance by a hand wheel or a lever. Here the bar is slightly drawn inwards while gripping the bar. Therefore the length of the bar can not be accurately set for machining.

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2) Adjustable angle cutter tool holder

This is similar in construction to the straight tool holder. But this tool holder has an angular slot. The tool is fitted into this slot by means of set screws. The inclination of the tool helps turning or boring operations close to the chuck jaws or to the shoulder of work piece.

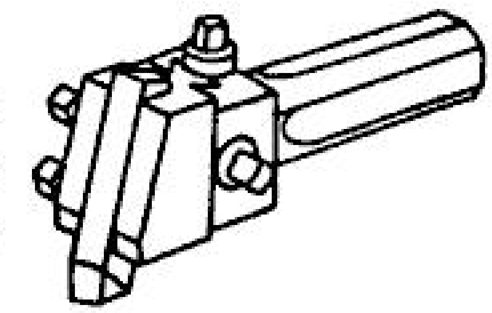

Figure 2.72

In this adjustable type holder, the accurate setting of the tool can be done by turning a micrometer screw. It is shown in fig. 2.72 and fig. 2.73.

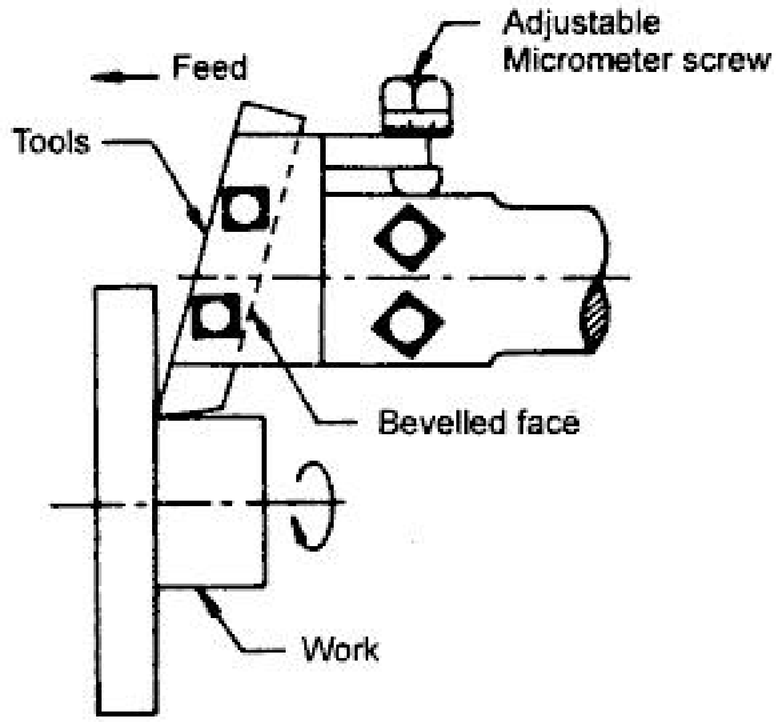

Figure 2.73. Adjustable angle cutter tool holder

3) Multiple cutter holder

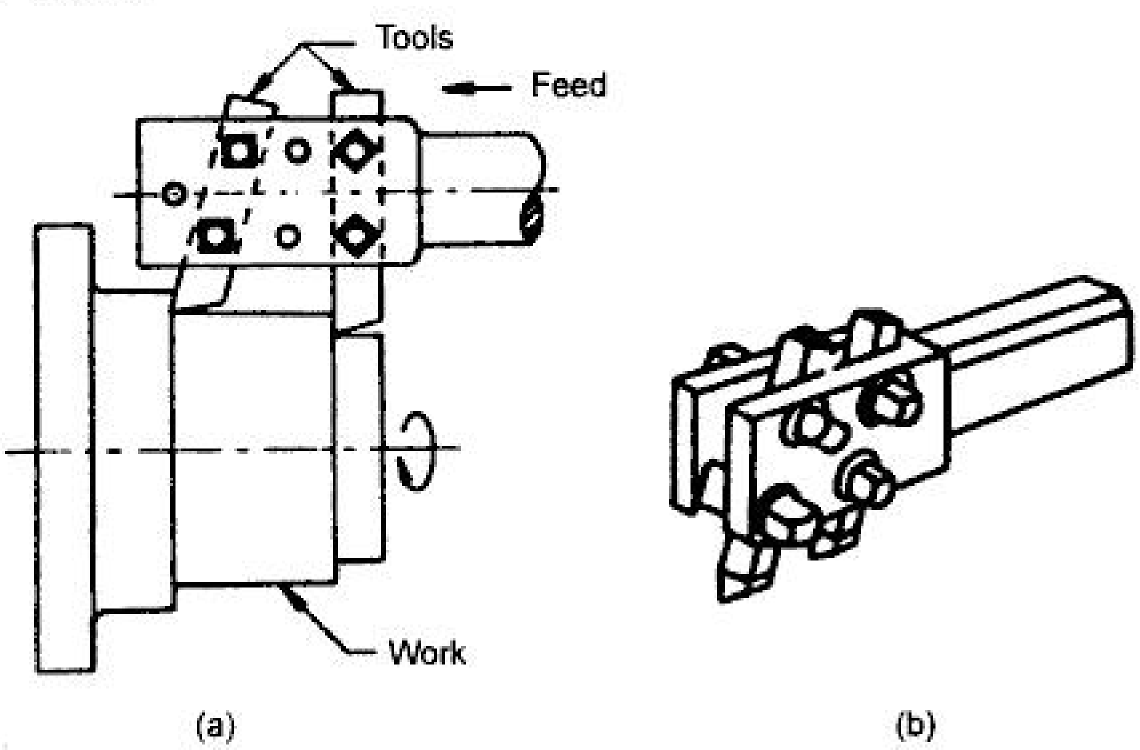

Figure 2.74. Multiple cutter holder

The multiple cutter holder can hold two or more at a time. By this arrangement turning of two different workpieces can be done simultaneously. This will reduce the time of machining. Turning and chamfering tools can be fitted and used simultaneously.

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The boring tool is held in the boring bar. The turning tools arc positioned in such a way that they cut metals at different diameters of the work piece at the same time. The figure shows the position of the tools at the end of the machining operation. The combination tool holder is directly fitted to the turret head through a flange. The tool holder has a guide bush. The pilot bar projecting from the head stock of the machine, slides inside the guide bush. This gives additional support while cutting.

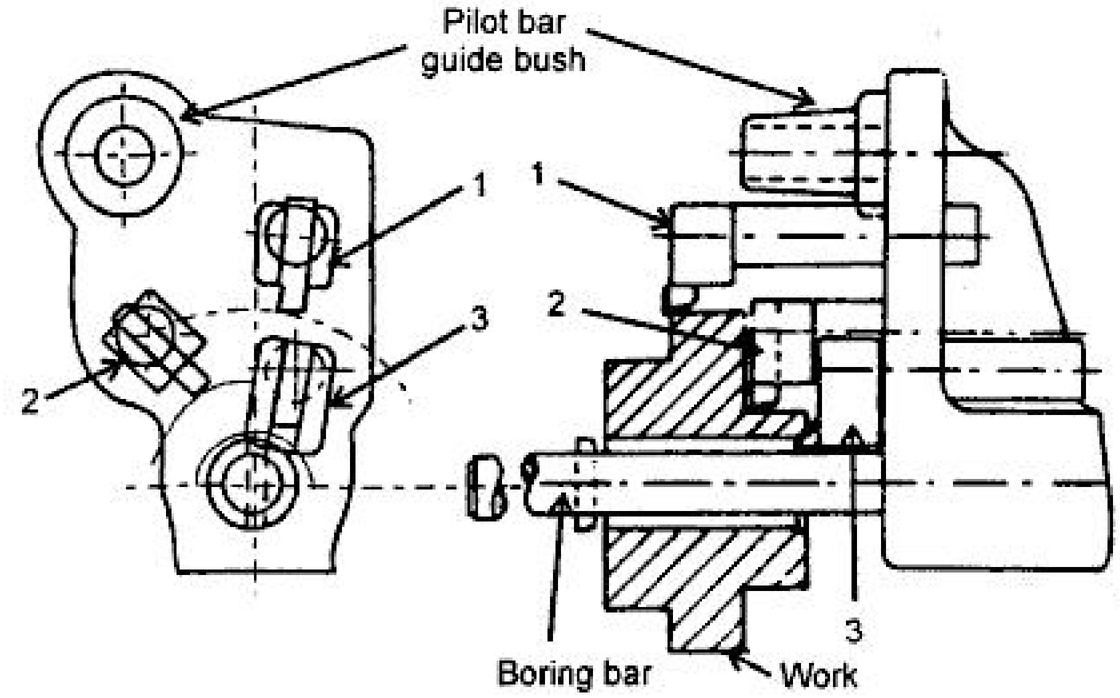

Figure 2.81. Combination tool holder

Figure 2.81 shows a simpler type of combination holder. This has one turning tool for external turning and a boring bar for internal turning.

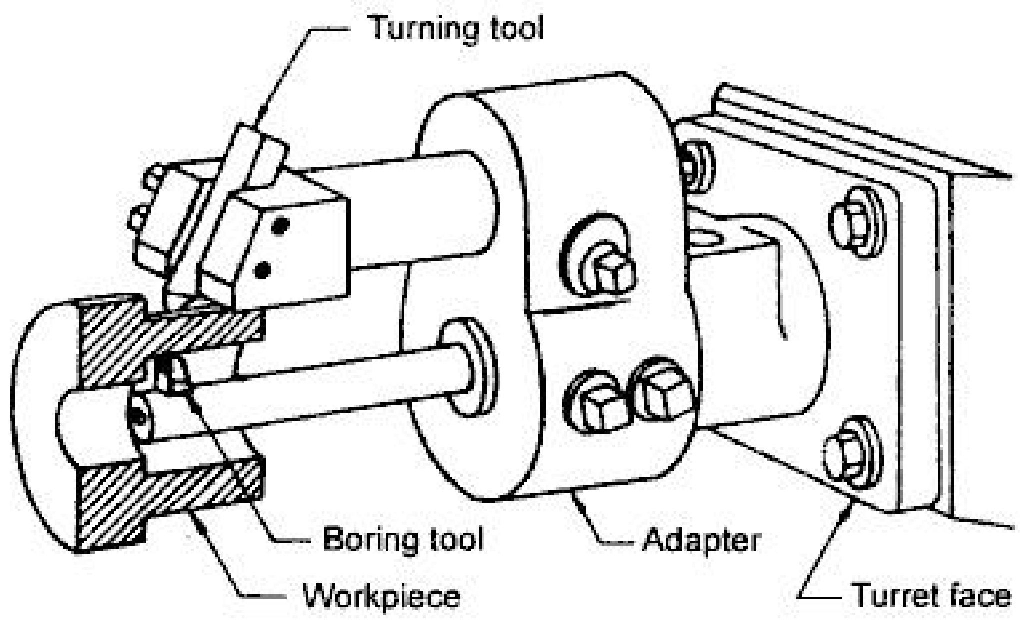

Figure 2.82. Combination tool holder

Using a combination tool holder, we can machine different external diameters as well as the internal diameter of the workpiece at the same time.

10) Self opening die holder

Self opening die holder is used for cutting accurate external threads on the work piece for a fixed length. The die holder has four thread cutting blades called chasers. These chasers automatically

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8.	A turret lathe may carry either a reach-over type or side-hung type carriage.	A capstan lathe is usually equipped with the reach-over type carriage only because it is used for relatively smaller jobs and, therefore, does act require a larger swing overbed. Also, this type of carriage provides better rigidity.
9.	Heavier designs of turret lathes are usually provided with pneumatic or hydraulic chucks to ensure a firmer grip over heavy jobs.	There is no such requirement in case of a capstan lathe.
10.	Some designs of turret lathes may carry provision for cross feeding of the hexagonal turret to enable cross feeding of turret head tools.	No such provision is made on capstan lathes.

2.21. TURRET AND CAPSTAN LATHE SIZES AND SPECIFICATIONS

The main sizes to be specified in case of horizontal capstan or turret lathes are :

(i) Maximum diameter of the workpiece that can be machined.

(ii) Maximum diameter of the bar that can be passed through the head-stock spindle.

In case of vertical saddle type or ram type Turret lathes the main dimensions to be specified are:

(i) Maximum diameter of the workpiece that can be machined without tbe side head.

(ii) Diameter of the rotating table.

But, in addition to the above principal dimensions, the following additional information is also needed in order to specify the machine fully:

For horizontal lathes

1. Power of main drive motor.
2. Range of spindle speeds.
3. Range of longitudinal and cross feed rates.
4. Overall dimensions.
5. Special features carried by the machine, such as preselector control, type of chucking-pneumatic, hydraulic, etc.
6. Total weight of the machine.

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The operations explained above can be tabulated as follows:

Operations	**Tool position**	**Tool used**
Feeding the bar to the required length.	Turret position- 1	Bat stop
Turning the bar to 16mm	Turret position-2	Box turning tool
diameter for 50mm length Forming the end	Turret position-3	End forming tool
Threading diameter 10 mm for 37mm length	Turret position-4	Self opening die head
Chamfering the bolt head	Front tool post	Chamfering tool
Parting off	Rear tool post	Parting off tool
Feeding the bar to the required length	Turret position- 1	Combination bar stop
Centre drilling	Turret position-2	Combination bar stop
Drilling the hole A	Turret position-3	Drill bit in the flange tool bar.
Reaming the hole B	Turret position-4	Reamer fitted in the floating tool holder.
Recessing the groove	Turret position-5	Recessing tool fitted in the quick acting sliding tool holder
Threading	Turret position-6	Collapsible tap
Parting off	Front tool post	Parting off tool

1. Bar stop in the turret face is brought to position.
2. The collet opens and the bar stock is pushed out by the bar feeding mechanism till is busts against the combination bar shop collet closes. The start drill positioned inside the bore of stock is now fed by hand. Thus the end work is centered.
3. The drill bit is the face 2 of the turret advances to drill the hole to the required length.
4. The thread diameters 'A' is bored by the boring tool fitted is the turret face 3.
5. The drilled holes 'B' is reamed to size with the reamer held is a floating holder is turret faces 4.

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3. Classification according to the position of spindles
    (a) Horizontal spindle type
    (b) Vertical spindle type
4. Classification according to the use
    (a) General purpose machine
    (b) Single purpose machine
5. Classification according to the feed control
    (a) Single cam shaft rotating at constant speeds.
    (b) Single can shaft with two speeds.
    (c) Two cam shafts.

1. Classification according to the type of work materials used

(a) Bar stock machine:

Hence collects are used for holding the work. The work material in the form of bar (or) pipe stock. Bar feeding mechanisms is used for feeding the bar stock. Components like screws, nuts, studs, bushes, rings, etc., are produced in this type of machines.

(b) Chucking Machine:

These machines are used for producing components in the shape of separate blanks. The blanks may be forgings and casings. They are held in jaw chuck (or) special fixtures. The feeding of the blanks is done by magazine loading devices. So this type of machine is also known as magazine loaded automats.

2. Classification according to the number of spindies

(a) Single spindle machine:

These machines, machine one component at a time as they have only one-spindle. Automatic cutting off machines and swish type machine belong to this type.

(b) Multi spindle machine:

These machine have 2 to 8 spindles. But 4 & 6 spindle machines are commonly used. Operations are performed simultaneously in all the spindles. Hence the rate of production is very high. Multi spindle machines are of two types. These are parallel action type and progressive action type.

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Typical parts produced in automatic cutting off machine are shown in figure 2.93. The size of part vary from 3 to 20 mm diameter.

2.24.2. Automatic screw cutting machine

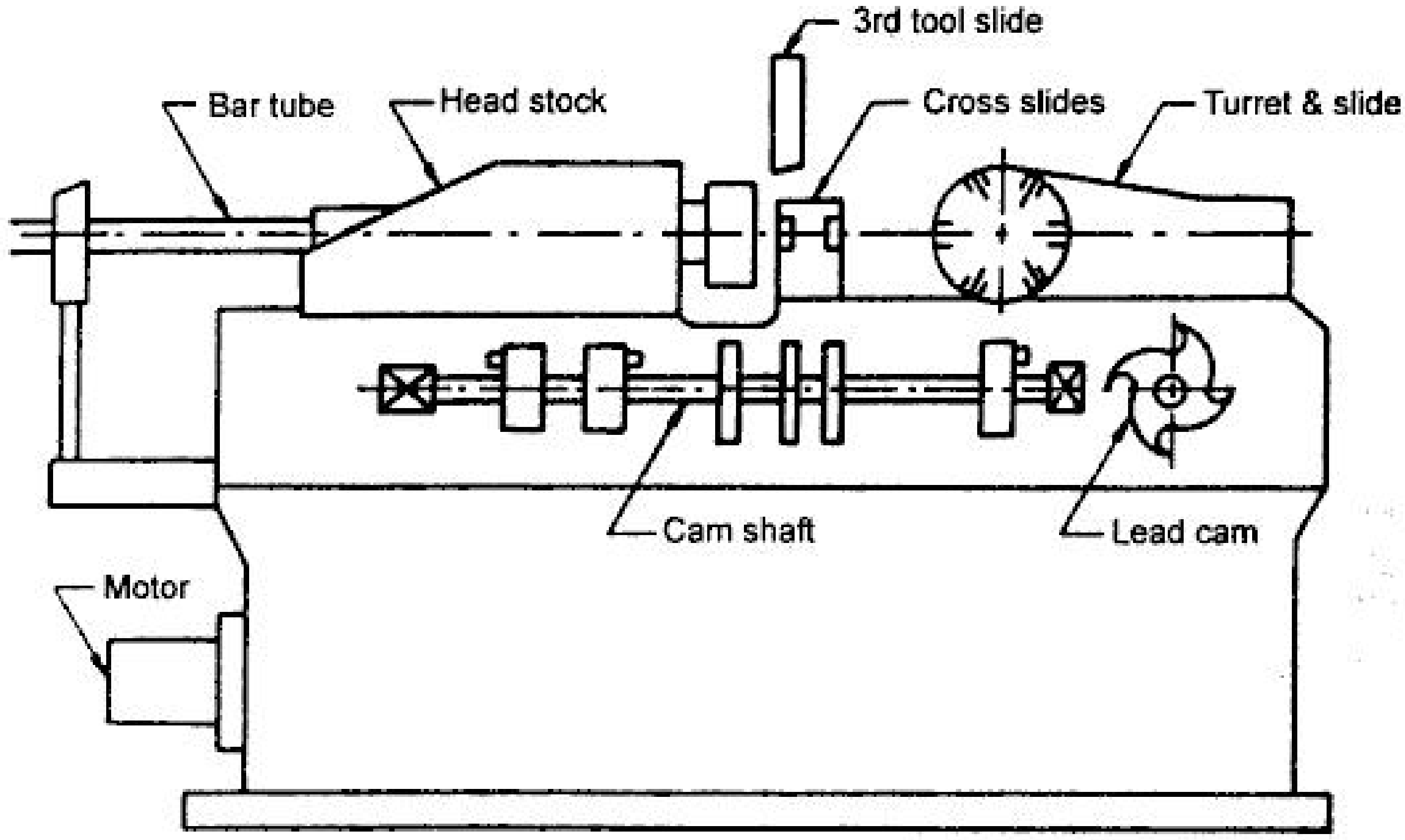

Figure 2.94. Automaic screw cutting machine

This machine is also called turret type automatic screw machine because it has a turret head. This machine is used for producing small screws of all types. Complex shapes on external and internal surface of parts can be produced. The parts are produced from bar stock or from separate blanks. The size of parts produced vary from 12.5 to 60mm diameter.

The different operations that can be performed in this machine are centering, turning cylindrical, tapered and formed surfaces, threading, drilling, boring, learning, soot facing, knurling, facing and cutting off.

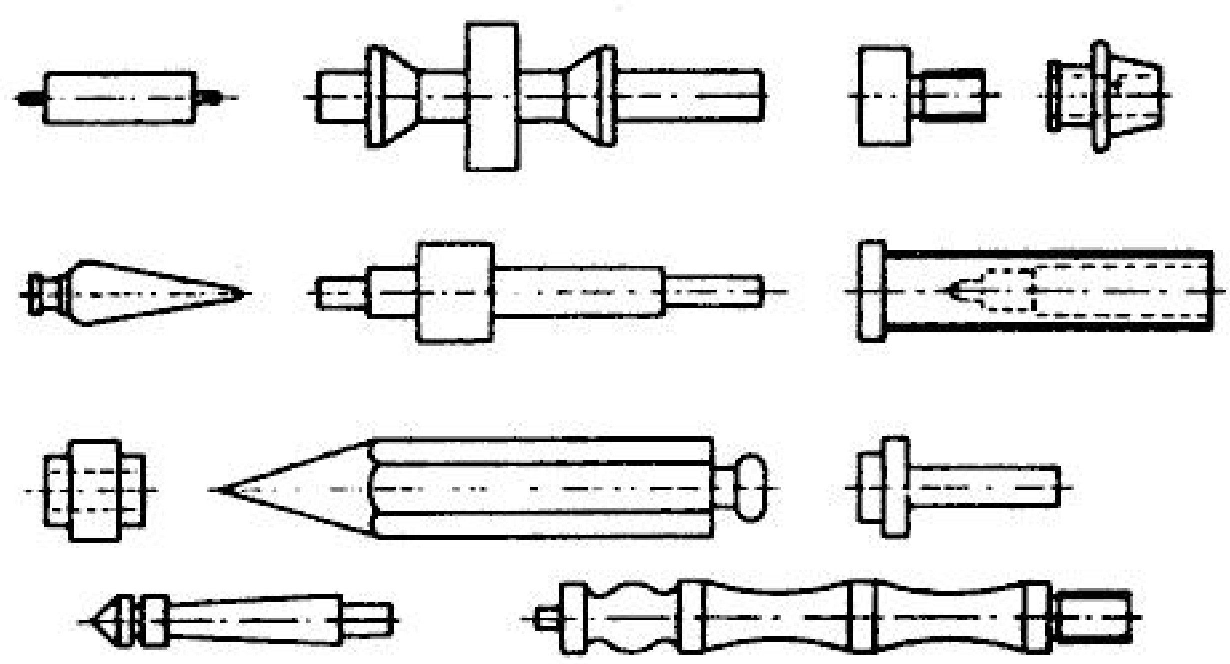

Figure 2.95

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2.25.1. Parallel action multi spindle automatic machine

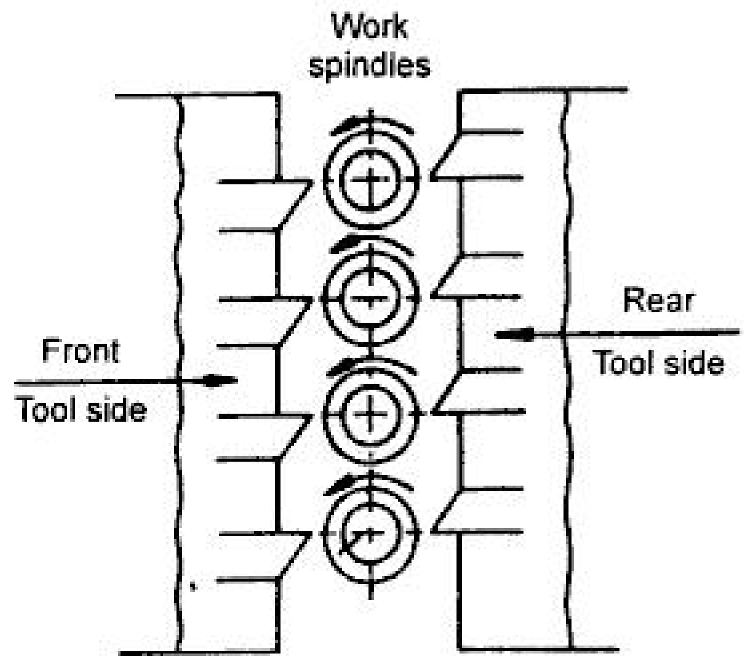

Figure 2.99. Parallel action multi spindle automatic machine

This is also called multi spindle flow machine. Same operation is done in all the spindles. The work piece is finished in each spindle in one working cycle, i.e., in one cycle, the number of components machined simultaneously is equal to the number of spindles in the machine. The rate of production is very high. This machine is suitable for production of small parts of simple shape from bar stock.

The machine has a frame with a head stock. In the head stock, horizontal work spindles are situated at both sides of the spindle. All the working motions and idle motions of the slides are obtained from a cam mounted on cam shaft.

2.25.2. Progressive action multi spindle machine

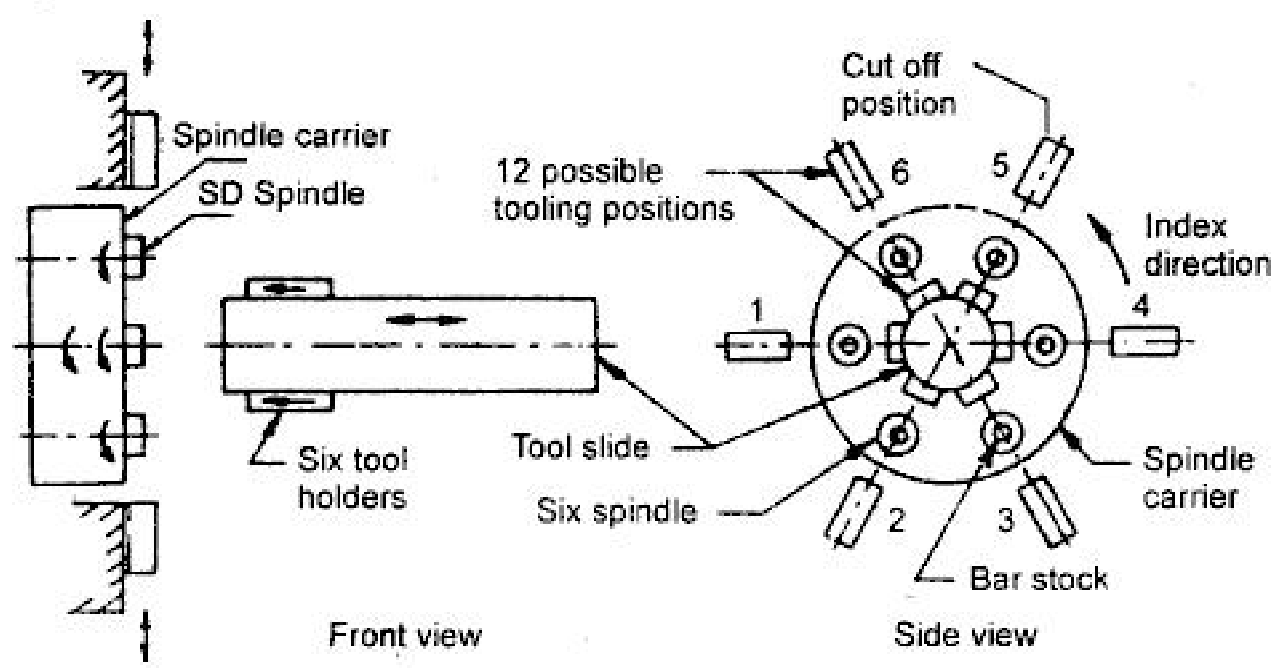

Figure 2.100. Progressive action multi spindle machine

In this type of machine, the workpieces are machined in stages. A six spindle progressive action multi spindle automatic lathe is shown in figure 2.100.

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8.	The time required to produce one component is the sum of all the turret operation times.	Time required to produce one component is the time of the longest cut in any one spindle.
9.	Tools in turret are indexed.	Workpieces held in spindles are indexed (Progressive action machine)

2.29. COMPARISON OF PARALLEL ACTION AND PROGRESSIVE ACTION MULTI-SPINDLE AUTOMATIC LATHES

	PARALLEL ACTION MACHINE	PROGRESSIVE ACTION MACHINE
1.	Same operation is done on all jobs in all the spindles.	Different operations are done on jobs at each station one after another.
2.	In one cycle the number of components produced simultaneously is equal to the number of spindles.	It is not so. (i.e.) The number of components produced in one cycle is not equal to the number of spindles. For every indexing of component (spindle) one component is produced
3.	Rate of production is very high.	Rate of production is moderate.
4.	If anything goes wrong in one station, the production in that particular station only is affected	If anything goes wrong in one station, the production is completely affected in all the stations.
5.	Small parts of simple shapes are produced.	Parts of complicate shapes can be produced.

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26. Give a simple sketch of a self opening die holder and explain its functions.
27. Draw a neat sketch of bar stop and describe its functions.
28. What is meant by tool layout of a turret lathe? Illustrate tool layout for a simple component with the help of neat sketch.
29. Prepare a tool layout for the manufacture of a hexagonal bolt from a hexagonal bar stock using a turret lathe.
30. How are automatic lathes classified? Briefly explain these machines.
31. Enumerate the various types of automatic lathes?
32. What are the essential differences between automatic and semi-automatic lathes?
33. Explain with sketches the salient features of a single spindle automatic lathe.
34. Explain the salient features of an automatic screw machines?
35. How are multi spindle automatic lathes classified?
36. Explain with a neat sketch parallel action multi spindle automatic lathe?

Saddle: Since the table is attached to the saddle, when the saddle is actuated by a horizontal screw (which is housed inside the cross rail), horizontal motion of the table is obtained. Screw can be rotated by hand or by power.

3.3.4. Table

Table is a box type casting. The front face of the table is supported by an adjustable support and the rear face is attached to the saddle. Its top and sides are perfectly machined and the sides are square with the top surface. Top and sides have 'T' slots for clamping the work pieces. The table has horizontal and vertical movements. Additional movements for the universal type shaper has been already discussed.

3.3.5. Ram

This is the reciprocating member which carries the tool head in the front end. Ram is semi-cylindrical in shape and is made highly rigid by the ribs inside. It is connected to the reciprocating mechanism housed inside the column. It contains a screw rod, by rotating it using a hand wheel, position of the stroke of the ram can be varied.

3.3.6. Tool head

Tool head (figure 3.4) provides vertical and angular feed movement of the tool. Tool head consists of a vertical tool slide, a clapper box, an apron and a tool holder.

By rotating the tool head on the graduated swivel base, tool slide can be turned to the require angle. This is required to give angular feed to the machine surfaces at an angle. The tool slide can be actuated by turning the down feed screw. A dial is fixed to the handle for accurate movement of the slide. The apron has a sector shaped slot and using a screw, it can be clamped to any position permitted by the slot. This arrangement is required to provide relief to the tool when making vertical or angular cuts. The apron consists of clapper box. Clapper block and tool post. Clapper block is hinged to the clapper box. Tool post is attached to the clapper block. During the forward

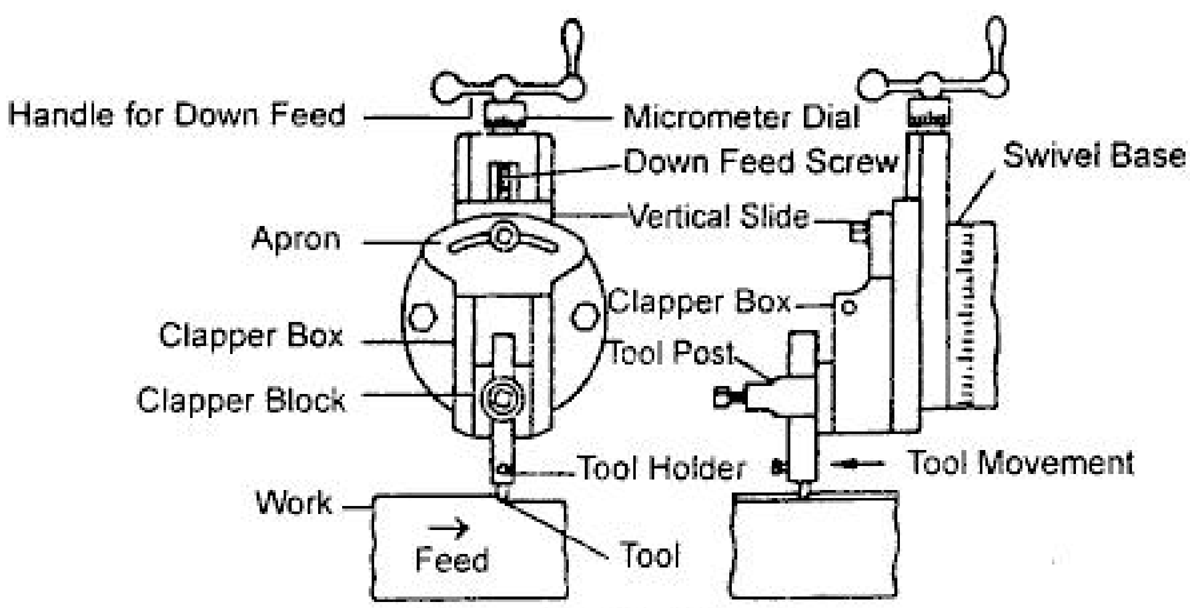

Figure 3.4 Tool Head

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When the pin A is at X, the ram is at its starting position of forward stroke. When the bull gear rotates in anticlockwise direction, the pin moves through the angle L, and reaches the point Y. It is the end position of cutting stroke, when the bull gear rotates further, from Y to X, it makes angle of B. It is return stroke. The angle B is smaller than angle L. The speed of bull gear is uniform; So the time taken for the return stroke is less than cutting stroke.

$$\frac{\text{Cutting time}}{\text{Return time}} = \frac{\text{Angle L}}{\text{Angle B}}$$

3.4.2.3. Hydraulic drive

The hydraulic control system for a shaper is illustrated in figure 3.9. The oil from the reservoir is pumped by gear pump. It is driven by an electric motor. The pump supplies constant quantity of oil at a moderate pressure. The oil is delivered to the cylinder, through the control valve. By changing the position of the control valve lever, the oil is delivered to the right or left side of the piston.

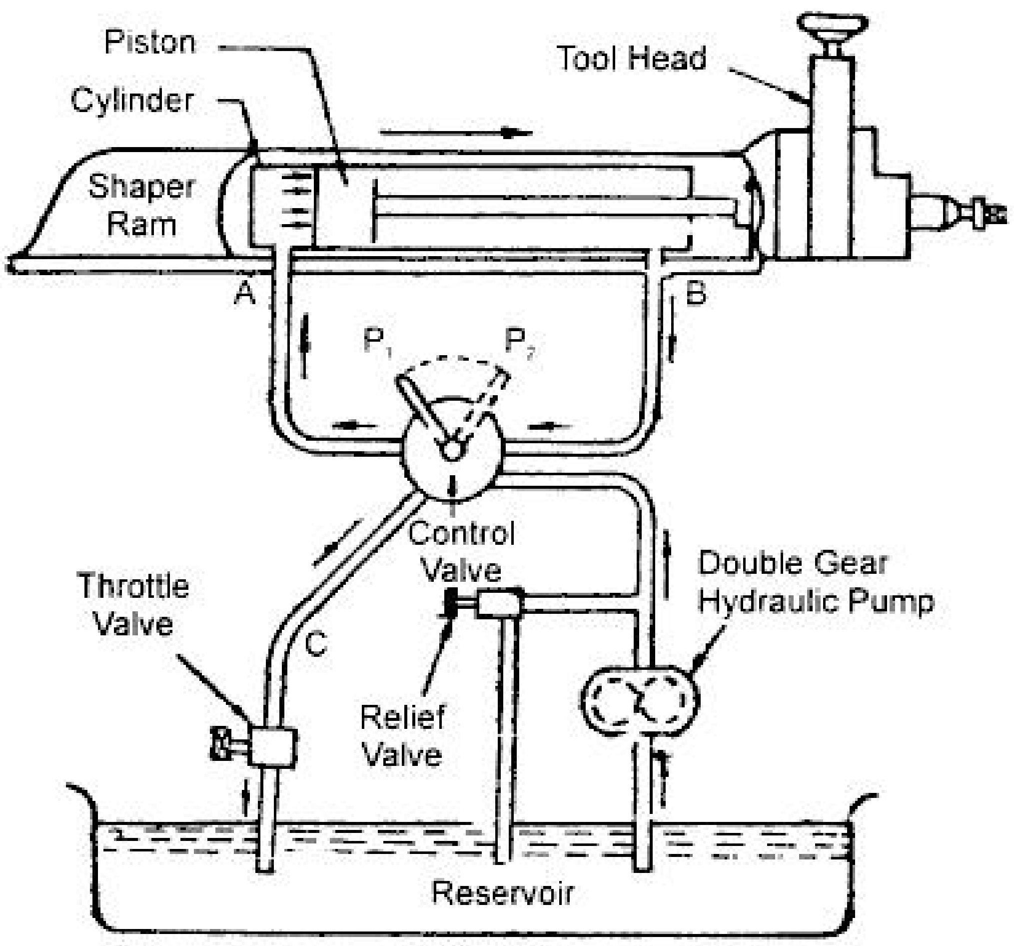

Figure 3.9 Hydraulic Mechanism

When the lever is in the position P_1, oil is delivered to the left side of the cylinder. Due to the oil force, the piston moves left to light. The piston is connected to the ram through piston red. So, the ram moves from left to right. It is cutting stroke. At the same time, oil in the right side it is supplied in the previous stroke) flows out of the cylinder. It goes to the reservoir through the control valve.

When the lever is in the position P_2, oil is delivered to the right side of the piston. It moves the ram from right to left. It is return stroke. At the same time, the oil on the left side of the

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Only single point cutting tools are used in a shaper. The rake angle clearance angle and other tool angles are similar to a lathe tool. Shaper tools are made more rigid and heavier. This is to with stand the shock load acting on the tool at the start of each cutting stroke. The shaper tools are classified as follows:

1. *According to the shape*

   – straight tool, cranked tool, goose necked tool.

2. *According to the direction of cutting*

   – Left hand tool and right hand tool.

3. *According to the finish required*

   – roughing tool, finishing tool

4. *According to the type of operation*

   – down cutting tool, parting off tool, squaring tool, side recessing tool etc.

5. *According to the shape of the cutting edge*

   – round nose tool, square nose tool.

The shaper tools commonly used are shown in figure 3.20

Round nose tool

This is used for roughing operations. The tool has no top rake. It has side rake angle, between 10 to 20°. Round nose tool is of two types - plain and bent types. The plain straight type is used for rough machining of horizontal surface. Round nose tool can be left handed or right handed. Another type of round nose tool which is cranked or bent is used for machining vertical surfaces. It is known as round nose cutting down tool.

Square nose tool

This tool is used for finishing operations. The cutting edge may have different widths. It is also used to machine the bottom surfaces of key ways and grooves.

Side recessing tools

This is a special tool used for machining T-slots and narrow vertical surfaces. This tool can be both left handed and right handed.

Parting off tool

This is used for parting off operation. It is also used for cutting narrow slots. It has no side rake angle. It has front and side clearance angle of 3°.

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3.9. SPECIFICATIONS OF A SHAPING MACHINE

1. Length of stroke, e.g. 600 mm. In general, length of stroke indicates the size of the shaper. Also, it indicates the maximum size of a cube that can be held and machined.

2. Ratio of cutting stroke time to return stroke time

3. Power required (eg 5 kW)

4. Space required (1.8 × 1m) and

5. Weight of the machine (1.5 ton) are the other important specifications.

3.10. MACHINING PARAMETERS

Cutting Speed, Feed and Depth of Cut

Cutting speed the rate at which the material is removed by the cutting tool and is expressed in metres/mm. In H lathe, the cutting action is continuous and hence the cutting speed is nothing but the periphera' speed of the work piece. In a shaping machine, cutting action is intermittent: the cutting speed is calculated only for the cutting stroke.

$$\text{Cutting Speed} = \frac{\text{Speed length of cutting stroke}}{\text{Time taken for the cutting stroke}}$$

Feed is the movement of the tool or work piece, in a direction perpendicular to the direction of reciprocation of the ram, per double stroke (cutting plus return strokes) and it is expressed in mm.

Depth of cut is the thickness of the metal removed in one cut, and is expressed in mm.

3.11. UNIVERSAL SHAPER

It has all principal parts as in standard shaper. Its table has three movements. They are vertical, horizontal and swivel. The table has a swivel base with degree markings. As the table is fitted to the column through this swivel base, it can be swiveled perpendicular to the column. i.e., it can be swiveled about an axis parallel to the ram movement.

3.12. DRAW CUT SHAPER

It has all principal parts. It is comparatively much heavier than plain type. In this type, the metal is cut during the return stroke, when the ram moves towards the column. Therefore, during cutting the tool draws the work towards the column. Hence it is called draw shaper. The cutting tool is fixed in a reverse direction to that of standard shaper.

The ram is supported by an overhead arm. This gives rigidity to the cutting tool. As the cutting force acts towards the column, there is no excessive loading in the cross rail and bearings. So heavy cuts are possible and vibration is eliminated.

3. Hydraulic drive.

The whitworth quick return mechanism used in slotter is the same as given in shaper.

3.15. FEED MECHANISM

In slotter, the feed is given by the table. It is given at the beginning of cutting stroke. The slotter has three type of feed movement.

1. Longitudinal feed: It is given by moving the table, (saddle) either towards or away from the column.
2. Cross Feed: It is given by moving the table (cross slide) parallel to the face of column.
3. Circular feed: It is given by rotating the table about a vertical axis.

The feed movement can be given either by hand or power. Hand feed is given by rotating the respective feed screw through hand wheels.

3.15.1. Automatic Feed Mechanism

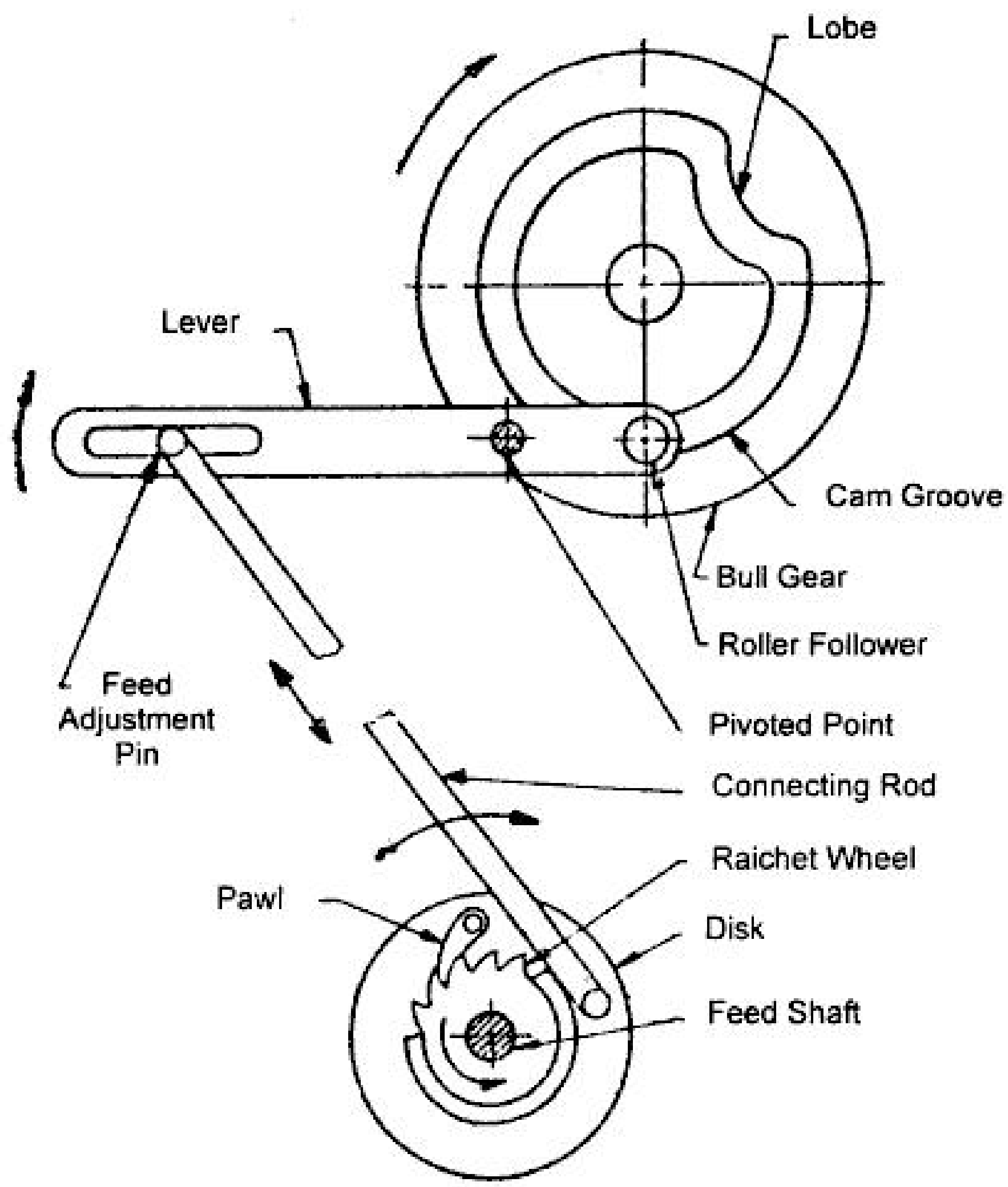

Figure 3.32. Automatic feed machanism

3.19. SPECIFICATION

The specification of slotter are:

1. The maximum stroke length
2. Diameter of rotary table
3. Maximum travel of saddle and cross slide
4. Type of drive used
5. Power rating of motor
6. Net weight of machine
7. Number and amount of feeds and
8. Floor area required

3.20. PLANNING MACHINE

3.20.1. Introduction

The planer, like a shaper, is a reciprocating machine tool mainly used for making plane and flat surfaces by a single point cutting tool. A planer is large and massive when compared with a shaper. Heavy and large work pieces, which cannot be machined in a shaper can be machined in a planer. It differs from shaper that the work table reciprocates while the cutting tool is stationary.

3.20.2. Principle of Operation

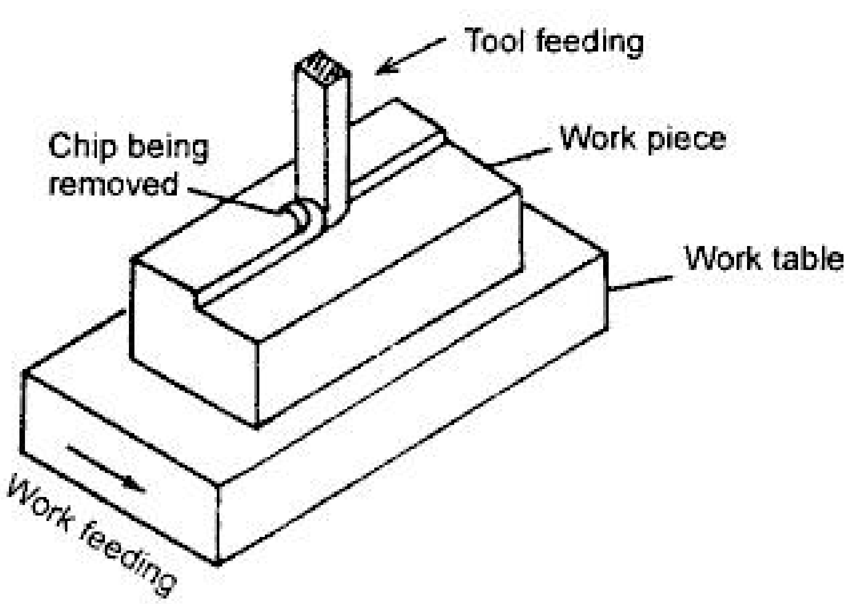

Figure 3.37. Working principle of a planer

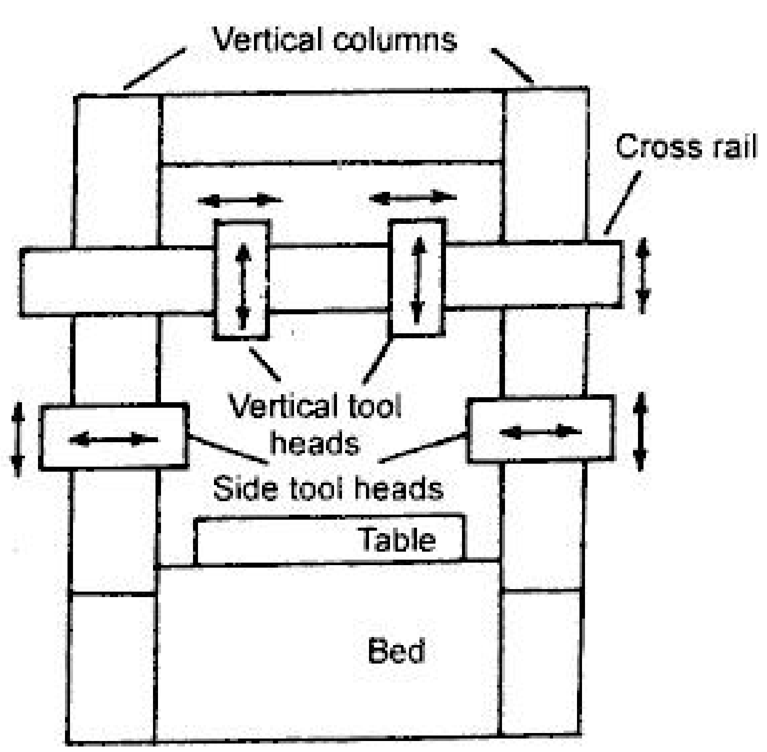

Figure 3.38. Principle of the planer

The basic principle of operation of a planning machine is illustrated in figure 3.37 & 3.38. The work is held rigidly on the work table of the machine. The tool is held in the tool head mounted

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stand on it and travel along with it during operation. Squaring or bevelling the edges of plate can be done in this machine. (Figure 3.41)

3.21.5. Divided Table Planer

It is similar to a standard planner. But, it has two reciprocating tables. When one table is made to reciprocate the other table may be kept stationary to set another job. They may be jointed together to hold long work.

Clamping the workpiece in a planer table may take a lot of time. The setting time is more, when we use standard planer because it has only one table. To avoid this here two tables are used.

When one table reciprocates for machining, setting of work is done on the other table. After the machining is finished in the first work piece, the table is brought to the end of the table. The finished work is removed and a new one is loaded. During this time, the second table is made to reciprocate for machining.

3.22. QUICK RETURN MECHANISM

3.22.1. Open and cross belt drive

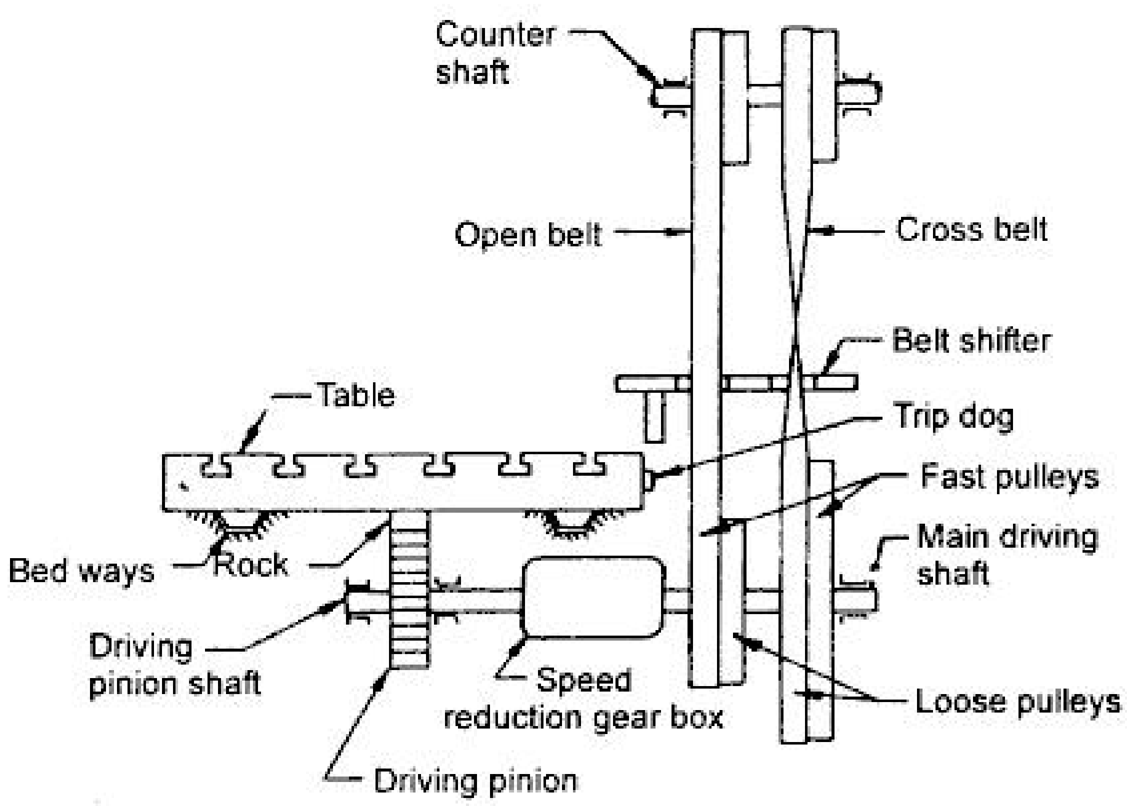

Figure 3.42. Open & Cross beld drive

It is an old method of quick return drive used for small planers. A counter shaft is driven by electric motor. This shaft carries two wide faced pulleys of equal diameter. One pulley drives the open belt. Another pulley drives the cross belt.

The main driving shaft is placed below the bed. One end of the shaft carries a set of two large pulleys and two small pulleys

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A trip dog is fitted to the planer table. At the end of the return stroke, the trip dog strikes a lever. A pawl attached to this lever rotates a ratchet. So a splined shaft attached to the ratchet rotates.

A bevel gear cast integral with a spur gear is fitted freely on the down feed screw. This bevel gear meshes with bevel gear slides on the splined shaft. The spur gear meshes with a gear keyed to the cross feed screw. So the power from the splined shaft is transmitted to the cross feed screw. Then the power is transmitted to the tool head through a nut. The tool head moves horizontally. It is known a cross feed.

At the end of the forward stroke, the trip dog strikes the lever. The lever comes to its original position. During this time, the pawl slips over the ratchet. The ratchet wheel does not rotate.

For giving automatic down feed, the gear fitted to the cross feed screw is disengaged. The bevel gear freely fitted to the down feed rod is keyed to the down feed rod. At the end of return stroke, the power is transmitted to the down feed rod through the lever, ratchet and bevel gears. Then the power is transmitted to the cross slide though another bevel gear arrangement. The tool moves downward.

3.24. WORK HOLDING DEVICES

Large and heavy work piece are normally machined on a planer. Large number of small identical pieces are also machined. Setting of work on a planer table requires skill. For holding the work on a planer table, different standard clamping devices are used. Special fixtures are also used.

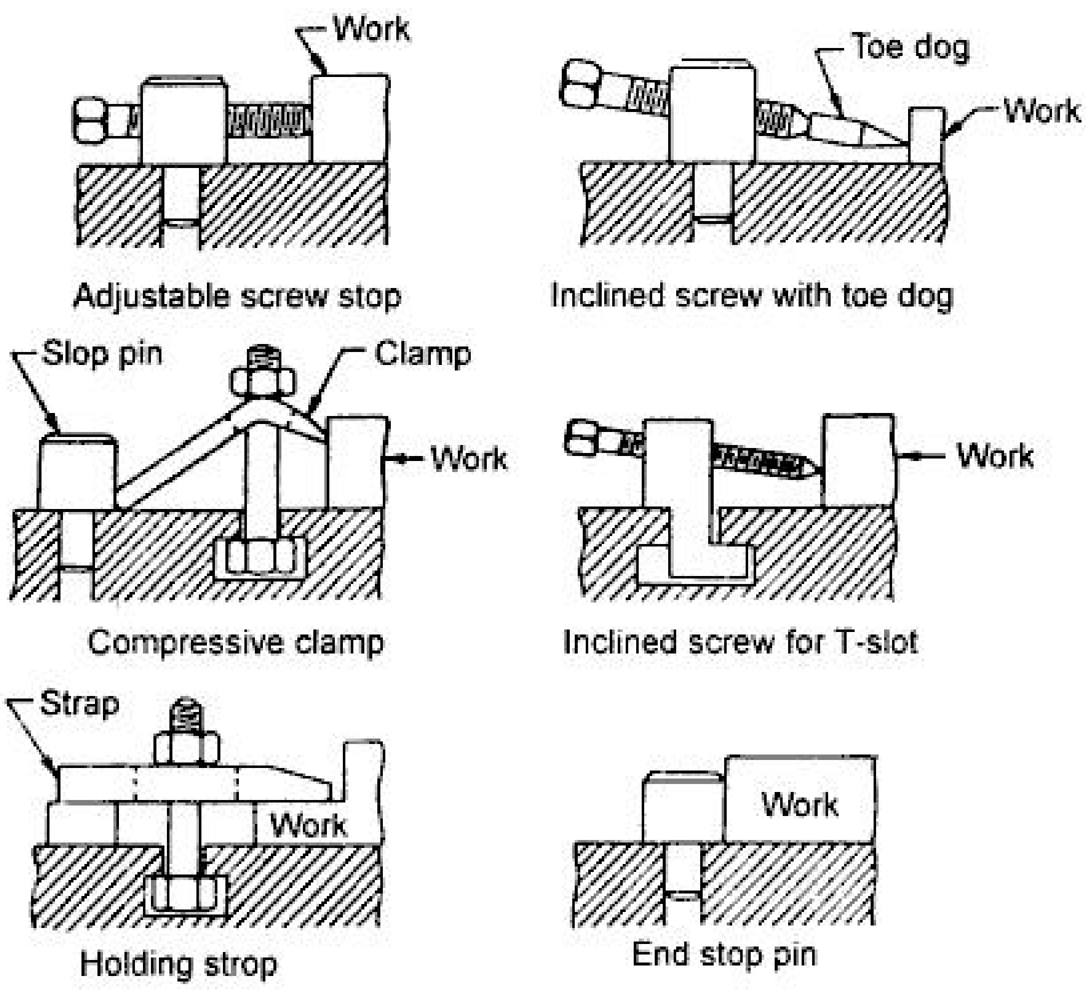

Figure 3.46. Work holding devices

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3.27. SPECIFICATIONS OF A PLANER

The planer can be specified by :

1. Horizontal distance between two vertical housings.
2. Maximum stroke length of table
3. Size of the table
4. Height of cross rail from the top of the table
5. Type of drive
6. Power required for the motor
7. Net weight
8. Type of feed

3.28. DIFFERENCE BETWEEN A SHAPER AND PLANER

Sl.No.	SHAPER	PLANER
1.	The tool reciprocates and the work is stationary.	The work reciprocates and the tool is stationary.
2.	The work is fed across the tool.	The tool is fed into the work.
3.	Feed is given to the work during the idle stroke of the ram.	Feed is given to the tool during the idle stroke of the work table.
4.	Suitable for machining small workpieces.	Suitable for machining large workpieces.
5.	Only light cuts can be applied.	Heavy cuts can be applied.
6.	Only one tool can be used at a time. So machining takes longer time.	Vertical and side tool heads can be used at the same time for machining. So machining is quicker.
7.	Setting the work piece is easy.	Setting the workpiece is difficult.
8.	Only one work piece can be machined at a time.	Several workpieces can be machined at the same time.
9.	Tools are smaller in size.	Large sized tools are used.
10.	They are lighter and smaller.	They are heavier and larger.

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It is driven by electric or pneumatic power at high speed. It can drill holes upto 12mm diameter. Hand drills, ratchet drills and pneumatic arms are examples of portable drilling machines.

4.2.2. Sensitive drilling machine

The sensitive drilling machine is a light, high speed drilling machine. If the machine is mounted on a bench it is called 'bench type' and if mounted on the floor it is called 'floor type'.

This is used generally for light duty and can drill from 1.5mm to 15mm diameter holes. The drill is fed into the pulley work by hand only. The operator can feel or sense the travel of the drill hence handle the machine is called as sensitive drilling machine.

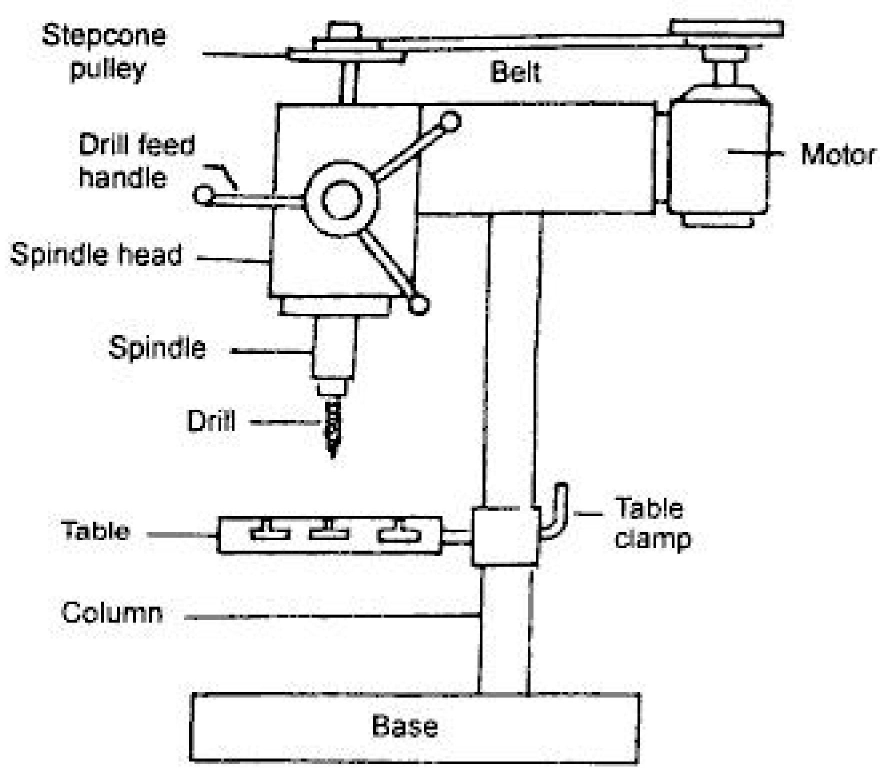

Figure 4.1 Bench type sensitive drilling machine

Figure 4.1 shows a schematic view of a sensitive bench type drilling.

(i) Base

The base is of heavy casting made up of cast iron. It supports the column and other parts of a machine.

(ii) Column

The column is a vertical upright cylinder, firmly attached to the base. It supports the table, spindle head, motor and the driving mechanism.

(iii) Table

Table is attached to the column by a clamp. It supports the workpiece and the work holding devices. The table can be moved up and down and can also be rotated around the column. It can also be fixed at the desired position using the clamp. It has T-slots for clamping the workpiece.

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4.2.5. Gang Drilling Machine (Figure 4.4)

The machine has a long common base and table. Four to six drill heads are mounted on the table. Each head has its own driving motor so that the speeds and feeds of individual units can be controlled independently. Gang drilling machines are used in production line where a series of operations like drilling, reaming and tapping are performed on a single job, in a successive manner, each spindle performing one particular operation only.

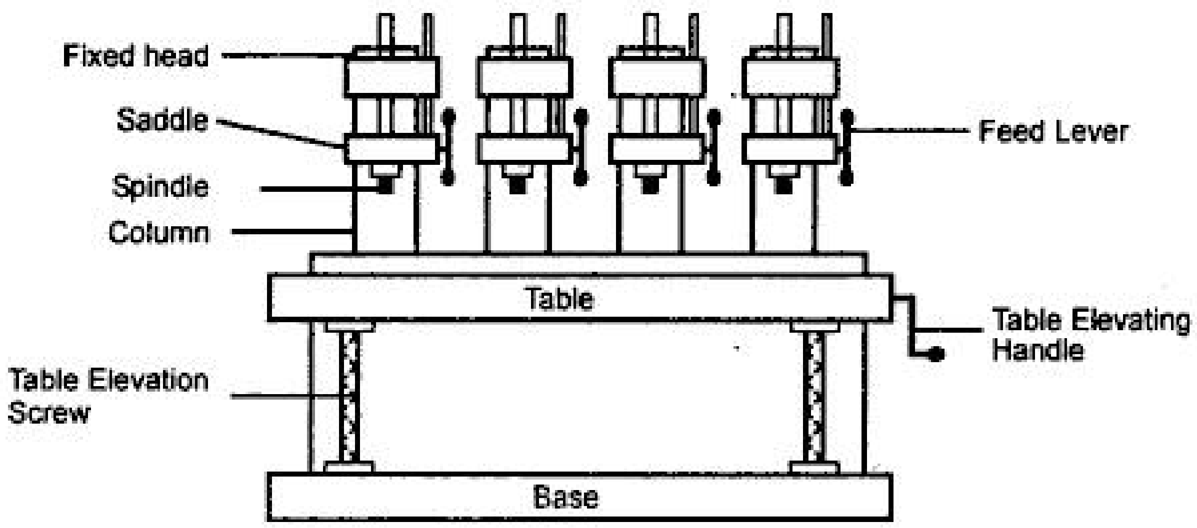

Figure 4.4. Gang Drilling machine

4.2.6. Multiple Spindle Drilling Machine (Figure 4.5)

In mass production, in order to reproduce a pattern of holes in a number of identical jobs, multiple spindle drilling machine is used. This is a special purpose drilling machine and is designed for a particular job or for a particular group of jobs.

The drill head has as many spindles as required for a particular group of jobs and the spindles are driven by a common motor. The distance between the spindles can be adjusted as required by the arrangement of holes. Drill jigs are used to guide the drills. Workpieces like pipe flanges, pump housings, compressor bodies, engine blocks etc are drilled in multi spindle drilling machines.

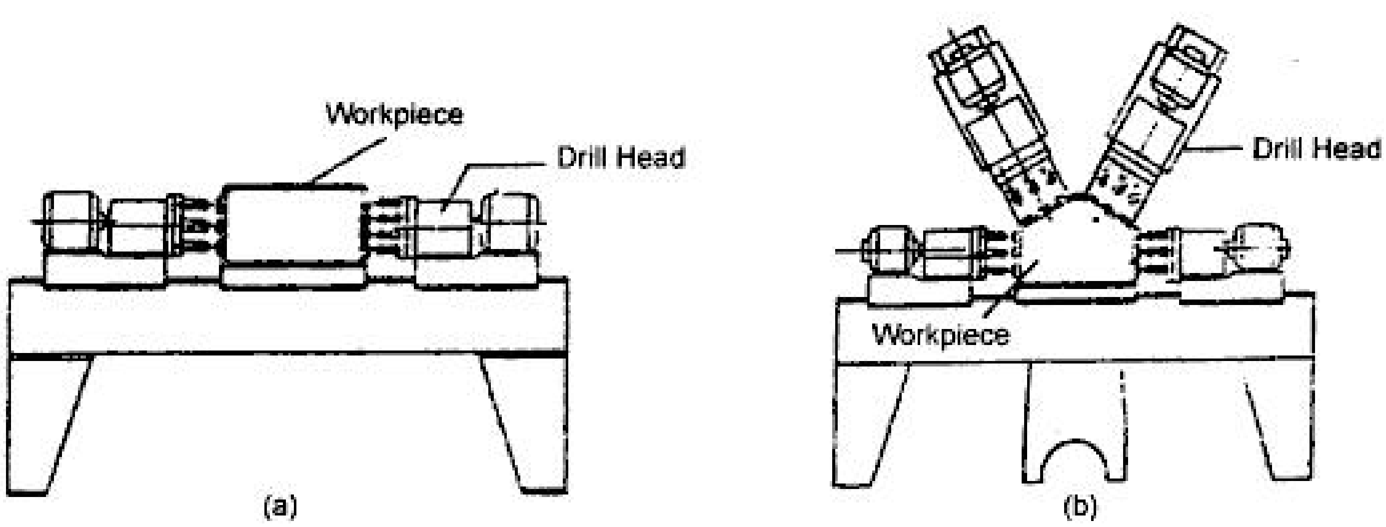

Figure 4.5. Unit-type multiple-spindle drilling machines

3. According to the length
    a) Short series drills
    b) Stub series drills
    c) long series drills
4. According to applications
    a) core drills
    b) drill for long hole drilling
    c) centre drilis
    d) masonary drills
5. According to the tool material
    a) High speed steel drills
    b) Carbide tipped drills
6. Oil hole drills

Then, there are large number of special drills manufactured against order to meet specific requirements. Such drills can be classed as special drills,

4.6. DRILLING TOOLS

A drill is a cutting tool used to originate or enlarge a hole in a solid material. A drill has flutes on its body. The types of drills generally used are:

1. Flat & spade drill
2. Twist drill
3. Straight fluted drill
4. Centre drill

4.6.1. Flat and spade drill

This is the earliest and simplest form of drill bit. It has a flat cutting edge. It is made from a round tool steel. The cutting edge is made flat by forging. The cutting angle varies from 90°to 120°. This drill is not used nowadays because it cannot produce accurate holes. Drill size gets reduced after every grinding. The metal chips remain inside the cutting edge of the drill. So the drill is spoiled very soon. (Figure 4.14)

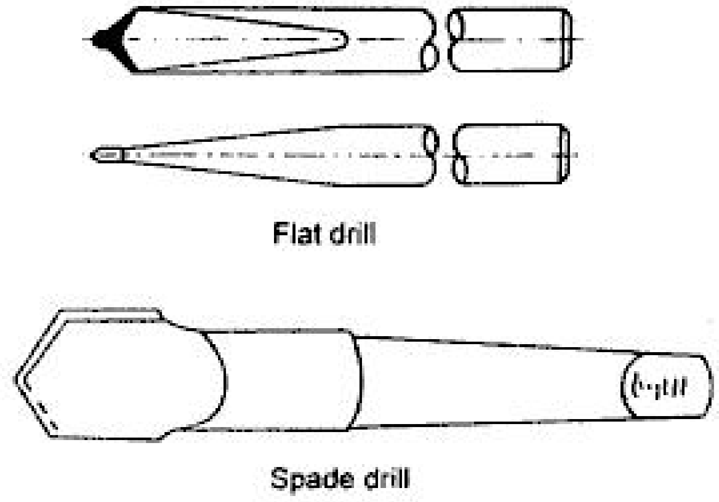

Figure 4.14

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4.7. DRILL HOLDING METHODS / TOOL HOLDING DEVICES

4.7.1. By directly fitting into the spindle hole

The spindle hole has a standard Morse taper to receive the taper shank of a drill. The drill shank is forced into the tapered hole and is held by friction. To ensure a positive drive from the spindle to the drill, the tang or tongue of the drill bit is inserted into a slot at the end of the tapered hole (Figure 4.19). In order to remove the drill, a wedge (Figure 4.20) known as drift is inserted into the slot and gently tapped.

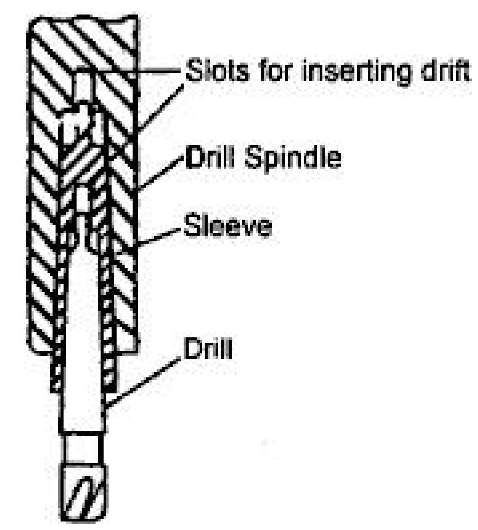


Figure 4.19. Drill inserted

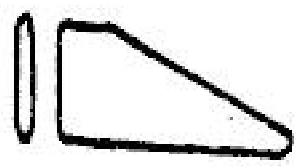
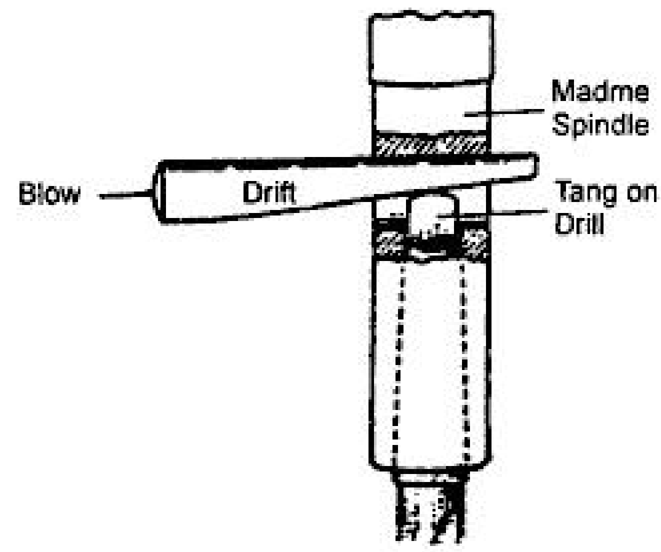


Figure 4.20 (a)



Drift Figure 4.20 (b)

4.7.2. By using a sleeve

Only one size of drill can be directly fitted into the spindle bore. For using other sizes of drills, sleeves as shown in Figure 4.21 (a) should be used. The outside taper of the sleeve matches the spindle taper and the inside taper of the sleeve matches the drill shank taper.

4.7.3. By using a socket (Figure 4.21 (b))

When the taper shank of a drill is larger than the taper hole in the spindle, a socket is used. The socket consists of a solid tapered shank and a cylindrical body. The shank taper conforms to the taper of the spindle hole and the inside taper of the body conforms to the shank taper of the drill to be used. The taper hole in the socket is larger than the taper hole in the drill spindle.

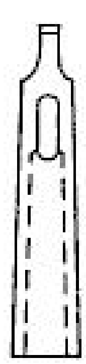


Fig. 4.21(a). Drill Sleeve

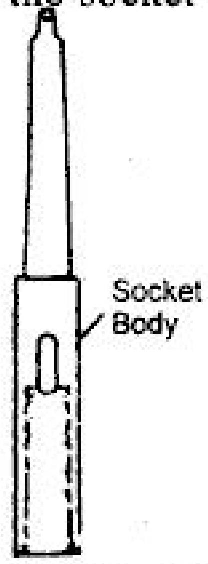


Fig. 4.21 (b) Drill Socket

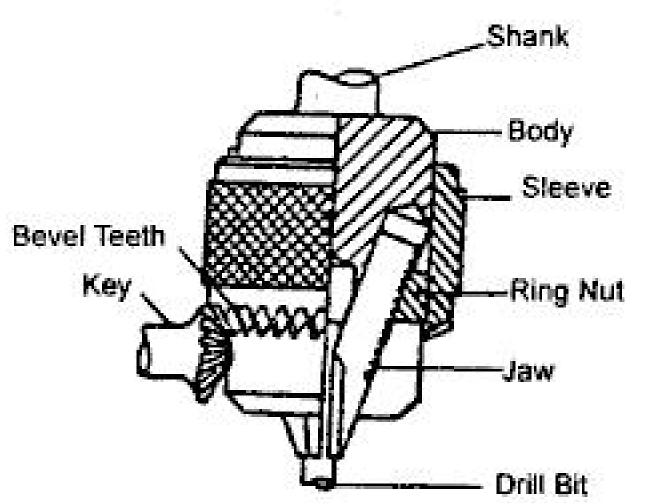


Fig 4.21 (c) Self Centering Drill Chuck

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3) Setting the dividing head on table

The dividing head and the tail stock are bolted on the machine table. Their axis must be set parallel to machine table.

The gear blank is held between the dividing head and tail stock using a mandrel. The mandrel is connected with the spindle of dividing head by a carrier and catch plate.

4) Selection of cutter and mounting it

For selection of the cutter, the following standard table of involute gear is used. According to the number of teeth to be cut (Z) the cutter is selected. There is a set of 8 cutters for each module.

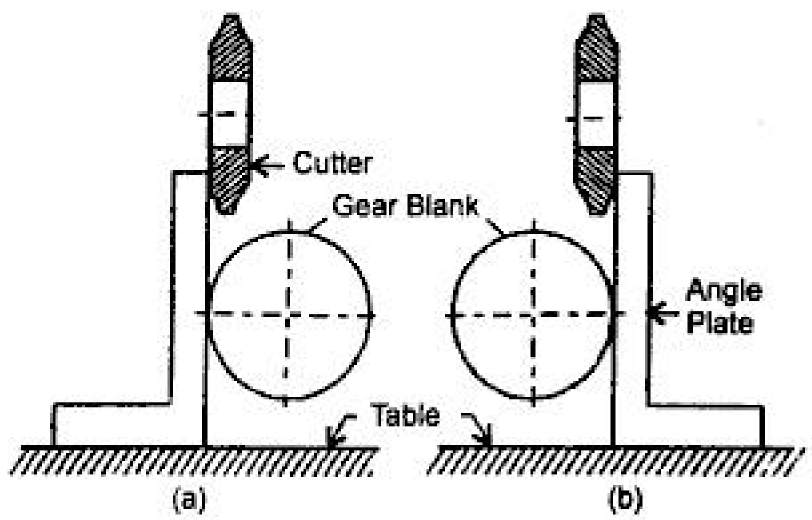

Figure 5.39

Standard table for involute gear cutter

Cutter No.	Number of teeth cut (Z)
1.	135 to rack.
2.	55 to 134
3	35 to 54
4.	26 to 34
5.	21 to 25
5.	17 to 20
7.	14 to 16
8.	12 to 13

The selected cutter is mounted on the arbor. The cutter is centered accurately with the gear blank.

For this, the following procedure is adopted,

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$$T_m = \frac{34.373}{4.8/10 \times 80} = 0.8951 \text{ min.}$$

5. A 300 × 50 mm CI piece is to be face milled with a carbide cutter. The cutting speed and feed are 50 m/min and 50 mm/min. If the cutter dia is 80 mm and. it has 12 cutting teeth, determine.

(i) Cutter rpm

(ii) Feed/tooth

(iii) Milling time.

Solution:

(i) $$\text{Cutter rpm} = \frac{V \times 1000}{\pi \times 80}$$

$$= \frac{50 \times 1000}{\pi \times 80} = 200 \text{ rpm}$$

(ii) $$\text{Feed/tooth} = \frac{\text{Feed / min}}{\text{N} \times \text{No. of teeth}} = \frac{50}{200 \times 12} = 0.02 \text{ mm / tooth}$$

(iii) For face milling:

$$\text{Over travel} = \frac{1}{2}\left(D - \sqrt{D^2 - W^2}\right)$$

$$= \frac{1}{2}\left(80 - \sqrt{80^2 - 50^2}\right) = 8.8 \text{ mm}$$

Total cutter travel = 300 + 8.8 = 309 mm

$$\text{Time for milling} = \frac{\text{Total cutter travel}}{\text{Feed/min}} = \frac{309}{50}$$

$$T_m = 6.18 \text{ min.}$$

6. A T-slot is to be cut in a C.I slab as shown in Fig. Estimate the machining time. Take cutting speed 25 m/min, feed is 0.25 mm/rev. Diameter of cutter for channel milling is 80 mm.

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6.2. TYPES OF GRINDING MACHINES

Grinding machines according to the quality of surface finish, may be classified as :

(i) Rough grinders.

(ii) Precision grinders.

i. Rough Grinders : Rough grinders are those grinding machines whose chief work is the removal of stock without any reference to the accuracy of results. They are mainly of the following types.

1. Floor stand and bench grinders.
2. Portable and flexible shaft grinders.
3. Swing frame grinders,
4. Abrasive belt grinders.

ii. Precision Grinders : Precision grinders are those that finish parts to a very accurate dimensions.

According to the type of surface generated or work done they may be classified as follows:

1. Cylindrical grinders
   - (a) Centre-type (Plain)
   - (b) Centre-type (Universal)
   - (c) Centre-less
2. Internal grinders
   - (a) Chucking
     - (i) Plain
     - (ii) Universal.
   - (b) Planetory
   - (c) Centre-less.
3. Surface grinders.
   - (a) Reciprocating table
     - (i) Horizontal spindle
     - (ii) Vertical spindle.
   - (b) Rotating table
     - (i) Horizontal spindle
     - (ii) Vertical spindle.

These grinding machines are intended primarily for grinding plain, cylindrical parts, although they can also be used for grinding contoured cylinders, tapers, faces and shoulders, fillets, and even cams and crank shafts.

6.4.2. Plain centre type cylindrical Grinding machine

A plain centre-type grinding machine is shown in the fig. 6.8. It is essentially a lathe on which a grinding wheel has been substituted for the single point tool. It consists of the following parts : 1. Base 2. Tables 3. Head stock 4. Tail stock 5. Wheel head.

1. Base: The base or bed is the main casting that rest on the floor and supports the parts mounted on it. On the top of the base are precision horizontal ways set at right angles for the table to slide on the base. The base also houses the table drive mechanism.

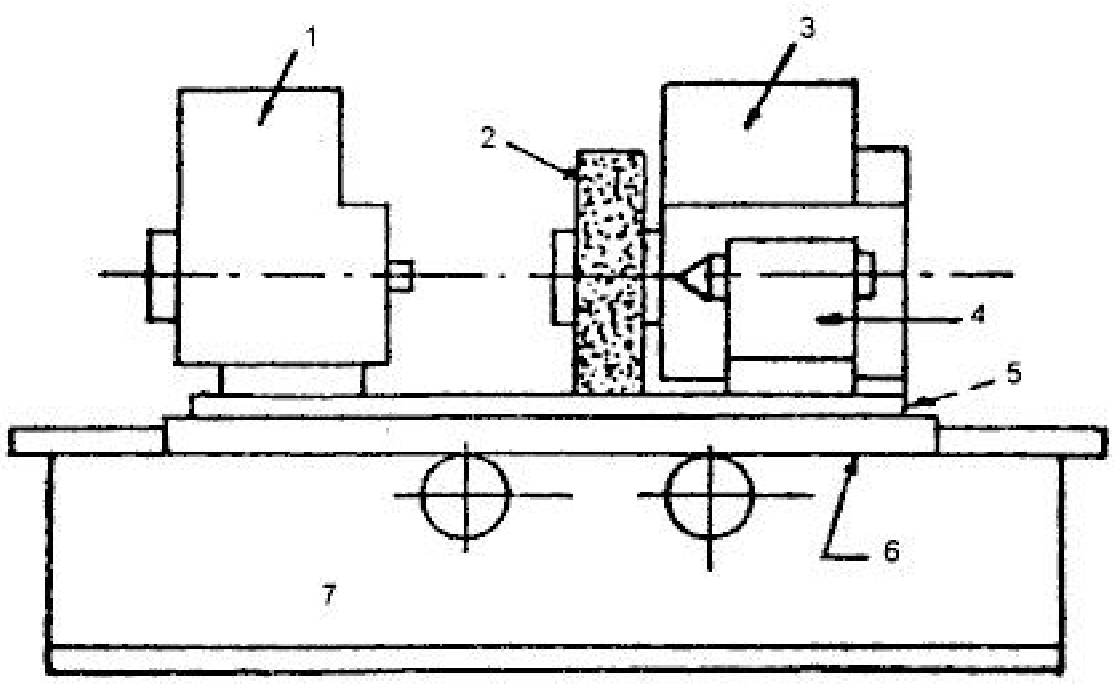

Figure 6.8 Block diagram of a plain centre type grinder

2. Tables: There are two tables, lower table and upper table. The lower table slides on ways on the bed and provides traverse of the work past the grinding wheel. It can be moved by hand or power within desired limits.

The upper table that is pivoted at its centre is mounted on the top of the sliding table. It has T-slots for securing the head stock and tail stock or foot stock and can be positioned along the table to suit the length of the work. The upper table can be swivelled and clamped in position to provide adjustment for grinding straight or tapered work as desired. Setting for tapers upto $\pm 10^{\circ}$ can be made in this way. Steep tapers are ground by swivelling the wheel head.

Adjustable dogs are clamped in longitudinal slots and they are provided at the side of the lower or sliding table and are set up to reverse the table at the ends of the stroke.

3. Head stock: The headstock supports the work piece by means of a dead centre and drives it by means of a dog, or it may hold and drive the work piece in a chuck.

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6.9.1. Abrasives

These are extremely hard and tough materials which can be used to cut or wear away other materials. When an abrasive is fractured, it forms sharp cutting edges and corners.

Types of abrasives: The abrasives are of two types

(i) Natural

(ii) Artificial or manufactured.

1. Natural abrasives: These are produced by uncontrolled forces of nature. 'These are obtained directly from mines. The following arc the generally found and used natural abrasives.

(a) Sandstone (or) solid quartz

(b) Emery (50-60% crystolone Al_2O_3 + iron oxide)

(c) Corundum (75-90% crystolone Al_2O_3 +iron oxide)

(d) Diamonds

(e) Garnet

2. Artificial Abrasives: These are manufactured under controlled conditions in closed electric furnaces in order to avoid the introduction of impurities and to achieve necessary temperature for the chemical reactions to take place. The efficiency of these abrasives is far better than that of natural abrasives. Most commonly used manufactured abrasives are (a) Silicon carbide (s_ic) (b) Aluminium oxide (Al_2O_3) (c) Boron carbide (BC).

(a) Silicon carbide (sic): It is available in variety of colours. A special variety of bluish-green is very suitable for grinding tipped tools. The trade names of it are "Carborandum", "CRYSTOLON", "ELECTROLON". It is denoted by letter 'S'.

(b) Aluminium oxide ($Al\ O_3$) : Its special form is white Aluminium oxide, which when pure looks like brilliant white crystal. It is most suitable for tool steels where heat generation due to grinding is low. The trade names for fused aluminium oxide are 'ALOXITE', 'ALUNDUM' and 'BOROLON'. It is denoted by letter 'A'.

(c) Efficiency of Abrasive particles: The efficiency of abrasive particles depends upon the following factors 1. Purity 2. Uniformity in composition 3. hardness 4. Toughness 5. Sharpness of fracture.

6.9.2. Bonds

Bond is an adhesive substance used to hold abrasive grains together in the grinding wheel. The following are the various types of bonds used:

(a) Vitrified bond - (V)

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2. Face grinding wheels

These are the wheels whose face is used for grinding. These wheels are mounted on vertical spindles.

(a) Ring or Cylindrical Wheels

These wheels are used for grinding small flat surfaces.

(b) Flaring Cup Wheels

These wheels are used fur tool and cutter grinding.

(c) Dish wheels

These wheels are also used for tool and cutter grinding. The thickness of the wheels are small enough to grind narrow grooves.

(d) Cup wheels

These are used for grinding large flat surfaces.

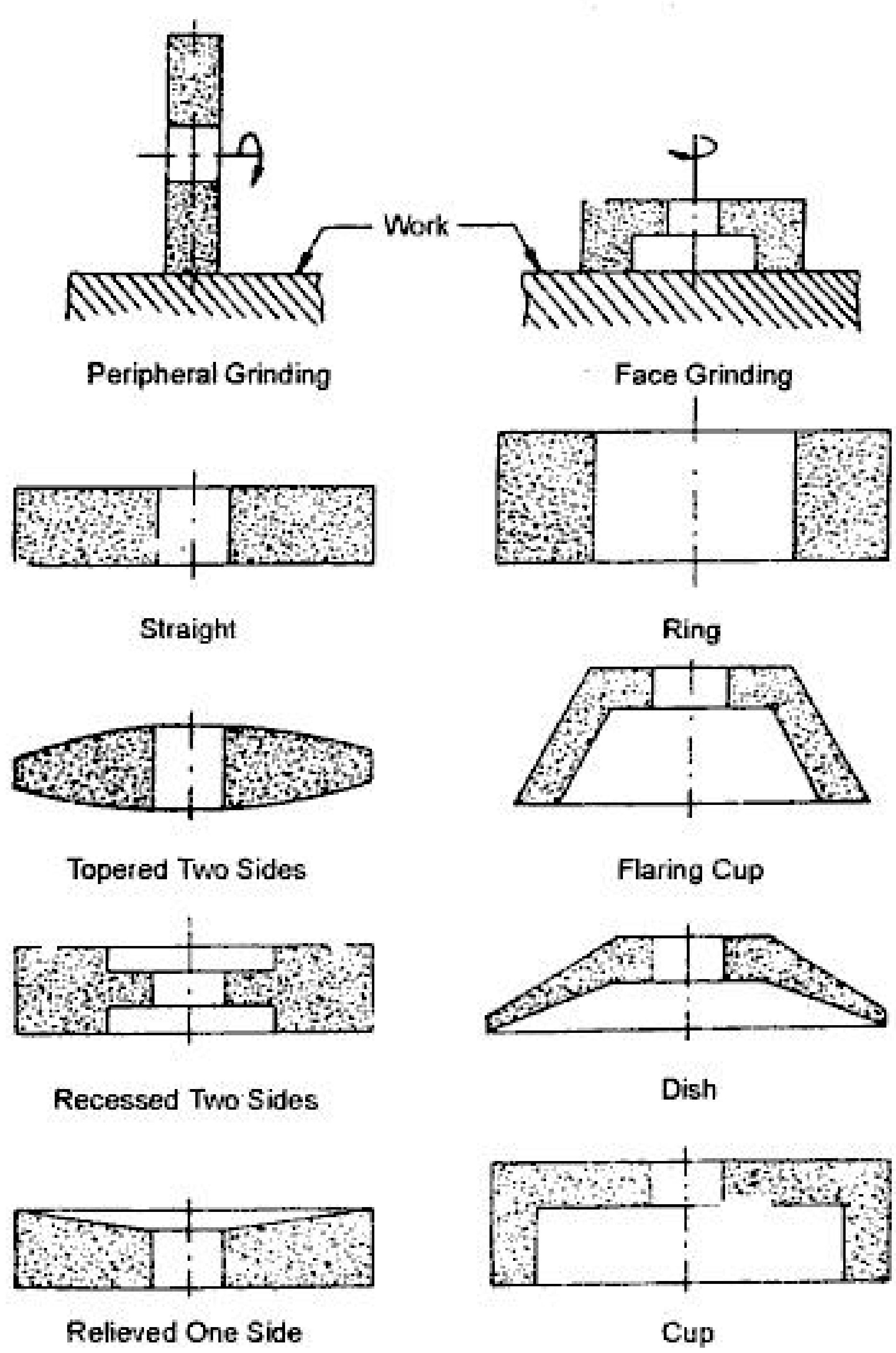

Figure 6.24 Grinding Wheels

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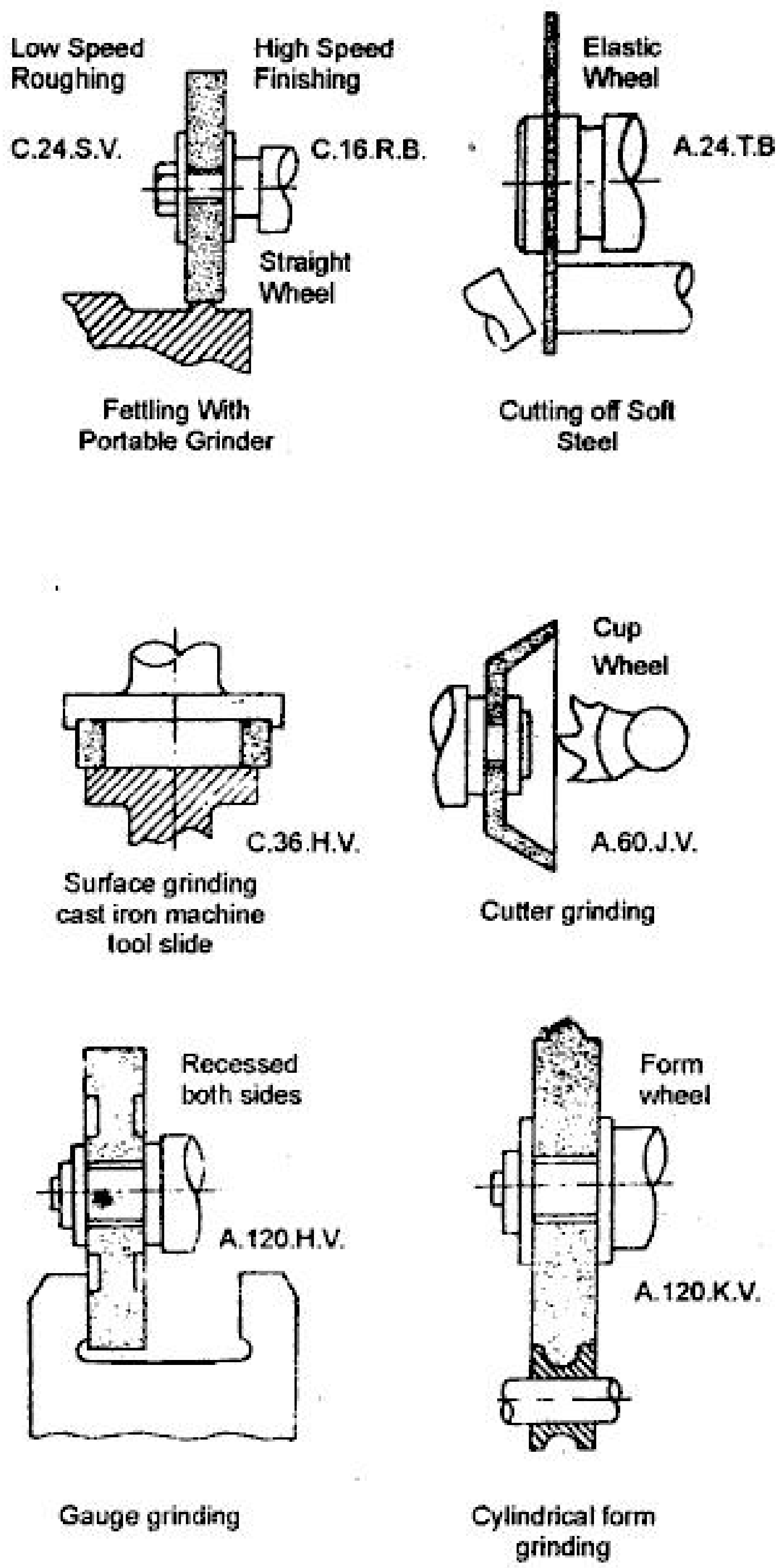

Figure 6.29 Application of grinding wheels

3. Area of contact

When the area of contact between the wheel and workpiece is small, a fine grained and dense structure wheel is used. When the area of contact is more, a coarse grained and open structure wheel is used.

4. Type and condition of grinding machine

Heavy, rigid and well maintained machine can use soft grade wheels. Light and poorly maintained machines should use hard grade wheels.

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Solution:

$$\text{Time required/stroke} = \frac{\text{Length of table}}{\text{Speed of table}} = \frac{90}{9\times 100} = \frac{1}{10}\text{ min}$$

$$\text{Feed} = 0.5 \text{ cm}$$

$$\text{Number of strokes required} = \frac{\text{width of table}}{\text{feed}}$$

$$= \frac{40}{0.5} = 80$$

$$\text{Time required/cut} = \text{Time/stroke} \times \text{Number of strokes}$$

$$= \frac{1}{10} \times 8 = 8 \text{ min}$$

$$\text{Total time required for 2 cuts} = 2 \times 8 = 16 \text{ min}$$

SUMMARY

- Grinding is a process of removing material by the abrasive action of revolving wheel on the surface of a workpiece in order to bring it to the required shape and size.
- Grinding machines according to the quality of surface finish, may be classified as : (i) Rough grinders, (ii) Precision grinders.
- ***Through feed:*** In through feed grinding, the regulating wheel is tilted at a small angle. This makes the work to move axially through the space between the grinding wheel and regulating wheel. Guides are provided at both the ends of the wheel.
- ***In feed:*** This is similar to plunge cut grinding. The work is placed on the work rest against an end stop. This prevents the axial movement of workpiece. The regulating wheel and the work rests with the workpiece are moved towards the grinding wheel by hand feed.
- ***Types of abrasives:*** The abrasives are of two types, (i) Natural, (ii) Artificial or manufactured.
- ***Bond:*** It is an adhesive substance used to hold abrasive grains together in the grinding wheel.
- ***Grit or grain:*** It indicates the size of the abrasive grains used in making a wheel. Grain size is denoted by a number indicating the number of meshes per linear inch (25.1 mm) of the screen through which the grains pass when they are graded after crushing.

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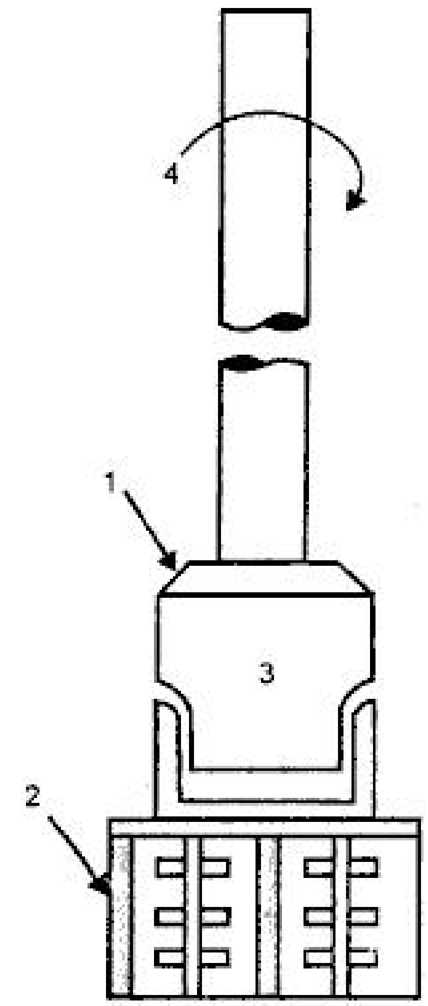
2. Provides superfine surface finish, greater uniformity and optical flatness. Commercial lapping operations can produce parts accurate upto limits of 0.0006 mm.
3. Provides liquid and gas tight seals without using gaskets between plunger and piston without rings.
4. Removes errors in gears which produce noise and undue wear.

7.3. HONING

Honing is a grinding or a abrading process mostly for finishing round holes by means of bonded abrasive stones, called hones. Honing is therefore a cutting operation and has been used to remove as much as 3 mm of stock but is normally confined to amounts less than 0.25mm. So honing is primarily used to correct some out of roundness, taper, tool marks, and axial distortion. Honing stones are made from common abrasive and bonding materials, often impregnated with sulphur, resin or wax to improve cutting action and lengthen tool life. Materials honed range from plastics, silver, aluminium, brass, and cast iron to hard steel and cemented carbides. This method is mostly used for finishing automobile crank shaft journals.



1. Adapter 2. Stone
3. Joint 4. Driver

Figure 7.1 Honing tool with adapter

When honing is done manually, tool is rotated, and the work piece is passed back and forth over the tool. For precision honing, the work is usually held in a fixture and the honing tool is given a slow reciprocating motion as it rotates. Honing stones may be loosely held in holders, cemented into metal shells which are clamped into holders, cemented directly in holders, or cast into plastic tabs which are held in holders. Some stones are spaced at regular intervals around the holders, while others are interlocking so that they present a continuous surface to the bore. A typical honing tool head is shown in, fig. 7.1.

Coolants are essential to the operation of this process to flush away small chips and to keep temperatures uniform. Sulphursed base oil or lard oil mixed with kerosen is used.

Honing is done on lathe, drill press, and portable drills.

7.4. SUPER FINISHING

A defect free high quality surface finish is achieved by the operation termed as 'Super finishing'. The main features of the system are:

(i) Complete absence of defects in surface layer,

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external broaching carries the guide way on a vertical surface. The broach is moved along the guideways.

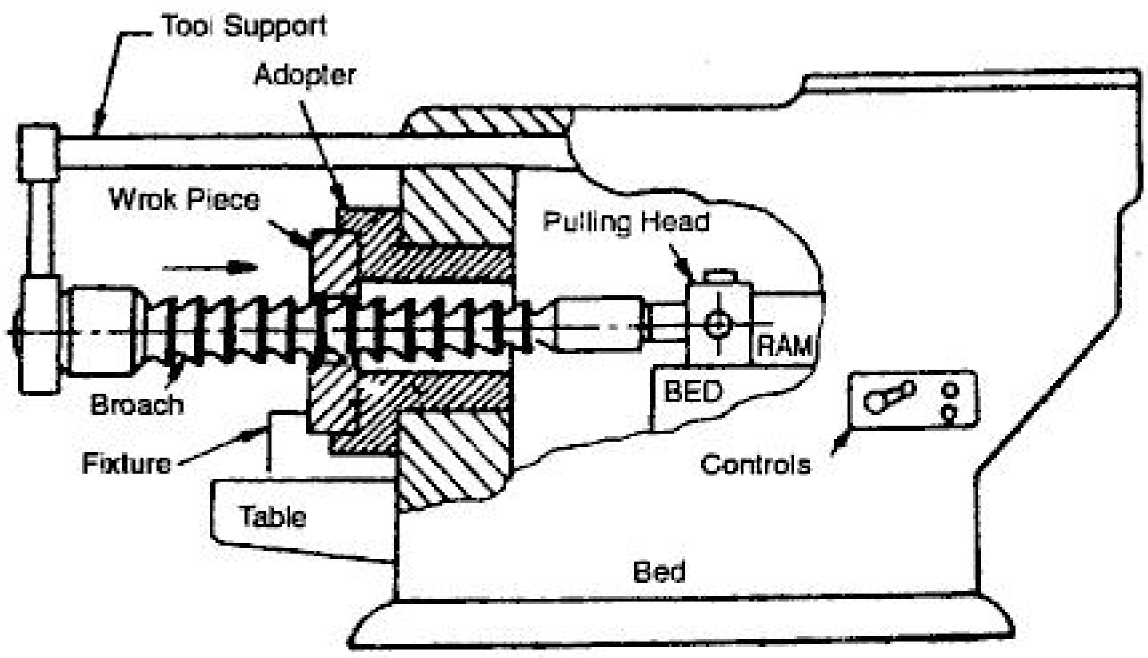

Figure 7.4 Horizontal broaching machine

These machines operate at a cutting speed of 4 to 15 mpm and have return stroke of 35 mpm. This machine may be fully automatic or semiautomatic. These machines are provided with automatic stops to control the length of the stoke of ram.

Horizontal type internal broaching machine is used for small kind medium sized work. It is used for making key ways splines, gun barrel refiling, serrations, cutting internal gears, internal helical gears with helix angle less that 15° etc.

Horizontal type surface broaching machines are used for small parts, like gear sector.

7.12.2. Vertical Broaching Machines

Vertical type broaching machines are of three types. They are pull up, pull down and push down type machines. The push down type is the most popular.

Vertical type external broaching machines are used for broaching connecting rods, connecting rod capes, and various types of casting and forgings. Vertical type internal broaching machines are used for broaching of holes and splines in various parts like gears, bushes etc.

Push down type: Push down type vertical broaching machine is shown in the Fig. 7.5. It is used for external broaching. In this type most of the machines are provided with receding table so that the fixture may be loaded and unloaded during its return stroke.

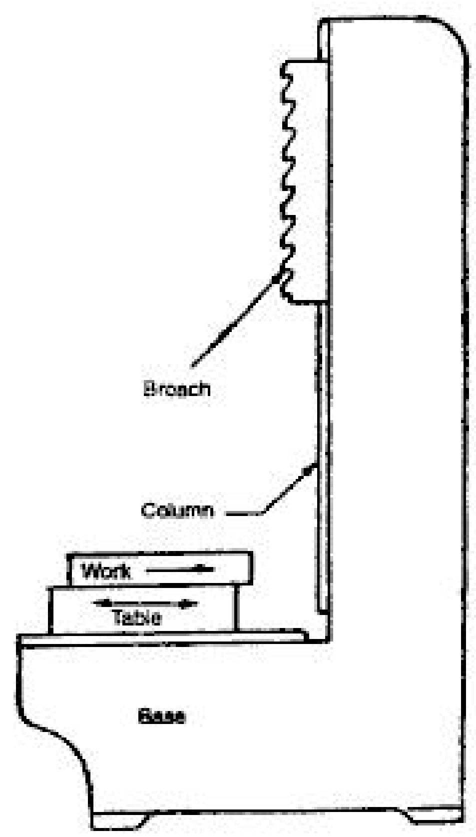

Figure 7.5 Push down type vertical machine

4. Finishing teeth:

These teeth are meant for finishing the hole to the size and shape.

5. Rear pilot :

This is meant for giving support to the broach after the last tooth leaves the work piece.

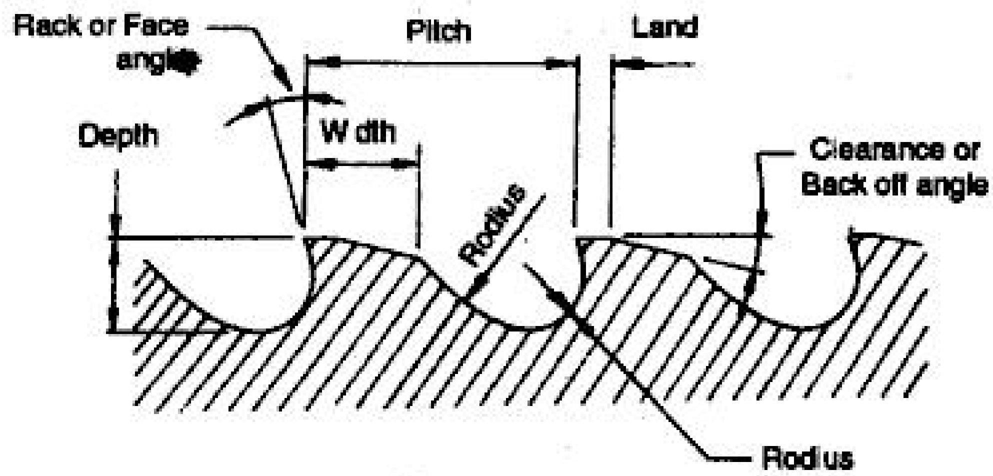

Figure 7.14

6. Land:

This is the top portion of the teeth.

7. Clearance or back off angle:

The back of the tooth is sloped to give the clearance angle.

8. Rake or face angle:

This is the angle made by sloping the front face of the tooth. Rake angle depends upon the work piece material.

9. Pitch:

Pitch is the linear distance between one tooth and the next tooth. Pitch will be more in roughing teeth. It will be less for finishing teeth.

7.16. BROACHING OPERATION

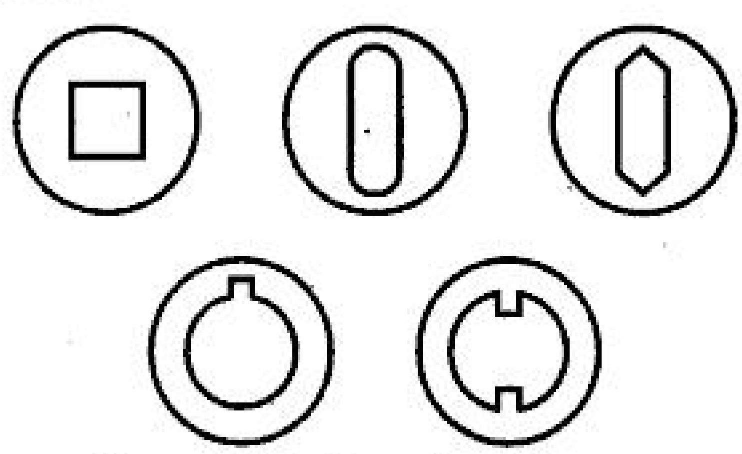

Figure 7.15. Broached Shapes

1. Surface broaching

Figure 7.16 shows a surface broaching operation. A push type solid broach is used in a vertical broaching machine.

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- ***Push down type:*** Push down type vertical broaching machine is used for external broaching. In this type most of the machines are provided with receding table so that the fixture may be loaded and unloaded during its return stroke.

- ***Pull down type:*** Vertical pull down broaching machines are used for internal broaching. This machine has an elevator at the top of the machine. The pulling mechanism is enclosed in the base of the machine. The work piece is mounted on the table by means of fixture.

- ***Push broach:*** This broach is pushed through work during broaching. This broach may bend under compressive load during cutting so that it is made shorter (ie)., it has less number of teeth. As it is shorter, it is easy to make, harden and handle. It is used for shorter length of work pieces. It is designed to remove less amount of material in one stroke.

- ***Pull broach:*** This broach is pulled through work during broaching. It comes under tensile load during cutting. So this will not bend during cutting. This broach is longer in size with large number of teeth.

- ***Pull end:*** This is the end which is connected to the pulling head of the broaching machine.

- ***Front pilot:*** This locates the broach centrally with the hole to be broached.

REVIEW

1. What is broaching?
2. Sketch a broach and indicate the salient nomenclature.
3. Write one type of broach used in practice with applications.
4. Explain progressive broaching?
5. Explain the different parts of broaching tool?
6. Explain with diagram the working principle of horizontal broaching machine?
7. What are the different type of broaching machines? Explain any one with sketch.
8. What is vertical broaching machine? Explain the working principle.
9. Explain the following:-
   - Push type broach
   - Pull type broach
10. Draw neat sketch of a internal pull broach and explain various elements angle.
11. Explain the method of broaching internal splines using pull type broach. Bring out the limitations of broaching.

UNIT - 8

JIGS, FIXTURES AND USES

8.1. LOCATING AND CLAMPING DEVICES

The successful running of any mass production depends upon the interchangeability to facilitate easy assembly and reduction of unit cost. So there is a necessity of special purpose tools which are used to facilitate production operations like machining, assembling, inspection etc.

Jigs and fixtures are designed to hold, support and locate the workpiece to ensure that each part is machined within the specified tolerance. Use of Jigs and fixture is the simpler, easier, faster and more profitable method of manufacturing different components under mass production.

8.2. JIGS

8.2.1. Work Holding Device

It is a work holding device that holds, supports and locates the workpiece and guides the cutting tool for a specific operation.

Jigs are usually fitted with hardened steel bushings for guiding or other cutting tools. The below Fig. 8.1 shows the referencing the tool to the work.

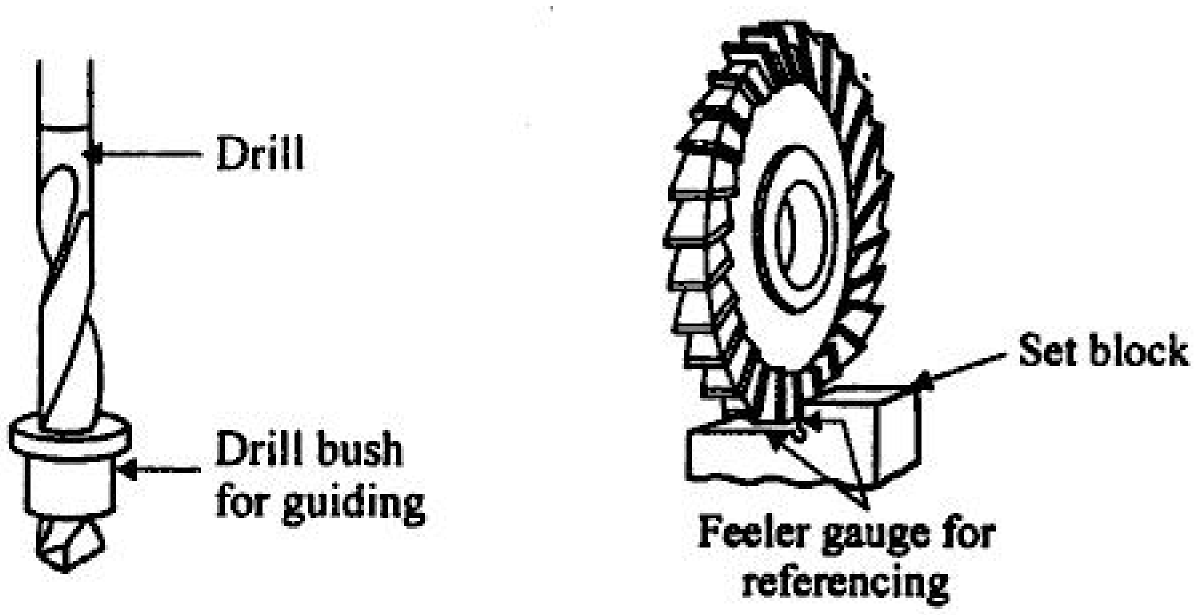


Figure 8.1. Referencing the Tool to the Work

Fixtures

It is a work holding device that holds, supports and locates the workpiece for a specific operation but does not guide the cutting tool. It provides only a reference surface or device.

The fixture should be clamped to the table of the machine upon which the work is done. But jigs are not fastened to the machine table because there is a necessity to move the jig around the table to bring each facing directly under the drill.

If however the holes above 6.35mm (0.25 inch) in diameter are to be drilled, it is usually necessary to fasten the jig to the table securely.

8.2.2. Difference between Jigs and Fixtures

Sl. No	Jigs	Fixtures
1.	It is a work holding device that holds, supports and locates the workpiece and guides the cutting tool for a specific operation.	It is a work holding device that holds, supports and locates the workpiece and guides the cutting tool for a specific operation.
2.	Jigs are not clamped to the drill press table unless large diameter to be drilled and there is a necessity to move the jig to bring one each bush directly under drill.	The fixtures should be securely clamped to the table of the machine upon which the work is done.
3.	The jigs are the special tools particularly in drilling, reaming, tapping and boring operation.	Fixtures are special tools used particularly in milling machines, planers, shapers and slotting machines
4.	Gauge blocks are not necessary	Gauge blocks may be provided effective handling
5.	Lighter in construction.	Heavier in construction.

8.2.3. Advantages of Jigs and Fixtures

Productivity

Jigs and fixtures increase the productivity by eliminating the individual marking, positioning and frequent checking. The operation time is also reduced due to increase in speed, feed and depth of cut because of high clamping rigidity.

Interchangeability and Quality

Jigs and fixtures facilitate the production of articles in large quantities with high degree of accuracy, uniform quality and interchangeability at a competitive cost.

Skill Reduction

There is no need for skillful setting of work on tool. Jigs and fixtures makes possible to employ unskilled or semi skilled machine operator to make savings in labour cost.

Cost Reduction

Higher production, reduction in scrap, easy assembly and savings in labour cost results in ultimate reduction in unit cost.

- It increases the versatility of machine tool.
- It becomes possible to accommodate several components at one setting and thus taking advantage of multiple machining.
- The use of jigs and fixtures partially automates the tool.
- The use of jigs and fixtures enable complex shaped parts to be machined by being held rigidly to the machine.
- Jigs and fixtures reduce the expenditure on the quality control of machine parts.

8.2.4. Fundamental Principles of Jigs and Fixtures Design

Locating Points

The most important requirement in jigs or fixture design are good facilities to be provided for locating the work, the article to be machined may easily be inserted and quickly taken out from the jig. So that no time is wasted in placing the workpiece in the position to perform operations.

The position of workpiece should be accurate with respect to tool guiding in the jig or setting elements in the fixture.

Tennon strips should be provided for bed accuracy and quick location of the fixture on the machine.

Fool Proof

The design of jigs and fixtures should be such that it would not permit the workpiece or the tool to be inserted in any position other than the correct one.

In this case, dowel pins or other devices can be placed to incorporate in correct position.

Clamping Device

It should be as simple as possible without sacrificing effectiveness. The strength of the clamp should be such that not only to hold the workpiece firmly in place but also to take the strain of the cutting tools without springing or "giving" when designing the jigs and fixtures. The direction in which the strain of the cutting tool or cutter acts upon the work should always be considered, and the clamps so placed that will have the highest degree of strength to resist the pressure of cut.

The clamps should be convenient, quickly operated and provide less fatigue to the operator. After detached from the work, the clamp should be still connected with jig or fixture itself.

Reduction of Idle Time

The idle time can be reduced by loading and unloading arrangements. Design of jigs and fixtures should be such that the process of loading, clamping and unloading time of the workpiece takes minimum as far as possible.

Weight of the Jigs or Fixtures

The jigs or fixtures should easily be handled, smaller in size and lower in cost in regard to the amount of material used for their making. But at the same time, it should not sacrifice any of the rigidity and stiffness.

Jigs Provided with Feet

Ordinary drill jigs should be always provided with feet or legs on all sides which are opposite the holes for the bushings. So that the jig can be placed level on the table of the machine on the sides of the jig where no feet are required if the body is made from a casting, it is of advantage to have small projecting legs for bearing surfaces when laying out and planning.

It may be seen that three Jig feets are preferable to use because jigs always obtain a bearing on all the three feet which it would not with four feet ie., the surface of the table with four feet may not be geometrically true and four feet will rock and invariably cause the operator to notice the defect.

Jig feets are generally cast solid with the jig frame. When the jig feet are made from machine steel sometimes in the cast iron jigs, detachable feets are used.

Materials Used for Jigs and Fixtures

Jigs and fixtures are made of hardened material to avoid frequent damage and to resist wear. The material used for jigs and fixture are mild steel, cast iron, die steel, carbon steel, high speed steel, Nickel-chrome steel, phosphor bronze, plastic materials etc.

8.2.5. Essential Features of Jigs or Fixtures

A jig or fixture must satisfy the following conditions.

1. Reduction of idle time

The design of jigs or fixtures should be such that the process of loading and unloading the components takes the minimum possible time and enables easy location and clamping should be such that idle time is reduced to minimum.

2. *Cleanliness*

It is of great importance that jigs or fixtures are so designed that there is no time is wasted in giving it to clear the scarf, burrs, chips etc., which otherwise, would spoil the locating faces and the equipment will always load like a collection through for these foreign materials.

The parts of jigs or fixture like channel ways, grooves, slots etc should not have any deposition of foreign materials.

3. *Replaceable parts or standardisation*

The locating and supporting surfaces, as far as possible should be replaceable that is not permanently fastened. When worn out, they may be replaced by new ones. Moreover, they should be standardised so that their interchangeable manufacture is possible.

4. *Provision for coolant*

The jigs or fixtures must have adequate arrangement for the cutting edge of the tool so that the tool is cooled and at the same time, the swarf or chips are washed away, and so that the operator need not waste his time in adjusting the coolant flow and cleaning the swarf or chips.

5. *Hardened surfaces*

All locating and supporting surfaces, such as faces of locating pins, should be made of hardened materials as far as conditions permit, so that they are not quickly worn out and their accuracy is retained for a longer time.

6. *Inserts or pads*

It is a very necessary provision in all jigs and fixtures. Inserts or pads of soft materials like brass, leather or fibre should always be riveted to those faces of the clamps which will come in contact with the finished surfaces of the workpieces, so that these surfaces are not spoiled as a result of the metallic contact.

7. *Fool-proofing*

Since the use of jigs and fixtures allows for the employment of unskilled worker, the design of such equipment should be such that it would not permit the workpiece or the tool be inserted in any position other than the correct one. For this, pins or other devices of simple nature are usually incorporated in the equipment in such position that they will always spoil the placement of the component or hinder the fitting of cutting tool until and unless the latter are in correct positions.

8. *Economic soundness*

The equipment to be used should be economically sound, ie., the cost of its designing and manufacturing should be in proportion to the quantity and price of the producer.

operation on a component to remove heat treatment distortion. Oil hardened to 60 to 64 RC. This steel is used widely for fine, intricate press tools.

6. Nickel chrome steels

Used mainly for gears, these steel contain 3 to 4% nickel, 0.6 to 1.1% chromium and less quantities of carbon, silicon and manganese. These can be case hardened to 61 to 63 RC. Alloy steel En 36 falls under this category.

7. High tensile steels

Used mainly for fasteners such as high tensile screws, these contain 0.4 to 0.6% carbon and 0.6 to 1% manganese. These can be oil hardened to 45 to 50 RC steel En 9 is a high tensile steel.

8. Mild steel

Used for most of the parts in jigs and fixtures, mild steel contains less than 0.3% carbon and 0.1 to 0.8% manganese steel En 2 falls under this category. This steel can be case hardened to 56 RC. Free cutting steel En 14 contains less than 0.15%C and cannot be hardened. Generally all parts which require no hardening are made of Mild Steel because it is the cheapest material available among the steels.

9. Cast Iron

Used for odd shapes to some machining and laborious fabrication, CI usage requires a pattern for casting. Pattern cost should be compared with cost of machining and fabrication. Cast Iron contains more than 2 %C. It can withstand vibrations well and is very suitable for base and bodies of milling fixtures. Self lubricating properties of Cast Iron make it suitable for machine slide and guide ways.

10. Nylon and fibre

These are used for soft lining for clamps to prevent denting in damage to workpiece due to clamping pressure. Nylon or fibre pads are screwed or stuck to Mild Steel clamps.

11. Phosphor bronze

When screw operated clamps are worn out then the screw as well as the nut needs to be replaced. Generally screws are longer and costlier than nuts. So nuts are made of phosphor bronze which has high tensile strength. As phosphor bronze is softer than mild steel it will wear out before the mating screw without causing much wear of the steel screw. Phosphor bronze nut bushes can be replaced periodically and thus, the life of the steel screw can be prolonged. Nuts for lead screws of most of the machine tools are made of phosphor bronze.

8.2.8. Factors to be Considered for Design of Jigs or Fixtures

The following are the essential factors which must be considered in designing a jig or fixture.

1. *Component*

a. The design of the component has to be studied carefully and ensure that the work is being performed in proper sequence.

b. As far as possible, the maximum number of operations should be performed on a machine in single setting.

2. *Capacity of the machine*

The type and capacity of the machine on which the operation is to be performed needs careful consideration.

3. *Production requirements*

Design of equipment should be made on the basis of actual production requirements. This leads to decision for use of manual, semi automatic tooling arrangements.

4. *Location*

a. Location refers to the dimensional and positional relationship between the workpiece and the cutting tool used on machine.

b. The locator should ensure equal distribution of clamping forces throughout all sequence of operation. The locator should be easily removable.

c. Location should be hardened, wear resistant and should have high degree of accuracy.

d. Location is the one that ensures the movement of the workpiece should be restricted.

e. Locator should be fool proofed to avoid improper locations of workpiece in the machine table.

f. Location system should facilitate easy and quick loading of workpiece. It should effect motion economy.

g. Redundant locators should be avoided.

h. Adjustable support may be placed with respect to the shape, strength and size of theworkpiece.

i. Sharp corners in the locating surface must be avoided.

j. Atleast one datum surface must be established.

The following locating devices may be used in different situations.

Sl. No.	Locating device	Application
1.	Six point locator (3-2-1) pin and button locators	Locating flat surface
2.	V-block	Locating round circular shaft
3.	Nesting locator	Locating cylindrical profile in vertical position
4.	V-block, horizontal (one side is fixed and other end is adjustable or cam operated) V-locator	Locating elliptical and irregular surfaces
5.	Jack pin locator	Locating a rough workpiece
6.	Eccentric locator	Variation in workpiece size

5. *Loading and unloading arrangements*

a. There should be adequate clearance for loading and unloading. Hence easy and quick loading and unloading is possible.

b. The manipulators of workpiece can be performed, only if there is a clearance.

c. Size variation must be accepted.

d. It should be of hardened material and non-sticky.

6. *Clamping arrangements*

a. Quick-acting clamps must be used as far as possible.

b. The clamping should not cause any deformation of workpiece.

c. The clamping should be always arranged directly above the points supporting the work.

d. The clamping and adjustment should be only on the sides of the workpiece.

e. The power driven clamps are operated either by pneumatic or hydraulic power, because power driven clamp are quick acting, controllable, reliable and operated without any fatigue to the operators.

f. The power clamps exerts high clamping pressure and suitable for gripping heavy workpiece.

In order to achieve the most efficient clamping, the following operational factors must be considered.

i. The clamping pressure should be exerted on the solid supporting part of the work to prevent distortion

ii. The clamping pressure should be kept low as far as possible. It should be sufficient to hold the work against the cutting pressure.

iii. The movement of the clamp for loading and unloading purposes should be kept Minimum.

iv. The clamp should be positively guided to facilitate loading action.

v. The clamp should be simple and fool-proof.

vi. The clamp should be sufficiently robust to avoid bending.

vii. The clamping should be effected by operating a lever, or a knurled knob. The hexagonal headed nuts and bolts should be avoided as far as possible to eliminate the use of spanners.

viii. The clamps should be case-hardened to prevent wear of the clamping faces.

ix. The clamps should be so arranged on the work to perform as many operations as possible in one setting.

The following types of clamps may be recommended in different situations.

Clamps	Situations
Strap clamp	Commonly used for rectangular workpieces
Swinging strap clamp	For easy loading and unloading
Cam operated clamp	Effective and fast, but should be used
Toggle clamp	Adopted to many types of fixtures
Screw clamp	Components is to gripped on
Equalising clamp	Exerting equal pressure to hold
Hydraulic and pneumatic clamp	Faster, uniform and effective
Hydraulic clamp with rack and pinion	Circular Rod in V-block
Spider clamp	Circular and symmetrical workpiece clamping
Edge clamp	Used during facing operation

7. Clearance between the Jig and the component

a. It is necessary to leave sufficient clearance between the jig body and the component to accommodate variable sizes of work which are manufactured either by casting or forging.

b. Clearance is also needed for chips to pass out through the opening between the component and the jig or fixture.

c. Swarf clearance is particularly important in small jigs and fixtures. Sharp corners must be avoided as swarf has the tendency to accumulate there.

ii. Renewable wearing bushing

a. Slip type - used when frequent change in bushing to perform more than one operation in a hole like drilling and reaming.
- quick removal.

b. Fixed type - used at long production runs and also for single production runs.

iii. Liner bushing - Also called master bushing.
- No head arrangements.

iv. Screw bushings - used when there is a necessity of bushing to hold the workpiece as well as to guide the tool.

11. Rigidity and vibration

Jigs and fixtures must possess enough rigidity. Milling fixture should be especially robust in design as they have to bear intermittent cut at rapid rate.

Jigs and fixtures should not vibrate. Vibration may lead to unwanted movement of workpiece and tools.

12. Safety device

Jigs and fixtures are designed to assure full safety to the operation. Protruding sharp edges should be avoided.

13. Cost

All components should be as simple as possible. The initial investment required to design and build the jig and fixture should be optimum.

14. Material list

Material list for various parts of jig or fixture can be shown in the table.

Sl. No.	Part Name	Material
1	Jig body	CI
2	Stud	MS
3	Drill /bush	Gun metal
4	Pin	MS
5	Nut	MS

8.3. DIFFERENT TYPES OF JIGS

Drill jigs are designed and constructed based on the structure of the workpiece. All these jigs are used for making hole in the workpieces, but they take different names depending upon their construction. Based on the requirements such as number of workpieces to be machined in a specified time, accuracy requirements, cost, available capacities of machine tools and other facilities, the jigs are made. Some of the types of jigs in use are listed below.

1. Template jig	2. Plate jig
3. Channel jig	4. Leaf jig
5. Pot jig	6. Turnover Jig or Table jig
7. Box jig or Tumble jig	8. Trunnion jig
9. Indexing jig	10. Post jig
11. Sandwich jig	12. Nut cracker jig
13. Pumping or universal	14. Latch jig
15. Vice jig	16. Solid jig
17. Angle plate jig	18. Angular post jig

1. Template Jig

Template jig is the simplest and most basic jig used in production. Such jigs are made of the same profile as the workpiece and so they can serve as layout guides for locating holes and contours or as a jig for low speed production of accurate workpiece.

Template jigs are generally made without clamp and depends on pins, nests or part shapes to reference them to the part. Since templates are the simplest form of jig, they are used extensively in low - volume production such as prototype work or short run jobs. Cost is another attractive feature of template jigs. Although templates lack the refinements of other types of jigs, they cost much less.

The main disadvantage in using template jig is that they are not as fool proof as other types of jigs. Unless the operator is careful, many parts could be inaccurately machined. In order to accommodate many types of parts, there are several forms of the template jig.

Flat	-	Plate template jigs
Circular	-	Plate template jigs
Nesting	-	Template jigs

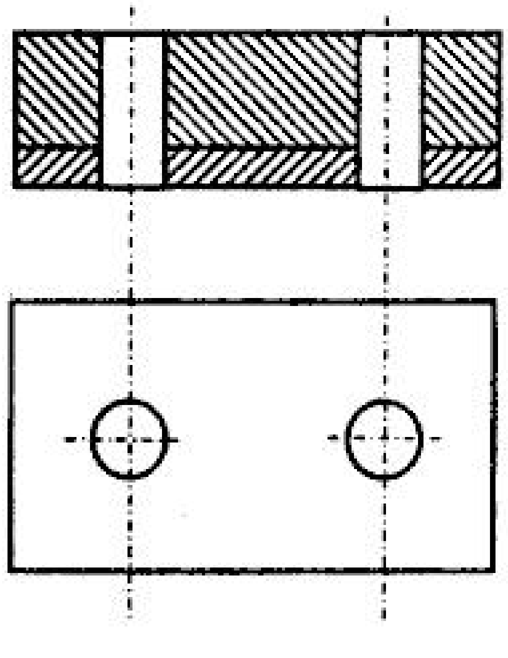


Figure 8.2. Flat Plate Template Jig

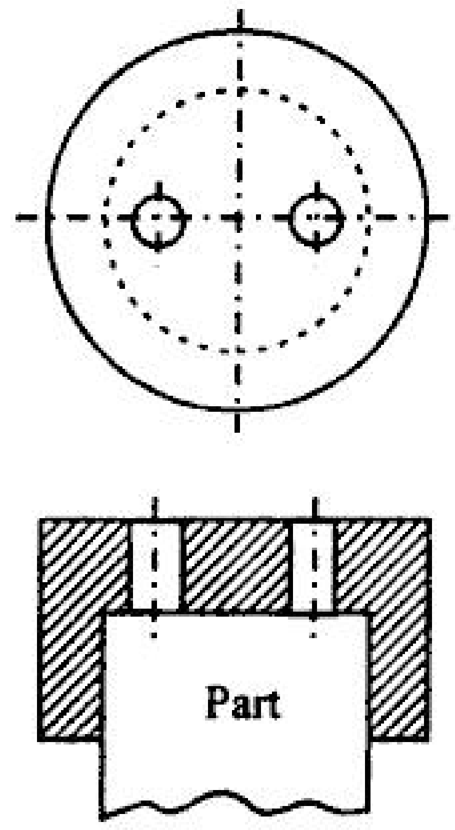


Figure 8.3. Circular Plate Template Jigs

Flat plate template jigs are used to locate holes on flat surfaces. This template is normally located with pins referenced from the edge or from other holes. The plate thickness, which should be specified normally depends on the diameter of the hole to be drilled. The general rule is that the main plate thickness should be equal to or twice the tool diameter.

Circular plate template jigs are used for cylindrical workpieces. They are usually located on a cylindrical portion of the part while any hole pattern can be machined with these jigs, they are generally used for round hole patterns.

Nesting template jigs use a cavity nest or a pin nest to locate the workpiece. They can accommodate almost any form or shape part; the only restriction is the complexity of the cavity. The more detailed the cavity, the more expensive the jig.

Plate jigs are actually from family of jigs, such as plain plate jigs, table jigs, sandwich jigs etc. Each variation of the basic plate jig has atleast a distinctive feature that separates it from others.

Plain plate jigs is the simplest and the most basic type. It uses a flat plate as one of its structural member, and all details are attached and referenced to this plate. The main advantages are minimal design, and fabricator time.

The table jigs are basically plain plate jigs with leg. It's main purpose is holding irregular or symmetrical workpiece that cannot be held in other plate jig forms.

Disadvantages of Plate Jigs

Only one surface can be drilled at one loading and drilling forces are generally directed towards the clamping device. It is therefore necessary that the clamping device be rigid enough to withstand drilling forces.

3. Channel Jig

This type of jig is channel shaped and sometimes is made from a standard channel section material. The workpiece is fitted within the channel. It is located and clamped by rotating knurled knob as shown in figure 8.6. Channel jig is limited to workpieces having simple symmetrical shape.

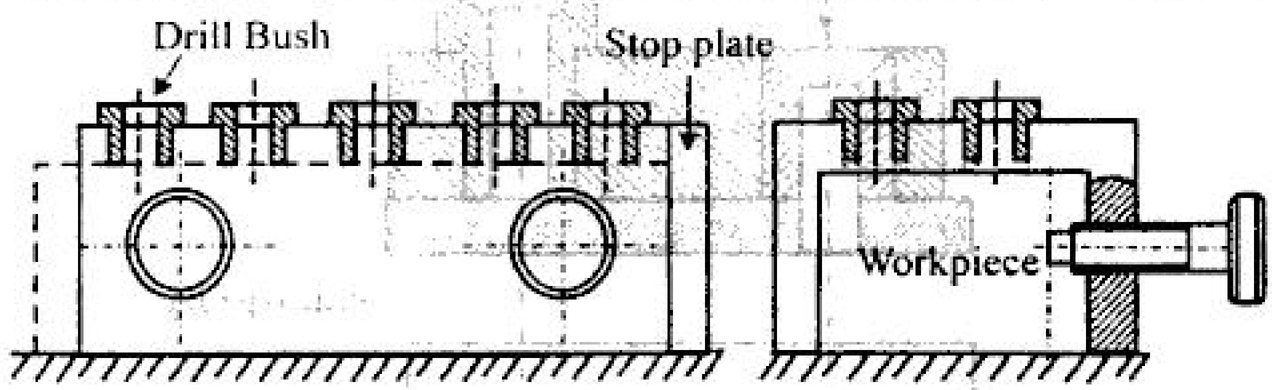


Figure 8.6. Channel Jig

4. Leaf Jig

Leaf jig is also called as latch jig. This type of jig is disintinguished by its hinged cover, a leaf which can swing open to load or unload the workpiece. After the workpiece has been located inside the jig, the leaf is firmly closed and locked inside the jig. The leaf is held on to the jig body with the help of an eyebolt where the eye is hinged to the body with a pin and a nut on the threaded portion of the bolt to tighten the leaf. The drill bushes are fitted in the leaf.

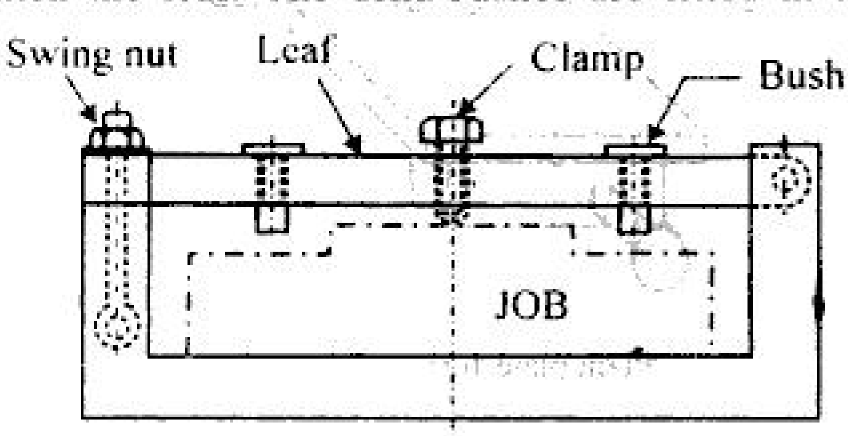


Figure 8.7. Leaf jig

Leaf jigs can be loaded and unloaded quickly and are suitable for complicated workpieces with irregular contours. The disadvantage of leaf jigs is that chips may accumulate inside and cause trouble unless provisions are made for disposing them. Also, if the drill bushing are fitted in the leaf, play in the hinges may affect drilling accuracy.

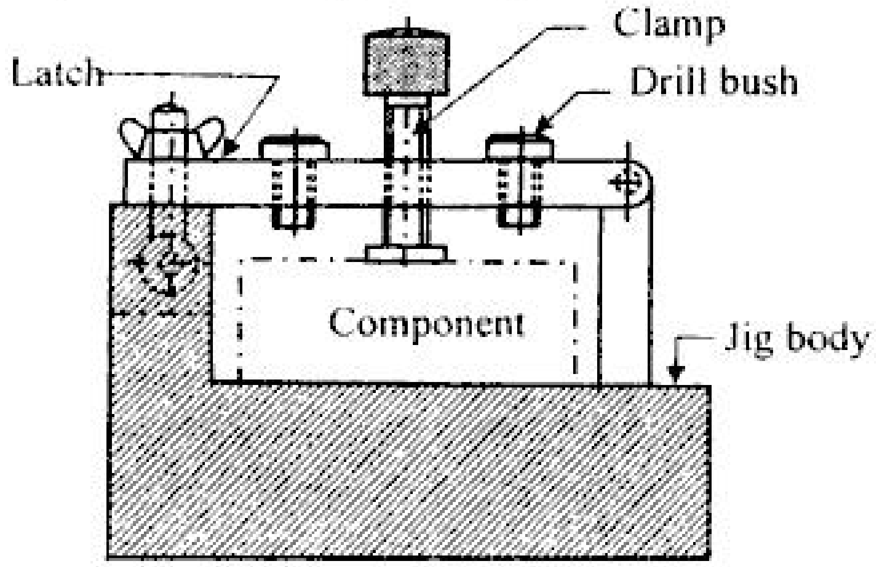


Figure 8.8. Leaf Jig

5. Pot Jig

Pot jig body is in the form of a pot in which the workpiece is supported and clamped Circular workpieces which have both an external diameter and an internal diameter suitable for location purposes are drilled in pot type jigs. The jig essentially consists of two parts. The body which is in the form of a pot carries the workpiece and also the bush plate.

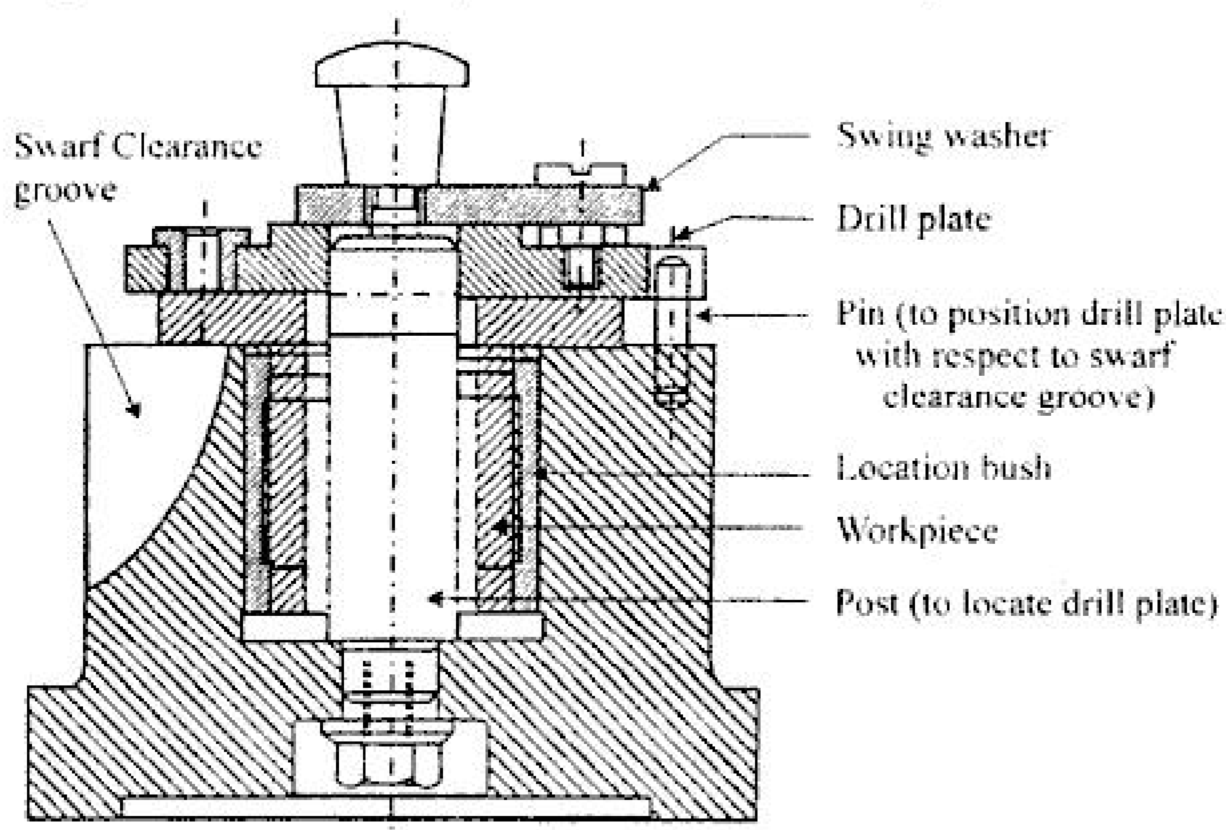


Figure 8.9. Pot Jig

Figure 8.9 illustrates a pot jig in which the workpiece is located from its outside in the bush, and the drill bush is located on a post; the workpiece is supported at the point of drilling and swarf clearances are provided; the drill plate is located to line up with the swarf clearance grooves.

6. Turn Over Jig or Table Jig

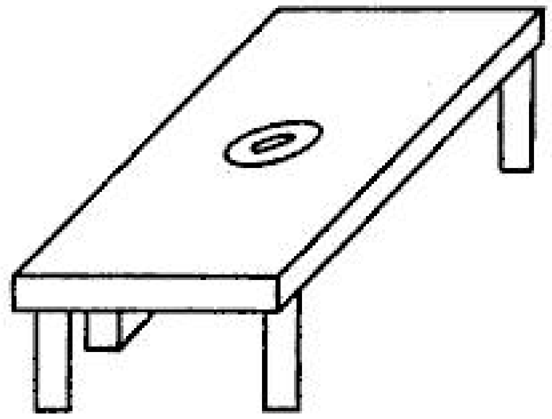
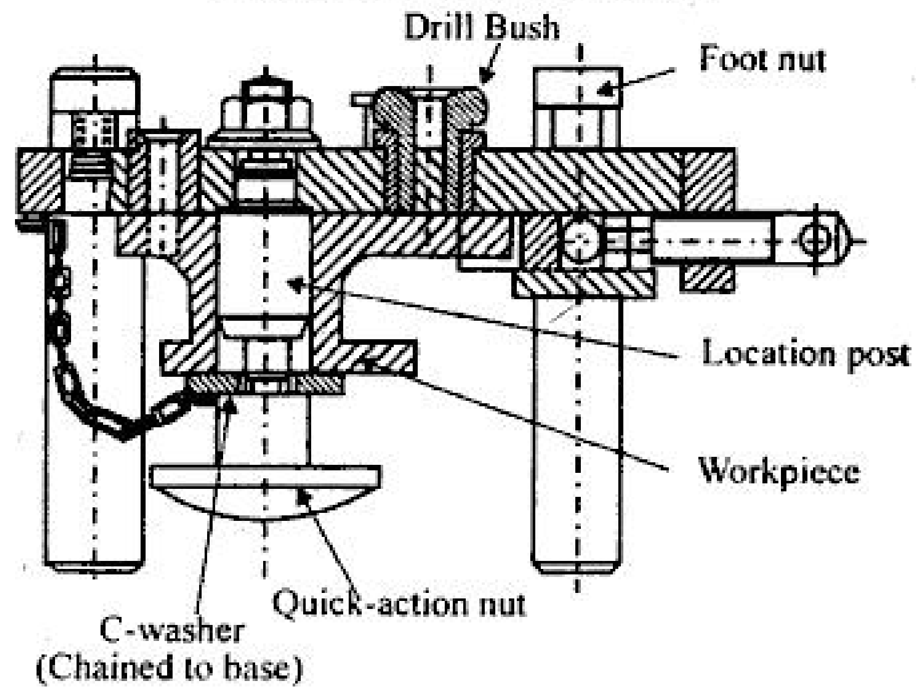


Figure 8.12 (a): Table jigs



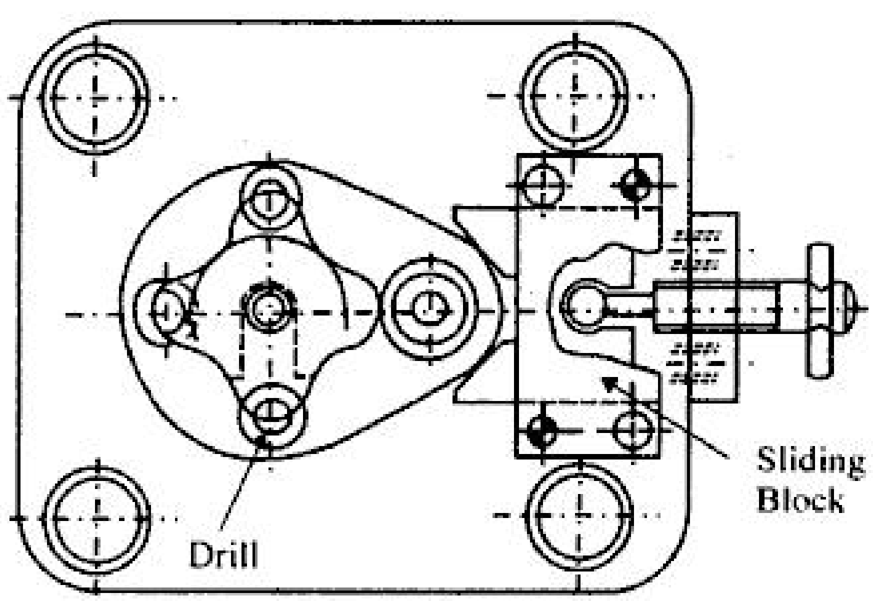


Figure 8.12 (b): Turnover jig

Turn over jig is so named because the workpiece is located from the face that is to be drilled and clamped in the jig. Then the jig is turned over for drilling. This jig is also known as open jig as the workpiece is not having any enclosure of the jig body around it. So, it presents no problems in chip disposal.

The figure 8.12(b), shows a turnover or open jig; the type is used when the foregoing types are unsuitable because of the workpiece shape. The jig is seated on the four foot-nuts when locating and clamping the workpiece, and inverted to the position shown when machining. This type is easy to load and swarf clearance is no problem; the main disadvantage associated with this type is the lack of support given to the workpiece beneath the point of cutting.

The disadvantage of turnover jig is that only the surface to be drilled, loading and drilling forces are generally directed towards the clamping devices. Therefore clamping devices should be rigid enough to withstand the drilling force.

7. Box Jigs or Tumble Jig

This type receives its name from its, shape which in general resembles a box. The workpiece is a steel block used as a specimen in an oil-testing machine. The hole is drilled and then reamed while in the jig, the loading is as follows. The cam rod is taken out of the jig and the workpiece is placed in position inside the jig. The cam rod is then replaced and rotated to its locking position. This holds the workpiece firmly so that the drilling operation can be performed.

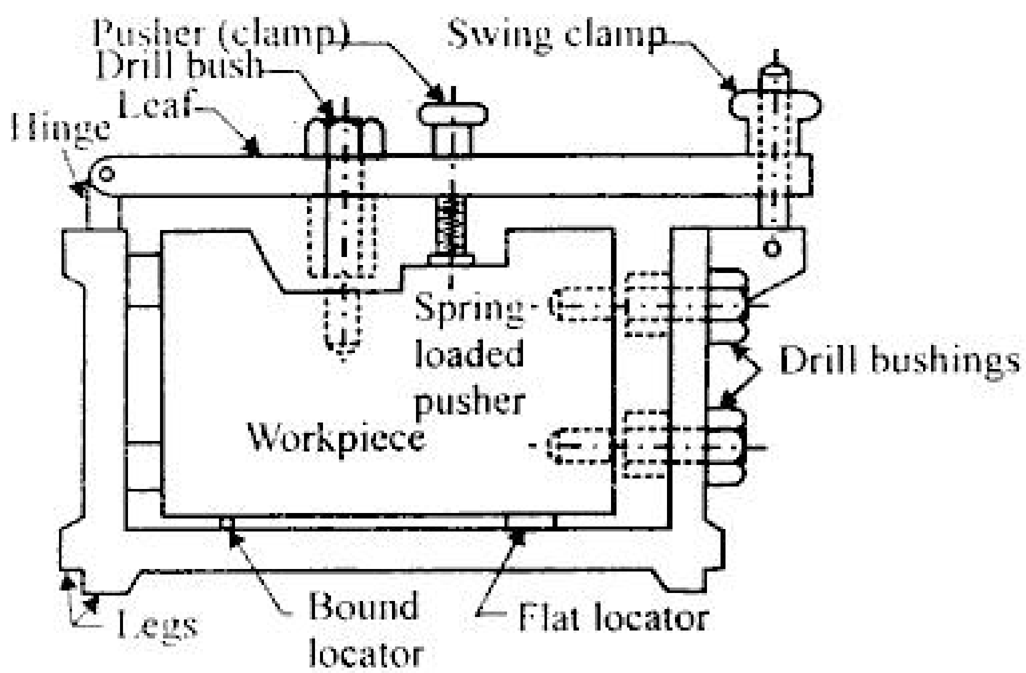


Figure 8.13. Box Jigs or Tumble Jig

When a box jig contains bushings on two or more sides, for the purpose of drilling hole on different sides of the part, it is referred to as a tumble jig. Such a jig has a set of jig feets on the opposite sides of the work faces. After one face is drilled, the next side may be drilled by simply flopping the jig to expose this side to the drill spindle. The advantage of tumble jig is that greater accuracy can be obtained and less part handling necessary.

8. Trunnion Jig

A Trunnion jig is similar to a box jig. When a large sized workpiece is to be drilled in several faces, it is mounted in a trunnion jig so that the faces requiring drilling operations can be turned easily and positioned. Every time, the jig is rotated and it is locked so that the face in which the hole is to be drilled is absolutely horizontal. The pin and the locating hole for locking the jig should be wear resistant.

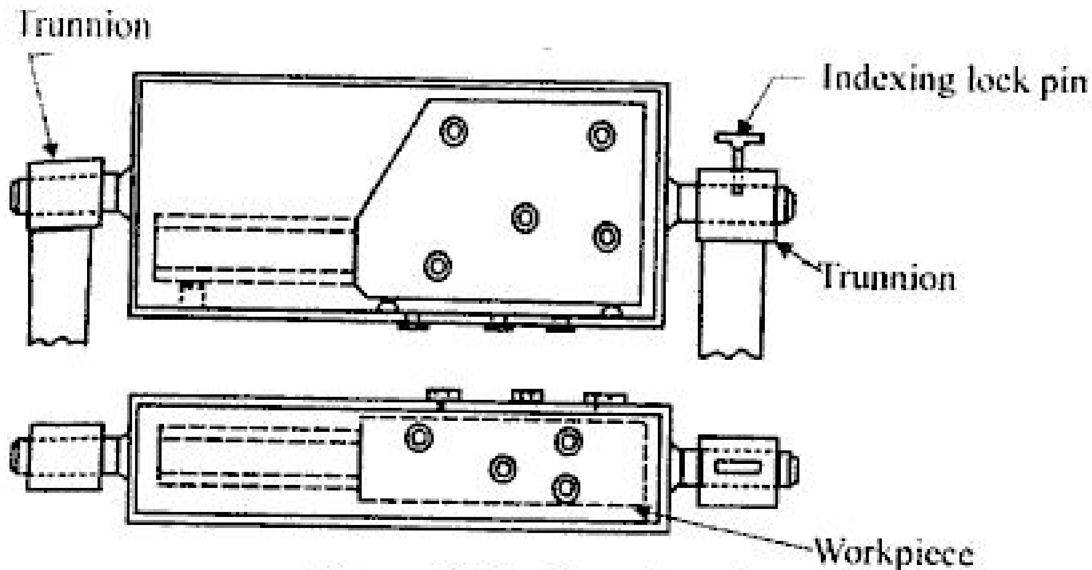


Figure 8.14. Trunnion Jig

9. Indexing Jig

Indexing jigs are used to drill holes on the periphery of cylindrical work at the required angular positions. For indexing, an indexing device is provided in the jig. The job is indexed the different positions successively.

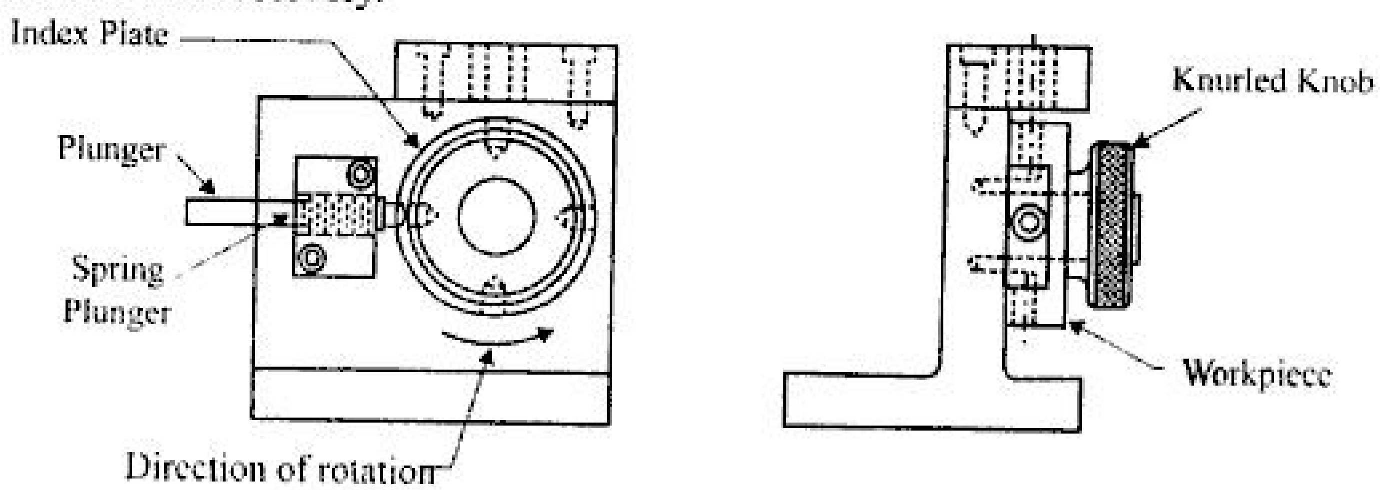


Figure 8.15. Indexing Jig

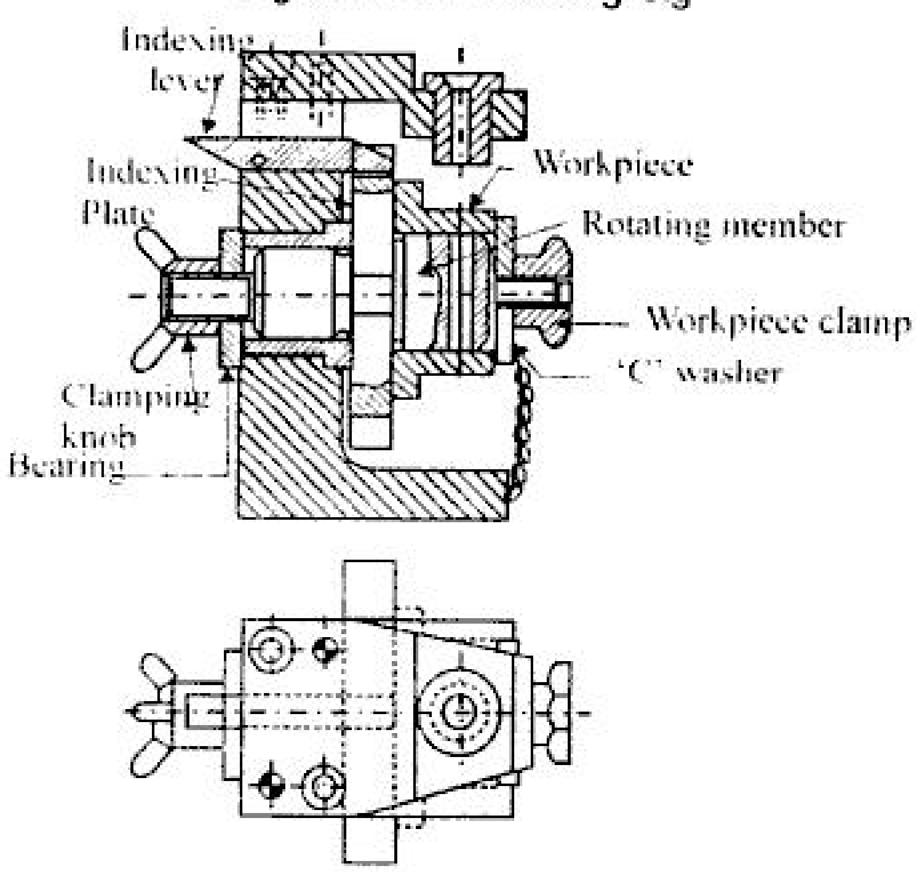


Figure 8.16. Indexing Drill Jig

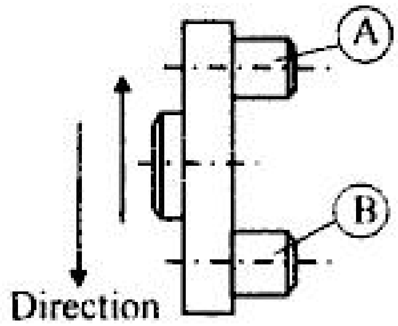


Figure 8.18. Linear Indexing

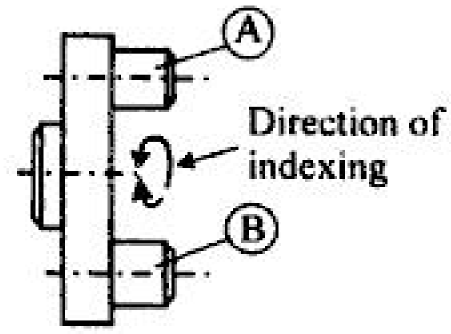


Figure 8.19. Rotational Indexing

Figure 8.19 shows how the problem is saved by linear indexing when the workpiece is moved so that the feature 'A' and 'B' are in turn positioned on the machine axis. Fig 8.20 shows rotational indexing applied to this problem. The workpiece is being rotated about an axis between those of the two features so that, again, each is positioned, rotational indexing is also used when holes have to be drilled on a large pitch circle.

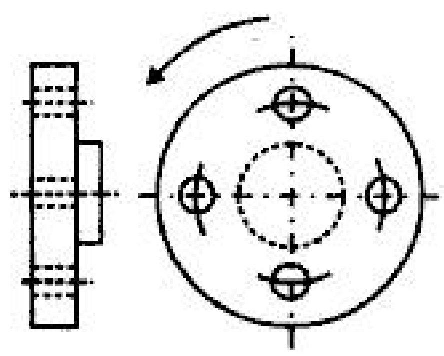


Figure 8.20. Rotational Indexing

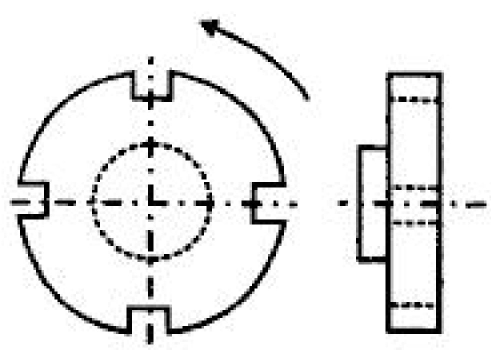


Figure 8.21. Rotational Indexing

In this example, one drilling station is used, and the component is rotated about the axisoi the pitch circle to position it for drilling each hole in turn. The above figure illustrates rotation! indexing when producing radial features. In the example shown, face slots are to be milled the periphery of a circular workpiece. Refer figure 8.21.

10. Post Jig

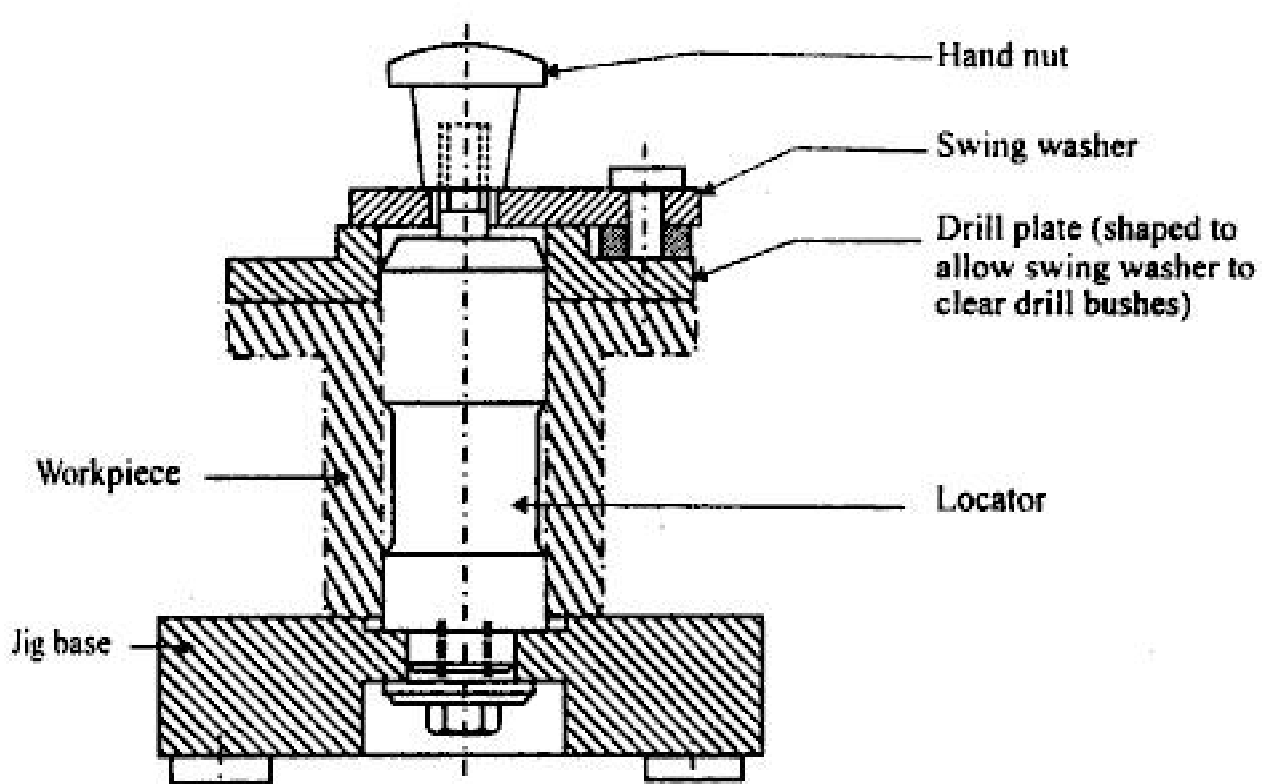


Figure 8.22 (a). Post Jig

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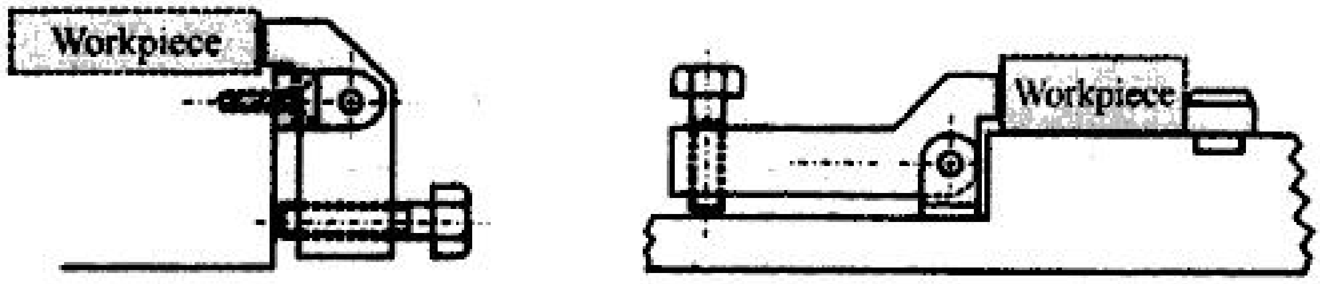

(b)

Figure 8.104. (a) Edge Strap Clamp; (b) Edge Clamps

In edge strap clamp tightening of hexagonal nut wedges the clamp between the workpiece and angular heel surface. Fig. 8.104(a). The Fig. 8.104(b) edge strap clamp is pivoted at one end.

17. Button Clamp

The diagram represents a button clamp.

18. Differential Clamp

Differential clamps adjust their position themselves to suit the workpiece. As a result, the clamps do not subject the workpiece to bending or any other distortion. They clamp the workpiece without shifting its position. The lower jaws are closed or opened by a turning screw which engages in T slot in the operating cam.

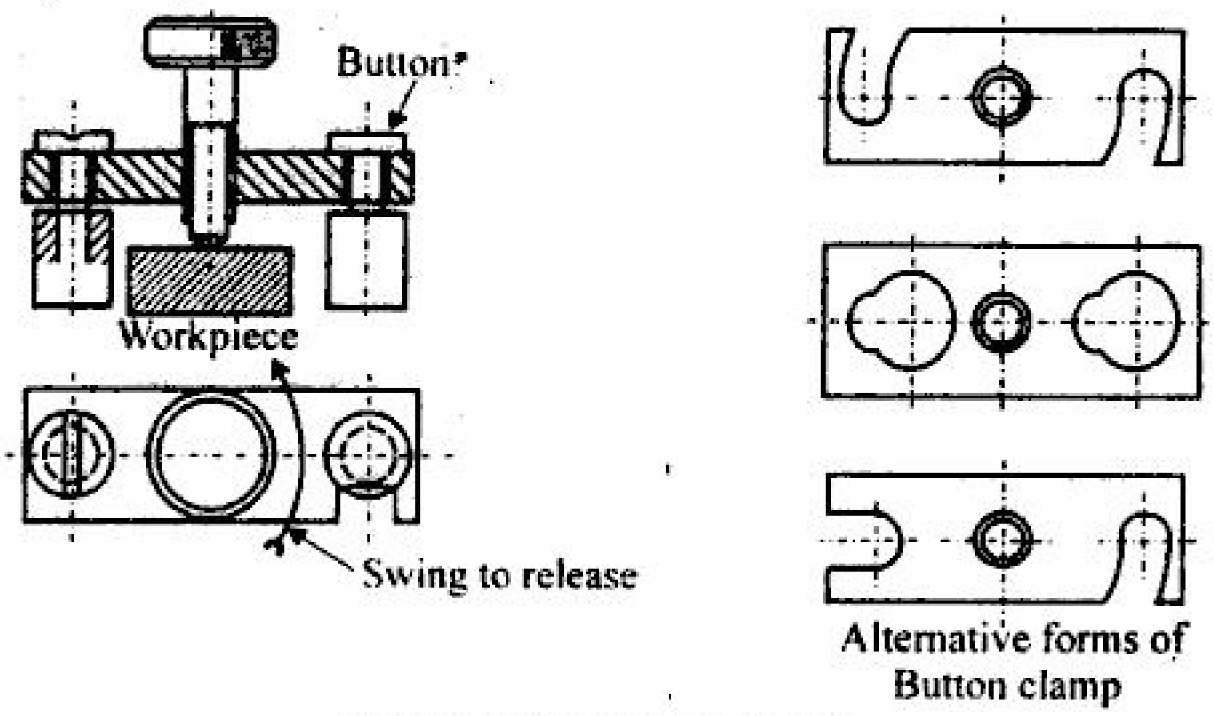

Figure 8.105. Button Clamp

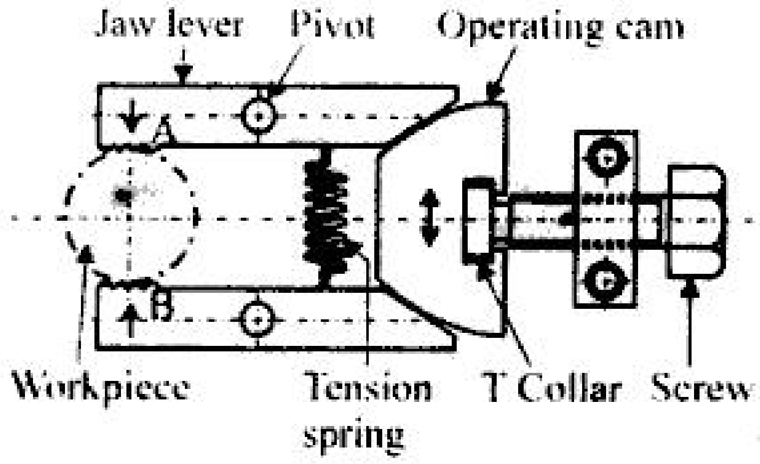

Figure 8.106. Differential Clamp

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ABOUT THE BOOK

The book **Machine Tools** has been written for the students of B.E./B.Tech., Mechanical and Production Engineering for JNTU as well as other Indian Universities.

Salient features of this book are:

- This book is an attempt to provide all necessary information about Machining Process.
- The subject matter has been presented in simple and systematic way with numerous diagrams so as to enable thorough understanding of the topic.
- Important review questions have been provided at the end of each chapter.

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