



ROHINI

COLLEGE OF ENGINEERING & TECHNOLOGY

Unit-II

①

SHAPER, MILLING & GEAR CUTTING Machines

Introduction:-

① The shaper is a reciprocating type of machine tool intended primarily to produce flat surfaces. These surfaces may be horizontal, vertical (or) inclined.

② Feed of a shaper is measured in terms of mm/stroke. It is defined as the movement of the cutting tool (or) workpiece per stroke of the cutting tool.

③ The cutting type of a shaper is an intermittent type as the cutting tool cuts the workpiece periodically during its stroke.

Classification of a Shaper:-

① According to the type of mechanism used for giving reciprocating motion to the ram

a) Crank type b) Geared type c) Hydraulic type

② According to the position & travel of the ram

a) Horizontal type b) Vertical type

c) Travelling head type

②

③ According to the movement given to the table

a) Standard shaper b) Universal shaper

④ According to the type of cutting stroke

a) Push type b) Draw type.

Crank Shaper:-

This is the most common type of shaper in which a single point cutting tool is given a reciprocating motion equal to the length of stroke desired while the work is clamped on an adjustable table. This shaper employs a crank mechanism to change a circular motion of a large gear called "bull gear" incorporated in a machine to reciprocating motion of the ram. The bull gear receives power from an electric motor.

Geared type:-

Here, the reciprocating motion of the ram

is obtained by a rack & pinion. The rack teeth which are cut below the ram mesh with a spur gear. This type of shaper is not widely used.

(3)

③ Hydraulic Shaper:—

Here, the reciprocating motion to the ram is obtained by hydraulic power. Oil under high pressure is pumped into the hydraulic cylinder fitted with a piston. The end of the piston rod is connected to the ram. The high pressure oil first acts on one side of the piston and then on the other causing the piston to reciprocate and the motion is transmitted to the ram. The piston speed is changed by varying the amount of liquid delivered by the pump.

Advantages of a hydraulic shaper:—

- ① It offers great flexibility in speed control.
- ② It eliminates shock by permitting slowing up of motion when the cutting tool is overloaded, thus protecting the parts (or) the tools from breakage.

③ The machine does not make any noise and operates very quietly.

④ Horizontal Shaper:-

In a horizontal shaper, the ram holding the tool reciprocates in a horizontal axis. This shaper is mainly used to produce flat surfaces.

⑤ Vertical Shaper:-

In a vertical shaper, the ram holding the tool reciprocates in a vertical axis. It may be crank driven, rack driven (or) hydraulic driven. The work table of a vertical shaper can be given cross, longitudinal & rotary movement. The tool used in a vertical shaper is entirely different from horizontal shaper. Vertical shaper is very convenient for machining

a) Internal surfaces such as keyways, slots (or) grooves.

b) Large internal & external gears by indexing arrangement of rotary table.

⑥ Travelling head shaper:—

⑤

① In this shaper, the ram carrying the tool while it reciprocates moves cross-wise to give the required feed.

② Heavy jobs which are very difficult to hold on the table of a standard shaper and fed past the tool are held on the basement of this shaper. While the ram reciprocates and supplies the feeding movements.

⑦ Standard shaper:—

A shaper is termed as standard (or) plain when the table has only two movements for table.

① Vertical feed ② Horizontal feed.

⑧ Universal shaper:—

In universal shaper, in addition to the two movements provided on the table of a standard shaper, the table can be swivelled about an axis parallel to the ram ways and an axis perpendicular to the ram ways.

As the work mounted on the table can be (6) adjusted in different planes, the machine is most suitable for different types of work and is given the name "universal". A universal shaper is mostly used in tool room work.

9) Push type Shaper:-

This is the most general type of shaper used in common practice. Here, the metal is removed when the ram moves away from the column (i.e.) pushes the work.

That is, here forward stroke is a cutting stroke and the return stroke is an idle stroke.

10) Draw Cut Shaper:-

① In this shaper, the metal is removed when the ram moves towards the column of the machine, (i.e.) draws the work towards the machine. Here, the forward stroke is an idle stroke and the return stroke is a cutting stroke.

② Here, the tool is set in a reversed direction to that of a standard shaper. (7)

③ Here, the ram is generally supported by an overhead arm which ensures rigidity and eliminates deflection of the tool.

④ In this shaper, the cutting pressure acts towards the column which relieves the cross-hair & other bearings from excessive loading and allows to take deep cuts. Vibration in these machines is practically eliminated.

Quick return mechanism:-

In shaper, the ram moves at a comparatively slower speed during the forward cutting stroke whereas during the return stroke, the ram moves at a faster speed to reduce the idle return time. This is called as "quick return motion" and the mechanism used to obtain this is called as "quick return mechanism". Generally there are 3 types of quick return mechanisms

used in a shaper. They are (8)

- a) Crank & slotted link mechanism
- b) Whitworth quick return mechanism
- c) Hydraulic mechanism.

Principle of shaper:-



In shaper, the metal is cut by the reciprocating movement of the cutting tool over the work piece which is fixed on the table. The following feeds are available in a shaper.

① Cross feed:-



It denotes the movement of the table perpendicular to the ram movement per stroke of the cutting tool. It is obtained by moving the saddle over the guide ways of the cross-rail.

② Vertical feed:-



It denotes the movement of the table in a vertical direction per stroke of the cutting tool. It is obtained by moving the cross-rail over the vertical guide ways of the column by rotating the elevating screw (or) by moving the tool

head vertically by rotating the down feed screw.

The vertical feed of the shaper is used to produce vertical plane surfaces.

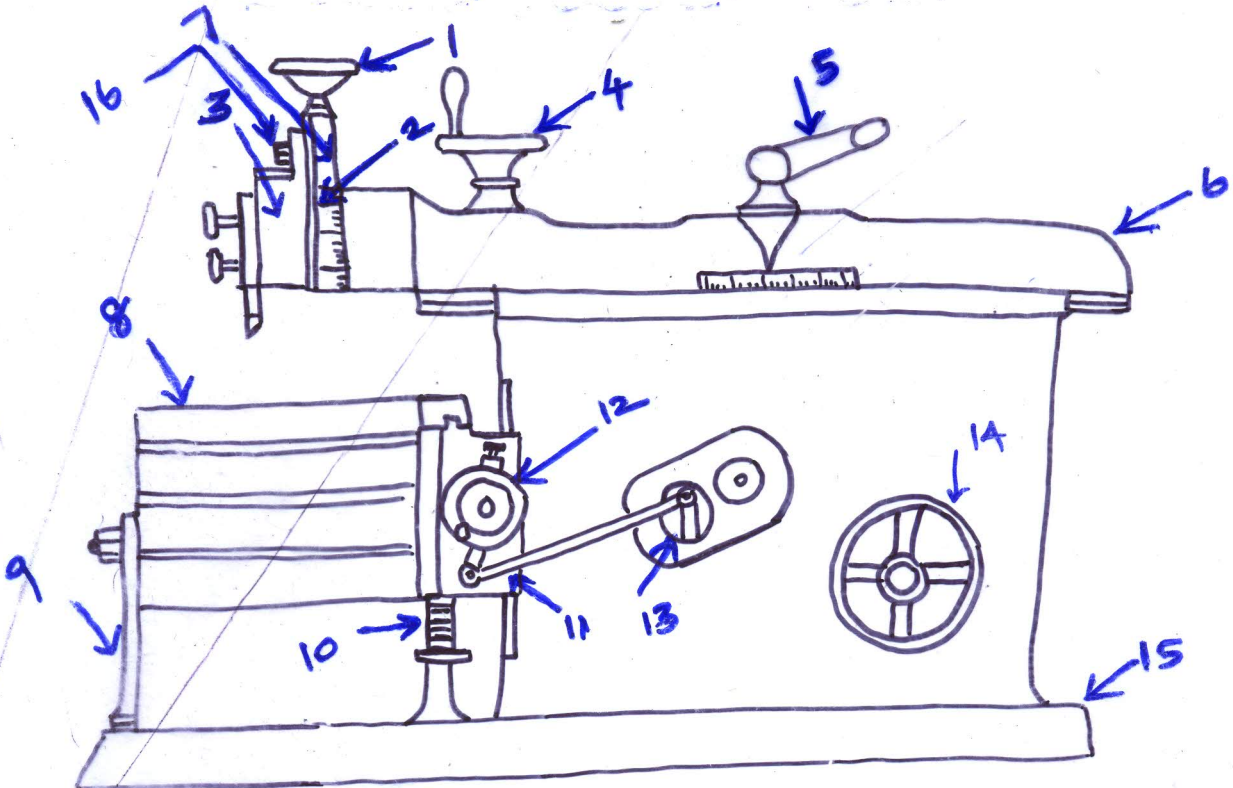
(9)

③ Angular feed:-

It denotes the movement of the cutting tool in a vertically angular direction per stroke of the cutting tool. It is obtained by first tilting the tool head to the required angle & then feeding the cutting tool in a vertical direction by rotating the down feed screw. The angular feed is used to produce angular surfaces.

Note:-

The angular feed & the vertical feed of a shaper is given only after tilting the apron to some angle. This is done to give the clearance b/w the cutting tool & the work piece to avoid the rubbing of the cutting tool with the work piece during machining.



- ① Down feed hand wheel
- ② Swivel Base
- ③ Clapper box
- ④ Stroke position hand wheel
- ⑤ Ram Locking handle
- ⑥ Ram
- ⑦ Tool Head
- ⑧ Table
- ⑨ Table Support
- ⑩ Elevating Screw
- ⑪ Cross-rail
- ⑫ Pawl & Ratchet mechanism
- ⑬ Feed disc
- ⑭ Driving Pulley
- ⑮ Base
- ⑯ Apron clamping bolt

Fig 3.1 - Construction of a Shaper

Construction of a Shaper:-

A shaper consists of the following principal parts.

- ① Base
- ② Column
- ③ Cross-rail
- ④ Saddle
- ⑤ Table
- ⑥ Ram
- ⑦ Tool Head

① Base:-

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It is necessary bed (or) support required for all machine tools. It may be rigidly bolted to the floor (or) on the bench according to the size of the machine. It is so designed that it can take up the entire load of the machine and the forces set up by the cutting tool over the work. It is made of **Cast Iron** to resist vibration and take up high compressive load.

② Column:-

It is a box like casting mounted upon the base. It encloses the ram driving mechanism. Two accurately machined guideways are provided on the top of the column on which the ram reciprocates. It has two vertically machined guideways on its front face, which serves as the guide ways for the cross-rail for its vertical movement. The other side of the column contains levers, handles etc., for operating the machine.

③ Cross-rail:-

It is mounted on the vertical guideways of the column. It has a accurately machined

Guide ways on its top, which is perpendicular to the ram axis. The table may be given a vertical feed by rotating an elevating screw. A horizontal cross feed screw which is fitted within the cross-rail and parallel to the top guide ways of the cross-rail actuates the table to move in a cross-wise direction.

④ Saddle:-

⑫

The saddle is mounted on the cross-rail which holds the table firmly on its top. Cross wise movement of the saddle by rotating the cross-feed screw by hand (or) power causes the table to move sideways.

⑤ Table:-

The table which is bolted to the saddle receives cross wise and vertical movements from the saddle & cross-rail. The table has T-slots both on the top and sides for clamping the work. In a universal shaper, the table can be tilted about an axis parallel to the ram ways and an axis perpendicular to the ram ways.

6) Ram:-

(13)

The ram is a reciprocating member of a shaper. This is semi-cylindrical in form. It slides on the accurately machined dove-tail guideways on the top of the column and is connected to the reciprocating mechanism contained within the column. It houses a screwed shaft for altering the position of the ram with respect to the work and it holds the tool head at its front end.

7) Tool head:- [Refer figure 3.2 in P.no:15]

① The tool head of a shaper holds the tool rigidly, provides the vertical and angular feed movement of the tool and allows the tool to have an automatic relief during its return stroke.

② The vertical slide of the tool head has a swivel base which is held on a circular seat on the ram. The swivel base is graduated in degrees, so that the vertical slide may be set

Perpendicular to the work surface (or) at any desired angle. By rotating the down feed screw handle, the vertical slide carrying the tool executes down feed (or) angular feed movement while machining vertical (or) angular surface. The amount of feed (or) depth of cut may be measured by a micrometer dial on the top of the down feed screw.

(14)

(3) The Apron consisting of clapper box, clapper block & the tool post is clamped upon the vertical slide by a screw. By releasing the apron clamping screw, the apron may be swivelled either towards right (or) left with respect to the vertical slide. This arrangement is necessary to provide relief to the tool while making vertical (or) angular cuts.

(4) The two vertical walls on the apron called clapper box houses the clapper block which is connected to it by means of a hinge pin. The tool post is mounted on the clapper block. On the forward cutting stroke, the clapper block fits securely to the clapper box to

make a rigid tool support. On the return stroke, a slight frictional drag of the tool lifts the clapper block out of the clapper box a sufficient amount preventing the tool cutting edge from dragging & consequent wear. The work surface is also prevented from any damage due to dragging.

(15)

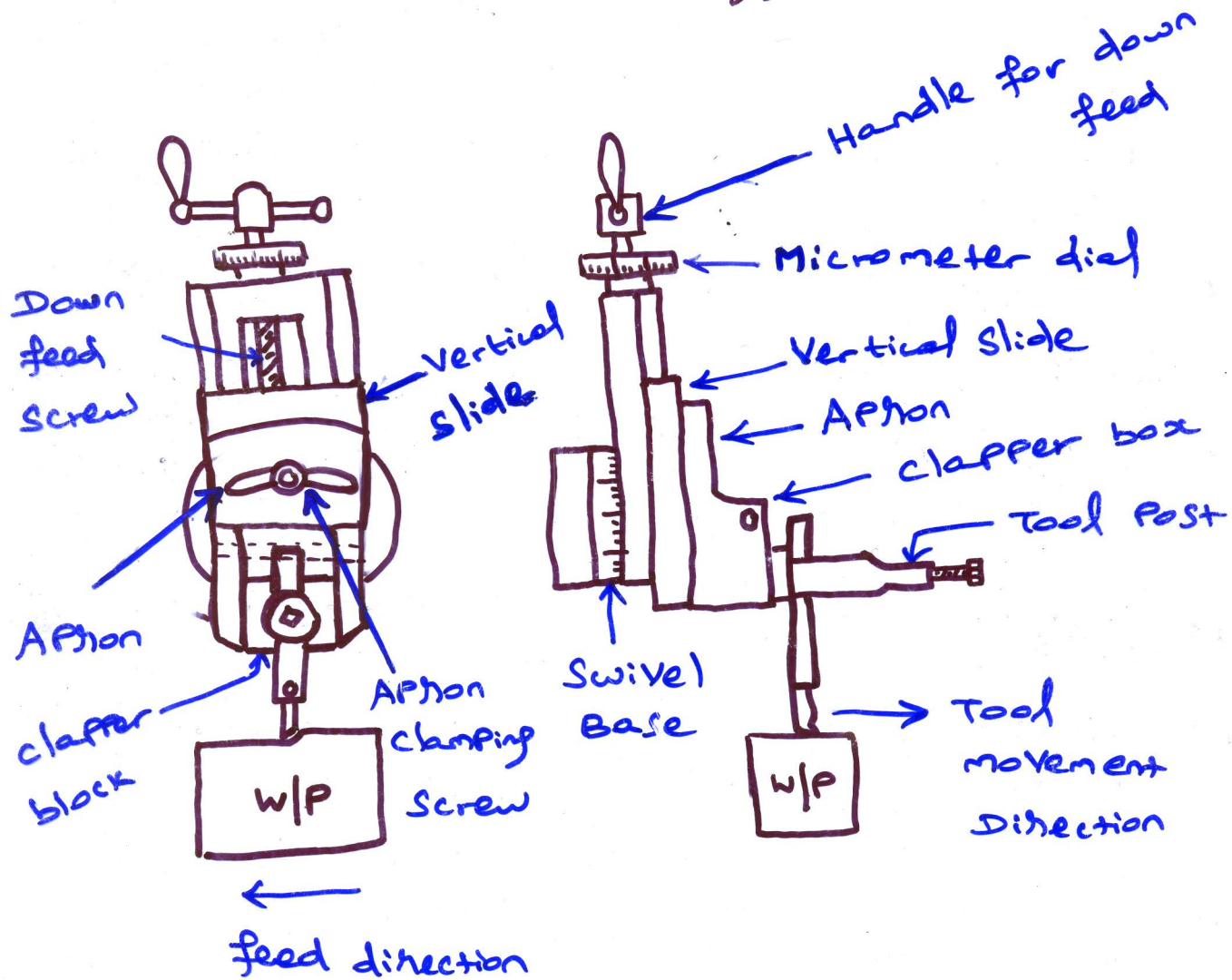


Fig 3.2 - Tool Head of a Shaper

SHAPER MECHANISMS!-

(16)

- ① In a Shaper, rotary movement of the drive is converted into the reciprocating motion of the ram by the mechanism contained within the column of the machine.
- ② In a Standard Shaper, the metal is removed during the forward cutting stroke and the return stroke is an idle stroke as no metal is removed during the return stroke.
- ③ To reduce the total machining time, it is necessary to reduce the time taken by the return stroke.
- ④ Thus the Shaper mechanism is so designed

that it can allow the ram holding the tool to move at a comparatively slower speed during the forward cutting stroke whereas during the return stroke, it can allow the ram to move at a faster rate to reduce the idle return time. This mechanism is known as "quick return mechanism".

(17)

⑤ There are 3 types of quick return mechanism used in the shaper.

- ① Crank & slotted link mechanism
- ② Whitworth quick return mechanism
- ③ Hydraulic drive mechanism

Crank & slotted link mechanism:

The motion (or) power is transmitted to the bull gear through a pinion which receives its motion from an individual motor through a stepped cone pulley & belt drive (or) a set of gear train. Speed of the bull gear can be changed by shifting the belt to various pulley in case of belt drive (or) by various gears in case of gear drive.

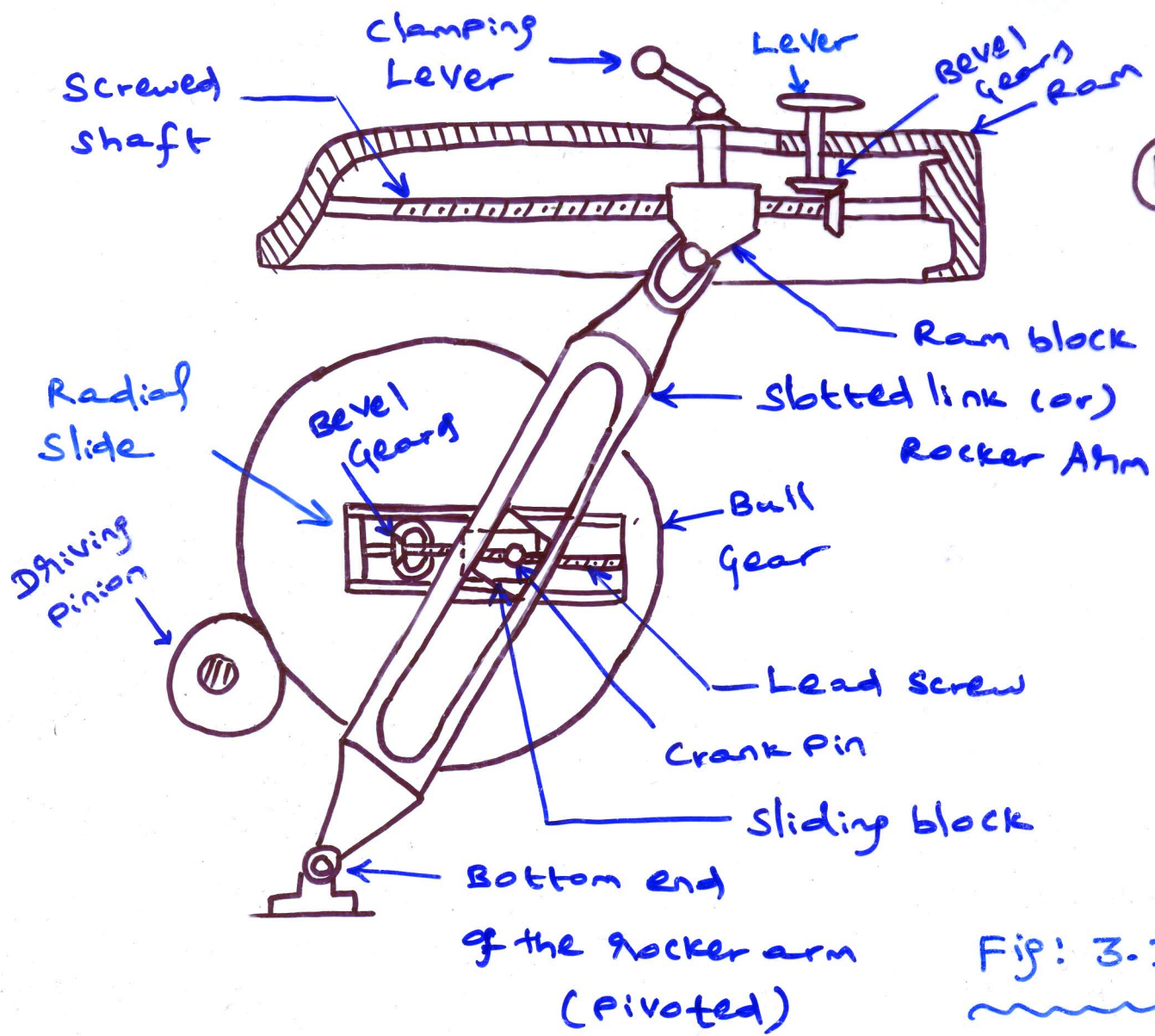


Fig: 3.3
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Bolted to the center of the bull gear is a radial slide which carries a sliding block into which the crank pin is fitted. Rotation of the bull gear will cause the crank pin to rotate at a uniform speed. Another sliding block is also there into the slot provided in the slotted link (or) rocker arm. It is fitted to the sliding block

in the radial slide by a crank pin. The rocker arm is pivoted at its bottom end and is attached to the frame of the column. The upper end of the rocker arm is forked & connected to the ram block by a pin. As the bull gear rotates, the crank pin will rotate on a crank pin circle. As the sliding block is connected with a crank pin, it also rotates along crank pin circle, which will give the rocker arm a rocking movement. As the rocker arm is connected to the ram by ram block, the ram gets a reciprocating motion from the rocking movement of the rocker arm. Thus the rotary motion of the bull gear is converted to the reciprocating movement of the ram.

To get quick return motion from Crank & Slotted link mechanism:- [ Refer 3.4 on Page no! 21 ]

From figure 3.3.3, it can be understood that when the link is in the position PM, the ram will be at the extreme backward position of its stroke & when it is at PN, the extreme forward position of the ram will have been reached.

PM & PN are tangent to the Crank Pin Circle at the extreme position of the forward & Return stroke. The forward cutting stroke takes place when the Crank Pin rotates through the angle  $C_1KC_2$  and the return stroke takes place when the Crank rotates through the angle  $C_2LC_1$ . It is evident that the angle  $C_1KC_2$  made by forward (or) cutting stroke is greater than the angle  $C_2LC_1$  made by the return stroke. As the angular velocity of the Crank Pin is constant, the return stroke is completed within a shorter time.

$$\frac{\text{Cutting time}}{\text{Return time}} = \frac{\text{Angle of } C_1KC_2}{\text{Angle of } C_2LC_1}$$

Cutting time to return time ratio usually varies between 2:1 and 3:2. From the figure 3.3.2, it can be understood that, the cutting speed is minimum at the extreme position of the ram & is maximum when the rocker arm is vertical. The only disadvantage of this method, cutting speed and return speed is not constant throughout the stroke.

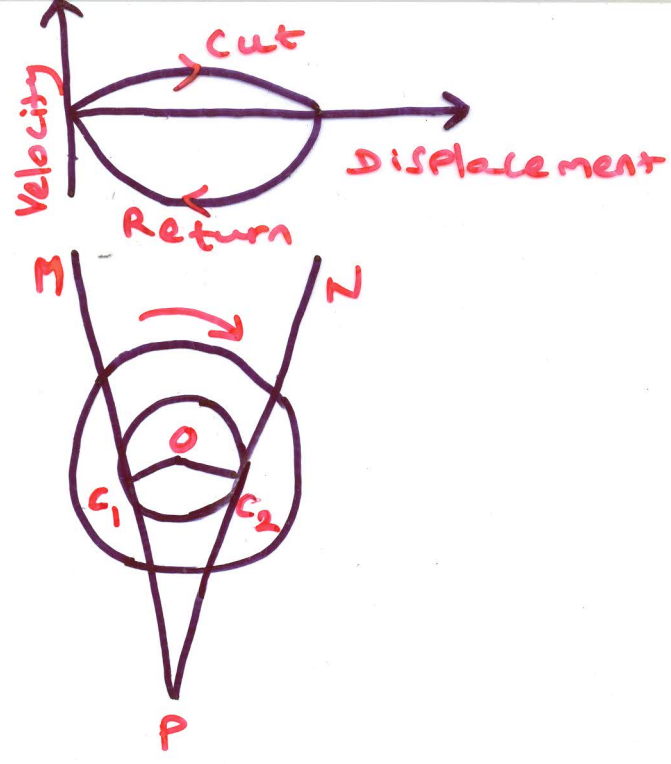


Fig: 3.4 - Quick return motion from Crank & slotted link mechanism

Adjusting the length of the stroke!:-

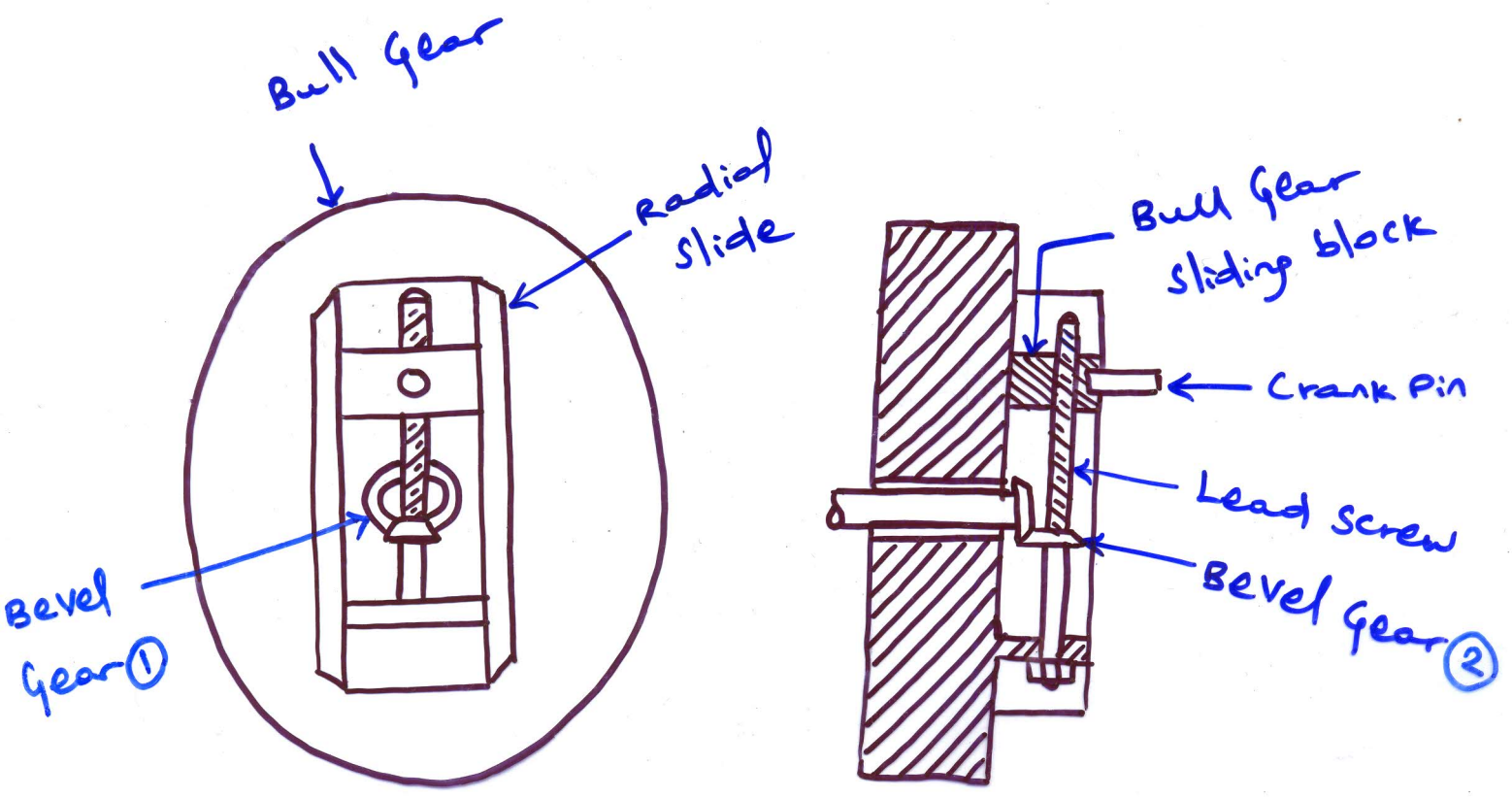


Fig: 3.5

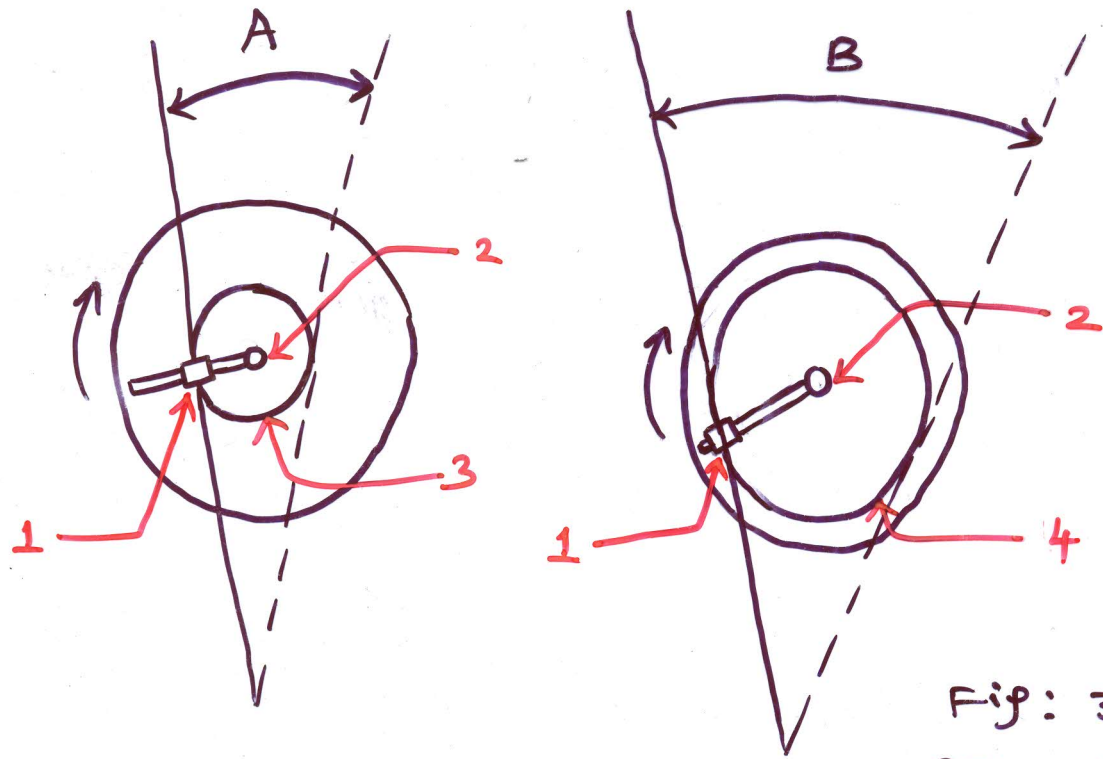


Fig: 3.6

- ① Position of the sliding block
- ② Center of bull gear
- ③ Shorter Crank Pin circle
- ④ Larger Crank Pin circle

A → Shorter Stroke length

B → Larger stroke length

The stroke length of the ram can be adjusted by moving the bull gear sliding block towards (or) away from the center of the bull gear. The bevel gear ① is placed at the center of the bull gear. It can be rotated by a handle. When the bevel gear ① is rotated, the bevel gear ② will rotate causing the lead screw to rotate. Thus the bull gear sliding block which engages with the

Lead screw can be moved towards (or) away from the center of the bull gear based on the direction of rotation of the lead screw. The closer the crank pin is brought to the center of the bull gear, the smaller will be the crank radius and hence the smaller will be the stroke length. The farther the crank pin is brought away from the center of bull gear, the bigger will be the crank radius & hence the larger will be the stroke length.

Maximum stroke length is obtained when the crank pin is shifted towards the farthest end of the slide.

Adjusting the position of the stroke! — [see Fig: 3.3]

Inside the ram of a Shaper, there are screwed shaft, Ram block, Bevel gears. The position of the ram with respect to the work piece can be adjusted by rotating the screwed shaft of the ram. For rotating the screwed shaft of the ram, first the clamping lever for the ram block is loosened & then the lever for the bevel gear is rotated. Now, the screwed shaft starts rotating.



As the ram block which acts as a nut is a (24) stationary one, the ram of the shaper will move forward (or) backward with respect to the ram block based on the direction of rotation of the screwed shaft. Thus the position of the ram with respect to the workpiece is adjusted.

Whitworth Quick Return Mechanism:-

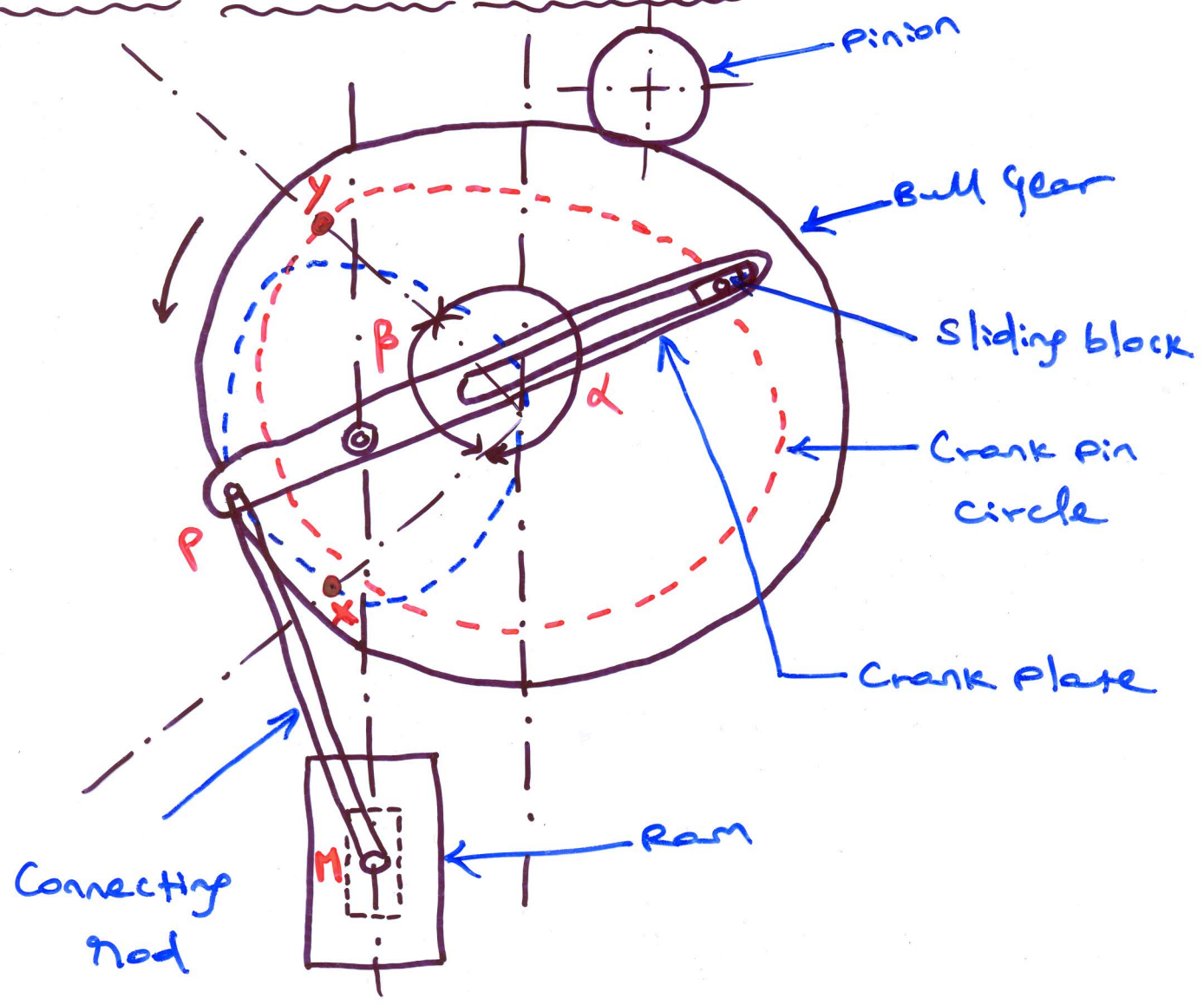


Fig: 3.7

Figure 3.7 illustrates the arrangement of various elements in Whitworth quick return mechanism. The shaft of an electric motor drives the pinion which rotates the bull gear. The bull gear has a sliding block which is fitted on the bull gear by a crank pin. The slotted crank plate is eccentrically pivoted on the bull gear at point "S". The sliding block in the bull gear slides into the slot of the crank plate. A connecting rod connects the crank plate by a pin at P on one end and the ram at the other end M. When the pinion rotates, the bull gear is also rotated along with the sliding block which slides into the slot of the crank plate. It makes the ram to move up & down [Reciprocating motion] by the connecting rod.

Position of the Crank Pin 'A' :-



- ① When the crank pin A is at X, the ram will be in forward stroke. At that time, the bull gear rotates in the Anti Clockwise direction at an angle "d".

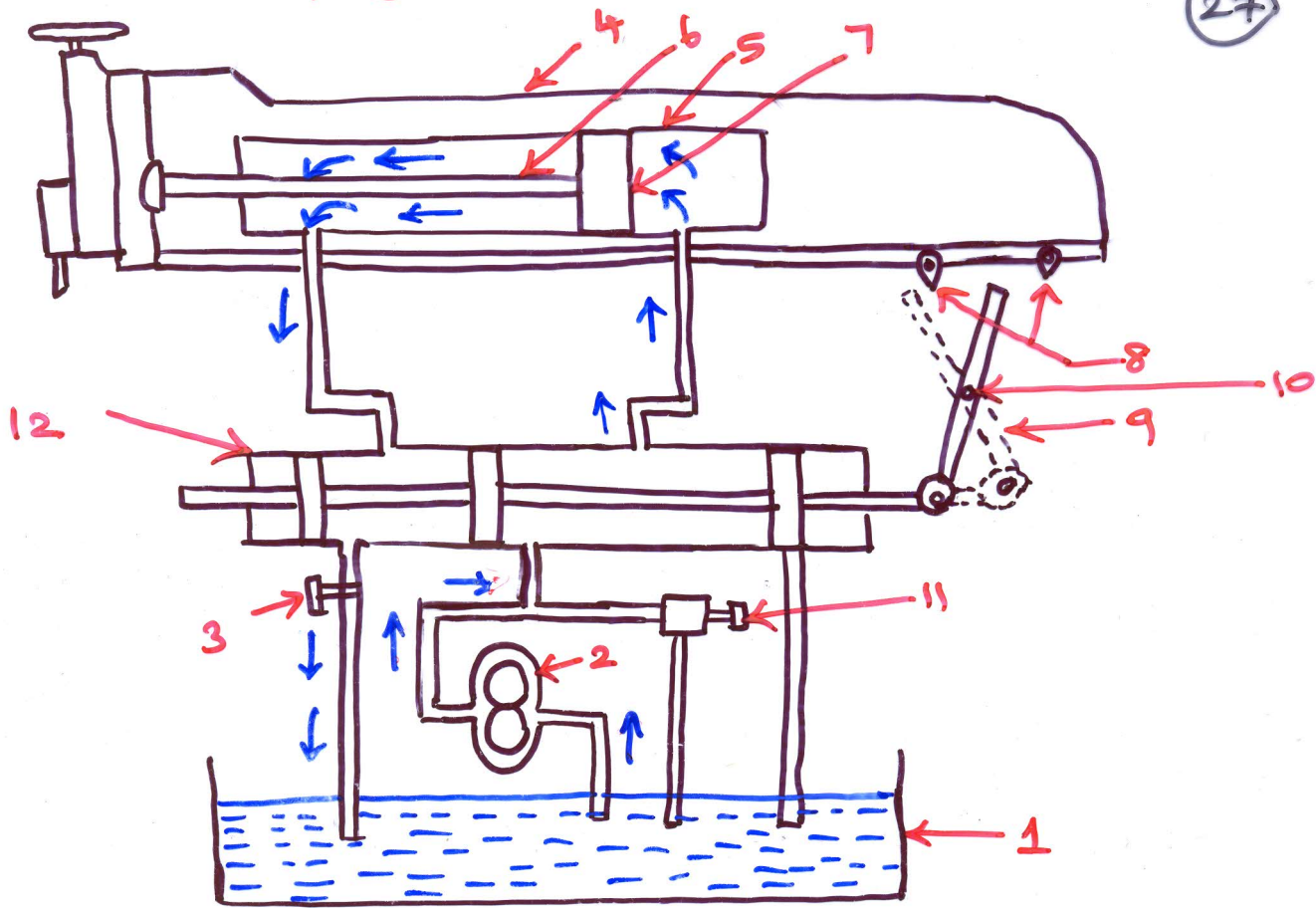
② when the bull gear rotates further in the same direction from y to x at an angle of  $\beta$ , the return stroke will take place. Here, the angle of  $\beta$  is less than  $\alpha$ . So, the time taken for the return stroke is reduced. (26)

$$m = \frac{\text{Cutting time}}{\text{Return time}} = \frac{\alpha}{\beta}$$

Reason for making the stroke length greater than the work piece length in a horizontal shaper:- 2 Mark

- ① To allow sufficient time for giving cross-feed.
- ② To allow sufficient time for the clapper box to attain its proper seat for cutting.
- ③ To allow the ram for obtaining the proper cutting speed.
- ④ To avoid the rubbing of the tool on the work surface during the return stroke.
- ⑤ To obtain the good surface finish.

## Hydraulic drive :-



- ① oil reservoir
- ② oil pump
- ③ throttle valve
- ④ Ram
- ⑤ Cylinder
- ⑥ Piston rod
- ⑦ Piston
- ⑧ Reversing dog
- ⑨ Reversing lever
- ⑩ Reversing lever pivot
- ⑪ Relief valve
- ⑫ Direction control valve.

① In a hydraulic shaper, the ram is moved forward & backward by a piston rod attached with a piston which is moving inside a hydraulic cylinder placed inside the ram.

- ② This mechanism consists of
  - a) constant oil discharge pump.

(b) Relief Valve (c) Direction control valve [DCV]

(d) Hydraulic Cylinder

(28)

(3) The position of the DCV is changed by a reversing dog at the end of each stroke. At one position of DCV, the oil flows through the piston side of the cylinder making forward stroke of the ram taking place. At another position of DCV, the oil flows through the piston rod of the cylinder making the return stroke of the ram taking place.

(4) The purpose of oil pump is to suck the oil from the reservoir & discharge it to the cylinder through DCV at high pressure.

(5) The volume of the cylinder in the piston rod side is less than the volume of the cylinder in the piston side. So, when the same amount of oil flows through the piston rod side, the pressure developed will be comparatively high, which in turn increases the speed of the ram during the return stroke. Thus, the quick

Return motion of the Ram is achieved.

(29)

(6) The speed of the ram can be increased (or) decreased by controlling the amount of oil discharged to the tank. This is done by adjusting the throttle valve. When the oil flows through one side of the cylinder, the oil in another side of the cylinder will be discharged to the tank through the throttle valve. For example, when the throttle valve is partially closed, the speed of the cylinder will be reduced. At the same time, the outlet pressure will be increased. In this time, the relief valve will open and discharge excess oil to the tank, thus maintaining the constant pressure in the system.

### Advantages of the Hydraulic drive! -

1. The cutting & return stroke speeds are practically constant throughout the stroke. This permits the cutting tool to work uniformly during the cutting stroke.

- ② The reversal of the ram is obtained quickly without any shock as the oil on the other end of the cylinder provides cushioning effect. (30)
- ③ Flexibility in obtaining various cutting speeds.
- ④ The relief valve ensures safety to the tool & the machine when the machine is overloaded.
- ⑤ The operation is smooth & silent.

### Feed Mechanism:-

① Hand feed mechanism

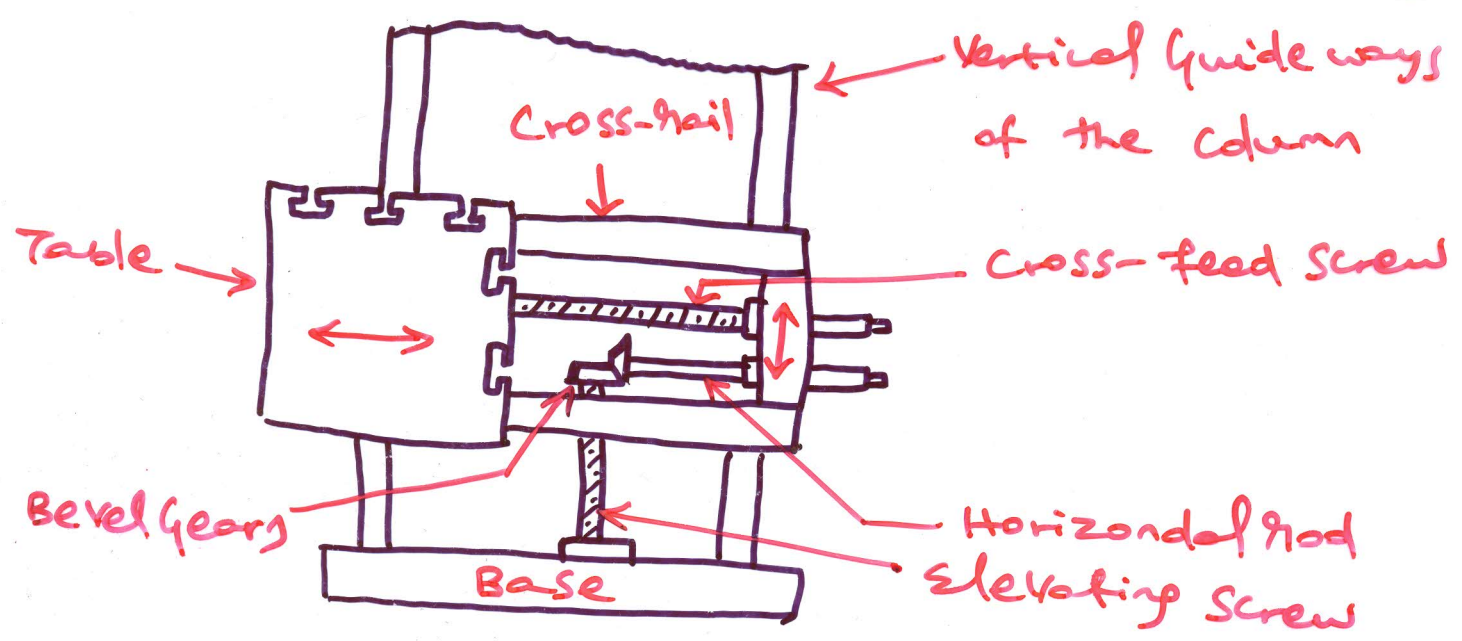
- Vertical feed by the toolhead
- Angular feed by the toolhead
- Vertical feed for the table
- Horizontal (or) Cross-feed for the table

② Auto-feed → Horizontal (or) Cross-feed for the table.

Unlike lathe, the feed movements in a shaper are provided intermittently & is given at the end of return stroke only.

## Hand feed mechanism for the table of the shaper:-

(31)



### ① Vertical Hand feed :-

When the horizontal rod is rotated by a key, the power will be transmitted to the elevating screw through a set of bevel gears. The rotation of the elevating screw makes the cross-rail of the shaper move along the vertical guide ways of the column, thus giving the vertical feed to the table.

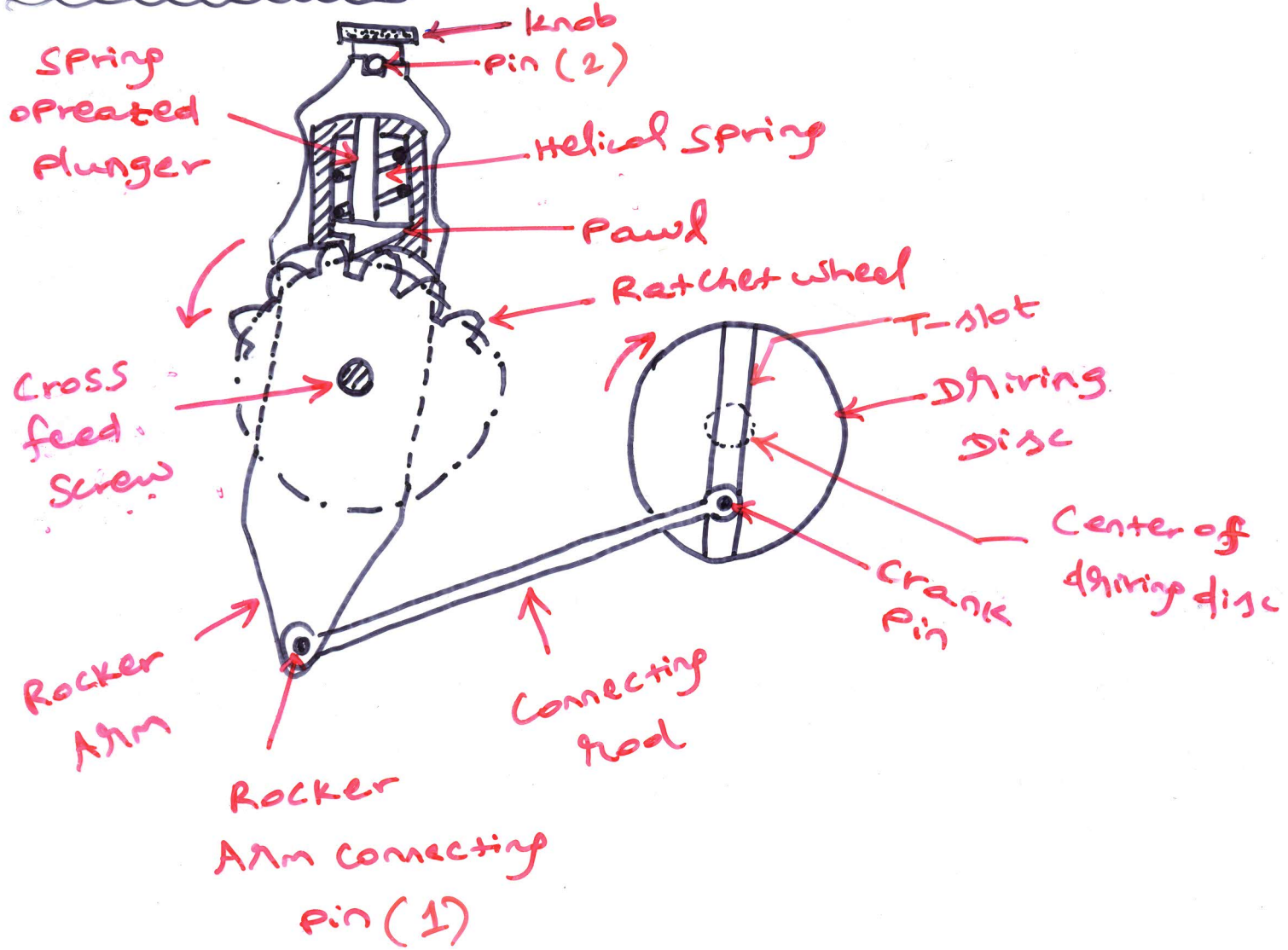
### ② Horizontal (or) Cross feed by hand:-

When the cross-feed screw is rotated by a key, the cross-feed screw will rotate. The



Rotation of the cross-feed screw make the saddle move along the horizontal flat guideways of the cross-rail, thus giving the horizontal (or) cross feed to the table of the shaper.

Auto Cross-feed Mechanism for a shaper:- (Pawl & Ratchet)



The above figure illustrates the automatic cross-feed mechanism of a shaper. The driving disc is connected to the bull gear. So, when the bull gear rotates, the driving disc will also rotate. The driving disc has a T-slot along

its diameter. The one end of the connecting rod is connected to the driving disc eccentrically by a crank pin. The other end of the connecting rod is connected to the bottom end of the rocker arm by a pin (1). The rocker arm is fulcrumed at the center of the ratchet wheel which is keyed to the cross-feed screw. The top portion of the rocker arm has a spring operated pawl which is straight on one side and slant (or) bevelled on the other side. The pawl is into the space between the teeth of the ratchet wheel. When the driving disc rotates through half of the revolution in a clockwise direction, the rocker arm starts rocking in a clockwise direction as it is connected with the driving disc by connecting rod. During the clockwise direction of the rocking arm, the pawl in the rocker arm just slips over the teeth of the ratchet wheel imparting no movement to the table of a shaper. When the driving disc rotates through another half in a clockwise direction, the rocker arm will start

Rocking in the Anti Clockwise direction. In this condition, the straight side of the pawl engages with the teeth of the ratchet wheel & rotate it. As the ratchet wheel is keyed to the cross feed screw, cross-feed screw will also rotate when the ratchet wheel rotates. Thus, the cross-feed is given to the table automatically. This cross-feed is given during the return stroke only.

(34)

The following points are worth noted.

- ① To reverse the <sup>direction of the</sup> cross-feed of the table, the pin (2) of the rocker arm is lifted from the slot & rotated through  $180^\circ$  so that the position of the pawl is reversed & the pin is again put into the slot. Now, the direction of Auto cross feed is reversed.
- ② The amount of cross feed may be altered by shifting the position of the crank pin with respect to the center of the driving disk. Greater the throw of eccentricity, more will be the rocking

movement for the rocker arm and the Pawl will rotate three (or) four teeth on the ratchet wheel at a time imparting greater feed 35 movement.

Work holding devices of a Shaper:—

The top & sides of the table of a Shaper

have T-slots for clamping the work. The work may be supported on the table by the following methods depending on the nature of the w/p.

- ① clamped in a Vise
- ② clamped on the table
- ③ clamped to the angle plate
- ④ clamped on a V-block
- ⑤ Held between the centers.

① Shaper vises:—

\* A vice is a quick method of holding and locating relatively small & regular shaped workpieces.

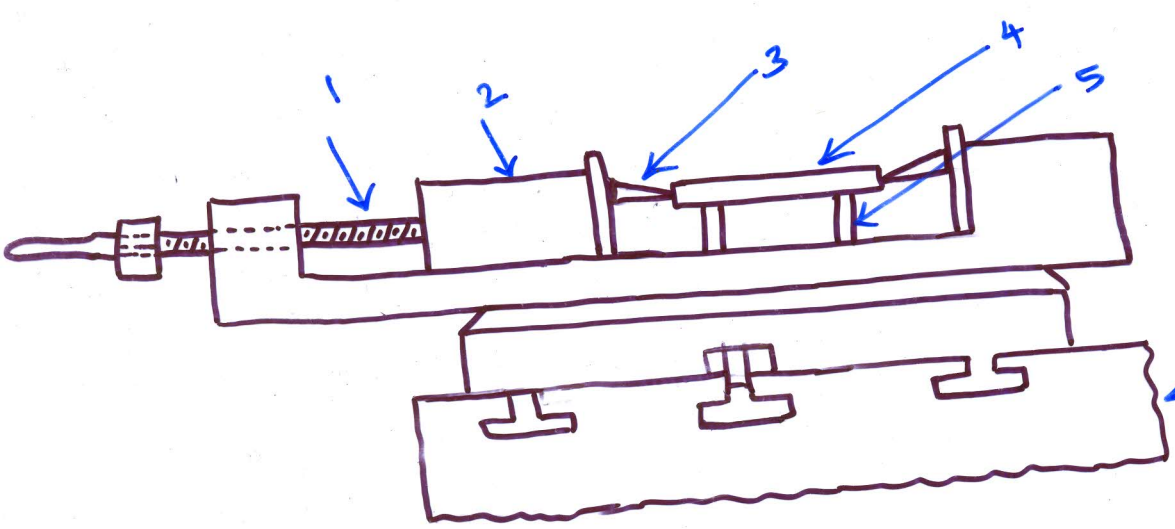
\* It consists of base, screw, fixed

and movable jaws.

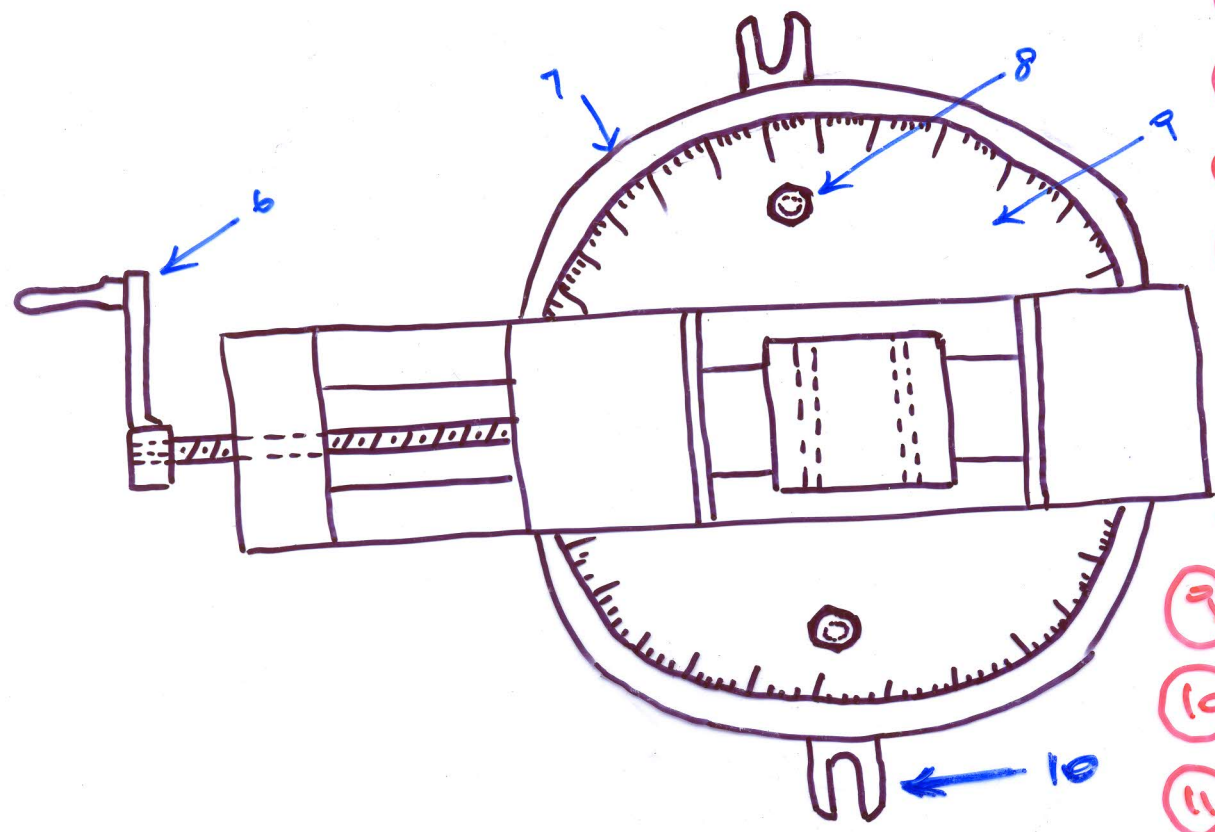
\* The base has a projection (or) tongue which fits into the slot of machine table.

\* For properly securing it to the table lugs are provided for clamping the vice by T-bolts.

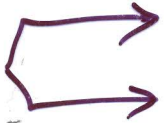
\* The work is clamped b/w the fixed & movable jaws by a screw.



- ① Screw
- ② Movable jaw
- ③ Hold down
- ④ Work
- ⑤ Parallels
- ⑥ Handle
- ⑦ Base
- ⑧ Clamping bolt
- ⑨ Swivel base
- ⑩ Lugs
- ⑪ Table of Shaper



A machine vice is classified into 3 types (37)

① plain vice  Single Screw  
Double Screw

② Swivel vice

③ Universal vice

Plain vice:-

It is the most simple of all the types. The vice may have a single screw (or) double screws for actuating the movable jaw. The double screws add gripping strength while taking deeper cuts (or) handling heavier jobs.

Swivel vice:-

In this vice, the base is graduated in degrees and the body of the vice may be swivelled at any desired angle on a horizontal plane. The swivelling arrangement is useful for machining horizontal bevelled surface of the workpiece.

Universal vice:-

In this vice, the body of the vice can be swivelled on a horizontal plane like a swivel vice.

In addition to that, the body can be tilted in a vertical plane upto  $90^\circ$  from the horizontal plane. It is used for Vertical Angular machining. (38)

### Parallels:-

- \* Parallels are square (or) rectangular bars of steel (or) cast iron which is hardened and ground with opposite sides parallel.
- \* When the height of the job is less than the height of the jaws of the vice, parallels are used to raise and seat the work piece above the jaws.
- \* Parallels are available in various sizes for seating the work piece of different heights and are always used in pairs.

### Hold-downs:-

- \* Hold-down is a hardened wedge shaped piece with the taper angle of  $5^\circ$ .
- \* Hold-downs are placed b/w the two jaws of vice & the work piece.
- \* It is used for holding thin pieces of work in a shaper vice. It is also used for holding the work of smaller height than the vice jaws where

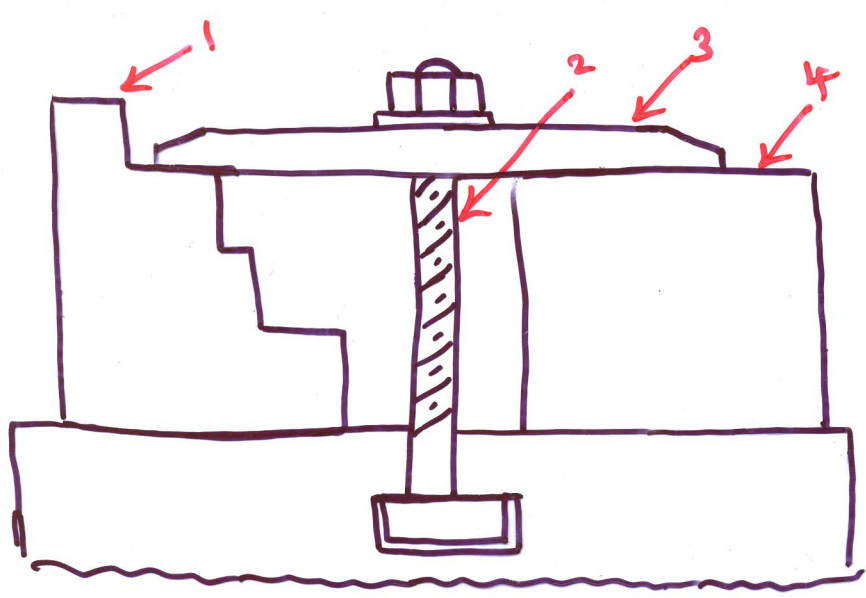
Suitable parallels are not available.

② clamping work on the table:-

When the workpiece is too large to be held in a vise, it must be fastened directly on the shaper table. The different methods employed to clamp different types of work on a shaper table are

- ① T-bolts & clamps
- ② Stop pins
- ③ Stop pins & toe dogs
- ④ Strip & stop pins.

① T-bolts & clamps:-



- ① step-block
- ② T-bolt
- ③ clamp
- ④ work

\* Figure illustrates the use of T-bolts and clamps for holding the work.

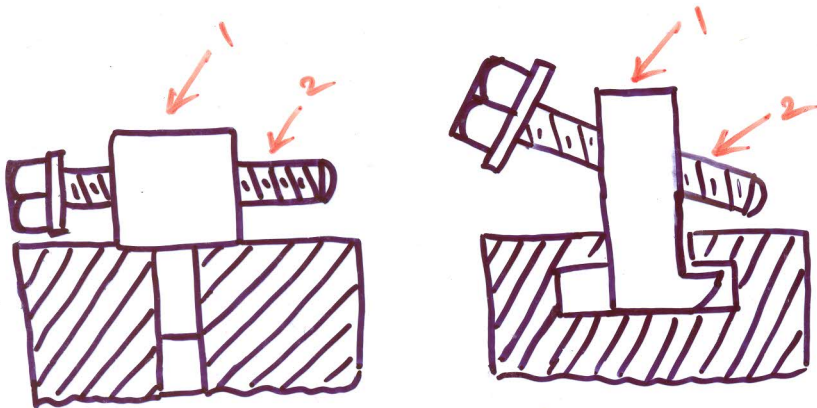
\* T-bolts having are fitted on the T-slot of the table. The length of the threaded portion is sufficiently long in order to accommodate different heights of work.



\* The clamps are made of steel having slots at the center for fitting the bolt. One end of the clamp rests on the side of the work while the other end rests on a block. (40)

\* To hold a large work on the table, a series of clamps and T-bolts are used all round the work.

### ② STOP PINS!—



① Body ② screw

\* A stop pin is a one leg screw clamp

\* It is used to prevent the work to get pushed out of its position during forward cutting stroke of the tool.

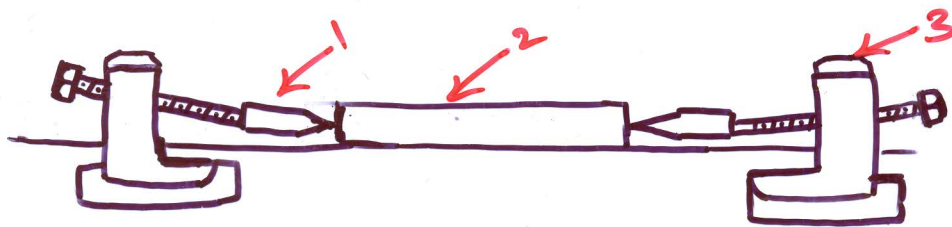
\* The body of the stop pin is fitted in the hole (or) slot on the table & the screw is tightened till it forces against the work.

### ③ STOP PINS & TOE DOPS!—

\* while holding the thin work pieces on the table, stop pin in conjunction with toe dops are

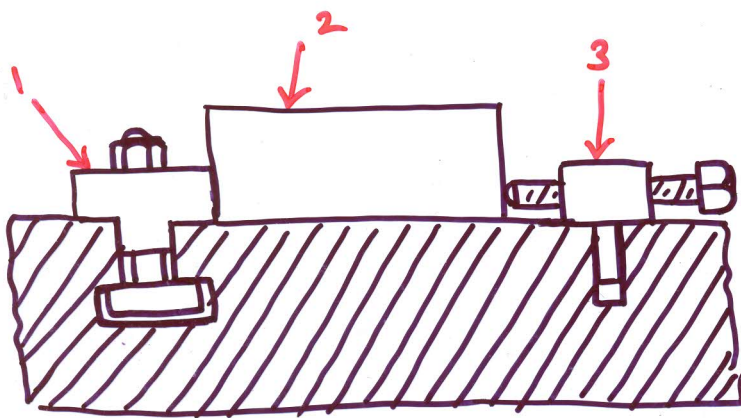
used.

\* A toe dog is similar in shape to that of a center punch (or) cold chisel. The head end of the toe dog is drilled slightly so that the end of the stop pin screw may fit into it. (4)



- ① Toe dog
- ② Thin w/p
- ③ Stop pin.

#### ④ Strip & Stop Pins!—



- ① Strip
- ② Work
- ③ Stop Pin

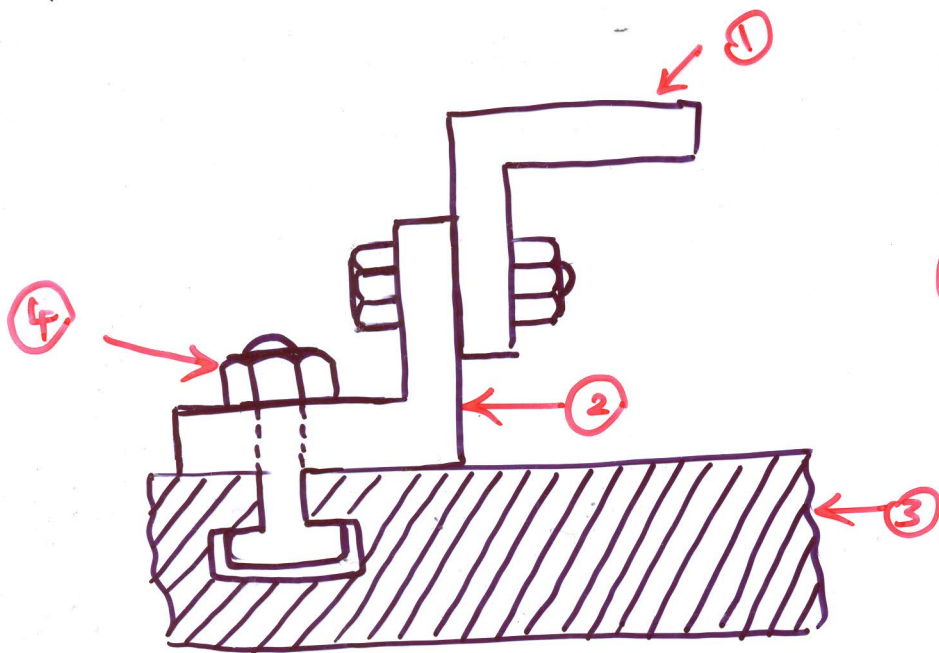
\* The above figure illustrates the working of strip & stop pin for holding the work.

\* Work having sufficient thickness is held on the table by strip & stop pins.

\* A strip is a long bar having a tongue with holes for fitting the T-bolts.

### ③ Clamping on an Angle plate!—

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- ① L-shaped w/p
- ② Angle plate
- ③ Table of a Shaper
- ④ T-bolt & Nut

\* For holding 'L' shaped work piece, angle plates are used.

\* Angle plates are made of cast Iron & has two plane surface bent at angle of  $90^\circ$ . One of the sides of the angle plate is fitted on the table of the shaper. Another side of the angle plate hold the 'L' shaped work piece by bolt & nut.

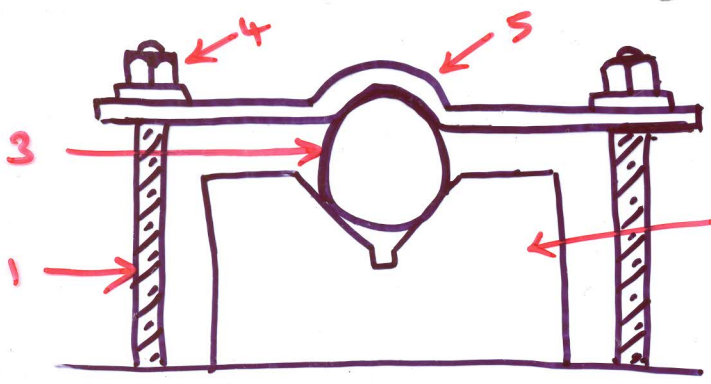
### ④ V-Block!—

\* For holding round rods, v-blocks are used.

\* Work may be supported on two v-block at two ends & is clamped to the table by T-bolts & clamps.

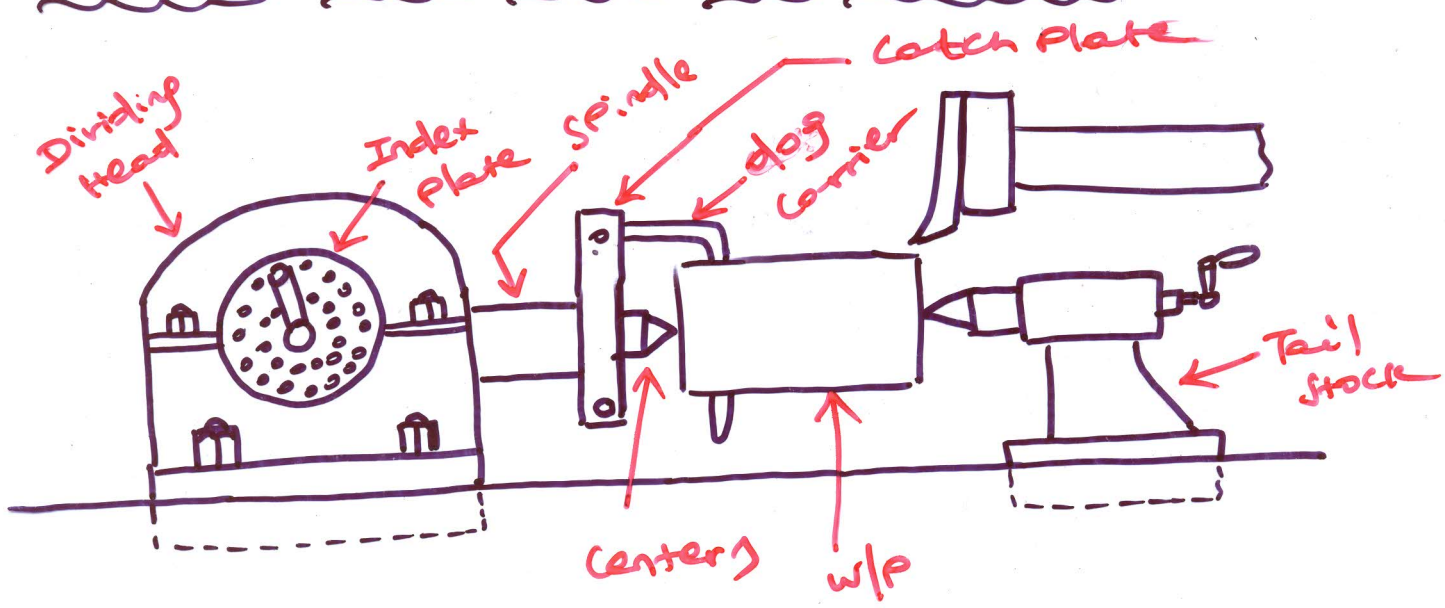
\* The tool may be made to reciprocate between the two clamps for cutting grooves (or) keyways.

(43)



- ① T-bolt
- ② V-block
- ③ Work
- ④ Nut
- ⑤ clamp

⑤ Clamping the workpiece b/w the centers:-



\* This is a special attachment for cutting equally spaced grooves (or) splines on the periphery of the round work. It may be also used for cutting gears.

\* After cutting each groove on the cylindrical work piece, the crank of the index plate will be

rotated along a selected hole circle to a predetermined amount so that the periphery of the w/p is equally divided.

(44)

\* Here, the work is held b/w the centers by means of catch plate & Dog carrier.

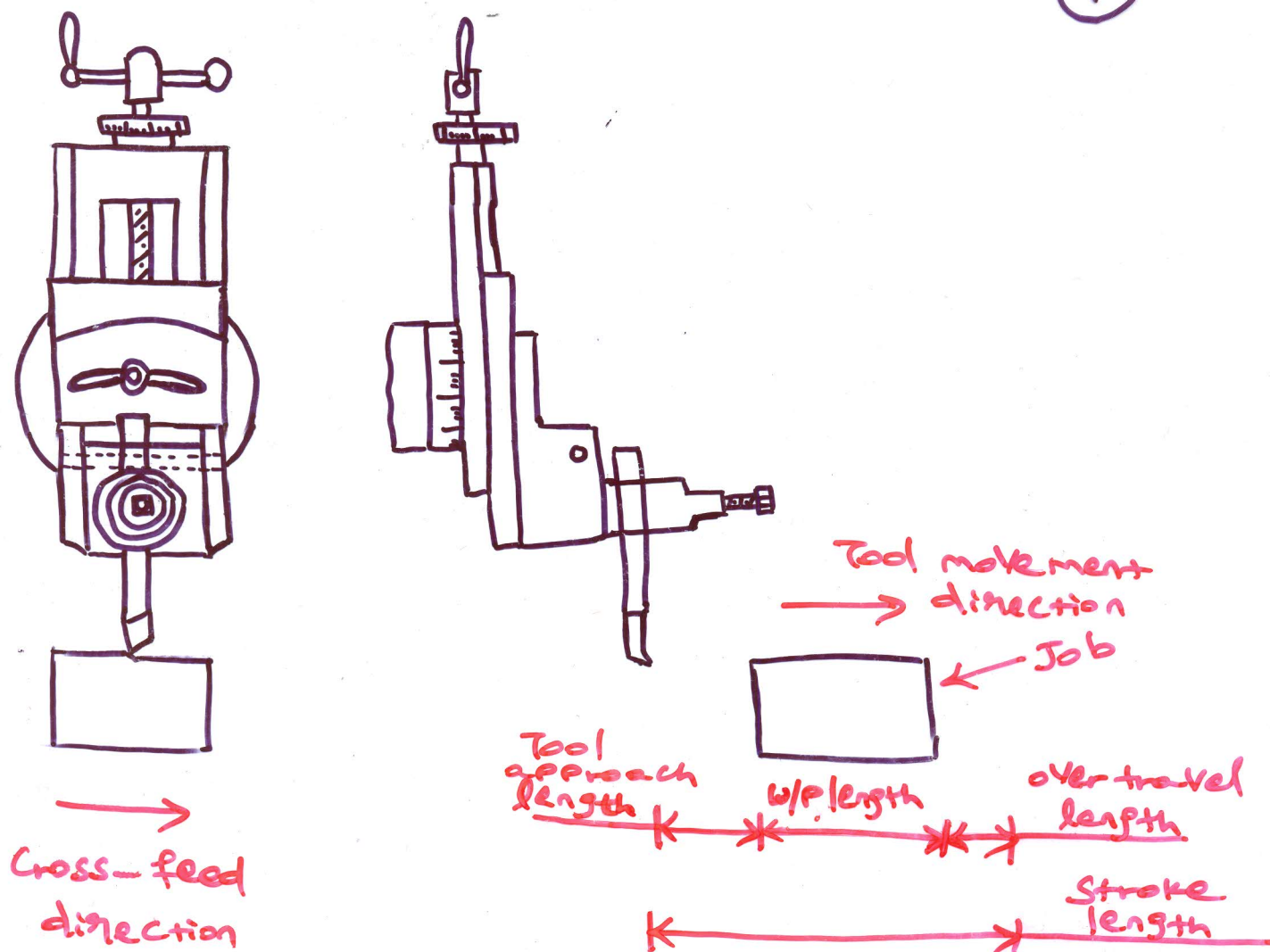
### Shaper operations:

A Shaper is a versatile machine tool primarily designed to generate a flat surface by a single point cutting tool. But it may also be used to perform many other operations. The different operations which a shaper can perform are as follows.

- ① Machining horizontal surface
- ② Machining vertical surface
- ③ Machining angular surface
- ④ Cutting slots, grooves & keyways.
- ⑤ Machining irregular surface
- ⑥ Machining splines (or) cutting gears.

# ① Machining a horizontal surface:-

KS



\* The above figure illustrates machining horizontal flat surface on the w/p.

\* Procedure for making horizontal flat surface on the w/p

① After the work is properly held on the table, a planing tool is set in the tool post with minimum overhang.

② The table is raised till there is a clearance of 25mm to 30mm between the tool & the workpiece.

③ The length & the position of the stroke are then adjusted.

4b

a) The length of stroke should be nearly 20mm longer than the work.

b) The position of the stroke is so adjusted that the tool begins to move from a distance of 12 to 15mm before the beginning of the cut and continues to move 5 to 8mm after the end of cut.

④ Proper cutting speed & feed is then adjusted.

⑤ Then the depth of cut is given by rotating the down feed screw.

⑥ Then the shaper is switched on. The cross feed is given at the end of return stroke.

⑦ Both roughing & finishing cuts are performed to complete the job.

Note:-

① For rough cuts, cutting speed is decreased while feed & depth of cut is increased.

depth of cut  
for rough work }  $\Rightarrow$  1.5 to 3mm

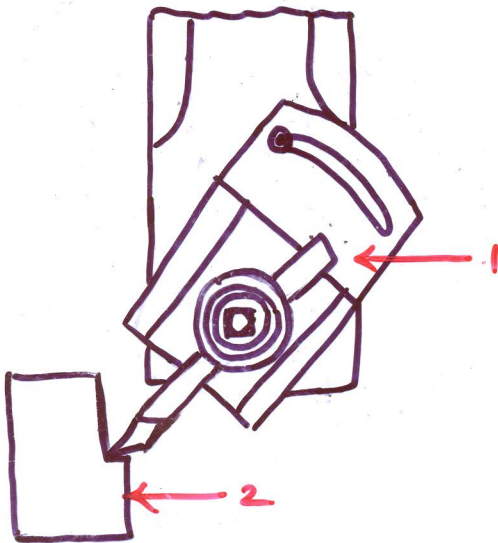
② For finishing cut, cutting speed is increased while the feed & depth of cut is decreased.

(47)

Depth of cut  
for finishing cut } = 0.075mm to 0.2mm.

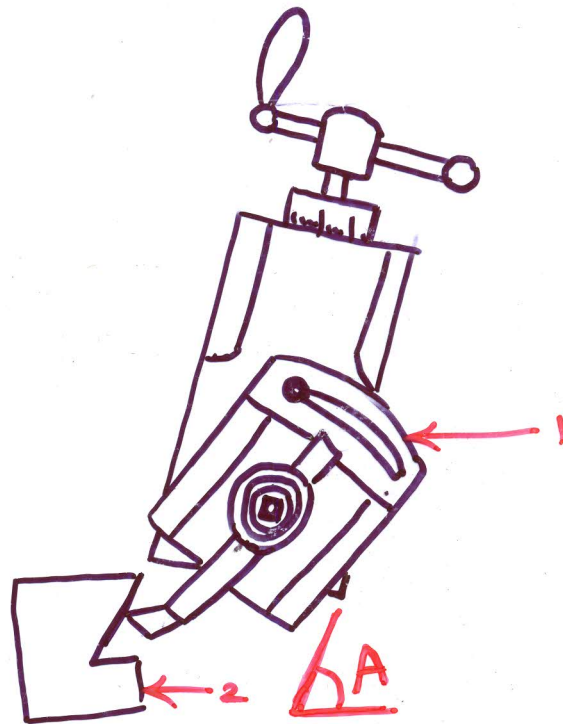
② Machining a Vertical flat Surface & Vertical

angular Surface!



① Apion ② work

Fig: 1



① Apion ② work

A → Swivelling Angle of Vertical Slide

Fig: 2

Steps in the machining of Vertical Surface!-

① Fig: ① illustrates the machining of Vertical flat Surface.

② The work is mounted on the vice (or) directly



on the table.

(48)

- ② The surface to be machined is carefully aligned with the axis of the ram.
- ④ A side cutting tool is set on the tool post and then position, length of stroke is adjusted.
- ⑤ The vertical slide is set exactly on zero angle position.
- ⑥ The apron is swivelled in a direction away from the surface being cut. This is necessary to enable to move upward and away from the work during the return stroke. This also prevents the side of the tool from dragging on the planed vertical surface during the return stroke.
- ⑦ Then the machine is switched on. At the end of return stroke, down feed of about 0.25 mm is given by rotating the down feed screw.
- ⑧ Both roughing & finishing cuts are performed to complete the job.

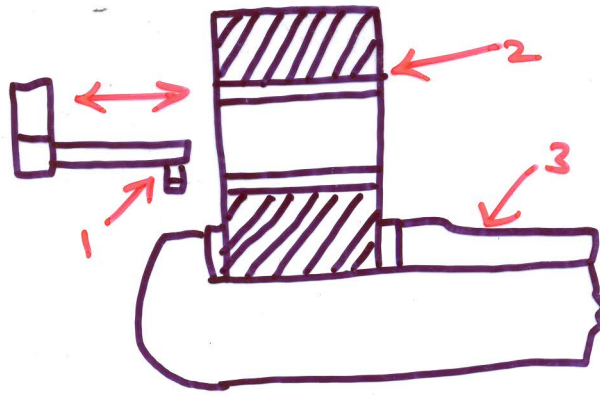
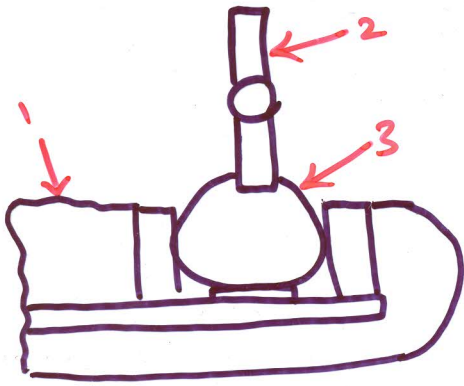
## Steps involved in machining of Angular Vertical Surface:-

(49)

- ① Fig: 2 illustrates the machining of Angular Vertical Surface.
- ② The work is set on the table and the Vertical slide of the tool head is swivelled to the required angle either towards right (or) left from the Vertical position.
- ③ Then the apron is swivelled away from the work.
- ④ Then the machine is switched on. The Angular down feed is given at the end of the return stroke by rotating the down feed screw.
- ⑤ Angular machining can also be machined in a universal shaper (or) by using universal vice without swivelling the tool head.

### ③ Cutting slots & keyways:—

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① Vise ② Tool ③ work

① Tool bit ② work ③ Vise.

#### Cutting External keyway

#### Cutting Internal keyway

#### Cutting External keyway

① For cutting slots (or) keyways, a square nose tool similar to the parting tool is selected.

② External keyway are cut on a shaft by first drilling a hole at the blind end of the keyway. The diameter of the hole should be 0.5 to 0.8 mm over size than the width of the keyway and the depth should be about 1.5 mm larger than the depth of the keyway. This is necessary for the clearance of the tool at the end of the return stroke.

- ③ The length & position of the stroke is carefully adjusted so that the stroke will terminate exactly at the clearance hole. The speed is reduced while cutting a keyway.

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### Cutting a Internal Keyway:-

- ① Internal keyways are cut by holding the tool on a special tool holder so that the tool post will not hit against the work at the end of the stroke.
- ② Clapper block is locked in the clapper box to prevent the tool from lifting during the return stroke.
- ③ Lubrication is necessary on the work to prevent the cutting edge of the tool from wear due to chipping.

### Machining Irregular Surface:-

- ① A shaper can also produce a contoured surface (i.e.) a convex (or) concave (or) a combination of any of the above surfaces.

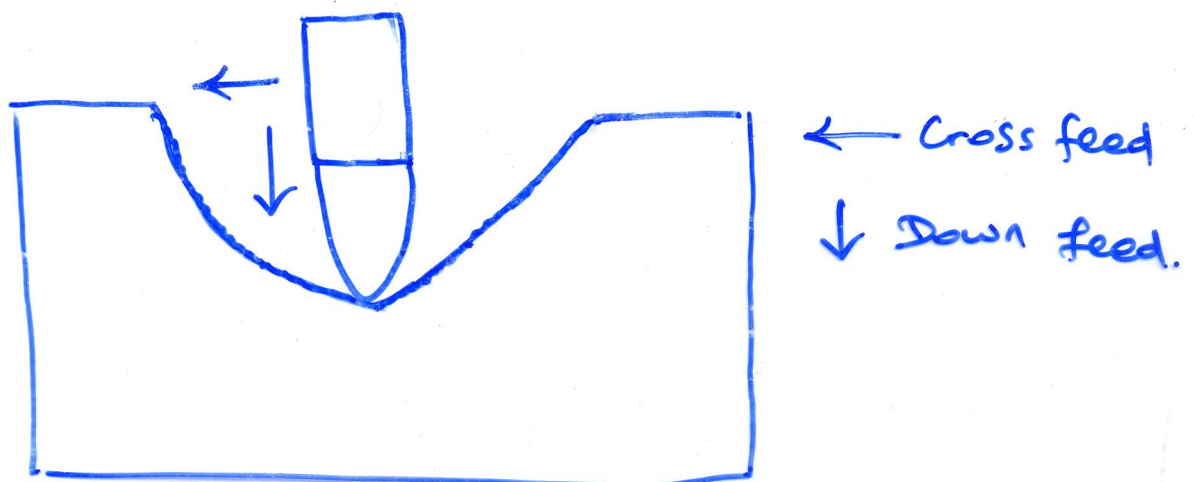
② To Produce a Small Contoured Surface, a forming tool is used.

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③ If the Curve is Sufficiently large, Power Cross-feed in conjunction with manual down feed is so adjusted that the tool will trace the required contour.

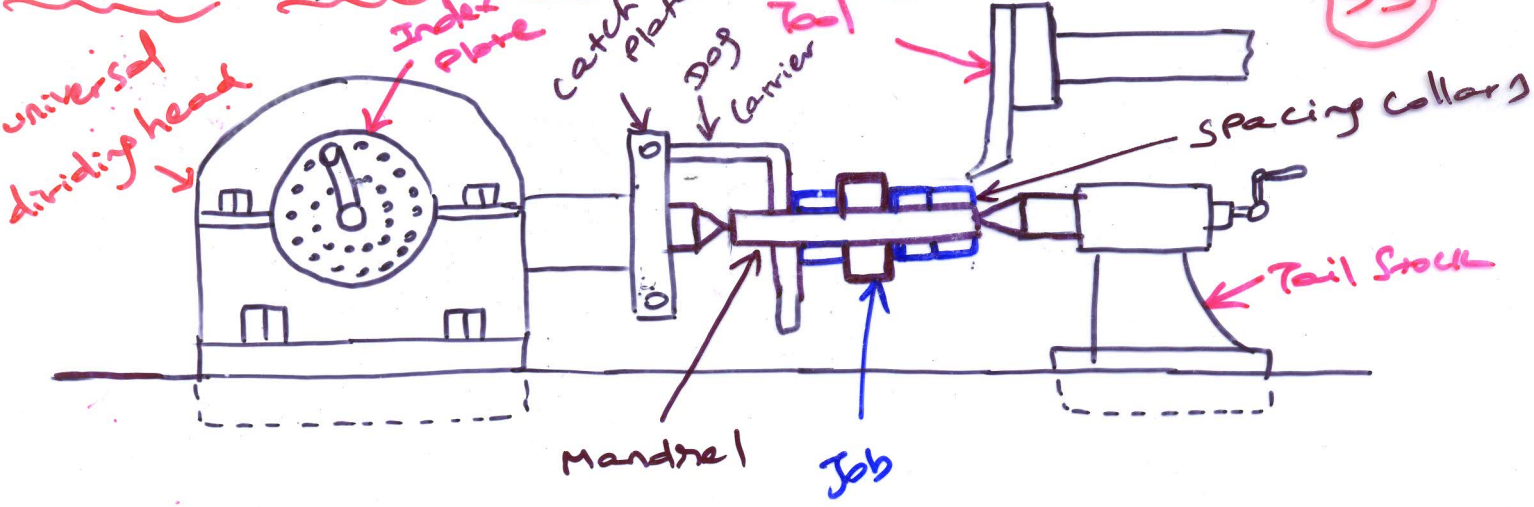
④ If the Contour has too many ups & down, both of the feeds are operated by hand. A ground nose tool is selected for machining irregular Surface.

⑤ For Shallow Cut, the apron may be set Vertical. But if the Curve is quite Sharp, the apron is swivelled towards right (or) left away from the Surface to be cut. The following figure Shows machining of concave Surface using a ground nose tool.



# Machining Splines (or) Cutting Gears:-

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\* Here, After each tooth is cut, the crank of the index plate is moved to a pre-determined amount along a selected hole circle so that the workpiece will be equally divided.

\* Here, a formed tool is used for cutting splines (or) Splines on the shaft.

## SHAPER SPECIFICATIONS:-

- ① Maximum length of stroke
- ② Maximum cross-wise movement of the table
- ③ Maximum vertical adjustment of the table
- ④ Type of driving mechanism
- ⑤ Power of the motor
- ⑥ Speed & feed available
- ⑦ Type of Shaper - Plain (or) Universal
- ⑧ Floor space required.
- ⑨ Total weight of the Shaper
- ⑩ Ratio of Cutting Stroke time to return Stroke time

$$m = \frac{\text{Cutting Stroke time}}{\text{Return Stroke time}} = \frac{\text{Cutting angle}}{\text{Return angle}} = \alpha / \beta$$

$m \sim 2:1 \text{ to } 3:2$

# Machining time calculation in a Shaper:—

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## Formulae's used:—

### ① Cutting Speed (v):—

$$\text{a) Time taken for cutting stroke} = \frac{\text{Length of cutting stroke (L) in mm}}{\text{Cutting Speed (v) } \times 1000 \text{ in m/min}}$$

$$= \frac{L}{1000v}$$

$$\text{b) The ratio b/w return to cutting time} = \frac{\text{Return time}}{\text{Cutting time}}$$

$$\therefore \text{Return time} = m \times \text{Cutting time}$$

$$= \frac{m \times L}{1000v}$$

$$\text{c) } \therefore \text{Time taken to complete one double stroke} = \frac{L}{1000v} [1 \text{ fm}]$$

$$\text{d) } \left. \begin{array}{l} \text{Number of double stroke (or)} \\ \text{Number of Revolution of bull gear per minute} \end{array} \right\} n = \frac{1}{\frac{L}{1000v} (1 \text{ fm})} = \frac{1000v}{L(1 \text{ fm})}$$

(e)  $\therefore$  Cutting Speed,  $v = \frac{nL(1+m)}{1000}$  m/minute

55

where

$n \rightarrow$  number of double stroke/min

$L \rightarrow$  Length of the stroke

$m \rightarrow$  Ratio of return time to cutting time

② Machining time:-

Let,

$L =$  Length of the stroke in mm

$B =$  Breadth of the work in mm

$S =$  feed in mm / double stroke

$m =$  the ratio of return to cutting time

$v =$  cutting speed in m/min

a) Time taken to complete one double stroke  $\left. \vphantom{\begin{matrix} a) \\ b) \\ c) \end{matrix}} \right\} = \frac{L}{1000 \times v} [1+m]$

b) Total number of double stroke  $\left. \vphantom{\begin{matrix} a) \\ b) \\ c) \end{matrix}} \right\} = \frac{B}{S}$

c) Total machining time  $= \frac{L \times B}{1000 \times v} [1+m]$



## Problems:-

① In a Shaper work, the length of the Stroke is 200mm, number of double strokes per minute is 30 and the ratio of return time to cutting time is 2:3. Find the cutting speed. (56)

Given:-

$$L = 200\text{mm}; \quad n = 30; \quad m = 2/3; \quad v = ?$$

Soln:-

$$n = \frac{1}{\frac{L}{1000 \times v} (1+m)} = \frac{1000 \times v}{L(1+m)}$$

$$\therefore v = \frac{nL(1+m)}{1000} = \frac{30 \times 200(1+2/3)}{1000}$$

$$v = 10 \text{ m/min}$$

---

② Find the time required for taking a complete cut on a plate 600 x 900mm if the cutting speed is 9 m/min. The return time to cutting time ratio is 1:4 and the feed is 3mm. The clearance at each end is 75mm.

Given:-

$$v = 9 \text{ m/min}; \quad m = \frac{1}{4}; \quad \text{feed}, \quad s = 3 \text{ mm};$$

(57)

$$\left. \begin{array}{l} \text{clearance at each} \\ \text{end} \end{array} \right\} = 75 \text{ mm};$$

Find:-

Machining time required for box 900mm w/p?

Sol:-

In a Shaper, a Stroke length of more than 900mm is not ordinarily available. So the work is placed on the table to take a cut of 600mm plus the clearances.

$$\therefore \text{Stroke length, } L = 600 + 75 + 75$$

$$\boxed{L = 750 \text{ mm}}$$

$$\left. \begin{array}{l} \text{No of double stroke} \\ \text{required} \end{array} \right\} = \frac{900}{3} = 300$$

$$\begin{aligned} \therefore \left. \begin{array}{l} \text{Total machining} \\ \text{time} \end{array} \right\} &\Rightarrow \frac{L}{600 \times v} (1 + m) \times 300 \\ &= \frac{750}{600 \times 9} (1 + \frac{1}{4}) \times 300 \end{aligned}$$

$$\boxed{\begin{array}{l} \text{Machining time} \\ \text{for single pass} \end{array} = 31.25 \text{ minutes.}}$$

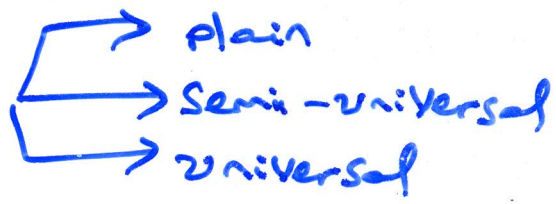
# Drilling Machine

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It is the machine used to drill a hole on the work piece quickly at a low cost.

Here the hole is generated by the rotating edge of the cutting tool known as drill bit which exerts large force on the work clamped on the table.

Types of drilling machine:-

- ① Portable drilling machine
- ② Sensitive drilling machine
- ③ Upright drilling machine
- ④ Radial drilling machine 
- ⑤ Gang drilling machine
- ⑥ Multiple spindle drilling machine
- ⑦ Automatic drilling machine
- ⑧ Deep hole drilling machine

## ① Portable drilling machine! —

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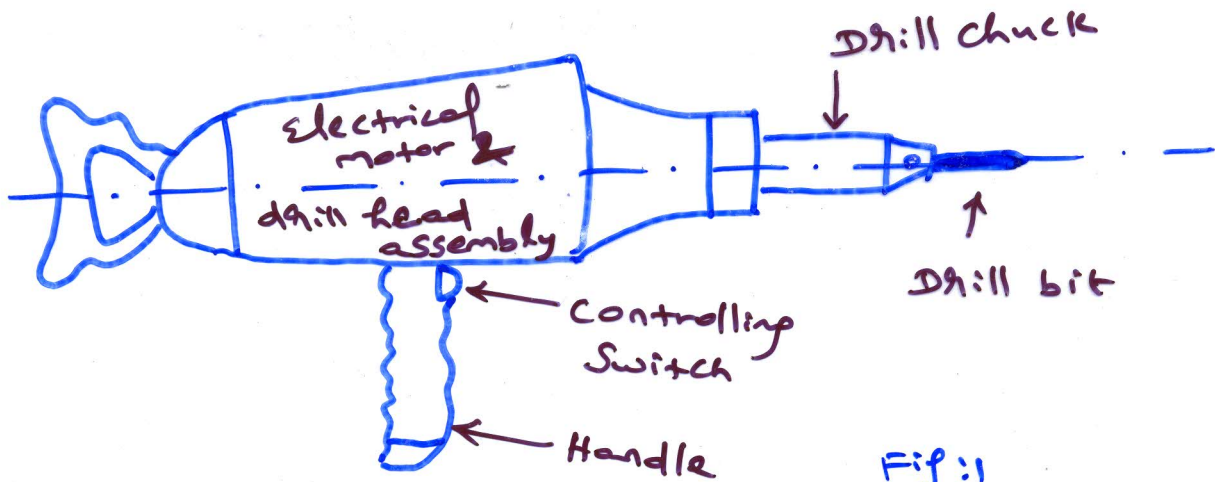


Fig: 1

\* It is small & compact in size & can be taken to anywhere & the holes can be produced on the workpiece in any position.

\* The maximum size of the drill that it can accommodate is not more than 12 to 18mm.

## ② Sensitive drilling machine! —

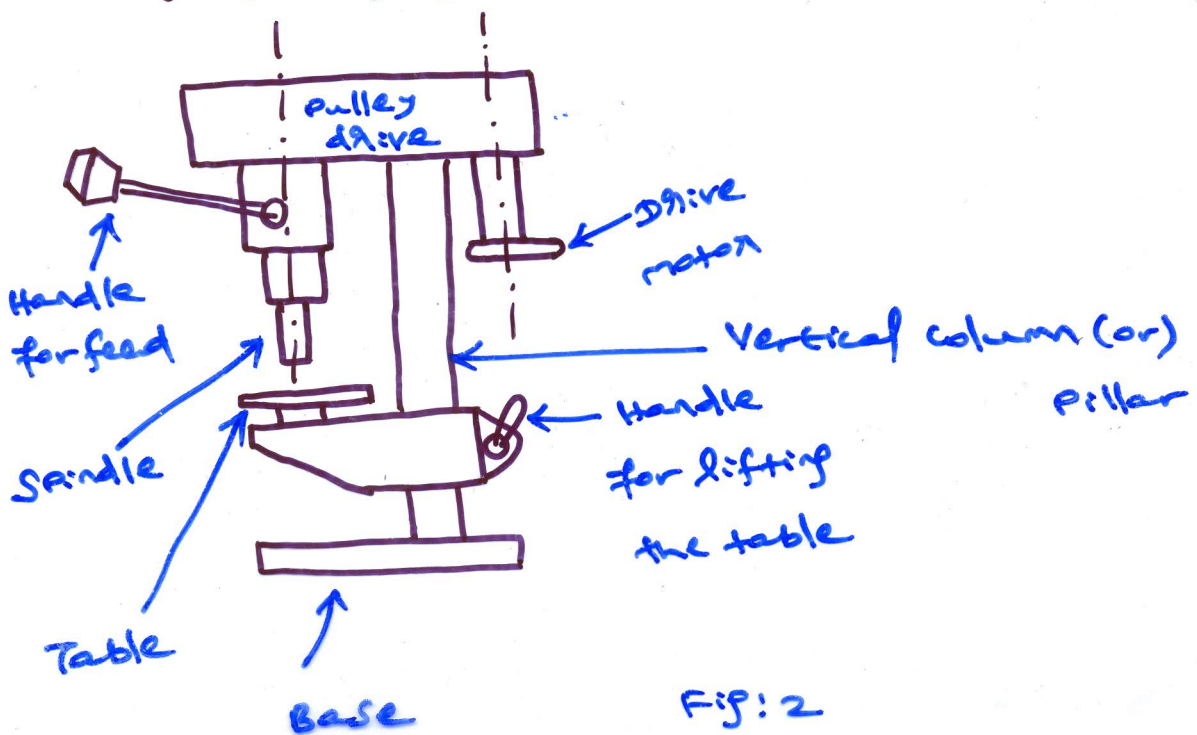


Fig: 2

\* used to produce small holes of dia from 1.5 to 15.5mm at high speed in light jobs.

(60)

\* The base of the machine may be mounted on a bench (or) on the floor.

\* It consists of

① horizontal table mounted on a pillar

② Vertical spindle for holding the drill bit.

③ Vertical column (or) pillar

④ Base ⑤ Mechanisms for driving the vertical spindle

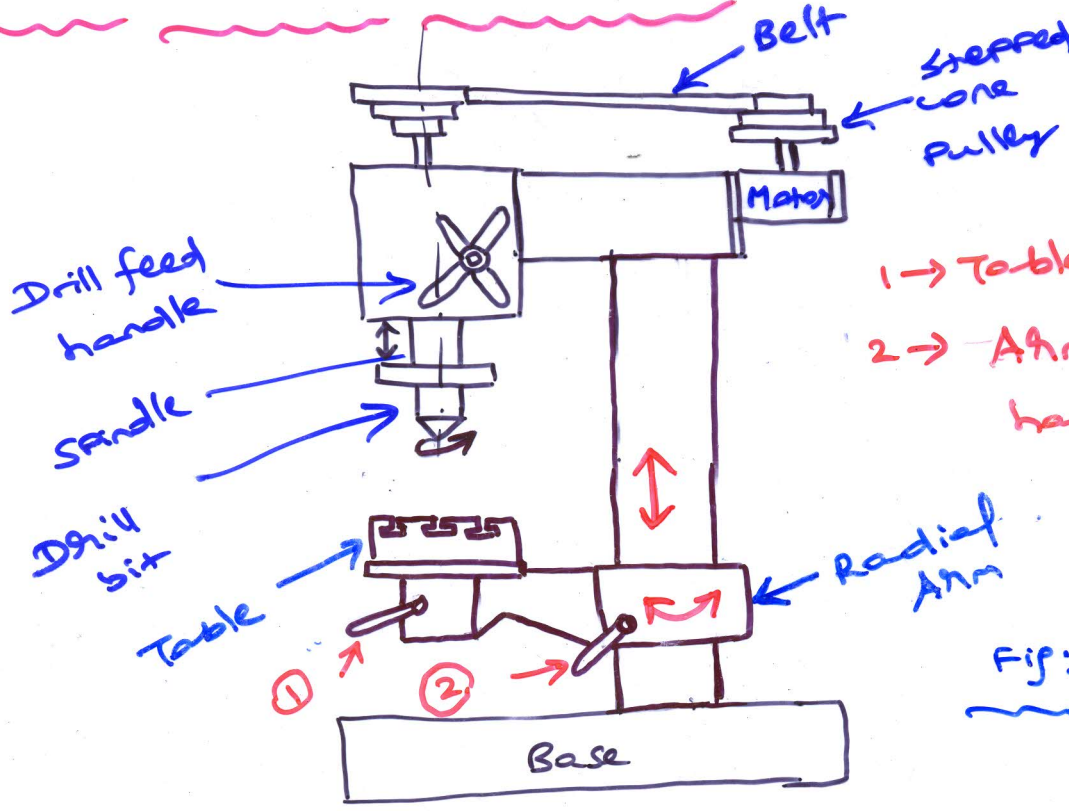
\* The various speed for the spindle is achieved by means of belt & pulley drive.

\* Here, there is no automatic feed. Feed is given manually.

\* Hand feed permits the operator to feel (or) sense the progress of the drill into the work so that if the drill becomes worn-out (or) jams into the work, the pressure on the drill may be released immediately to prevent it from breaking.

\* As the operator senses the cutting action at any instant, it is called "sensitive drilling machine".

Upright (or) Pillar Drilling M/c:-



1 → Table clamp handle  
 2 → Arm. Elevating clamp handle

Fig: 3

Radial Drilling Machine:-

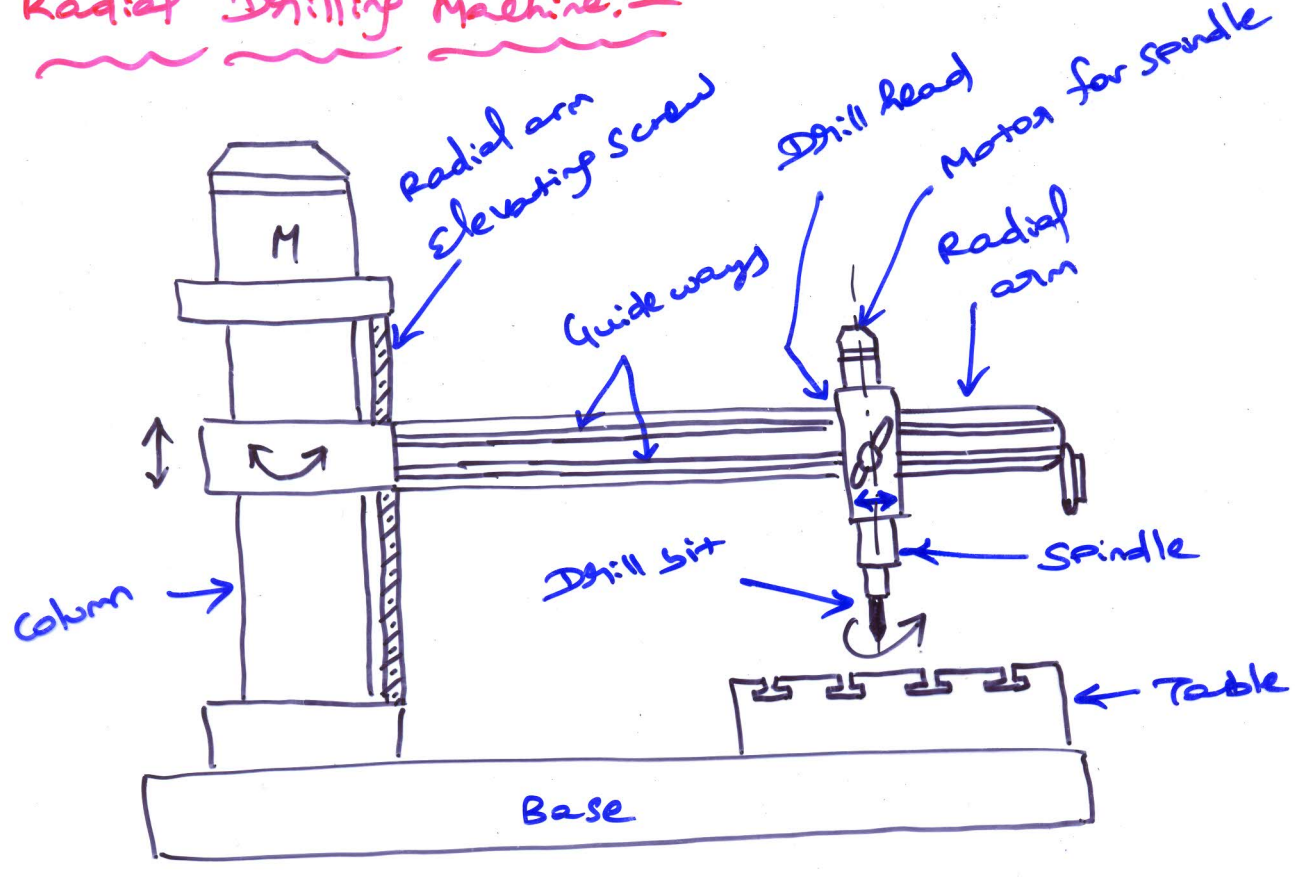


Fig: 4

### ③ Upright drilling machine [ see fig: 3 ] (b2)

- \* Designed for handling medium sized jobs
- \* In construction, it is similar to sensitive drilling machine but it is larger & heavier than sensitive drilling machine & is supplied with power feed arrangement.
- \* A large number of spindle speeds & feeds are available in this machine for drilling different types of work.
- \* The table of the machine have different types of adjustments.
- \* It is mounted on the floor.
- \* It consists of the following parts
  - ① Base
  - ② Vertical column
  - ③ Horizontal arm & the table
  - ④ spindle
  - ⑤ driving mechanisms for spindle

#### ① Base:-

It is a supporting member made up of cast iron. It has T-slots on its top surface for mounting the large workpieces directly on it.

## ② Column:—

(63)

\* Vertical member mounted on the base & carries the Radial arm & table, Spindle & its driving mechanism.

\* It may be of round type (or) Box type.  
(Pillar)

## ③ Radial arm & table:—

\* The table is mounted on a Radial arm which is mounted on a vertical column.

\* It has following movements

- ① The movement of the Radial arm in a vertical direction along the column
- ② The Swivelling movement of the Radial arm around the column upto  $180^\circ$
- ③ The Swivelling of the table about its own center upto  $360^\circ$ .

\* By means of the above movements, the workpiece can be drilled in various positions.

## ④ Spindle:—

\* used to hold the drill bit of various sizes

\* The various speed for the spindle is achieved by Step cone pulley & belt drive.



\* The following feeds are available for Spindle

- ① Sensitive hand feed
- ② Quick traverse hand feed
- ③ Auto-feed.

64

④ Radial drilling machine:- [See: Fig. 4]

\* This drilling machine is intended for medium to large & heavy workpieces.

\* This machine consists of the following parts

- ① Base
- ② Column
- ③ Radial Arm
- ④ Drill head
- ⑤ Spindle Mechanisms.

① Base:-

- \* It is a large rectangular casting
- \* It supports the vertical column & table.
- \* The top surface of the base is accurately machined with T-slots to mount the large size workpieces on it.

② Column:-

- \* This machine consists of heavy, ground, vertical column mounted on a large base.
- \* The column supports a radial arm which can be raised (or) lowered over the column & swung around

Column.

\* An elevating screw is provided on the side of the column to move the radial arm up & down by a motor.

### (3) Radial arm:-

(65)

- \* It is mounted on a vertical column
- \* It can be moved up & down over the column and can be swung around the column.
- \* It supports the drill head.
- \* It has horizontal flat guide ways to move the drill head along a radial arm.
- \* By means of the above movements for a radial arm, the workpiece can be machined at different positions.

### (4) Drill head:-

- \* It is mounted on a radial arm.
- \* It has a mechanism for driving the spindle & moving the drill head along the guide ways of the radial arm.
- \* The drill head has a spindle which carries the drill bit.

## ⑤ Mechanisms for driving the spindle:—

66

\* The different speeds for a spindle is achieved through a gear box.

\* The following feed for the spindle is available

① Sensitive hand feed

② Quick traverse feed

③ Automatic feed.

Radial drilling machine may be classified with respect to the movement of radial arm & tool head.

① Plain type    ② Semi-universal type

③ Universal type.

### ① Plain type:—

The following movements are available for a plain type radial drilling machine

\* Up & down movement of the radial arm over the column.

\* Swivelling movement of the radial arm around the column

\* Movement of the tool head along the radial arm.

## 2) Semi-universal type!

(67)

\* In this type of radial drilling machine, in addition to the above three movements of the plain type radial drilling machine, the drill head can be swung about a horizontal axis perpendicular to the arm.

\* The fourth movement of the drill head permits drilling hole at an angle to the horizontal plane other than the normal position.

## 3) Universal type!

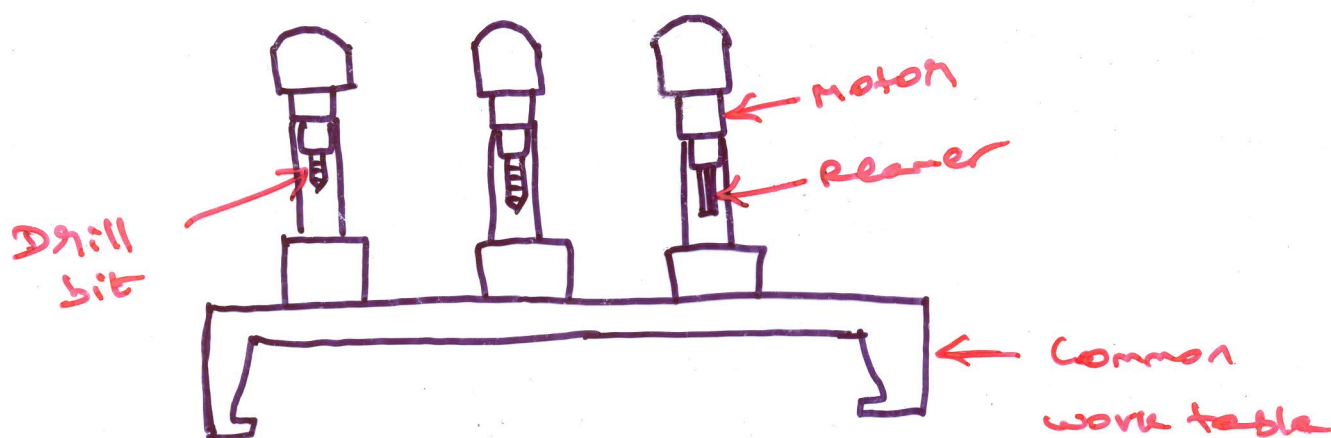
\* In a universal machine, in addition to the above four movements, the arm holding the drill head may be rotated on a horizontal axis.

\* All these five movements in a universal machine enables it to drill a work piece at any angle.

## 5) Gang drilling machine!

\* When a number of single spindle drilling machine columns are placed side by side on a common work table which is mounted on a common base, the machine is known as "Gang drilling machine".

- \* Four to six spindles may be mounted side by side.
- \* In some machines, the drill spindles are permanently placed & in others, the position of the column may be adjusted so that the space between the spindle may be varied. (68)
- \* The speed & feed of the spindles are controlled independently.
- \* This type of machine is specially adapted for production work.
- \* A series of operations may be performed on the work by simply shifting the work from one position to the other on the work table.
- \* Each spindle may be set up properly with different tools for different operations.



### 6) Multiple spindle drilling machine:-

- \* This is used to drill a number of holes in a piece of work simultaneously & to reproduce

the same pattern of holes in a number of identical pieces in a mass production work.

(69)

\* It has several spindles driven by a single motor & all the spindles holding drills are fed into the work simultaneously.

\* Feeding motion is usually obtained by raising the table (or) lowering the tool head.

\* The center distance b/w the spindles can be varied based on the different operations required.

### ⑦ Automatic drilling machine:-

\* It can perform a series of machining operations at successive units and transfer the work from one unit to the other unit automatically.

\* Once the work is loaded at first machine, the work will move from one machine to the other where different operations are done and the finished work comes out from the last unit without any manual handling.

\* It is used purely for production purposes.

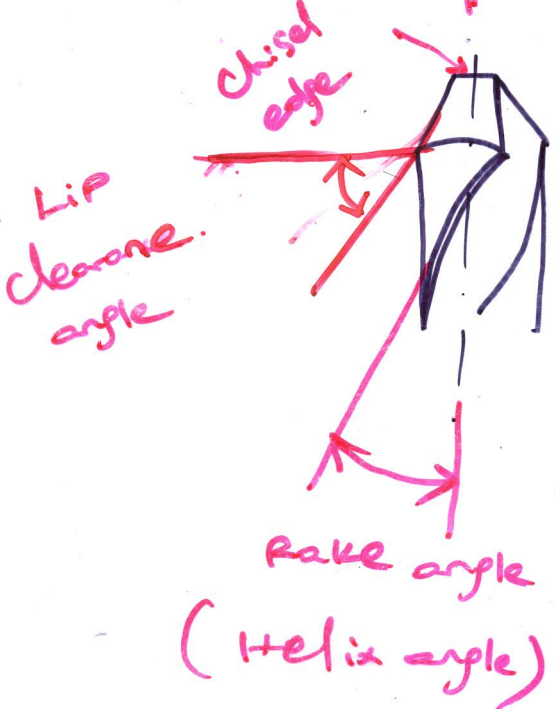
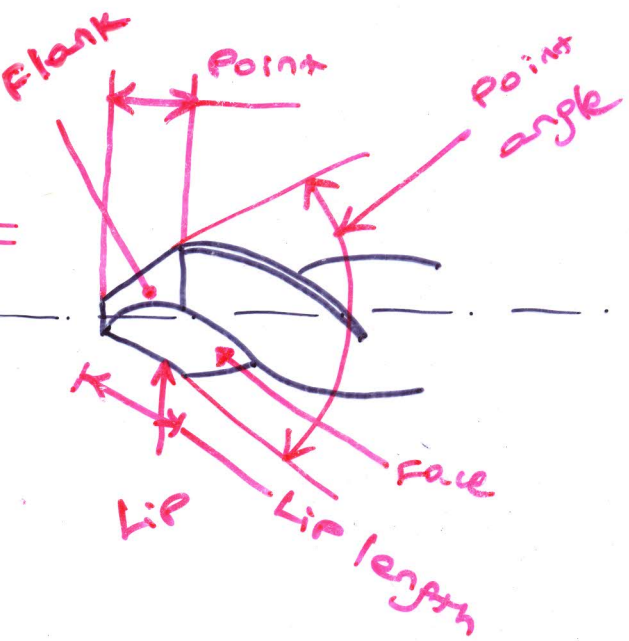
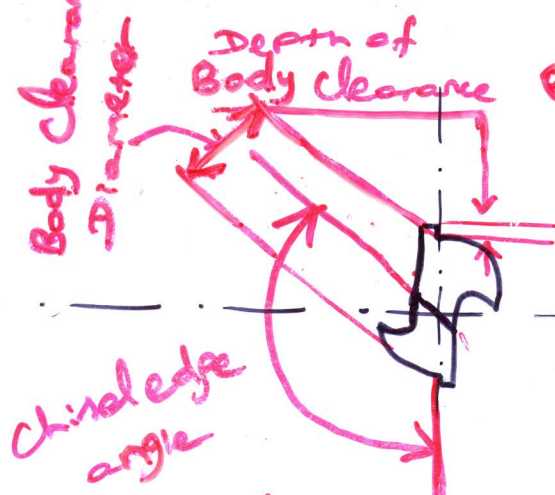
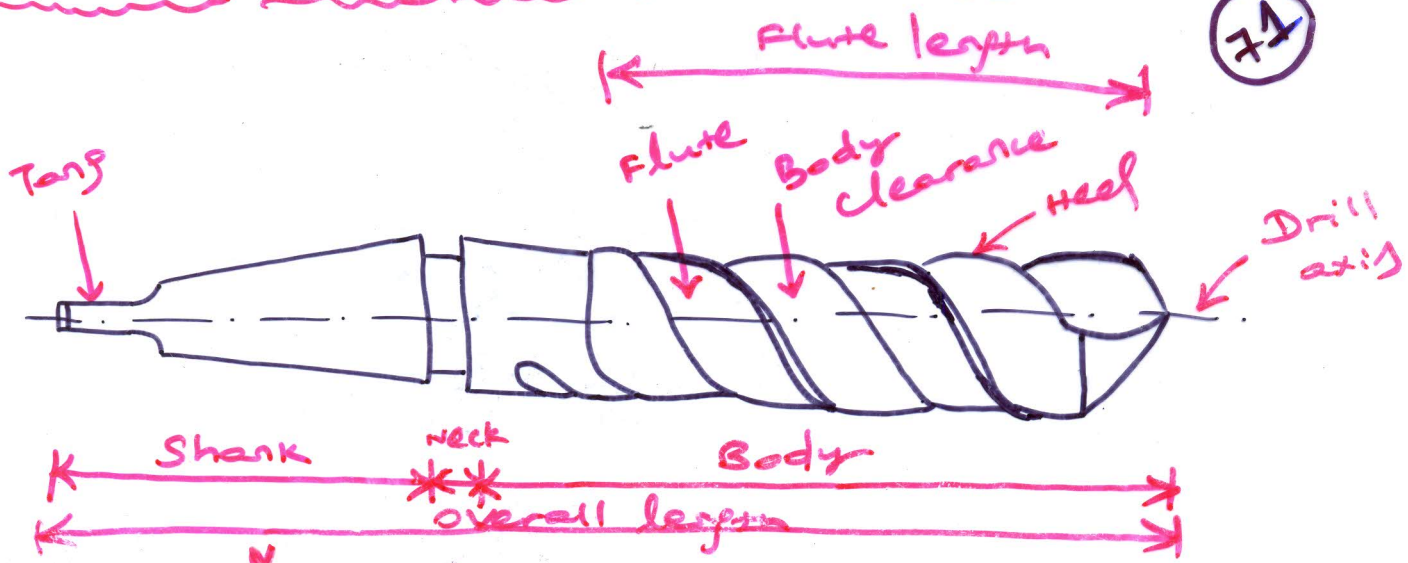
## Deep hole drilling:-

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- \* Deep hole drilling is the operation of making a deep holes in a long shaft such as rifle barrels, Crank shaft etc.   
 of  $L/D$  ratio from 6-30.
- \* Deep hole drilling machines is operated at high speed & low feed.
- \* Sufficient quantity of lubricant is pumped to the cutting points for removal of chips and cooling the cutting edges of the drill.
- \* A long shaft is usually supported at several points to prevent any deflection.
- \* Here, the work is usually rotated while the drill is fed into the work. This helps in feeding the drill in a straight path.
- \* In some machine, both the drill & the work are rotated for accurate location.
- \* The machine may be horizontal (or) vertical type.
- \* In some machines, step feed is applied. The drill is withdrawn automatically each time when it penetrates into the work equal to its diameter. This process permits the chip to clear out from the work.

# Drill Tool [Twist Drill] Nomenclature!

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- ① Point angle - 118°
- ② Helix (or) rake angle  
30° - 45°
- ③ chisel edge angle - 120° - 135°
- ④ Lip clearance angle - 12°



① Axis:- the longitudinal center line of the drill.

② Body:-

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Portion of the drill extending from its extreme point to the commencement of the neck

③ Shank:-

Portion of the drill by which it is held into the spindle & driven. The most common types of shank are the taper shank & the straight shank.

④ Tang:-

The flattened end of the taper shank intended into a drift slot in the spindle. The tang ensures positive drive of the drill from the drill spindle.

⑤ Neck:-

The diametrically undercut portion between the body and the shank of the drill. Diameter and other particulars of the drill are engraved at the neck.

⑥ Flutes:-

It denotes the grooves in the body of the drill.

the function of the flutes are

(73)

- ① To form the cutting edges of the drill
- ② To allow the chips to escape
- ③ To cause the chips to curl
- ④ To permit the cutting fluid to reach the cutting edge

⑦ Flank:-

It denotes the surface on the drill point.

⑧ Face:-

The portion of the flute surface in the point of the drill. The chip impinges on the face as it is cut from the work.

⑨ Lip (cutting edge):-

The edge formed by the intersection of flank & face.

⑩ Chisel edge:-

The edge formed by the intersection of the flanks. It is sometimes called "Dead Center". A great amount of axial thrust is required to cut a

hole by a chisel edge.

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(11) Body clearance:-

The portion of the body surface which is reduced in diameter to provide diametral clearance.

(12) Heel:-

The edge formed by the intersection of flute surface & the body clearance.

(13) Lands:-

The cylindrically ground surface on the edges of the drill flutes.

(14) Heel:-

The edge formed by the intersection of body clearance & the flute.

(15) Point:-

The sharpened end of the drill, which is shaped to produce lips, faces, flanks and chisel edge.

## (16) Drill angles:-

(75)

Following are the drill angles which are ground on a twist drill for efficient removal of metal.

- ① Chisel edge angle
- ② Helix angle (or) rake angle
- ③ Point angle
- ④ Lip clearance angle

### Chisel edge angle:-

The obtuse angle included b/w the chisel edge & the lip as viewed from the end of the drill. It varies from  $120^\circ$  to  $135^\circ$ .

### Helix angle (or) Rake angle:-

\* It is the angle formed by the leading edge of the land with the axis of the drill.

\* The usual angle of the rake =  $30^\circ - 45^\circ$

### Point angle:-

\* It is the angle included between the two lips. The usual point angle is  $118^\circ$ , but for harder steel alloys, the angle increases.

## Lip clearance angle:-

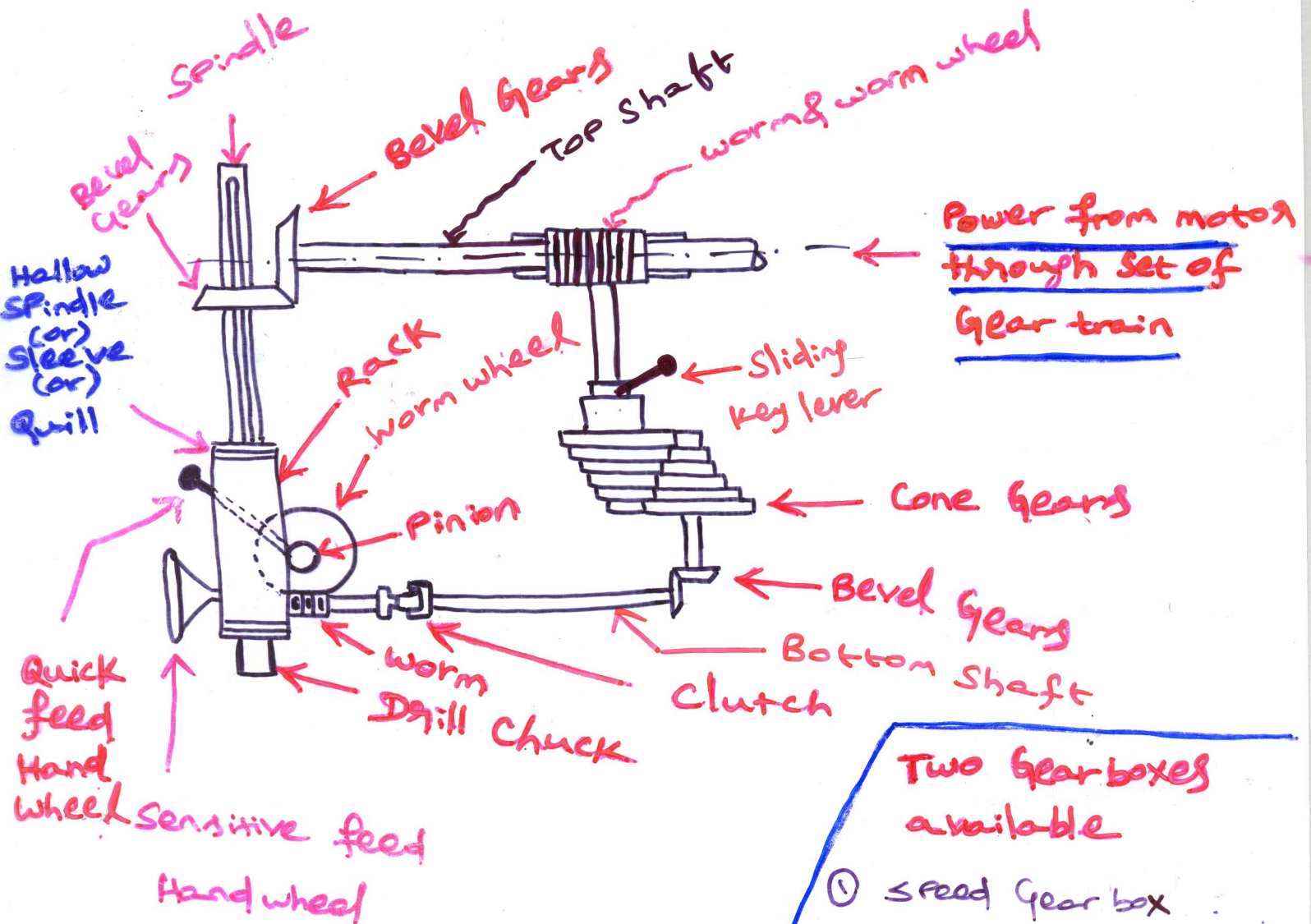
(76)

The angle formed by the lip and a plane at right angle to the drill axis. The clearance angle is  $12^\circ$  in most cases.

## Specification of Drilling machine:-

- ① Maximum Size of the drill in mm that the machine can hold.
- ② Table Size in Square meter.
- ③ Maximum Spindle travel.
- ④ Number of Spindle speeds & range of speeds in R.P.M
- ⑤ Number of auto Spindle feed & feed range in mm/rev
- ⑥ Morse taper number of the drill Spindle taper portion
- ⑦ Power input of the machine in H.P
- ⑧ Floor Space Required in Square meter
- ⑨ Net weight of the machine in Tonne

Quill Mechanism (or) Feed Mechanism :-



Two Gearboxes available

- ① Speed Gear box
- ② Feed Gear box

there are 3 types of feed which can be obtained in drilling machine

- ① Automatic feed for Spindle
- ② Sensitive Hand feed
- ③ Quick traverse Hand feed.

## ① Auto feed for Spindle:

(78)

\* The automatic feed is applied while drilling large diameter holes as the cutting pressure required is sufficiently great.

\* The power from the top shaft is transferred to the six speed feed box through worm & worm wheel.

\* In the feed box,

① Six gears mounted on the worm gear shaft are constantly in mesh with another six gears mounted on the driven shaft.

② Gears on the driven shaft are all keyed to the shaft & rotate with it.

③ Gears on the worm gear shaft are all free to rotate, but may be keyed to the shaft by a sliding key only by one gear at a time.

\* When the sliding key is in the first gear, the motion is transmitted to the driven shaft from the first gear. Other gears on the worm shaft revolve freely with their mating gear on the driven shaft.

\* Thus Six different Speed for the driver Shaft are obtained by Sliding the key to engage with Six different gears on the worm gear shaft.

(79)

\* The motion from the driver shaft is transmitted to the bottom shaft through a set of bevel gears.

\* The worm at the end of the bottom shaft receives the power by a clutch on the bottom shaft.

\* When the worm at the end of the bottom shaft rotates, the worm wheel meshing with that also rotates. At the end of this worm wheel shaft, there is a pinion. This pinion meshes with the rack which is bolted to the quill (or) spindle.

\* The rotation of the pinion causes the quill to move up & down giving spindle feed.

## (2) Sensitive Hand feed:—

\* When the sensitive hand feed is applied, the clutch is disconnected.

\* The sensitive hand feed wheel is attached to the gear end of the bottom shaft.



\* So, the rotation of the sensitive hand wheel will cause the worm & worm gear to rotate and a slow but a sensitive feed is obtained.

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### ③ Quick traverse hand feed:-

\* Quick traverse hand feed is obtained by rotating quick traverse hand wheel which is attached with pinion

\* One turn of the quick traverse hand wheel will cause the pinion to rotate through one complete revolution giving quick hand feed movement of the spindle.

\* Clutch should be disengaged when giving the quick traverse hand feed.

# Methods of mounting (or) holding the drill bit

## into the spindle (or) tool holding devices

81

- ① By directly fitting in the spindle
- ② By using sleeve
- ③ By using socket
- ④ By using Drill Chuck.

### ① Directly holding the tool:-

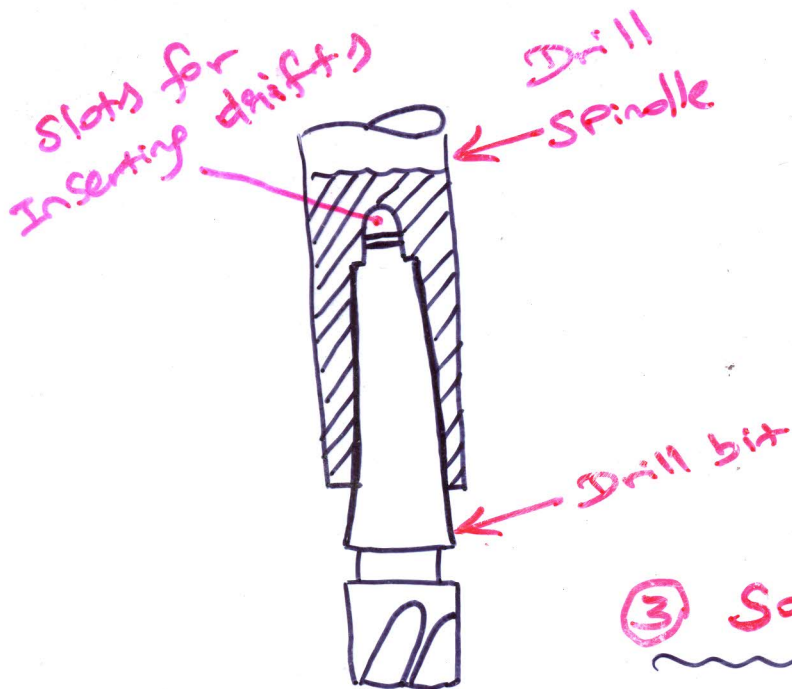


Fig:1

Drift



### ③ Socket

### ② Sleeve:-

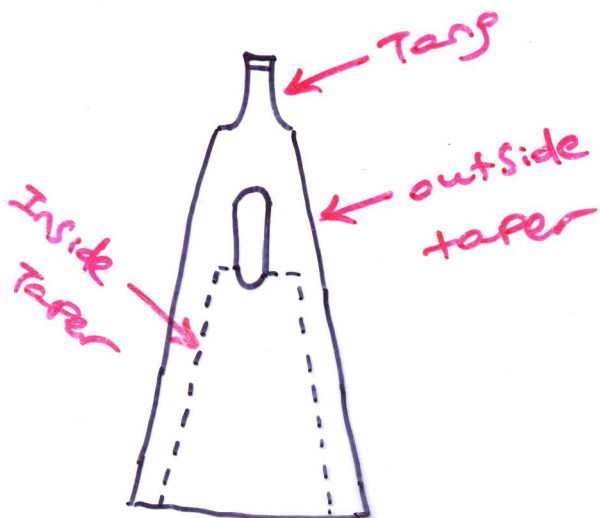


Fig:2

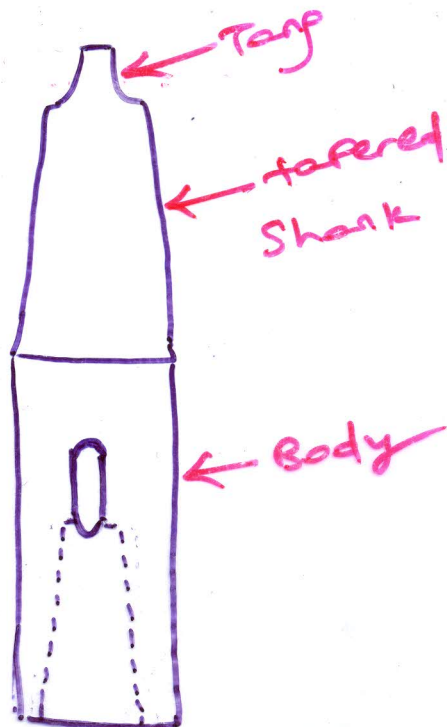
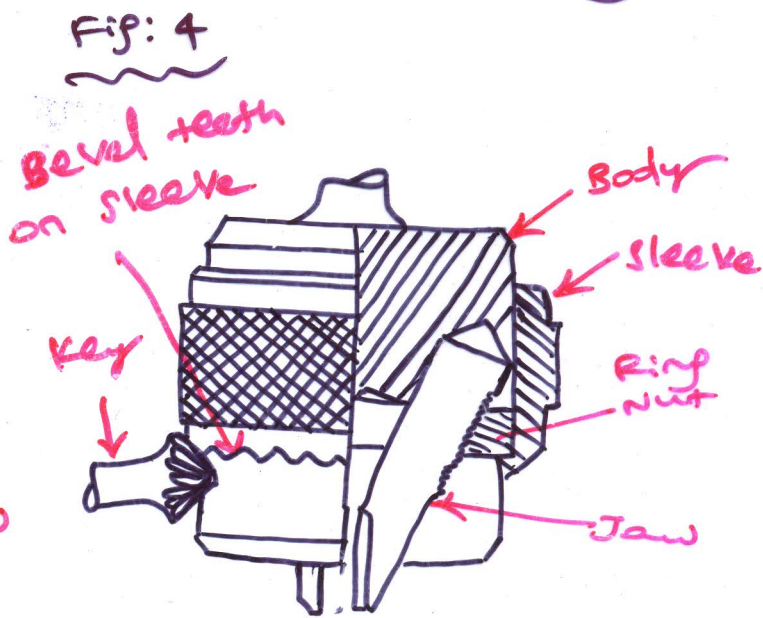
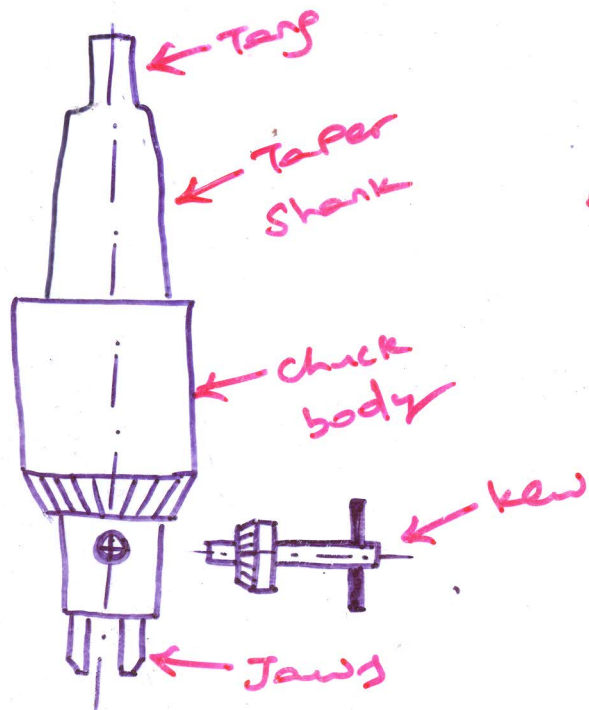


Fig:3

# Drill Chuck:-

82



Directly holding the tool:- [ see fig:1 ]

\* All general purpose drilling machine have the spindle bored out to a standard taper to receive the taper shank of the tool.

\* The taper used in the drill spindle is usually **Morse standard taper** which is approximately 1:20.

\* While fitting the tool, the shank is forced into the tapered hole & the tool is gripped by friction.

\* The tool may be rotated with the spindle by friction between the tapered surface of the spindle

and Shank of the tool; but to ensure a positive drive, the tang (or) tongue of the tool fits into a slot at the end of the taper hole of the spindle.

\* The tool may be removed by pressing a tapered wedge known as drift into the slotted hole of the spindle.

(83)

\* It can be noted that the spindle should not be affected while the drift is pushed to take out the drill bit. Usually a mallet should be used in stead of a hammer.

Sleeve :- [ Fig: 2 ]

\* The drill spindle is suitable for holding only one size of the Shank.

\* If the taper Shank of the tool is smaller than the taper in the spindle hole, a taper sleeve is used.

\* The outside taper of the sleeve conforms to the drill spindle taper and the inside taper of the sleeve holds the Shank of the smaller size tools.

\* The sleeve has a flattened end (or) tang which fits into the slot of the spindle.

\* The tang of the tool fits into the slot provided at the end of the taper hole of the sleeve.

\* The tool from the sleeve & the sleeve from the spindle may be removed by forcing the drift into the corresponding slot by a mallet. (84)

\* Different sizes of tool shanks may be held in the spindle by using different sizes of sleeve

\* The taper on the outer surface of the sleeve doesn't change but the inner taper surface varies with different sizes of the tool shanks.

### ③ Socket :- [see fig: 3]

\* When the tapered tool shank is larger than the spindle taper, drill sockets are used to hold the tool. Drill sockets are much longer in size than the drill sleeves.

\* The tapered shank of the socket conforms to taper hole of drill spindle & fits into it.

\* The body of the socket has a taper hole larger than the drill spindle taper into which the taper shank of any tool may be fitted.

④ Three jaw self centering Chuck: - [ See fig: 4 ]

\* This type of chuck is particularly adapted for holding the tools having straight shanks.

85

\* Three slots are cut  $120^\circ$  apart in the chuck body which houses three jaws having threads cut at the back that meshes with a ring nut.

\* The ring nut is attached to the sleeve.

\* Bevel teeth are cut all round the sleeve body

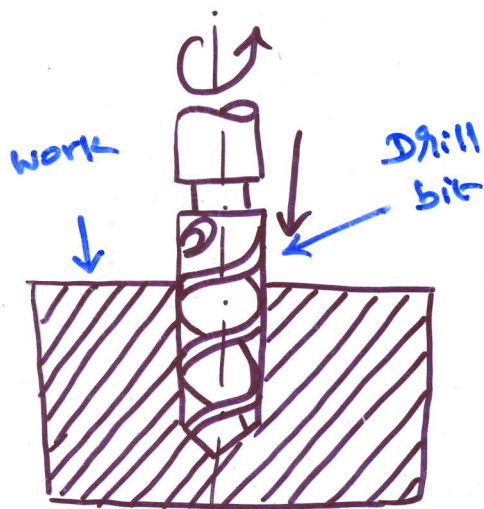
\* The sleeve may be rotated by rotating a key having bevel teeth cut on its face which meshes with the bevel teeth on the sleeve.

\* The rotation of the sleeve causes the ring nut to rotate in a fixed position and all the three jaws will move simultaneously by the same amount. and hold the drill bit having straight shanks.

## Drilling Machine operations!-

- ① Drilling
- ② Reaming
- ③ Boring
- ④ Counter Boring
- ⑤ Counter Sinking
- ⑥ Spot facing
- ⑦ Tapping
- ⑧ Lapping
- ⑨ Grinding
- ⑩ Trepanning.

## Drilling:-



\* Drilling is the operation of producing a cylindrical hole by feeding the rotating drill into the work piece.

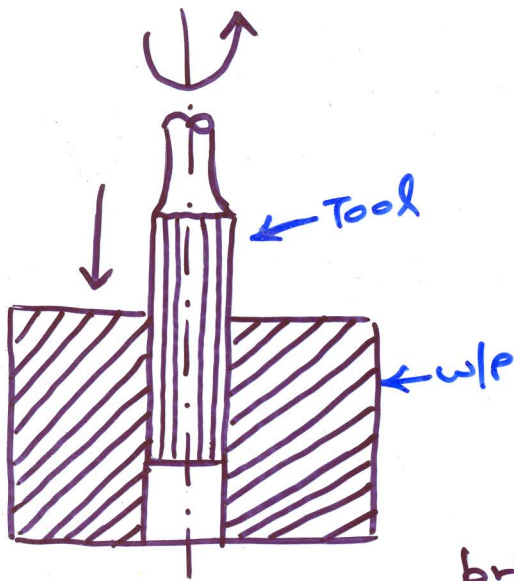
\* Before drilling, the center of the hole is located on the w/p by drawing two lines at right angle to each other & the center punch is used to produce

an indentation at the center. The drill point is pressed at this center point to produce the required hole.

\* Drilling does not produce an accurate hole in a work piece and the hole so generated by drilling becomes rough and the hole is always slightly over size than the drill used due to the vibration of the spindle & drill.

\* A 12mm drill may produce a hole which 0.125mm over size  
A 22mm drill may produce a hole which 0.5mm over size

## Reaming:-



\* It is the operation of sizing & finishing a hole which has been already drilled. The tool used for this operation is called as "Reamer" (or) "Reaming tool".

\* In order to finish a hole & to bring it to the accurate size, the

hole is drilled slightly under size.

\* The spindle speed is made half of the speed for drilling operation & auto feed may be given.

\* Reaming tool (or) Reamer has multiple cutting edges and it does not originate a hole. It simply follows the path which has been already drilled and removes a very small amount of metal.

\* For this reason, a reamer cannot correct a hole.

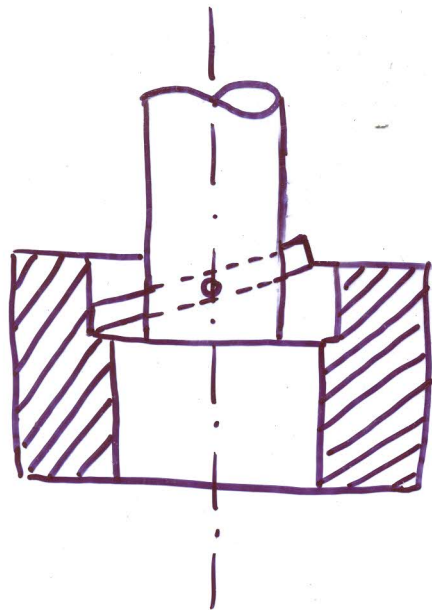
\* The material removed by this process is around 0.375 mm.

## Boring:-

\* It is the operation of enlarging the already drilled hole by an adjustable cutting tool with only one cutting



edge called "Boring tool".

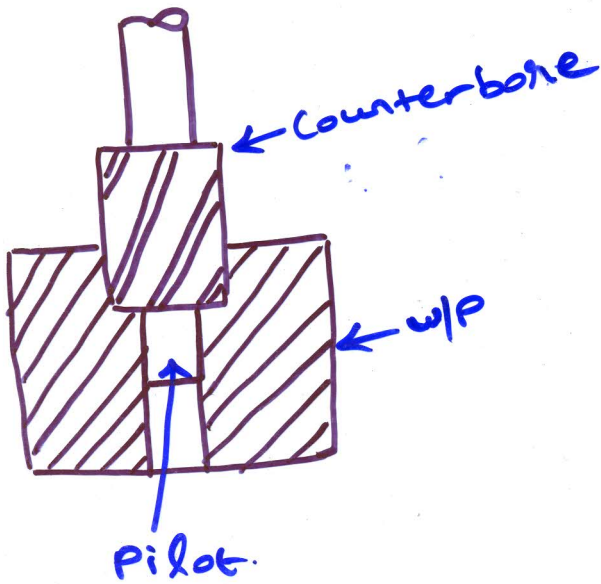


\* Boring operation is performed in a drilling machine for the following reason.

- ① To enlarge a hole by an adjustable cutting tool with only one cutting edge. This is necessary where suitable sized drill is not available.
- ② To finish a hole accurately & to bring it to the required size.
- ③ To machine the internal surface of a hole already produced in the casting.
- ④ To correct out of roundness of a hole.
- ⑤ To correct the location of the hole as the boring tool follows an independent path with respect to the hole.

- \* Here the cutting tool is held in a boring bar which has a taper Shank to fit into the Spindle Socket.

### Counter boring! -



- \* It is the operation of enlarging the end of a hole cylindrically.

- \* The enlarged hole forms a square shoulder with the original hole. It is necessary in some cases to accommodate the heads of bolts, studs, pins etc.,

- \* The tool used for counterboring operation is called as Counter bore. It is made with tapered (or) straight shank to fit into the drill spindle. The cutting edges may be straight (or) spiral teeth.

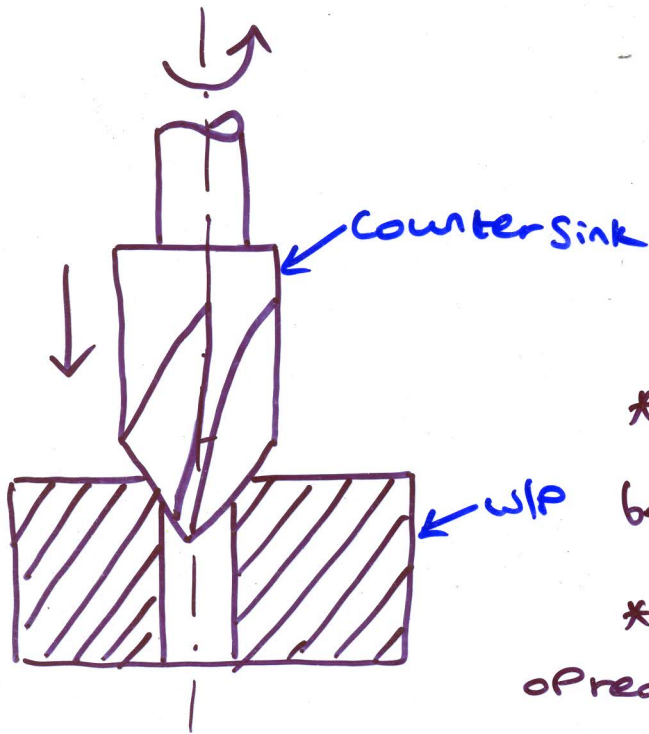
- \* The tool is guided by a pilot which fits into the small diameter hole having running clearance & maintains the alignment of the tool.

- \* These pilots may be interchanged for enlarging different sizes of holes.

### Counter Sinking! -

It is the operation of making cone-shaped

enlargement of the end of the hole to provide access for a flat head screw (or) counter sunk rivet.

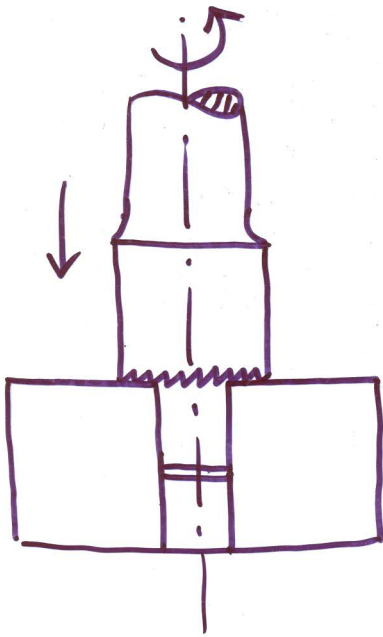


\* The tool used for counter sinking operation is called a counter sink.

\* Standard counter sinks have  $60^\circ$ ,  $82^\circ$  (or)  $90^\circ$  included angle.

\* The cutting speed for this operation is 25% less than that of drilling.

### Spot facing:-

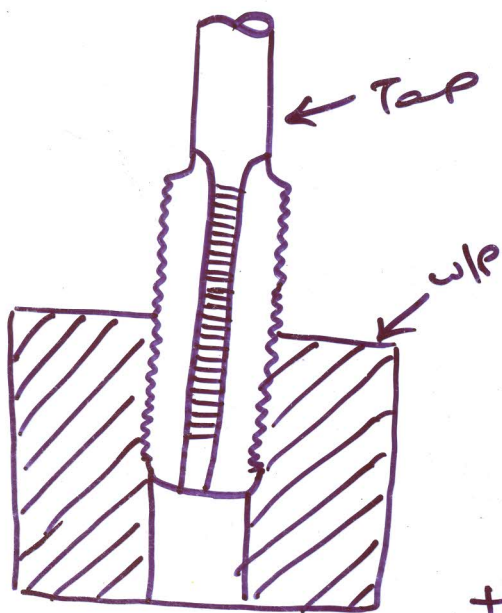


\* It is the operation of smoothing and squaring the surface around a hole for the seat for a nut (or) the head of screw.

\* A counter bore (or) special spot facing tool may be employed for this purpose.

### Tapping:-

It is the operation of cutting internal threads into the already drilled hole by means of a cutting tool called a "tap".



\* A tap may be considered as a bolt with accurate threads cut on it.

\* The threads act as cutting edges which are hardened and ground.

\* When the tap is screwed into the hole, it removes metal and cuts internal threads which will fit into the external threads of the same size.

### Tap drill size:-

\* As the size of the thread is the outside diameter of the threads, the drilled hole must be smaller than the tap by twice the depth of the thread.

\* Tap drill size may thus be derived from the following

formula

$$D = T - 2d$$

$D \rightarrow$  Dia of drilled hole

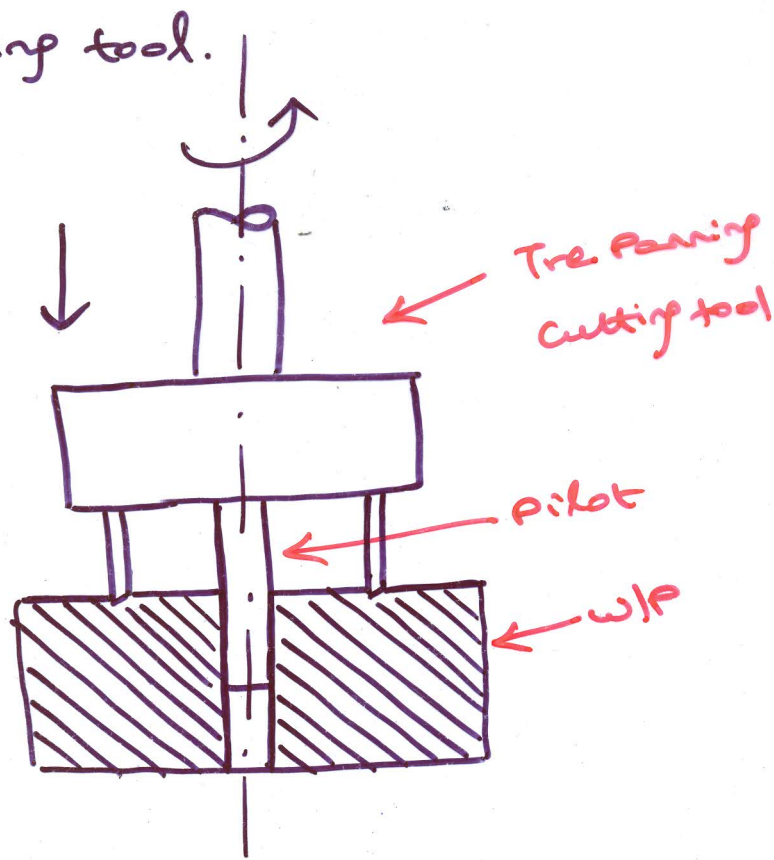
$T \rightarrow$  Dia of tap

$d \rightarrow$  depth of thread of the tap

### Trepannings:-

\* It is the operation of producing a hole by removing the metal along the circumference of the

hallow cutting tool.



\* It is performed for producing bigger holes

\* Fewer chips are removed when machining.

\* Tre-panning operation are done at higher speeds.

\* This is one of the efficient method for producing a bigger hole

Feed, Cutting Speed, depth of cut of a drilling

operation:-

Cutting Speed:-

It denotes the peripheral speed of a cutting point on the surface of the drill in contact with work

$$V = \frac{\pi d n}{1000} \text{ m/min}$$

$V \rightarrow$  cutting speed

$d \rightarrow$  dia of the drill in mm

$n \rightarrow$  rpm of the drill

### Feed:-

It denotes the distance the drill moves into the work at each revolution of the spindle. It is expressed in mm/rev (or) mm/min.

The feed per minute can be calculated as

$$S_m = S_f \times n$$

$S_m =$  feed in mm/min

$S_f =$  feed in mm/rev

$n =$  r.p.m of the drill.

### Depth of cut:-

Depth of cut is generally taken as one-half of drill diameter

$$t = \frac{d}{2} \quad t = \text{depth of cut in mm.}$$

## Machining time in drilling: -

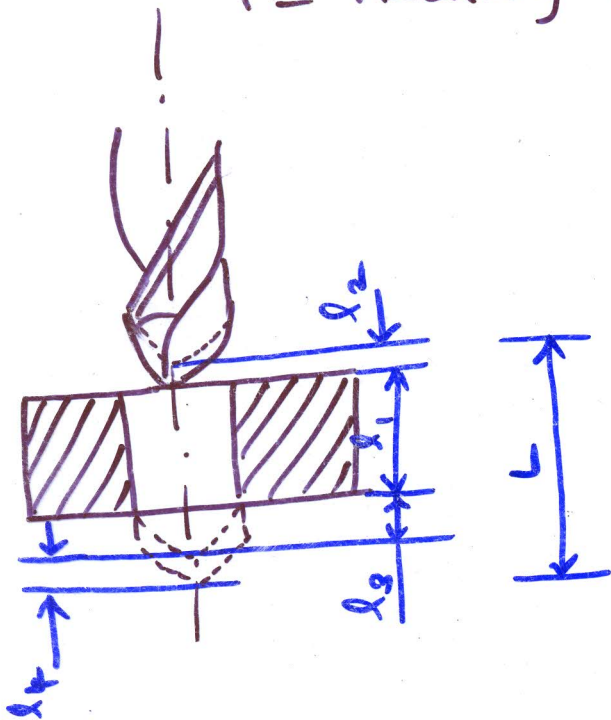
$$T = \frac{L}{n \times S_n} \text{ min}$$

$n$  = r.p.m of the drill

$S_n$  = feed of the drill in mm/rev

$L$  = Length of travel of drill in mm

$T$  = Machining time in min.



$$L = l_1 + l_2 + l_3 + l_4$$

where

$l_1$  = length of the w/p

$l_2$  = Approach of the drill

$l_3$  = length of the drill

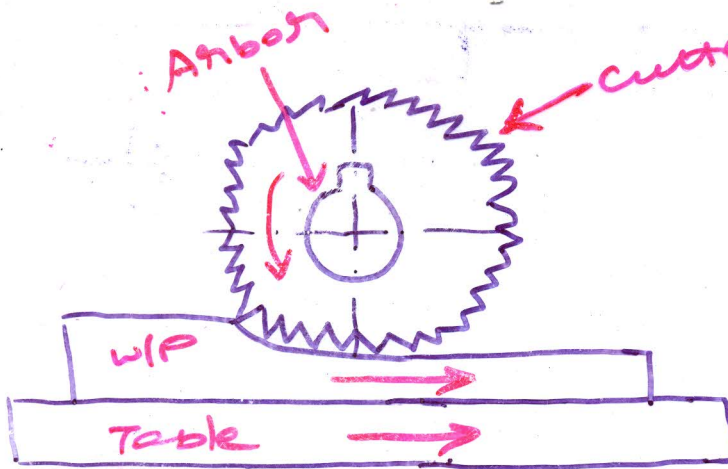
Point (0.29d)

$l_4$  = over travel.

# MILLING

①

## Principle of operation:-



\* feed:-

longitudinal, cross,  
vertical feed.

\* More life to the cutting  
edge.

## Classification of milling m/c:-

- ① Column & knee type
  - Plain (or) Horizontal
  - Vertical
  - Ram type
  - Universal
  - Omniuniversal milling m/c's
- ② Bed-type milling m/c
  - (a) Simplex milling m/c
  - (b) Duplex milling m/c
  - (c) Triplex milling m/c
- ③ Plane type milling machine
- ④ Special purpose milling machine

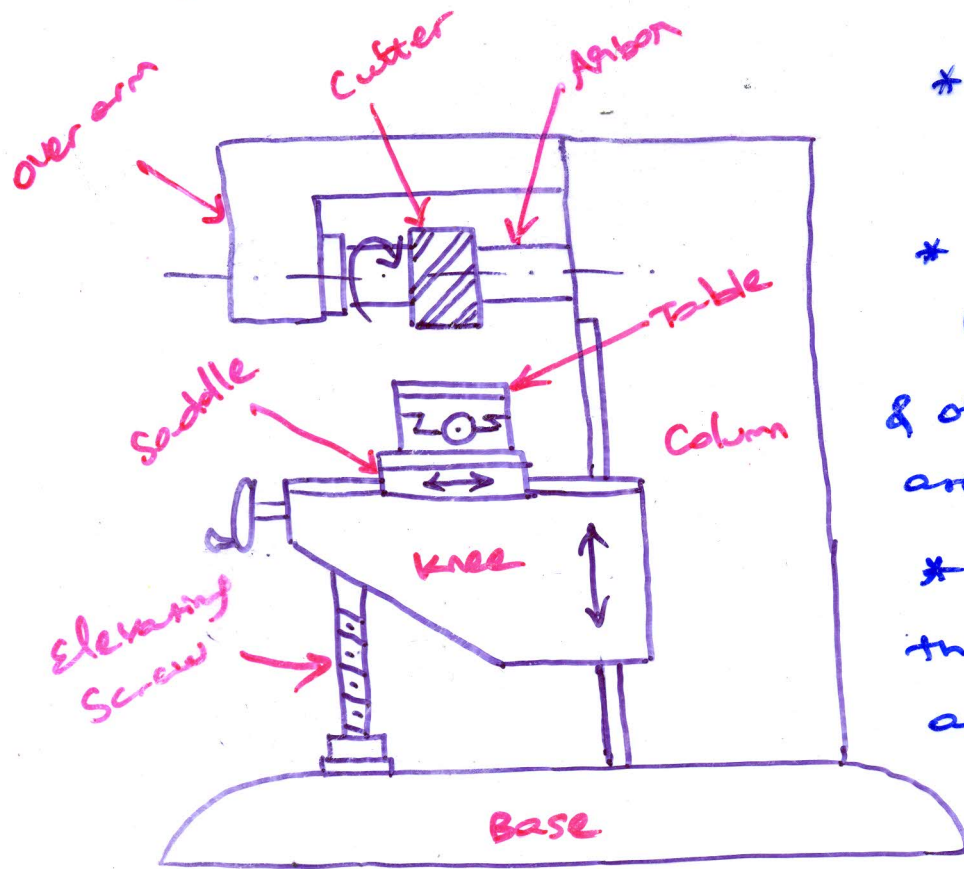
(a) Rotary table milling machine

(b) Drum milling machine

(c) Profile milling machine.



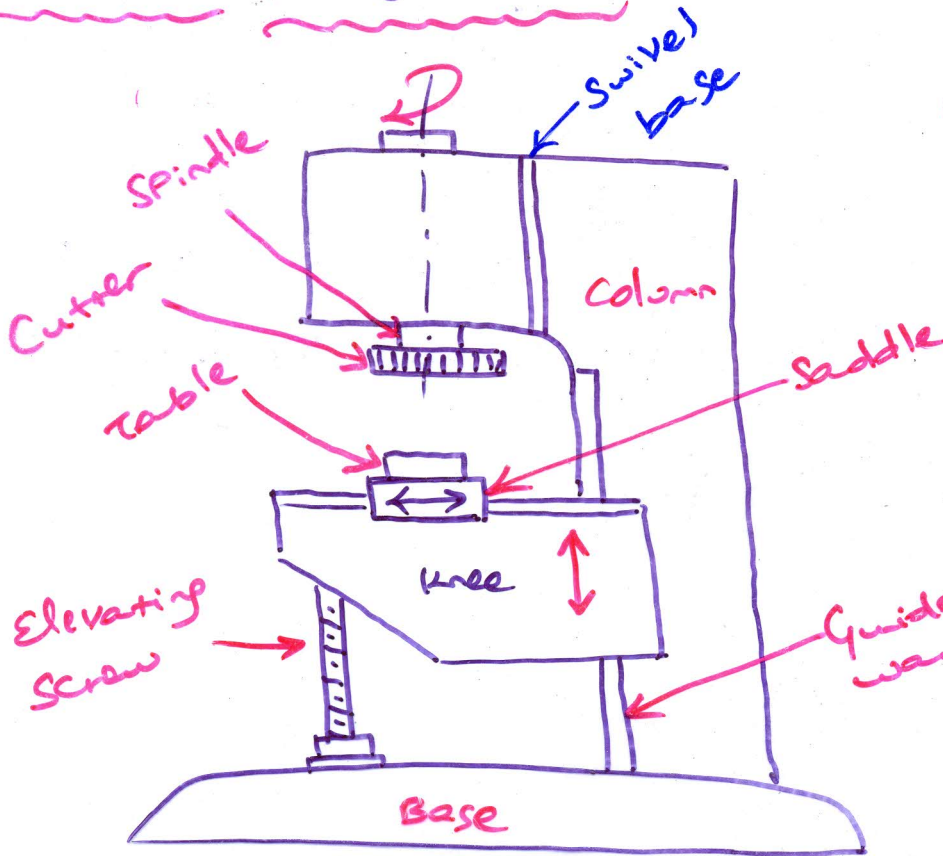
① Plain (or) Horizontal milling machine:-



②

- \* Base made of grey C.I. serves as reservoir for cutting fluid.
- \* Column supports & guides the knee. Motor & other driving mechanisms are housed in it.
- \* Overarm supports the outer end of the arbor to prevent it from bending.

② Vertical milling machine:-



Common feeds

- ① Longitudinal by table
- ② cross by saddle
- ③ Vertical by knee
- ④ Rotation of Spindle

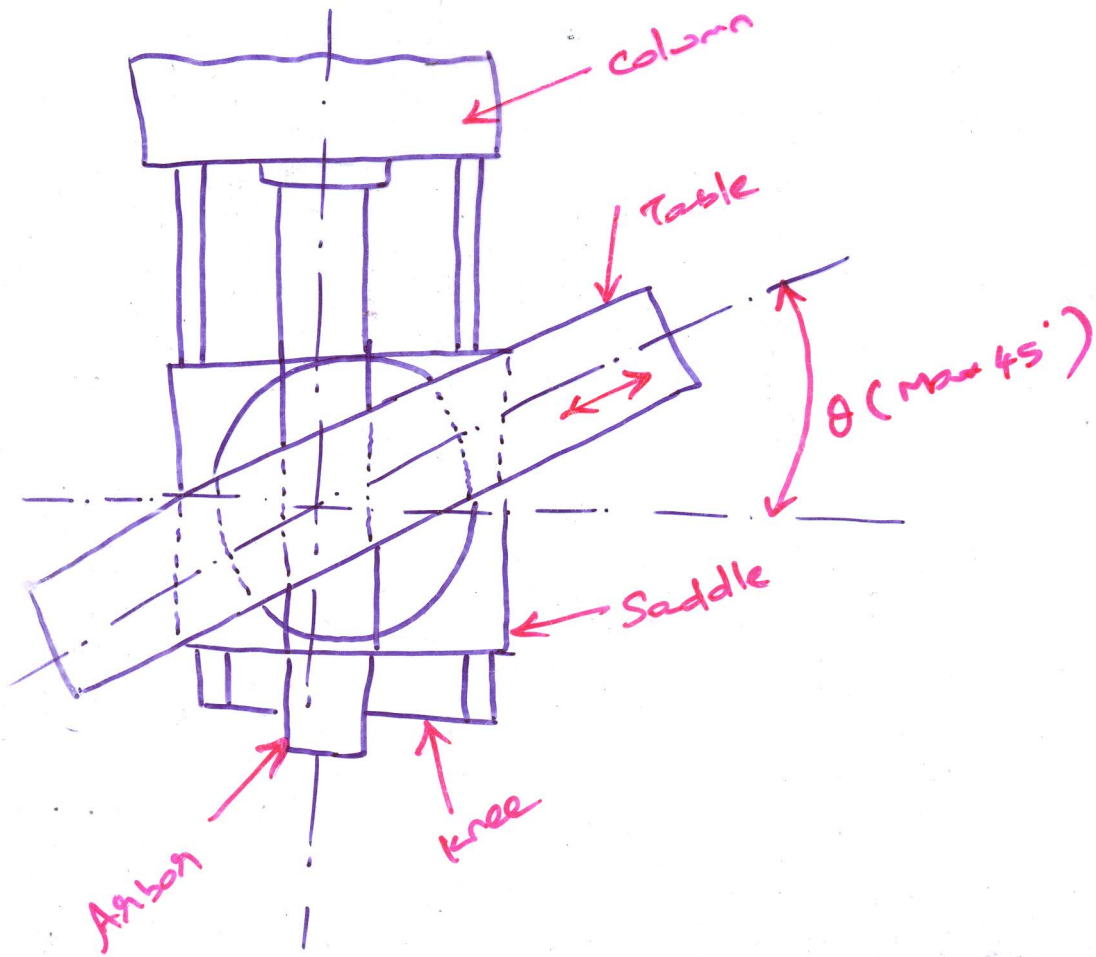
with this mechanism, the spindle head can be swivelled at an angle.

\* Mainly used for end milling and face milling operations.

Power feed - Saddle & Table

# Universal Milling Machine:-

(3)

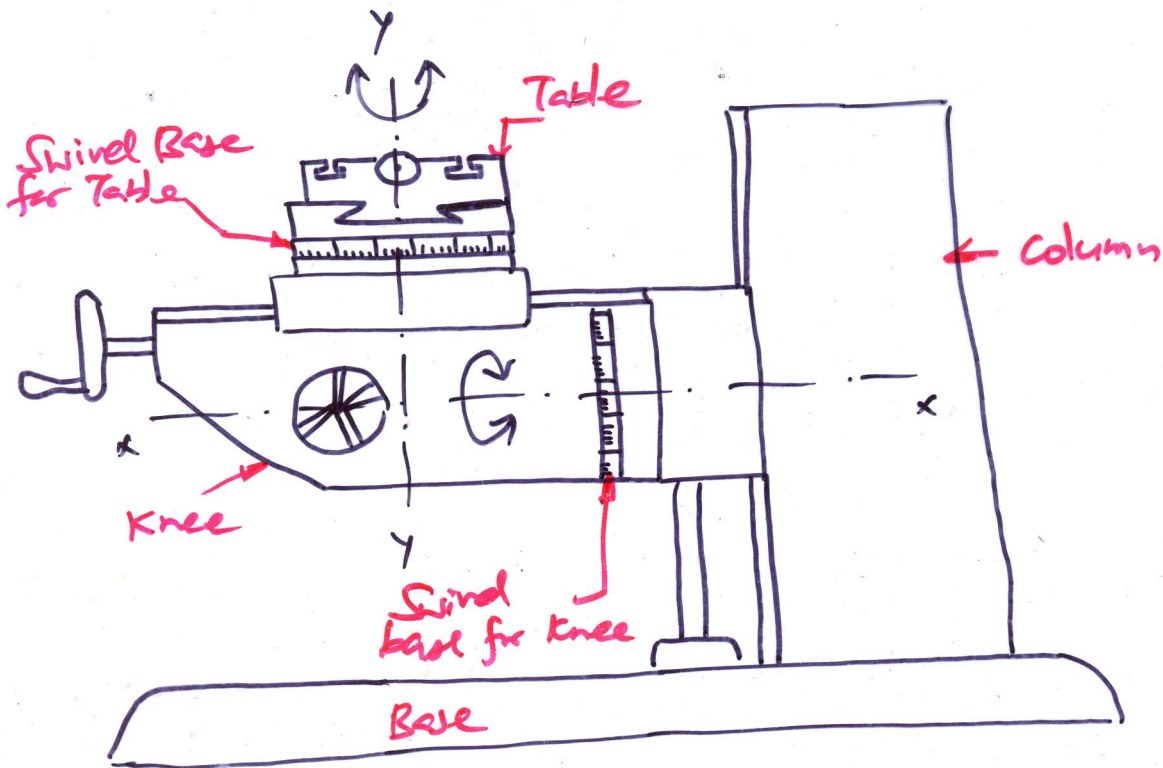


## Comparison b/w Plain & Universal milling machine:-

- ① Table movements
- ② Plain milling m/c → Spur Gears, Splined Shafts, making a round rod into square, pentagon, hexagonal shaped block by using dividing head, Horizontal milling, Side face milling etc.,
- Universal milling m/c → with all the ops done on plain milling m/c, Helical gears, Spiral bevel gears, twist drills, reamers, milling cutters, all types of milling, drilling, Shaping ops

## Omniuniversal Milling m/c:-

(4)



### Applications:-

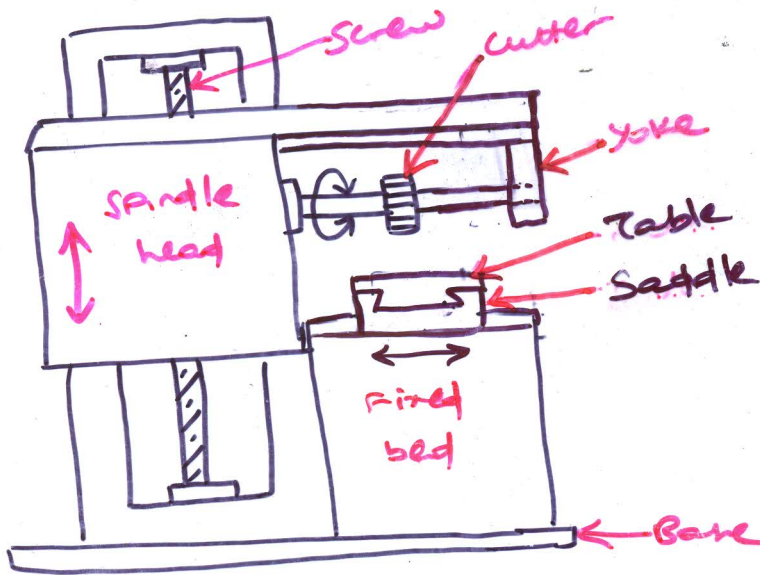
Taper Spiral Grooves in reamers & bevel Gears,  
Twist Drill, Spur & Helical Gears, milling cutters &  
All types of milling, drilling & Shaping ops.

### Bed type Milling m/c:-

- \* Comparatively large, heavy in construction
- \* Vertical motion imparted to Spindle instead of Table
- \* Dep on no of Spindle, Simplex, Duplex Triplex bed type milling m/c.

① Simplex (Fixed bed type) Milling m/c:-

5

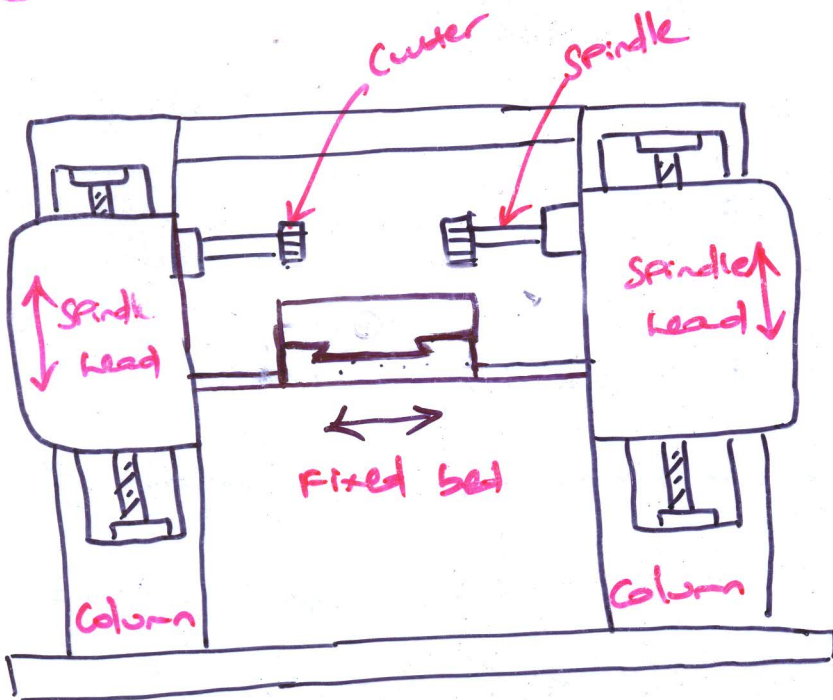


Since the bed is fixed, it can not move up, down

The spindle head carries the spindle, which can be moved up & down along the column ways.

Table → Cross-wise movement  
longitudinal movement

② Duplex head fixed bed type milling m/c:-

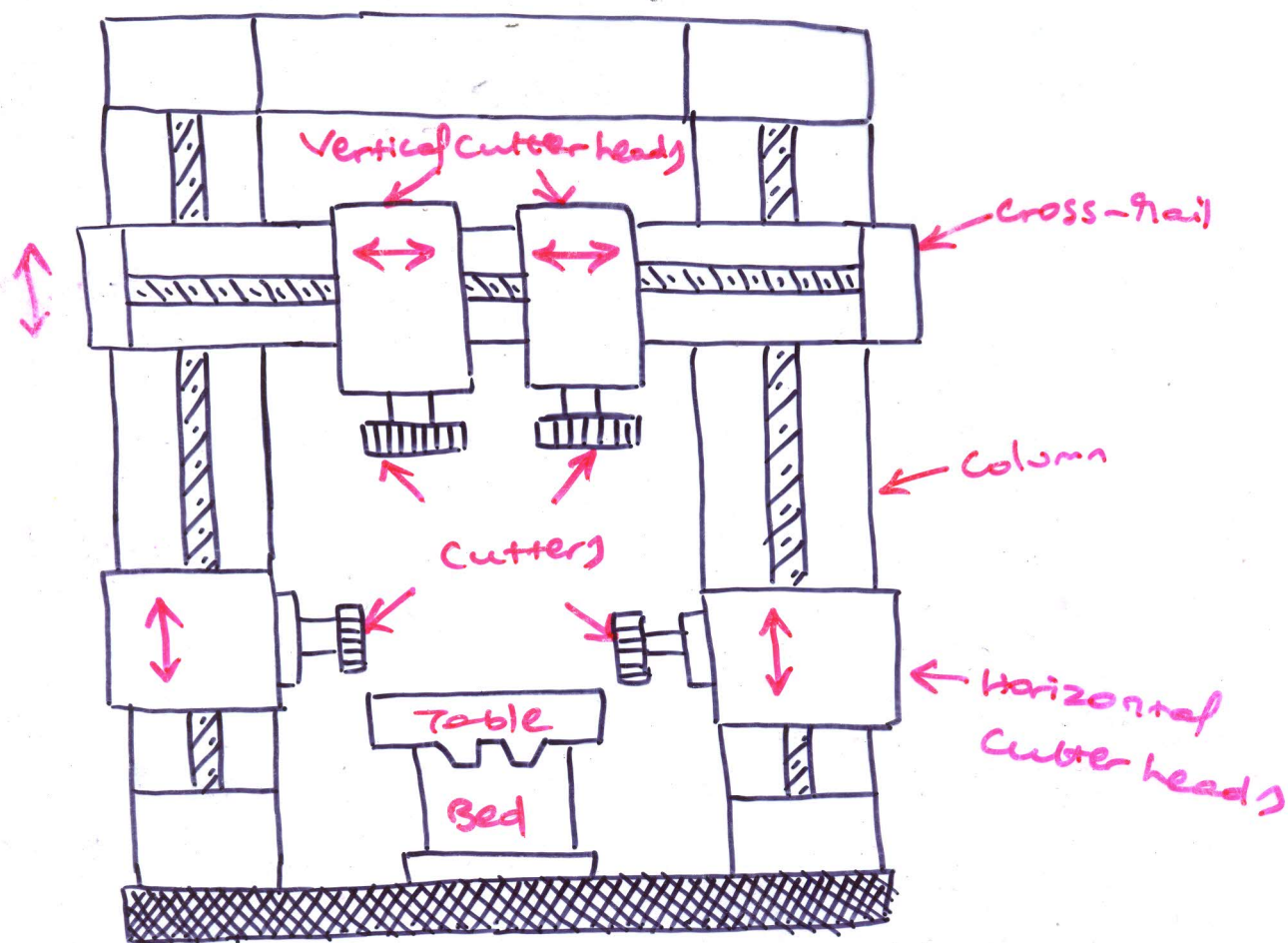


③ Triplex head fixed bed type milling machine:-

Three spindles - Two horizontal  
one vertical.

## Plano-type milling machine.

(6)



The w/p can be machined in 4 different ways.

- ① By moving the table & rotating the cutters in position
- ② By keeping the table stationary & feeding the cutters
- ③ By moving the table & milling head simultaneously
- ④ By keeping the table stationary and moving the cross-rail downwards & also the side cutters up & down.

## Work Holding Devices:-

(7)

- ① T-bolt & clamps
- ② Angle plates
- ③ V-blocks
- ④ Machine vice
- ⑤ Dividing head
- ⑥ Universal vice
- ⑦ Fixtures.

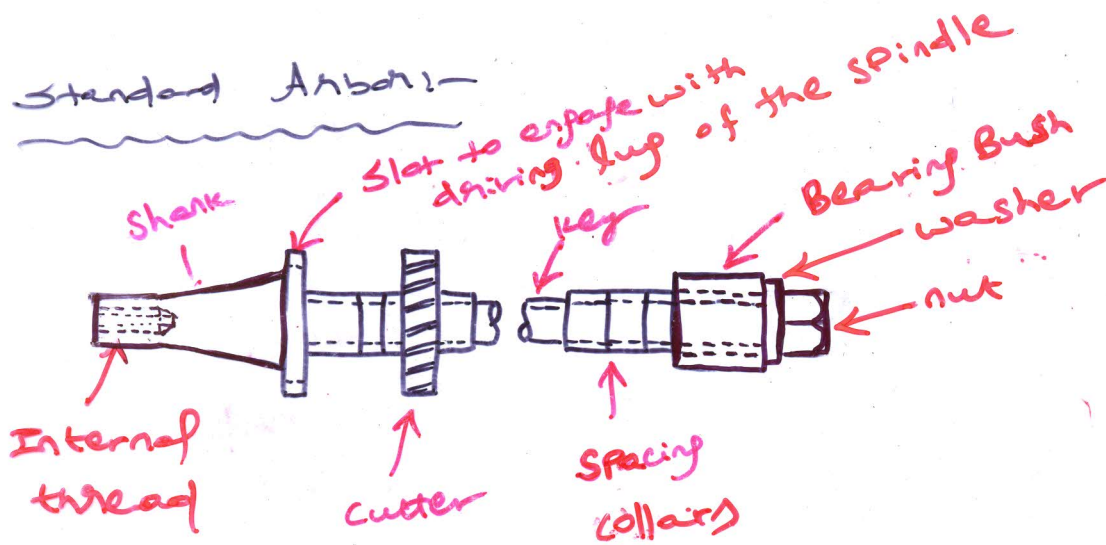
## Tool-holding Devices:-

- ① Arbors
- ② Adaptors
- ③ Collets

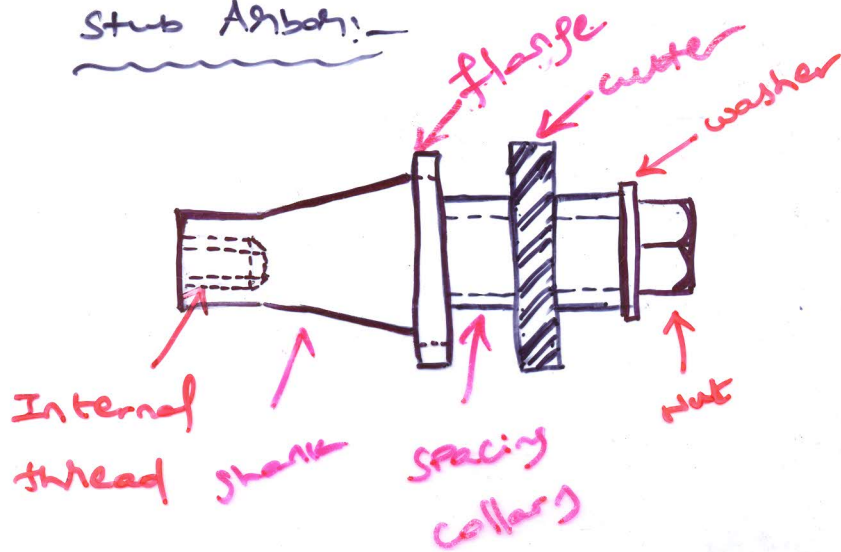
### Arbors:-

- (i) Standard Arbor (ii) Stub Arbor

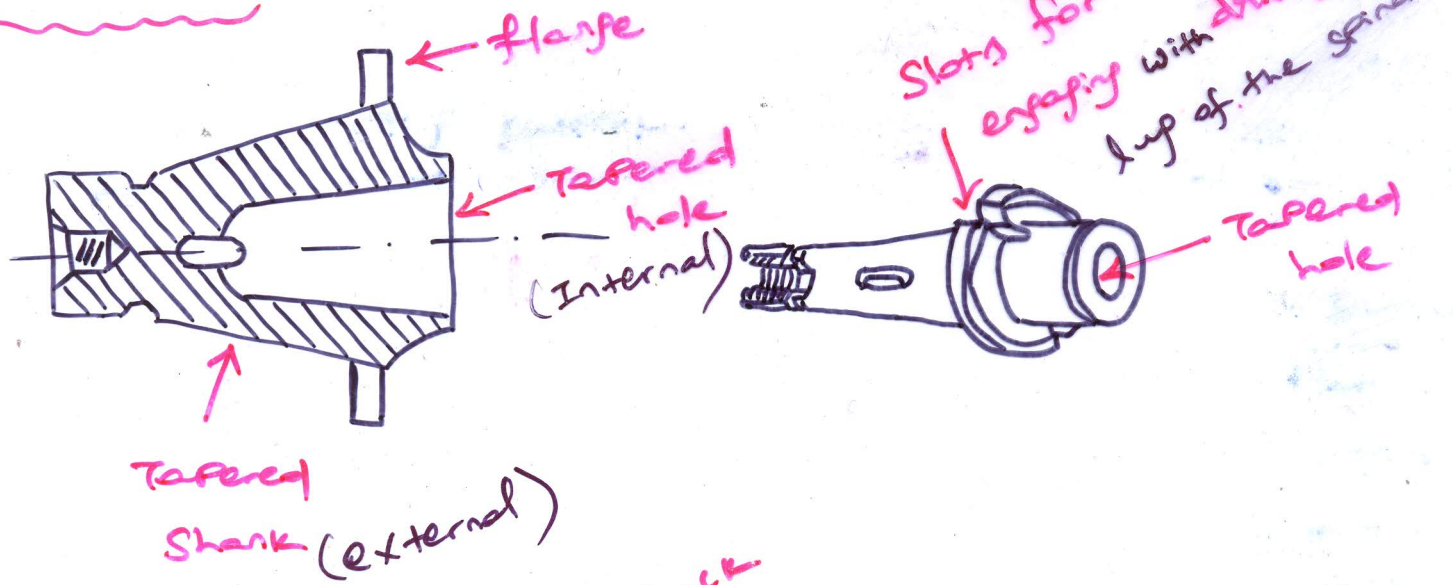
#### Standard Arbor:-



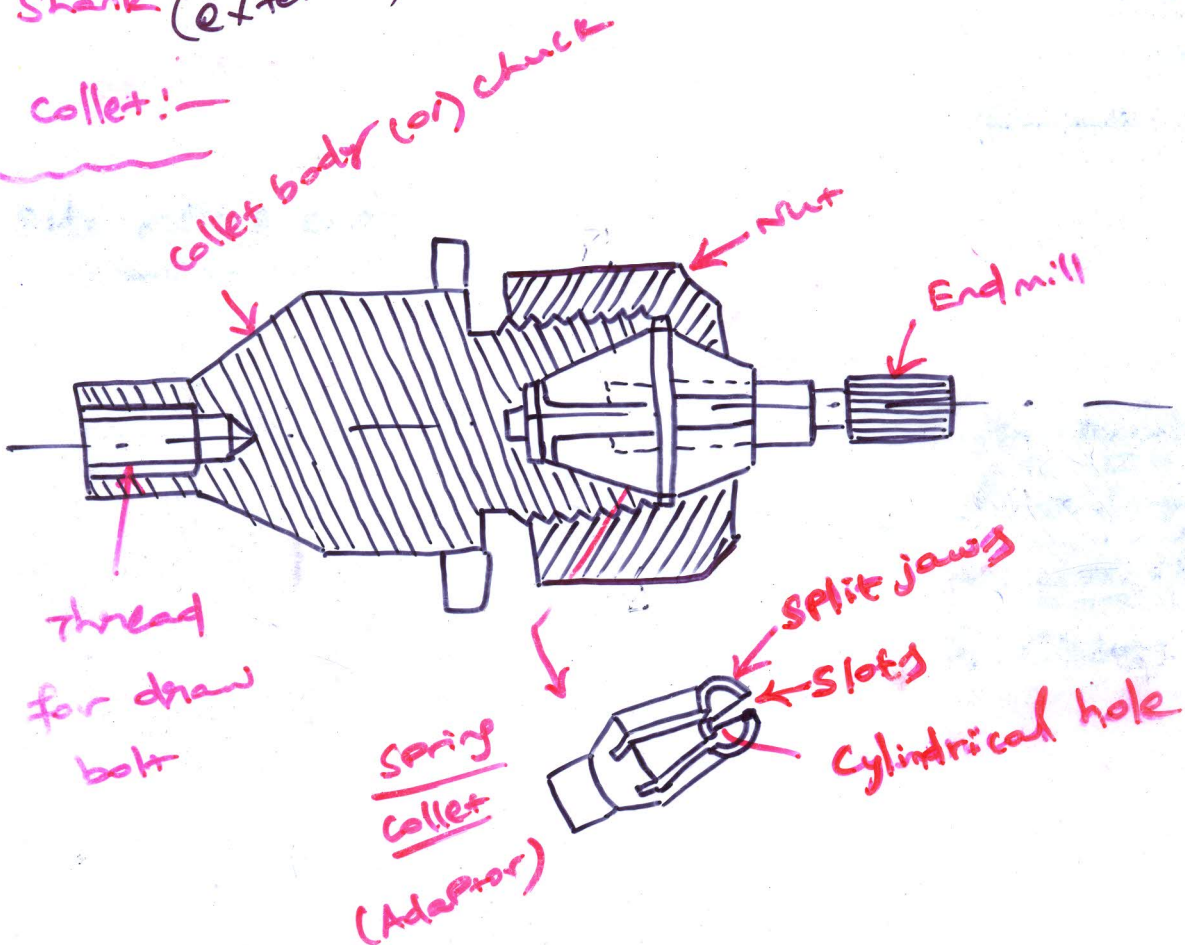
#### Stub Arbor:-



Adaptor:-



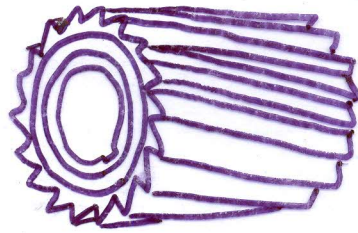
Spring collet:-



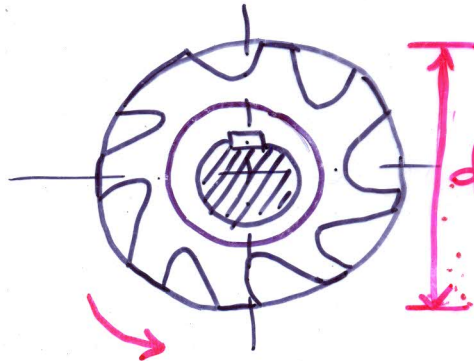
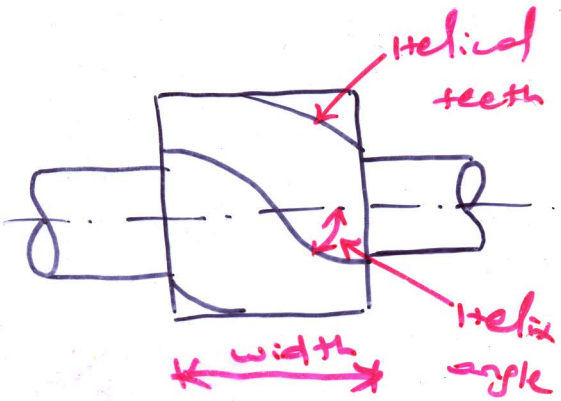
- ① Collet chuck -
- ① tapered shank to fit into the tapered hole of the spindle nose.
  - ② Internal threaded hole on back side
  - ③ Internal tapered hole on its front
  - ④ External threaded portion for nut.

# Milling cutters:-

## ① plain milling cutter:-

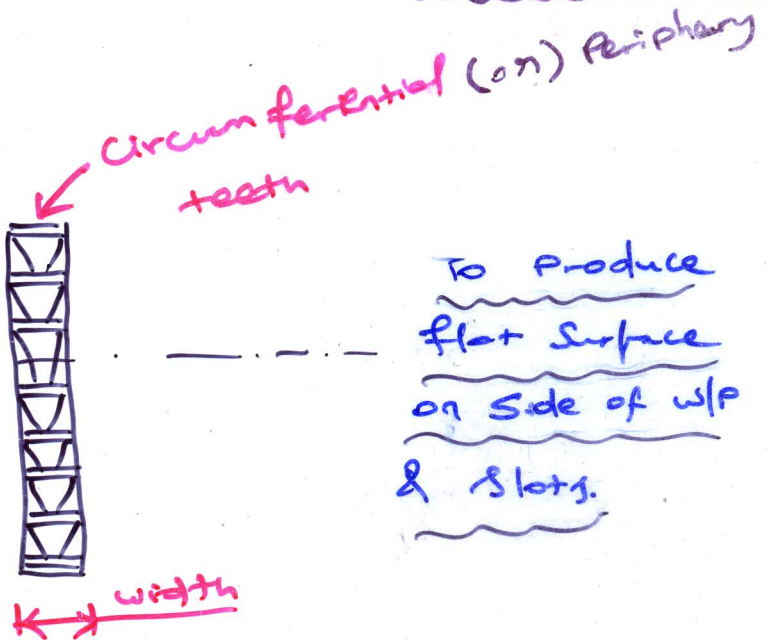
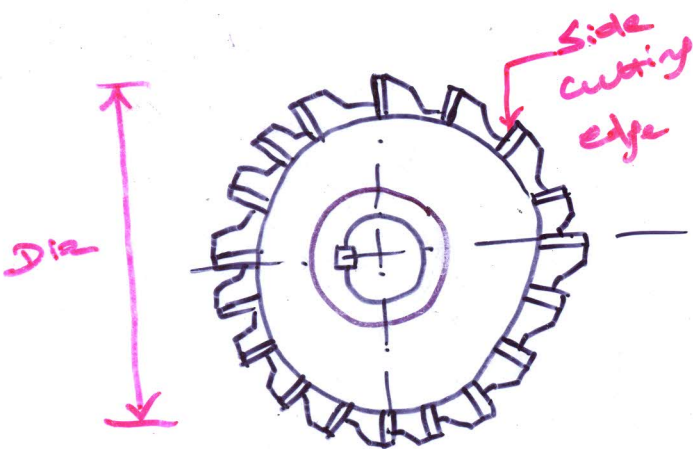


Straight teeth plain milling cutter



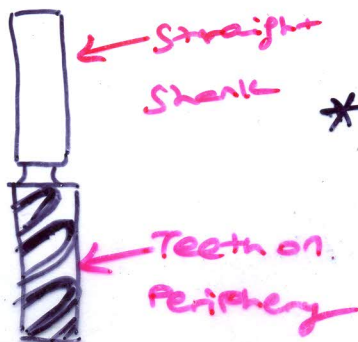
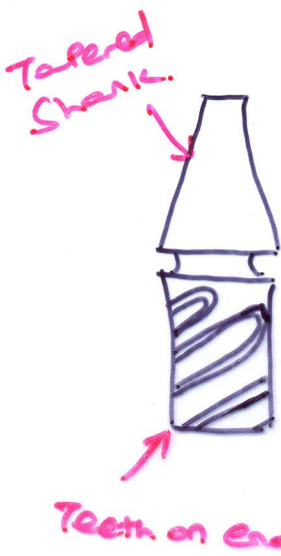
To produce flat surface // to the axis of rotation of cutter

## ② Side milling cutter:-



To produce flat surface on side of w/p & slots.

## ③ End milling cutters:-

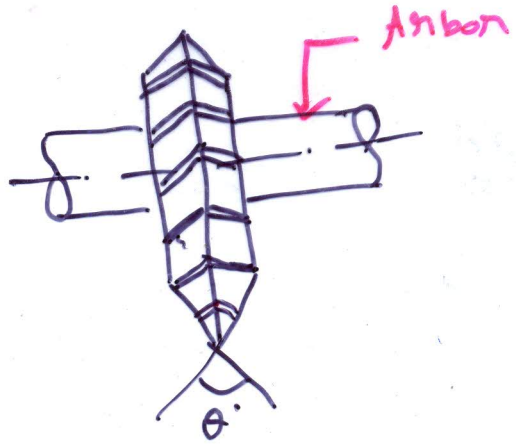
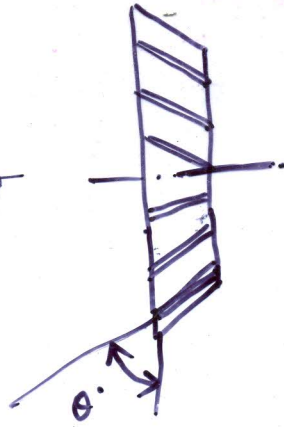
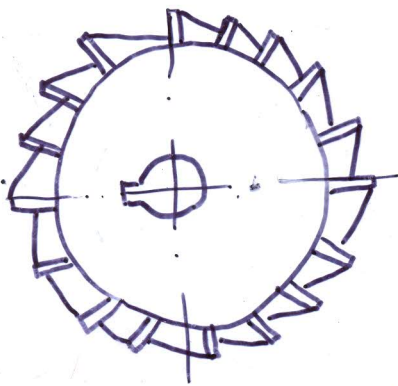


- \* Periphery teeth may be Helical (or) straight
- \* Used to produce slots Profile milling & to produce accurate holes.



④ Angle Milling Cutters:-

④

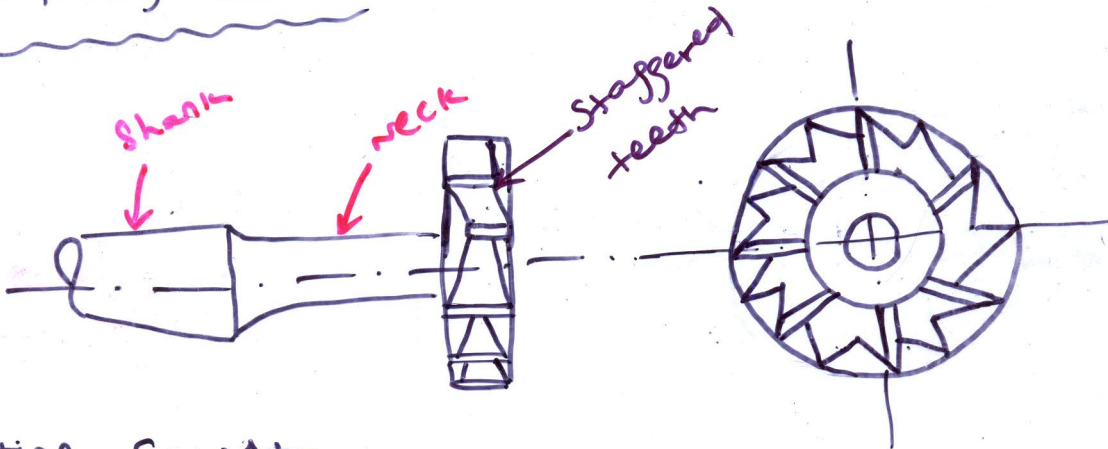


Single angle milling cutter

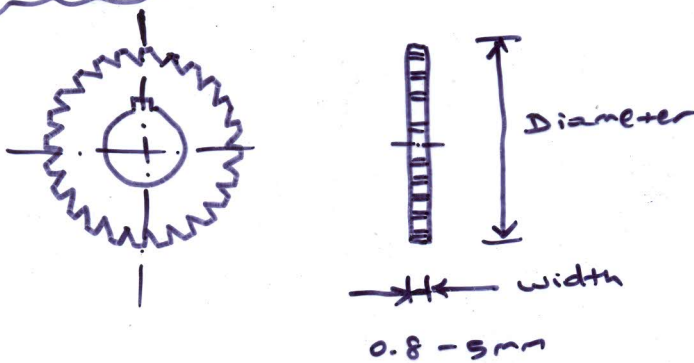
V-grooves,  
Dove-tail slots

Double Angle milling cutter

⑤ T-slot milling cutter:-



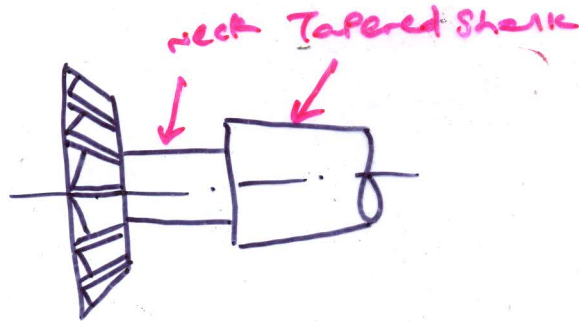
⑥ Slitting Saws:-



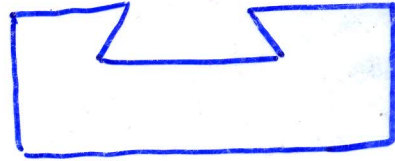
Deep slots, Parting off the w/p.

Dove-tail Slot milling cutter:-

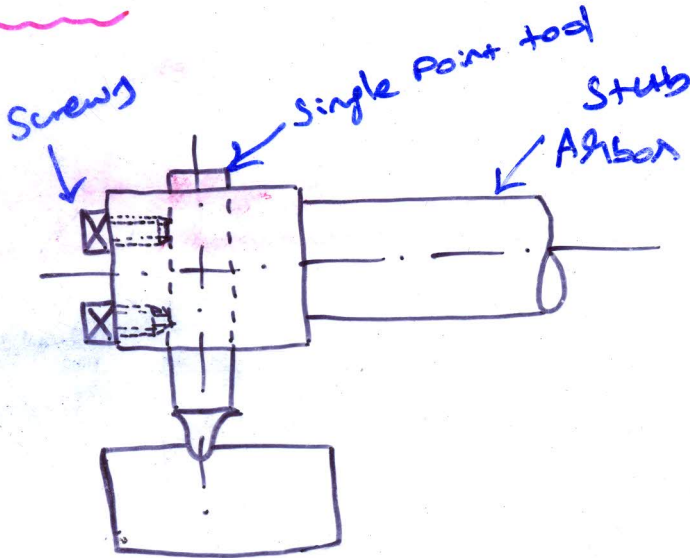
①



for making  
Dove-tail Slots



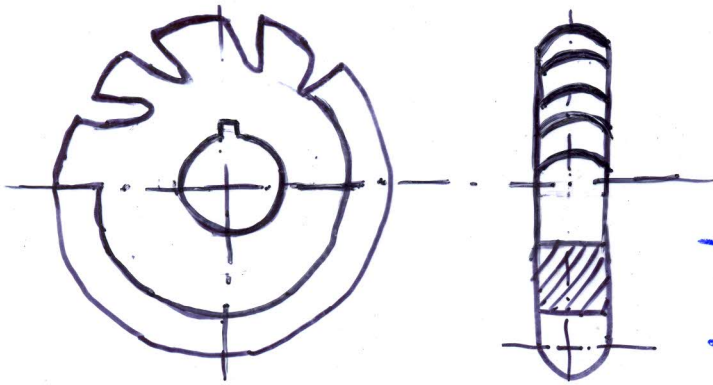
Fly-cutters:-



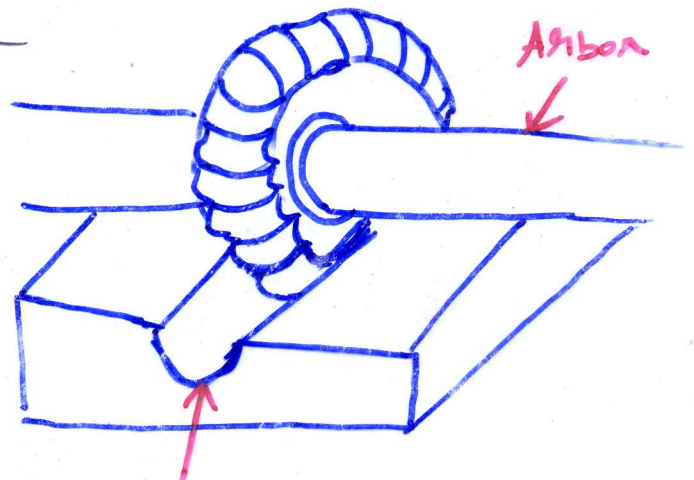
- \* The cutting edge may be formed to reproduce contoured Surface.
- \* considered as emergency tool when the standard tool is not available.

Formed cutters:-

①



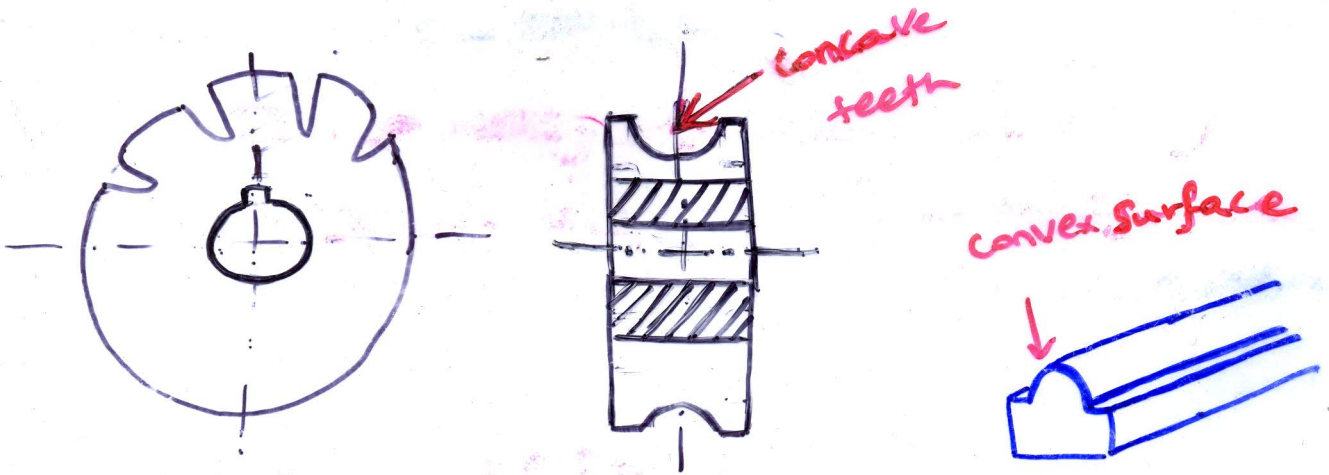
Convex milling  
Cutter



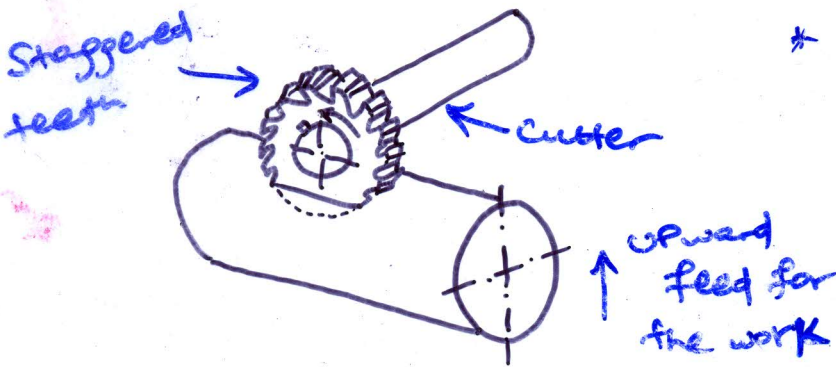
Concave Surface

② Concave Cutter

12



Woodruff Key Slot milling cutter:-



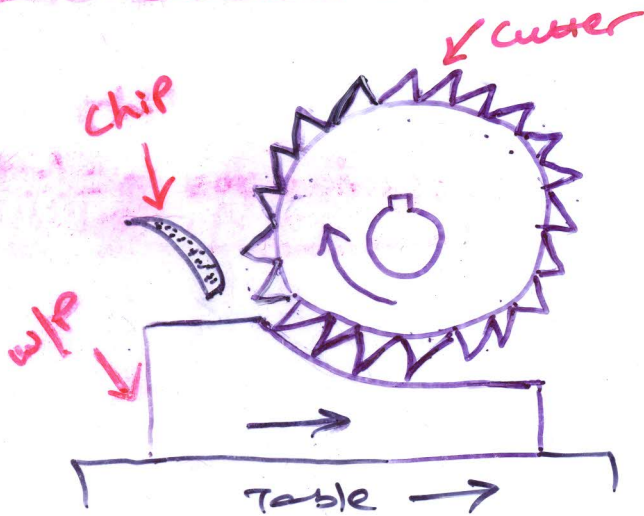
- \* It has staggered (or) straight teeth.
- \* Sides of the cutter ground **convex**
- \* used to cut woodruff key slot.

# MILLING PROCESS

13

- ① Peripheral milling - Milled surface  $\parallel$  to the axis of rotation of cutter
  - a) UP milling (or) Conventional milling
  - b) Down milling (or) Climb milling
- ② Face milling - Milled surface  $\perp$  to the axis of rotation of cutter

## UP milling (or) Conventional milling:-

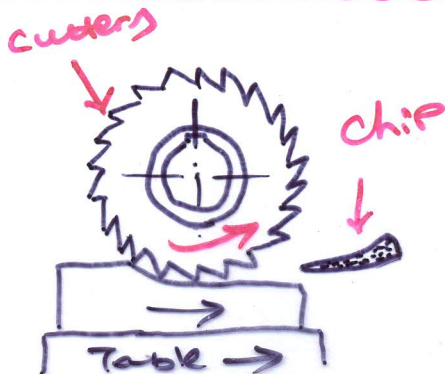


- \* Direction of rotation
- \* Chip thickness
- \* cutting force direction
- \* Preferred over climb milling in the case of backlash.
- \* chip welding & heat dissipation

### Advantage:-

- \* Backlash eliminator is not required
- \* Safer operation

## Down (or) Climb milling:-



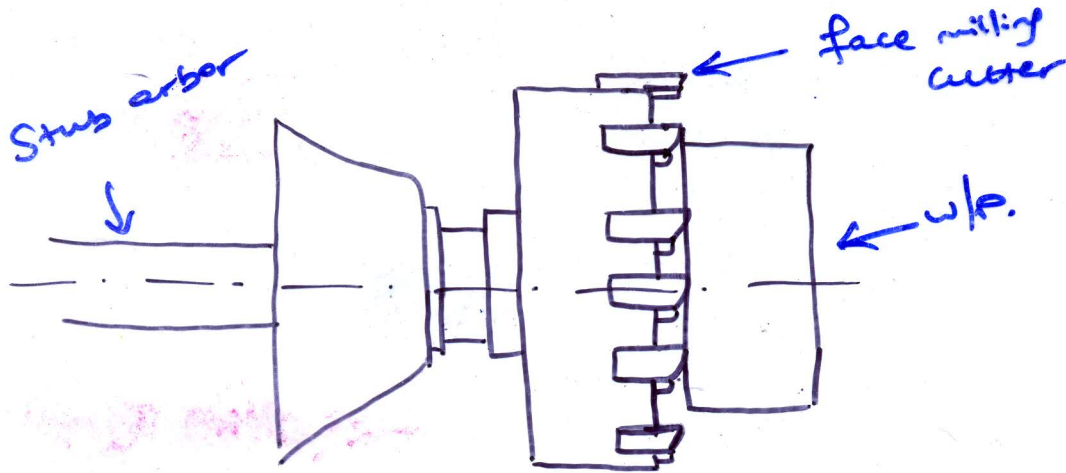
### Advantage:-

- \* cutter with high rake angle.
- \* cutter wear is less

## Face milling

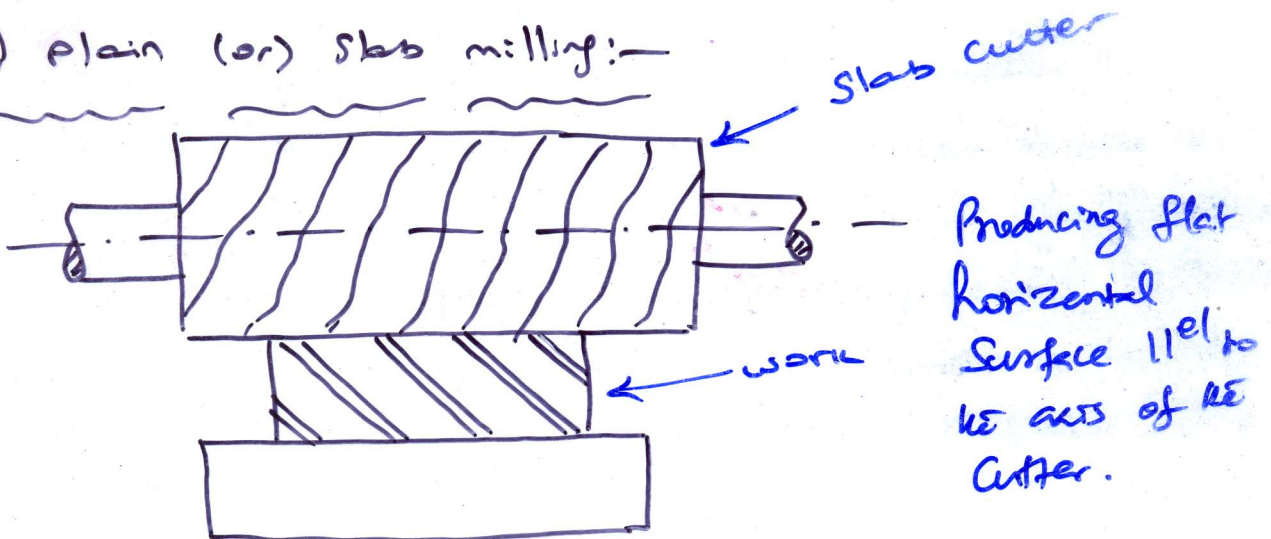
(14)

- \* Machined surface  $\perp$  to the axis of rotation of cutter.
- \* Generally face milling cutter used for finishing.

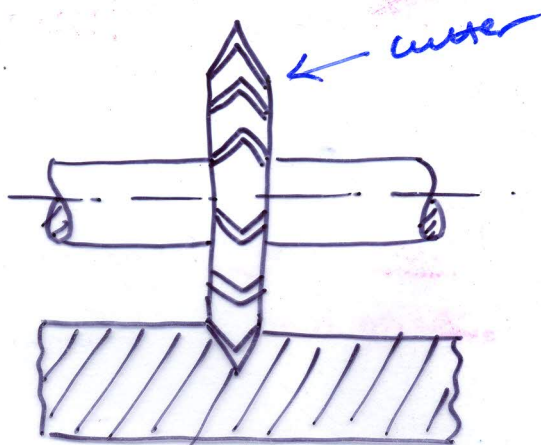


## Milling operations:

### ① Plain (or) Slab milling:



### ② Angular (or) Bevel milling:



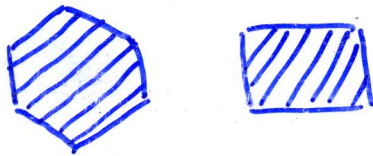
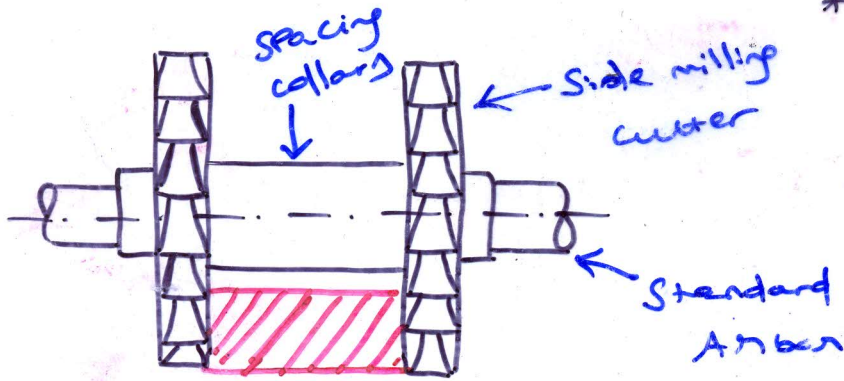
operation of machining a flat surface at an angle, other than right angle to the axis of the revolving cutter.

## Straddle Milling:-

(15)

\* Production of two vertical flat surfaces on both sides.

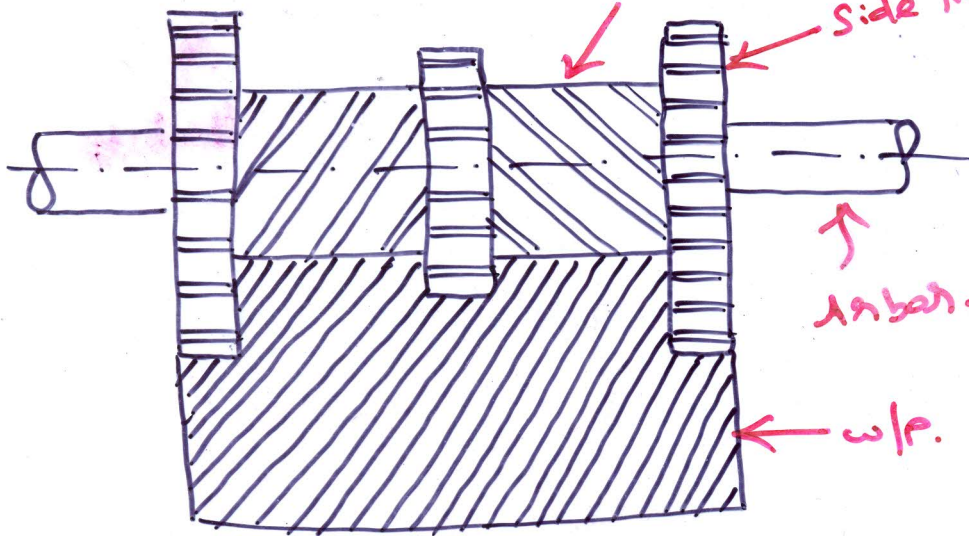
\* Commonly used for milling square and hexagonal surfaces.



## Gang Milling:-

plain milling cutter

Side milling cutter

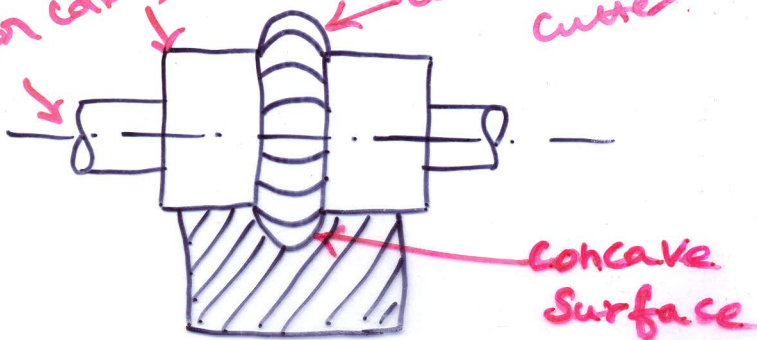


Production of many surfaces of a job simultaneously by feeding the table against a number of required cutters

## Form milling:-

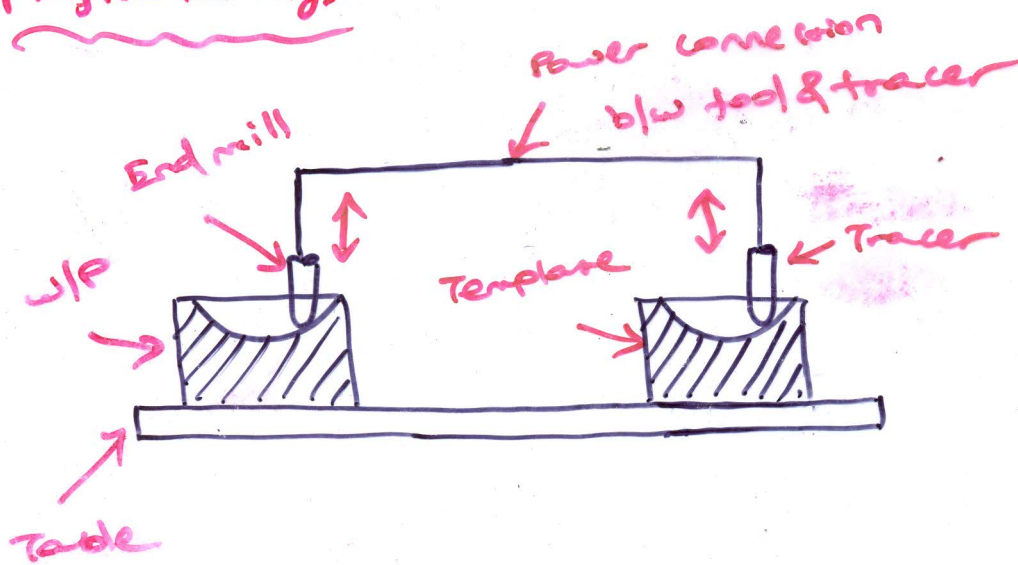
Arbor collars

convex milling cutter



\* Production of irregular surface by using form cutter.

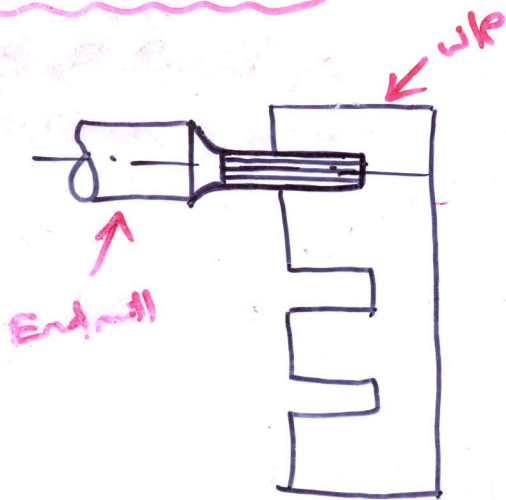
## Profile milling:-



16

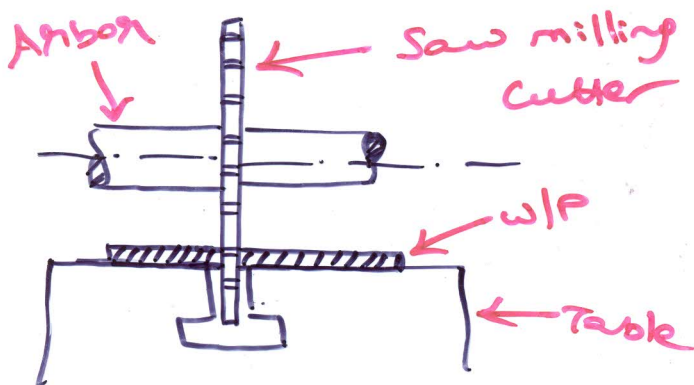
\* Reproduction of outline of Template (or) Complex shape of master die on the workpiece.

## End milling:-



\* used to produce flat surface which may be vertical, horizontal (or) inclined to the table surface  
\* slots, keyways, Grooves etc.

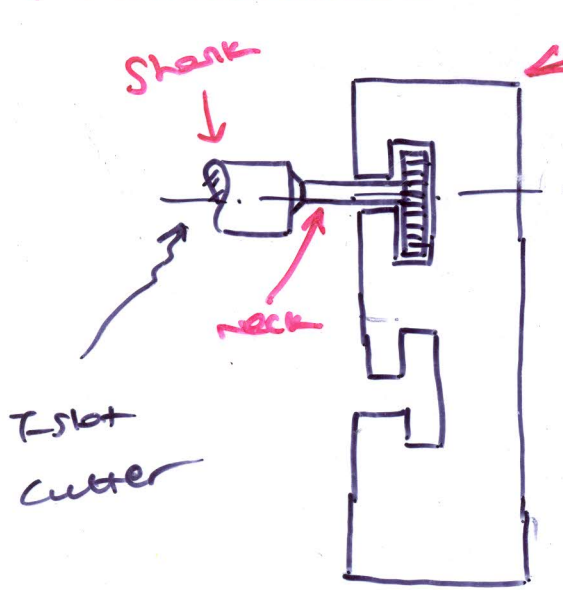
## Saw milling:-



\* narrow slots & narrow Grooves on a W/P.  
\* Also used for parting off the workpiece

## T-slot milling:-

(17)

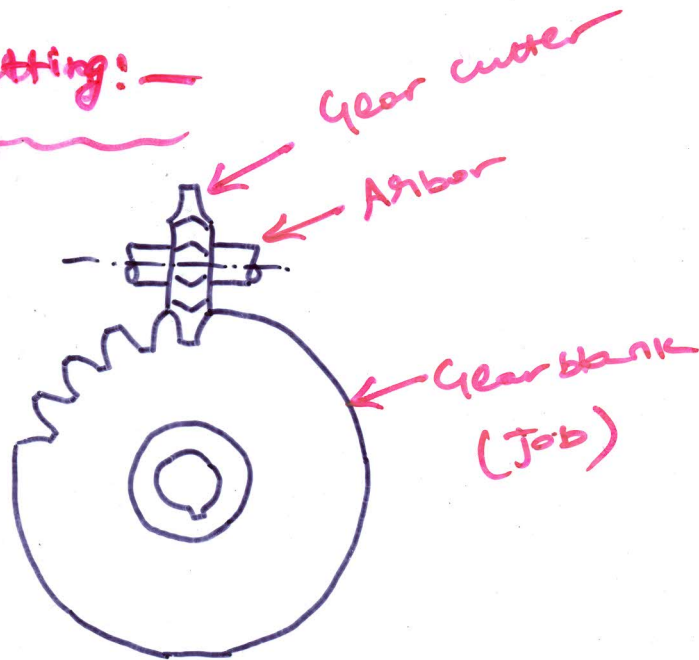


w/p. \* used to produce T-slots on a w/p using T-slot cutter.

First stage :- Plain slot is made by using end milling cutter.

Second stage :- T-slot is made by using T-slot cutter.

## Gear Cutting:-





# Gear cutting

①

## Machining Process:-

### ① Formed cutter method

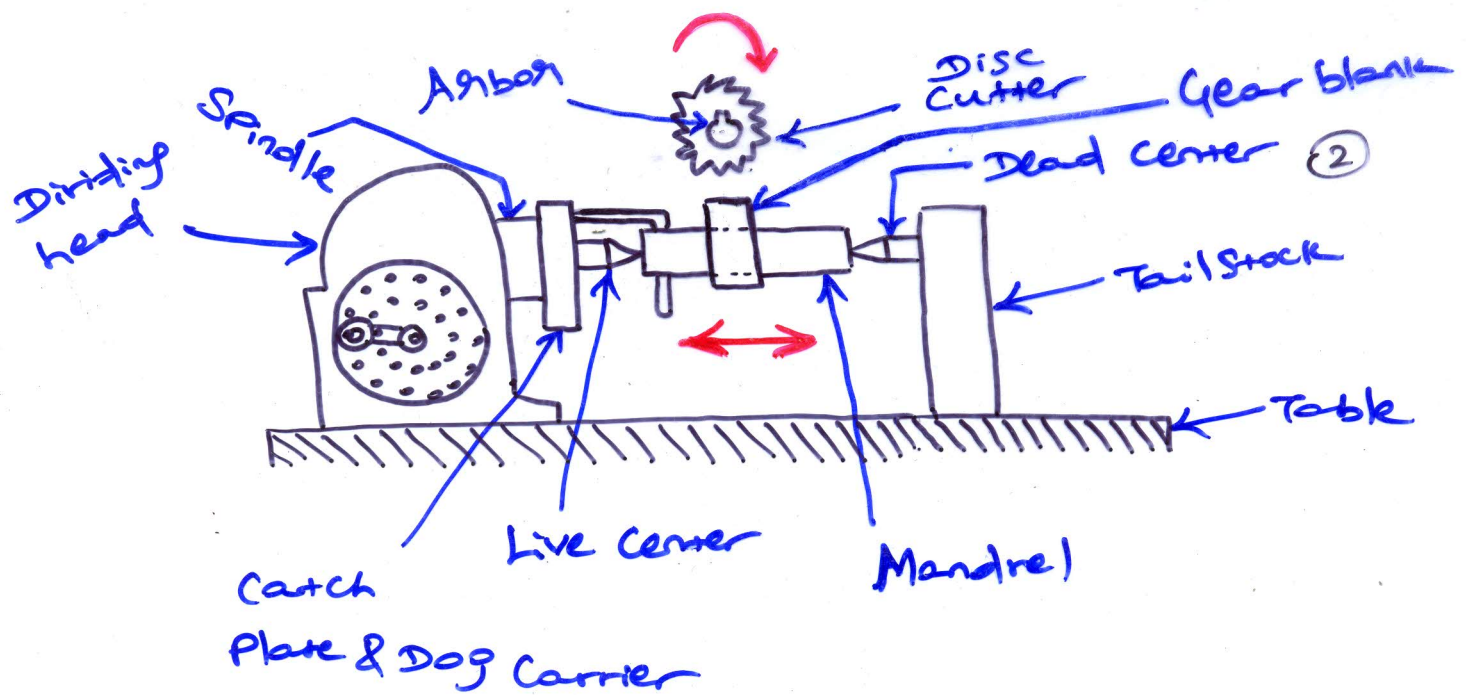
- (a) by formed disc cutter in Horizontal milling m/c
- (b) by formed End mill in Vertical Milling m/c
- (c) by Single point form tool in Shaper (or) Planer
- (d) by Shear speed Shaping process
- (e) by Gear broaching
- (f) by template method.

### ② Gear Generation

- (a) Gear Shaping process
- (b) Gear Planing process
- (c) Gear Hobbing process.

## ① Gear cutting by formed disc cutter in Horizontal milling machine:-

① To form a spur gear column & knee type horizontal milling machine is used.



- ② Universal Dividing head & Tail Stock is fit in the correct position on the table.
- ③ The Dividing Head Spindle has Inner bore & outer threaded portion for holding the Live Center and Catch Plate respectively.
- ④ The Gear blank is fit into the mandrel which is supported in between Live & Dead Center with the help of Catch Plate & Dog Carrier.
- ⑤ Now, the formed disc Cutter of required Profile is taken & is fit into arbor of the milling machine.
- ⑥ The cutter teeth is made to coincide with the Spindle axis by various movements available in the milling machine.

⑦ Based on the number of divisions required on the <sup>③</sup> work piece, Indexing method is selected & then Indexing calculation is done so that required amount of Crank movement along the hole circle of Index plate after each tooth is formed can be found out.

⑧ Now, the depth of cut is given by elevating the table & the workpiece is fed against the rotating cutter.

⑨ After one tooth is formed, it will be indexed to the next position by rotating the Indexing Crank upto the required number of holes in the selected hole circle of the Indexing Plate.

⑩ In this way, Spur Gear is formed in the Column & knee type Horizontal milling machine.

Spur gear calculation:-

(a) Blank diameter =  $m(Z+2)$

(b) Tooth Depth = 2.25 m

(c) Cutter Pitch = 3m.

Indexing:-

No of holes to be moved by Crank } =  $\frac{40}{Z}$

## Dividing Head & Indexing:-

(4)

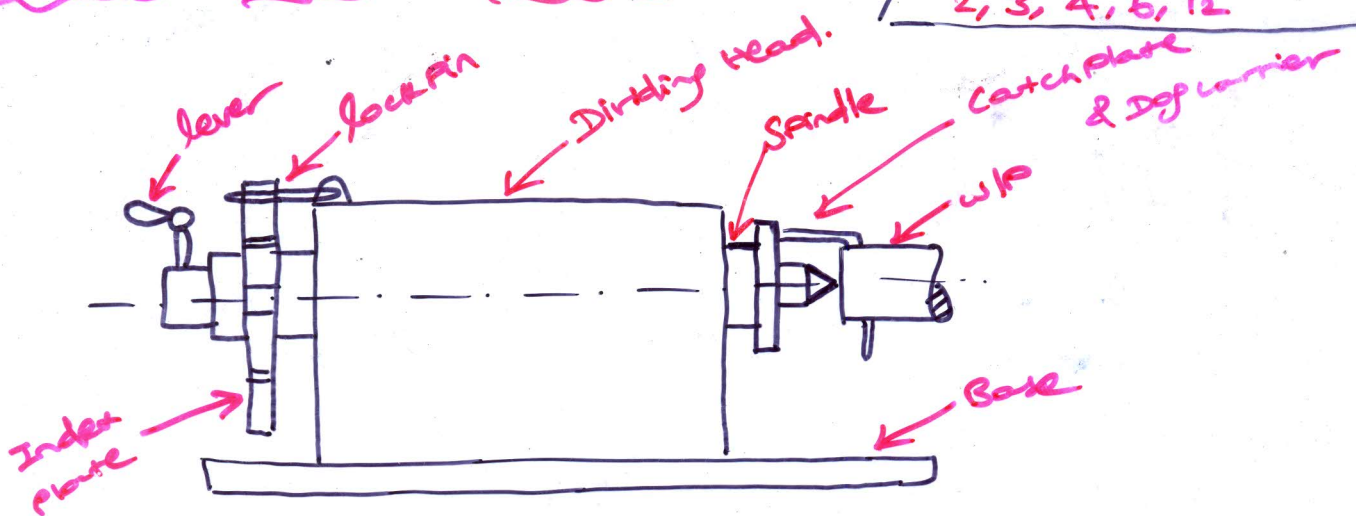
- Indexing is the process of dividing the periphery of a job into equal number of divisions.

- For doing this indexing, An attachment called dividing head is used with the milling m/c. There are 3 types of dividing head

- ① Plain (or) Simple dividing head
- ② Universal dividing head
- ③ Optical dividing head.

### Plain (or) Simple dividing head:-

24 (or) 12 slots  
2, 3, 4, 6, 12 & 24  
2, 3, 4, 6, 12

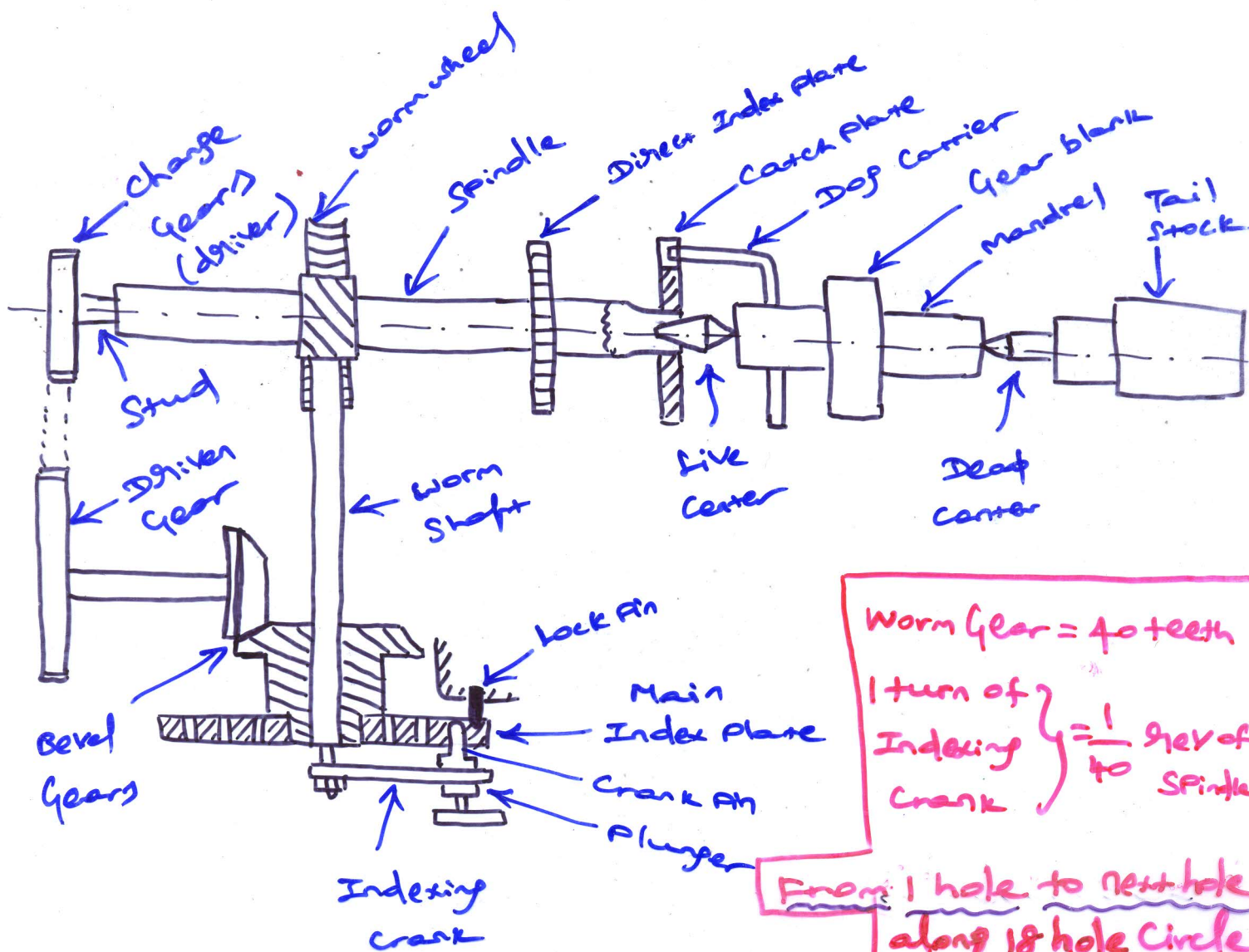
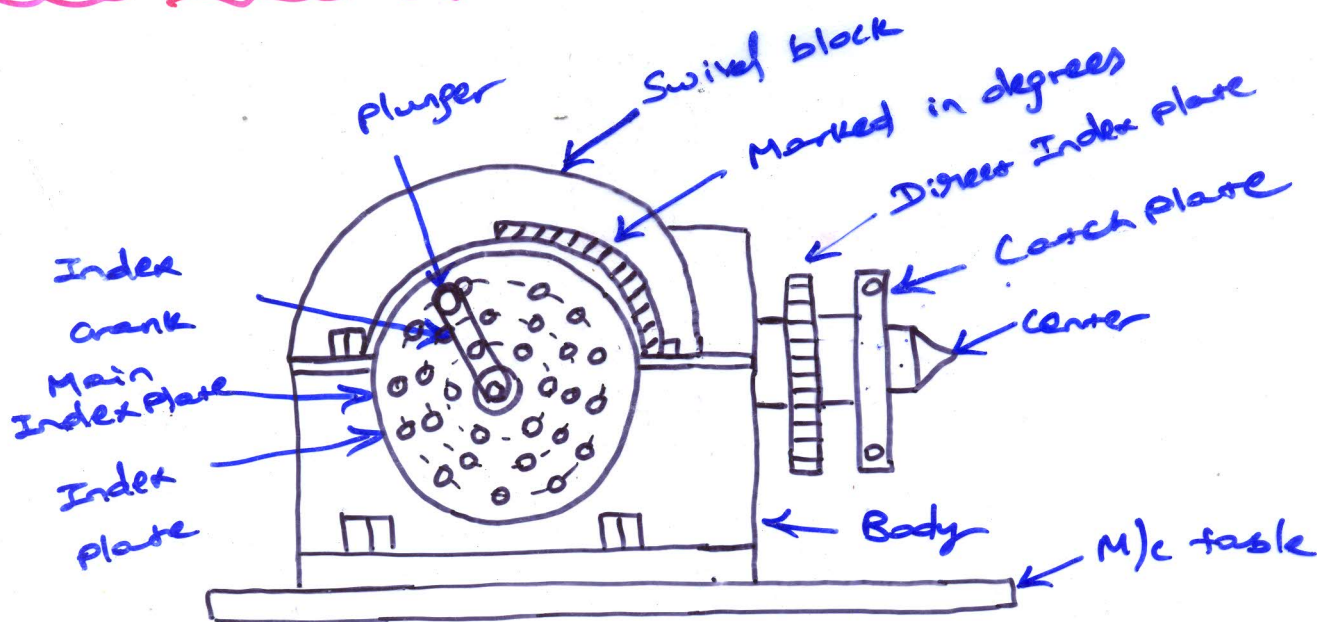


\* Simplest of all dividing heads

\* Used for making small number of divisions on the periphery of the w/p [up to 24]

# Universal Dinding Head:-

(5)



Worm Gear = 40 teeth  
 1 turn of Indexing } =  $\frac{1}{40}$  rev of Crank } Spindle

From 1 hole to next hole along 18 hole Circle

$$\frac{1}{40} \times \frac{1}{18} = \frac{1}{720} \text{ rev of spindle}$$

## Uses:-

(6)

- ① To set the w/p in desired position [Horizontal, Vertical (or) Inclined] in relation to the m/c table

5° below horizontal & 10° beyond vertical

- ② To turn a workpiece periodically through a given angle (Indexing)
- ③ To provide continuous rotary movement to the job during milling of helical gears
- ④ To hold the workpiece & support it in conjunction with the tailstock

## Indexing Methods:-

- ① Direct (or) Rapid Indexing
- ② Plain (or) Simple Indexing
- ③ Differential Indexing
- ④ Compound Indexing
- ⑤ Angular Indexing.

### ① Direct (or) Rapid Indexing:-

- \* obtained by plain (or) universal dividing head.
- \* In universal dividing head, it is obtained by rotating the spindle by hand after disengaging the worm wheel & worm.

\* Direct Index plate - 24 holes

Factors of 24 → (2, 3, 4, 6, 8, 12, 24)

## Rules for Direct (or) Rapid Indexing:-

(7)

$$\text{No of holes to be moved} = \frac{2A}{N}$$

N = No of divisions required.

Example!-1 Find out Index Crank movement to mill a hexagonal bolt by direct indexing.

$$\text{No of holes to be moved} = \frac{24}{6} = 4$$

So, After machining one side, the Index plate will have to be moved by 4 holes for 6 number of times to machining the remaining faces of the bolt.

## Simple (or) Plain Indexing:-

\* Suitable for divisions beyond the range of Rapid Indexing.

Formula for Simple (or) Plain Indexing

$$\text{No of holes to be moved} = \frac{40}{N} \quad \text{N - No of divisions required}$$

**B&S Index Plate:**

Plate no: 1 - 15, 16, 17, 18, 19, 20

Plate no: 2 - 21, 23, 27, 29, 31, 33

Plate no: 3 - 37, 39, 41, 43, 47, 49

Brown (B)  
& Sharp (S)  
Mfg Company

Example!-2

Set the dividing head to mill 30 teeth on a spur wheel blank by Simple Indexing.

$$\text{Index Crank movement} = \frac{40}{30} = 1\frac{1}{3} = 1\frac{1}{3} \times \frac{7}{7} \quad (8)$$

$$= 1\frac{7}{21}$$

Thus for Indexing, one complete turn and 7 holes in 21 hole circle of Index plate will have to be moved by the Index Crank.

### Compound Indexing!

\* Called Compound Indexing due to the two separate movements of the Index Crank in two different hole circle of one Index plate.

\* First movement — is as plain Indexing

Second movement —

- ① Crank pin engaged with Index plate

- ② Lock pin at rear side of the plate is disengaged.

- ③ Then Index plate with the Crank pin is rotated either forward (or) backward along the selected hole circle to the required amount.

\* The effective movement will be the summation of the two movements.



## example for compound Indexing

(9)

①

first movement:— 3 holes on a 15 hole circle by crank pin

Second movement:— 4 holes on a 12 hole circle forward by Index plate

So, effective movement by worm }  $\frac{3}{15} + \frac{4}{12} = \frac{8}{15}$  revolution

Since 40 turn of worm rotates the spindle by 1 rev,

$\frac{8}{15}$  rev of worm rotates the spindle by  $\frac{8}{15} \times \frac{1}{40} = \frac{1}{75}$  rev

∴ 75 divisions can be produced on workpiece

②

first movement:— 6 holes on 18 hole circle by crank

Second movement:— 4 holes on 16 hole circle backward by Index plate

So, effective movement by worm }  $\frac{6}{18} - \frac{4}{16} = \frac{1}{12}$  rev

∴ Spindle movement =  $\frac{1}{12} \times \frac{1}{40} = \frac{1}{480}$  rev

∴ 480 divisions can be produced on the w.p.

Rules for Compound Indexing:

$$\frac{40}{N} = \frac{n_1}{N_1} \pm \frac{n_2}{N_2}$$

where,

$n$  = number of divisions required

(10)

$N_1, N_2$  = The hole circle used by the Crank Pin & lock pin respectively

$n_1$  = no of hole spaces moved by the Crank pin in  $N_1$  hole circle

$n_2$  = no of hole spaces moved by the lock pin in  $N_2$  hole circle

### Procedure for Indexing—

For example, take a indexing for 69 division by Compound Indexing.

① Resolve into factors the number of divisions required

$$69 = 23 \times 3$$

$$\begin{array}{r} 3 \overline{) 69} \\ \underline{23} \\ 1 \end{array}$$

② Choose at random hole circle

$$23 \ \& \ 33$$

$$\text{Plate no: 2} \Rightarrow 21, 23, 27, 29, 31, 33$$

③ Subtract the hole number of one circle from

other

$$33 - 23 = 10$$

④ Factor the difference

$$10 = 2 \times 5$$

$$\begin{array}{r} 2 \overline{) 10} \\ \underline{5} \phantom{0} \\ 5 \\ \underline{5} \\ 0 \end{array}$$

⑩

⑤ Factor the no of turns required by the worm to make one revolution of the spindle

$$40 = 2 \times 2 \times 2 \times 5$$

$$\begin{array}{r} 2 \overline{) 40} \\ \underline{20} \\ 20 \\ \underline{10} \\ 10 \\ \underline{5} \\ 5 \\ \underline{5} \\ 0 \end{array}$$

⑥ Factor the selected hole circle

$$33 = 3 \times 11$$

$$23 = 23 \times 1$$

⑦ Place the factors for no of divisions required & the factors for difference of hole circles above the horizontal line and place the factors for no of turns required by worm for 1 rev of spindle & hole circles selected below the horizontal line.

$$69 = \cancel{2} \cancel{3} \times \cancel{3}$$

$$10 = \cancel{2} \times \cancel{5}$$

---

$$40 = \cancel{2} \times 2 \times 2 \times \cancel{5}$$

$$23 = \cancel{2} \cancel{3} \times 1$$

$$33 = \cancel{3} \times 11$$

⑧ Cancel out the common terms. If the all the factors above the horizontal line is cancelled, the chosen hole circles are correct. otherwise choose

another set of hole circles. In this case, the chosen hole circles [23 & 33] are correct as all the factors above the horizontal line are cancelled.

(10.2)

(9) The no of hole spaces to be moved by the pin along the hole circle is found out by multiplying all the remaining factors below the horizontal line

$$2 \times 2 \times 1 \times 11 = 44$$

(10)  $\therefore \frac{40}{69} = \frac{44}{23} - \frac{44}{33} = 1 \frac{21}{23} - 1 \frac{11}{33}$

$$\frac{40}{69} = \frac{21}{23} - \frac{11}{33}$$

Therefore, After each tooth is cut

(1) First, move the Crank of Index plate by 21 holes along 23 hole circle.

(2) Second, move the lock pin on the back side of the index plate by 11 holes along 33 hole circle in a reverse direction.

## ④ Differential Indexing:-

④

- ① The movement of Index Crank similar to the Simple Indexing
- ② The Simultaneous movement of the Index Plate, when the crank is turned.

Change gears :- 24, 28, 32, 40, 44, 48, 56, 64,  
72, 86, 100.

With this Change gears & B&S Index plate, It is possible to Index any number ~~from~~ upto 382.

Special gears :- 46, 47, 52, 58, 68, 70, 76, 84

With this gears, Index = 383 to 1008

Example:- 4

Index 83 divisions.

First of all, check it can be indexed by plain indexing (or) not.

$$\text{Index crank movement} = \frac{40}{N} = \frac{40}{83}$$

As 83 hole circle <sup>is not</sup> available, So, Differential Indexing ~~can~~ <sup>can</sup> be used.

## Rule for Differential Indexing:-

$$\text{① Gear ratio} = \frac{\text{Driving gear on spindle}}{\text{Driven gears on bevel gear shaft}} = \frac{(A-N) \times 40}{A}$$

where,

(12)

$A =$  the Selected number which can be indexed by plain indexing & the number should be nearer to the no of divisions required.

$N =$  Number of divisions to be indexed.

(2) Index crank movement =  $\frac{40}{A}$

then the index crank will have to be moved by an amount for  $N$  number of times for complete division of work.

If  $(A-N)$  is positive, the index plate must rotate in the same direction.

If  $(A-N)$  is negative, the index plate must rotate in a opposite direction to the crank.

To achieve these conditions, the number of idle gears used depends on the following factors:

- (a) gear train is simple &  $(A-N)$  is positive, only one idle gear is used.
- (b) gear train is compound &  $(A-N)$  is positive, no idle gear is used.
- (c) gear train is simple &  $(A-N)$  is negative, two idle gears are used.
- (d) gear train is compound and  $(A-N)$  is negative, only one idle gear is used.

Example: 4

(13)

Index for 83 divisions.

First of all, find out whether the number can be indexed by plain indexing (or) not.

$$\text{Index crank movement} = \frac{40}{N} = \frac{40}{83}$$

Since, there is no 83 hole circle, the number cannot be indexed by plain indexing. Therefore it is the case of differential indexing.

Plate no: 3 37, 39, 41, 43, 47, 49

Assume A as 86

$$\begin{aligned} \textcircled{1} \text{ Gear ratio} &= (A - N) \times \frac{40}{A} = (86 - 83) \times \frac{40}{86} \\ &= 3 \times \frac{40}{86} = \frac{72}{24} \times \frac{40}{86} \end{aligned}$$

$\textcircled{2}$  therefore, Drivers = 72, 40  
Driven = 24, 86.

$$\textcircled{3} \text{ Index crank movement} = \frac{40}{86} = \frac{20}{43}$$

For complete indexing, the index crank will have to be moved by 20 holes in 43 hole circle for 83 times.

$\textcircled{4}$  As (A - N) is positive & the gear ratio is compound, no idle gear is required.

## Angular Indexing:-

(14)

$$40 \text{ Rev of the Crank} = 1 \text{ Rev of the Spindle} \\ = 360^\circ$$

$$\therefore 1 \text{ Rev of the Crank} = \frac{360}{40} = 9^\circ$$

Formula:-

$$\text{Index Crank movement} = \frac{\text{Angular Displacement of work}}{9} \\ = \frac{\text{Ang. Dis of work in minutes}}{540} \\ = \frac{\text{Ang. displa of work in sec}}{32400}$$

Example:-

Index an angle  $19^\circ 40'$

$$19^\circ 40' = (19 \times 60) + 40 \\ = 1180'$$

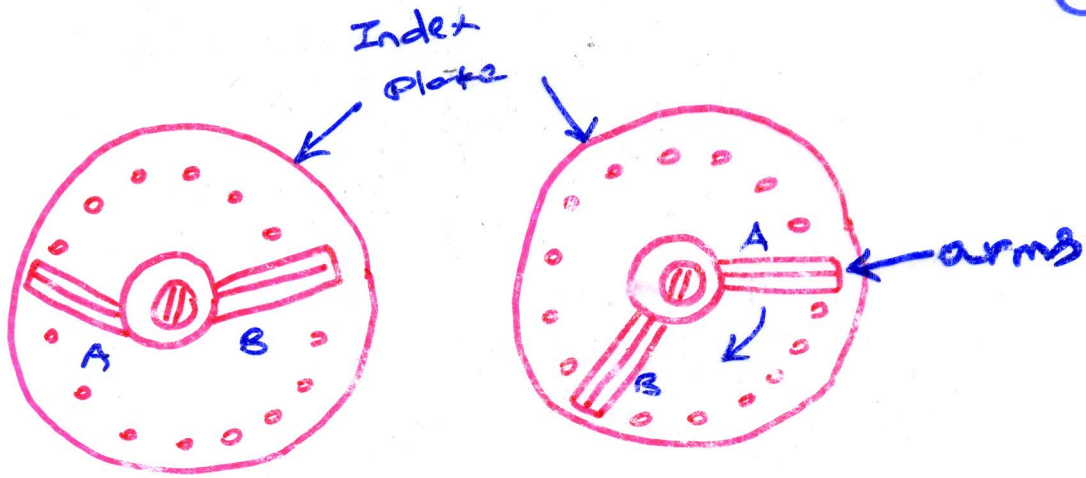
$$\therefore \text{Index Crank movement} = \frac{1180}{540} = 2 \frac{5}{27}$$

The index crank should be moved two complete turns & 5 holes in 27 hole circle.



Sector arms:-

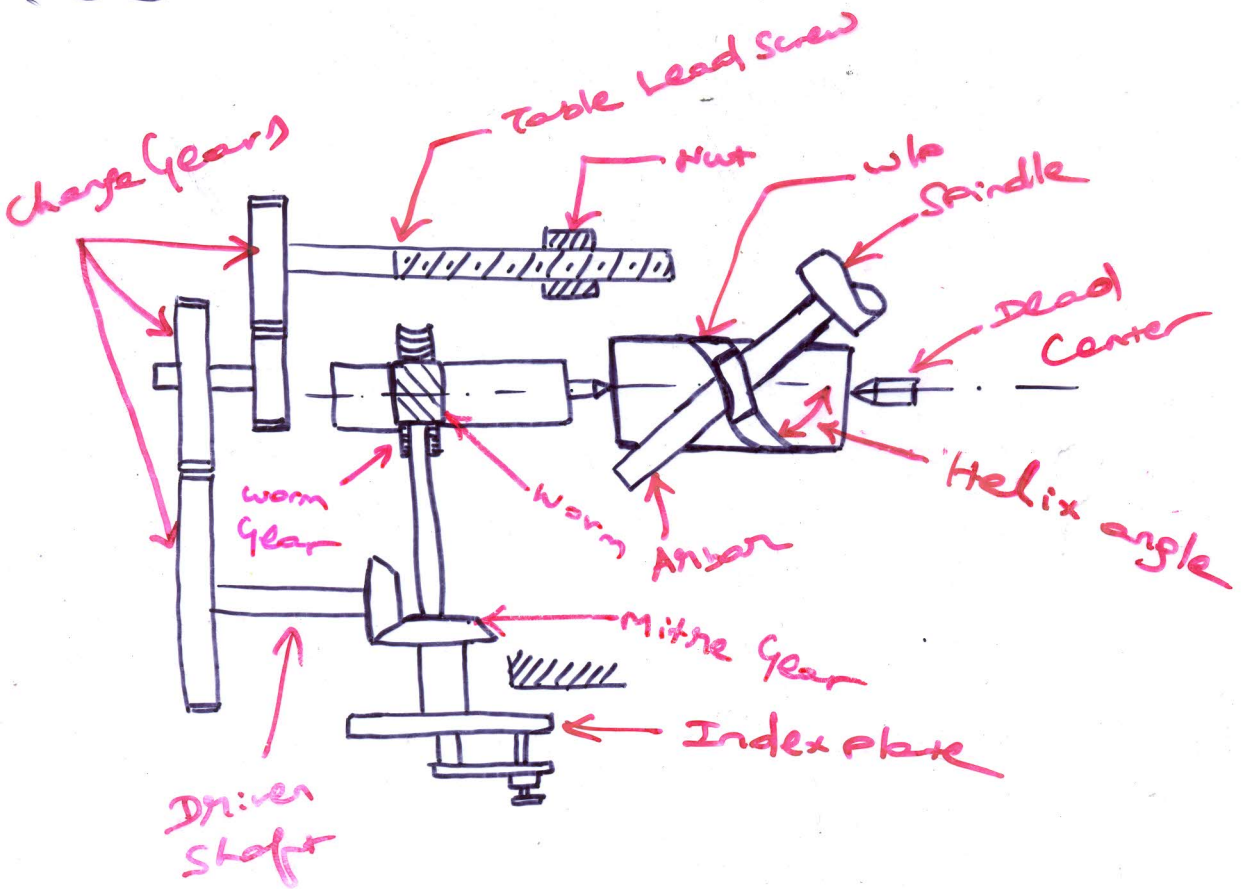
(15)



\* Radial distance b/w the arms can be adjusted depending on the no of holes to be moved.

# Helical Gear milling in universal milling machine:-

(6)



① The Gear blank is fit into the mandrel which is supported in between Live center & Dead center of universal dividing head & Tail stock respectively.

② Cutter of required profile is taken & fit into the arbor of the milling m/c.

③ Then the workpiece axis is made to coincide with the cutter teeth by various movements available in the milling machine.

④ Then, the table is swivelled to the required Helix angle.

⑤ \* For forming a Helical teeth, the Gear blank should be rotated to a distance of lead <sup>of the Helical gear</sup> when machining takes place. So, here the Mitre Gear of the Universal dividing head is connected to the table lead screw through a Gear train.

\* So when the feed is given, Continuous rotary motion is given to the workpiece from the table lead screw through a set of gear train in the Universal dividing head.

\* As the gear train is connected to the table lead screw, differential indexing cannot be done. Only simple indexing method is used for indexing.

⑥ Now, the table is fed against the rotating cutter to form a tooth on a Gear blank.

⑦ After one tooth is formed, w/p is indexed to the next position by moving the indexing crank to the required number of holes in the selected hole circle and the next tooth is formed.

⑧ In this way, Helical is formed by universal milling machine.

Helical Gear milling calculation:-

(a) Blank Diameter =  $m \left( \frac{z}{\cos \beta} + 2 \right)$

$\beta \rightarrow$  Helix angle  
 $m \rightarrow$  Module of Gear  
 $z \rightarrow$  No of teeth  
 $N \rightarrow$  No of divisions

(b) Tooth depth =  $2.25m$

(c) Cutter Pitch =  $6m$

(d) Index crank movement =  $\frac{40}{N}$

(e) Lead of the Helical Gear,  $T_2 = \frac{\pi D}{\tan \beta}$

(f) Gear ratio =  $\frac{\text{Driver}}{\text{Driven}} = \frac{40T_1}{T_2}$

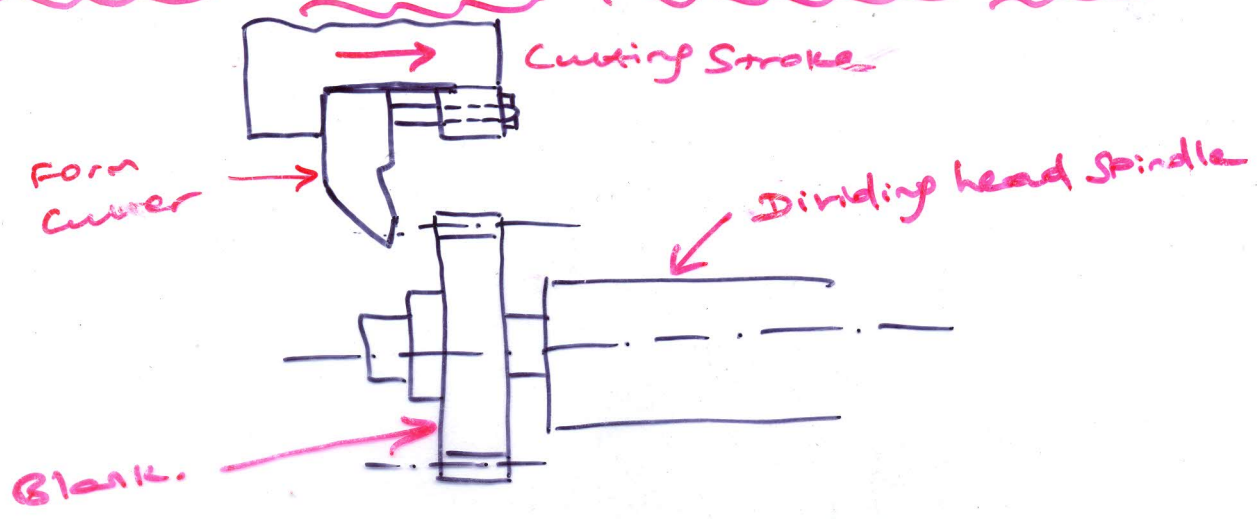
$T_1 \rightarrow$  Pitch of lead screw  
 $T_2 \rightarrow$  lead of Helical Gear.

(3) Cutter teeth,  $z' = \frac{z}{\cos^2 \beta}$

| Cutter NO | No of teeth to be cut |
|-----------|-----------------------|
| No. 1     | from 135              |
| No. 2     | 55 - 134              |
| No. 3     | 35 - 54               |
| No. 4     | 26 - 34               |
| No. 5     | 21 - 25               |
| No. 6     | 17 - 20               |
| No. 7     | 14 - 16               |
| No. 8     | 12 - 13               |

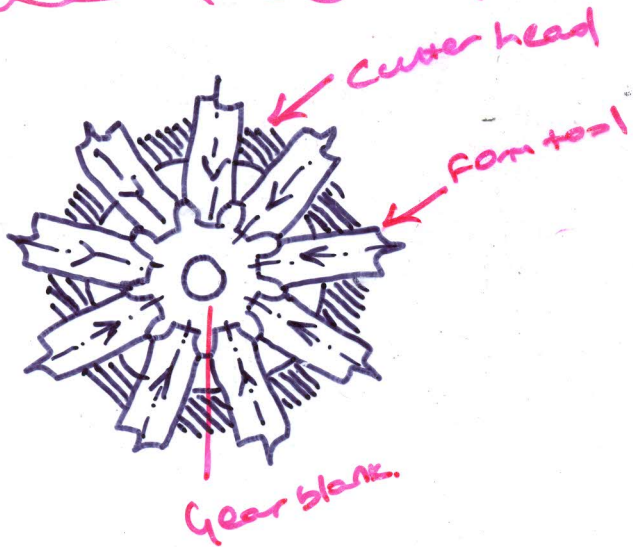
Based on  $z'$  value, the Cutter should be chosen from the table.

Gear cutting by single point formed tool:-



## Gear cutting by Shear Speed Process:-

(a)

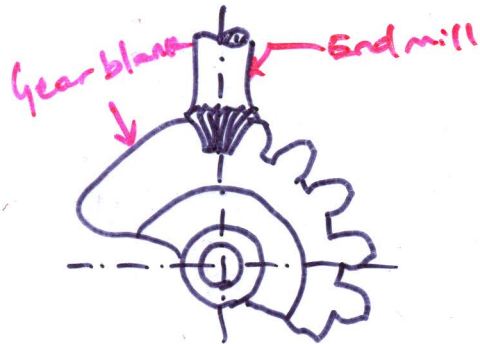


- \* All teeth are formed simultaneously by a ring of formed blades
- \* Work - Ram & reciprocates
- \* Radial Adjustment for the cutter for
  - ① relief during retraction
  - ② Depth of cut.

### uses:-

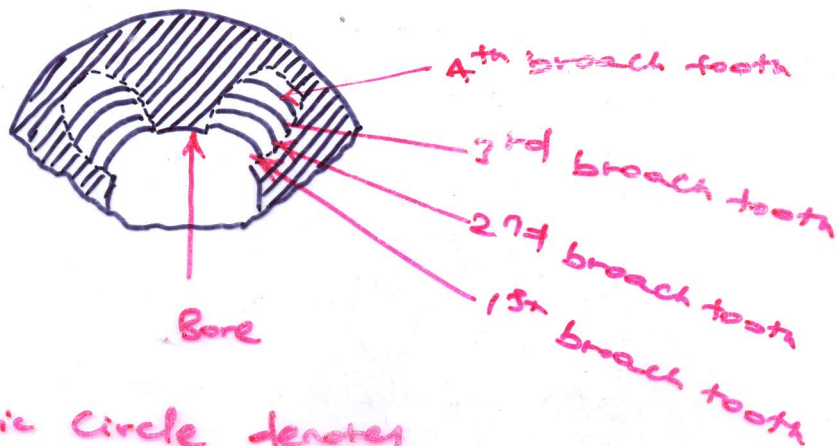
Spur gears, Splined shaft, Ratchet wheels etc.,

## Gear milling using a formed End mill:-



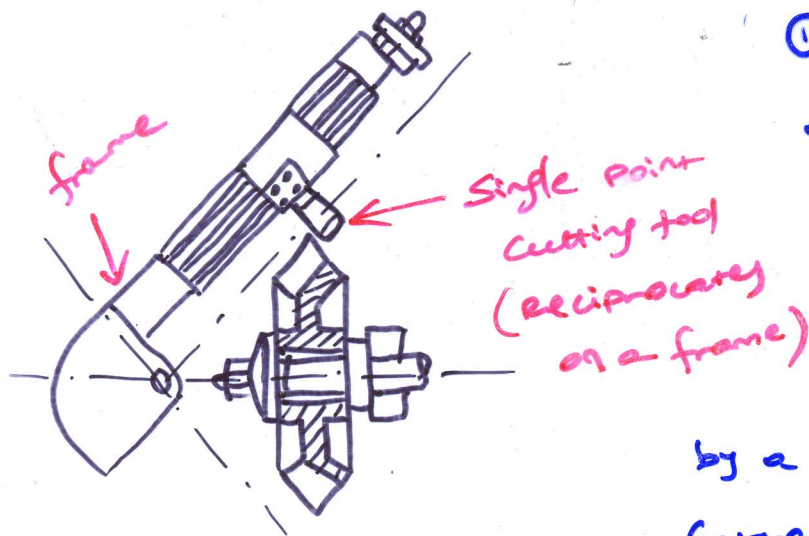
- \* Done in vmc
- \* Simple Indexing is used  
Crank movement =  $\frac{A_0}{Z}$
- \* Spur, helical, herringbone gears.

## Gear broaching:-



Concentric circle denotes depth of cut per tooth.

## Template Method:-



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① It involves the production of a gear tooth profile by a single point cutting tool which is reciprocated & made to follow a guided path by a template whose profile corresponds to the shape of the gear tooth being cut.

## Gear Generating method:-

- ① Gear Shaping Process
- ② Gear Planing Process
- ③ Gear Hobbing Process

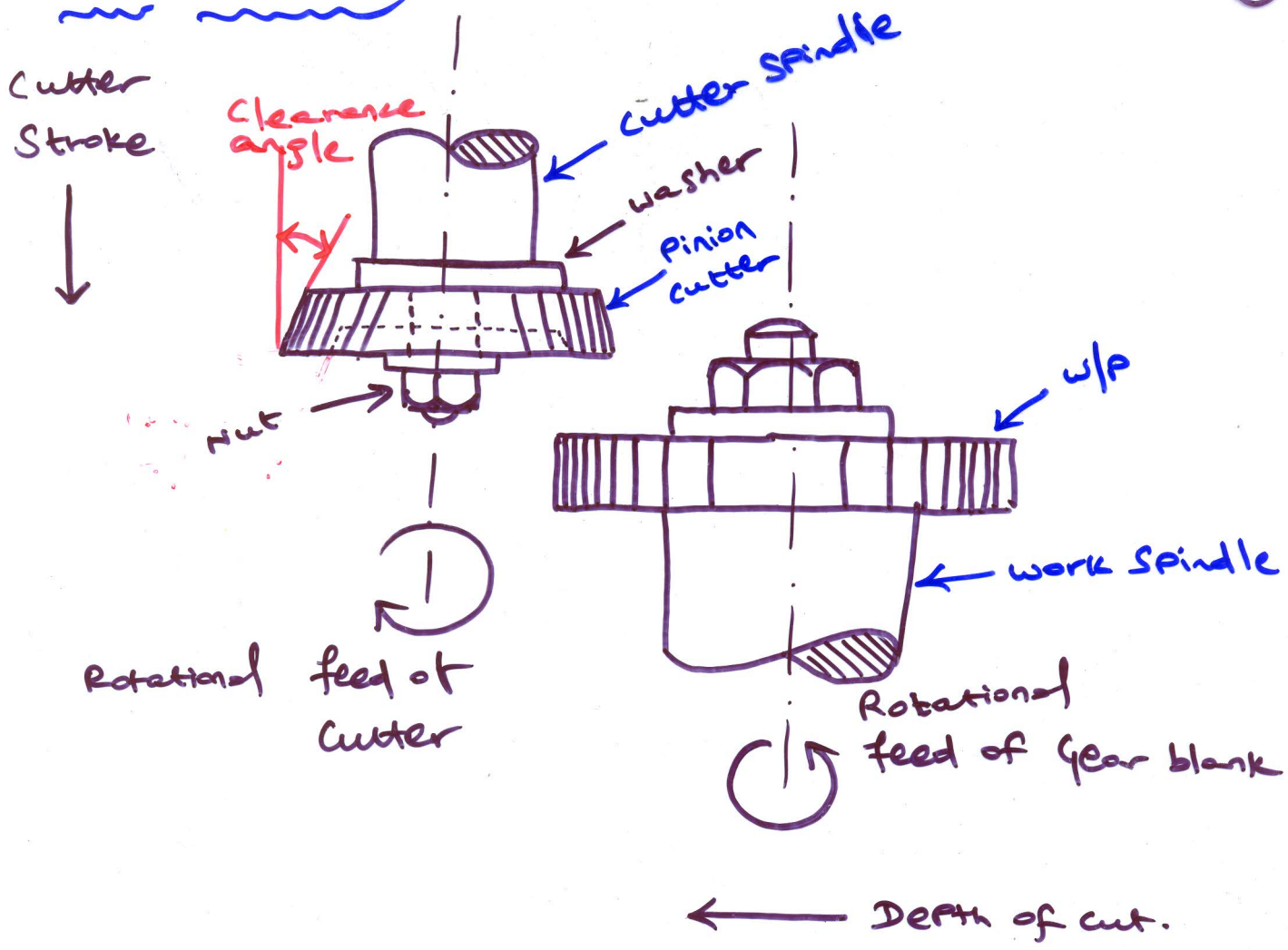
## Principle:-

Gear Generation is based on the fact that any two involute gears will mesh together.

- \* Here one gear is made as a cutter & the other is made as a gear blank.
- \* Cutter is made to reciprocate over the entire width of the gear blank.
- \* Cutter is fed towards w/p (or) vice-versa to give a depth of cut.

Due to the relative rolling motion b/w the cutter & blank, gear teeth are generated on the gear blank.

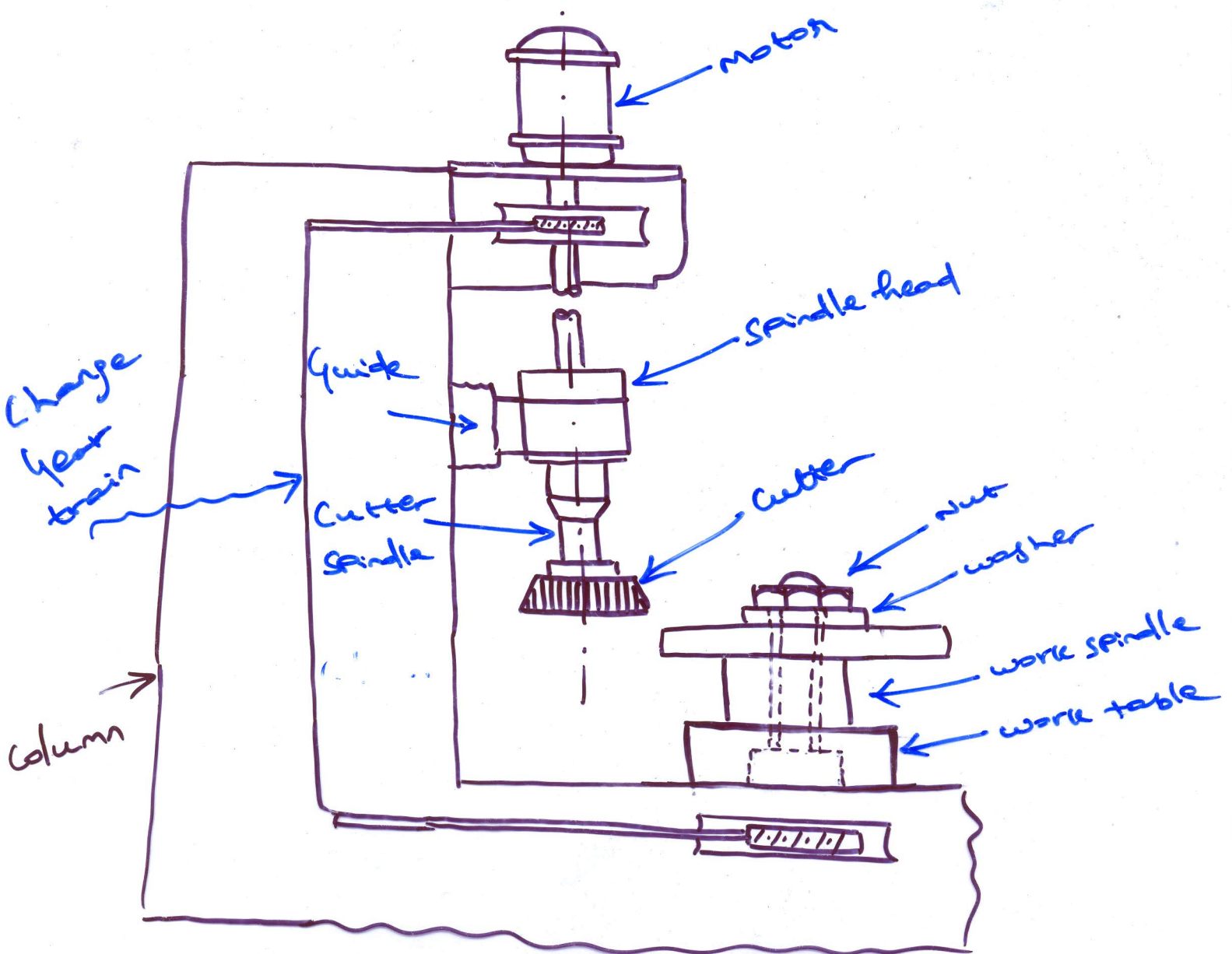
# Gear Shaping



- \* Gear Shaping is one of Gear Generation method used for cutting cylindrical external gears.
- \* Gear Shaping is done on a special type of machine called Gear Shaper.
- \* Here, pinion type cutter with proper rake & clearance angle is used.
- \* Here, the axis of rotation of cutter & Gear blank are parallel.

\* Here the cutter & work spindle are separately connected with gear train. It gives correct relative speed of rotation to these two spindles. So, the rotation of the cutter generates the tooth profile on the gear blank. The rolling movement is continued until all the teeth on the blank are cut.

\* During return stroke, the work is relieved from the cutter by a suitable mechanism. It is done to avoid the rubbing of cutter over the cut surface.



Gear shaper



The various movements available in the gear shaper are given below.

- ① Rotational feed for cutter & workpiece
- ② Radial feed of the cutter towards the blank for giving the depth of cut.
- ③ Reciprocating motion of the cutter along the width of the gear blank
- ④ withdrawal motion of the blank away from the cutter during return stroke

Application!-

- ① Gear shaping is used for generating both internal & external spur gear.
- ② Helical gear can also be generated using special Attachment.

Advantages:-

- ① Both internal & external gears can be generated.
- ② Various sizes of gears can be generated using a single cutter.

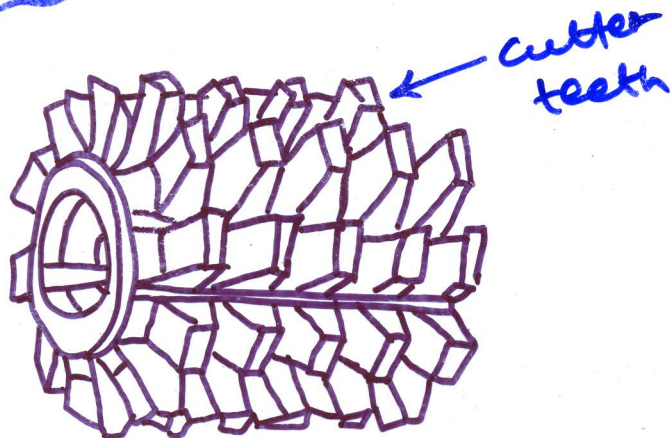
- ③ For the same module, a single type cutter can be used irrespective of the number of teeth in the gear.
- ④ As the cutting action is continuous, the rate of production will be high.

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Limitations:-

- ① Worm Gear can not be produced.
- ② There is no cutting in the return stroke of the cutter. So, there is a need to make return stroke faster than the cutting stroke.

Gear Hobbing:-



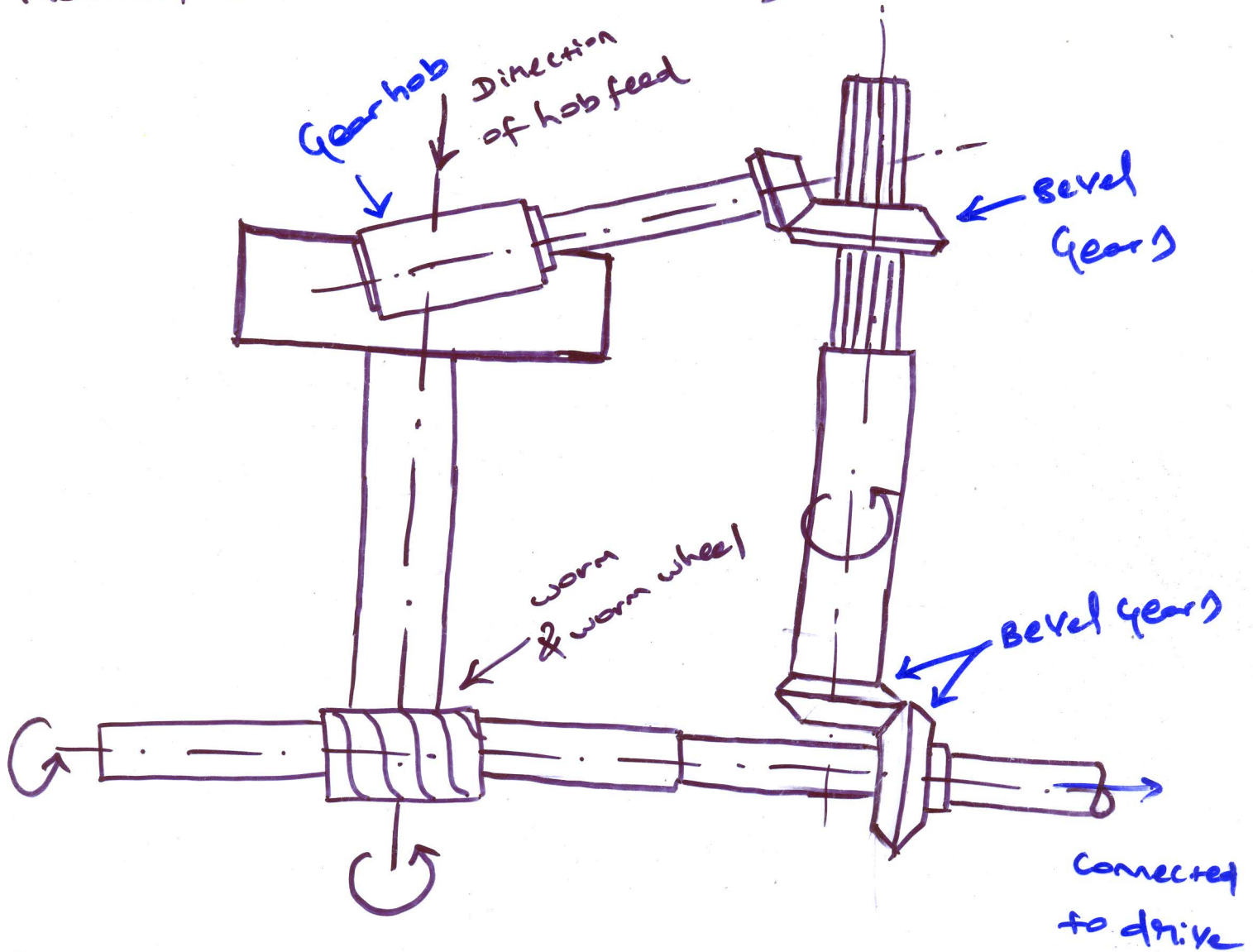
Hob

- \* The process of generating a gear by means of a multi-point rotating cutter called "hob" is known as hobbing.
- \* This hob looks like a worm & this process looks like a meshing of worm & worm wheel.

\* The hob may be either single threaded (or) multi threaded part.

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\* In gear hobbing operation, the gear blank is mounted on a vertical arbor but the hob is mounted on a horizontal rotating arbor.

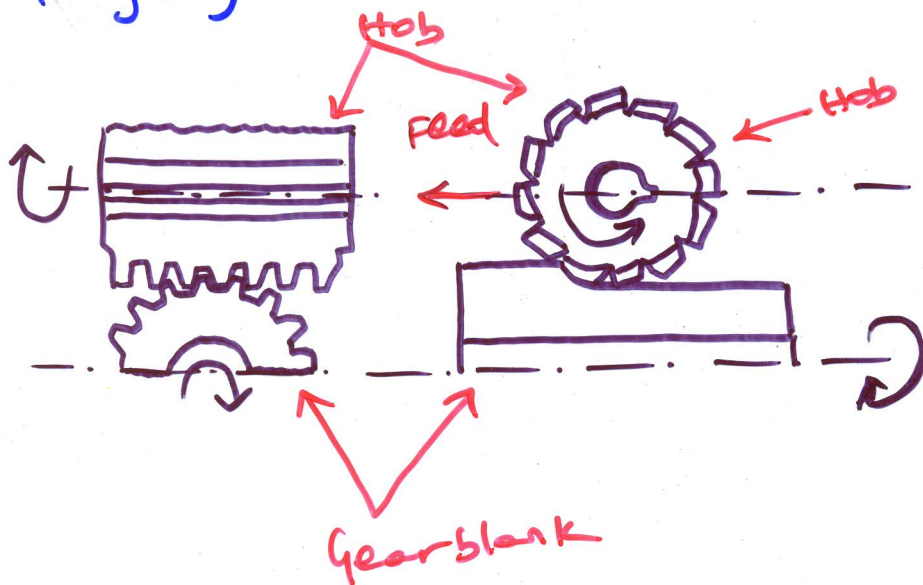


The various movements available in a gear hobbing machine

- ① Rotation of the hob [cutter]
- ② Vertical feed of the hob over the width of the gear blank

③ Rotational feed of the work piece

④ Radial feed of gear blank towards the cutter for giving the depth of cut.



\* In gear hobbing, the axis of rotation of cutter (hob) & the work piece are perpendicular to each other.

\* Here both gear blank & hob are made to rotate like worm & worm gear in mesh.

For cutting a helical gear, the axis of hob is inclined to 'd'.

Lead angle,  $d = \theta + (90^\circ - d_1)$  - Helix of the hob & gear blank are different.

$d = \theta - (90^\circ - d_1)$  - Helix of hob & gear blank are same

where,

$\theta \rightarrow$  Helix angle of the gear to be formed.

$d_1 \rightarrow$  Helix angle of the hob.

## Applications:-

Hobbing is used for generating spur, helical & worm gears.

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## Advantages:-

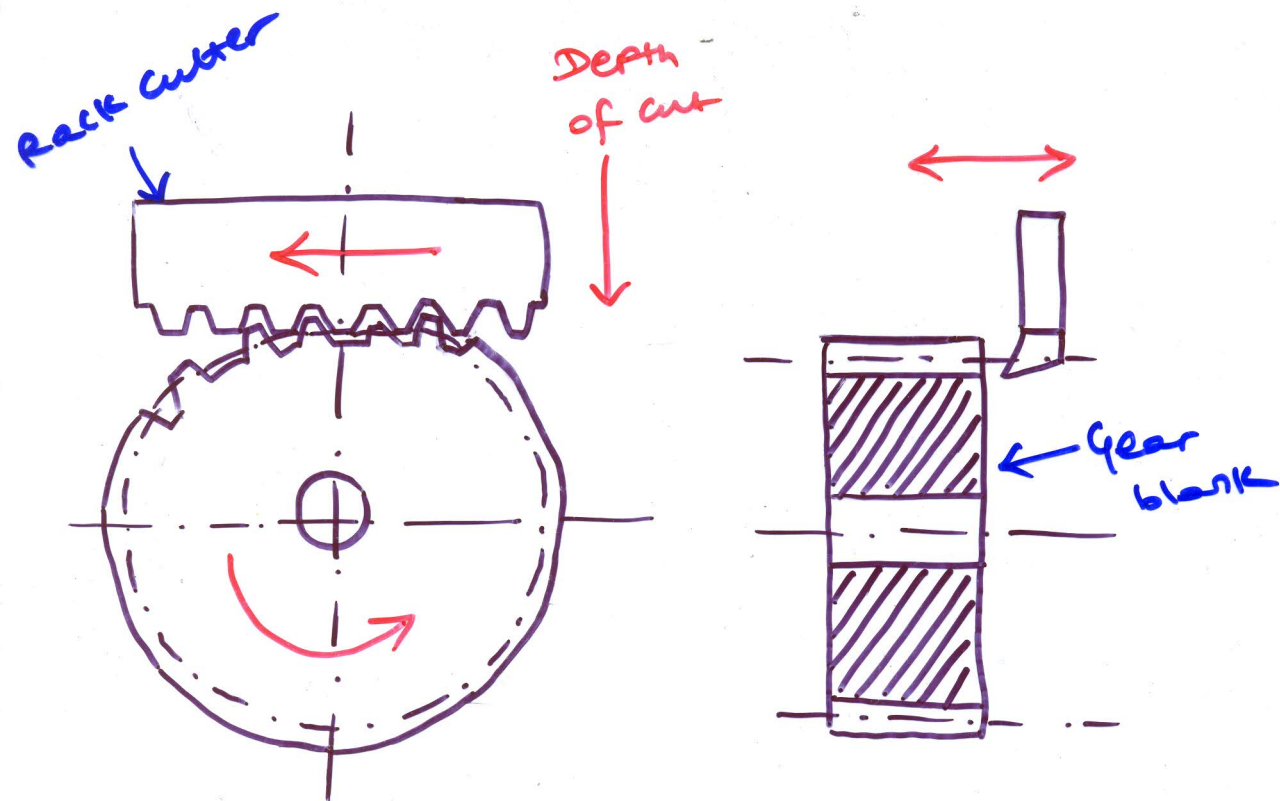
- ① Using a single hob, any number of teeth of the same module can be produced.
- ② Spur & helical gear can be produced using the same hob.
- ③ Several gear blanks mounted on the same arbor can be processed simultaneously. So it can be used for mass production.

## Limitations:-

- ① Internal gear cannot be produced.
- ② Rolling motion b/w the gear blank & hob is not continuous. So, production time is more.

# Gear planning:-

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- \* It is done on the Gear Planner.
- \* Here rack cutter is used for making the teeth on the Gear blank.
- \* Here, the cutter & the gear blank's movements are like a movement of a rack & pinion in mesh.
- \* Here the Gear blank is fitted on the table. The relative rolling movement between the Gear blank & cutter is obtained by the Gear train.
- \* Here, after the Rack has cut 2 (or) 3 teeth on the Gear blank, it will be brought to the starting position & the operation is repeated till

all the teeth are cut on the Gear blank (29)

\* In the Gear Planning Process, the following movements will be given.

- ① Radial feed of the cutter towards the gear blank for giving the depth of cut.
- ② Relative rotational feed & horizontal feed of the gear blank & cutter respectively
- ③ Reciprocating movement of cutter over the width of the gear blank.
- ④ The withdrawal of cutter from the gear blank during the return stroke. It will avoid the rubbing action of cutter during the return stroke.

Application:-

used to cut external spur & helical gear.

Advantage:-

- ① The same module gear of any number of teeth can be cut using a single rack cutter.
- ② Used to cut external spur & helical gear.

Limitation:-

- ① Internal & worm gear cannot be produced.
- ② Due to stepping back of cutter, production time is high.

## Gear Finishing Process:-

- \* Gears manufactured by different machining process will have rough surfaces.
- \* The machined gears may have errors in tooth profiles, concentricity, helix angles.
- \* For quiet & smooth operation of gears, these errors & rough surfaces should be removed. Gear finishing operations are done for this purpose.

- ① Burnishing - for gears not hardened.
- ② Shaving - for gears not hardened.

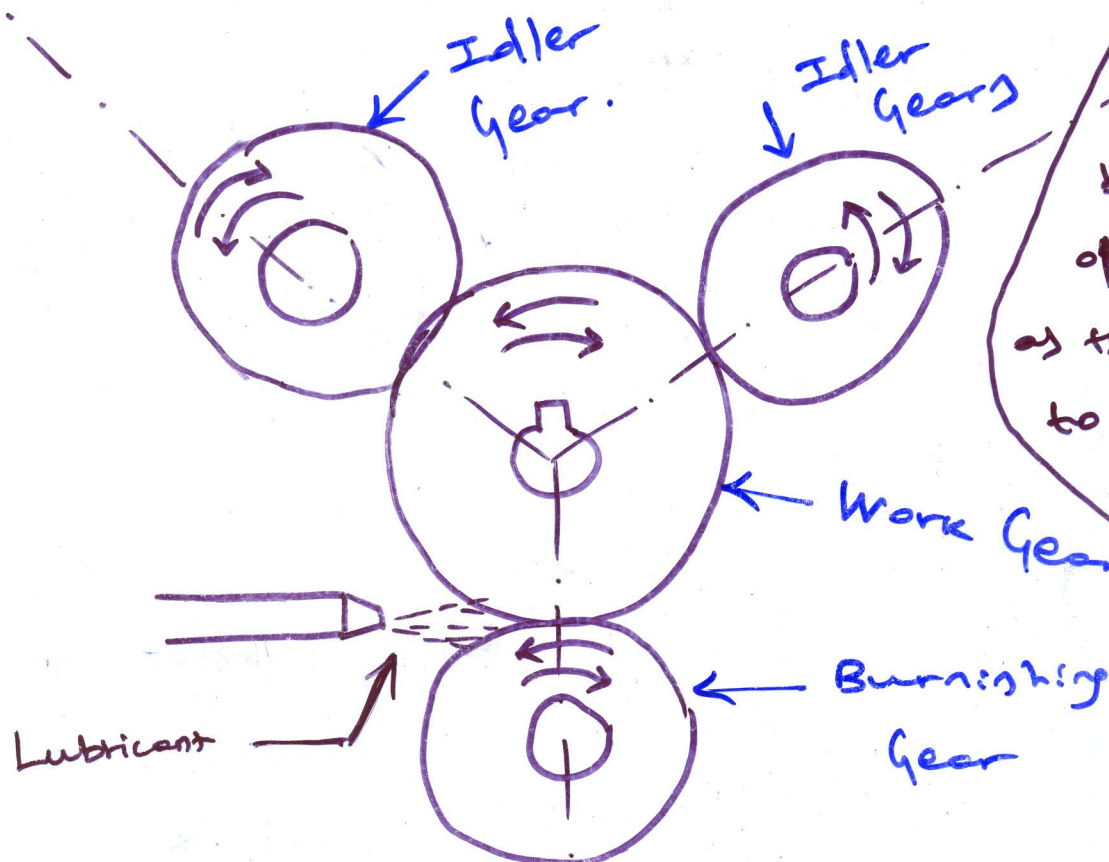


③ Grinding - for Gears which are hardened.

④ Lapping - for Gears which are hardened.

③

### Gear Burnishing:



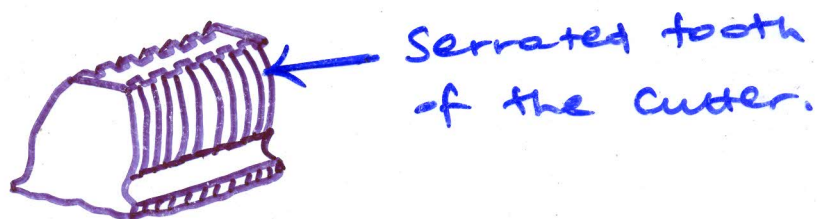
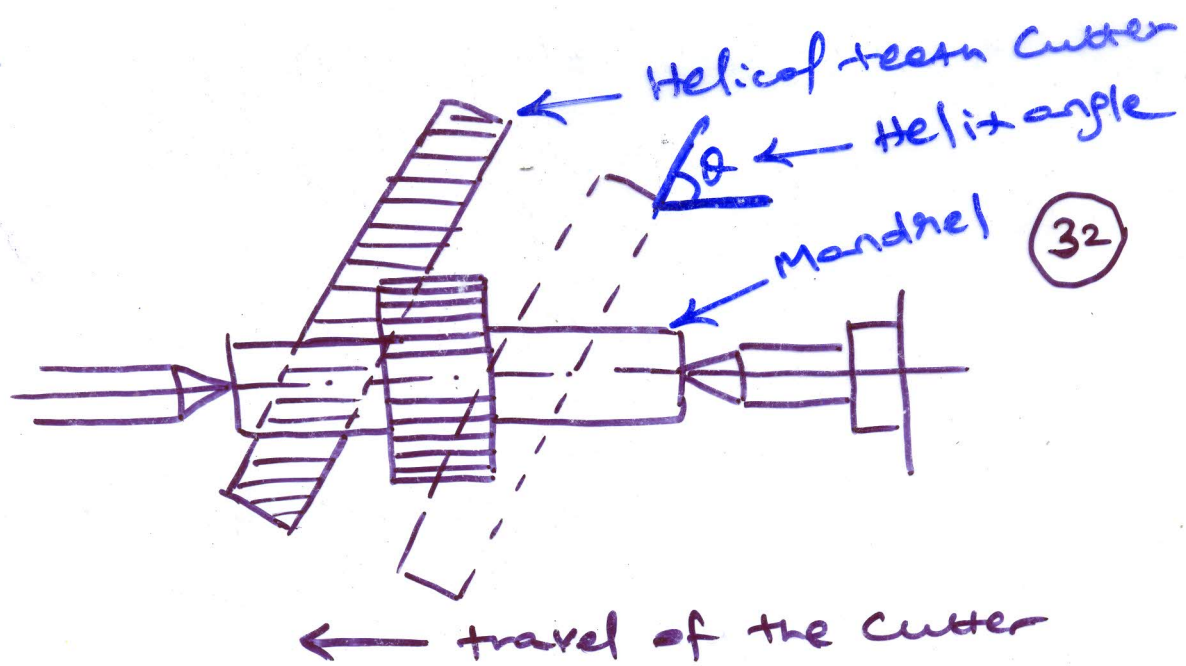
① Here, the hardened burnishing gear of same module as that of the gear to be finished is made to mesh with the gear to be finished.

② The idler gears are used to support & give the pressure.

### Gear Shaving:

\* Most common method of gear finishing.

\* In this method, a very hard gear shaving cutter is used to remove fine chips from the gear teeth.



- \* Rotation of the work gear
- \* Rotation of cutter & Reciprocation of Shaving cutter.

## Gear Grinding

It is used for finishing of gears after hardening. Gear Grinding is done for

- 1) Increasing the accuracy & surface finish of the gears
- 2) Removing the distortion after heat treatment.

There are two methods of Gear Grinding.

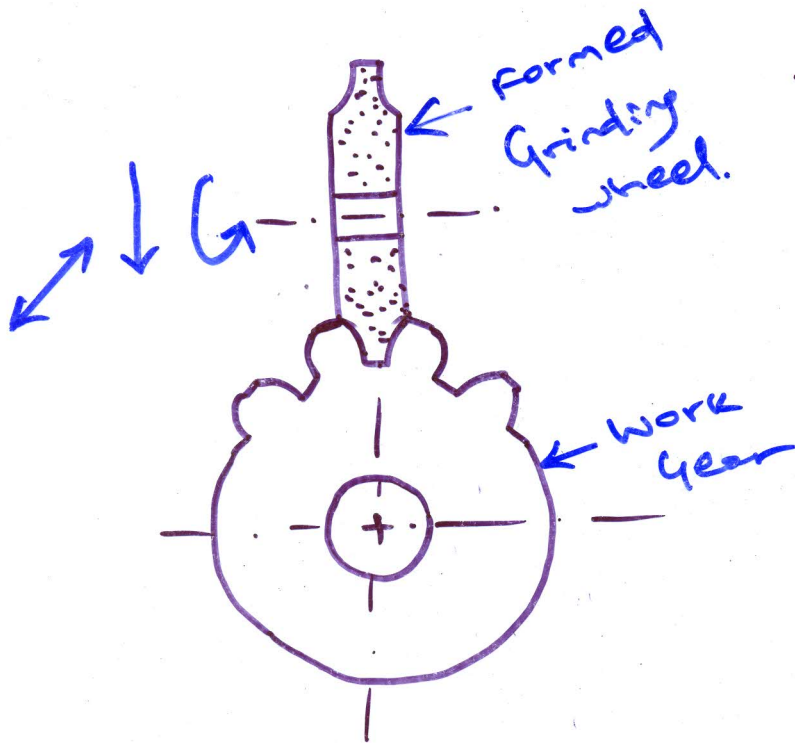
They are

(33)

a) Formed wheel Grinding

b) Generation Gear Grinding.

Formed wheel Grinding:—

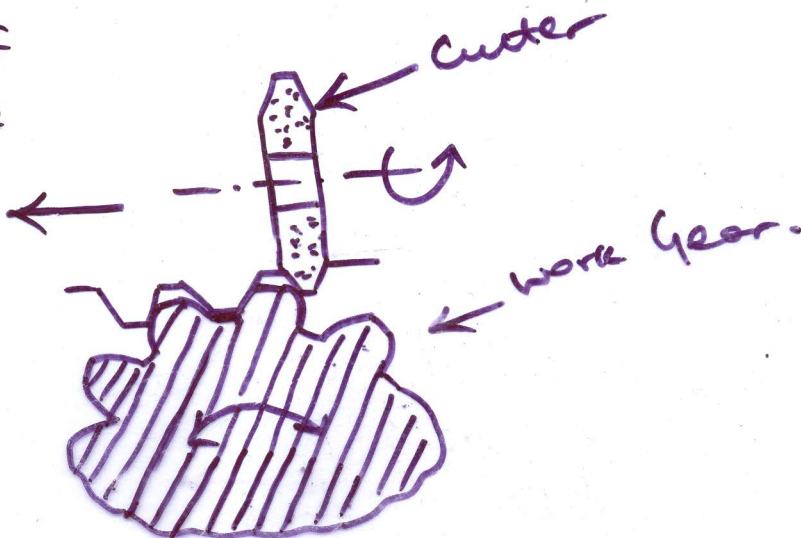


\* Three Passes required for completing one tooth space.

\* Coolant should be used while finishing.

Generation Gear Grinding:—

Movement of  
Cutter like  
a rack  
over pinion

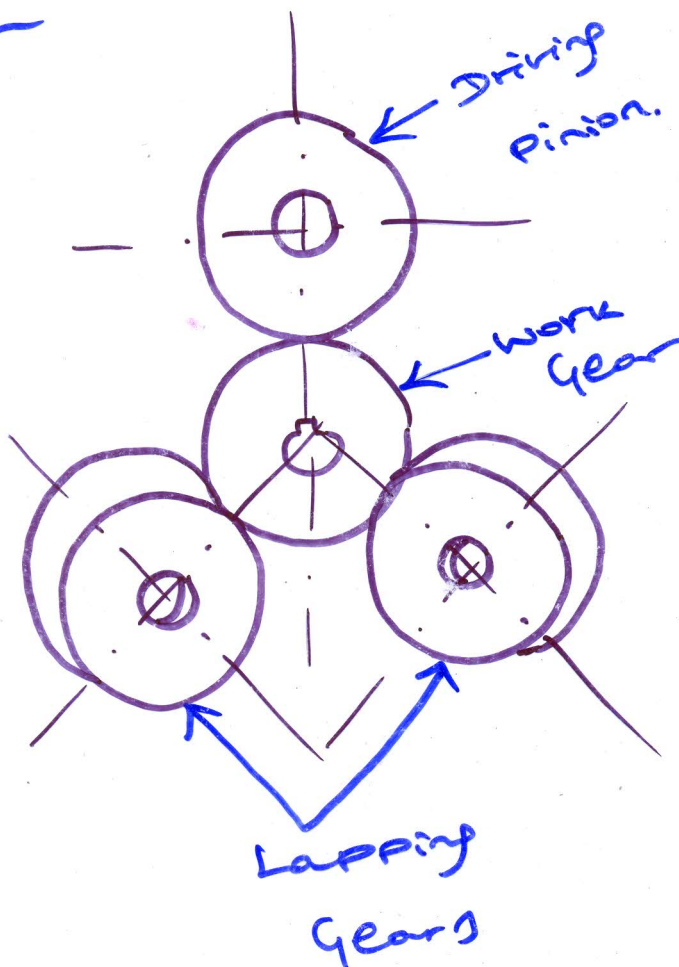


\* The work gear is rolled along an imaginary rack.

\* Rolling is done in both the direction to grind both sides of the tooth.

\* The Grinding wheel rotates & reciprocates along the length of the tooth.

Gear lapping:-



\* The surface of the lapping gears are inclined at about  $4^\circ$  to the work gear surface where the surface of the driving pinion is  $\parallel$  to the work gear surface.

\* when the gears rotate, a lapping compound is applied b/w them. The compound is a mixture of a very fine abrasive powder and kerosene.