ATME College of Engineering

Machining Science & Metrology BME402

Module-2
Introduction to Milling Machine

MODULE-2

Milling Machines: up milling & down milling, classification of milling machines, constructional features (Column and Knee and vertical milling machine), milling cutter nomenclature, various milling operations, calculation of machining time.

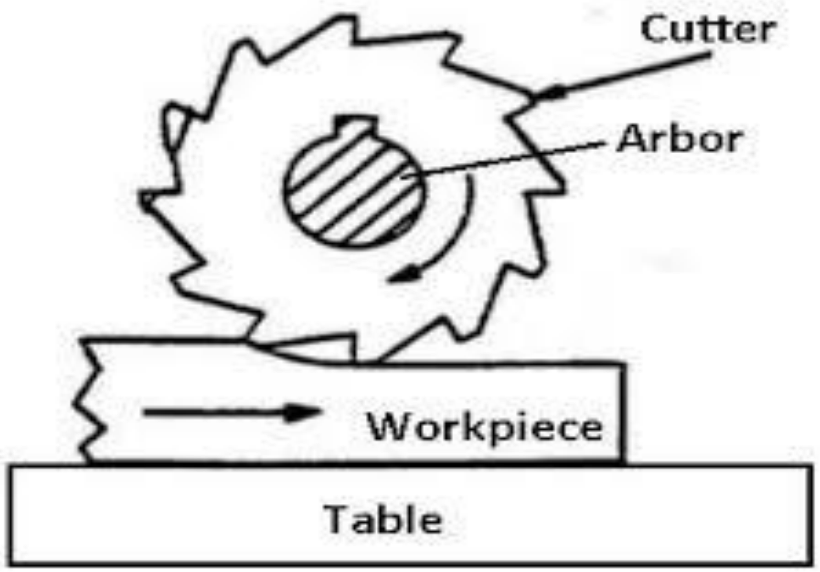
Indexing: Need of indexing Simple, compound and differential indexing calculations. Simple numerical on indexing.

Shaping, Slotting and Planning Machines Tools: Driving mechanisms of Shaper, Slotter and Planer. Operations done on Shaper, Planer & Slotter Difference between shaping and planning operations.

Drilling Machines: Constructional features (Radial & Bench drilling Machines), operations, types of drill & drill bit nomenclature. Calculation of machining time.

Grinding: Grinding operation, classification of grinding processes: cylindrical, surface & centerless grinding.

Milling:



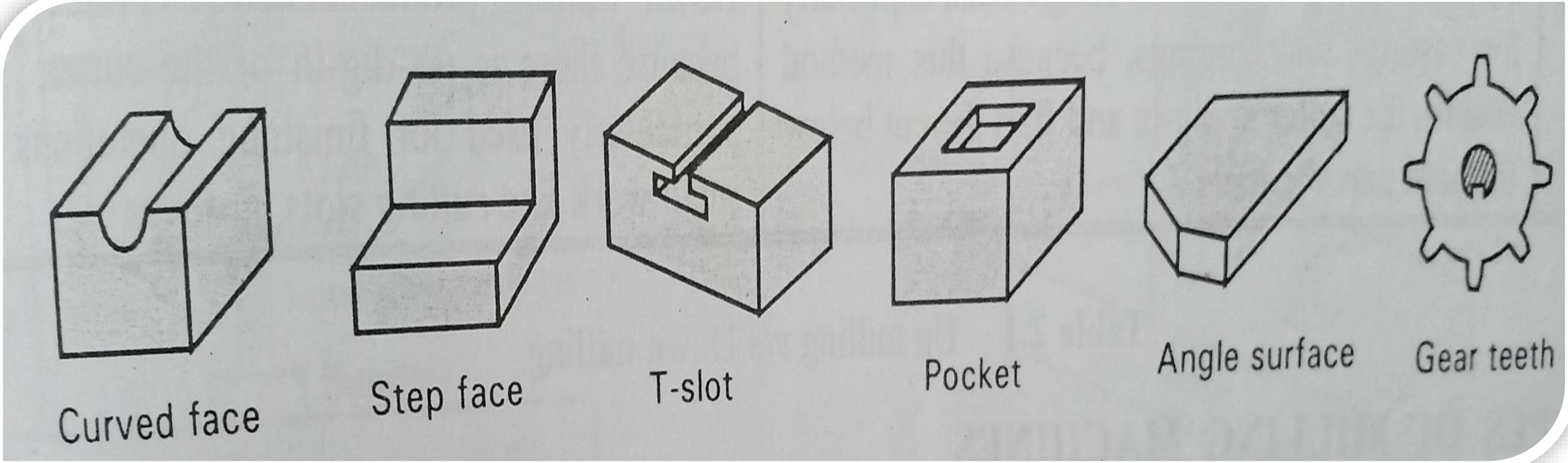
Milling is a manufacturing process in which the excess material from the workpiece is removed by a rotating multipoint cutting tool called *milling cutter.*

Principle of Milling

- In milling the cutter is held in the spindle of the machine and made to rotate suitable speeds
- The workpiece is also held rigidly by a suitable device and is fed slowly against the rotating cutter
- The workpiece can be fed in two different directions with respect to cutter rotation that is
  - **Up milling**
  - **Down Milling**

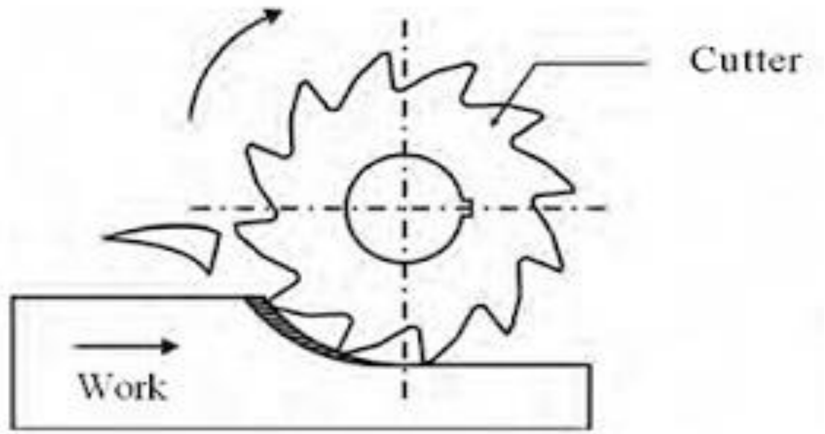
Type of Milling Cutter

Various Shaped Produced by Milling



Methods of Milling:

Based on the motion between the workpiece and the cutter, milling is classified into *up milling* and *down milling.*

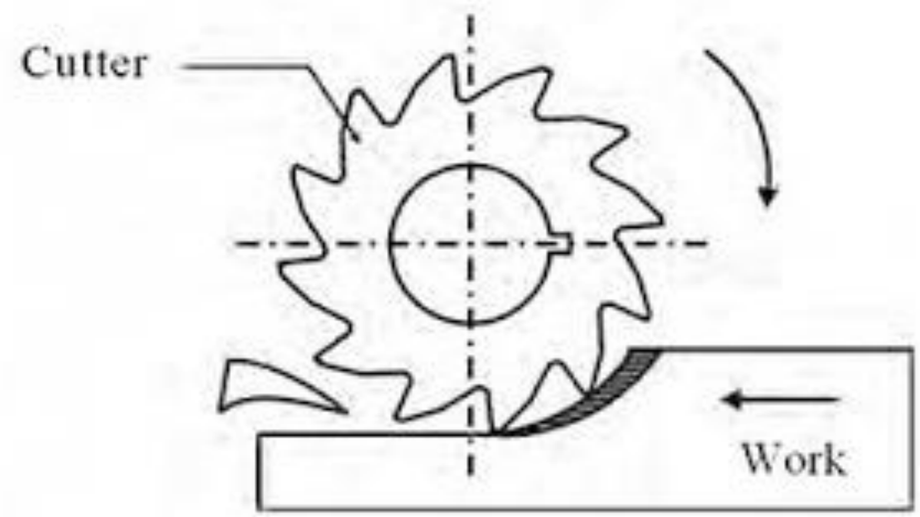


Upmilling

Up milling: In up milling, the workpiece is fed in the direction opposite to that of the rotating cutter.

Down Milling:

In down milling, the workpiece is fed in the same direction as that of the rotating cutter.



Downmilling

Comparison between Up milling and Down milling

Sl. No	Up milling	Down milling
1	Here the workpiece is fed in the direction opposite to that of the rotating cutter.	Here the workpiece is fed in the same direction as that of the rotating cutter.
2	The thickness of chip is minimum at the beginning of cut and reaches to a maximum when the cut ends.	The thickness of chip is maximum at the beginning of cut and reaches to the minimum when the cut ends.
3	Here the cutting force is directed upwards. This tends to lift the workpiece from the worktable. Hence, greater clamping force for the workpiece becomes necessary.	Here the cutting force is directed downwards, and this tends to keep the workpiece firmly on the worktable thereby permitting lesser clamping forces.

Comparison between Up milling and Down milling

Sl. No	Up milling	Down milling
4	Up milling is preferred for rough cuts, especially for castings and forgings.	Down milling produces better surface finish and hence it is used for finishing operations
5	During up milling, the chip gets accumulated at the cutting zone.	In down milling, the chips do not interfere with the revolving cutter, since they are disposed easily by the cutter
6	In up milling, it is difficult for efficient circulation of coolant. The cutter rotating in the upward direction carries away the coolant from the cutting zone.	In down milling, the coolant can be easily reach the cutting zone. Hence, efficient cooling of the tool and the workpiece can be achieved.

Classification of Milling Machines:

- Milling machine is one of the most versatile machine tool in existence.
- There are variety of machines: each having their own features and designed for a particular application.
- The different types of milling machines are classified as follows:

Classification of Milling Machines:

(1) Column and Knee milling machines

(a) Plain Column and Knee milling machines

- Horizontal spindle type
- Vertical spindle type

(b) Universal column and knee type milling machine

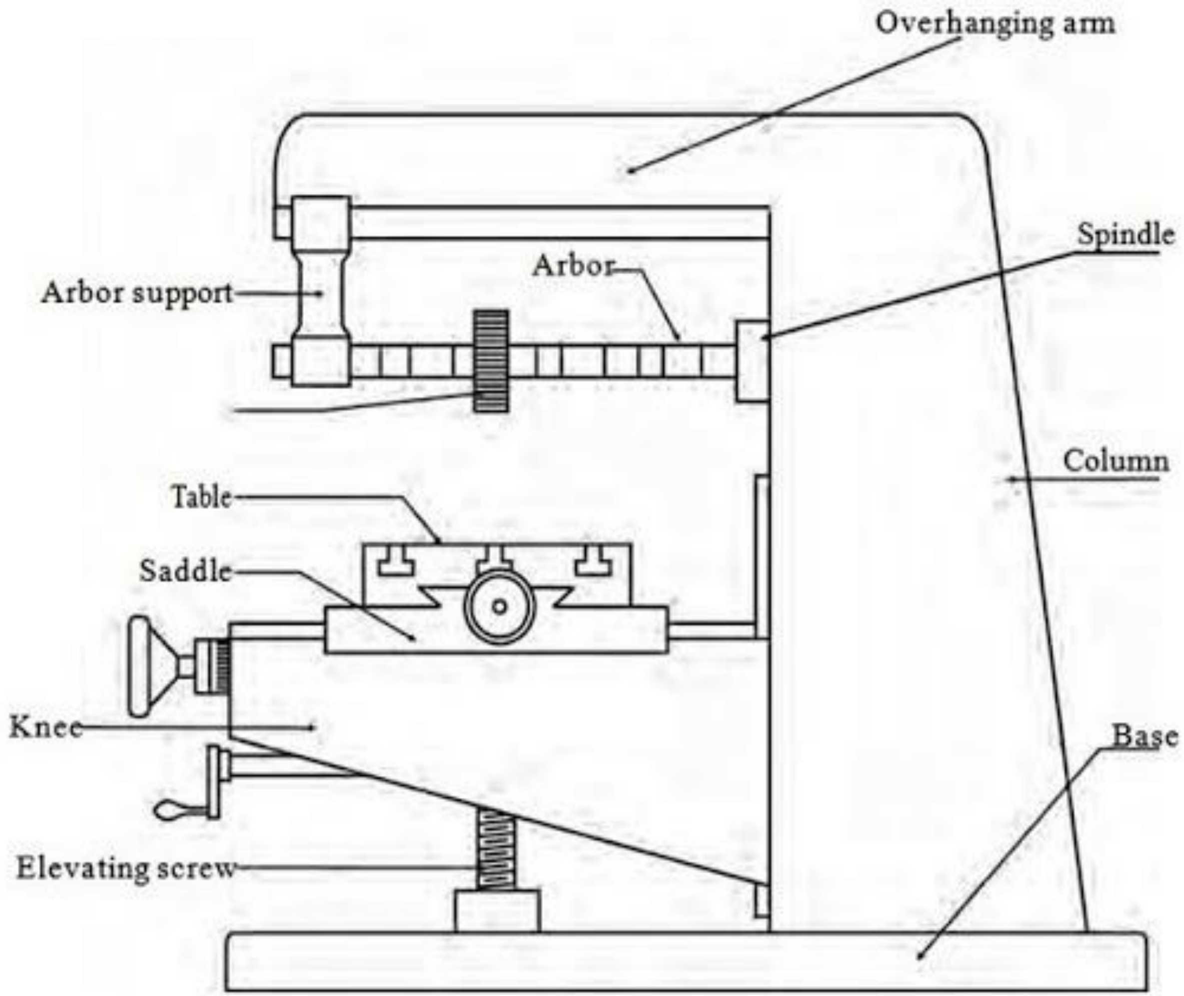
(c) Ram type milling machine

(2) Bed type milling machine

(3) Planer type milling machine

(4) Special purpose milling machines

Horizontal – Spindle Column and Knee Milling Machine:



It is one of the most popular type of milling machines and is commonly called ***horizontal milling machine,*** **because of the horizontal position of the spindle.**

This type of machine is used to cut grooves, slots, keyways, gear teeth etc.

The machine consists of the following parts:

Base: The base is usually a strong and hollow part, which forms the foundation of the machine and upon which all the other parts are mounted.

The hole provided in the centre of the base houses the support for the screw that raises and lowers the knee.

Column: The column is a vertical hollow casting and is usually combined with the base to form a single casting. **The column houses the spindle and bearings as well as the drive units for *transmitting power from the electric motor to the spindle at desired speeds.***

The machine consists of following parts:

Spindle: The spindle is a hollow shaft supported by the column with suitable bearings.

The spindle obtains the power from the motor and transmits it to the arbor. The arbor carrying the cutter rotates about a horizontal axis.

Overarm: An adjustable overarm mounted on the vertical column supports the yoke, which in turn supports the free end of the arbor.

The machine consists of following parts:

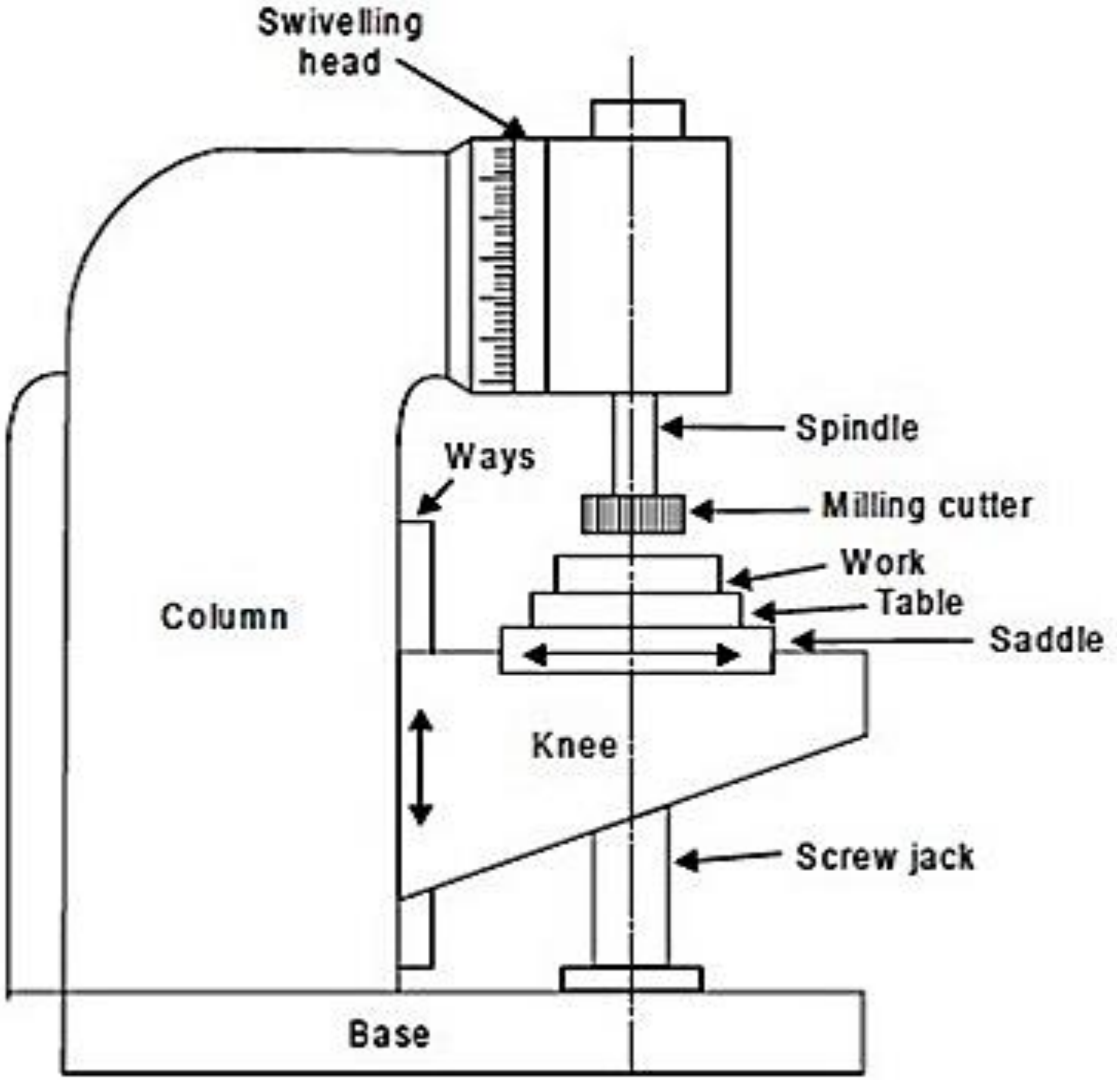
Knee: The knee is a casting that slides up and down on the vertical guideways provided on the column by means of an elevating screw. The knee supports the saddle.

Saddle: The saddle rests on the knee and constitutes the intermediate part between the knee and the table. The saddle moves transversely, i.e., crosswise (in or out) on guide ways provided on the knee.

Worktable: The worktable is larger in size and rests on the saddle. The worktable is provided with T-slots all along its length for mounting vice or other work holding devices.

This enables the workpiece to be clamped rigidly on the table.

Vertical- Spindle Column and Knee Milling Machine:



Vertical spindle milling machines are similar in construction to the horizontal milling machines, **except that the spindle is held in a vertical position.** ***This type of machine is generally used to perform end milling and face milling operations.***

Constructional details: Refer the details given for horizontal milling machines.

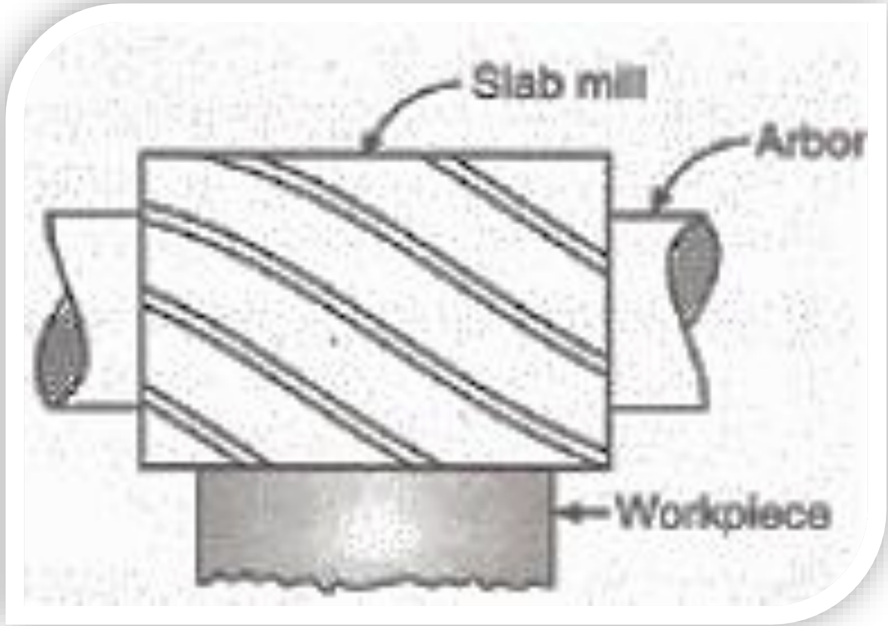
Milling Operations:

Some of the operations performed on milling machine are:

- Plain or Slab Milling
- Face Milling
- End Milling
- Slot Milling
- Angular Milling
- Form Milling
- Straddle Milling
- Gang Milling
- Keyway Milling
- Gear Cutting
- Thread Milling

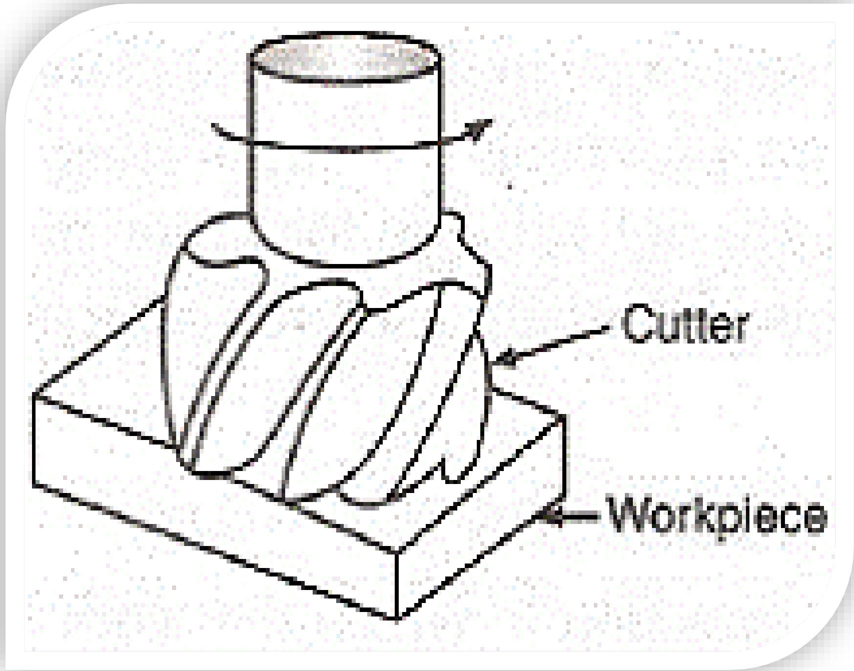
Plain or Slab Milling:

Plain Milling, also called *surface milling* or *slab milling* is the operation of producing ***a plain horizontal surface with a milling cutter whose axis is parallel to the surface of the workpiece being machined.***



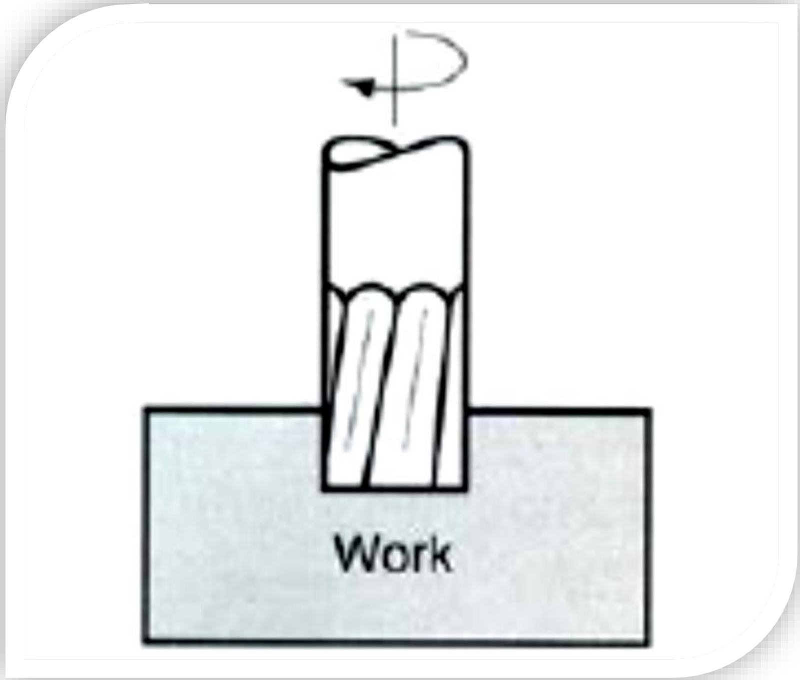
Face Milling:

Face Milling is the operation carried out for producing <u>a flat surface, which is perpendicular to the axis of the rotating cutter.</u>



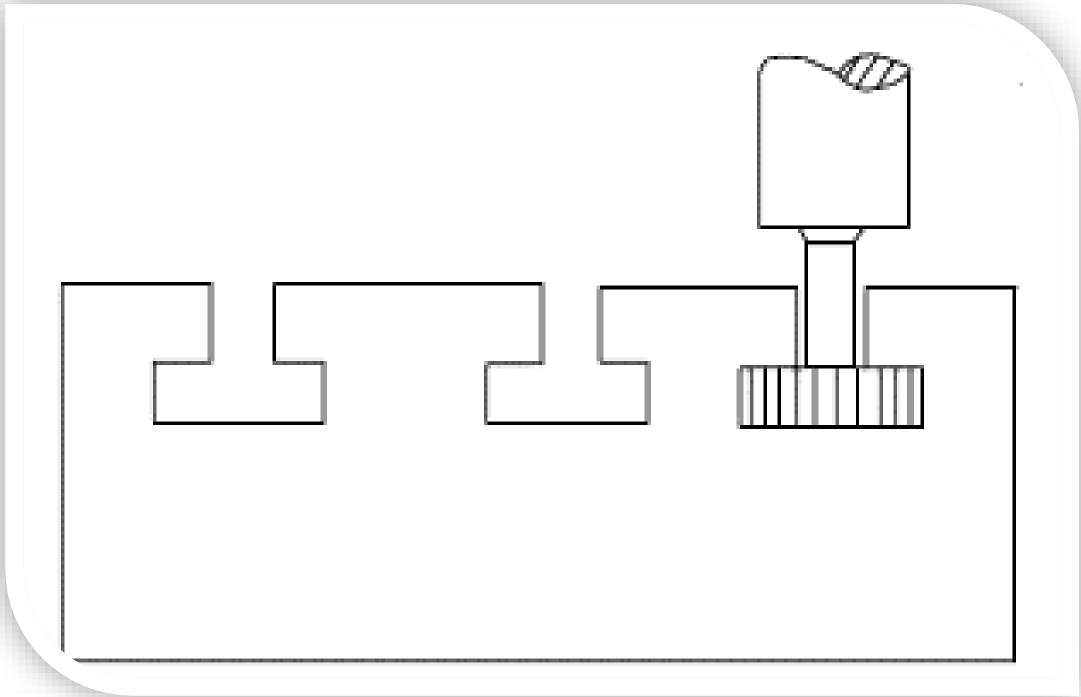
End Milling:

End Milling is the operation for producing flat surfaces, slots, grooves or finishing the edges of the workpiece by means of a tool called *end mill* or *end milling cutter.*



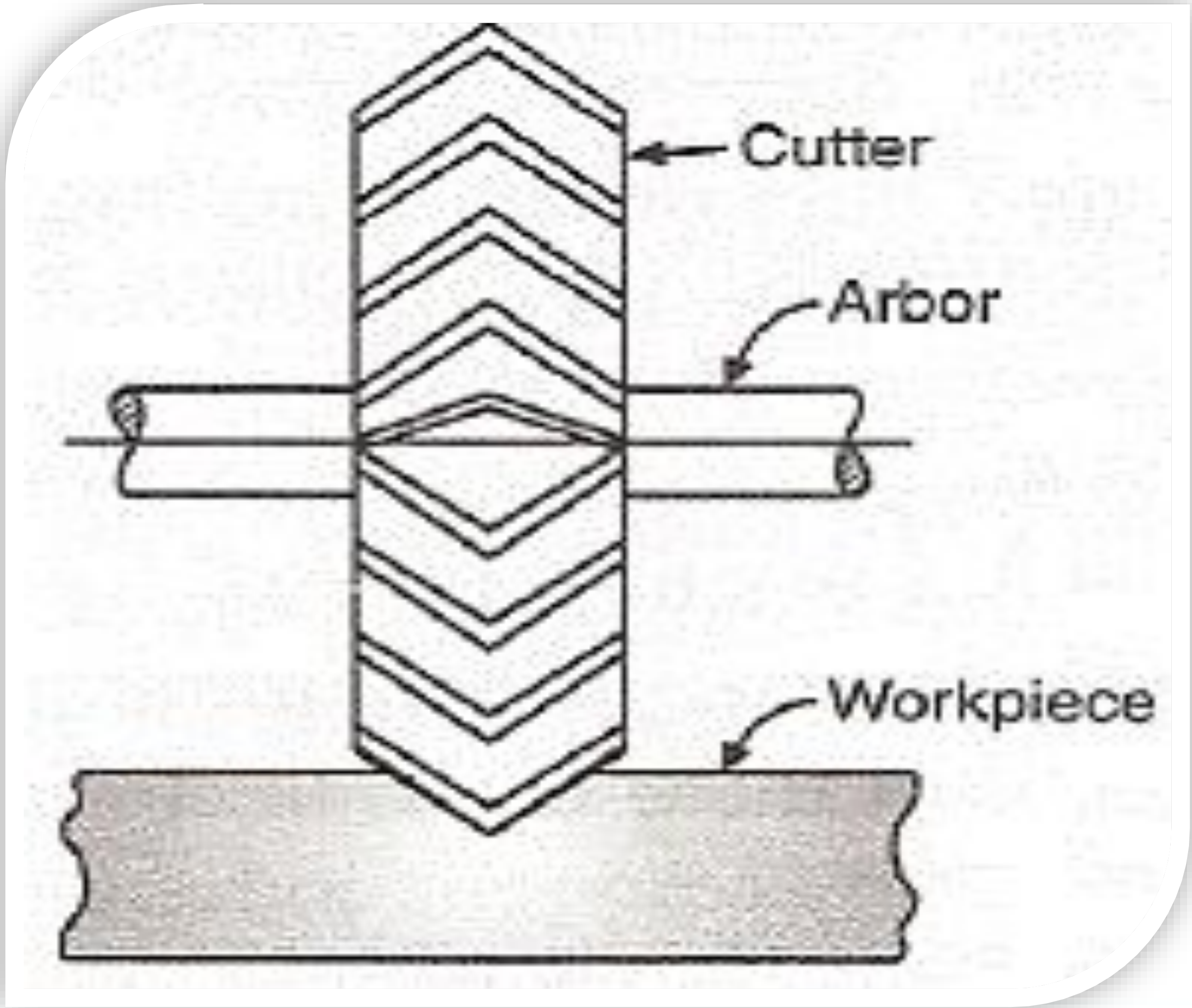
Slot Milling:

Slot Milling is the operation of producing slots like T-slots, plain slots, dovetail slots etc., in worktable fixtures and other work holding devices. The operation may be performed using either end milling cutter, T-slot cutter or side milling cutter.



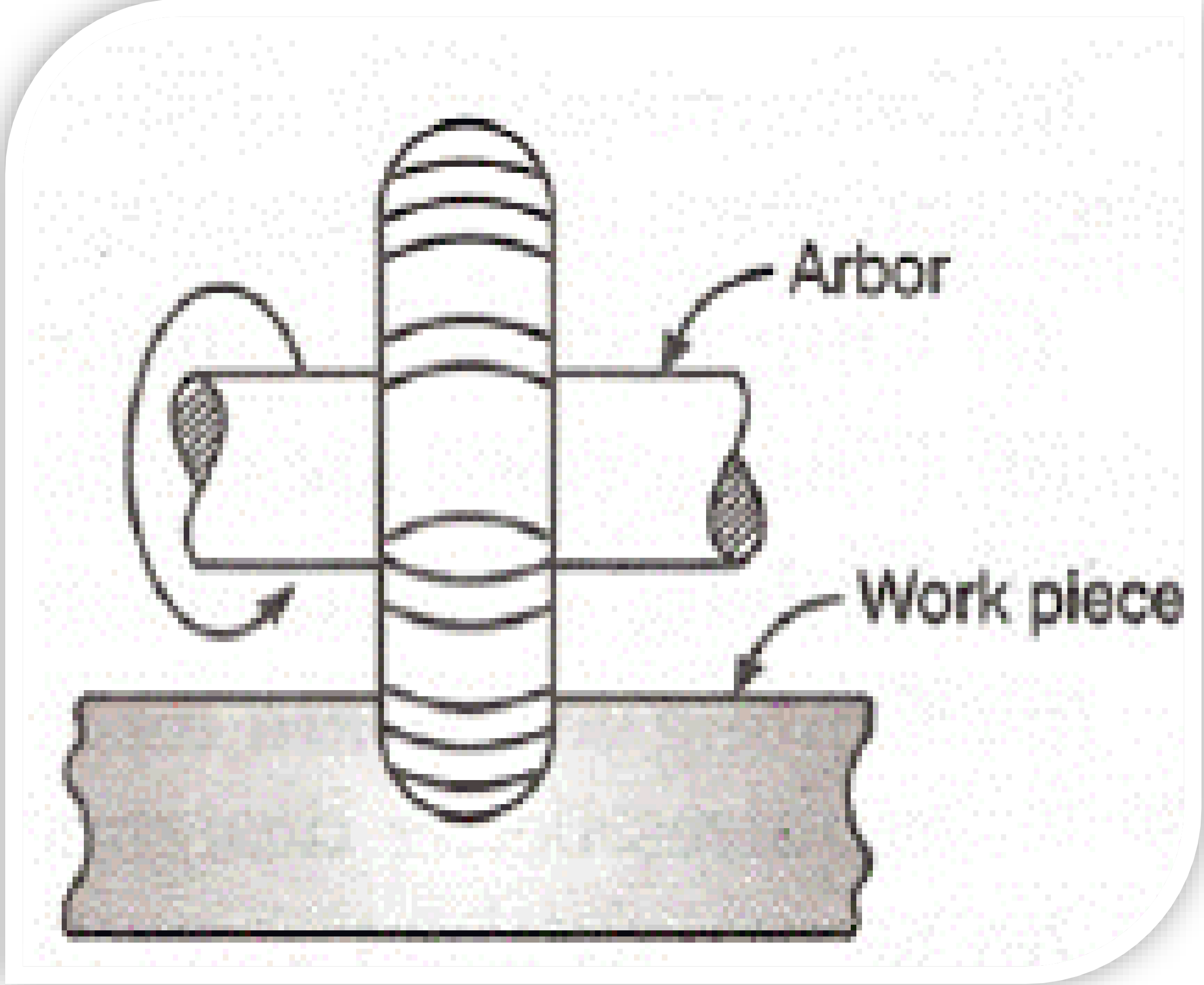
Angular Milling:

Angular Milling or angle milling is the operation of producing all types of angular cuts like V-notches and grooves, serrations and other angular surfaces.



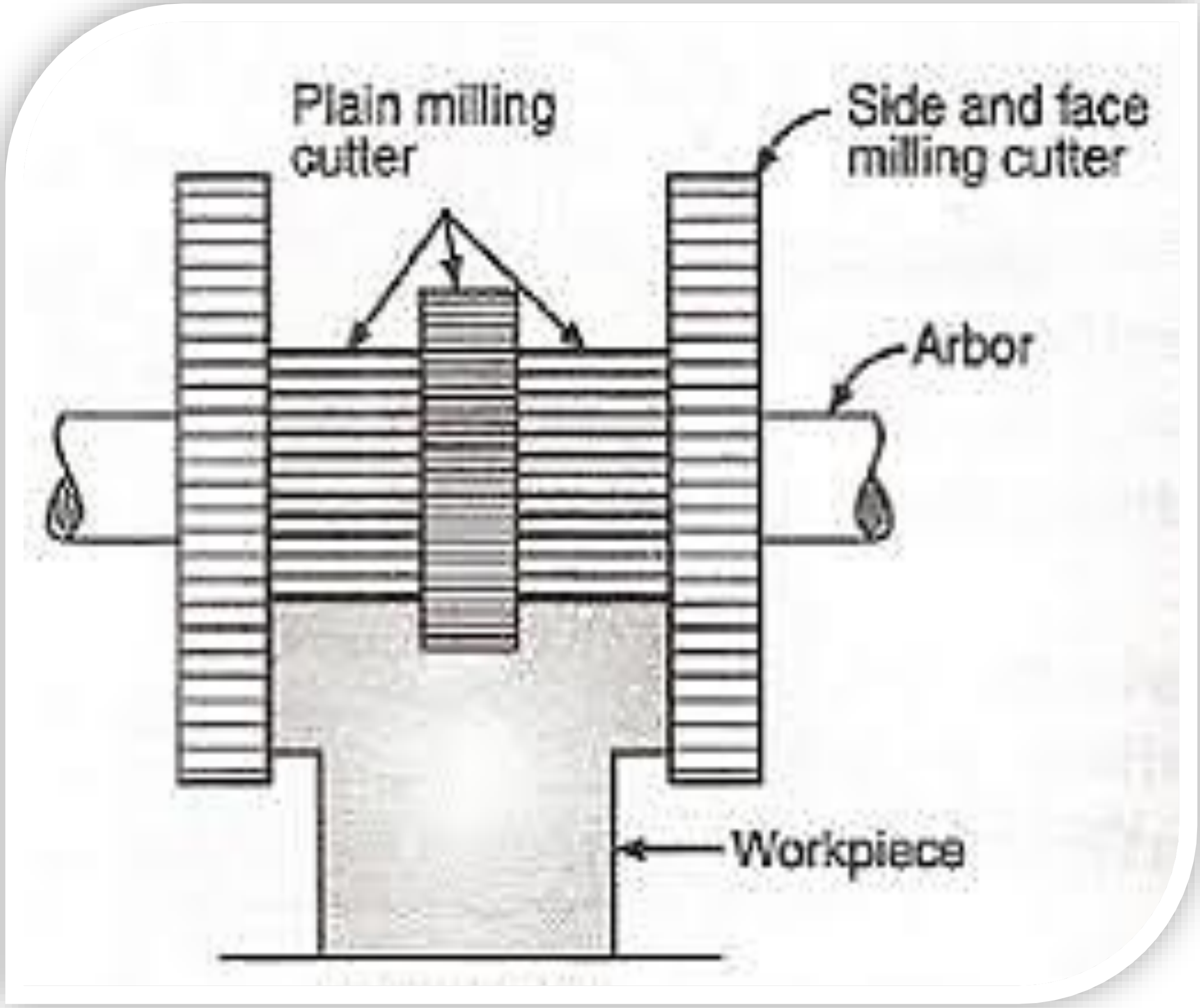
Form Milling:

Form Milling is the operation of producing curved profiles with a variety of shapes like concave, convex, spline etc., using cutters whose edge is shaped to produce a special configuration on the surface of the workpiece.



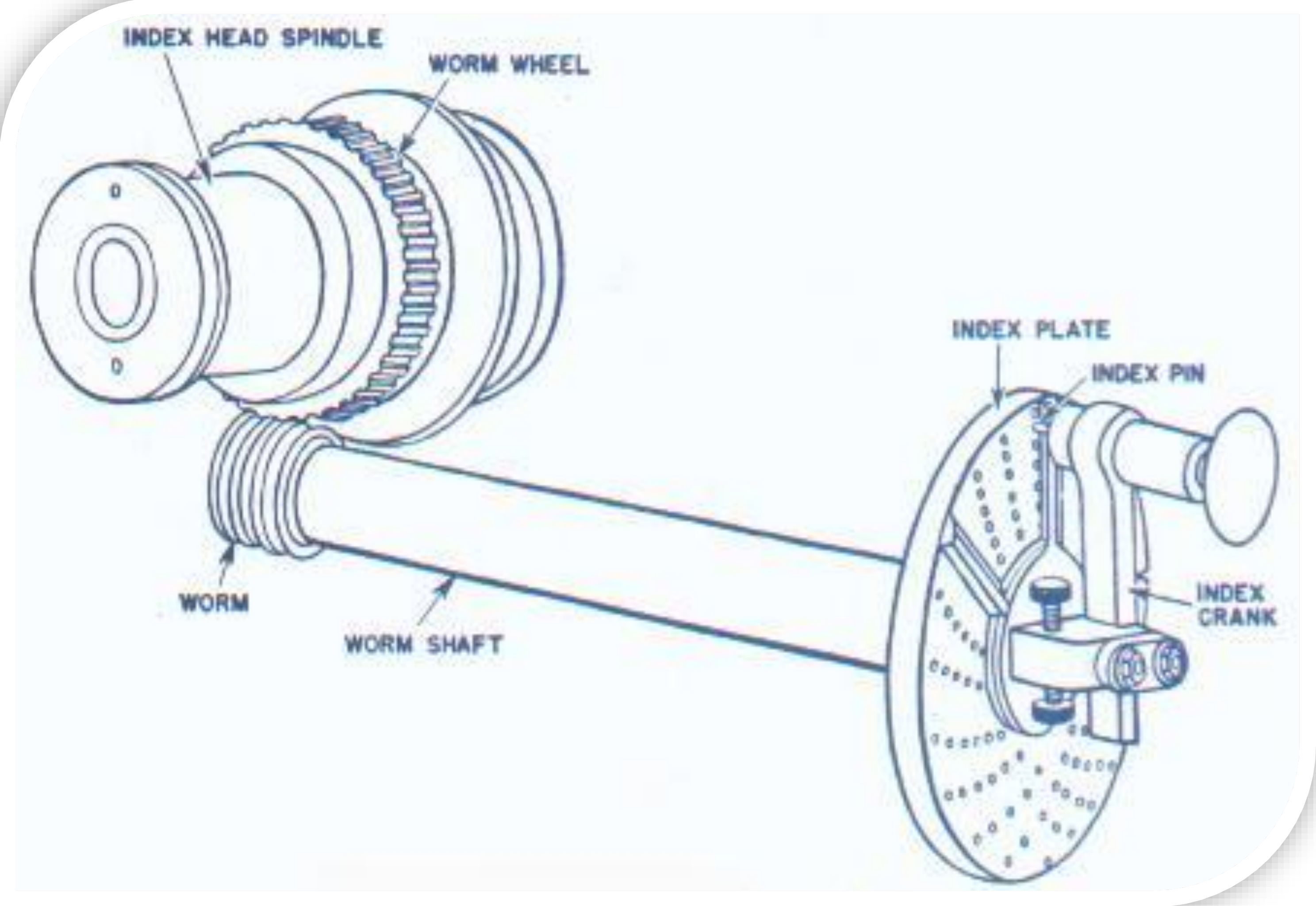
Gang Milling:

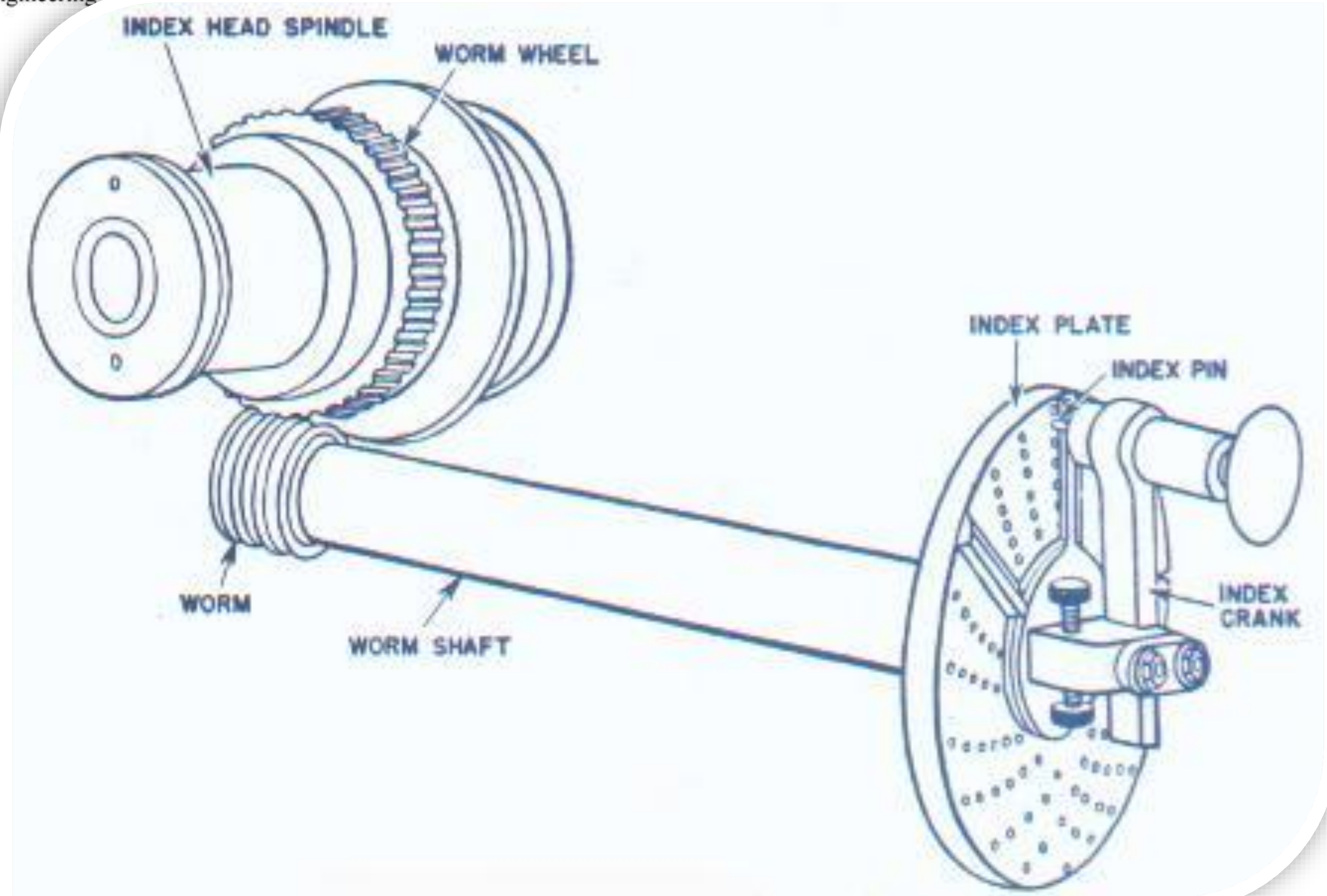
Gang Milling is the operation in which two or more cutters are mounted on the same arbor, so that different profiles required on the workpiece can be machined simultaneously in a single pass.



INDEXING Mechanism

- **Simple indexing mechanism as shown:**
- It consisting of **40 tooth worm wheel Fastened the to index head spindle, a single start threaded worm, a crank for turning the worm shaft and index plate.**




INDEX HEAD SPINDLE
WORM WHEEL
INDEX PLATE
INDEX PIN
INDEX CRANK
WORM
WORM SHAFT

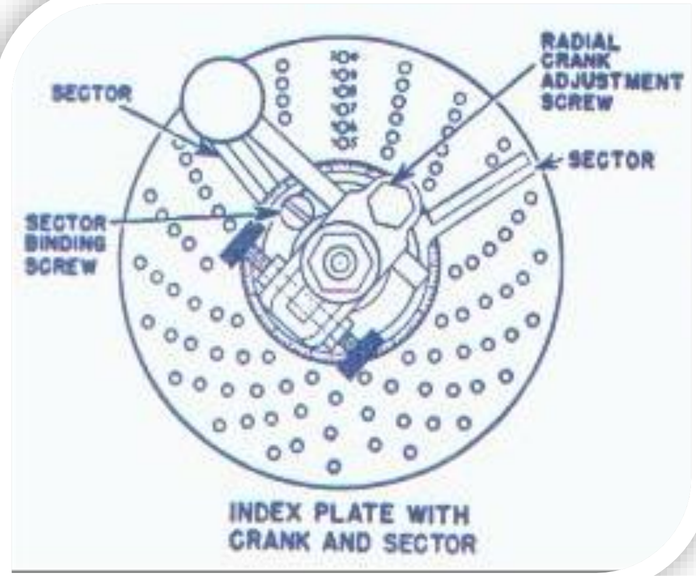
Indexing:

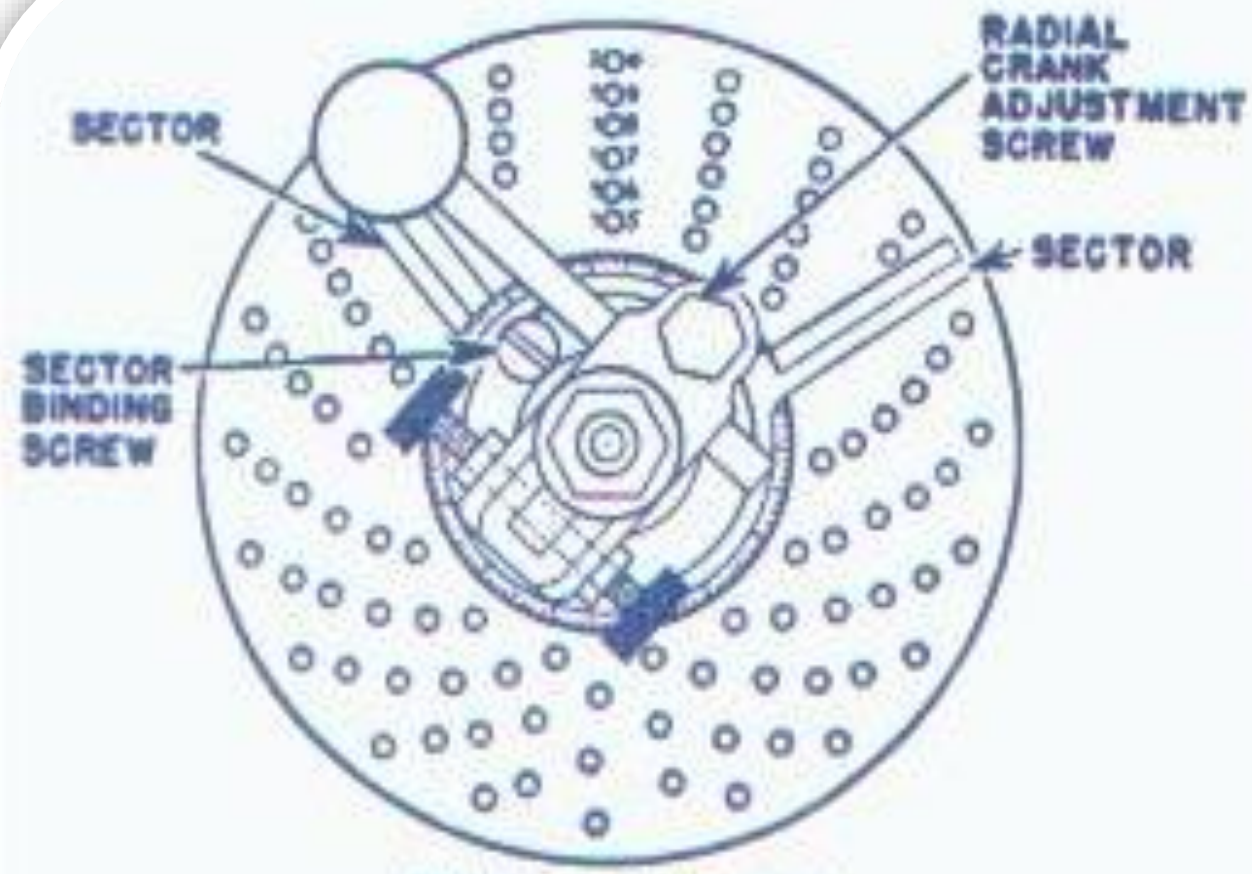
- In Milling, it may sometimes become necessary to rotate the workpiece, beyond the rotation offered in machines.
- For instance, in gear cutting operation, after cutting the first teeth, the workpiece has to be rotated to the correct angle for cutting the next teeth and so on.
- The rotation of workpiece is achieved by means of a specialized attachment called ***indexing head or dividing head*** that allows a workpiece to be rotated to any angle. **The process is called *indexing*.**

Use of index Plate

- index plate is provided with a series of circle of equally spaced holes
- the index plate comes with 3 Sets each carrying different number of holes in them
- Type 1 has 3 plates of 6 circles each, drilled as follows:

Plate 1 - 15, 16, 17, 18, 19, 20 holes.
Plate 2 - 21, 23, 27, 29, 31, 33 holes.
Plate 3 - 37, 39, 41, 43, 47, 49 holes.





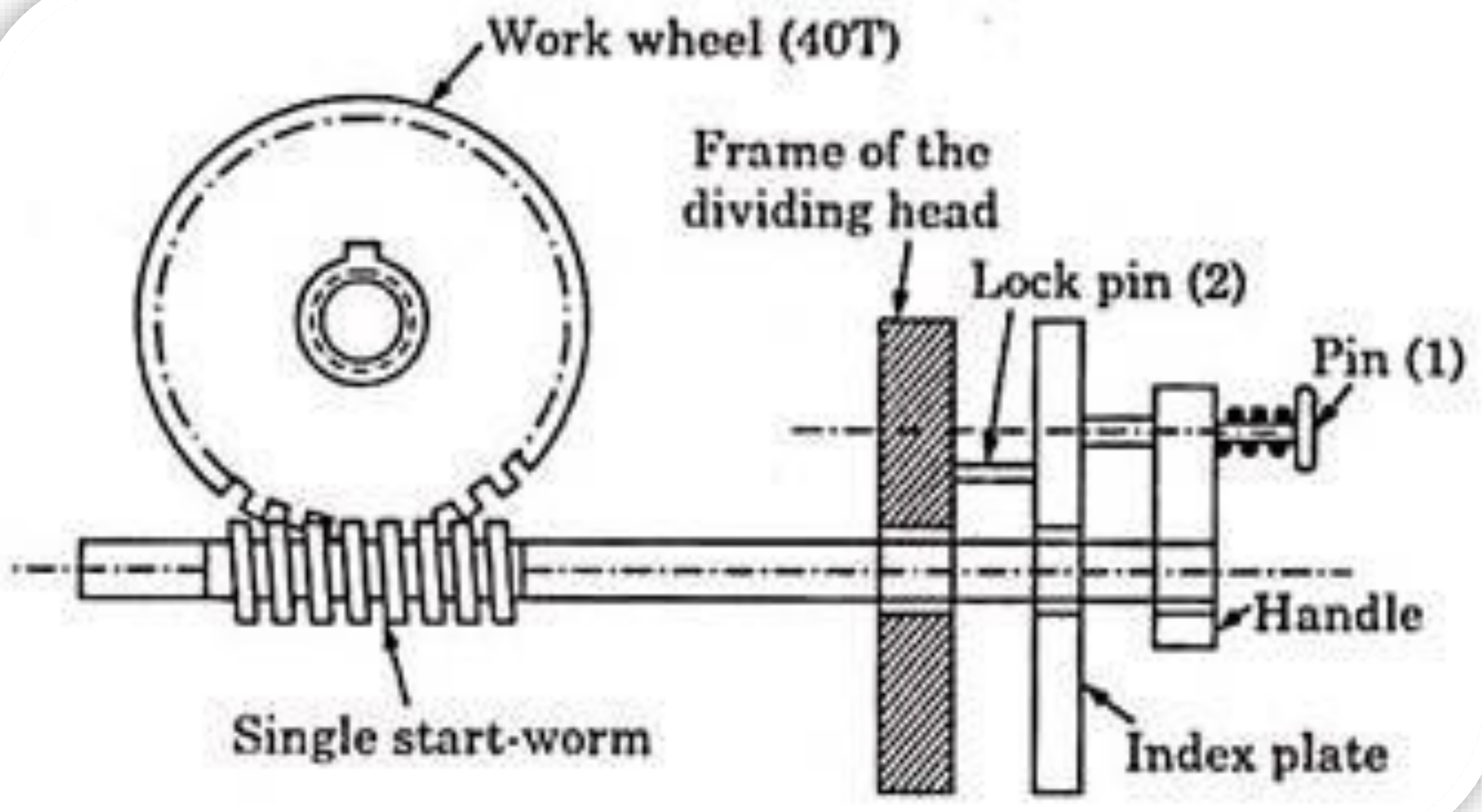
INDEX PLATE WITH CRANK AND SECTOR

METHODS OF INDEXING

- Simple or Plain Indexing
- Compound Indexing
- Differential Indexing
- Angular Indexing

Simple or Plain Indexing

- In this case, different index plates with varying number of holes are used to increase the range of indexing.
- The index is fixed in position by a pin called lock pin. The spindle is then rotated by rotating the handle which is keyed to the worm-shaft as shown in.



The following relation is used for simple indexing: T = 40/N, where T gives the number of turns or parts of a turn through which the index crank must be rotated to obtain the required number of divisions (N) on the job periphery.

Let us take an example of a gear blank on which 24 teeth are to be cut.

$$\text{Here } T = \frac{40}{N} = \frac{40}{24} = 1\frac{16}{24} \text{ or } 1\frac{2}{3}$$

i.e., the worm is to be rotated by the handle through one complete rotation and two-third of the number of holes of any circle.

Simple or Plain Indexing

- The worm wheel has 40 teeth. Simple indexing consisting of worm and worm wheel, with one turn of the crank (worm) the worm wheel will rotate through one pitch distance i.e. 1/40 of a revolution.
- Similarly, two turns of the crank will make the workpiece to rotate through 2/40 (or 1/20) and 3 turns through 3/40 of a revolution.
- Hence, the crank will have to be rotated through 40 turns, to rotate the workpiece through one complete turn. The rotation of the index crank is subdivided by the holes in the index plate.

For dividing the workpiece into a number of divisions, the crank movement are as follows:

- **For two divisions on the work piece, the crank will make 40/2=20 i.e. 20 turns for each division.**
- **For four divisions on the work piece, the crank will make 40/4=10 i.e. 10 turns for each division.**
- **For ten divisions on the work piece, the crank will make 40/10=4 i.e. 4 turns for each division.**
- **Hence for "n" divisions on the workpiece, the crank will make 40/n turns.**

For example, the workpiece is to be divided into 23 equal divisions, then the corresponding crank movement will be: Crank movement=40/n = 40/23= 1(17/23).

Now in the obtained result a whole number represents the number of full turns the crank has to make through and the fraction indicates the part of the turn that the crank has to make, in addition to the above.

- ***One indicating that- the crank has to move one complete rotation i.e. whole number and then the fractional number, to rotate the workpiece.***
- **In the fraction, the numerator indicates the number of holes to be moved and denominator indicates the number of holes on the circle to be used.**
- **Hence, in the above indexing, for each division on the workpiece, the crank will make one complete revolution and will move further through 17 holes on 23 holes circle.**
- **To avoid error and confusion while counting the holes every time and to set the spacing on the index plate , sector arms are used.**

Examples on Simple Indexing

Compound Indexing

- **The principle of operation of compound indexing is the same as that of simple indexing,**
- ***But the only difference is that compound indexing uses two different circles of one plate*** **and hence also sometimes referred to as hit and trial method.**

The principle of compound indexing is to obtain the required division in two stages:

(i) By rotating the crank or handle in usual way keeping the index plate fixed.
(ii) By releasing the back pin and then rotating the index plate with the handle.

For example, if a 27 teeth gear is to be cut, then T = 40/27 i.e., the rotation required for one tooth spacing is 40/27 which may be written as 2/3 + 22/27 or 12/18 + 22/27.

So for each tooth, the worm will be rotated by 12 holes of 18 hole circle with the help of the crank and then the index plate along with the crank is rotated by 22 holes of the 27 hole circle.

Compound Indexing:

Formula:

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

N=the number of divisions required

N1= the no. of holes circle used by the crank pin

N2= the no. of holes circle used by lock pin

n1= the no. of holes (or space) moved by the crank pin in N1 hole circle

n2=the no. of holes (or space) moved by the plate and crank pin in N2 hole circle.

Procedure:

1) Resolve the number of divisions into factors
2) Select two hole circles at random [preferably the multiples of the factors at step(1) above.]
3) Subtract the hole numbers of one circle from the other.
4) Factor the difference.
5) Place the factors of the divisions required and the factors of the difference above a horizontal line

6) Factor the number of turns of the crank required for one revolution of the spindle (40), and also factor the hole circles chosen.

7) Place these three new factors below the horizontal line

8) Cancel the common factors above and below line. If all the factors above the line can be cancelled by those placed below, then the two circles chosen can be used for indexing. If the factors above the line can not be cancelled completely, then two other hole circles should chosen for trial calculations.

9) The factors which will remain un cancelled below the line, should be multiplied to obtain the spaces in the hole circle to be moved by the two indexing movements.

Example: Index 87 divisions by compound indexing.

87 divisions=29 x 3=87

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

Step 1- 87 = 29 x 3

Step 2 – Choose index circle i.e. 29 & 33

Step 3 – 33 -29 =4 difference

Step 4 – 4= 2 x 2

Step 5 – 87 = 29 x 3
4 = 2 x 2

Step 6 – 40 (standard ratio) = 2 x 2 x 2 x 5
29 = 29 x 1
33 = 3 x 11

Step 7 & 8 87 = 29 x 3
4 = 2 x 2
----
40 = 2 x 2 x 2 x 5
29 = 29 x 1
33 = 3 x 11

We have taken N1 = 29 and N2 = 33

Step 9 – the remainder in the denominator

= 2 x 5 x 11 = 110

$$\frac{40}{87} = \frac{110}{29} - \frac{110}{33} \qquad \frac{40}{87} = 3\,\frac{23}{29} - 3\,\frac{11}{33}$$

$$\frac{23}{29} - \frac{11}{33}$$

1) To move crank pin by 23 holes in 29 hole plate
2) To move crank pin and along with index plate(lock pin) by 11 holes in 33 holes plate in opposite direction.

Example 8-7: Index 69 divisions, using compound indexing.

Solution: For 69 divisions, the movement of the crank index plate is given by,

$$\frac{40}{69} = \frac{n_1}{N_1} \pm \frac{n_2}{N_2}$$

Follow the nine steps, as per the procedure explained above.

1) $69 = 23 \times 3$
2) chose 23 and 33 as index circles.
3) $33 - 23 = 10$
4) $10 = 2 \times 5$
5) $69 = 23 \times 3$

   $\underline{10 = 2 \times 5}$
6) $40 = 2 \times 2 \times 2 \times 5$

   $23 = 23 \times 1$

   $33 = 3 \times 11$

7) and 8)

$69 = \not{23} \times \not{3}$

$\underline{10 = \not{2} \times \not{5}}$

$40 = \not{2} \times 2 \times 2 \times \not{5}$

$23 = \not{23} \times 1$

$33 = \not{3} \times 11$

Since all the factors above the line got cancelled, the chosen hole circles 23 and 33 can be used for indexing.

Thus, $N_1 = 23$ and $N_2 = 33$

9) $2 \times 2 \times 11 = 44$

44 is the number of holes to be moved for indexing. The expression can be written as-

$$\frac{40}{69} = \frac{44}{23} - \frac{44}{33} = 1\frac{21}{23} - 1\frac{11}{33} = \frac{21}{23} - \frac{11}{33}$$

Hence, for indexing 69 divisions, the index crank should be moved by 21 holes in 23 hole circle in forward direction (because the fraction 21/23 is positive), and then the plate with the crank should be moved by 11 holes in 33 hole circle in the backward direction (because the fraction $\frac{11}{33}$ is negative).

Example 8-8: It is required to divide the circumference of a circle into 91 equal parts by compound indexing. Suggest suitable indexing.

Solution:

Follow the steps explained earlier.

1) Resolve the number into factors.

   91 = 13 x 7

2) Select two hole circles [Hint: Select multiples of the factors at step (1)]
   Say 21 and 39 (note that 21 is a multiple of 7 and 39 is a multiple of 13).

3) 39 – 21 = 18

4) 18 = 2 x 3 x 3

5) to 7)

   91 = ~~13~~ x ~~7~~
   18 = ~~2~~ x ~~3~~ x ~~3~~
   40 = ~~2~~ x 2 x 2 x 5
   21 = ~~3~~ x ~~7~~
   39 = ~~13~~ x ~~3~~

9) 2 x 2 x 5 = 20

$\therefore$ The indexing is, $\frac{40}{91} = \frac{20}{21} - \frac{20}{39}$

i.e., for indexing 91 divisions, the index crank should be moved by 20 holes in 21 hole circle in forward direction (+ve) and then the crank should be moved in backward 20 holes in 39 hole circle in backward direction (-ve).

procedure for determining the index circles

1) Resolve the No. of divisions into factors.
2) Select two hole circles at random. [Preferably the multiples of the factors at step (1) above].
3) Subtract the hole Nos. of one circle from the other.
4) Factor the difference.
5) Place the factors of the divisions required and the factors of the difference above a horizontal line.
6) Factor the No. of turns of the crank required for one revolution of the spindle (40) and also factor the hole circles chosen.

7) Place these three factors below the horizontal line.

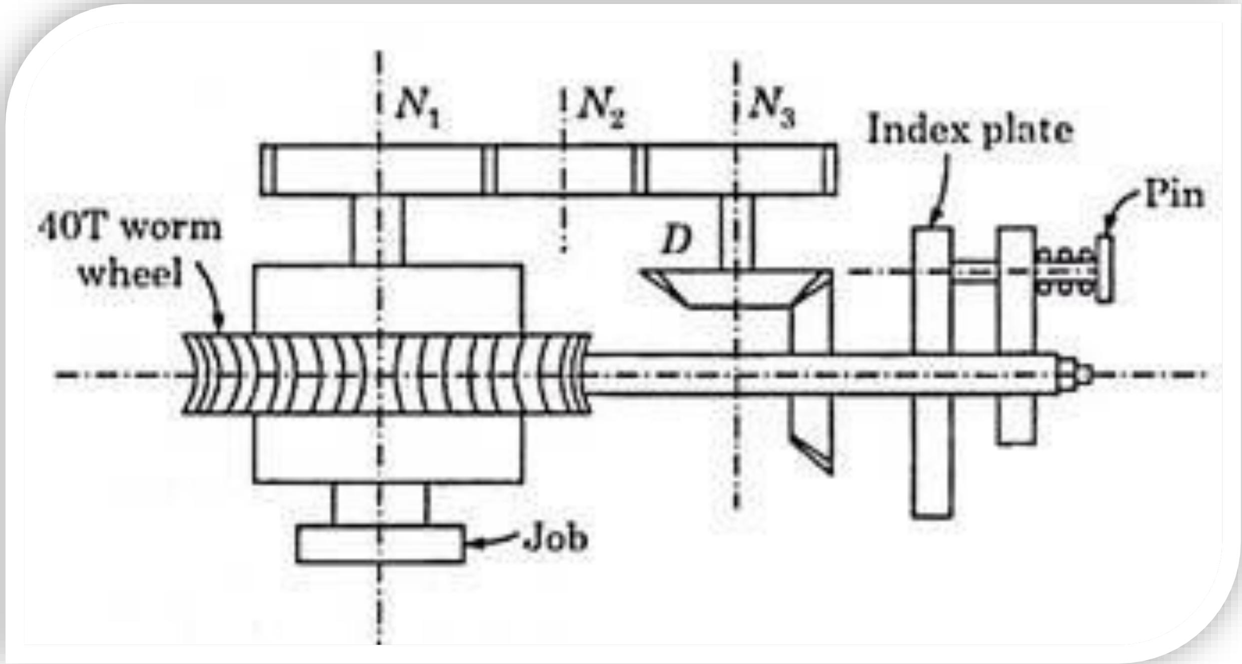
8) Cancel the common factors above and below the line. If all the factors above the line can be cancelled by those placed below, then the 2 circles chosen can be used for indexing.

   If the factors above the line cannot be cancelled completely, then two other hole circles should be chosen for trial calculations.

9) The factors which remain uncancelled below the line, should be multiplied to obtain the spaces in the hole circle to be moved by the two indexing movements.

Differential Indexing:

- Available number of index plates with different hole circles, sometimes confine the range of plain indexing.
- In such cases, differential indexing is found to be more suitable. Between the indexing plate and spindle of dividing head, a certain set of the gears is incorporated extra.
- Dividing heads are provided with such standard set of gears.



- During the differential indexing, the index-plate is unlocked and connected to a train of gears which receive their motion from the worm gear spindle.
- As the handle is turned, the index plate also turns, but at a different rate and perhaps in the opposite direction.
- Differential indexing makes it possible to rotate the work by any fraction of revolution with the usual index plates furnished with the equipment

Differential Indexing heads are generally furnished with change gears as follow
24,24,28,32,40,44,48,56,64,72,86,100 with these index gears and three sets of standard index plate (B&S) it is possible to index any number from 1 to 383. Special gears having 46,47,52,58,68,70,76 & 84 teeth we can cut division from 383 to 1008.

Gear ratio: $\frac{(A-N)\times 40}{A}$

A= The selected number which can be indexed by plain indexing and the number is approximately equal to N

N= The required number of divisions to be indexed.

In gear ratio **numerator is driver gear** and **denominators is driven gear.**

Index crank movement = $\frac{40}{A}$

For Simple Gear Train if (A-N) is positive only one idle gear is required

If negative then TWO idle gears are required.

For compound gear train if (A-N) is positive no idle gear is required.

If negative one idle gear is required.

For positive result both crank and index plate will move in same direction.

For negative result both will move in opposite direction

Numerical: Index 83 divisions

Solution:

Formula: For index movement $\frac{(A-N)\times 40}{A}$

For Gear ratio:

Let us assume A=86

For Index movement $\frac{40}{A} = \frac{40}{86} = \frac{20}{43}$

43 hole circle plate is available and we have to move 20 hole.

Now gear Train = $\frac{(A-N)\times 40}{A} = \frac{(86-83)\times 40}{86}$

$= 3\frac{40}{86} = 3\frac{20}{43}$ (Compound gear train)

24 teeth gear is available $3\frac{24}{24}\times\frac{20}{43} = \frac{72}{24}\times\frac{20}{43}$

So 72 and 20 are Driver gear & 24 and 43 are driver gear

Drilling Machine

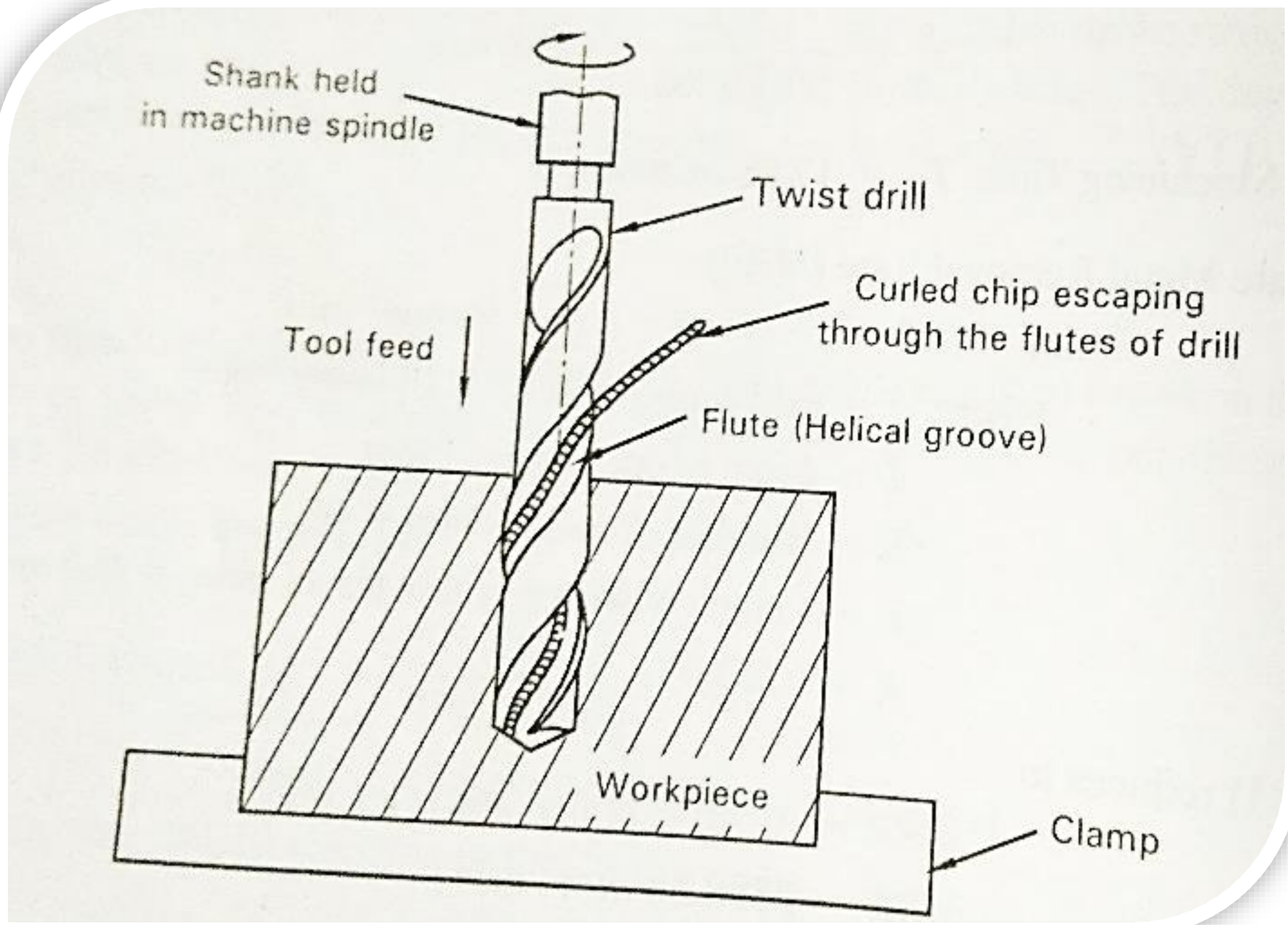
Drilling is a machining operation of producing a cylindrical hole in a solid workpiece by means of a revolving tool called ***drill bit***.

The tool is also called ***twist drill*** since it has sharp twisted edges formed around a cylindrical body.

- Drilling can be called as the operation of producing a cylindrical hole of required diameter and depth by removing metal by the rotating edges of a drill. The cutting tool known as drill is fitted into the spindle of the drilling machine.
- A mark of indentation is made at the required location with a centre punch. The rotating drill is pressed at the location and is fed into the work. The hole can be made upto a required depth.

Construction of a drilling machine

- The basic parts of a drilling machine are a base, column, drill head and spindle. The base made of cast iron may rest on a bench, pedestal or floor depending upon the design.
- Larger and heavyduty machines are grounded on the floor. The column is mounted vertically upon the base. It is accurately machined and the table can be moved up and down on it.
- The drill spindle, an electric motor and the mechanism meant for driving the spindle at different speeds are mounted on the top of the column. Power is transmitted from the electric motor to the spindle through a flat belt or a 'V' belt.


Shank held
in machine spindle
Twist drill
Curled chip escaping
through the flutes of drill
Tool feed
Flute (Helical groove)
Workpiece
Clamp

Classification of Drilling machines:

Drilling machines are classified according to their general construction and type of work they are required to do. The different types of drilling machines include:

- Portable drilling machine
- Bench or sensitive drilling machine
- Radial drilling machine
- Upright drilling machine
- Multi-spindle drilling machine
- Gang drilling machine
- Automatic drilling machine
- Deep hole drilling machine
- CNC drilling machine

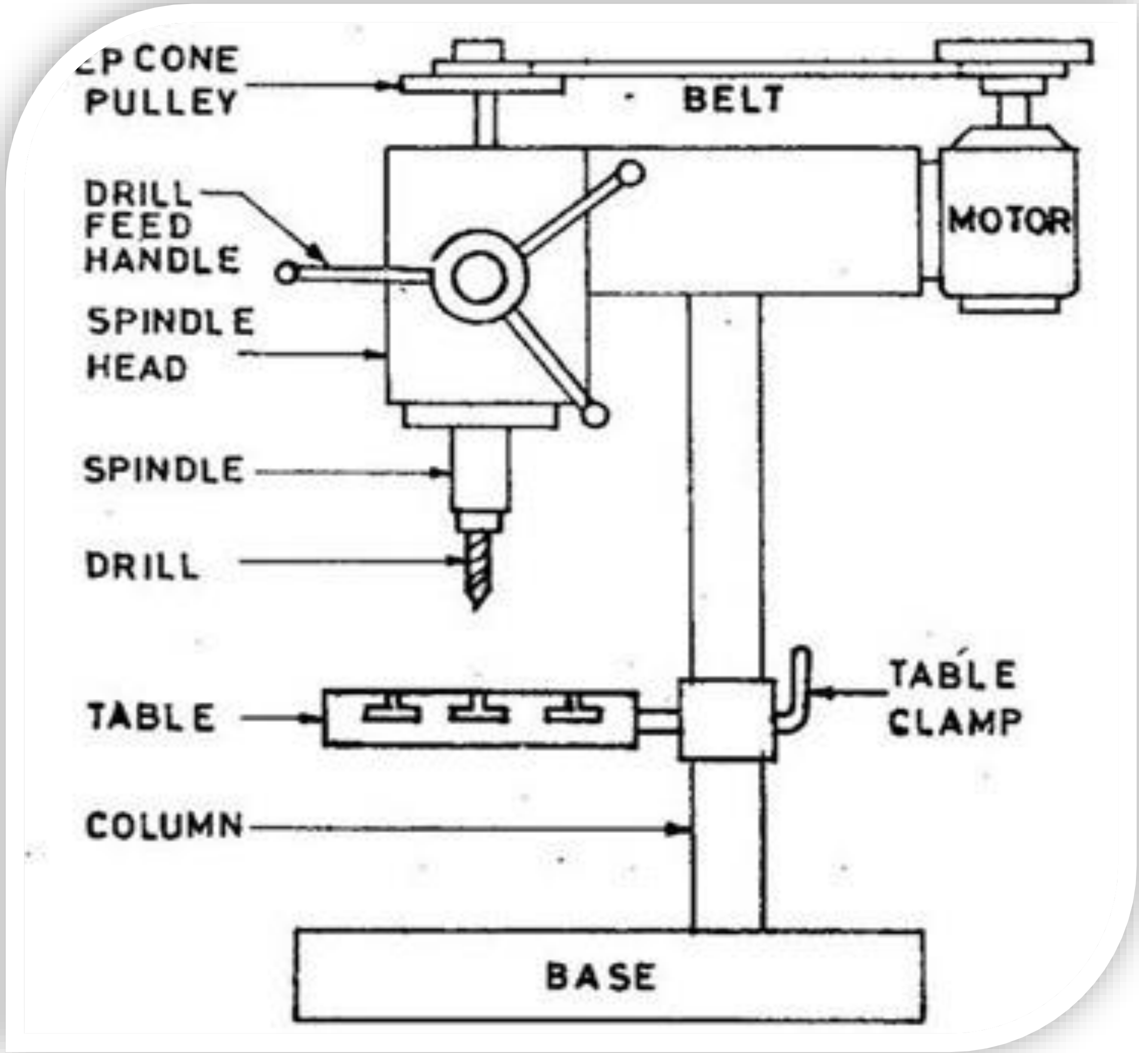
Bench or Sensitive Drilling machine:

It is designed for drilling small holes at high speeds in light jobs. High speed and hand feed are necessary for drilling small holes. The base of the machine is mounted either on a bench or on the floor by means of bolts and nuts.

It can handle drills upto 15.5mm of diameter. The drill is fed into the work purely by hand. The operator can sense the progress of the drill into the work because of hand feed. The machine is named so because of this reason.

A sensitive drilling machine consists of a base, column, table, spindle, drill head and the driving mechanism. A sensitive drilling machine is shown in Figure below.

Bench or Sensitive Drilling machine:



Main parts of Bench or Sensitive Drilling machine:

Base

The base is made of cast iron and so can withstand vibrations. It may be mounted on a bench or on the floor. It supports all the other parts of the machine on it.

Column

The column stands vertically on the base at one end. It supports the work table and the drill head. The drill head has drill spindle and the driving motor on either side of the column.

Table

The table is mounted on the vertical column and can be adjusted up and down on it. The table has ‘T’-slots on it for holding the workpieces or to hold any other work holding device. The table can be adjusted vertically to accommodate workpieces of different heights and can be clamped at the
required position.

Drill head

- Drill head is mounted on the top side of the column. The drill spindle and the driving motor are connected by means of a V-belt and cone pulleys. The motion is transmitted to the spindle from the motor by the belt.
- The pinion attached to the handle meshes with the rack on the sleeve of the spindle for providing the drill the required down feed. There is no power feed arrangement in this machine. The spindle rotates at a speed ranging from 50 to 2000 r.p.m.

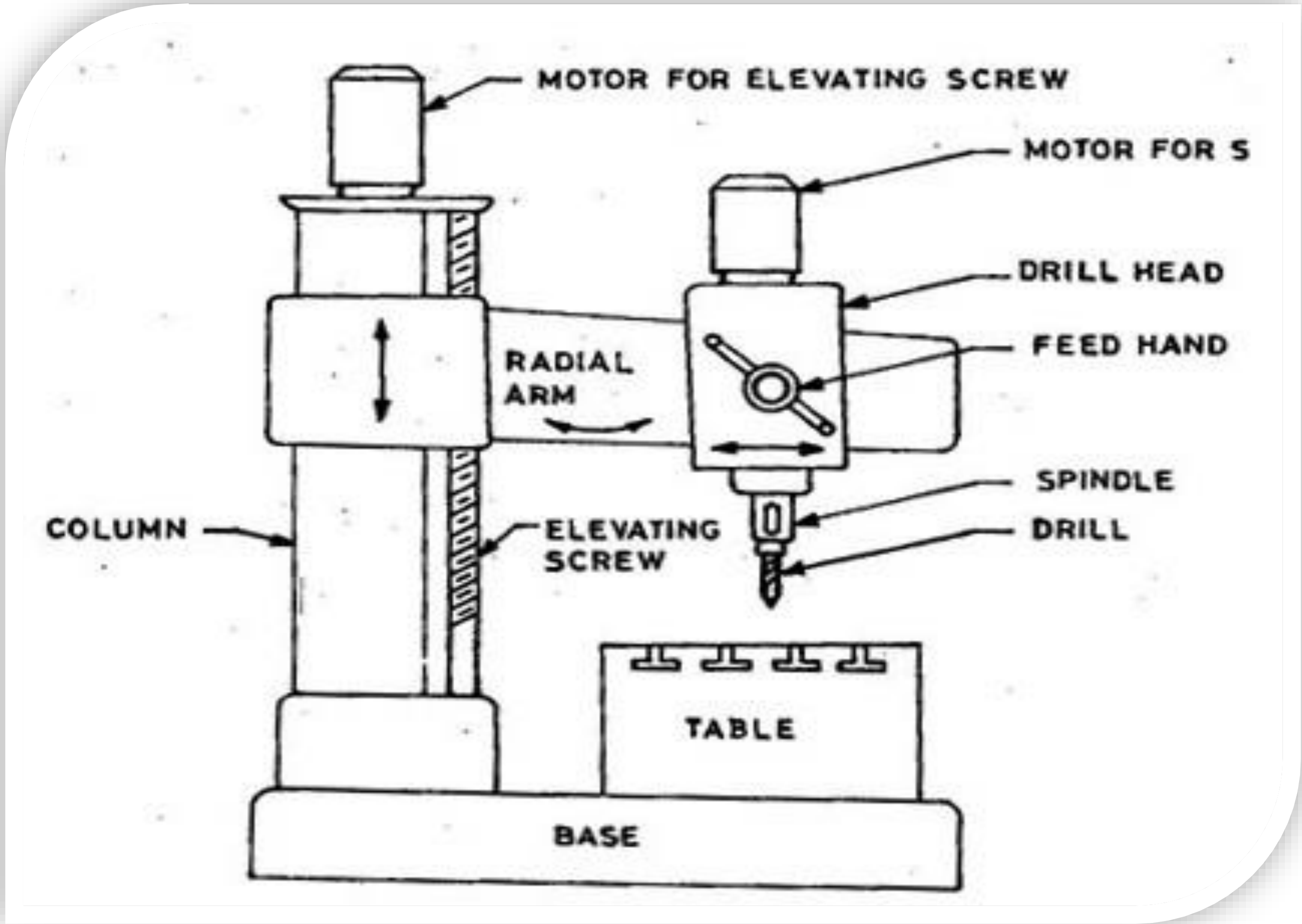
Radial drilling machine

The radial drilling machine is intended for drilling on medium to large and heavy workpieces. It has a heavy round column mounted on a large base. The column supports a radial arm, which can be raised or lowered to enable the table to accommodate workpieces of different heights.

The arm, which has the drill head on it, can be swung around to any position. The drill head can be made to slide on the radial arm. The machine is named so because of this reason.

It consists of parts like base, column, radial arm, drill head and driving mechanism. A radial drilling machine is illustrated
in Figure below.

Radial Drilling machine



Drilling and related operations

A variety of operations are performed on a drilling machine. These include:

a) Reaming

b) Boring

c) Tapping

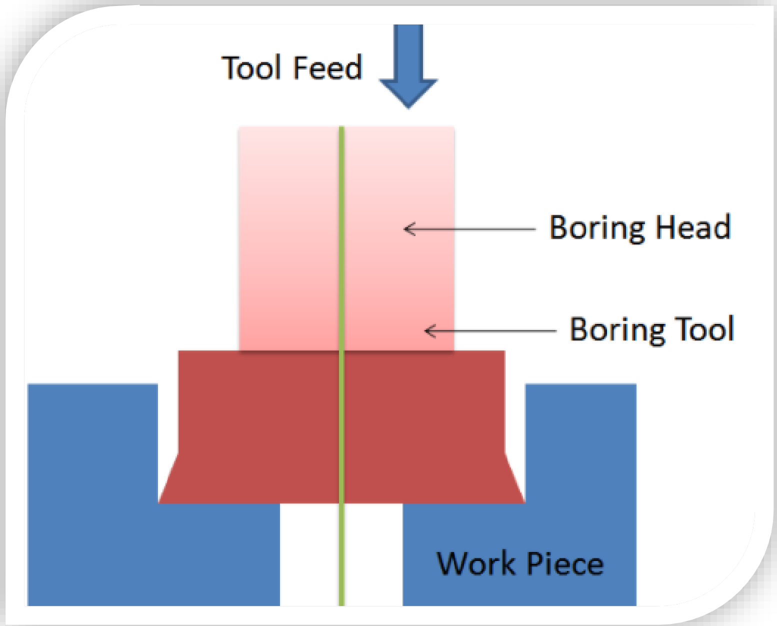
d) Counter boring

e) Counter sinking

f) Trepanning

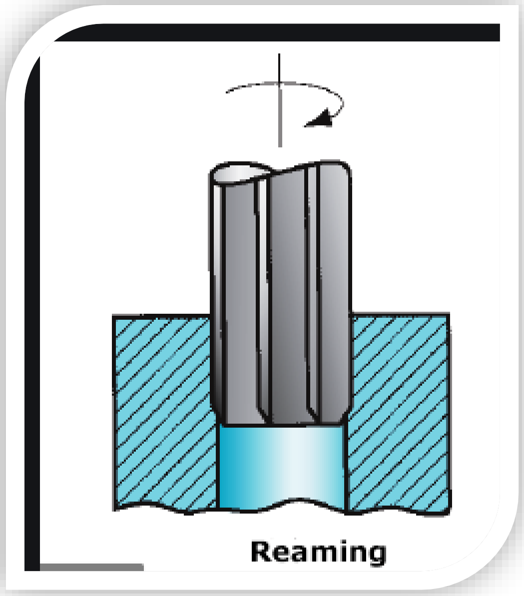
Boring operation

- When you need to **enlarge the diameter of the existing hole you need to perform the boring operation**, but the accuracy is not greater than reaming operation. The boring tool is generally a single-point cutting tool



Reaming operation

- Finally, reaming is a cutting process that involves the use of a rotary cutting tool to create smooth interior walls in an existing hole in a workpiece.
- The rotary cutting tool used in reaming is known as a reamer.
- Like drill bits, reamers also remove material from the workpiece on which they are used.



Drilling	Boring	Reaming
Drilling is performed to originate a hole.	Boring is performed to enlarge the diameter of an existing hole.	Reaming is performed to finish hole surfaces and to improve tolerance.
Cutting tool used for drilling is known as drill.	Cutting tool used for boring is known as boring bar.	Cutting tool used for reaming is called reamer.
Drill is a double point cutting tool.	Boring bar is a single point cutting tool.	Reamer is a multi-point cutting tool.
Drilling is first phase of hole fabrication. It does not require any special feature prior to operation.	A pre-drilled hole (or a hollow portion made by casting) is mandatory for performing boring.	Similar to boring, reaming can be performed only if a hollow part or hole exists.
Drilling can increase length of the hole but not diameter (limited to drill diameter).	Boring can increase diameter of an existing hole but not length.	Neither diameter nor length can be increased substantially by reaming.
Surface quality of drilled hole is not very good.	Here surface quality is better than drilling.	Reaming produces highly finished surface.
Material Removal Rate (MRR) in drilling operation is higher.	MRR is lower than drilling but higher than reaming.	MRR is poor; in fact, MRR is not an issue in reaming.

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Module-2
Introduction to Boring Machine

Boring:

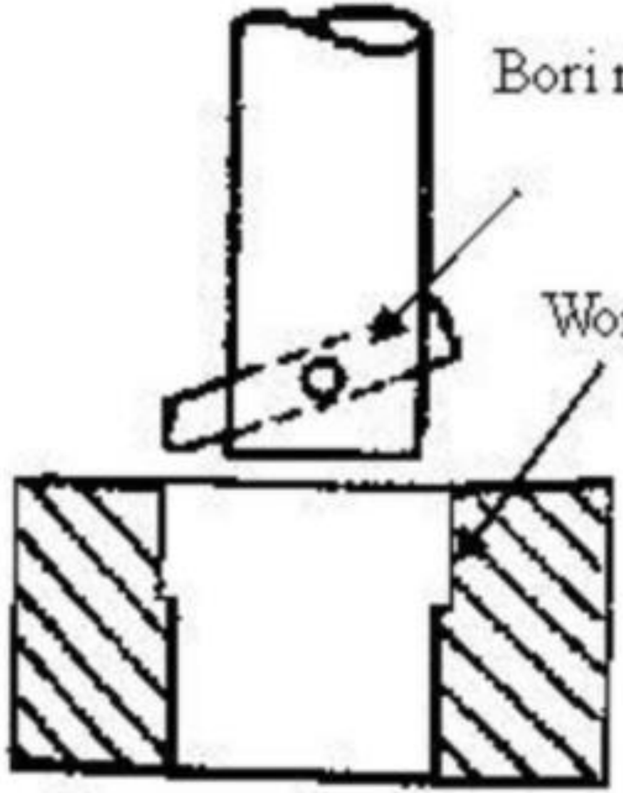
- Done on a drilling machine to increase the size of an already drilled hole

When a suitable size drill is not available,

- Initially a hole is drilled to the nearest size
- Using a single point cutting tool, the size of the hole is increased to required size

By lowering the tool while it is continuously rotating,

- The size of the hole is increased to its entire depth.



What is Boring

- Performed to enlarge a hole made previously.
- Used for circular internal profiles in hollow workpieces

BORING Machine

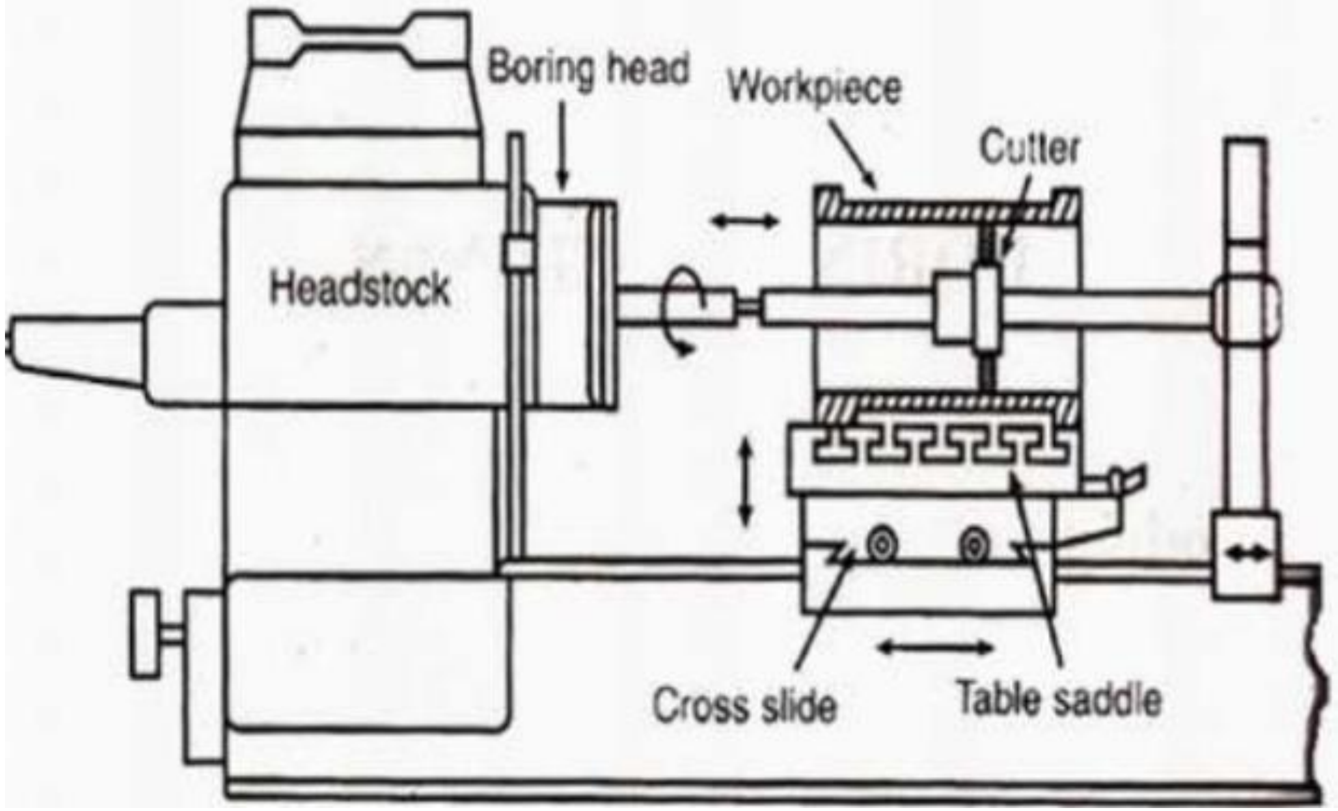
Classification of Boring machine

- Horizontal Boring Machine
- Vertical Boring machine
- Jig Boring machine
- Diamond Boring Machine
- CNC Boring Machine

Table Type Horizontal Boring machine

Components of a Boring Machine

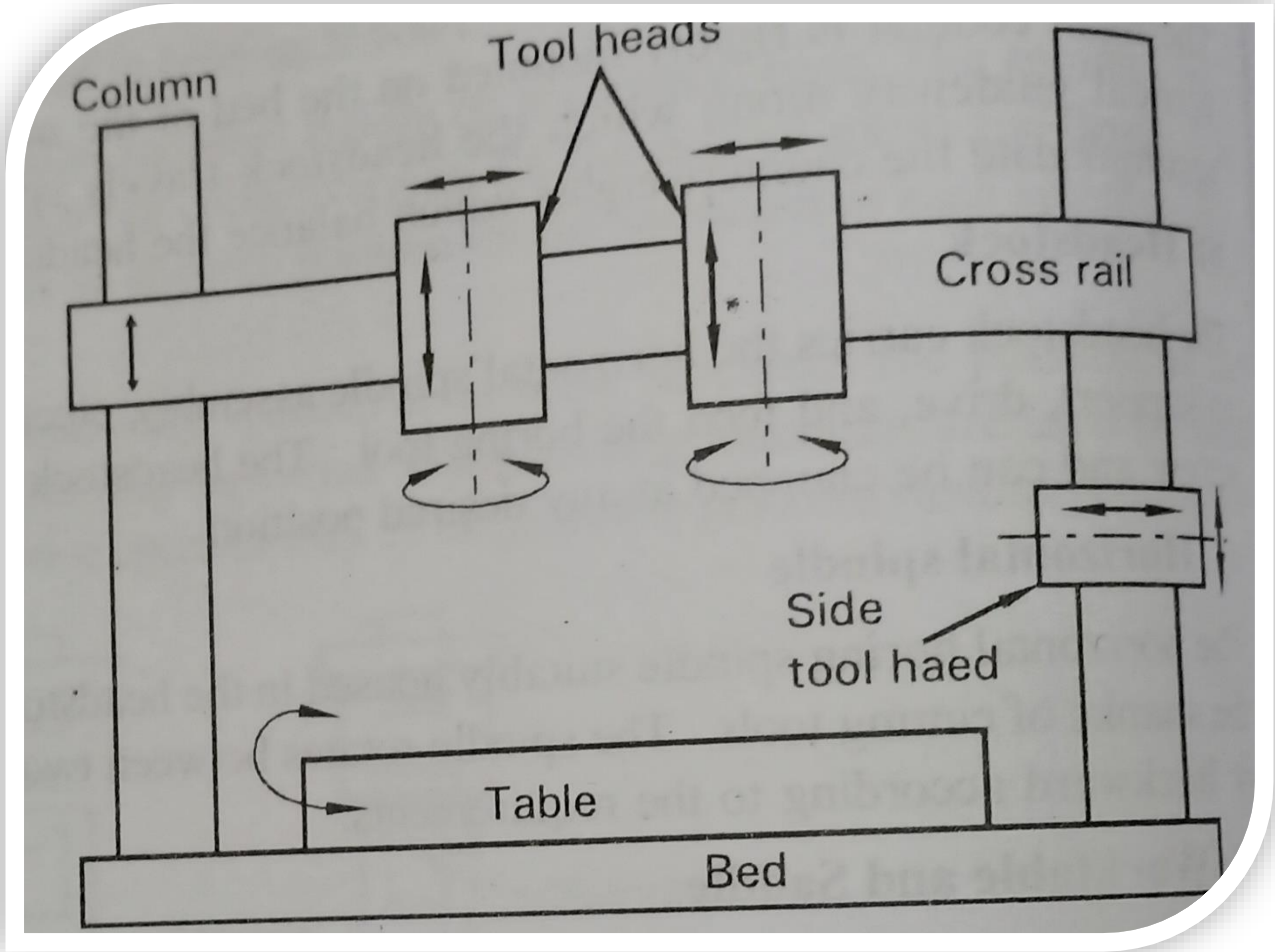
- Bed
- Floor Plate
- Base
- Table
- Column
- Head Stock
- End Supporting Column
- Cross Rail



Specification of boring Machine

- Spindle Diameter
- Spindle Travel
- Motor Capacity and range of Spindle speeds
- Worktable Dimensions
- Height of spindle axis from table surface
- Longitudinal work table traverse
- Cross movement of worktable

Vertical Boring machine



Specification of boring Machine

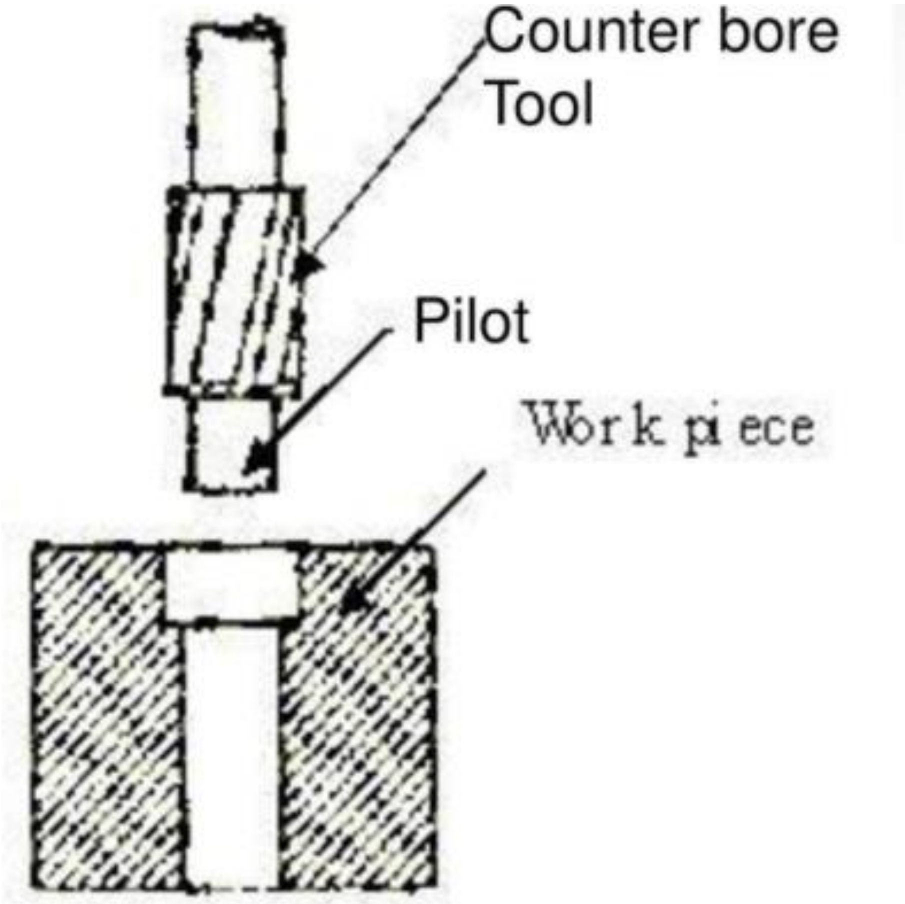
- Maximum Turning Diameter of work
- Worktable Diameter
- Speed range of worktable
- Maximum weight of work that can be accommodated on worktable
- Maximum working height of workpiece

Counter boring

It is to increase the size of a hole at one end only through a small depth

It forms a larger sized recess or a shoulder to the exiting hole

- The cutting tool will have a small cylindrical projection known as **pilot**
- It guides the tool



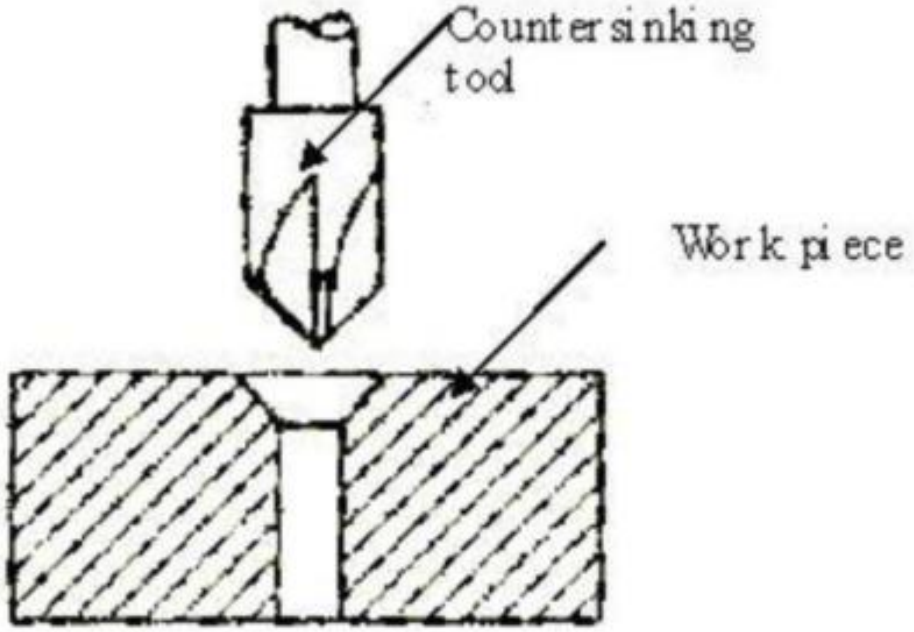
Countersinking

It is the operation of making the end of the hole into a conical shape

- Using countersinking tool
- May also be employed for deburring the holes

Cutting speed

One - half of that used for similar size drill



Use:

When the countersunk screws are to be screwed into the holes, so that their top faces have to be flushed with the top surface of

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Module-2

Introduction to Shaper and planar Machine

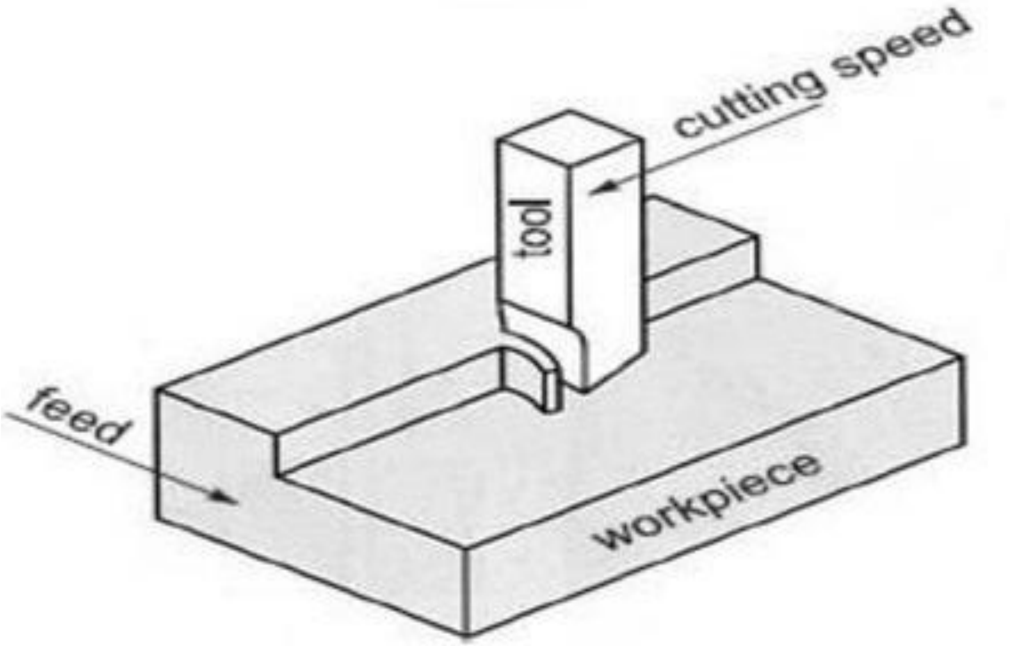
Shaping, Slotting and Planning Machines Tools: Driving mechanisms of Shaper, Slotter and Planer. Operations done on Shaper, Planer & Slotter Difference between shaping and planning operations.

Shaping:

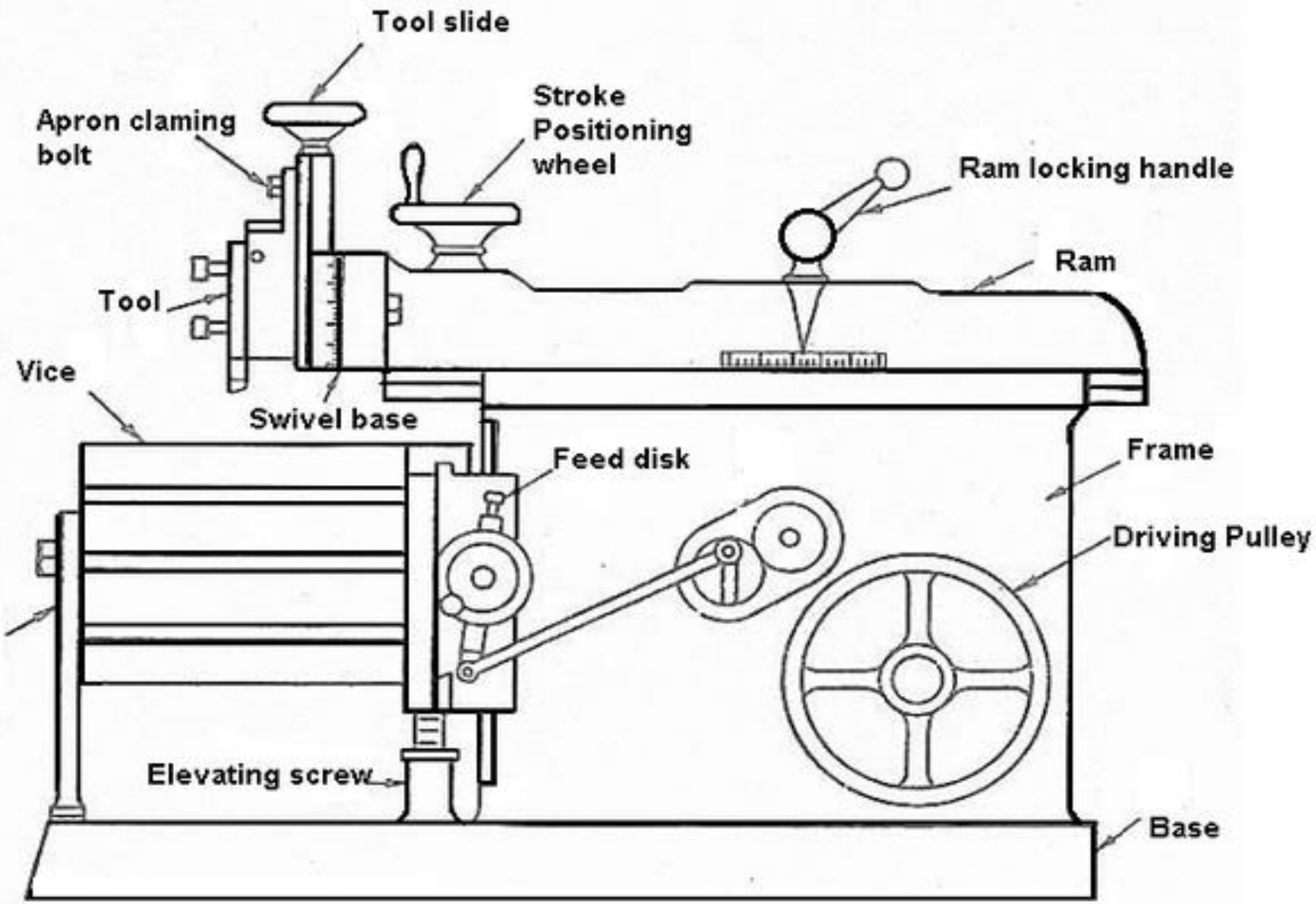
Shaping is a machining process of removing the excess material from the workpiece by means of a single point cutting tool held in a **reciprocating ram.** The process is employed to produce **flat surfaces, grooves, T-slots and dovetails.**

The machine used for performing the operation is called ***shaping machine* or *shaper.***

Removing material through a reciprocating cutting motion, resulting in the desired shape or contour.



Horizontal Shaper:



Classification of shaping Machine (Shaper)

Classification based on:

1. Design of Worktable:

(a) Standard shaper (b) Universal shaper

2. Driving Mechanism:

(a) Crank shaper (b) Geared shaper (c)Hydraulic shaper

3. Design of travel of Ram:

(a) Horizontal shaper (b) Vertical shaper travelling head shaper

4. Nature of cutting Stroke:

(a) Push cut shaper (b) Draw cut(pull type) shaper

Horizontal shaper consists of the following parts:

Base: The base of the horizontal shaper is a heavy cast iron body that supports all the other parts of the machine.

Column: The column is a rigid hollow casting mounted on the base. It houses the driving motor, control devices and the mechanism for driving the ram and the worktable. At the top of the column, there are two machined guideways on which the ram reciprocates.

Cross-rail: The cross-rail is mounted on the front vertical guideways of the column. It can be raised or lowered by means of an elevating screw to accommodate workpiece of different heights.

Worktable: The worktable is a box shaped casting bolted to the saddle. The table is provided with two movements in the horizontal and vertical movements. The worktable is provided with T-slots on its top and on one of its side for clamping the workpiece.

Ram: The ram is a rigidly braced casting, and of semi-cylindrical form located on the top of the column. The ram reciprocates on the guideways provided on the top of the column by means of a slotted link mechanism.

Tool head: The tool head is mounted at the front end of the ram. The tool head holds the tool and imparts the tool, the necessary vertical and angular feed movements.

Specification of a Shaper:

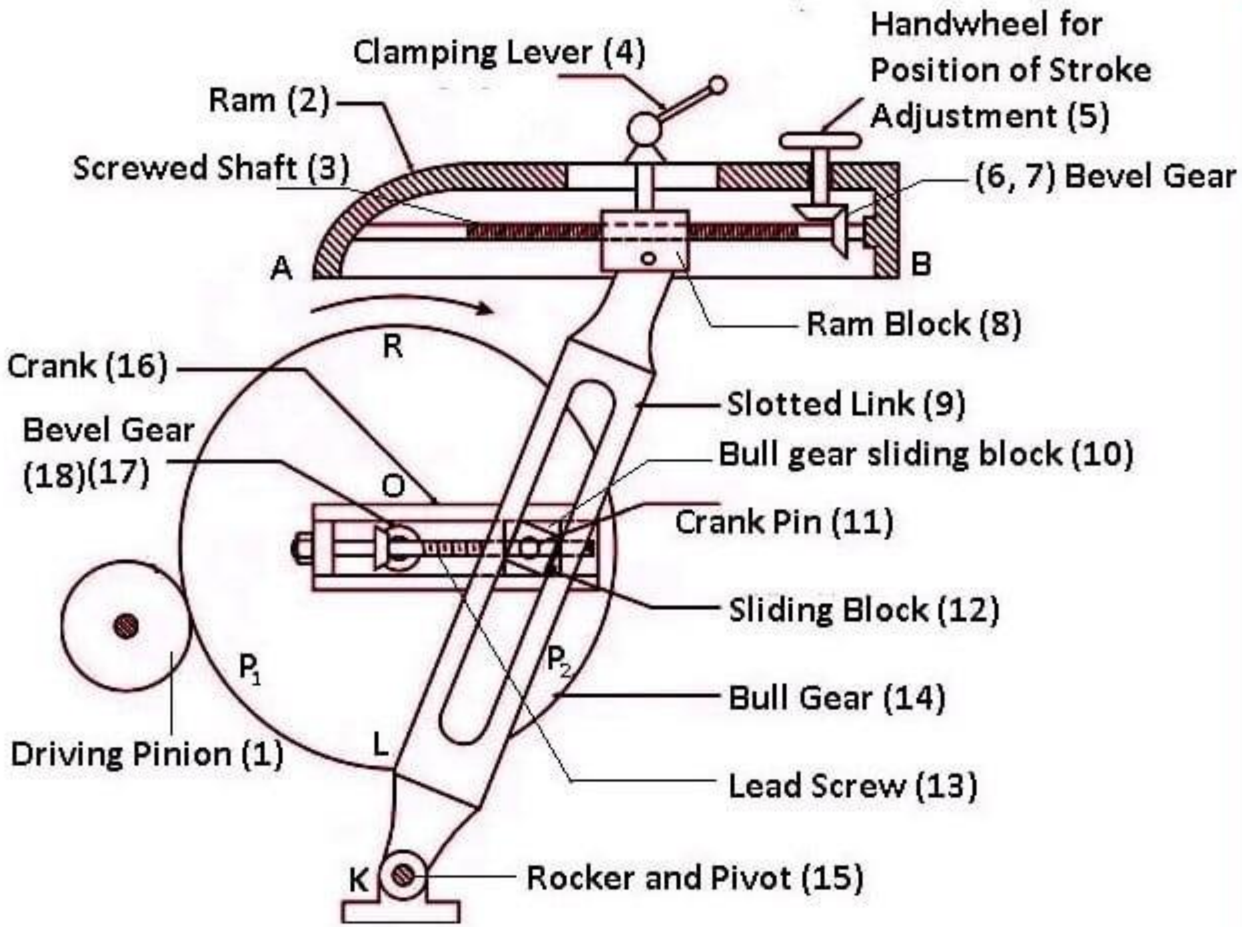
The size of the shaper is specified by one of the following criteria:

- ***Maximum length of stroke of Ram,*** say 700mm.
- ***Maximum travel of the Worktable,*** say 700mm in horizontal direction and 320mm in vertical direction.
- ***Dimensions of Table working surface,*** say 700 * 450mm.
- ***Power of motor*** ranging from 2-5 hp.

Driving Mechanism of a Shaper

Crank and Slotted Link Mechanism

This mechanism translates rotational motion into linear motion and is commonly used in shaping machines such as slotters and shapers to produce flat surfaces on workpieces. Notably, the return stroke is significantly faster than the forward stroke in this mechanism.



Crank and Slotted Link Mechanism

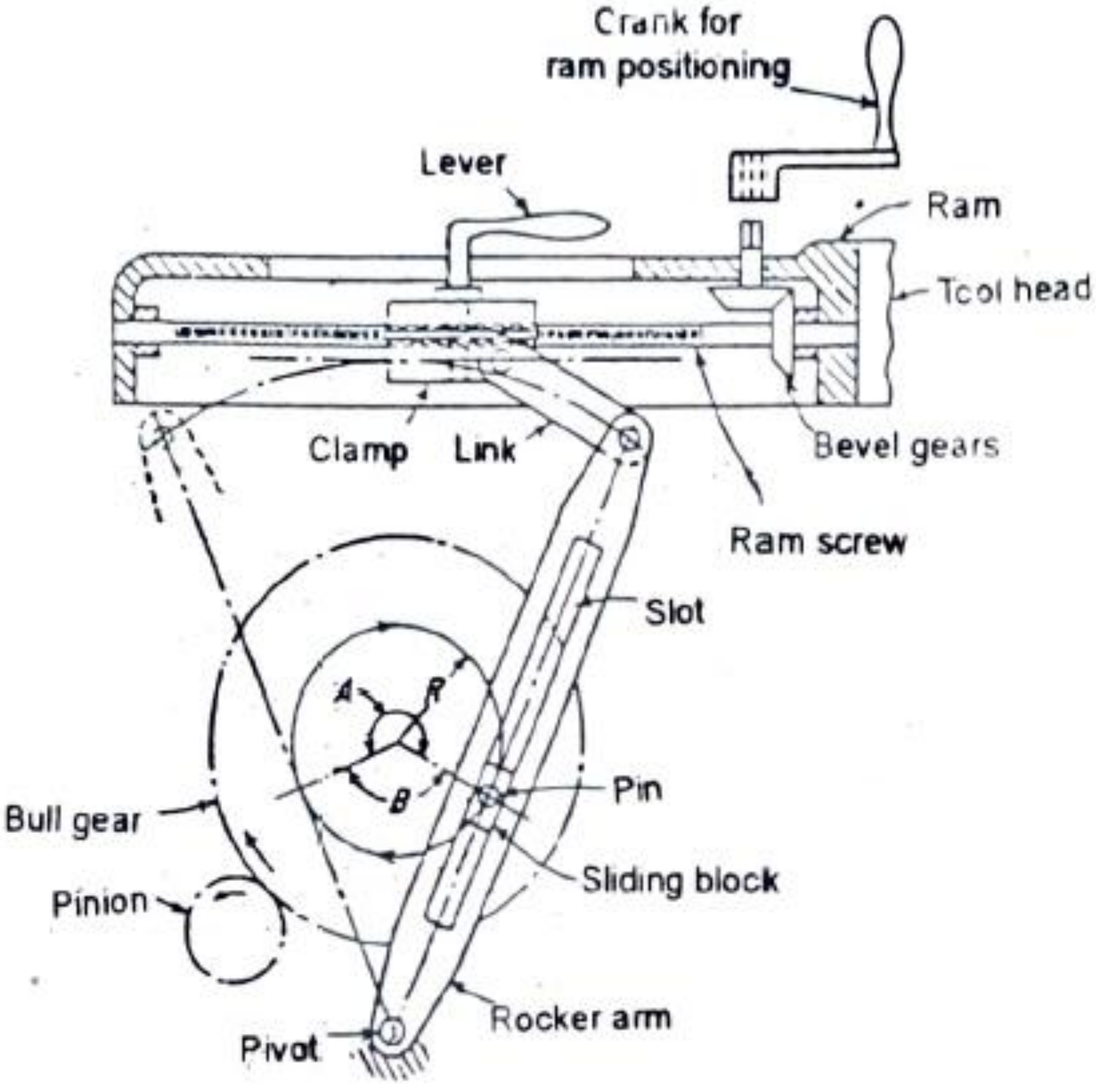


Fig. 6-2. Crank & slotted link mechanism

Crank and Slotted Link Mechanism

- A crank and slotted link type of quick return mechanism is shown in figure 6-2. power from an electric motor is transmitted through a clutch and gears to the pinion and bull gear.
- The bull gear rotates with a pin in a circular path. This pin fits freely into a hole in the block that can slide in a slotted link or rocker arm as shown in figure. As the bull gear rotates, the pivoted rocker arm swings back and forth about its stationary pivot point.
- This drive arrangements provides a suitable cutting speed as the drive pin rotates through angle A and a quick return as it rotates through angle B.

- The length of the shaper is changed by changing the radius R of the circular path traversed by the drive pin. The position of the stroke can e adjusted by lowering the ram positioning clamp and turning the lever which rotates the ram positioning screw.
- This moves the ram forward or backward with respect to the ram block position, thereby changing the position of the stroke.

Hydraulic quick return Mechanism

- A Shaper using this mechanism is called a "hydraulic shaper". The construction and principle of operation of a Hydraulic quick return Mechanism for a shaper is shown in figure 6-4.
- It consists of a constant discharge oil pump P, a valve chamber, a piston and cylinder arrangement in the ram as shown in figure. Here the piston rod is fastened to the ram body and the forward and reverse strokes of the ram are obtained because of the movement of the piston in the cylinder.

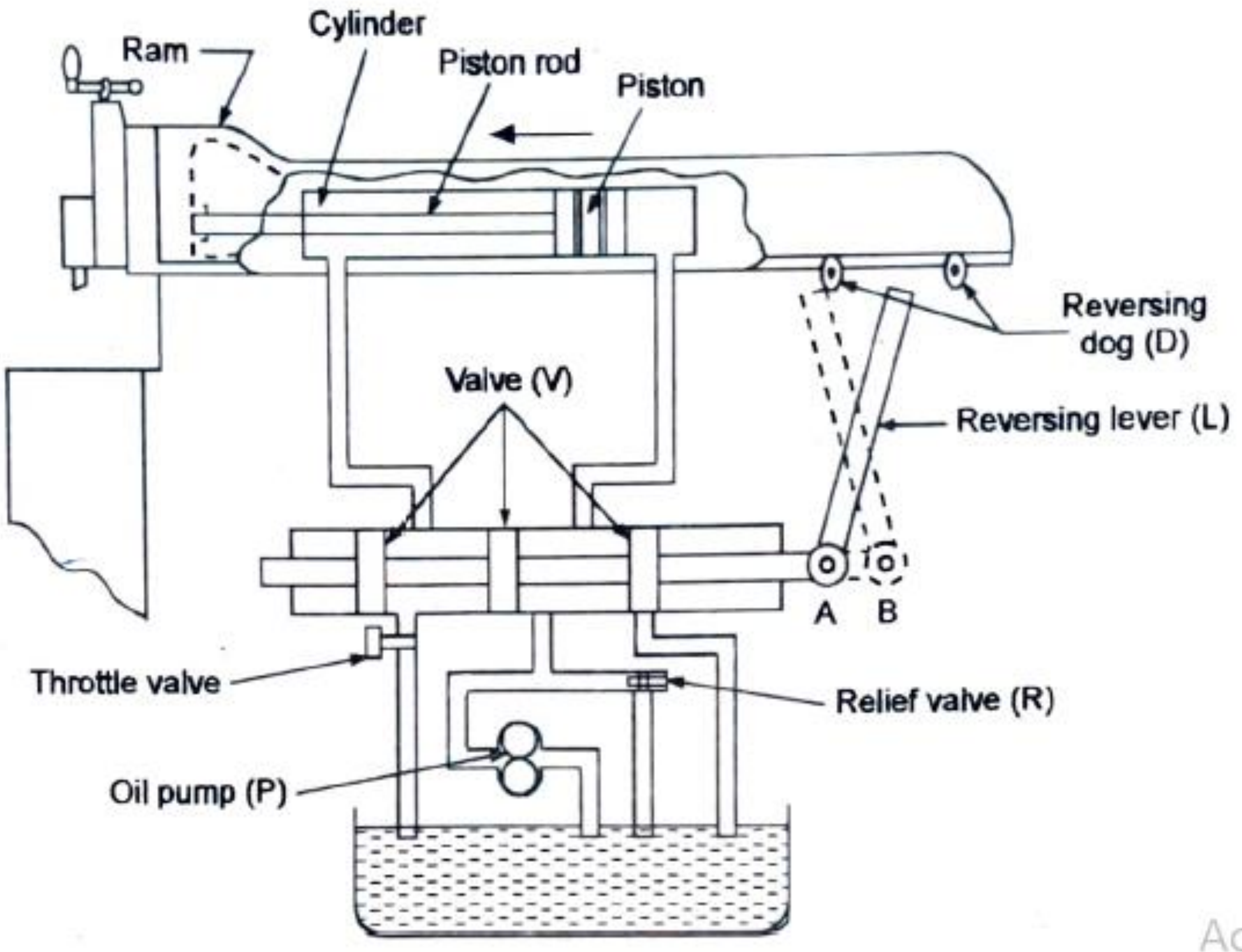
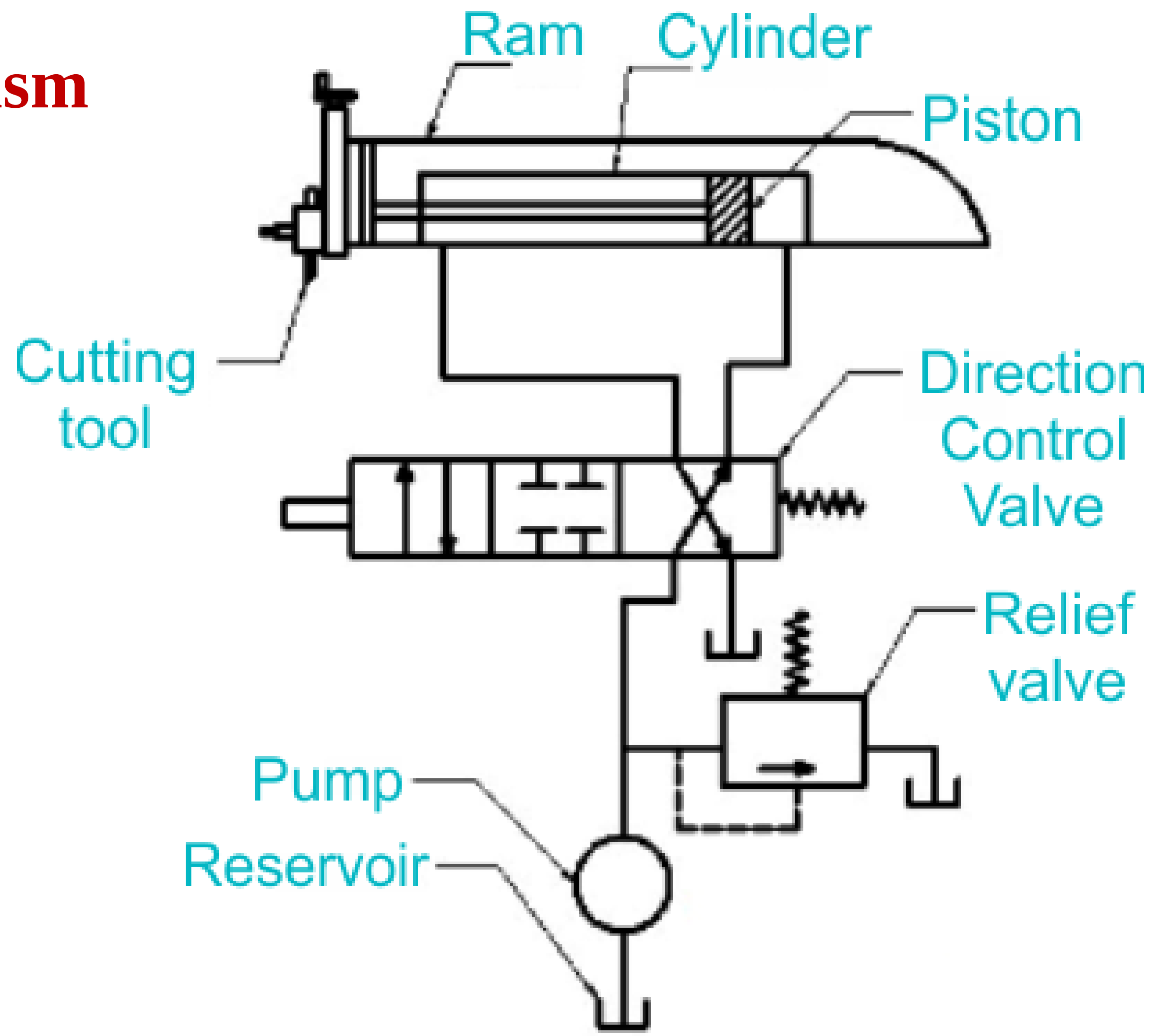
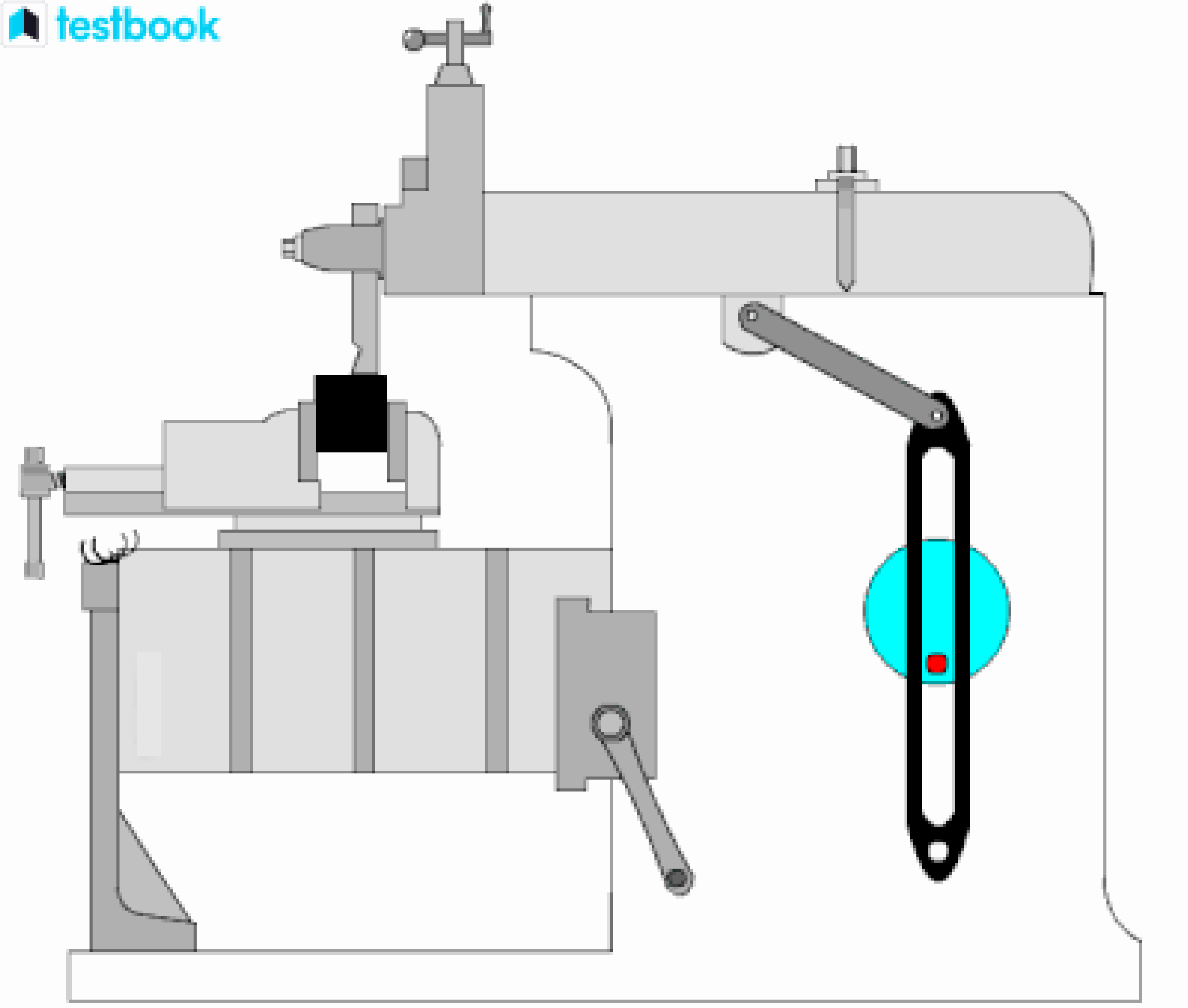


Figure:6-4 Hydraulic Quick Return Mechanism

In operation, when the oil pumped from the reservoir passes through the valve into the cylinder to the right side of the piston, it exerts pressure on it and the piston moves forward, hence the ram. In the mean time, the piston exerts pressure on the oil at its left side (of previous stroke) and the oil passes to the reservoir through the valve chamber. At the end of the forward stroke, the shaper dog **D** hits the reversing lever **L** causing the valves **V** to change position from **A** to **B**. Now, the oil under pressure enters the left side of the piston causing the return stroke of the ram, and discharge of oil from the right side of the piston to the reservoir. At the end of the reverse stroke another dog hits the lever to change the valve position from B to A. At valve position A again forward stroke is performed, and the cycle repeats.

Hydraulic Mechanism

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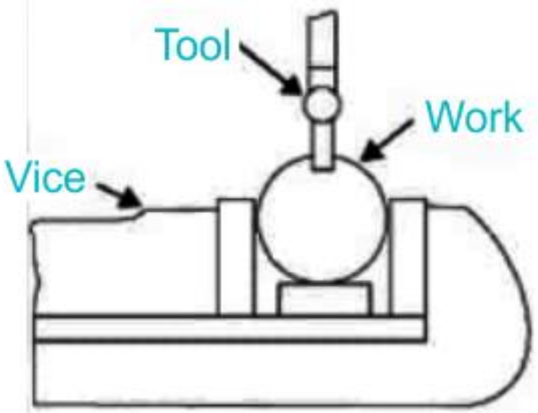
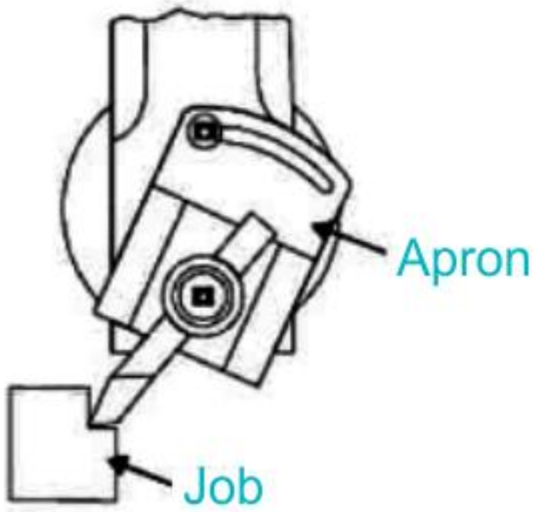
Horizontal Type Shaping Machine

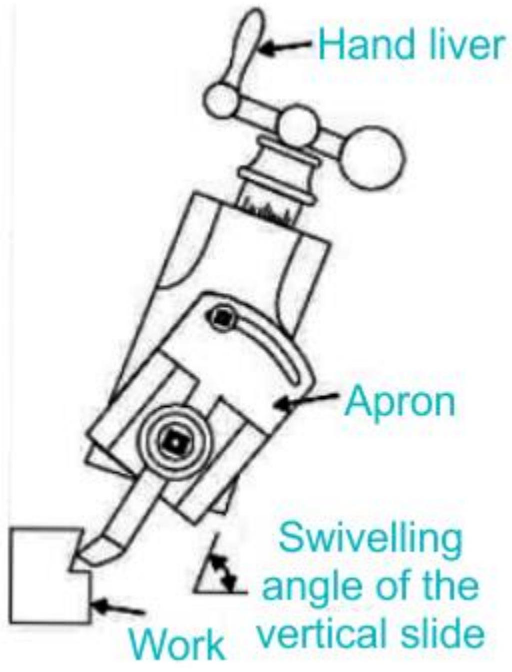
Shaping Operations



Slot Cutting

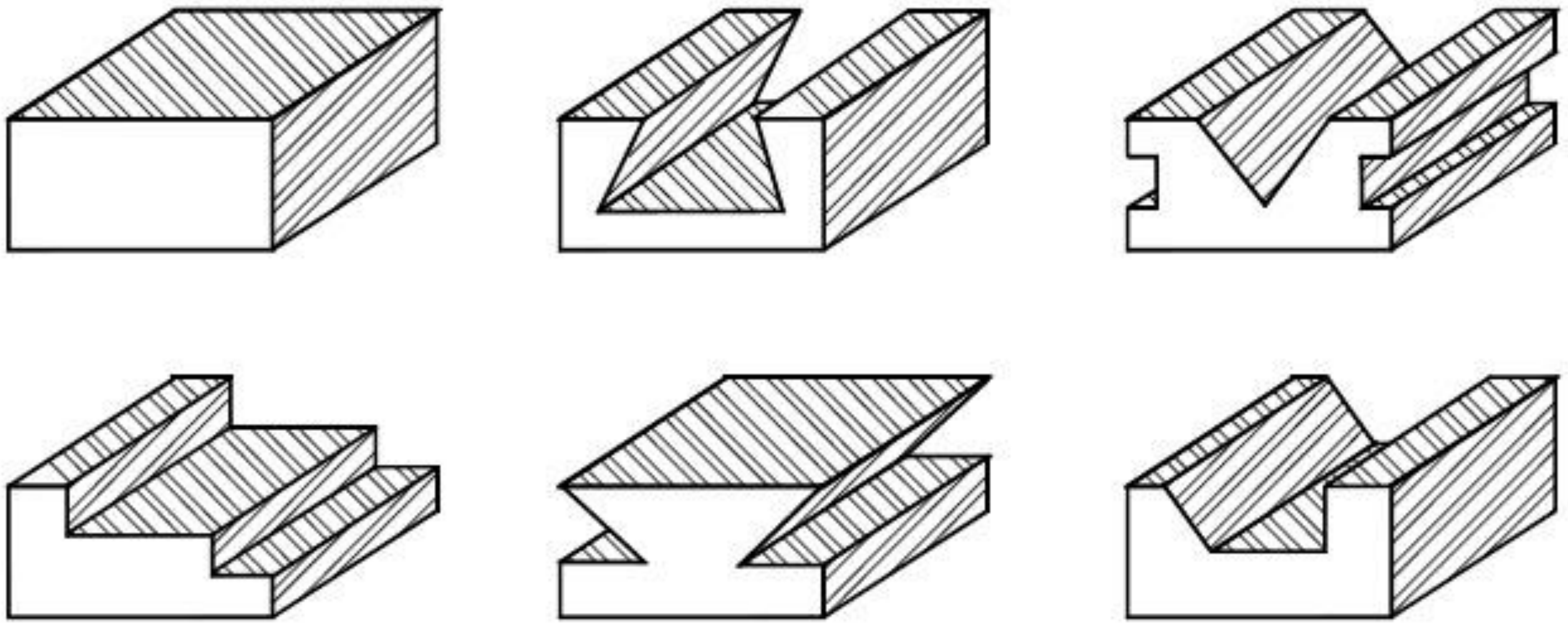


Machining Vertical surface



Machining Inclined Surface

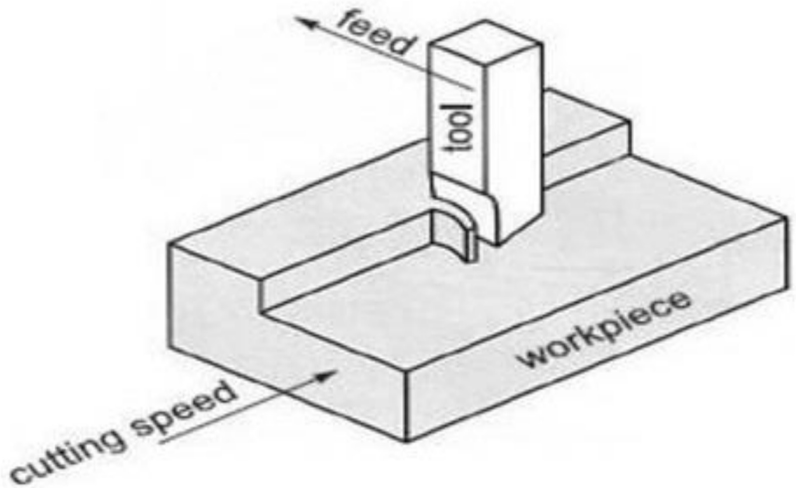
Parts produced by Shaping Operations



Planing Machine

Planing:

Planing is the machining operation of removing excess material from the workpiece by means of a single point cutting tool, which is held stationary while the worktable carrying the workpiece is being reciprocated beneath the cutting tool. Planing is preferred primarily for large and heavy workpieces that cannot be worked by shaping operation.



Planing Machine

Planer or Planing machine is a machine tool, which is like shaper produces flat surfaces in horizontal, vertical or Inclined plane. The fundamental difference is that the planer operates with an action opposite to that of the shapers, i.e, the work piece reciprocates past with one or more stationary single point cutting tool.

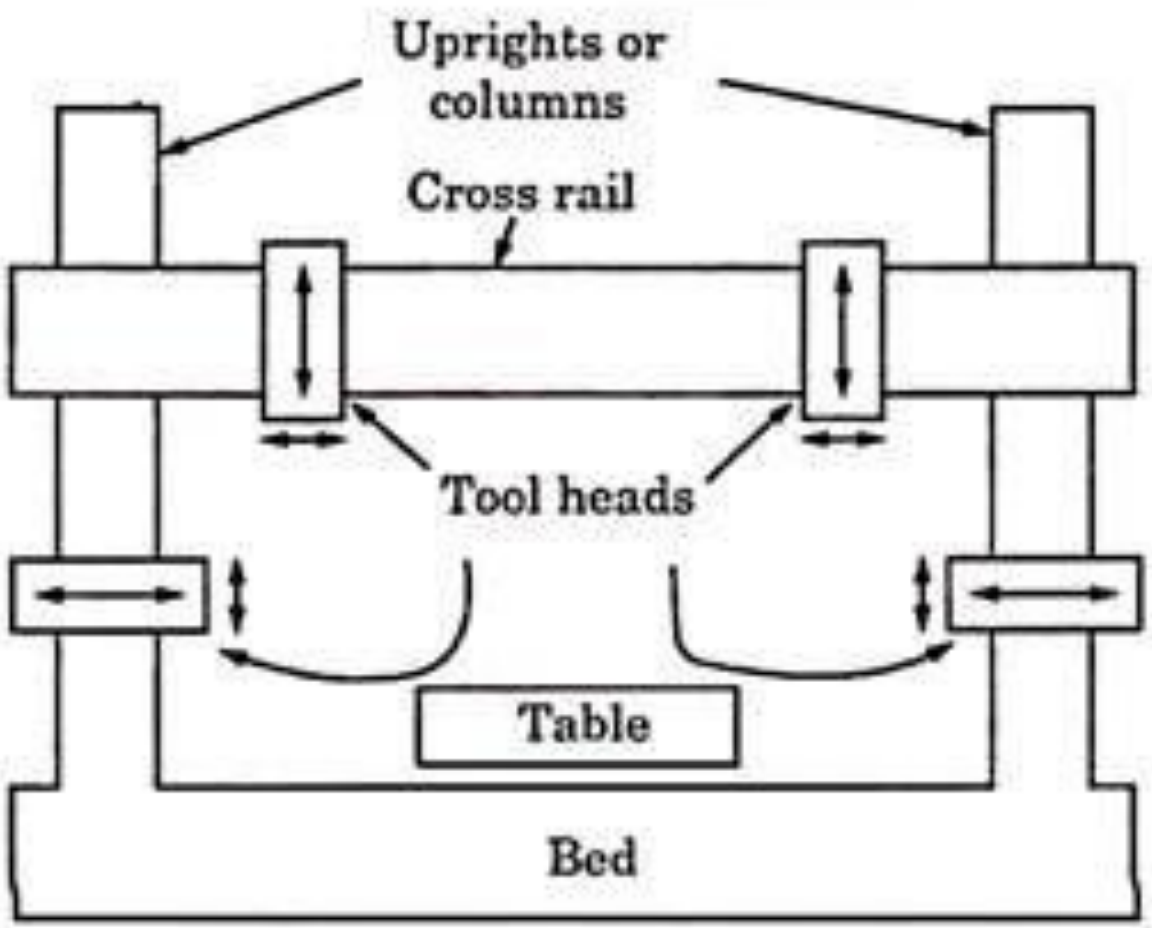
Planers are meant for machining large sized work pieces, which cannot be machined by the shaping machines. The work table is moved back and forth on the bed beneath the cutting head either by mechanical means , such as a rack and pinion gear or by a hydraulic cylinder.

Classification of Planner

Planers are generally divided into into 5 types

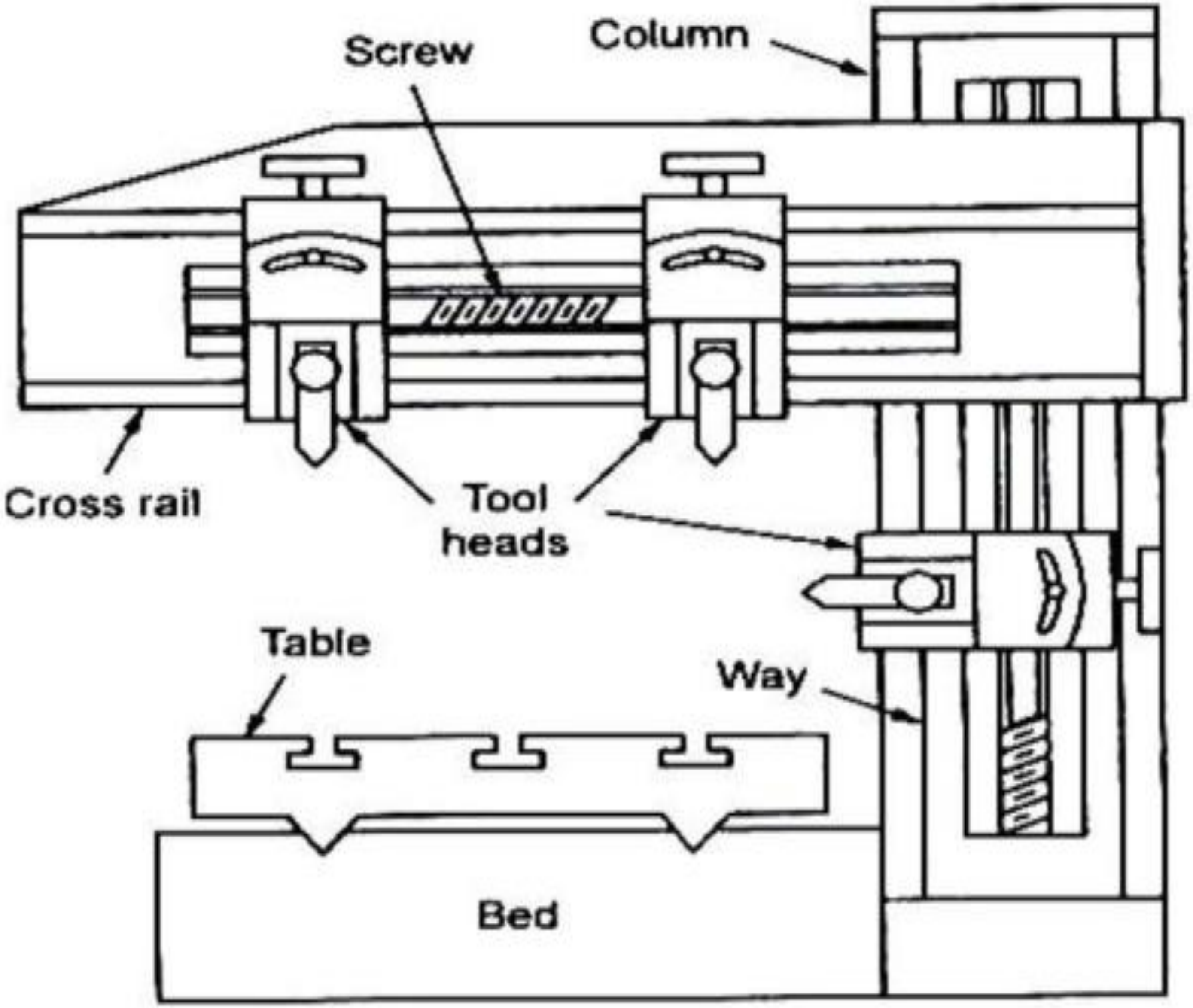
- Double Housing Planer
- Open side Planer
- Edge type Planer
- Divide table planer
- Pit type Planer

Double Housing Planer:



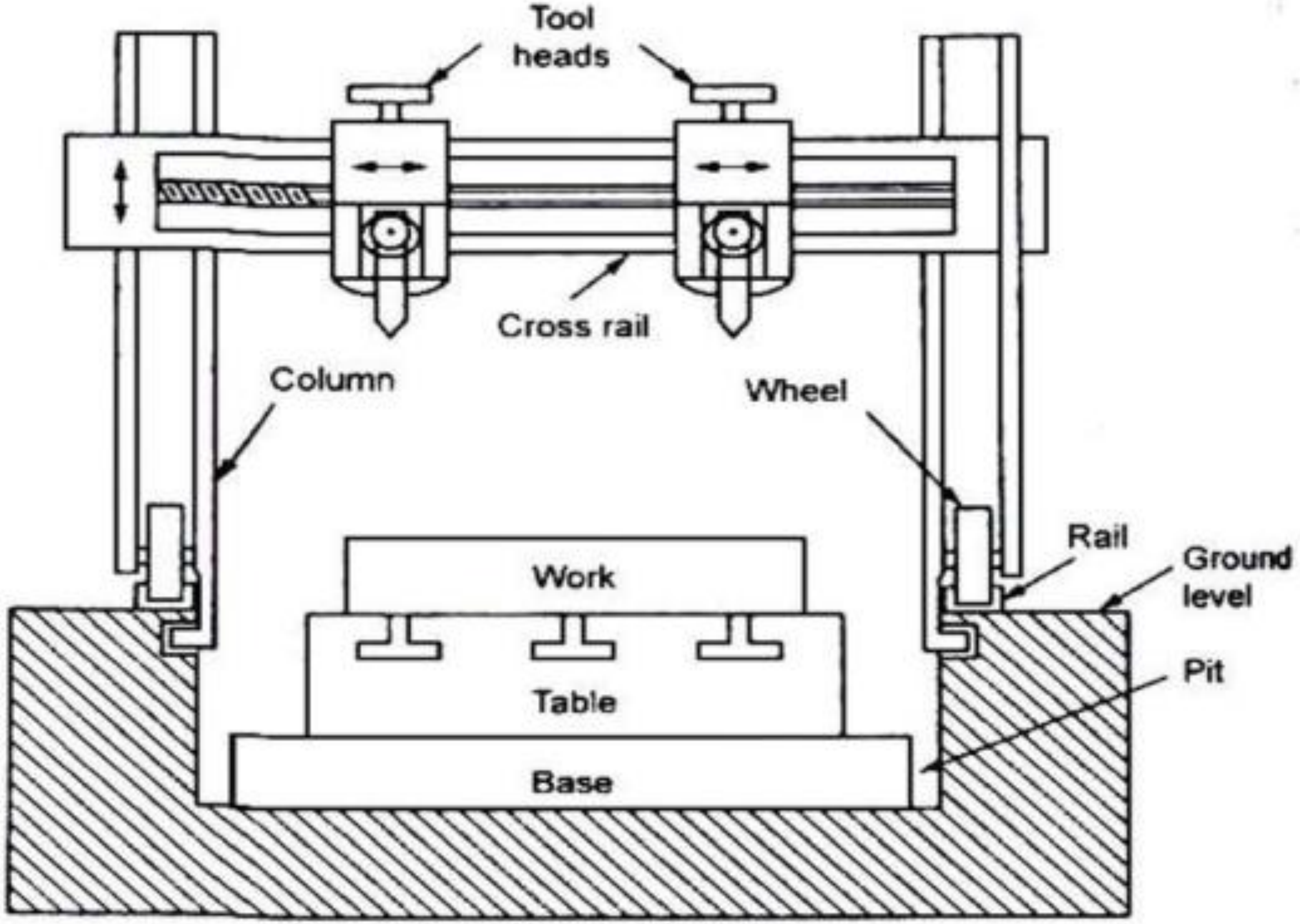
It is the commonly used type of Planer. It consists of mainly a massive bed on which the worktable reciprocates, and two vertical columns: one on each side of the bed. Each column carries a tool head that can slide up and down on the column. A cross-rail fitted between the two columns may carry one or two tool heads that can slide horizontally on the cross-rail. All the tool heads can be clamped in position, and can be used collectively or individually depending on the requirements.

Open side Planer



Open side planer: This type consists of only one housing (column) located on one side of the bed and the other side is left without any obstruction (cantilever type, supported on a single column on one side). Due to this, only three toolheads can be fitted to this type of planer. The main advantage here is that it can machine components which are usually wider than the two columns of a double housing planer. Rest of the construction is similar to a double housing planer.

Pit Planer


Tool
heads
Cross rail
Column
Wheel
Rail
Ground
level
Work
Table
Pit
Base

PIT PLANER:

This machine is specially designed for machining long, heavy and tall work, that can't be machined on the conventional type of planers. The job is mounted either on stationary table or on the floor inside a pit. The machine is provided with two short vertical housing which carry cross-rail. One or two tool heads are mounted on the cross rail and two side tool posts on the housings. This whole unit travels along the horizontal ways to and fro and thus the tool moves past the work for machining the surface. The horizontal and inclined surfaces of the work piece are machined on these planers.

Pit Planer: Sometimes, when the jobs are tall, heavy or long, then they are mounted on a stationary table or on a pit on the floor. The machine has two short vertical housings which carry one or two toolheads. A cross rail is provided connecting the two housings which carry vertical toolheads. The two housings (columns) travel along two horizontal rails placed along the pit (i.e. the whole unit travels along these rails). Hence, the tool moves past for machining the surface of the WP in this case, while the WP is stationary.

Specification of a Planer:

The planer is specified by the following parameters:

- Radial distance between the top of the table and the bottom most position of the cross rail.
- Maximum length of the table and maximum stroke length of table.
- Power of the motor.
- Range of speeds and feeds available.
- Type of feed and type of drives required.

Comparison between Shaper and Planer:

Sl. No	Shaper	Planer
1	A shaper is a light machine employed for machining small sized workpieces.	A planer is a heavy duty machine employed for machining medium and large size workpieces.
2	In a shaper, the workpiece is held stationary, while the cutting tool reciprocates across the work surface.	In a planar, the tool remains stationary, while the workpiece reciprocates under the tool.
3	A shaper uses one cutting tool at a time.	A planar is designed to use up to four tools, either separately or simultaneously for machining a number of surfaces at a time.
4	Occupies less floor area.	Occupies more floor area.
5	Machine is cheaper.	Costlier.

Feature	Shaper Machine	Planer Machine
Workpiece Size	Smaller and lighter	Larger and heavier
Cutting Speed	Higher cutting speed	Lower cutting speed
Workpiece Mounting	Clamped on the table	Fixed on the machine bed
Cutting Direction	Vertical or inclined	Horizontal
Cutting Tool	Single-point tool	Multiple cutting tools
Surface Finish	Relatively rough	Relatively smoother
Applications	Ideal for small parts	Suitable for larger parts
Material Removal Rate	Lower material removal	Higher material removal
Machining Operations	Suitable for intricate	Suitable for flat

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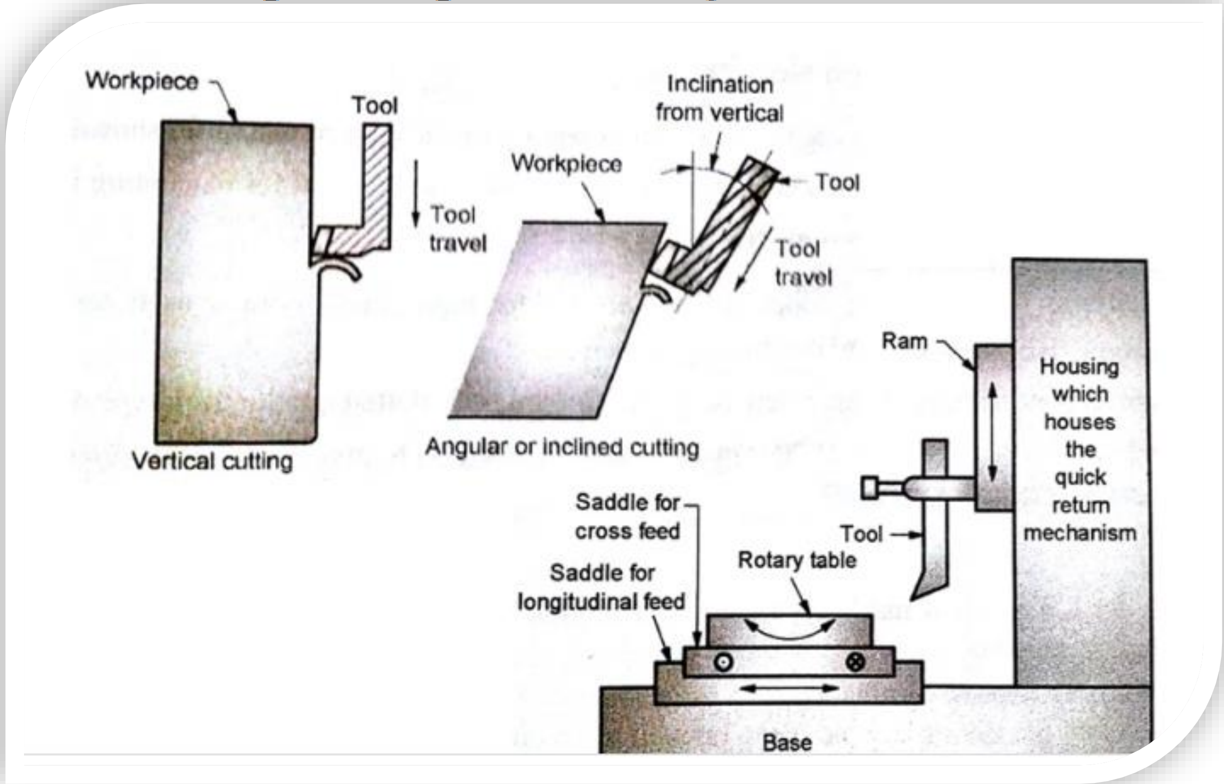
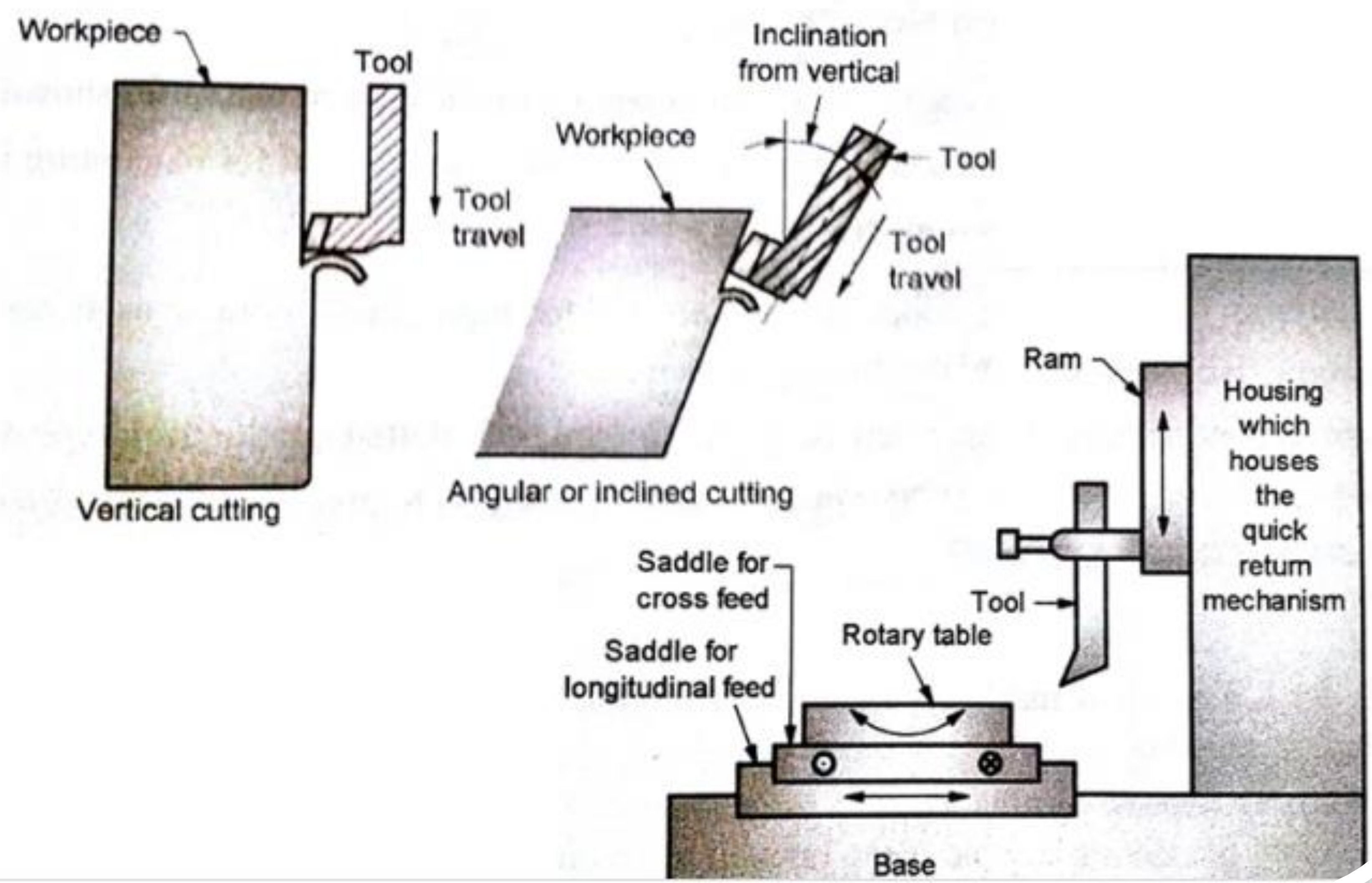
Module-2

Introduction to Slotting and Grinding Machine

Slotting Machine

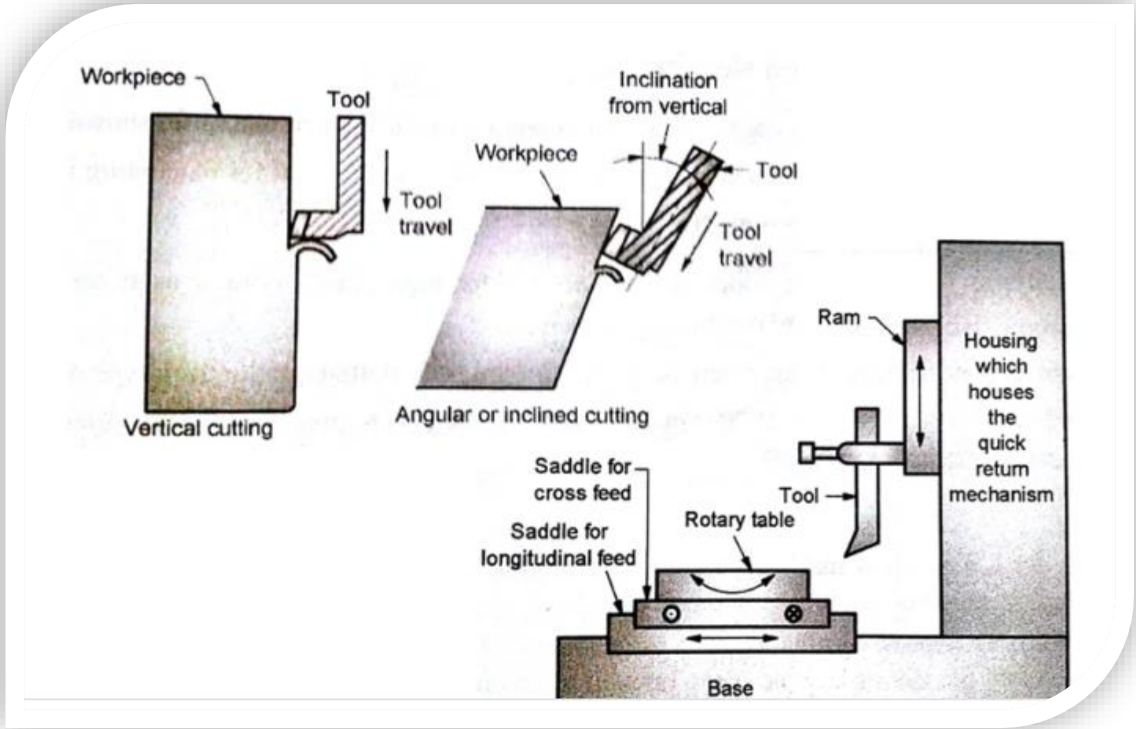
Slotting machine (slotter) is a reciprocating type of machine tool similar to a shaper or a planer machine. It may be considered as a vertical shaper. The main difference between a slotter and a shaper is the direction of the cutting action. The slotting machine operates in a manner similar to the shaper. However, the cutting tool moves vertically direction rather than in a horizontal direction. The work piece is held stationary. The slotting machine has a vertical ram and a hand or power operated rotary table.




Workpiece
Tool
Tool travel
Vertical cutting
Inclination from vertical
Workpiece
Tool
Tool travel
Angular or inclined cutting
Ram
Housing which houses the quick return mechanism
Saddle for cross feed
Tool
Rotary table
Saddle for longitudinal feed
Base

Slotting Machine

- Slotting is a machining for producing ***slots Splines , keyways and for creating internal and external forms or profiles in work parts.***
- Similar to Shaper
- Cutting tool during slotting reciprocates in vertical direction across the rigidly held workpiece.
- Cutting action taking place during the down word stroke only.
- Slotting machine also called slotter is considered as a vertical Shaper



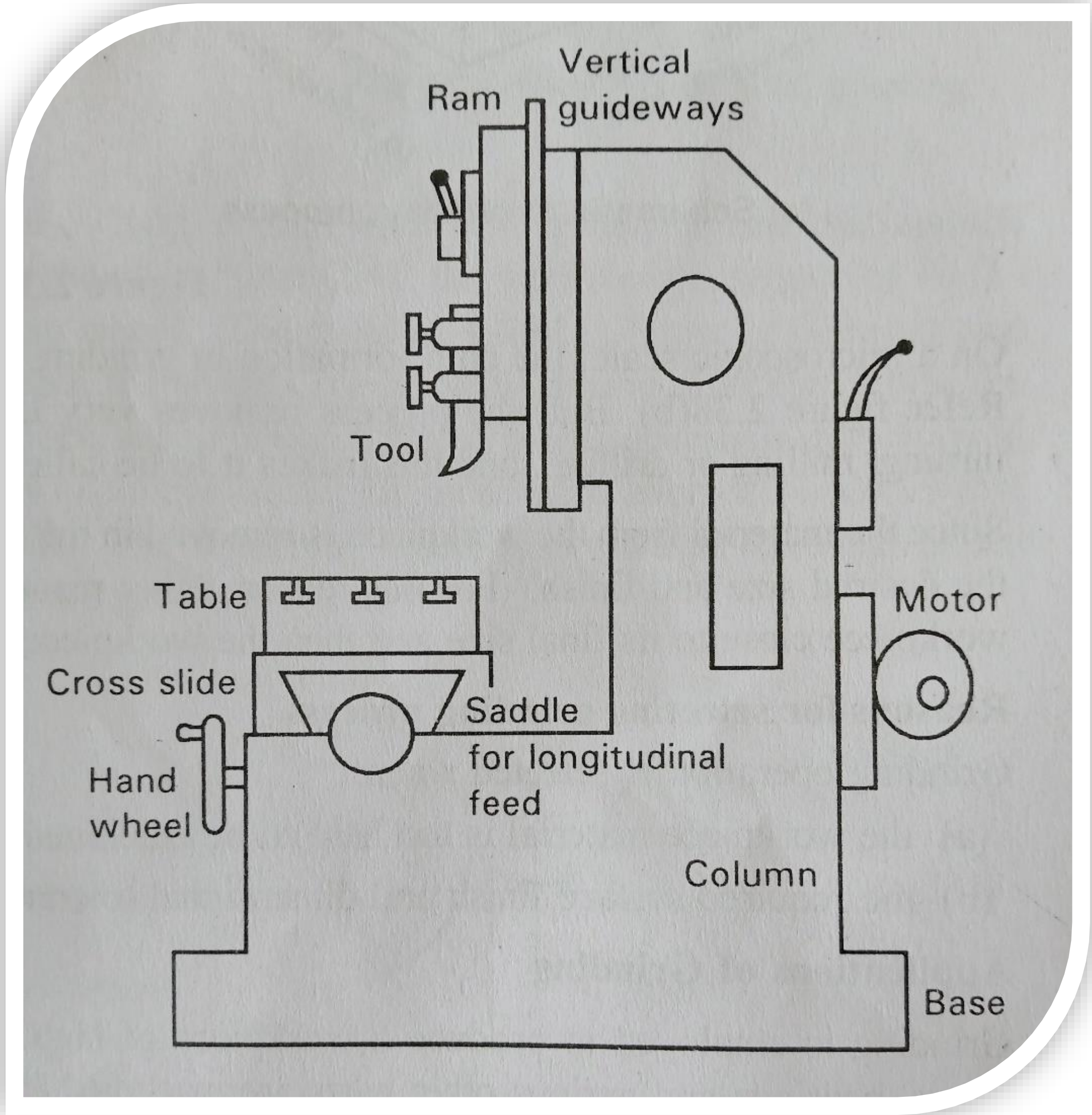
Slotting Machine

Slotting machines are mainly three types:

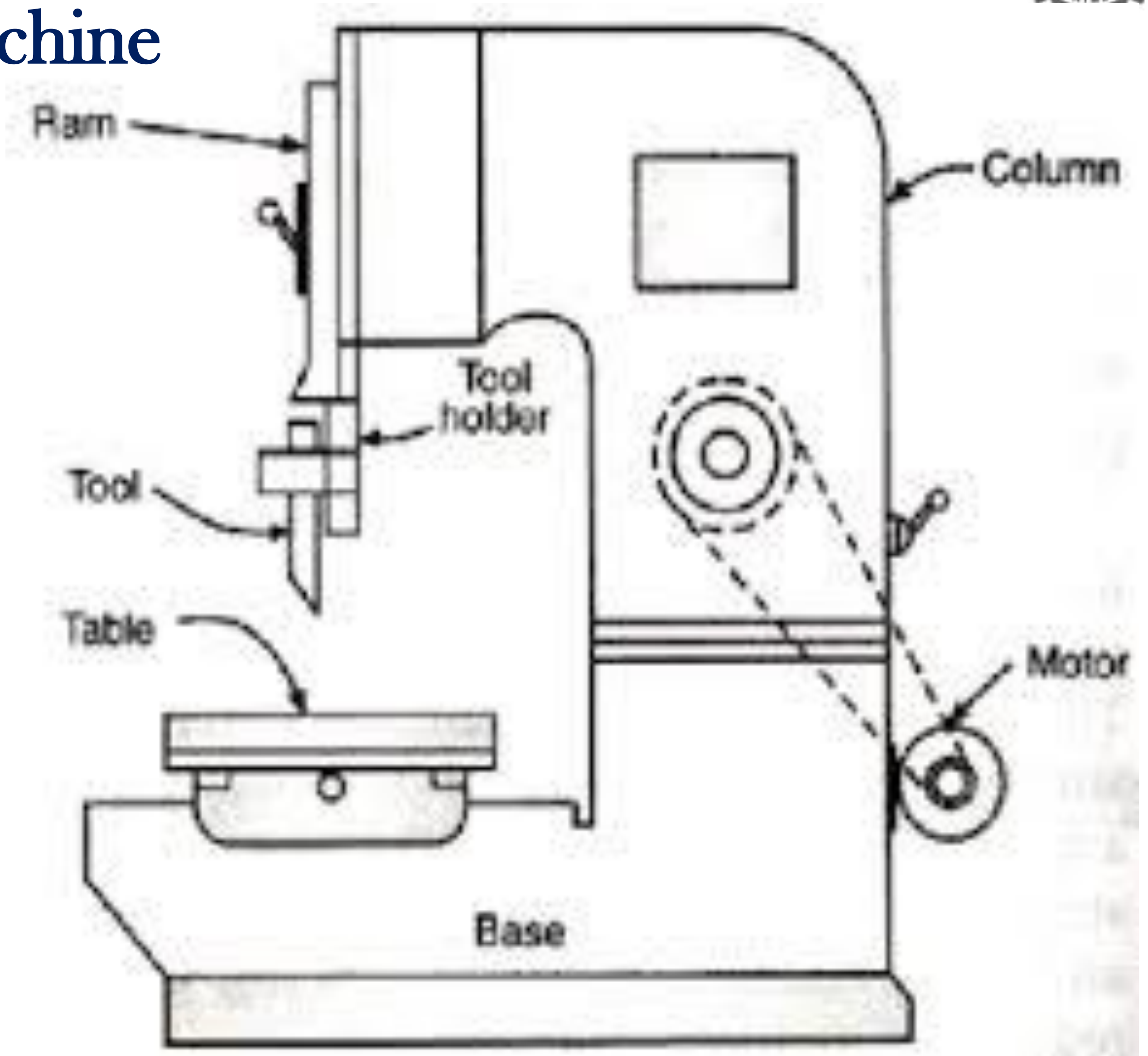
- Puncher Slotters
- Production Slotters
- Tool Room Slotters

Slotting Machine

- Base
- Column
- Saddle
- Worktable
- Ram



Slotting Machine



Main Parts of a Slotting Machine

1. **Base:** It is a heavy cast Iron construction and acts as a support for the column, the driving mechanism ram, table and all other fittings. At its top it carries horizontally ways along which the table can be traversed.

2. **Column:** It is another heavy cast Iron body, which acts as a housing for the complete driving mechanism. At its front it carries vertical ways, along which the ram moves up and down.

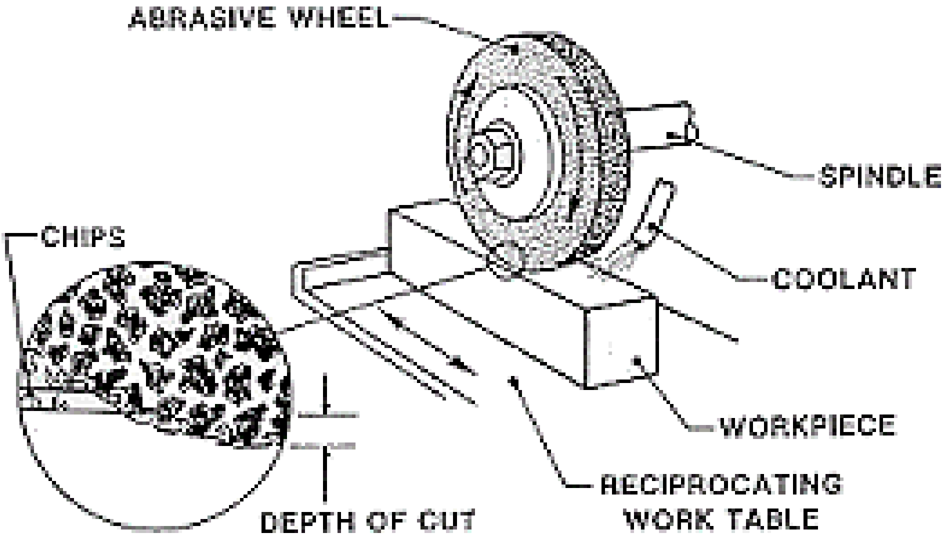
3. **Table:** Usually circular table is provided on the top of the table are provided T-slots to clamp the work or facilitate the use of fixtures.

4. **Ram:** It moves in vertical direction, between the vertical guide ways provided in front of the column. At its bottom, it carries the tool post in which the tool is held. The cutting action takes place during the down ward movement of the ram.

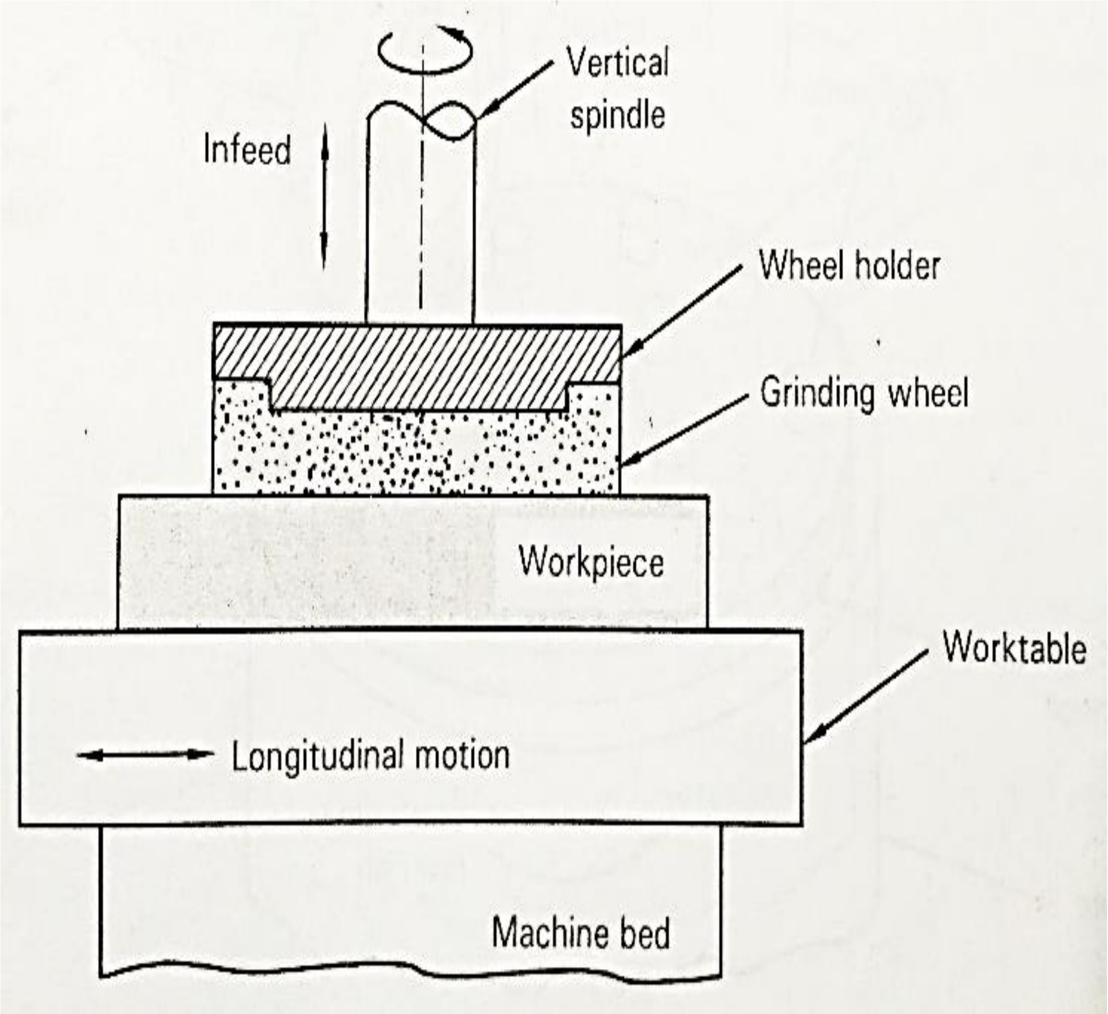
Grinding Machine & Operation

Grinding:

Grinding is a process of removing excess material from the workpiece by the mechanical action of abrasive particles that are held together by an adhesive, generally in the form of a solid wheel. The wheel known as *grinding wheel* is rotated at high speeds, and when the surface of the rotating wheel is brought in contact with the workpiece, material is removed in the form of fine chips or powder.



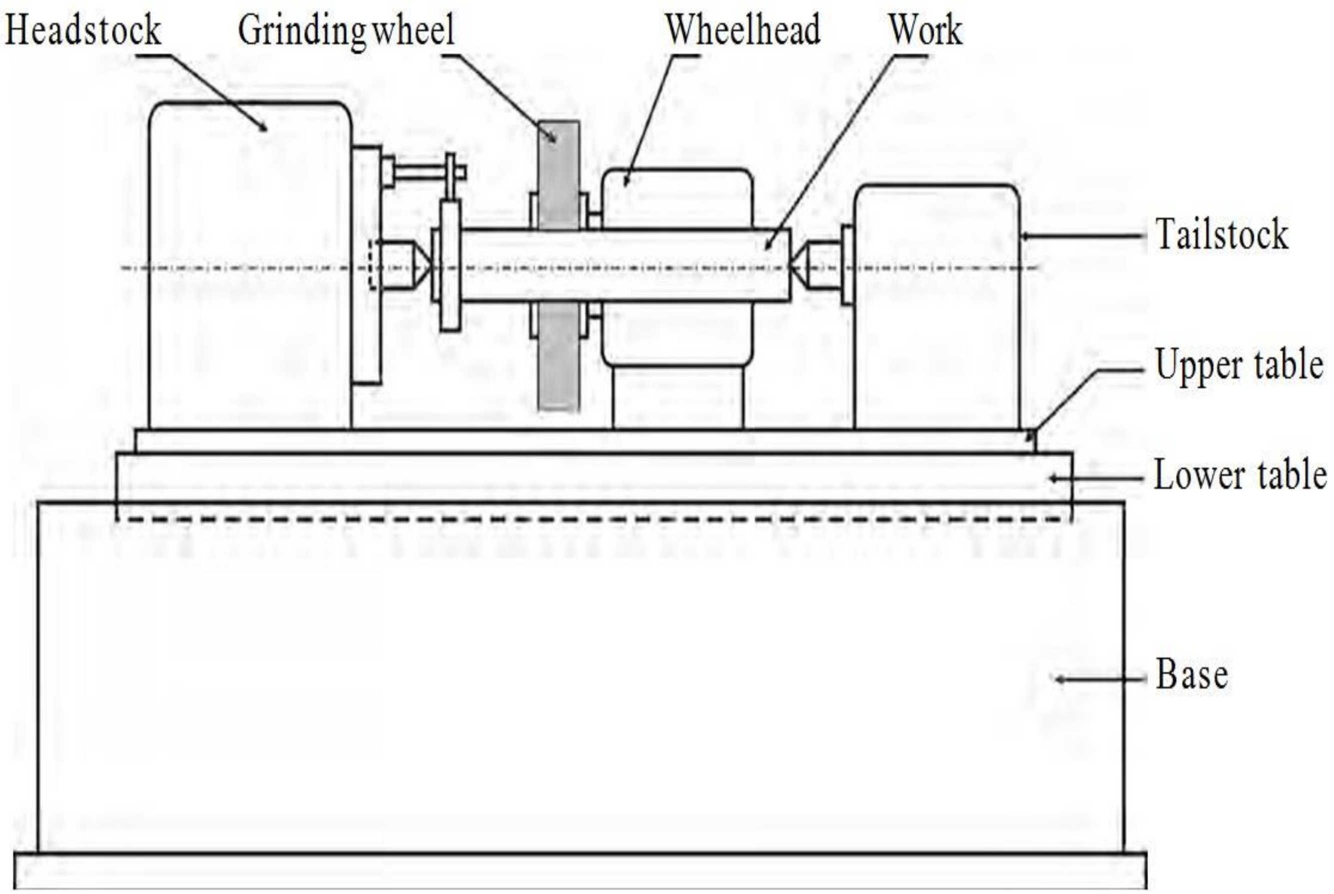
Surface Grinding Machine:



Surface grinding machines are used primarily to produce and finish flat surfaces. However, with the use of special fixtures and form dressing devices, angular and formed surfaces can also be finished.

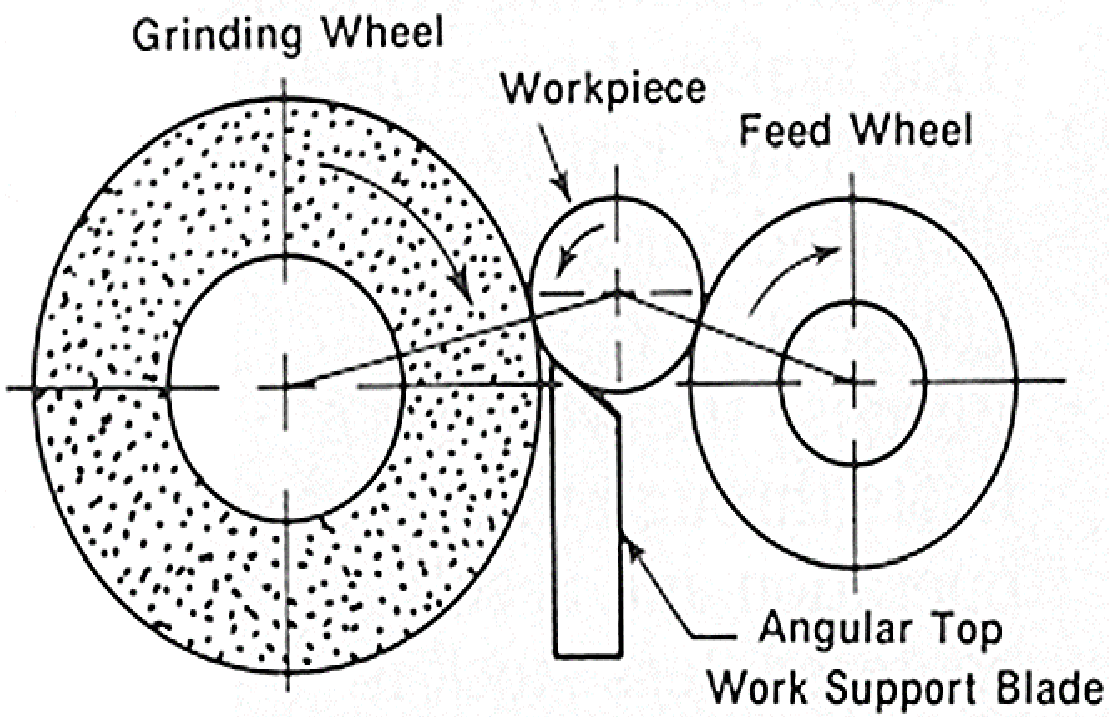
The machine consists of a grinding wheel, either a cup type or cylinder type mounted on a vertical spindle. The diameter of the grinding wheel should exceed the width of the workpiece surface to be ground. Since the contact area of the grinding wheel on the surface of the workpiece is more, material is removed at a faster rate and hence, such machines are used for high production applications.

Centre type cylindrical grinding machine:



Centre type cylindrical grinding machine is used for grinding external cylindrical surfaces of single and multi-diameter shafts. The workpiece to be ground is held and rotated between two centres: the headstock and tailstock centre, and hence the name *centre type grinding machine*. The machine resembles to a centre lathe except with slight modifications in its construction and operation.

Centreless Grinding Machine:



Centreless type of machine is used for grinding surfaces of long, slender rods that cannot be held and rotated between centres. In other words, the workpiece is not rotated between centres and hence the name *centreless grinding*.