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DEPARTMENT OF MECHANICAL ENGINEERING

FOURTH SEMESTER

SUBJECT

MET-45 MACHINING PROCESSES

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UNIT - I: TURING OPERATIONS

A lathe is a father of all machine tools. It is the most important machine used in any workshop. The main function of a lathe is to remove metal from a piece of work to obtain the required shape and size. A lathe removes metal by rotating the work piece against a single point cutting tool.

Generally, lathe is used to machine cylindrical shapes. The parts to be machined can be held between two rigid supports called live and dead centres. The tool is moved perpendicular to the work piece axis to produce a flat surface. The tool is moved at an angle to the axis of work piece to produce tapered surface.

The following operations can be done by using lathe: turning, taper turning, eccentric turning, chamfering, facing, drilling, boring, reaming tapping, knurling, forming, grooving, polishing, spinning and thread cutting.

CONSTRUCTIONAL FEATURES OF A LATHE

The principal parts of an engine lathe are labelled and shown in fig 1. Following are the principal parts of the lathe.

(i) Bed
(ii) Head stock
(iii) Tail stock
(iv) Carriage
(v) Feed mechanism

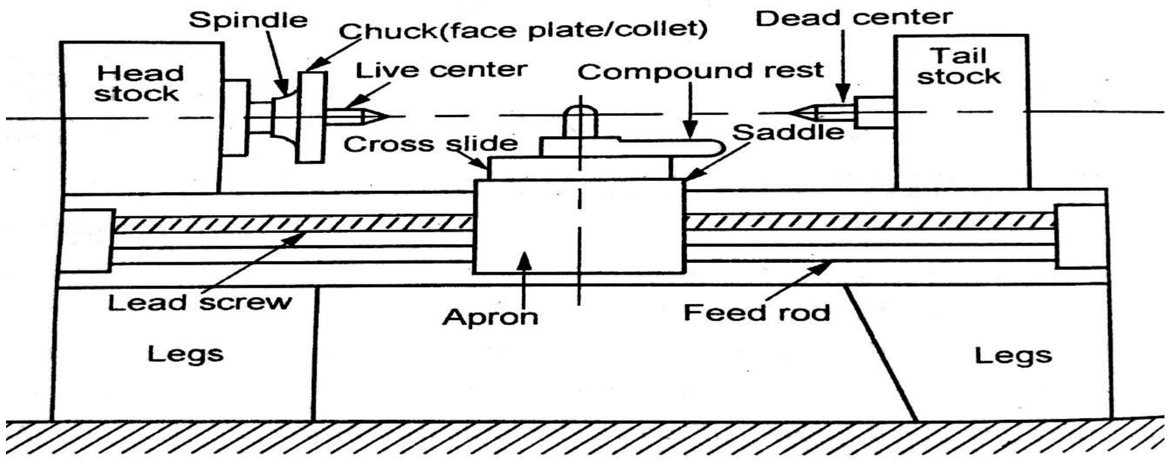


Figure 1 Engine Lathe

A brief description of these parts is as follows:

1) Bed

- Bed is the base of the machine.
- It carries a headstock on its left end and tailstock on its right end. Carriage is mounted on middle of the bed.
- Headstock is stationary one. Both the tailstock and carriage move over the bed.
- The bed has V and dovetail guide ways as shown in fig.2.
- The bed is very strong to resist the cutting forces and vibrations.
- It is held rigidly by cross ribs supported by cast iron supports.

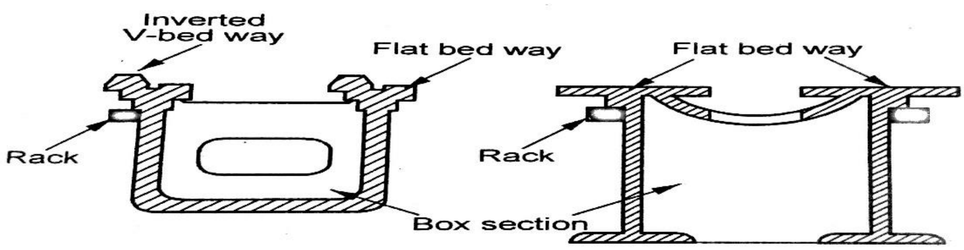


Figure 2 Lathe Bed

- The guide ways are very accurate for getting accuracy in jobs. It should be sufficiently rigid to prevent deflection under high cutting pressure transmitted through the tool post and carriage. There is a rack under the front way of the bed.
- A pinion gear is meshed with rack for moving the carriage when the hand wheel is turned.
- The bed is made of cast iron alloyed with nickel and chromium.

2) Headstock

- The headstock assembly is permanently fastened to left end of the bed.
- It carries a hollow spindle so that the bars can be passed through it if necessary.
- The spindle nose of the spindle is threaded to hold the chuck or face plate.
- The spindle is rotated by a combination of gears and cone pulleys or by gears alone. The spindle has a taper at the front end for holding centres and other tools having a tapered shank.
- A live centre can be attached into the spindle. This centre is called live centre because it turns with the work.
- The headstock has the driving and speed changing mechanism.
- The headstock may be of back-geared type or all geared type. There are speed changing and feed changing leavers attached to the headstock.

3) Tailstock

- Tailstock is situated at the right end of the bed. It is used for supporting the right end of work.
- It consists of a taper hole adjusting screw and hand wheel. It can be moved along the bed and clamped to the bed at the desired location.
- It is also used to hold drill reamer or tap for drilling, reaming or tapping operations.

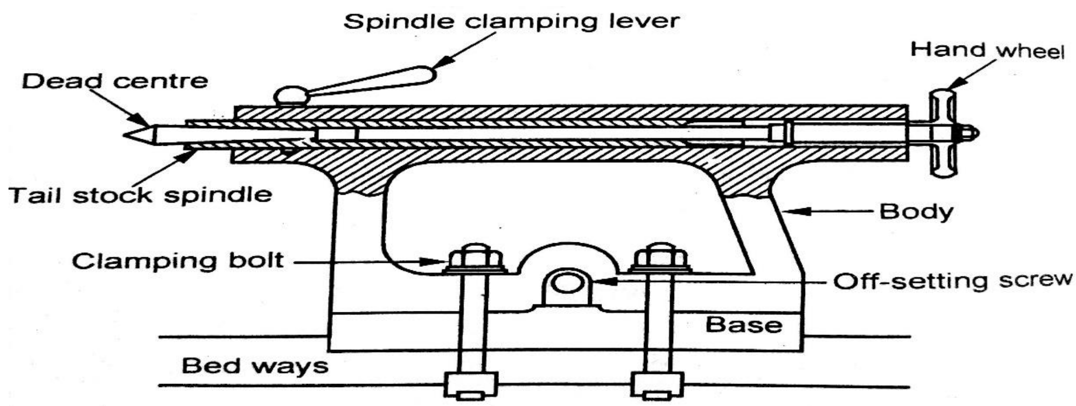


Figure 3 Tail Stock

- Tailstock consists of two main parts. The lower part rests directly on the bed ways, and the upper part rests on the lower part. Adjusting screws hold the two parts together.
- The upper body of the tailstock can be moved towards or away from the operator for taper turning.
- The tailstock body is bored and the tailstock spindle or quill moves through it. The spindle can be moved axially by means of a hand wheel.
- The dead centre is fixed into the taper hole of the spindle for supporting the end of the work.

4) Carriage

The carriage is a moving part that slides over the guide ways between headstock and the tailstock. It carries the following parts.

♣ ***<u>Saddle:</u>***

- It is an H shaped component fitted across the lathe bed.
- It moves along the guide way.
- It carries the cross slide and tool post to provide various kinds of motion to the tools.
- It can be moved anywhere along the bed and locked to the required position.

♣ ***Cross Slide:***

- The cross slide is attached to the saddle.
- It carries the compound rest and tool post. The cross slide can be moved by power or by hand.
- There is a micrometer dial fitted on the cross slide hand wheel with an accuracy of 0.05mm.

♣ ***Compound rest:***

- Compound rest is mounted on the top of the cross slide.
- It is used for supporting the tool post and cutting tool in various positions.
- The base of the compound rest is marked in degrees.
- The tool post can be swivelled to various angular positions for different turning operation, i.e. taper turning. There is no power feed to the compound rest.
- It is operated only by hand to feed the tool longitudinally or at an angle to the lathe axis. There is a micrometer dial for showing the depth of cut.

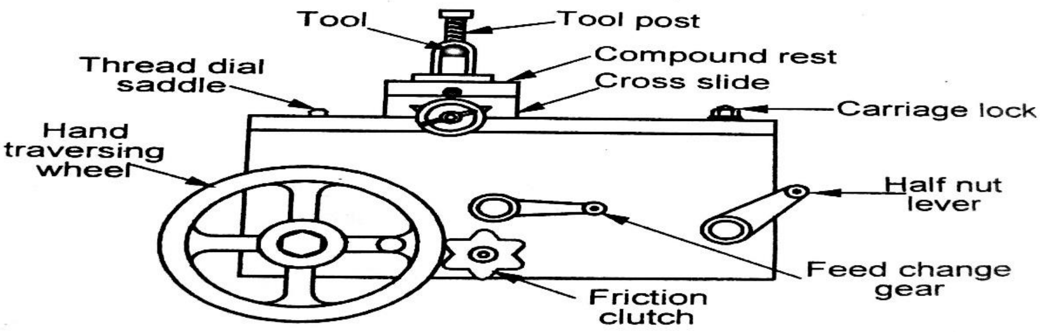


Figure 4 Carriage

5) *Tool Post*

A tool post is used to hold various tools and tool holders to create convenient working conditions. The tool post is fitted over the compound rest. The various types of tool posts are

(a) Single screw tool post.

(b) Open side tool post.

(c) Four bolt tool post.

(d) Four way tool post.

(a) Single screw tool post:

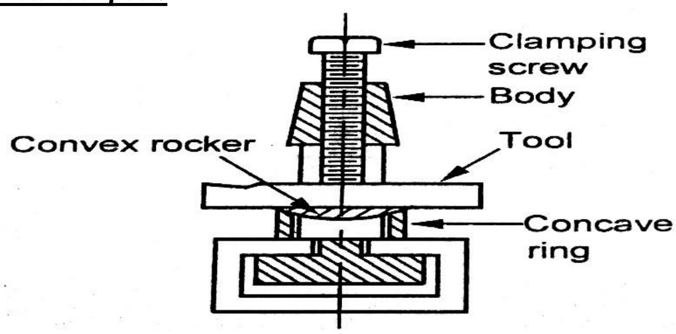


Figure 5. (a) Single screw tool post

- This tool post is used to hold single tool only.
- The tool is clamped by a clamping screw.
- The tool rests on the top flat surface of the convex rocker. The convex rocker has a convex surface at its bottom.
- This convex rocker is placed over a concave ring. The height of the tool is adjusted by this arrangement.

(b) Open side tool post:

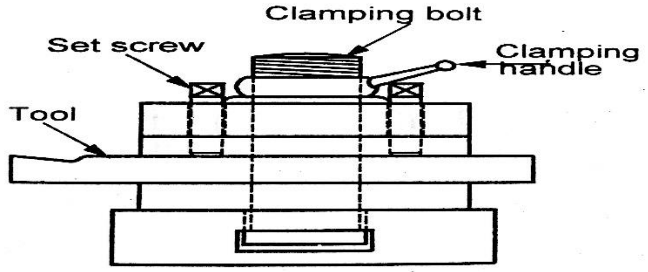


Figure 5. (b) Open side tool post

- This type of tool post is shown in fig. 5(b). The tool is held in position by set of screws.
- In order to adjust the height of the cutting point, parallel packing strips are used.
- The tool post is fitted on the compound rest by using clamping bolt through T-slot.
- The tool post can be tilted to any angle by loosening the clamping bolt and clamped.

(c) Four bolt tool post:

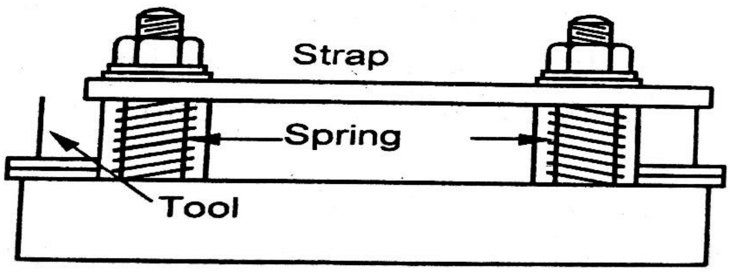


Figure 5. (c) Four bolt tool post

- In this type of tool post, two tools may be held in position by two straps and four bolts.
- The tool height is adjusted by placing parallel strips under the tool.
- It is generally used in heavy lathes as it gives more support to the tool.

(d) Four way tool post:

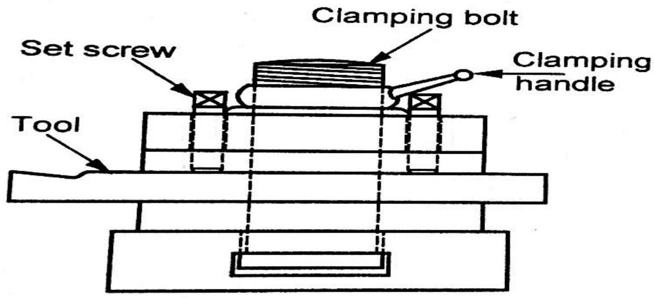


Figure 5. (d) Four way tool post

- It is commonly used tool post now-a-days, because it facilitates to hold four various tools in a tool post at a time as shown in fig. 5(d).
- It can be swivelled in the central screw and clamped at any angle. Here also tool height can be adjusted by using parallel strips.

SPECIFICATIONS OF A LATHE

The size of the lathe is generally specified as follows:

1) The length of bed.
2) Maximum distance between dead and live centres.
3) Type of bed i.e. straight, semi gap or gap type.
4) The height of centres from the bed.
5) Swing over the bed.
6) Swing over the cross slide.
7) Width of the bed.
8) Spindle bore.
9) Spindle speed.
10) H.P. of main motor and rpm.
11) Number of spindle speeds.
12) Spindle nose diameter.
13) Feeds.
14) Floor space required.

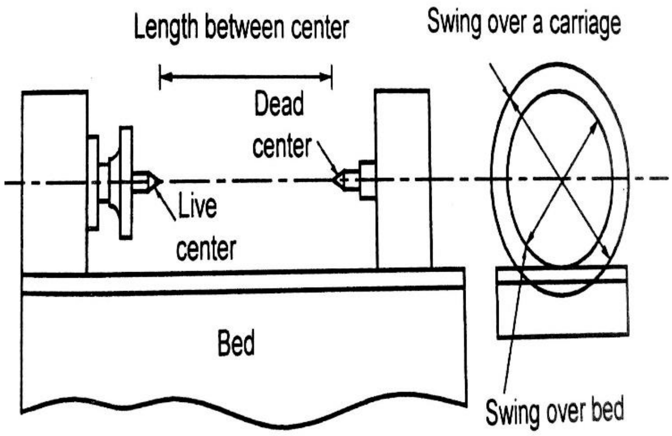


Figure 6 Specification of Lathe

TYPES OF LATHE

To suit for different machining conditions, various types of lathes have been developed. Lathes are classified in many ways with respect to Size, design, method of drive and purpose. The different types of lathes are as follows:

1) Speed Lathe
    a. Wood working lathe
    b. Metal spinning lathe
    c. Metal turning lathe
    d. Polishing lathe
2) Engine lathe
    a. Step cone pulley drive lathe
    b. Geared lathe
    c. Variable speed lathe
3) Bench lathe
4) Tool room lathe
5) Semi-Automatic lathe
    a. Capstan lathe
    b. Turret lathe
6) Automatic lathe
7) Special purpose lathe
    a. Crank shaft lathe
    b. Wheel lathe
    c. Duplicating lathe
8) Copying lathe

1) Speed Lathe

- The speed lathe is the simplest of all lathes.
- It consists of headstock, bed, tailstock and adjustable slide.
- There is no lead screw, feed box and apron mechanism. Tool is fed by hand only.
- Usually, this lathe is driven by a variable speed motor fitted in the headstock. The spindle is driven by a high-speed motor through belts and step cone pulley.
- The work is held between the centres and rotated at high speeds (1200 to 3600rpm).
- The tool is supported on the tool post and fed by hand. It is mainly used for wood turning, spinning and polishing works.

2) *Engine Lathe or Centre Lathe*

- Engine lathe is more important and widely used. In earlier days, it was driven by steam engine and hence it was called engine lathe.
- It has the headstock, tailstock, carriage and bed.
- Automatic feed is also available.
- It differs from the speed lathe in that it is provided with additional features for controlling the spindle speed and the feed of the cutting tool, feed rod, lead screw and change gears are provided.
- The tool may be fed cross wise or longitudinally. The tool is fed by hand or automatically to remove metal.
- Engine lathes are usually driven by a constant speed motor mounted on a lathe. It is used for medium and large type of work.
- It is used for many operations like turning, taper turning, threading, drilling, knurling, reaming and forming.

3) *Bench Lathe*

- It is a small lathe that can be mounted on a workbench.
- It has all parts like a centre lathe and is used for many works.
- Only difference is that its small size and mountings. It is used for machining small parts cheaply and accurately at rapid rate.

4) *Tool Room Lathe*

- A tool room lathe consists of all the necessary attachments required for accurate and precision machining.
- It has more range of speeds and feeds. It is equipped with central steady rest, quick change gear mechanism, taper turning attachment, lead screw, feed rod, accurate collet chuck, thread cutting attachment, pump for coolant, micrometer stop, follower and centre rests etc.
- This lathe is very costly due to its higher accuracy and precision attachments.

5) *Semi-Automatic Lathe*

- As the name implies, some operations are done manually and some by automatic means.
- Capstan and turret lathers are of this type. These lathes are heavy lathes used for mass production.
- The headstock is heavier than centre lathe and has more speeds and feeds.
- There is no tailstock. Instead of that it has a turret head.
- Number of tools may be fitted in the turret head. They are fed into the work in proper sequence.
- There are two tool posts, a front tool post and a rear tool post. The front tool post carries four tools.
- The rear tool post carries a parting tool. Many operations can be done simultaneously by the front tool post, rear tool post and turret. Hence, the production time is minimized.
- The accuracy will be more. These lathes are used in mass production. They are used to produce identical parts.

6) *Automatic Lathe*

- In this lathe, all the operations and job handling movements are done automatically.
- It is a high speed heavy duty lathe which is used for mass production. The loading and unloading of work are done automatically in this type of lathe.
- There is a camshaft carrying number of cams. The cams will make speed, feed and tool changing.
- After initial setting of tools, it will do all the operations automatically till the job is parted off. After completing one cycle, the machine will repeat the same operation and hence it will produce identical parts only.
- But machining time is very less. One operator can handle many lathes at the same time.

7) *Special Purpose Lathe*

- These lathes are specially designed for carrying out specific operations only.
- These lathes are used to do various operations that cannot be done on ordinary lathes.
- The headstock, tailstock and carriage of these lathes are made according to the requirements of the special operations to be performed.
- For example, a shell lathe is used for turning shells only. A wheel lathe is used efficiently for making locomotive wheels. A crankshaft lathe can be used only for turning crankshafts.

8) *Copying Lathe*

- The tool of this lathe follows a template or master through a stylus or tracer. The tracer is connected to the cutting tool through hydraulic devices.
- According to the tracer movement, the tool moves to machine the job.

WORK HOLDING DEVICES

Some of the standard works holding devices used to hold the work in a lathe are

1. Chucks
2. Centres
3. Face plate
4. Angle plate
5. Mandrels
6. Steady and Follower rest

1) Chuck

- Chucks are used to hold the work pieces of small length (L < 4D) and large diameters.
- It can also hold irregular shape work pieces. Work pieces which cannot be mounted between centers are mounted in chucks.
- A chuck is attached to the headstock spindle of the lathe.
- The work is clamped between the jaws of the chuck and jaws are tightened. The right end of the work piece can be supported by the dead centre if needed. There are three types of chucks.
  - (a) Three jaw chuck (or) self-centering chuck.
  - (b) Four jaw chuck (or) Independent chuck.
  - (c) Magnetic chuck.

(a) __Three jaw chuck or self-centering chuck:__

- As the name implies, it has three jaws.
- When chuck key is turned, all the jaws will move equal distance in radial direction.
- The chuck has internal mechanism to move the three jaws simultaneously.
- Hence, work can be centered automatically and quickly.

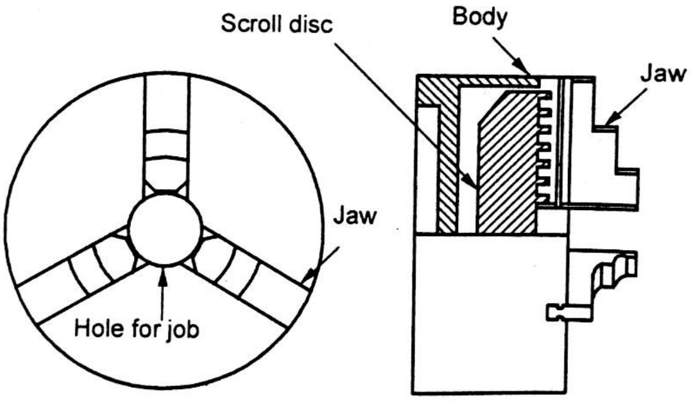


Figure 7(a) Three jaw chuck

- It consists of a circular disc.
- The disc has a spiral scroll of the front and bevel teeth at its back.
- Three bevel pinions are fitted with the bevel teeth of disc. By rotating any one of these bevel pinions, the disc rotates. Hence, jaws are meshed with spiral scroll move.
- This chuck is used for holding round, hexagonal and other regular shaped work piece.

(b) __Four jaw chuck or self-centering chuck:__

- It has four jaws. Each jaw can be moved independently.
- These jaws have slots as the backside to mesh with screws. These screws can be screwed in or out of the body. The screws have square hole at the top to receive chuck key.
- When the chuck key is turned in the slot, the particular jaw only will be moved.
- Therefore, irregular job can be held in this chuck. The jaws can be reversed for holding large hollow work piece.
- Concentric circles are inscribed on the face of the chuck for centering of work pieces.

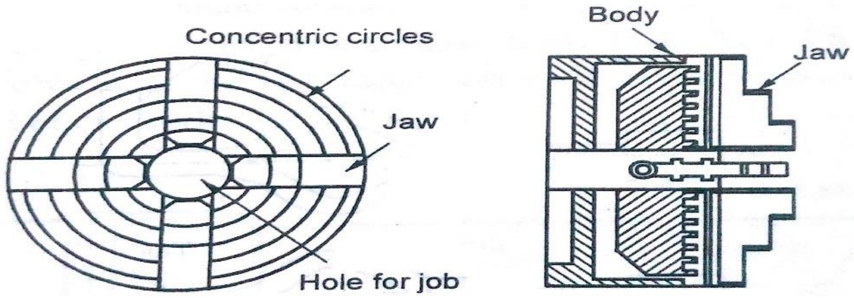


Figure 7(b) Four jaw chuck

(c) <u>Magnetic chuck:</u>

- Thin jobs can be held by means of magnetic chuck.
- The chuck gets magnetic mower from an electro-magnet.
- Due to magnetic power, the job is held in position on flat face.
- The main disadvantage is that the magnetic material only can be held on this chuck.

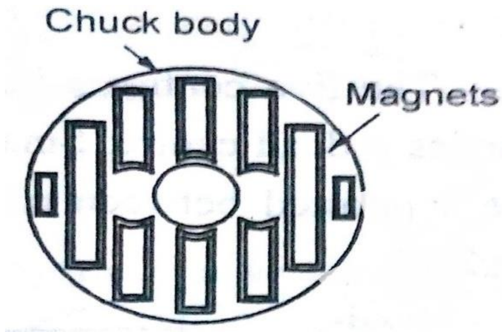


Figure 7(c) Magnetic chuck

2) Centres

- Generally, long shaft can be held between centres.
- Catch plate and dog carrier is used to hold the job between centres.
- Catch plate is in the form of circular disc when is screwed on the spindle nose.

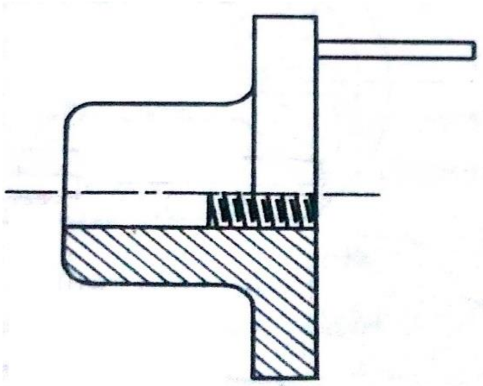


Figure 8 (a) Catch plate

- The various dog carriers are shown in fig 8 (b). These dog carriers are clamped to the job by a screw. The tail of the dog carrier is attached to the catch plate.

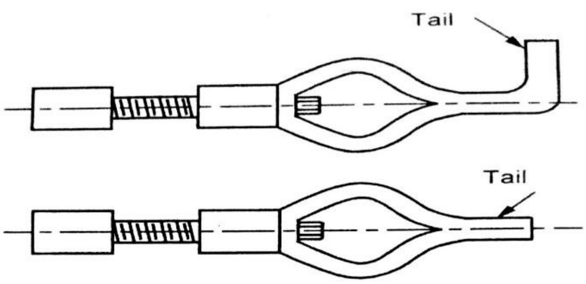


Figure 8 (b) Lathe dogs

- The live centre is inserted in the head stock spindle.
- The tailstock carries a dead centre. Small holes are drilled on both ends of the job and are supported between centres. The various lathe centres are shown in fig 8(c).

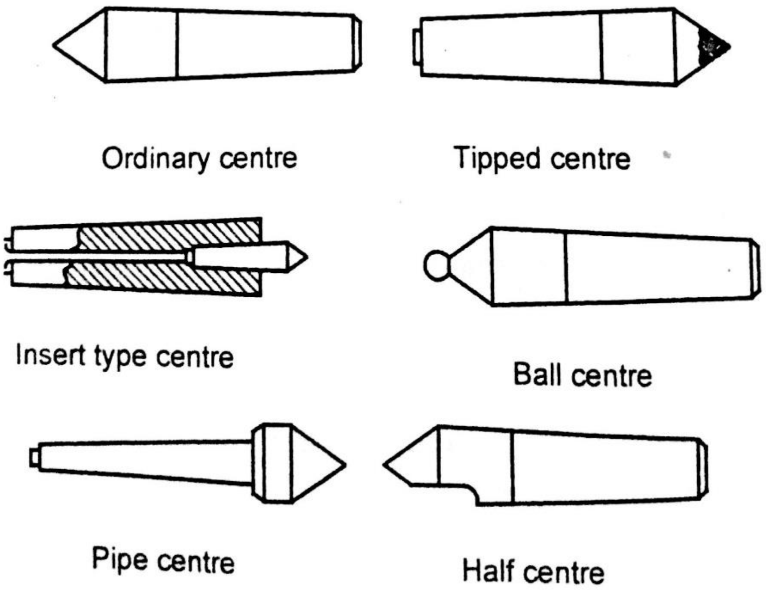


Figure 8 (c) Lathe centres

- When the spindle rotates, the work piece will rotate through the catch plate and carrier arrangement shown in fig 8(d).
- The live centre will revolve with the wok piece and the dead centre will support the right end of the work.

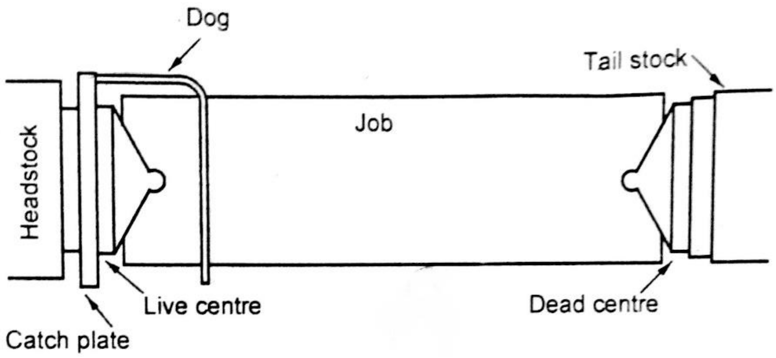


Figure 8 (d) Work held between centres

3) ***Faceplate***
   - Faceplate is a circular cast iron disc and has four T-slots and a number of plain radial slots as shown in fig 9.
   - These slots are used for holding work by bolts and clamps.
   - It is highly efficient for holding asymmetrical work or work of complex and irregular shape which is inconvenient to clamp by other means.
   - When the spindle rotates, the faceplate will also be rotated and so the work will rotate.

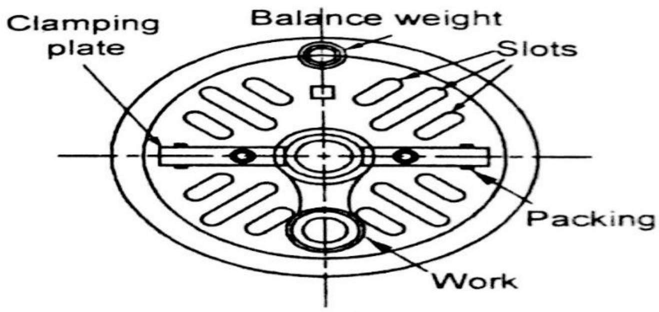


Figure 9 Face plate

4) Angle plate

- Angle plate is a cast iron block and has two accurately machined faces at right angles to each other.
- It has holes and slots on both the faces so that its one face may be clamped on a face plate and the work piece is mounted on the other face.
- When the spindle rotates, the faceplate will also rotate. So, the angle plate and job also will rotate. Usually, counter weights are fitted to balance the weight of the job.
- The job is fitted eccentrically or fitted in angle plate. The angle plate is used for holding elbow pieces as shown in fig 10.

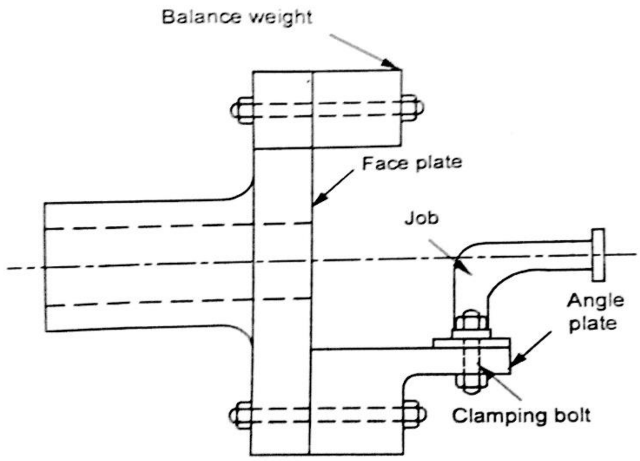


Figure 10 Angle plate

5) Mandrels

- Mandrels are used for holding hollow work pieces.
- The work revolves with the mandrel which is mounted between two centres.
- There are different types of mandrels used for different types of jobs. These are shown in fig 11.
- The outside diameter of mandrel should be equal to the inside diameter of job.

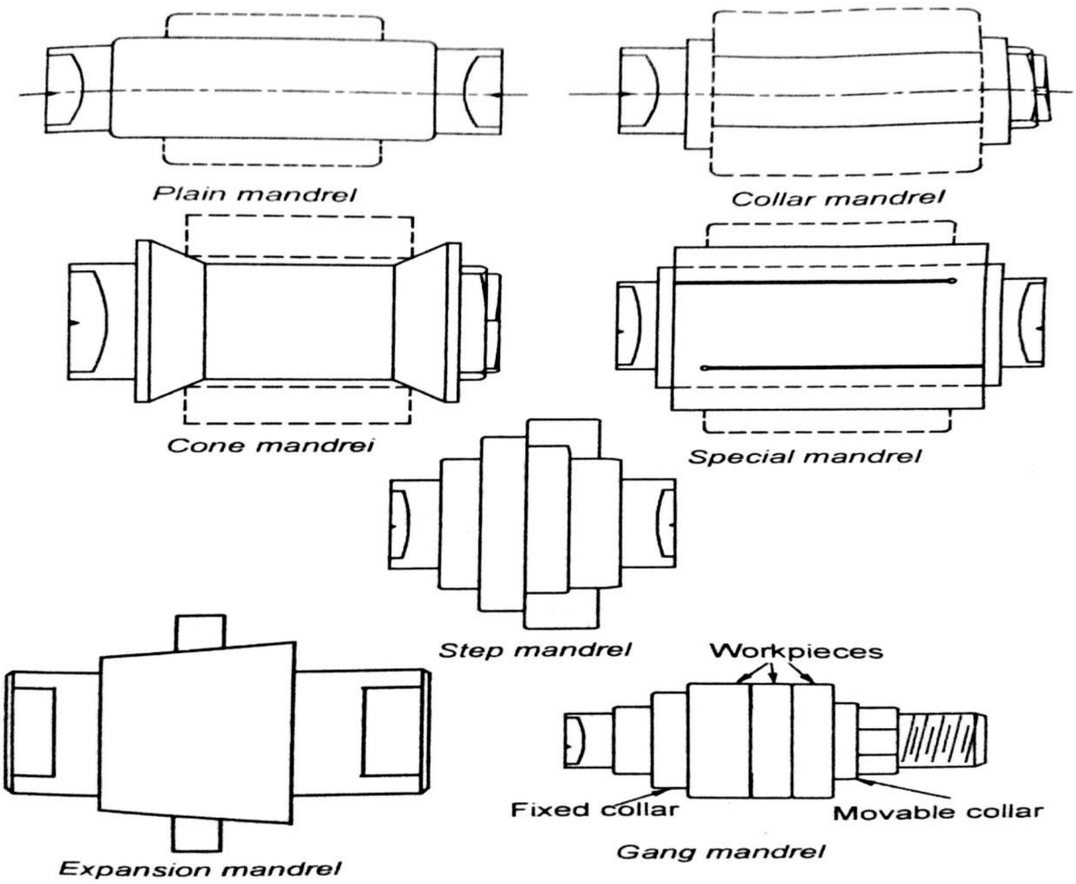


Figure 11 Various types of Mandrels

6) ***Steady and Follower rest***

- Rest is a device which supports long work pieces ($\frac{L}{D} > 10\ (or) 12$) when machined between centres or by a chuck.
- It is placed in between headstock and tailstock. It prevents vibration and bending of the piece.
- There are two types of rests.
    (a) Steady rest.
    (b) Follower rest.

(a) ***<u>Steady rest:</u>***

- These types of rests are fixed on bed ways of the lathe by clamping the bolts.
- There is a cast iron base which is used to clamp the rest on the bed.
- The upper portion of the rest is hinged at one end.
- This is used to remove the job without disturbing the steady rest.
- The work piece is supported by three jaws arranged as shown in fig 12(a). The jaws can be separately adjusted radially.
- For the work to be turned in high velocity, jaws have built up by balls or roller bearings to support it.
- After setting the jaws over the work piece, the rest is clamped to the lathe led to the required position.
- Since, the carriage cannot pass it, the job will be turned in two stages by reversing one end after half machining the length. For longer work pieces, two or more steady rests can be used.

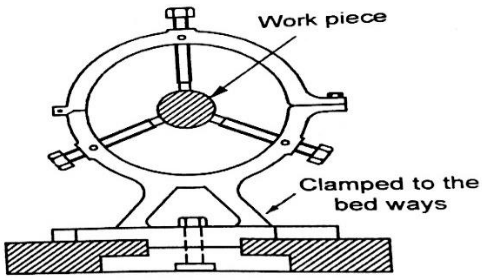


Figure 12 (a) Steady rest

(b) ***<u>Follower rest:</u>***

- The rest is mounted on the saddle and moves together with the tool, lit has a C type casting and two adjustable jaws to support the work piece shown in fig 12 (b).
- The jaws always follow the tool. Therefore, it gives continuous support to the work piece.

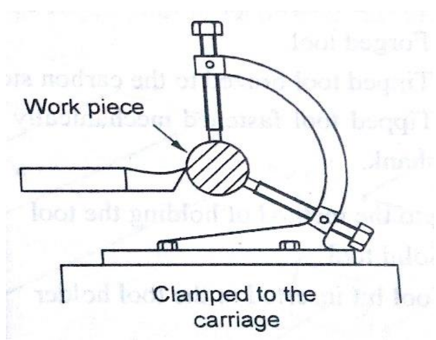


Figure 12 (b) Follower rest

VARIOUS OPERATIONS PERFORMED ON A LATHE

In order to complete a job, several operations are required. Different operations carried out on a lathe are: centering, straight| turning, taper turning, Eccentric turning, Shoulder turning, chamfering, thread-cutting, facing, parting-off, drilling, boring, reaming, tapping, knurling, filing, grooving, spinning, forming, milling, grinding etc.

1) ***Centering***

- When the work is required to be turned between the centres, a conical shape holes must be provided at the ends of the work piece to provide bearing surface for lathe centres.

- Centering is the operation of producing conical holes on both ends of the work piece.
- First, the centres of the work piece ends are marked by using centre punch. The work piece is held by a three-jaw chuck.
- The drill bit is held using tailstock by drill chuck or socket.
- When the job rotates, the drill bit will move into the work by turning the tailstock hand wheel.

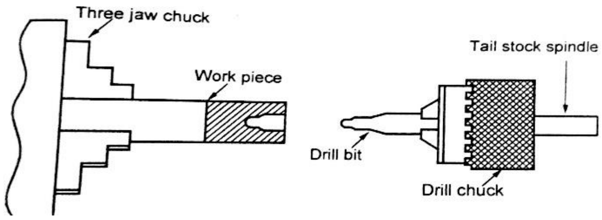


Figure 15 Centering operation

2) ***Straight Turing***

- Straight turning is the operation of producing a cylindrical surface by removing material from the outside diameter of a work piece.
- It is done by rotating he work piece about the lathe axis and feeding the tool parallel to the lathe axis.

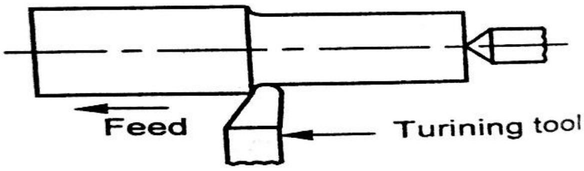


Figure 16 Straight turning

- The job is held between the centres or held in chuck.
- The trueness or centreness of the work piece is checked by dial indicator or scriber against the rotating work piece. A right hand turning tool is clamped on the tool post.
- For light cuts, the tool may be inclined towards the headstock but the tool may be inclined towards the tailstock for heavy cuts. Automatic or hand feed cannot be used.

There are two types of straight turning.

- ❖ Rough turning.
- ❖ Finish turning.

(a) ***<u>Rough turning</u>***

- For rough turning, the rate of feed of the tool is fast and depth of cut is heavy.
- The depth of cut for this turning is about 2 to 5 mm and the feed rate is about 0.3 to \.5mm per revolution.
- For rough turning, the rough turning tool is used.

(b) ***<u>Finish turning</u>***

- For finish turning, the high cutting speed, small feed and very small depth of cut are required.
- A finish turning tool having sharp cutting edge is used.
- The depth of cut will be-from 0.5 to 1mm and feed rate from 0.1 to 0.3 mm per revolution of the work piece

3) ***Straight Turing***

- Stepped diameter work piece are turned at the shoulder. It is called as *shouldering*.
- The various types of shoulders are shown in fig 17. For turning square shoulder or bevelled shoulder, a right hand facing tool is used.
- A round nose tool is used to produce radius shoulder. For making undercut shoulder, parting tool may be used.

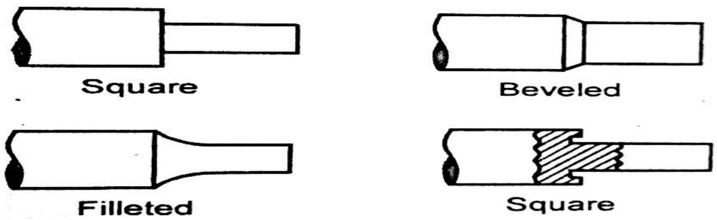


Figure 17 Shouldering

4) ***Facing***

- Machining the end of the work piece to produce flat surface is called facing.
- The work may be held in a chuck or between centers. The work is rotated about the lathe axis.
- A facing tool is fed perpendicular to the axis of the lathe.
- The feeding may be done by hand or power.

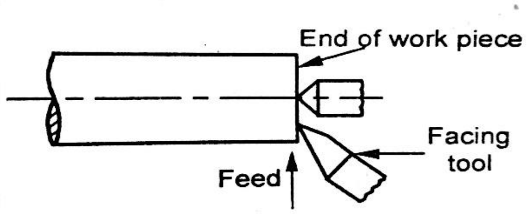


Figure 18 Facing

5) ***Chamfering***

- Chamfering is the process of bevelling or turning a slope at the end of the work piece.
- This is done for removing burrs and blends the sharp edges.
- Generally, chamfering is done for jobs after knurling, rough turning and thread cutting.
- A chamfering tool is moved perpendicular to the lathe axis.

6) ***Knurling***

- Knurling is the process of producing a diamond shaped pattern or impression on the surface of the work piece.
- It is used to give a good gripping surface on the work piece.
- It is also done slightly to increase the diameter of the work piece.
- A knurling tool is used to produce knurled surface.
- A knurling tool has two hardened steel rollers.
- The rollers have teeth out on their cylindrical surface.
- The teeth may be fine, coarse or medium.
- The tool is held in the tool post and pressed against the rotating work as shown in fig 19 (b).
- Automatic speed may be given to the tool, very slow speed and feed are used. Knurling tool will not cut the metal instead of that it produces impression on the work piece.
- After the first cut is over, the tool should not be drawn back. It should be reversed the direction to bring tool into starting position before giving the next cut.

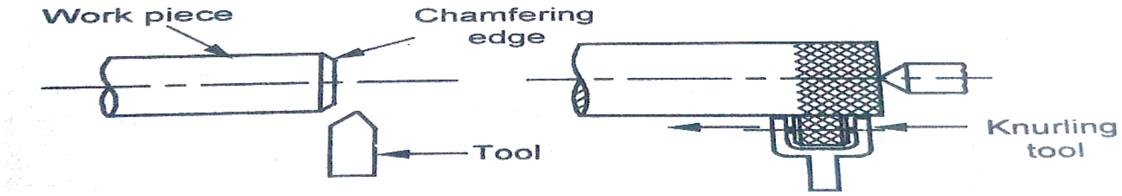


Figure 19 (a) & (b) Chamfering & Knurling

7) ***Filing***

- Filing is the process of removing burs, sharp corners, and feed marks on a work piece by removing very small amount of metal.
- It is also used to bring the work piece into required size during finishing operation.
- The operation consists of passing a flat single cui file over the rotating work piece.
- Very high cutting speed and slow feed are given during this operation.

8) ***Forming***

- Forming is the process of producing concave, convex and my irregular shape on the work piece by a form tool.
- The cutting edge of the tool is ground to the required form.
- Work piece is held between centers or a chuck and the form tool is moved perpendicular to the revolving work piece.

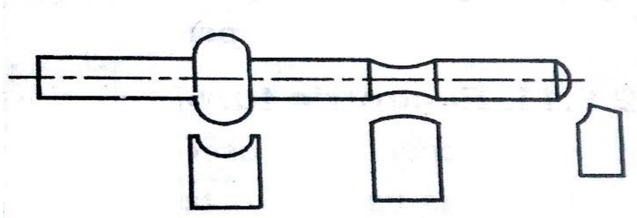


Figure 20 Forming

9) Grooving

- Grooving is the process of reducing the diameter of the work piece over a very narrow surface as shown in fig 21.
- It is also known as recessing, undercutting or necking.
- It is generally done at the end of the thread or adjacent to a shoulder. Work piece is held in a chuck.
- The grooving tool is fed cross wise against the rotating work piece.

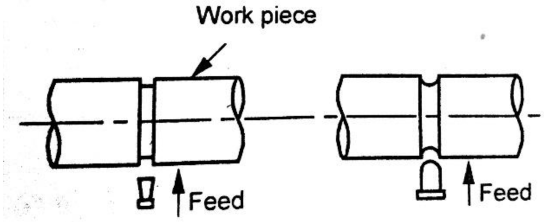


Figure 21 Grooving

10) Parting – off

- Parting-off is the process of cutting the workpiece into two halves.
- For this operation carriage is locked at the required position and % spindle speed should be reduced to half of the speed to that of turning.
- The tool is fed slowly perpendicular to the lathe axis.

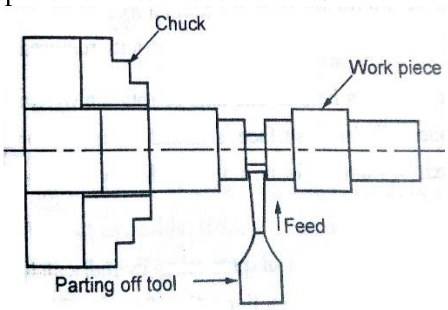


Figure 22 Parting off

11) Eccentric turning

- An eccentric is used for obtaining reciprocating motion from rotary motion.
- It is useful for turning a crankshaft, camshaft or an eccentric of a shaft. In such parts, the centre of one cylinder is out of the centre of other cylinder. Turning of such parts is called eccentric turning.
- To turn eccentric surface two set of centre holes are punched at the end of work piece. The centre holes are off set from the normal axis of the work piece.
- The amount of offset is equal to half of the eccentricity required.
- The work piece is held in one axis of rotation by fixing it between centres and one cylindrical surface is turned.
- Then the job is remounted on the other axis of rotation for turning the other cylindrical surface

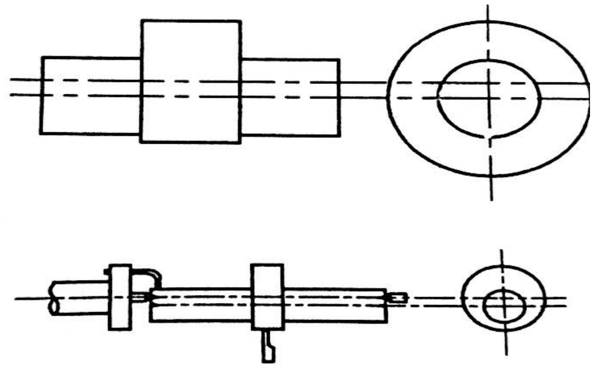


Figure 23 Eccentric turning

12) Drilling

- Drilling is the operation of producing cylindrical hole in a work piece. It is done by rotating the cutting edge of a cutter known as *drill*.

  It is performed by either of the following method.

  ⇒ The job is held in a chuck or faceplate. The drill is fitted into the tailstock spindle. The tailstock is moved over the bed and clamped near the work piece. When the job rotates, the drill bit is fed into work by turning tailstock hand wheel. This process is shown in fig 24.

  ⇒ The drill is held in a chuck which is attached to the headstock and the work is held against a pad or crotch supported by the tailstock spindle. When the drill bit is rotated, the work will be fed by tailstock hand wheel.

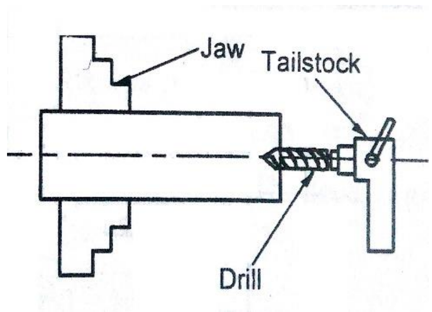


Figure 24 Drilling

13) Reaming

- Reaming is the operation of finishing and sizing hole which is already drilled. Reamer is used for this purpose. It has a multiple cutting edges. The work is held in a chuck and revolves.
- The reamer is held in a tailstock spindle and held stationary while the work is revolved at a very slow speed.

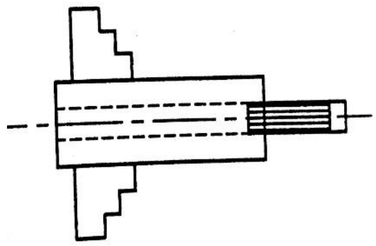


Figure 25 Reaming

14) Boring

- Boring is the operation of enlarging a hole.
- Boring is used when correct size drill is not available. Boring is not used to make a hole but it corrects the size of a hole.
- The work piece is held and rotated in a chuck or faceplate.
- The boring tool is fitted on the tool post and fed parallel to axis of the lathe. Boring is similar to internal turning operation.
- For smaller holes single piece boring tool is used. For large holes, a boring bar with a tool bit is used.

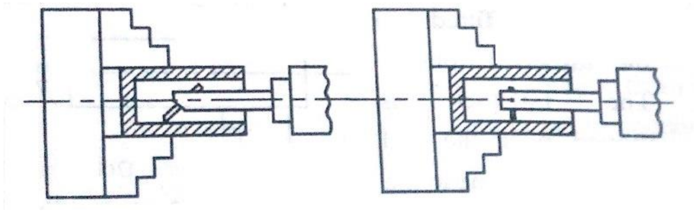


Figure 26 Boring

15) Milling

- Milling is the operation of removing metal by rotating the cutter having multiple cutting edges.
- Small milling cutters are held in the headstock and revolved.
- The work piece is clamped in a vice which is mounted over the top of the compound rest instead of the tool post. It is only used for small works.

16) Grinding

- Grinding is the operation of removing the metal by using rotating abrasive wheels.
- Both internal and external grinding can be done on a lathe.
- For external grinding, the work is revolved between centres and the grinding wheel is attached on a compound rest by special arrangement called tool post grinder.
- For internal grinding, the work piece is held in a chuck or mounted to the faceplate. This grinding wheel is held by tool post grinder which is placed on compound rest.
- The feeding is done by carriage and depth of cut is given by cross slide Grinding is done in a lathe for simple jobs like grinding mandrels of reamers, turning chuck jaws, sharpening lathe centres and milling cutters, or sizing a work piece after it has been hardened.

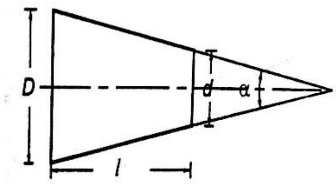
17) Tapping

- Tapping is the operation of forming internal thread, of small diameter by using a multipoint tool called tap.
- The work, is mounted on a chuck or on a faceplate and revolved-at very slow speed.
- A tap is mounted on a tailstock spindle by a special fixture.
- The axis of the tap should coincide exactly with the axis of the work.
- The feed is given by the special fixture automatically.

18) Tapper Turing

- A taper is defined as a uniform change in the diameter, of a work piece measured along its length, taper may be expressed in two ways.
  - ⇒ Ratio of difference in diameter to the length.
  - ⇒ In degrees of half the included angle.

Taper turning is the operation of producing conical surface on the cylindrical work piece on lathe.



D - Large diameter of die taper.
d- Small diameter of the taper.
l- Length of tapered part,
α- Half taper angle.

Generally, taper is specified by the term conicity. Conicity is defined as the ratio of the difference in diameters of the taper to its length.

$$\text{Conicity, } K = \frac{D-d}{l}$$

<u>Tapper Turing methods</u>

- Form tool method.
- Tailstock set over method.
- Compound rest method.
- Taper turning attachment method.

(a) <u>Form Tool Method:</u>

- It is one of the simplest methods to produce short taper.
- The method is shown in fig27. The form tool is ground to the required angle.
- When the work piece rotates, the tool is fed perpendicular to the lathe axis.
- The taper length should be less than the tool cutting edge length.
- As the entire cutting edge removes metal, it creates lot of vibrations to machine tools and large force is required.
- It is done in a slow speed.

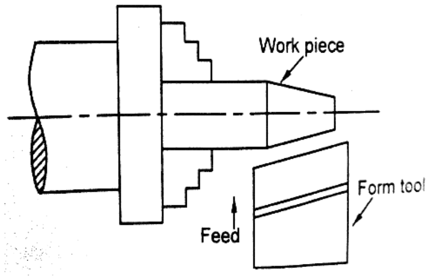


Figure 27 Form tool method

(b) <u>Tailstock Set Over Method:</u>

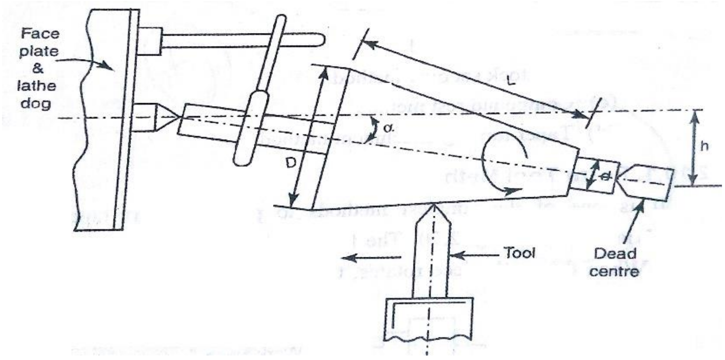


Figure 28 Tailstock Set Over method

$$h = \frac{D-d}{2}$$

- This method is employed when the angle of taper is very small (less than 8°).
- The work piece is held between the live centre and the dead centre.
- Now, the tailstock is moved cross wise i.e., perpendicular to the lathe axis by turning the set-over screw.
- This process is called as tailstock set-over. Hence, the job is inclined to the required angle.
- The tool is moved parallel to the lathe axis when the work piece rotates.
- So, the taper will be turned on the work piece.

(c) <u>Compound Rest Method:</u>

- This method is used to produce short and steep taper.
- In this method, work is held in a chuck and is rotated about the lathe axis.
- The compound rest is swivelled to the required angle and clamped in position.

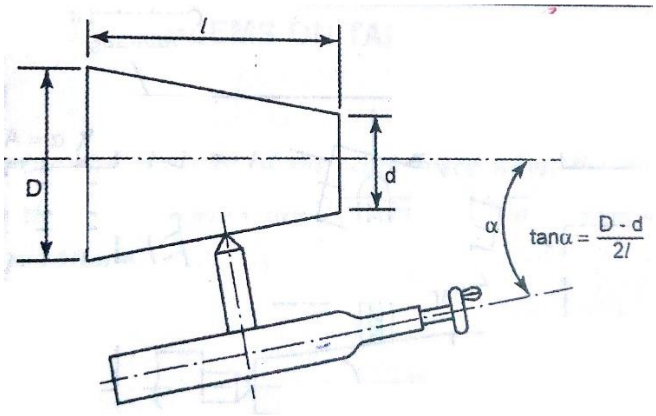


Figure 29 Compound rest method

The angle is determined by using the formula, tan α = $\frac{D-d}{2l}$

- Then the tool is fed by the compound rest hand wheel.
- This method is used for producing both internal and external taper.
- The compound rest can be swivelled up to 45° on both sides. The tool should be moved by hand.

(d) <u>Taper Turning Attachment Method:</u>

- A taper turning attachment is attached to the rear end of the bed by using bottom plate or bracket.
- It has a guide bar which is pivoted as its centre. This guide bar can swing and set at any required angle. It has graduations in degrees.
- The guide bar can be swivelled to a maximum of 10° on either side.
- It has a guide block which connects to the rear end of the cross slide and moves on the guide bar.
- Before connecting the cross slide, the binder screw is removed such that the cross slide is free from the cross slide screw.
- During taper turning, the job is held between centres or in a chuck. The guide bar is turned to a required angle.
- The angle is determined by using the formula, tan α = $\frac{D-d}{2l}$

When the division is given in mm instead of degrees. Then the angular distance (in mm) of the guide bar to be tilted is given by

$$S = \frac{D-d}{2l} \times L_g$$

`Where, L_g - Half of the total length of the guide bar.
S - Number of divisions in mm.

- When the longitudinal feed is given, the tool will move at angular path as the guide block moves at an angle on the guide bar. Compound rest hand wheel is used to give depth of cut. The guide is set at half taper angle. By this method, any type of taper can be turned.

19) Thread Cutting

- Thread cutting is the operation of producing helical groove on a cylindrical work piece.
- When job rotates, the tool is automatically fed longitudinally by using locknut and lead screw arrangement.
- The longitudinal feed should be equal to the pitch of the thread to be cut per revolution of the work.
- The lead screw has definite pitch.
- A definite ratio between the rotation of headstock spindle (i.e., work piece) and longitudinal feed is found out so that the screw of desired pitch can be obtained.
- The lead screw and spindle are connected by number of gears which are called as change gear.
- The operation of thread cutting is shown in fig 30.

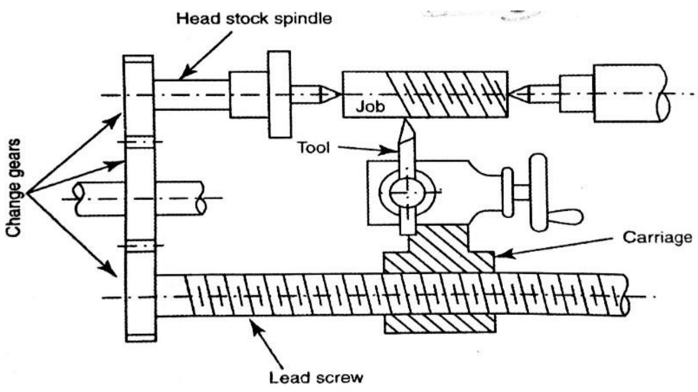


Figure 30 Thread cutting

- The lead screw is connected to carriage by engaging half nut with lead screw.
- So, when the spindle rotates, the lead screw will rotate at the same speed and the pitch of work will be equal to the pitch of lead screw.
- Hence, the speed of the lead screw should be changed by fixing proper change gears between headstock spindle and lead screw for obtaining different pitches on the work.
- The number of teeth on various [change gears may be calculated as follows

$$\frac{driver\ teeth}{driven\ teeth} = \frac{teeth\ on\ spindle\ gear}{teeth\ on\ lead\ screw\ gear}$$

$$= \frac{pitch\ to\ be\ cut\ on\ work}{pitch\ of\ lead\ screw}$$

For example, if the pitch of the lead screw is 6mm and the pitch of the work is 2mm.

$$\frac{driver\ teeth}{driven\ teeth} = \frac{pitch\ of\ the\ work}{pitch\ of\ lead\ screw}$$

$$= \frac{2}{6} = \frac{1}{3}$$

- Therefore, spindle must rotate 3 times the speed of the lead screw. After finding above gear ratio, the numerator and denominator should be multiplied with the same number for obtaining number of teeth of change gears.
- The lathe is supplied with a set of gears from 20 to 120 teeth in steps of 5 and a one gear with 127 teeth.
- Therefore, when multiplying the fraction, a number is chosen in such a way that the numbers are within the above range

$$\frac{Number\ of\ teeth\ on\ spindle\ gear}{number\ of\ teeth\ on\ lead\ screw\ gear} = \frac{1}{3} \text{ x } \frac{20}{20}$$

$$= \frac{20}{60}$$

Usually, there are two types of gear trains employed

- Simple gear train.
- Compound gear train.

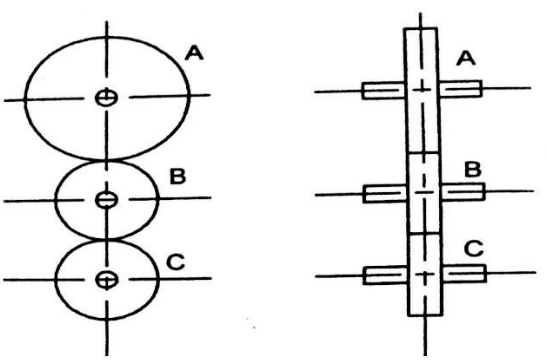


Figure 31 Simple gear train

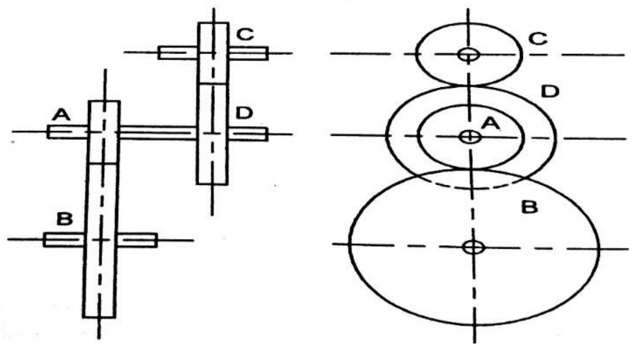


Figure 32 Compound gear train

The above figures 31 & 32 illustrate the two types of gear trains.

- For cutting right hand thread, the lead screw is rotated in clockwise direction i.e. same direction of the lathe spindle. The carriage moves towards the headstock.
- For cutting left hand thread, the lead screw rotates in anticlockwise direction when the carriage moves towards tailstock.

PROCEDURE:

<u>External thread cutting</u>

(i) The job is mounted between centres or in a chuck.
(ii) The work piece is turned to the required diameter i.e. maximum diameter.
(iii) The gear ratio and number of teeth required on change gears are calculated.
(iv) The current size of gears in the change gear train is fixed.
(v) The rotation of spindle should be sent one fourth of the speed required for turning. This is for the purpose of getting good surface finish on threads.
(vi) Appropriate tool is selected which is accurately shaped and grounded. The form and setting of the tool is checked with the help of a thread template or centre gauge.
(vii) The cutting tool height is set which is equal to the centre of work piece and it is normal to the axis of work as shown in fig. 33.

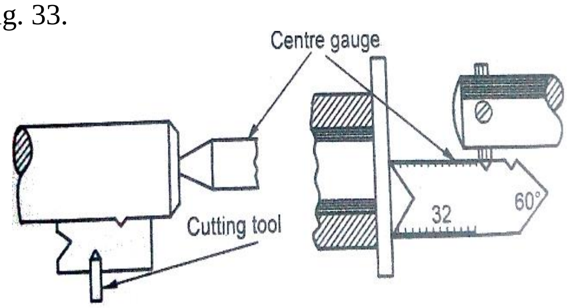


Figure 33 Centre gauge

(viii) The cross slide hand wheel is rotated till the tool touches the work piece. Now adjust the micrometer meter dial to zero which is provided in the cross slide and moves the carriage away from the work piece.
(ix) The tool is fed towards the centre to a distance equal to the depth of cut per pass.
(x) The half nut is engaged when any one marking on the dial coincide with a reference mark on chasing dial. Now, the tool will move in the helical path on work piece to form thread.
(xi) After one pass, the half nut is disengaged and the tool is withdrawn simultaneously. Then the carriage is brought to the starting position.
(xii) The tool is adjusted to the required depth of cut and reengaged the half nut for repeating the same procedure till the required depth is obtained.
(xiii) Before reengaging the half nut for second pass, it is necessary to ensure that the tool will follow the same path it has travelled in the previous cut. It is called thread catching or picking-up the thread.

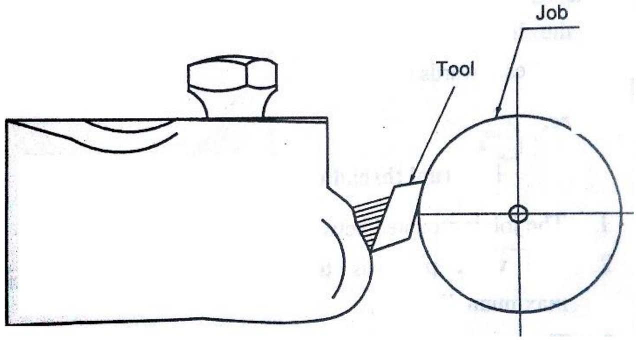


Figure 34 Setting of cutting tool

UNIT - II: DRILLING AND ALLIED OPERATIONS

Drilling is the process of producing hole, on the work piece by using a rotating cutter called *drill*. The machine on which the drilling is carried out is called *drilling machines*. The drilling machine sometimes called *drill press* as the machine exerts vertical pressure to originate a hole. The hole is produced either by giving axial movement to the rotating drill or moving the work axially against the revolving drill.

Though drilling may be done in a lathe or a vertical milling machine. It can be done conveniently, quickly and at low cost in drilling machine. Drilling machine can be also used for boring, counter-boring, counter- sinking, reaming, tapping and spot facing operations. Drilling machines are used in machine assembly, repair shop, tool room, maintenance work, agricultural machinery etc.

CLASSIFICATION OF DRILLING MACHIENS

The drilling machines are classified as follows:

1. Portable drilling machine
2. Sensitive drilling machine
    a. Bench type
    b. Floor type
3. Upright drilling machines
    a. Round column type or pillar type
    b. Box column type or square section type
4. Radial drilling machine
    a. Plain type
    b. Semi-universal type
    c. Universal type
5. Gang drilling machine
6. Multiple spindle drilling machine
7. Automatic drilling machine
8. Deep hole drilling machine

1) PORTABLE DRILLING MACHINE

- This type of machine is light in weight, compact in a smaller unit and easily handled with respect to the work piece.
- It is used for making small hole (up to 18mm) in large work piece. It is operated by hand power, pneumatic power or electric power. Fig 1 shows the schematic diagram of electrically operated portable drilling machine

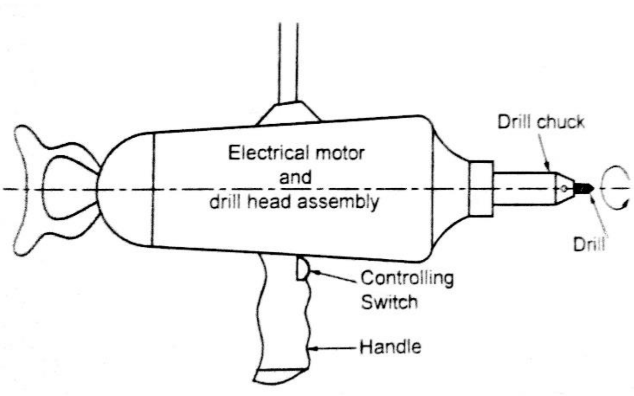


Figure 1 Portable drilling machine

2) *SENSITIVE DRILLING MACHINE*

- Sensitive drilling machines are lightweight, high-speed machines which are generally bench type drilling machines, but pillar type machines also available.
- It is used for light duty work and drill holes up to 15mm diameter.
- There is no power feeding arrangement feeding is purely on hand control of the operator so that the operator can sense the feeding or can control the feeding. That is why the machine is called sensitive drilling machine.

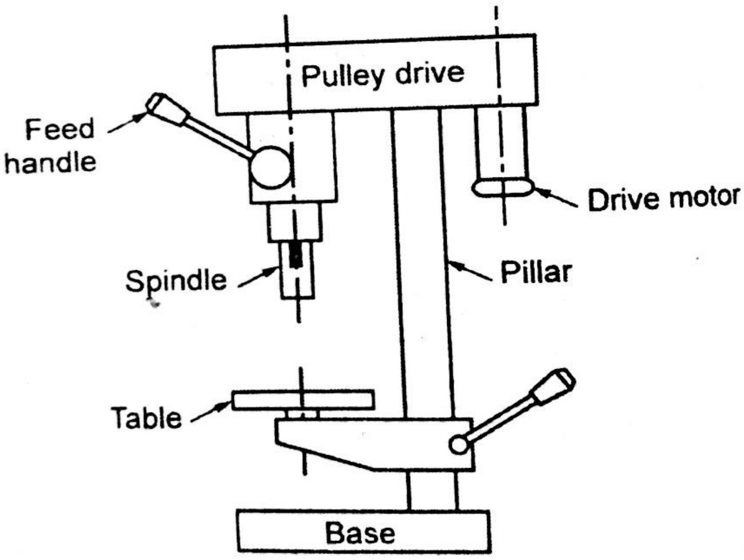


Figure 2 Sensitive Drilling Machine

The main parts of the sensitive drilling machines are base, column- table, spindle and driving mechanism.

(a) <u>Column:</u>
- The column vertically stands on its base.
- It is a cylindrical post.
- It Lnports the table, the spindle head, motor and the driving mechanism.

(b) <u>Table:</u>
- The job on which the hole to be produced is mounted on the table.
- It can be moved vertically along the column and clamped in any position.
- It can also be adjusted radially around the column. It has T-slots for clamping work piece or work holding device.

(c) <u>Spindle and driving mechanism:</u>
- It is mounted at the top of the column.
- It has an electrical drive motor on one-side where as it has the spindle assembly on the other side.
- The motor drives the spindle through cone pulley and V-belt arrangement.
- The belt can be shifted to different sets of pulleys to get different spindle speeds.
- The spindle is fed into the work piece manually using a hand lever.
- The spindle has a Morse taper bore at its bottom end to hold the drill chuck. Drill chuck holds the drill bit.

3) *UPRIGHT OR PILLAR DRILLING MACHINE*

- Upright drilling machine is a higher capacity version of sensitive drilling machine.
- It is stationary floor mounted drilling machine.
- It is used for medium sized work pieces and having medium speed.
- The spindle head and the drive arrangement in this machine are similar to a sensitive drilling machine.
- But in this case, power-feeding arrangements pre available.
- The main parts of the machine are base, column, work table and spindle head.

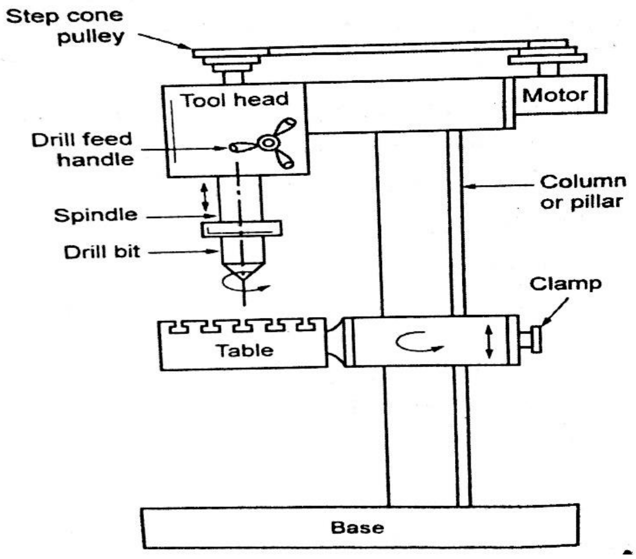


Figure 3 Upright (or) Pillar Drilling Machine

(a) ***Base:***
- It is a supporting member on which all the parts; of the machine are mounted. It is generally made of cast iron.
- The top surface of the base is accurately machined.
- The base has T- I slots which is used for mounting large work piece directly on it.

(b) ***Column:***
- It is a vertical member mounted on the base and carries table, spindle and pulley drive mechanism.
- It should be very strong to take the heavy cutting forces. It may be of round type or box type.
- In round type, the column is round in section also named as pillar.
- The table holding work piece can be rotated 360° about the column for locating work piece under the spindle.
- Drill upto 50mm diameter is possible in this type.
- In box type, the column is-square in section, heavier, more strengthy and rigid than round type.
- It can only be raised or lowered by an elevator screw and will not rotate.
- Drill diameter more than 50 mm and upto 75 mm is possible by this type.

(c) ***Table:***
- The worktable is attached to the column by means of clamping screw.
- It has T-sIots on the surface to hold work pieces.
- It can move vertically along the column and can be adjusted radially about the column.
- As already stated, the column may be rotated about its own axis only in round column type.

(d) ***Spindle head and drive mechanism:***
- The spindle head is mounted on the top of the vertical column.
- It is driven by a motor through belt and step cone drive.
- Sensitive hand feed is available.
- A quick traverse hand feed is also available to bring down the drill quickly to the hole location and withdrawn after drilling.
- The different spindle speeds are obtained by using step cone pulley arrangement.

4) RADIAL DRILLING MACHINE

- This type of machine is mounted on floor and suitable for drilling medium to large and heavy work pieces.
- The most significant feature of this machine is a radial arm which can swing about a column.
- The arm can also be moved up and down with respect to the column which can be locked at any desired position as per job size. Fig 3 shows the radial drilling machine.

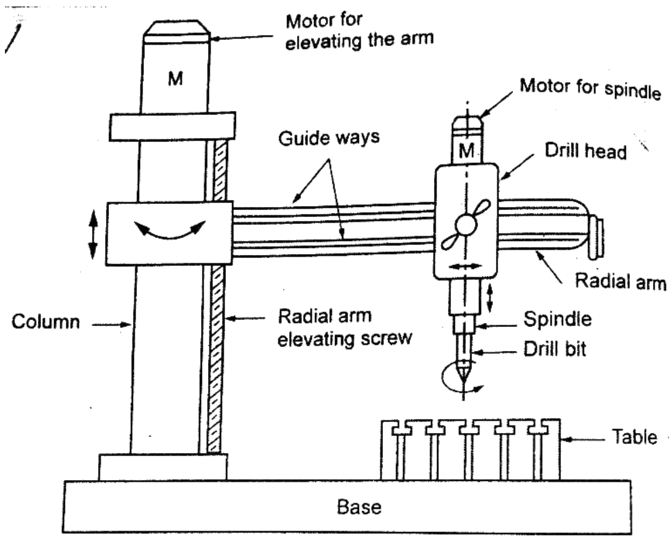


Figure 4 Radial Drilling Machine

The main parts of the machine are base, column, radial arm. drill pad, spindle speed and feed mechanism.

(a) ***<u>Base:</u>***
- It is a large rectangular casting.
- It supports the vertical column and table.
- The top surface of the base is accurately machined with T-slots to mount the large size work pieces.

(b) ***<u>Column:</u>***
- Column is a cylindrical casting mounted on the base.
- It supports radial arm, drill head and motor.
- The column face should be accurately machined to slide the radial arm up and down.
- An elevating screw is provided on the side of the column to move the radial arm up and down.
- The elevating screw is rotated by the motor.

(c) ***<u>Radial arm:</u>***
- It is a heavy casting mounted on the column.
- The drill head is mounted on the radial arm.
- It has guide ways to move the drill head.
- The arm can be swiveled around the column.
- It can be moved up and down by rotating an elevator screw.

(d) ***<u>Drill head:</u>***
- The drill head is mounted, on the radial arm.
- The drill head is equipped with seperate motor.
- The drill head is moved along the arm manually or with power assistance.
- Drill head has a spindle which carries drill bit.

(e) ***<u>Spindle head and feed mechanism:</u>***
- The spindle is driven through a gearbox.
- Feed can be manual or automatic.
- Depth settings for production work with automatic reversal is a standard feature.
- Radial drilling machine may be classified with respect to the movements of radial arm and tool head.
- The various types of radial drilling machines are:
  - *(i)* *<u>Plain type:</u>*
    The following adjustments are available in this type.
    - Vertical movement of the radial arm with respect to the column.
    - Circular movement of thfe radial arm about column.
    - Horizontal movement of the tool along the arm ways.
  - *(ii)* *<u>Plain type:</u>*
    In addition to the above three movements as 'in case of plain type, the fourth movement of the tool post can be swung about a horizontal axis perpendicular to the arm. This arrangement permits for drilling a hole inclined at any angle to the horizontal plane.

(iii) *Universal type:*

In addition to the above fourth movement as"in case of semi- universal type, the fifth movement of the radial arm !s rotated (tilted) on a horizontal axis.

- All these movements enable the universal drilling machine to drill on a job at any angle either in horizontal plane or in vertical plane or in both the planes.

5) MULTI SPINDLE DRILLING MACHINE

- This machine is suitable for mass production. In this machine several hole of different sizes can be drilled simultaneously.
- It has several spindles.
- They are driven by a single motor by using a set of gears.
- The center distance of spindles may be adjusted to any desired length.
- All the spindles holding the drills are fed into the work at the same time.
- The feed is given either by raising the table or by lowering the spindle head.
- Drill jigs are sometimes used to guide drills accurately into the work.

6) GANG DRILLING MACHINE

- When a number of single spindles with essential speed and feed is mounted side by side on one base and have common worktable is known as the *gang-drilling machine*.
- The number of spindles varies from four to six.
- The drilling heads of each spindle have individual driving motors.
- So, the speed and feeds of the spindles are controlled independently.
- Gang drilling machine is a mass production type machine.

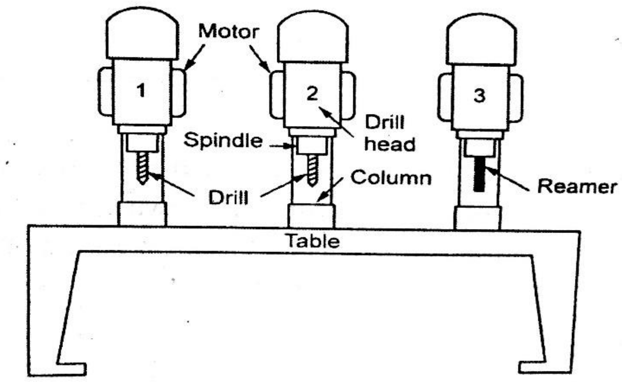


Figure 5 Gang Drilling Machine

- A series of operation can be done one by one.
- Each spindle of this machine is fixed with respective speed, feed, tool and position of the spindle as per operations required for a production job with the arrangement of job movement by using suitable jig and fixture.

SPECIFICATION OF DRILLING MACHINE

A drilling machine is specified by the following items:

1) Maximum size of the drill in mm that the machine can operate.
2) Table size of maximum dimensions of a job can mount on a table in square metre.
3) Maximum spindle travel in mm.
4) Number of spindle speed and range of spindle speeds-inr.p.m.
5) Number of automatic spindle feeds or feed range available in mm/rev.
6) Morse taper number of the drill spindle nose.
7) Power input of the machine HP.
8) Floor space required in m^2.
9) Net weight of the machine in Tonne.

DRILLING OPERATIONS

The various operations done in a drilling machine are explained as follows.

1) DRILLING

- Drilling is the operation of cutting a round hole by a rotating tool called drill.

- Before drilling, the center of the hole is located on the work piece.
- For this, two lines at right angles to each other are drawn.
- A center punch is lused to mark the center point at the intersection of the two lines.
- The rotating drill is pressed at the center point marked on the work piece to produce the hole.

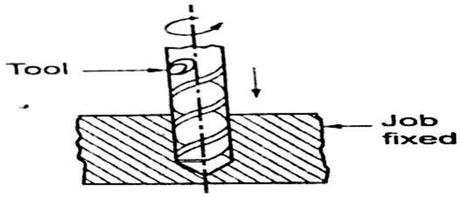


Figure 6 Drilling

- Drilling does not produce an accurate hole.
- The internal surface produced by drilling will be tough.
- The hole is lightly larger than the size of the pll used.
- This is because of the vibration of the drill.

2) REAMING

- Reaming is the process of sizing and finishing the already drilled hole.
- The tool used for reaming is known as a reamer.
- Reamer is a cylindrical tool having many cutting edges.
- Reamer cannot produce a hole.
- It simply follows the path of the already drilled hole.
- It removes a small amount of metal.
- The amount of metal removed in reamingabout 0.375mm.
- In reaming, the spindle speed is half that of drilling.

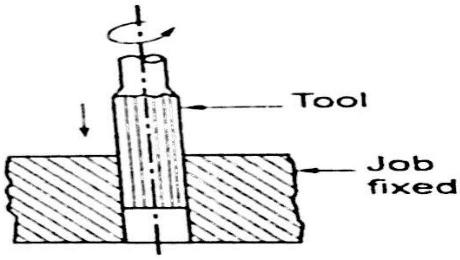


Figure 7 Reaming

3) BORING

- Boring is an operation of enlarging a hole by a single point cutting tool. Boring is done where suitable size drill is not available.
- If the hole size is very large it cannot be drilled.
- Then boring is done to enlarge the hole.
- By boring, the hole is finished accurately to the required size.
- The internal surface of a hole in a casting is machined by boring.
- Boring corrects the out of roundness of the hole.
- The cutter is held in a boring bar.
- The boring bar has a tapped shank to fit into spindle hole.
- Boring is a slow process.

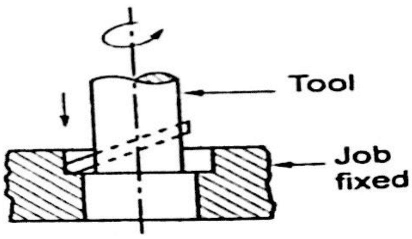


Figure 8 Boring

4) COUNTER BORING

- The operation of enlarging the end of a hole cylindrical Is known as counter boring.

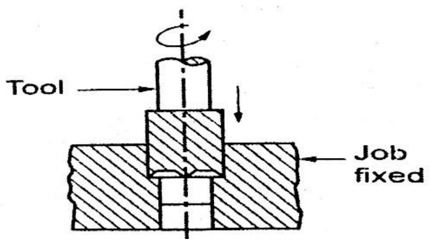


Figure 9 Counter Boring

5) COUNTER SINKING

- The operation of making a cone shaped enlargement of the end of a hole is known as counter sinking.

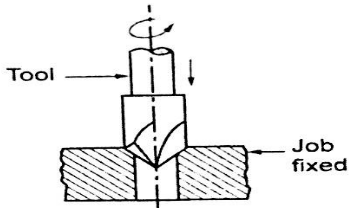


Figure 10 Counter Sinking

6) SPOT FACING

- The operation of squaring and smoothing the surface around a hole is known as spot facing. Fig 11 illustrates the process of spot facing.

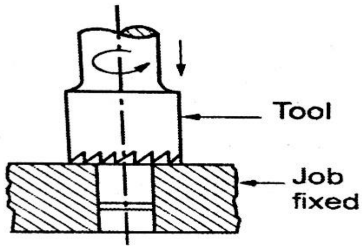


Figure 11 Spot Facing

7) TAPPING

- Tapping is an operation of cutting internal threads in a hole by using a cutting tool called tap.
- A tap has cutting edges in the shape of threads.
- When the tap is screwed into the hole, it will remove metal and fcut internal threads.
- The drilled hole will be smaller than the tap size.
- Tap drill size = 0.8 x Outside diameter of the thread.

8) TREPANNING

- The operation of producing a large hole (diameter over 50mm) by removing metal along the circumference of a hollow cutting tool is pown as trepanning.
- There is a pilot inside the trepanning tool which jfers the small previously drilled hole to produce the larger hole Concentric.
- It is used for the diameter more than capacity of particular achine and where hole depth is much more in comparison with normal work.

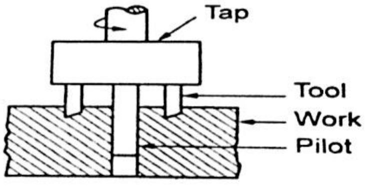


Figure 12 Trepanning

9) UNDERCUTTING

- The operation of enlarging the hole somewhere between its ends is known as undercutting.

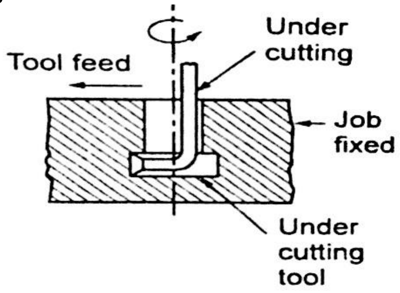


Figure 13 Undercutting

10) GRINDING

- The operation of removing large amount of stock with respect to lapping and honing operations from hardened material and super finishing a surface accuracy upto ± 0.0025mm by,means of a tool, named as grinding wheel is known as grinding.

11) LAPPING

- The operation of sizing hardened holes and extremely limited in stock removal is known as lapping.

12) HONING

- The operation of finishing relatively large holes such as automobile cylinders by means of relatively slow moving abrasives is known as honing.

DRILL TOOL NOMENCLATURE

A drill or twist drill is a fluted end-cutting tool used for making holes in solid material. It basically consists of two parts.

1) The body consisting of the cutting edges and
2) The shank used for holding purposes.

The various parts and angle of the twist drill are shown in fig 14.

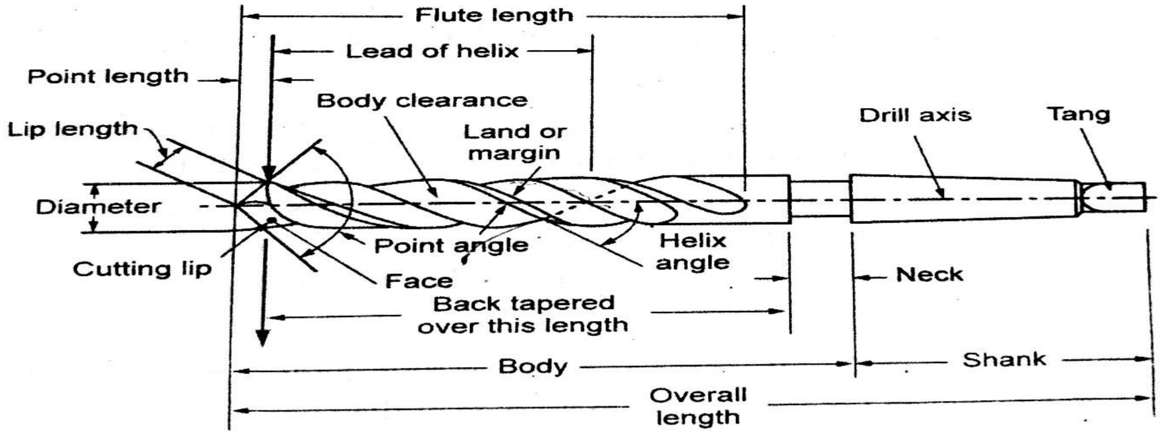


Figure 14 Drilling tool nomenclature

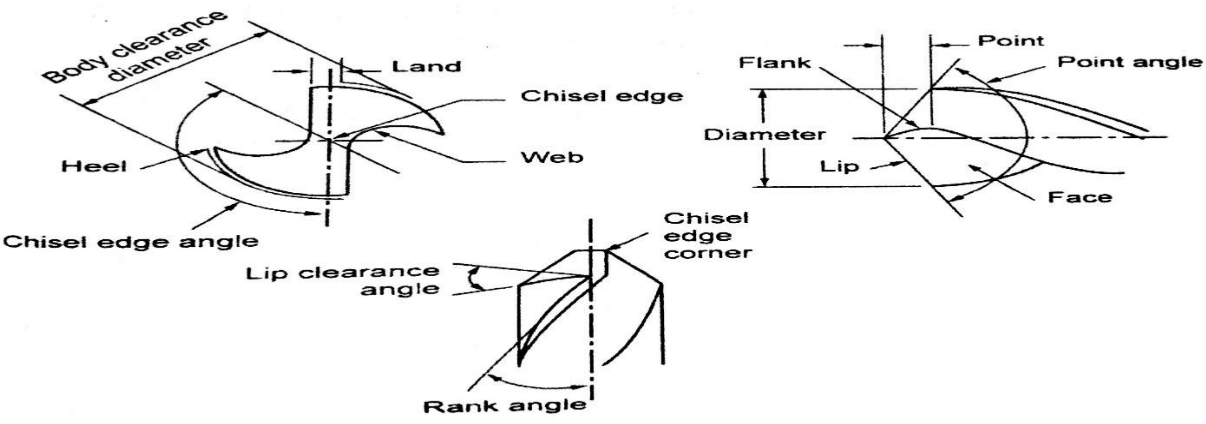


Figure 15 Nomenclature of twist drill

1) Body:

- The body of the twist drill has spiral flutes cut on it.
- These flutes serve to provide clearance to the chips produced at the cutting edge.
- They also allow the cutting fluid to reach the cutting edges.

2) Shank:

- It is a part that fits into the drill chuck or sleeve.
- It may be parallel shank or taper shank.
- Smaller diameter drills have straight shank.
- Morse taper is commonly provided for large diameter tapered drills.
- The taper shank carries the tang at the end of shank.
- This fits into a slot in the machine spindle, sleeve or socket and gives a positive grip.

3) Neck:

- It is the undercut portion between the body and the shank.
- Generally, size and other details are marked at the neck.

4) Point:

- It is the cone shaped end of the drill.
- The point is shaped to produce lip, face, flank and chisel edge or dead center.

5) Land or Margin:

- It is a narrow strip.
- It extends back on the edges of the drill flutes.
- The size of the drill is measured across the lands at the point end.
- Land keeps the drill aligned.

6) Web:

- It is the central portion of drill situated between the roots of the flutes and extending from the point towards the shank.

7) Chisel edge:

- The intersection of flanks forms the chisel edge.
- This acts as a flat drill.
- It cuts a small hole in the work piece at the beginning.
- Then the cutting edges remove further material to complete the hole.

8) Cutting edge:

- The cutting edges of a drill are known as lips.
- Both lips should have equal length, same angle of inclination and correct clearance.

9) Flank:

- The surface behind the lip to the following flute is called flank.

10) Face:

- This is the portion of the flute surface adjacent to the lip. The chip impinges on it.

11) Heel:

- The edge which is formed by the intersection of the flute surface and the body clearance is known as heel.

12) Point angle:

- It is the angle between the cutting edges. It is generally 118°. Its value depends upon the hardness of the work piece to be drilled. For jdiarder material, larger angels are used.

13) Rack angle:

- It is the angle between the face and the line parallel to the drill axis.
- At the periphery of the drill, it is equal to the helix angled.
- The usual values of rake angle are 30° and 45°.

14) Helix angle:

- It is the angle between the leading edge of the land and the axis of the drill. It is also called as spiral angle.

15) Lip clearance angle:

- It is the angle formed by the portion of the flank adjacent to the and a plane at right angles to the drill axis, measured at the periphery of the drill.

16) **Chisel edge angle:**

- It is the obtuse angle between the chisel edge and the lip. Generally, this angle is 120° and 135°.

MOUNTING OF DRILL TOOL

Both taper shank and straight shank drills can be mounted on the ' drilling machine spindle in a number of ways. They are:

1. Fitting directly in the spindle.
2. By using a sleeve.
3. By using a socket.
4. By means of chucks.

1. Fitting directly in the spindle:

- The drill is directly held in the spindle by friction.
- The spindle of the drilling machine and the shank of the drill has a standard tapered bore.
- The taper shank of the drill is forced into it.
- To get a positive drive, (without slipping) the tang of drill fits into a slot at the end of taper bore in the spindle.
- To remove the drill from the spindle, a tapered wedge called drift is forced into the slotted hole in the spindle referred in fig 16.

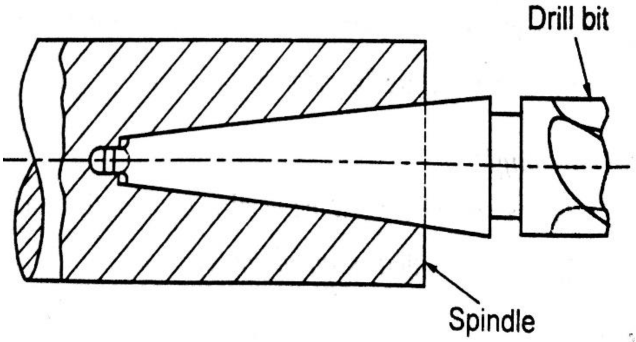


Figure 16 Drill fitted in the spindle

2. By Using a Sleeve:

- If the taper shank of drill is smaller than the taper in the spindle hole, a sleeve is used.
- The sleeve with drill is fitted in the hole of the Spindle.
- The sleeve has outside taper surface.
- This fits into the tapered hole of the spindle.
- The inside taper of the sleeve can hold the drill or a smaller sleeve.
- In sleeve also, there is a tang which is used for the same manner as explained in previous case.

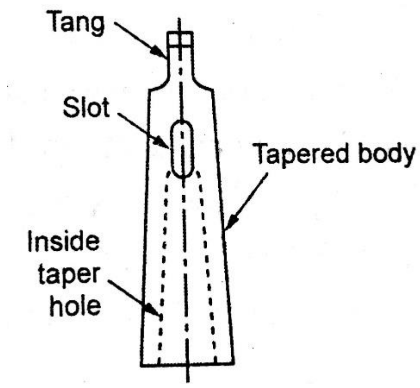


Figure 17 Drill sleeve

3. By Using a Socket:

- Socket is used to hold the tool into the spindle when the taper shank of the drill is larger than the taper hole of the spindle.
- The body of the socket has taper hole which is larger than the drill spindle bore.
- So, a bigger drill can be fitted into the socket.

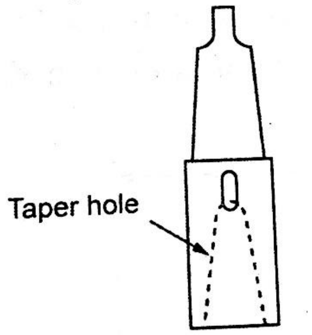


Figure 18 Drilling socket

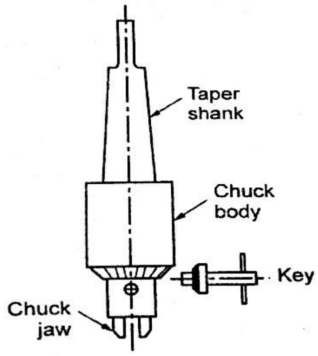


Figure 19 Drill chuck

4. By Using Chucks:

- Drill chucks are. suitable for holding any smaller size drills, straight shank drills and other tools not having taper at the holding end.
- Drill chucks have tapered shanks which fit into the machine spindle.
- The body of the chuck has three slots at 120°.
- It is used to house the three jaws.
- The jaws have threads at the back to mesh with a ring nut.
- The ring nut is attached to a sleeve.
- The sleeve has bevel teeth on the peripheral face.
- A key having bevel teeth is used to rotate. Refer fig 19.
- When the ring nut rotates, the jaws will move in or out.
- Thus, the ring nut causes the jaws to close or open for holding or releasing the drill.

REAMING TOOL

- A reamer is a multi-tooth cutter which rotates and moves linearly into an already existing hole.
- It is used to give smooth surface as well as close tolerance on the already drilled or bored hole.
- Reamer is more like a form tool, since the cylindrical shape and size of the reamer is reproduced in the hole.
- At the bottom of the reamer, the flutes are made slightly tapered to facilitate its entry into the existing hole.
- Generally, the reamer is expected to cut from the sides not from the end.
- Reamer is usually manufactured with two or more peripheral grooves of flutes either parallel to thd axis or as a right-angled helix as shown in fig 20 and 21.

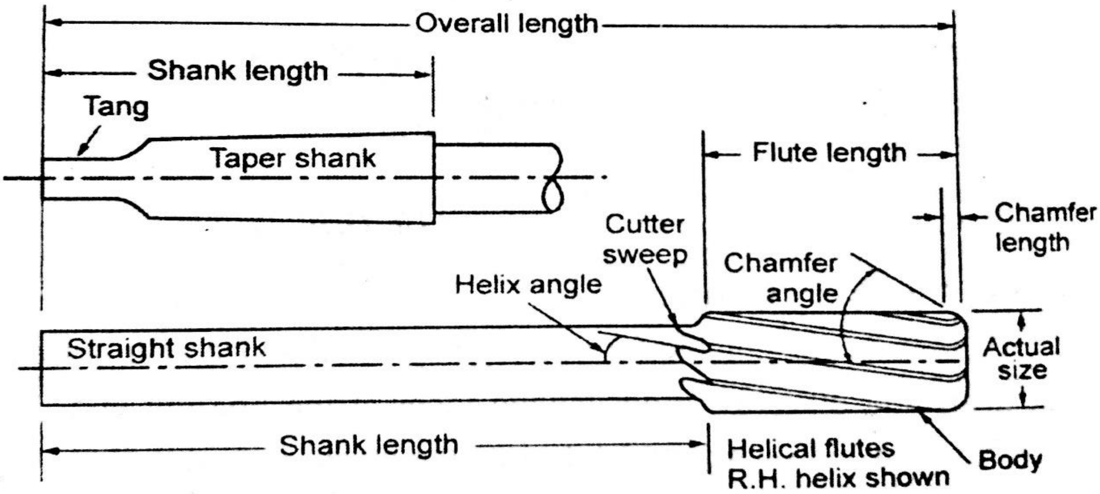


Figure 20 Reamer with helical flutes

- The reamer with helical flutes provides smooth shear cutting action and provides better surface finish.
- The pitch of the flutes is made uneven to reduce vibration.
- Small size reamers are made with straight shank whereas large size reamers are made with taper shank.
- There are different kinds of reamers for different applications.

- Shell reamers are used for reaming larger holes.
- For better dimensional control, adjustable reamers are used.
- Taper reamers are used for reaming holes to receive taper pins.

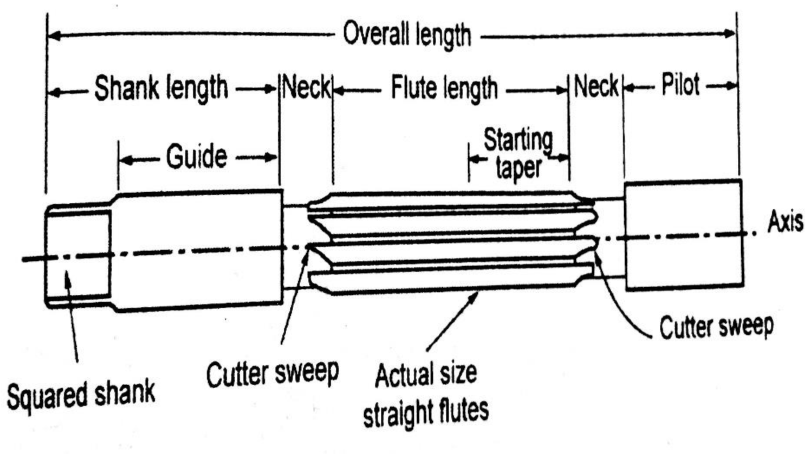


Figure 21 Reamer straight flutes

- Since the reamer follows the already existing hole, any misalignment present in the hole is likely to break the reamer if mounted in conventional spindle.
- Hence, a floating reamer is used between the machine spindle and the reamer to adjust for any small misalignment between the spindle axis and the hole axis.
- Reamers are operated at lower speeds and higher feeds than drills of the corresponding diameter.
- Generally, speeds of reaming will be approximately 60 to 70% of that for drilling the same material. Feeds % be 2 to 3 times of that of drilling.
- Reamers are made of HSS or with carbide tips.
- Solid carbide reamers are widely used today.

TAPPING TOOL

- A tap is a tool which is used for makirig internal threads in a machine component.
- A tap is a multi-fluted cutting tool with cutting edges on each blade resembling the shape of threads to be cut.

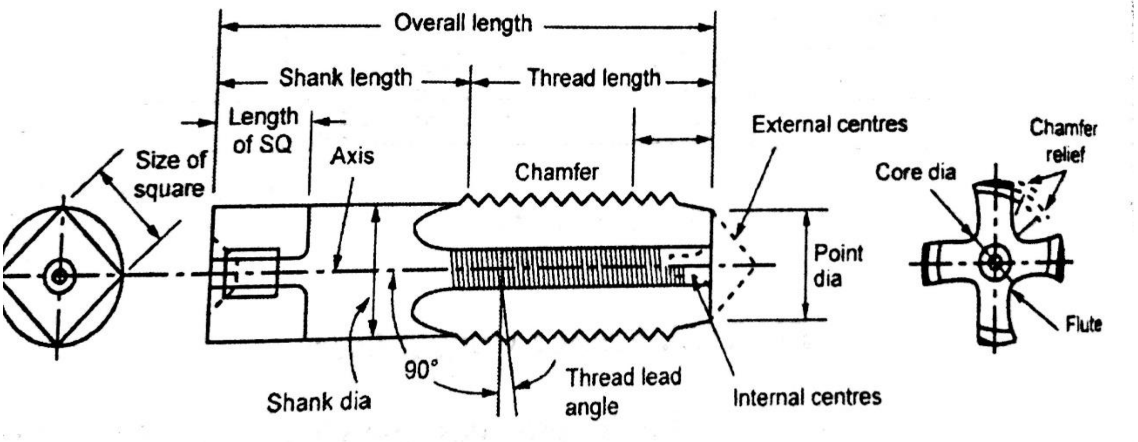


Figure 22 Tapping tool

- A tap is used, after carrying out the pre-drilling operation corresponding to the required size.
- The leading end of the tap is tapered as shown in fig22 to help in starting the tap and to distribute the majority of the cutting actions over a number of threads.
- This type of tap is used for tapping through hole only.
- For blind holes, a flat or special bottom taps without a taper have to be used.
- The thread of the tap may be cut and hardened or cut, hardened and ground. The latter is used for precision threading operation.

DRILLING CALCULATIONS

1. ***CUTTING SPEED***

- It is the peripheral speed of a point on the surface of the drill in contact with the work piece.
- It is usually expressed in m/min.

Let, D = Diameter of drill in mm
N= r.p.m. of drill spindle
V= cutting speed in m/min

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

Cutting speed mainly depends upon the following factors.

1. Type of material to be drilled.
2. Type of material of drill.
3. Type of finish required.
4. Type of coolant used.
5. Capacity of machine and tool life.

2. ***FEED***

- It is the distance of the drill moved into the work at each revolution of the spindle.
- It is expressed in mm/rev.
- It may also be expressed in feed per minute.

Feed per minute = Nxf
Where, N =r.p.m. of the drill spindle
f= feed in mm/rev

3. ***DEPTH OF CUT***

- Depth of cut is generally one half of the drill diameter.

Depth of cut = $\frac{D}{2}$
Where, D = Diameter of drill,

4. ***MACHINING TIME***

- The machining time can be calculated by using the following relation.

$$\text{Machining time, } t = \frac{Length\ of\ tool\ in\ mm}{Feed\ in\ mm/rev\ x\ r.p.m.of\ spindle}$$

Where, Length of tool travel = thickness of metal in mm + 0.3 D + Over travel

- The length of the point of the drill is added with the thickness of the metal because the drill point must clear the metal to complete the hole.
- It is generally taken as 0.3D, if the over travel of the drill is not specifically given.

5. ***POWER OF DRILLING***

- When a drill cuts, it should overcome the resistance offered by the metal and a twisting effort is necessary to turn it.
- The effort is called torque on the drill. The torque is depending upon the various factors.
- The relation between torques, diameter of drill and feed is as follows:

$$T = C \times f^{0.75} \times D^{1.8}$$

Where, T= Torque in N-m
f= Feed in mm/rev
D = Diameter of drill
C = Constant.

- Depending upon the material being drilled. The values of C are given in table 1 for different materials.

Material to be drilled	**Value of C**
Aluminium	0.11
Mild steel	0.56
Cast iron	0.07
Soft brass	0.084
Carbon tool steal	0.4

Table 1

Power, P = $\frac{2\pi NT}{60}$ Watts

Where, N – Speed of the drill in r.p.m.

UNIT - III: BASIC MACHINING OPERATION

- The one and only basic machine is lathe.
- Except this lathe, other basic machines are .shaper, planer, slotter, drilling, grinding, boring, milling and broaching machines.
- Shaper, planer and slotter are used for machining flat surface which may be horizontal, vertical or inclined.
- Single point cutting tools are mainly used in these machines.
- Drilling, grinding, boring, milling and broaching machines are not used for machining flat surfaces but they are performing specific operations by using multi-point cutting tool.

PRINCIPLE OF OPERATION

- The shaper which is having a reciprocating type of machine to with single point cutting tool used to produce flat surface.
- The flat surface may be horizontal, vertical or inclined.
- It has the three important parts such as.
    1. Table
    2. Tool head
    3. Ram
- The tool head is fitted on the front end of the ram while the job is rigidly fixed on the table.
- The tool is mounted on the tool post or head.
- The ram reciprocates along with the tool to remove the metal in the forward stroke called as cutting stroke.
- The tool does not cut the metal in the return stroke called as idle stroke.
- Therefore, one pass is nothing but the combination one forward and return stroke or one cutting and one idle stroke.
- So, we are in a position to reduce idle stroke time by increasing the speed of the return stroke.
- That is, the speed of cutting stroke will be lower than the speed of return stroke.
- This is done to reduce the time required for one pass.
- Hence, the overall time required will be reduced drastically.
- This quick return of the ram during idle stroke is obtained by a quick return mechanism.
- At the end of each cutting stroke, the-feed (depth of cut) is given.

MACHINING VARIOUS TYPES OF FLAT SURFACES

1. The table is moved in a cross-wise direction to machine horizontal surfaces.
2. The tool head is moved perpendicular to the table in down ward direction to machine vertical surfaces.
3. The tool head is fed at an angle to produce inclined surfaces.

CLASSIFICATION OF SHAPERS

Generally, shapers are classified as follows.

1. According to the type of driving mechanism
    a. Crank drive type
    b. Whit worth driving mechanism type
    c. Hydraulic drive type
2. According to the position of ram
    a. Horizontal shaper
    b. Vertical shaper.
    c. Travelling head shaper
3. According to the table design
    a. Standard or plain shaper
    b. Universal shaper
4. According to the type of cutting stroke
    a. Push out type
    b. Draw cut type

PRINCIPLE PARTS OF A SHAPER

The different parts of a shaper are listed and described below.

1. Base

2. Column
3. Cross rail
4. Saddle
5. Table
6. Ram
7. Tool head

1. ***Base:***
   - The base is a heavy and robust in construction which is made of cast iron by casting process.
   - It is the only part to support all other because all parts are mounted on the top of this base.
   - So, it should be made to absorb vibrations due to load and cutting forces while machining.

2. ***Column:***
   - The column has a box type structure which is made of cast iron.
   - The inside surface is made as hollow to reduce the total weight of the shaper.
   - It is mounted on the base.
   - The ram driving (Quick return) mechanism is housed.
   - The two guide ways are provided on the top.
   - The ram reciprocates on this guide ways.
   - Similarly, there are two guide ways at the front vertical face of the column to move the cross rail along these guide ways.

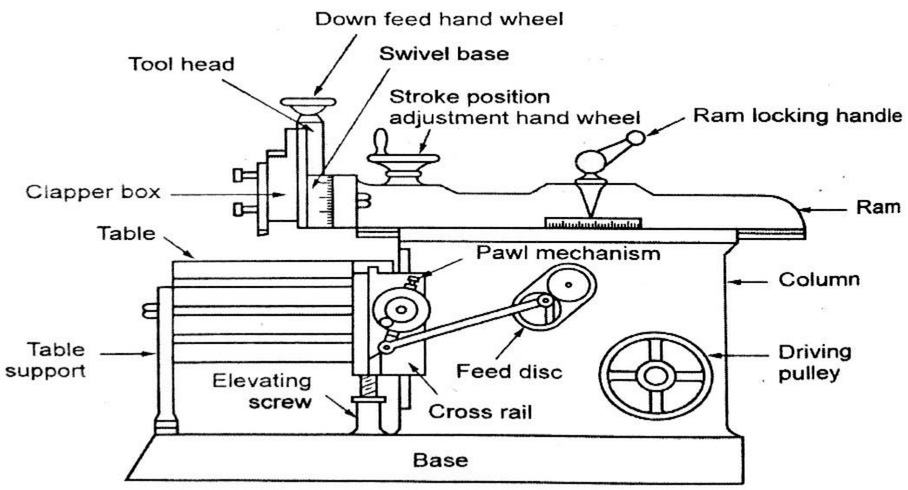


Figure 1 Standard Shaper

3. ***Cross rail:***
   - It is also a heavy cast iron construction.
   - It slides on the front vertical ways of the column with two mechanisms.
   - One is for elevating the table and the other one is for cross travel of the table.
   - A saddle slides over two guide ways already provided in the front face of the cross slide.
   - The crosswise movement of the table is obtained by cross feed screw and the vertical movement of the cross rail is obtained by an elevating screw.

4. ***Saddle:***
   - It is mounted on the cross rail which holds the table in position on its top without any shake.

5. ***Table:***
   - It is also a box type rectangular hollow cast iron block.
   - This table slides along the horizontal guide ways of the cross rail.
   - The work is held in the table. The table has machined surfaces on the top and sides of T-slots for clamping work.
   - It can be moved vertically by the elevating screw.
   - An adjustable table support supports the front face of the table.

6. ***Ram:***
   - Ram of cast iron has cross ribs for rigidity.
   - Generally, it is a reciprocating type which slides over the guide ways on the top of the column.
   - It is connected to driving mechanism of any one and also it carries the tool head at the front end.

7. ***Tool head:***
    - It holds the tool rigidly having swivel base with degree graduation.
    - So, the tool head can be swivelled to any angle as required.
    - The tool head has a vertical slide and apron to provide vertical and angular feed to the tool.
    - A feed screw with graduated dial moves the vertical slide vertically to set the accurate movement.

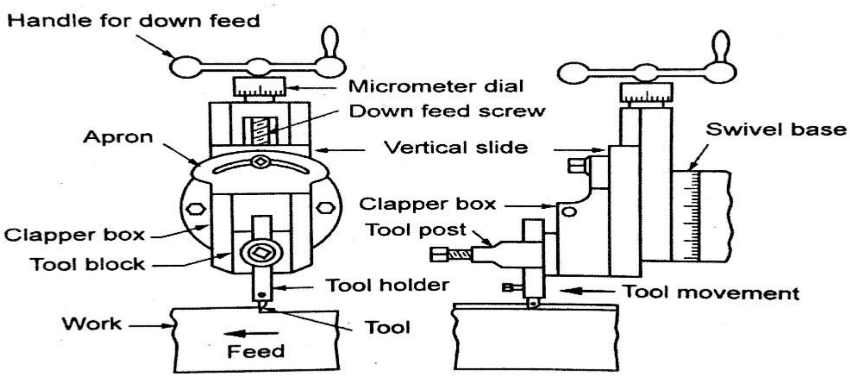


Figure 2 Tool head

- Apron is clamped upon the vertical slide which can be tilted to right or left and also clamped at a correct position.
- The clapper box hinges a tool block already fitted with apron.
- The tool block holds a tool post to mount the tool.
- During cutting stroke, the tool block fits inside the clapper box rigidly.
- During the return stroke, the tool block lifts out of clapper box to avoid rubbing of the tool on the job.

OTHER TYPES OF SHAPER

The following other types of shaper are briefly described below:

1. ***Standard or Plain Shaper***
    - This type of shaper has all the above-described parts.
    - In addition to this, it has plain table called plain shaper, the horizontal and vertical movement of the table with or without vertical supports at its front.
    - So, it can be adjusted to any suitable height of the work piece.
    - Usually the metal is removed during forward stroke called as push type shaper.

2. ***Universal Shaper***
    - It has all the same parts as that of standard shaper.
    - In addition to this, a special provision of table which can be swivelled about an axis parallel to the ram movement.
    - The swivel base is graduated in degrees.

3. ***Draw Cut Shaper***
    - It has all principal parts but heavier than plain type.
    - The main difference in this draw cut shaper is that the metal will be cut during the return stroke.
    - During cutting, the tool draws the work towards the column called as draw cut shaper.
    - So, the cutting is fitted in a reverse direction.
    - Hence, heavy cuts are possible and vibration is eliminated.

SHAPER SPECIFICATIONS

Generally, the specifications of a typical shaper are listed below:

1. Maximum length of stroke.
2. Maximum crosswise movement of the table.
3. Maximum vertical adjustment of the table.
4. Type of driving mechanism.
5. Power of the motor.
6. Speed and 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.

DRIVES

- To convert rotary motion of motor into reciprocating motion of the tool, the various types of drives are provided in shaper because the metal is removed in the forward stroke.
- But no metal is cut during the return stroke.
- Due to this, the time taken for the return stroke should be reduced by making the return stroke faster than the cutting stroke.
- This is achieved by some quick return mechanism.

Types of Quick return mechanism

The flowing three types of quick return mechanisms are

1. Hydraulic drive.
2. Crank and slotted link mechanism.
3. Whitworth mechanism.

1. Hydraulic drive

- A piston reciprocates inside the hydraulic cylinder.
- A piston rod is connected between the piston and ram.
- So, the ram reciprocates along with the piston.
- Two parts or entries are provided near the each end of the cylinder.
- A four-way control valve connects these two entries with the reservoir.
- The reservoir connects the value through a drain pipe and a supply pipe.
- The supply pipe is again connected to the reservoir by a pump and relief valve.
- The valve is actuated by the lever and trip dog fitted to the ram.
- Oil is sucked by a gear pump from the reservoir at a particular pressure.
- This high-pressure oil goes to the cylinder through four-way valve.
- The oil is allowed from the pump to the left side of the piston which forces the piston to move the ram towards right (R).
- It is called as forward or cutting stroke.
- In this stroke, oil flows out on the right side entry to the reservoir through the four way valve and drain pipe.
- The lever hit one trip dog (P1) at the end of this stroke.
- Now, the lever position is changed.
- Due to this, the supply pipe supplies the oil on the right side of the piston which moves the ram towards left (L) called as return stroke or non-cutting stroke. In this stroke, the high-pressure oil covers on lesser area on the cylinder.
- Due to this, the pressure force will increase. Hence, this return stroke is faster by supplying the same quantity of oil.

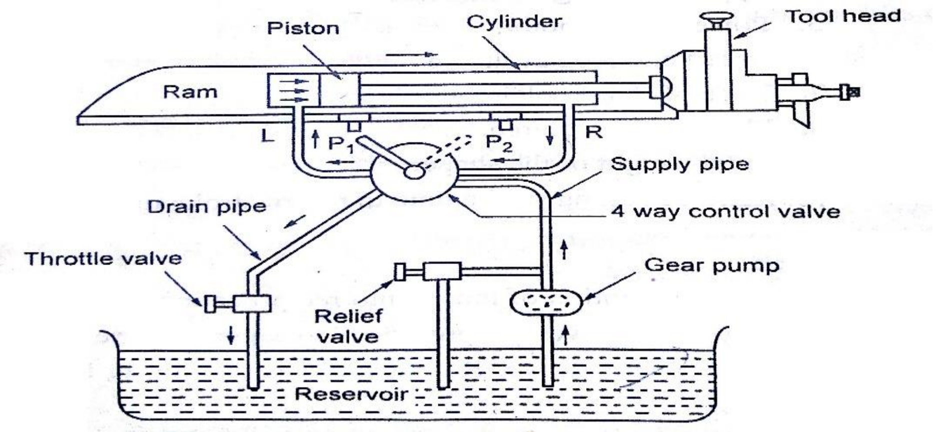


Figure 3 Hydraulic drive

Advantages of hydraulic drive

1. Smooth cutting operation can be obtained by uniform speed.
2. Changing of cutting speed is easier.
3. Higher cutting to return ratio can be obtained.
4. Infinite range of cutting speeds is available.
5. The operation is more safety due to relief valve.
6. Stroke length can be easily adjusted without stopping the machine.

2. Crank and Slotted Link Mechanism

- In this mechanism, the ram is actuated by gear drives associated with electric motor.
- First, the electric motor drives the pinion gear.
- Next, the pinion gear drives the bull gear which rotates in opposite direction due to external gear meshing.
- A radial slide is provided on the bull gear, sliding block is assembled on this slide.
- The block can be positioned in radial direction by rotating the stroke adjustment screw.

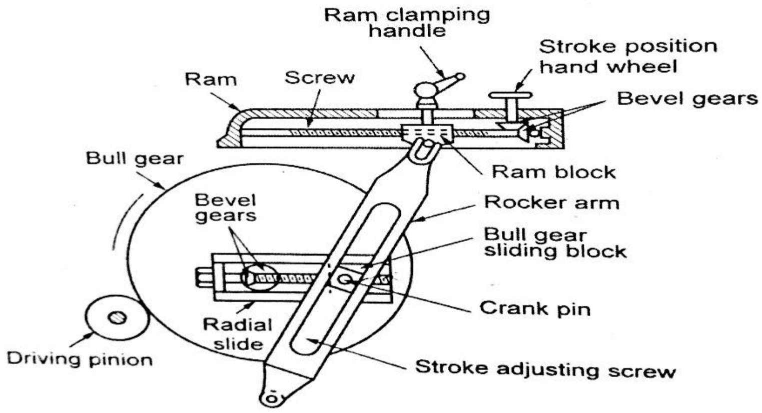


Figure 4 Crank and Slotted Link Mechanism

- The sliding block has a crank pin.
- A rocker arm is freely fitted to this crank pin.
- The rocker arm sliding block slides in the slot provided in the rocker arm called as slotted link.
- The bottom end of the rocker is pivoted and its upper end has fork which is connected to the ram block by a pin.
- When the pinion gear rotates along with bull gear, the crank will also rotate.
- Due to this, the rocker arm sliding block also rotates in the same circle.
- Simultaneously, the sliding block slides up and down in the slot.
- This movement is transmitted to the ram which reciprocates.
- Hence, the rotary motion is converted into reciprocating motion by this.

3. Quick Return Principle

- From the fig 5, A1 and A2 are rear and forward extreme positions of link.
- S1 and S2 are two extreme positions of crank pin.
- During forward stroke, the link moves from A1 to A2 as the sliding block moves from S1 to S2 in clockwise direction at an angle of α.
- During return stroke, the sliding block moves from S2 to S1 in clockwise direction through an angle of β.
- But, the speed of bull gear is constant throughout.
- Therefore, the time taken during these two strokes is directly proportional to these angles α and β.
- But the angle β is smaller than α.
- So, the time taken by the return stroke will be reduced.

$$m = \frac{cutting\ time}{return\ time} = \frac{\alpha}{\beta} = \frac{cutting\ angle}{return\ angle}$$

'*m*' varies from 2:1 to 3:2

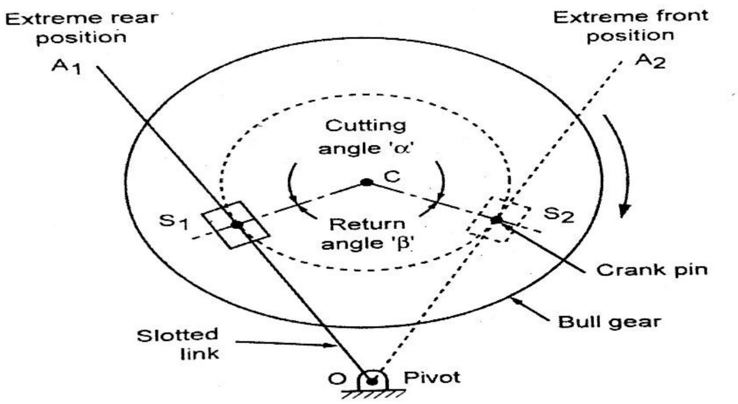


Figure 5 Quick Return Mechanism

4. ***Whitworth Quick Return Mechanism***
   - The shaft of an electric motor drives the pinion which rotates the bull gear.
   - The bull gear has crank pin.
   - A sliding block slides over this crankpin and slides inside the slot of a crank plate.
   - This crank plate is pivoted at the point S eccentrically.
   - A connecting rod connects the pin at P on one end and ram at the other end M.
   - When the pinion rotates, the bull is also rotated along with the crank pin.
   - At the same time, the sliding block slides on the slot provided on the crank plate.
   - This makes the ram to move up and down (reciprocating motion) by the connecting rod.
   - The two important cases are discussed below.
     1. When the pin A is at X, the ram is in forward stroke. At that time, the bull gear rotates in anticlockwise direction at angle of α.
     2. When the bull gear rotates further in the same direction from Y to X at an angle of β, the return stroke will take place. Here, the angle β is lesser than α. So, the time taken for the return stroke is reduced.

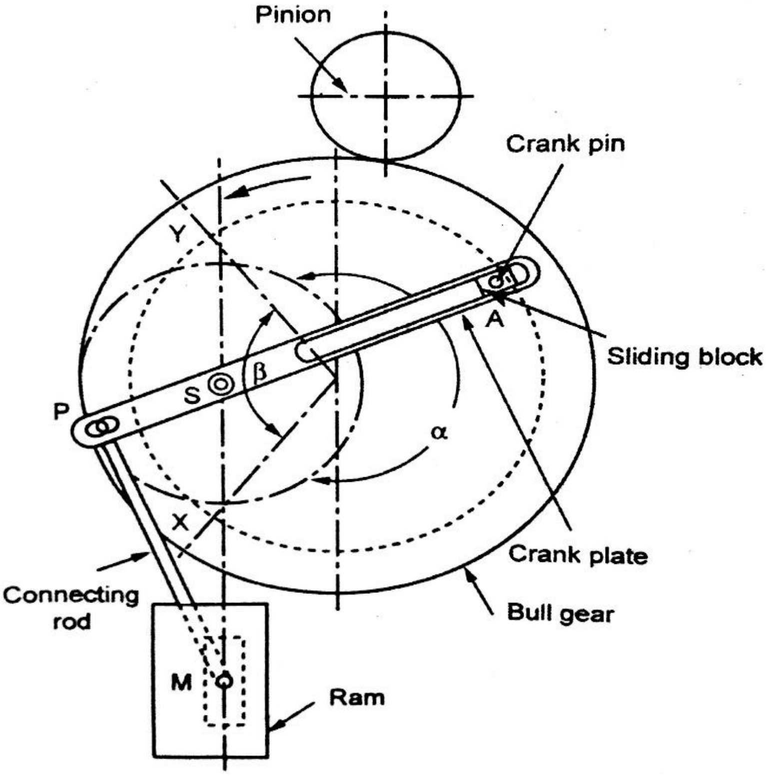


Figure 6 Whitworth Quick Return Mechanism

$$m = \frac{cutting\ time}{return\ time} = \frac{angle\ \alpha}{angle\ \beta}$$

STROKE LENGTH ADJUSTMENT

The stroke length can be adjusted by moving the crank pin in radial direction with sliding block by adjustment screw. It is rotated by a handle. The following two important points are to be remembered while adjusting the stroke length.

1. If the crank pin is adjusted very nearer to the center of the bull gear, the rocker arm reciprocates for a smaller distance. Therefore, the stroke is reduced.
2. If the crank pin is adjusted in such way away from the center of the bull gear, the rocker arm reciprocates for a larger distance. So, the stroke length is increased.
3. The stroke length should always be greater than the work length, i.e. some amount of approach and over travel or over run should be provided to the tool movement.

Reasons for making the stroke length greater than work length

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

POSITION ADJUSTMENT

The following steps are listed below to adjust the position.

1. The clamping handle is loosened.
2. The stroke position hand wheel is rotated to rotate the screw inside the ram to make the ram movement both in forward and backward direction.
3. Finally, the clamping handle is tightened to adjust the position of stroke.

FEED MECHANISM

- The mechanism in which the feed is given at the end of each return stroke is known as feed mechanism.
- It may be anyone of the following three types such as horizontal, vertical and inclined.
- Vertical and inclined feed is given by rotating the hand wheel of the cross feed screw on the tool head by hand.

1. ***Hand Feed***
   - If the table is moved perpendicular to the ram movement, it is called as cross feed.
   - It is given by rotating the hand wheel of the cross feed screws on the tool head.
   - The vertical adjustment is made by rotating the elevating screw through the horizontal rod to hold the work piece at various heights.
   - Vertical and angular feeds are given by the tool head.
   - But the only difference in angular feed is that the feed will be given after setting the work to its required angle.

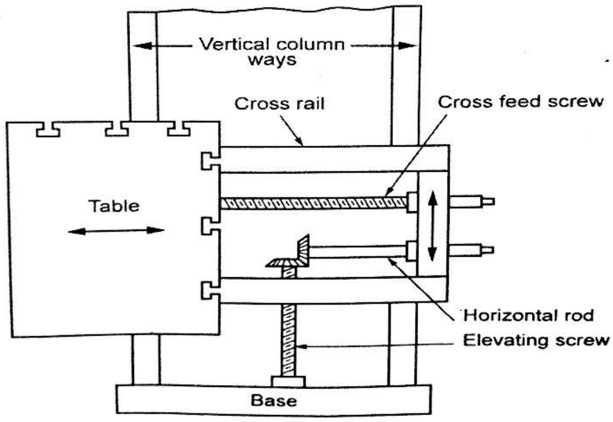


Figure 7 Hand Feed

2. ***Automatic Table Feed***
   - The automatic feed for the shaper table is given by a pawl and ratchet mechanism.
   - This mechanism is connected with the rocker arm and connecting rod.
   - Finally, it is connected with the driving disc having T slots through crank pin.
   - Before this, the pawl is connected with pin and knob through the spring.
   - The pawl is freely slipped up and down when the ratchet wheel rotates.
   - During the first half revolution of the disc in the clockwise direction, the rocker arm rotates in the same direction but the pawl slips over the teeth of the ratchet wheel on that time, no movement is given to the table.
   - This movement takes place only on cutting stroke.

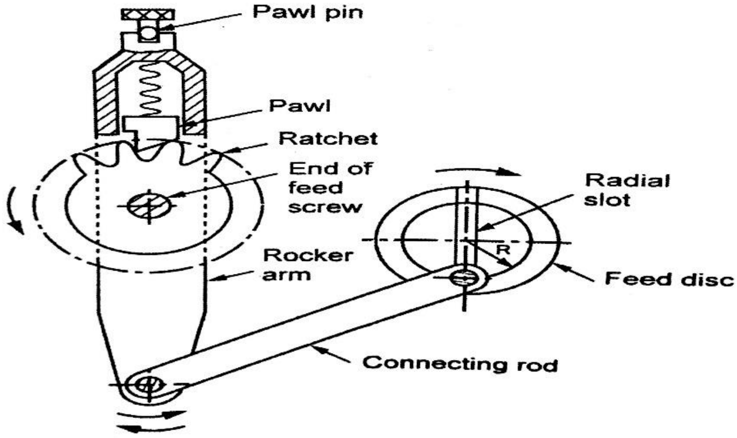


Figure 8 Automatic Table Feed

- During the next half revolution of the disc in the same clockwise direction, the rocker arm rotates in the anticlockwise direction. Therefore, the pawl again slips over the teeth of the ratchet wheel.
- This takes place only on return stroke.
- The reverse feed mechanism is obtained by turning the pawl through 180° after lifting the pawl.
- Then the cross feed is varied by changing the crank pin position on the disc radially.

WORK HOLDING DEVICES

- The work piece should be clamped tightly by using some holding devices in a shaper called as *work holding devices*.
- These devices are selected dependent on the shape and size of job, and the type operation to be performed.
- Usually, the clamping devices are wedge strip, step block, stop pin, toe dog, hold down, parallel, clamp and U-clamp etc.
- The following methods that are commonly used are shown below.

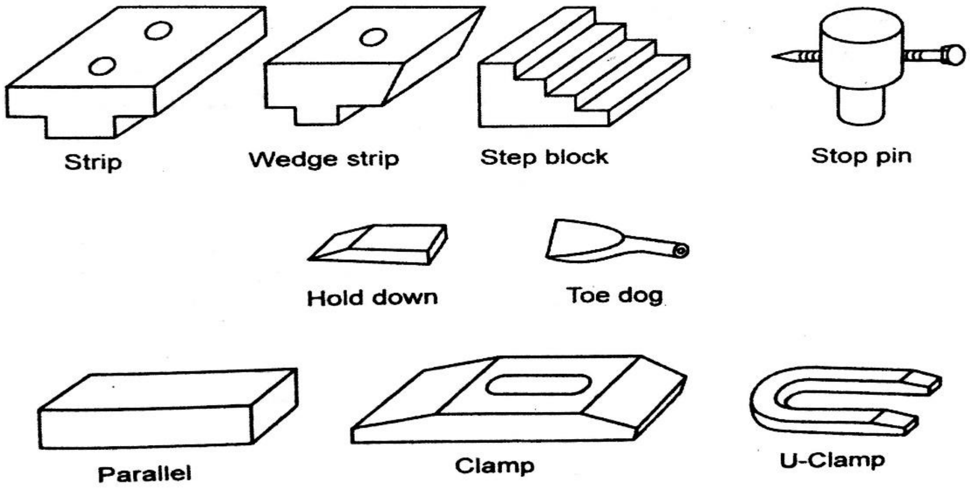


Figure 9 Work Holding Devices

METHODS OF CLAMPING

1. ***Clamp in a Vise***
   - Work is held quickly in a swivel base machine vice between two jaws.
   - Parallels are used to raise and set small works.
   - It should not spoil the machined surface of work.

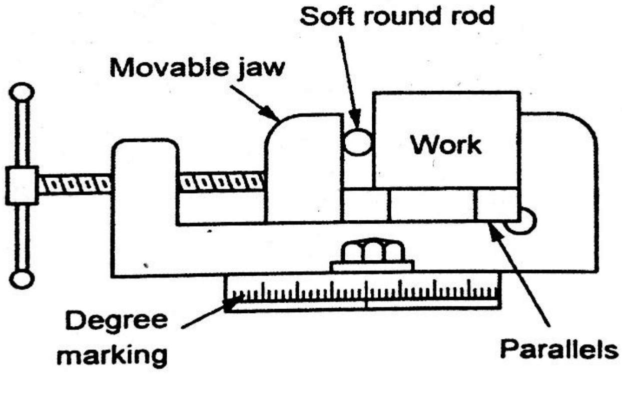


Figure 10 Vise

2. ***Clamping On the Table***

- The work is clamped by T-bolt, step block and clamp as shown in fig 11.
- The height of the step should be approximately equal to the height of work.
- 'T' bolts should be placed near to the work.
- Work is held between a strip and stop pin.
- Tightening the stop pin screws are done by butting the work with strip.
- Due to no interference of clamps, machining can be performed on the entire surface.

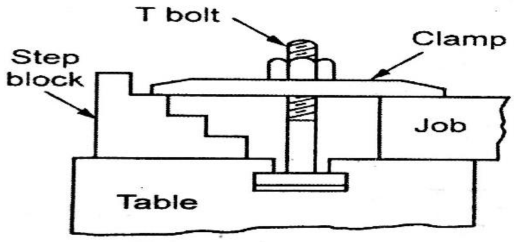


Figure 11(a) T bolt and Clamp

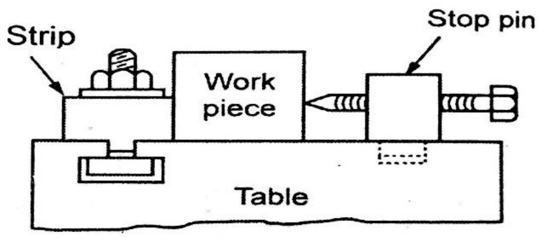


Figure 11(b) Strip and stop pin

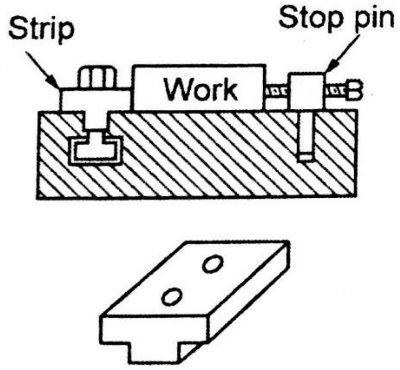


Figure 11(c) Strip and stop pin

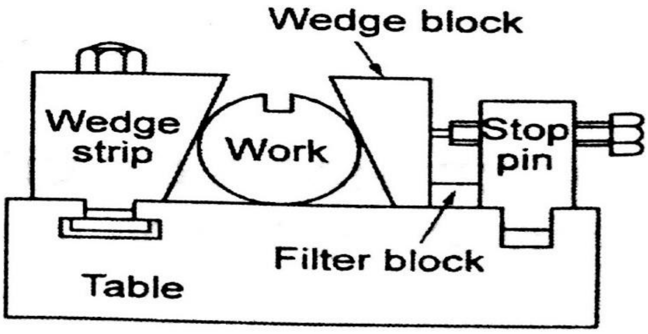


Figure 11(d) Wedge strip and stop pin

3. ***Clamping On a V Block***
   - The small cylindrical work pieces are clamped by using 'T' bolts.
   - Machining can be done on the surface free from clamps.
   - The work is clamped between two-wedge blocks.
   - Then it is firmly gripped by tightening the stop pin screws.

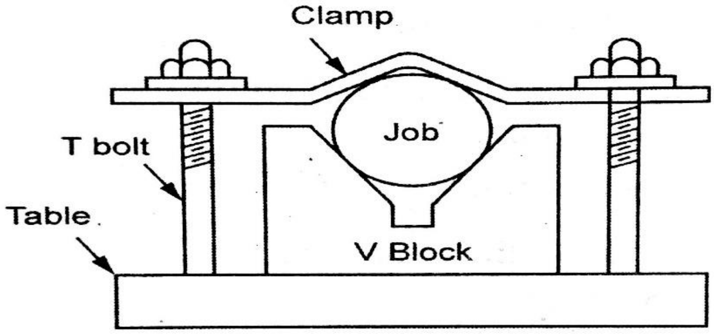


Figure 12 Clamping On a V Block

4. ***Clamping On Angle Plate***
   - The irregular shape of work piece is held on angle plates.
   - The details are shown in fig 13.
   - The work is clamped by bolts.
   - Packing pieces or wedges are used to give support the work wherever it is necessary.

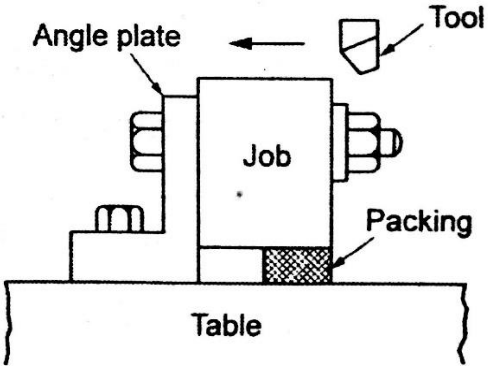


Figure 13 Angle plate

5. ***Fixture***
    - Fixture is a specially designed work holding device using T bolts, V-blocks and clamps.
    - Locating, clamping and unloading of work can be easily and quickly done.
    - The total production time and cost are reduced.
    - Accuracy of machining is improved.

TYPES OF TOOL

- Usually, the shaping tools are made of H.S.S. or forged tools.
- It is single point cutting tool.
- It is made to various clearance angles.
- It should make in the form of withstanding shock load during the starting of cut.
- The tools are classified as below:
    1. According to the shape.
        a. Straight tool.
        b. Cranked tool.
        c. Goose necked tool.
    2. According to the direction of cutting.
        a. Left hand tool.
        b. Right hand tool.
    3. According to the finish required.
        a. Roughing tool.
        b. Finishing tool.
    4. According to the type of operation.
        a. Down cutting tool.
        b. Parting off tool.
        c. Squaring tool.
        d. Side recessing tool.
    5. According to the shape of the cutting edge.
        a. Round nose tool.
        b. Square nose tool.

SHAPING OPERATIONS

The following operations can be performed on a shaper.

1. Machining horizontal surface.
2. Machining vertical surface.
3. Machining angular surface.
4. Machining slots, grooves and keyways.
5. Machining irregular surfaces.

1. ***Machining Horizontal Surface***
    - The work is held on a table and the tool is fitted in the tool post with minimum overhung.
    - It should prevent the rubbing of tool on the work while returning.
    - The tool is adjusted vertically by some clearance and the stroke length is set longer than work piece, i.e. 12mm tool approach and 8mm tool over run are added to the length of the work.
    - Then the proper cutting speed and feed are chosen.
    - During starting of the shaper to machine the work, the tool is just made to touch the job.
    - Afterwards the depth of cut is given at each end of the return stroke by rotating the down feed screw.
    - In any machines, the roughing cut is performed by giving more depth of cut with slow cutting speed and faster feed.
    - Similarly, the finishing cut is performed by giving less depth of cut with faster cutting speed and slow feed.

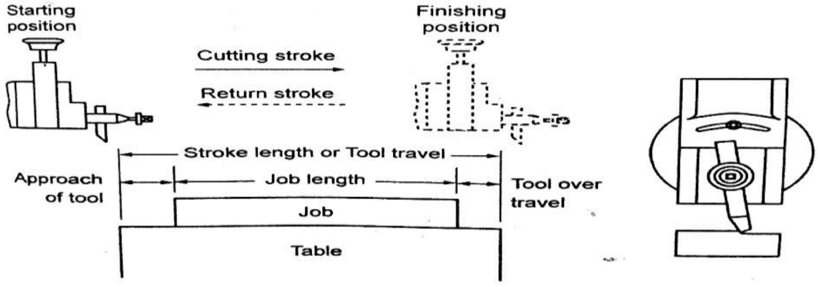


Figure 14 Machining horizontal surface

2. Machining Vertical Surface

- The job is held on the table and the tool is set on the tool holder.
- The tool position and the stroke length are adjusted to a required dimension.
- Then the value on the vertical slide dial is set at zero.
- The apron is swivelled to avoid rubbing of the tool on the work surface during the return stroke.
- Depth of cut is given by raising or elevating the table.
- Feed is given by rotating the down feed screws of tool head at the end of return stroke.

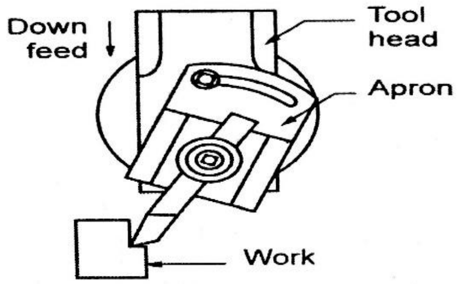


Figure 15 ***Machining Vertical Surface***

3. Machining Angular Surface

- The job is mounted on the table and the tool is set at required angle on the tool head position and stroke lengths are adjusted and also proper cutting speed and feed are chosen.
- The apron is set away from the machining surface.
- Depth of cut and feed are given the same as that of machining vertical surface.
- Dovetail is nothing but the surface having angular surface on both sides.
- To make dovetail, the vertical slide with right hand tool is at the required angle on right side of the work.
- Just giving feed and depth of cut, the right side dovetail is finished.
- Then the vertical slide with left hand tool is set the required angle on left side of the work.
- Here also just by giving feed and depth of cut, the left side dovetail is finished.

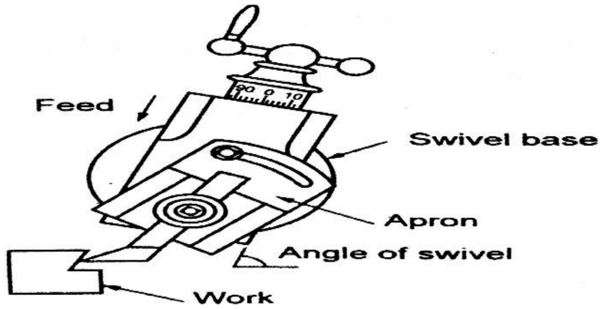


Figure 16 ***Machining Angular Surface***

4. Machining Slots, Grooves and Keyways

- The work is held in a vice using ‘V’ blocks and parallels.
- First a hole is drilled to a required keyway depth at the end of the work piece.
- The diameter of the hole should greater than the width of keyway.
- Then, the position and stroke length are adjusted.
- The keyway-cutting tool is set on the tool head.
- Finally, the external keyway is machined with reduced speed.

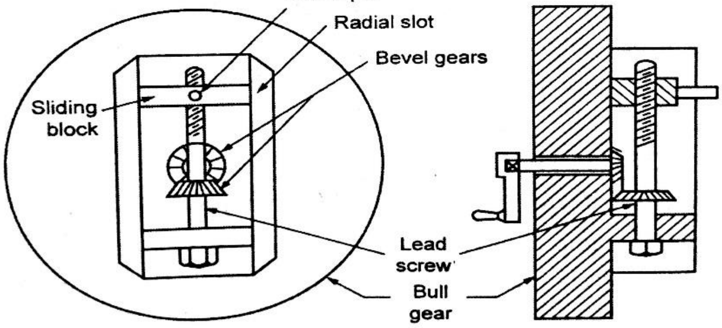


Figure 17 ***Machining Slots, Grooves and Keyways***

5. ***Machining Irregular Surface***
    - For machining irregular surface, a round nose tool is set on the tool head.
    - By giving both the cross feed and vertical feed at the same time the irregular surface is obtained.
    - The cross feed is given through the table and the vertical feed is given by the tool head.
    - The apron is fitted to some angle away from the machined surface to avoid rubbing of the tool on the work during return stroke.

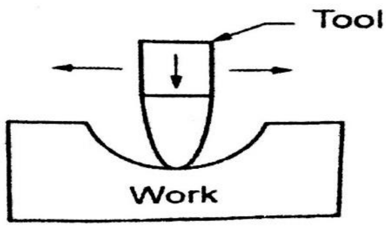


Figure 17 ***Machining Irregular Surface***

MACHINING CALCULATIONS

1. ***Cutting speed (V)***
   It is the velocity at which the metal is removed by the tool.
   Cutting speed, V = $\frac{Length\ of\ the\ cutting\ stroke}{Time\ taken\ for\ the\ same\ cutting\ stroke}$

   $= \frac{LN(1+m)}{1000}$

   Where, L – Length or cutting stroke in mm.
   N – Speed in rpm.
   M – Ratio between cutting and return time.

2. ***Feed (f)***
   The relative movement of tool with respect to the work piece axis is known as feed.

3. ***Depth of cut (t)***
   Amount of metal removed in one revolution or in cut is known as depth of cut.

4. ***Machining time (T)***
   Time required for machining for work surface to the required dimensions.

   $$\boldsymbol{T} = \frac{L}{N\ x\ f} = \frac{L}{V} + m\ \frac{L}{V} = \frac{L(1+m)}{V}$$

   Where, L – Length or cutting stroke in mm. (L = l + approach + over run)
   N – Speed in rpm.
   f – feed.
   L – Work piece length.
   L/V – time for cutting stroke.
   mL/V – Time for return stroke.

5. ***No. of strokes required (S_N)***
   The ratio between the width of the work and feed per stroke.

   $S_N = \frac{W}{f}$

6. ***Total machining time (T_t)***
   The time required for machining the entire surface of the work per requirements.

7. ***Metal removal rate (w)***
   The volume of metal removed per unit time.

   mmr (or) w=f t L S

   Where, f – Feed
   T - Depth of cut
   L - Length of work
   S -Strokes per minute.

8. ***Power required***

$$P = k \times w$$

Where, k – Machining constant

9. ***Number passes***

$$n = \frac{Stock\ to\ be\ removed}{Depth\ of\ cut} = \frac{S}{t}$$

PLANER

- In planer, the work piece mounted on the table reciprocates but the tool is stationary.
- A single point cutting tool is used for machining the work surface.
- This tool is always fitted vertically the tool holder which moves on a cross-rail while feeding.
- Planer is mainly used for machining large and heavy work pieces.
- The machined surface may be horizontal, vertical or inclined surface.

PRINCIPLE OF OPERATION

- Planer is a very large reciprocating machine tool.
- The work is mounted on the table by any one of the work holding devices.
- Two vertical columns with vertical guide ways are provided on both sides of the bed and connected by a cross-rail to mount the tool heads and also connected by a cross beam at the top.
- These tool heads are used to hold the tools.
- The tool cuts the work piece when the table reciprocates.
- The cross feed is given by moving the tool head along the cross rail and the vertical feed is given by moving down the tool.
- The tool slide can be tilted or swivelled at any required angle using a swivel head for machining inclined surfaces.
- The feed can be given by both manually and automatically.
- The horizontal movement of the cross rail can be done on the guide ways vertically and vertical movement by elevating screw.
- In planer also, the metal is removed during the cutting stroke called forward stroke and no metal is removed during the return stroke called idle stroke.
- Hence, cutting stroke takes place at a slower speed and return stroke with faster speed. Feeding is given at the each end of the cutting stroke.
- To obtain the quick return of the table, the planer is also driven by a quick return mechanism to reduce the time of return stroke.
- So, the planer is used for machining heavy and large casting. Example: lathe bed guide ways, machine guide ways etc.

TYPES OF PLANER

The various types of planer are as follows:

1. Double hosing planer
2. Open side planer
3. Pit planer
4. Edge planer
5. Divided table planer.

1. *Double hosing planer*

The double planer has the following parts

1. Bed
2. Table
3. Columns
4. Cross rail
5. Tool head

a) Bed

- The bed is a very strong and rigid of box type which is made by casting process.
- The bed length is made twice the length of table with 'V' guide ways.
- The table is mounted over the bed which houses various mechanisms.
- Cross ribs are used to increase the strength of the bed.

b) Table

- It is also a box type structure which reciprocates on the bed guide ways.
- It is also having 'T' slots [reamed holes at regular intervals, stop pins and troughs] as that of shaper for clamping the work piece.

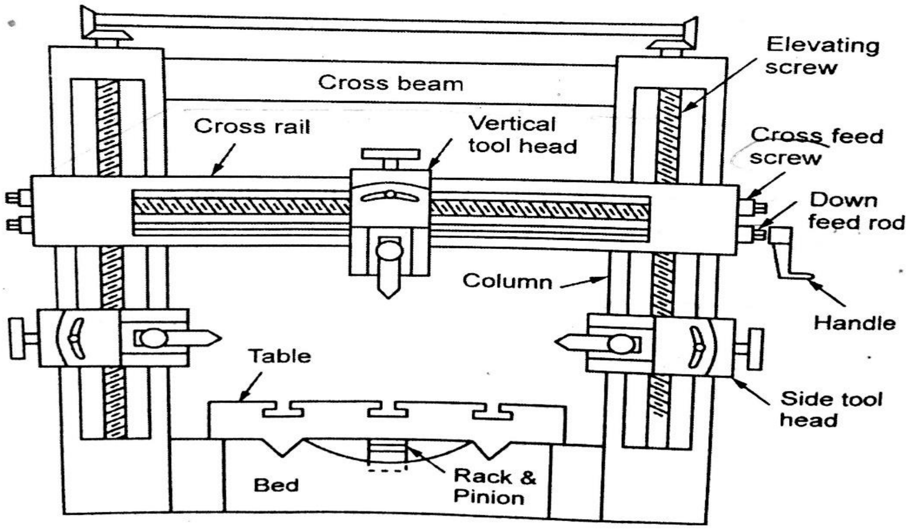


Figure 18 Double hosing planer

c) *Columns*

- The two long structural member along with guide ways provided on both sides of the member.
- The two long columns connected cross rail and cross beam.
- The cross rail slides on these guide ways.
- It carries feed mechanism and power transmission links.

d) Cross rail

- It is a rigid structural member mounted between two columns and slides on the guide ways already provided on the columns.
- The cross-rail can be set or clamped at any height.
- It carries tool heads.

e) Tool heads

- Maximum four tool heads can be mounted on the planner.
- Two is on the cross rail and another two are on the guide ways of both the columns.
- It may tilt to any required angle.

2. Open Side Planer

- The only difference in this type is that only one vertical column is provided on one side of the bed and other side is left free.
- So, large and heavier jobs can be mounted on the table.
- All other construction and working principle are same as that of a double housing planer.

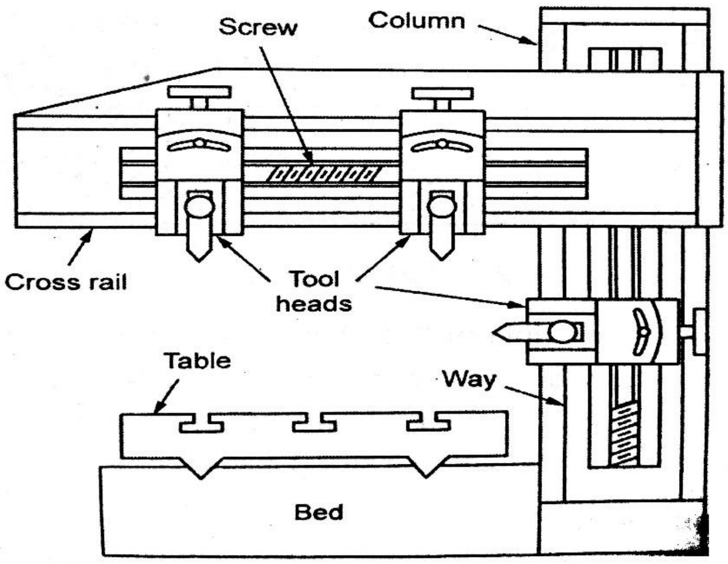


Figure 19 Open side planer

3. ***Pit Planer***

- The working principle of this planer is same as that of other types of planer.
- But the table of the planer is kept in a pit as the floor coincides with the top surface of the table.
- So, heavy and large work can be held and machined easily.

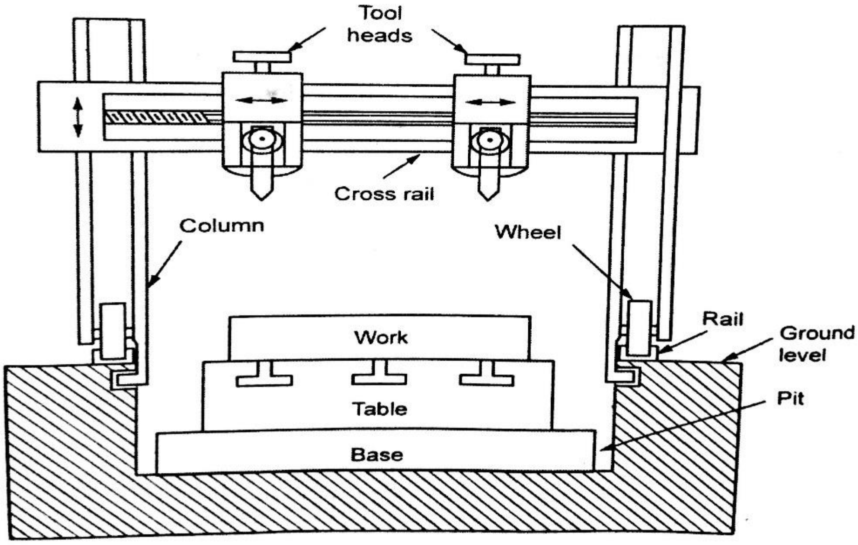


Figure 20 Pit planer

4. ***Edge Planer***

- In this type of edge planer, the bed and table are stationary and the tool head is mounted on a carriage.
- The carriage can be moved longitudinally on guide ways.
- A platform is provided to stand and travel along with it while machining.
- It is mainly used for machining the edges of steel plates.

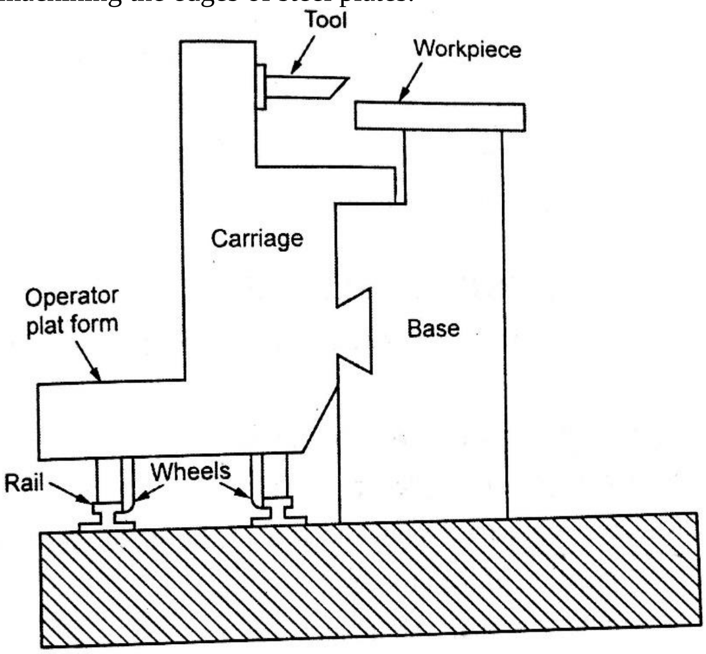


Figure 21 Edge planer

5. ***Divided Table Planer***

- The working principle is similar to that of a standard planer.
- But it has two reciprocating table.
- Generally, the time required to set the work on the planer is more.
- To reduce the setting time of work in the planer, the two same machining are combined by using two tables.
- When the first job is machining, that first table will be only reciprocated and the second table is stationary.
- On that time, the setting of work can be carried out.
- After machining the first work piece, the table is brought to rest and another one work is set.
- On that time, the second table is in machining operation.

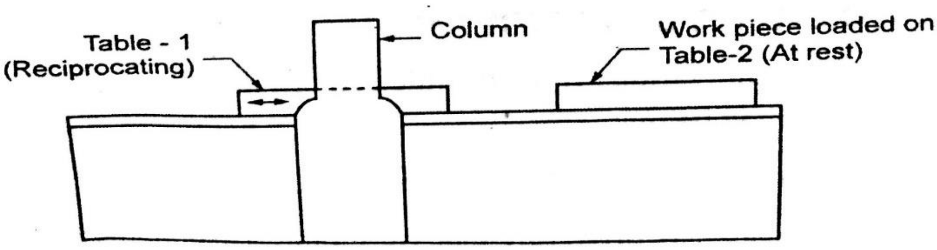


Figure 22 Divided table planer

SPECIFICATIONS OF PLANER

Generally, the planers are specified by the following parameters as below.

1. The distance between two columns.
2. Stroke length of the planer.
3. Radial distance between the top of the table and the bottom most position of the cross rail.
4. Maximum length of the table.
5. Power of the motor.
6. Range of speeds and feed available.
7. Type of drives required.

WORK HOLDING DEVICES

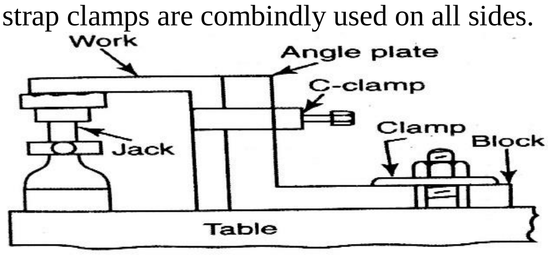
Mostly works are clamped directly on the table by using T bolts and clamps. These T bolts and clamps are fixed on the table having holes on regular intervals.

The following clamping devices are listed below:

1. Angle plate.
2. Stop block.
3. Planer jacks.
4. Adjustable screw stop.

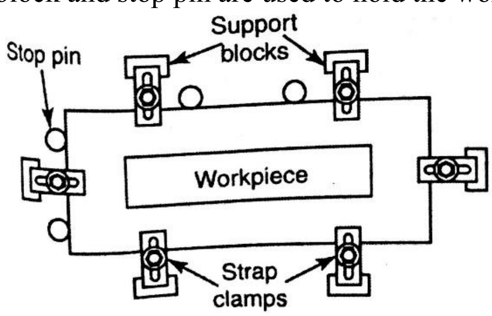
1. Angle plate

- In this method, T bolts and strap clamps are combindly used on all sides.



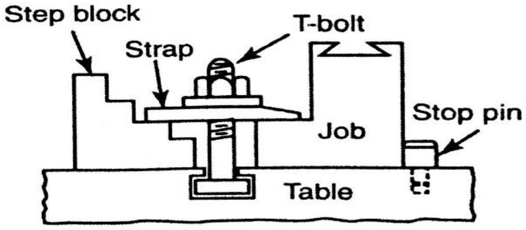
2. Stop block

- Here also, 'T' bolts with step block and stop pin are used to hold the work pieces rigidly.

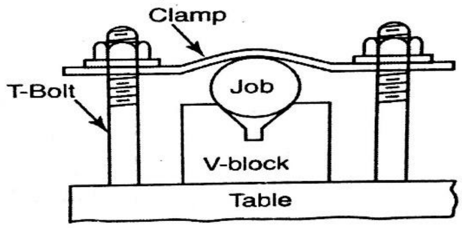


3. Planer jacks

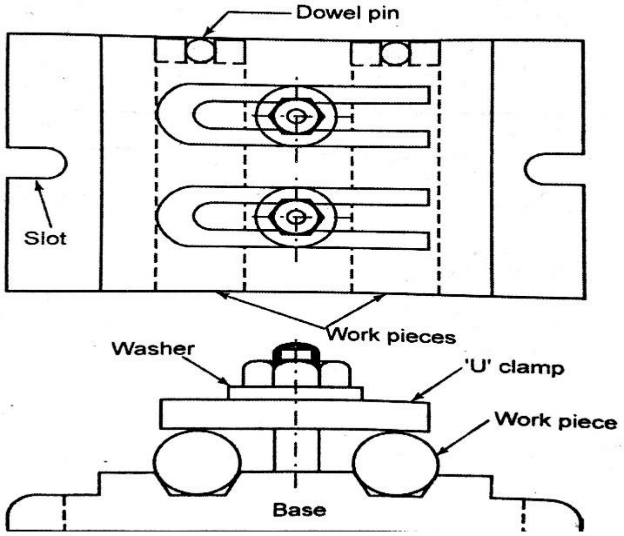
- It is used to support a work piece at one end.
- The planer jack is nothing but an integral part of jack, C-clamp, angle plates and "T bolts.



4. ***Other work holding devices***
    - 'V blocks, 'T bolts and clamps are used to clamp cylindrical work piece.



5. ***Planing fixtures***
    - For producing larger quantities, planing fixtures are used.
    - It is mainly used for machining flat surface on an axle.
    - It has a steel base with two ‘V’ grooves which locates the axle in correct position.
    - Studs are mounted in between V grooves.
    - It is used to clamp the work piece by using U clamps.



TYPES OF TOOLS

- Generally, the tools used in planer are made heavier and larger in cross section to withstand heavy cut.
- The tools may be solid, forged or bit type.
- And also it may be of H.S.S. and tungsten carbide.
- All the tools used in planer are single point cutting tools.
- To perform horizontal surfaces, right hand or left hand straight tools are used.
- Rough cutting tools are used to remove more amount of stock and finishing tool is used for finishing.

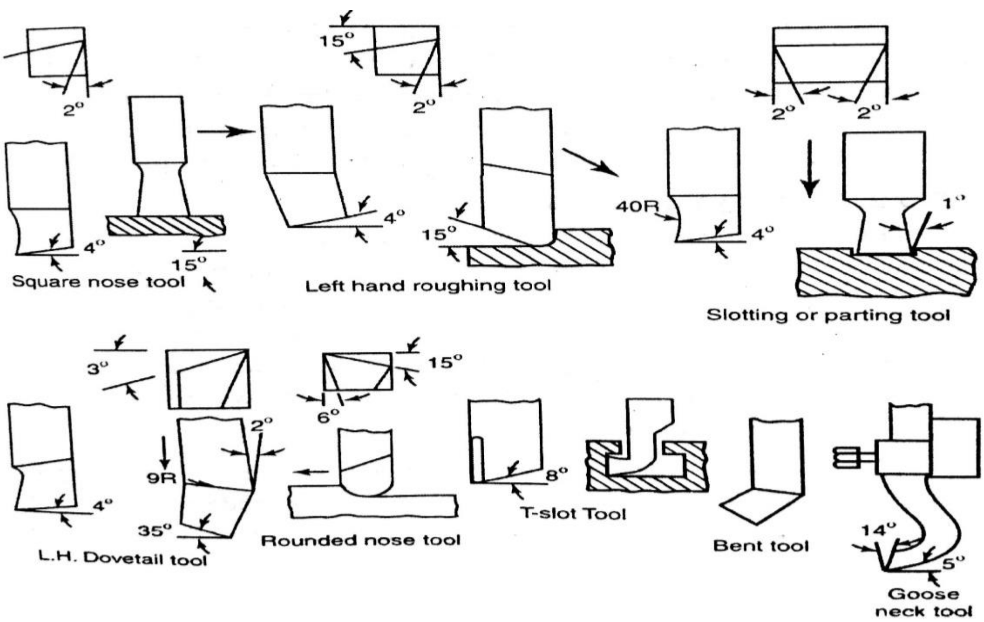


Figure 24 Types of tools

PLANER OPERATIONS

The following operations generally performed in a planer are:

1. Planing horizontal surface.
2. Planing of an angle.
3. Planing vertical surface
4. Planing curved surface.

1. Planing Horizontal Surface

- The work is clamped rigidly on the table.
- Right or left hand tool is used and held on the tool post.
- Necessary feed and speed required are selected.
- The depth of cut is given by feeding the down feed screw but the feed is given through rotating cross feed.
- The setting of tool in the head is same that of shaper.
- First roughening cuts and then finishing cuts are taken to finish the work completely.
- Both tool heads are used to larger size work piece.

2. Planing Vertical Surface

- Here also, the work is held rigidly on the table.
- Clamps should not be provided at the side of the work as per the clamping principle.
- The vertical slide of the tool post is adjusted perpendicular to the planer table.
- The apron is swivelled to certain angle which prevents the dragging over the tool during return stroke.
- The speed and feed should be selected properly.
- By rotating the cross feed screw, the depth of cut is given.
- Feed is given by rotating the down feed screw.
- The vertical surface of the work piece is finished by using bend tool.
- For this purpose, the slide of the tool head is made perpendicular to the work piece.
- Swivelling the apron is not necessary.
- Feed is given by moving the tool head in the vertical direction.

3. Planing Angular Surface

- Angular surfaces such as V- grooves, dovetail machining are done in planer in the same manner as that of shaper.
- The tool is set in the vertical tool head.
- The vertical slide is set to the required angle.
- This is for providing necessary relief to the cutting edge of the tool. Feed is given by the down feed screw.
- The tool moves in angular direction.

4. Planing Curved Surfaces

- A special attachment is used for machining curved surfaces.
- Fig 23 illustrates this attachment which consists of a radius arm and a bracket.
- The bracket is fitted to the overhead arm.
- One end of the radius arm is pivoted to the bracket whereas the other end is connected to the vertical slide of the tool head.
- At this position, down feed screw of the tool head is disengaged.
- Now, the tool head moves crosswise and the slide moves up and down by rotating the cross feed screw.
- As both the movement takes place at a time, the tool moves in a curved path.
- Thus, it produces *curved surface***.**

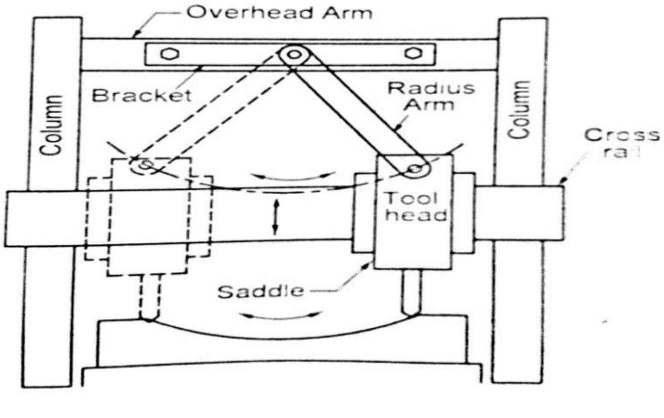


Figure 24 ***Planing Curved Surfaces***

DIFFERENCE BETWEEN SHAPER AND PLANER

Tool is stationary and work reciprocates.	Tool reciprocal and the work is stationary.
This machine is used for machining large and heavy work pieces.	This machine is used for machining medium and small work pieces.
It gives more accuracy as the tool is rigidly supported during cutting.	Less accuracy due to the overhanging of ram.
Production time is more since it has single tool head.	Production time is less since it has two or four tool heads.
Work setting requires more skill.	Work setting is easier.
Heavy cut can be given as it has rigid base and uses strong tools.	Heavy cut cannot be given.

SLOTTER

PRINCIPAL PARTS OF SLOTTER

- Slotter is a reciprocating type machine tool.
- In this machine, the ram reciprocates vertically.
- The tool held in the ram cuts during downward stroke only.
- The parts of slotter are explained below.

1. ***Base***
   - It is a heavy cast iron construction.
   - It supports the column and the saddle.
   - It has horizontal guide ways on its top.
   - These guide ways are perpendicular to the column.
2. ***Column***
   - It is cast integral with base.
   - It houses driving mechanism of ram and feeding mechanism.
   - The top vertical from face has guide ways.
   - The ram slides vertically in it.
3. ***Saddle***
   - It moves on the guide ways provided on the base.
   - It moves either towards or away from the column.
   - It is for longitudinal feed.
   - The top face of saddle has guide ways.
   - These guide ways are perpendicular to the guide ways on the base.
   - A cross slide moves on this guide ways.
   - It moves parallel to the face of the column.
   - It is for cross feed.
4. ***Rotary table***
   - The rotary table is a circular table.
   - It is mounted on the top of the cross slide.
   - It can be rotated about a vertical axis.
   - It has T slots on the top.
   - The T slots are for holding the work.
   - The table bottom is graduated in degrees.
5. ***Ram and tool head***
   - Ram is a reciprocating member.
   - It slides vertically on the guide ways of the column.
   - It has tool head at its bottom end.

- The ram has a slot at the back surface.
- It is for changing the position of ram.
- The tool is set in the tool holder.

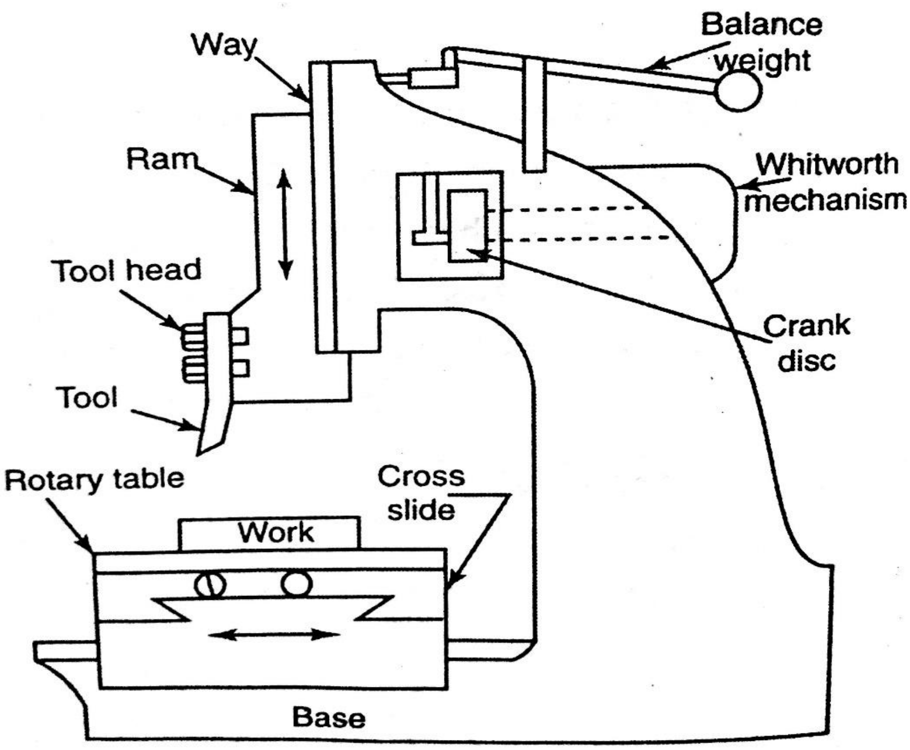


Figure 25 Slotter

METHOD OF OPERATION

- The job is held in a vice or clamped directly on the table.
- The tool is held in the tool post.
- The ram holding the tool reciprocates vertically.
- The ram gets power from the driving mechanism.
- The tool cuts the material in the forward stroke.
- The return stroke is idle.
- The feed and depth of cut are given by moving the table.
- The depth of cut is given by longitudinal movement of the table.
- The feed is given by cross movement or rotary movement of the table.
- All feed movement can be given either by hand or power.
- Hand feed is given by rotating the respective feed screw through hand wheels.

Automatic Feed Mechanism

- The bull gear has a cam groove on its face.
- A roller follower slides in this groove.
- The roller is attached to a lever.
- This lever has a slot on the other end.
- The lever is pivoted at the middle with the body.
- A feed adjustment pin is fitted in the slot of the lever.
- One end of connecting rod is connected to a disc.
- The disc rotates freely on the feed shaft.
- The disc carries a pawl.
- The roller follows the groove when the bull gear rotates.
- When the cam lobe passes the roller, the lever has oscillation.
- This oscillation is transmitted to the disc through connecting rod.
- Now the pawl moves on both directions.
- When the pawl moves in anticlockwise direction, it rotates the ratchet wheel.
- The feed shaft keyed to the ratchet wheel rotates.
- The feed shaft may be engaged to the longitudinal, cross or rotary feed screws.
- The amount of feed is adjusted by adjusting the position of the feed adjustment pin.

WORK HOLDING DEVICES

- The work is held on a slotter table by a vice, using 'T' bolts and clamps or by special fixtures.
- The work is placed above the parallel or packing pieces.
- This permits the over travel of tool.
- Fig 26 illustrates the method of holding a work (gear) on the slotter table for cutting internal keyway.
- The gear is placed on a ring block.

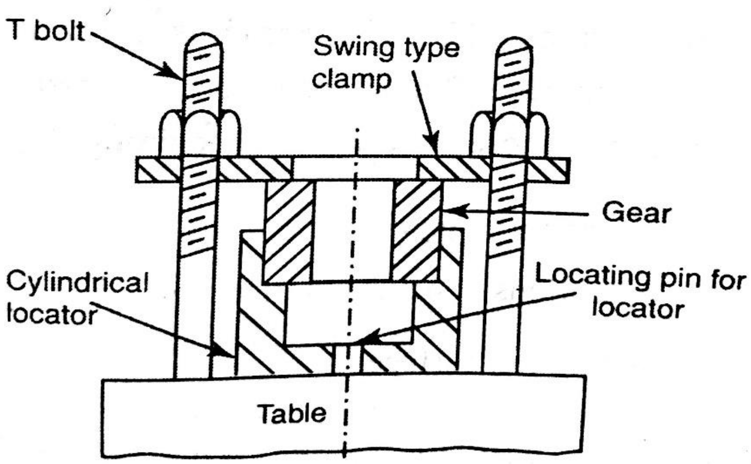


Figure 26 Slotting fixture

- The axis of gear is aligned with the axis of the rotary table.
- It is clamped by using 'T' bolts and clamps.
- Cylindrical jobs can be held in vice by using ‘V’ block as shown in lie fig 27 vice is clamped in the table.
- Special fixtures can be used as shown in fig 26.
- In this, a gear blank is located by a cylindrical locator.
- The cylindrical locator is located by a pin at the center of table.
- Hence axis of gear is located at the center of table.
- The clamping plate and T bolts are used to clamp the work.

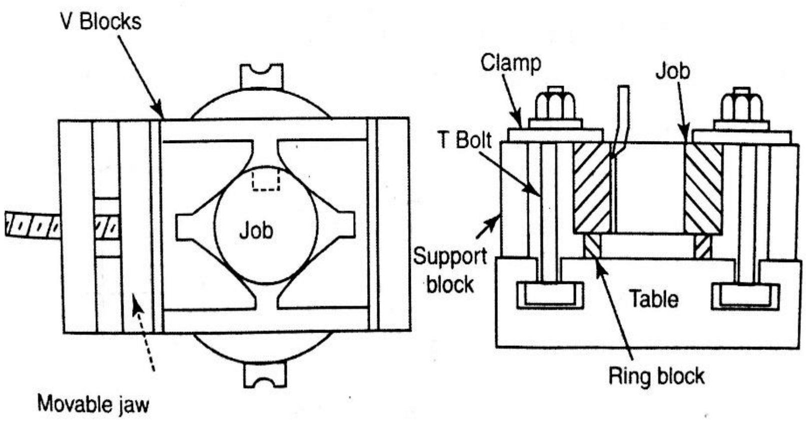


Figure 27 Job in vice

SLOTTER TOOLS

- The tool in a slotter removes metal during its vertical cutting stroke.
- So the cutting pressure acts along the length of the tool.
- Therefore, it has thick cross section.
- The tool angles are given with respect to vertical plane.
- Usually, the tools are forged type.
- Bit tools, held in heavy tool holders, are also used.
- The tools are provided with top rake, front clearance and side clearance.
- No side rake is given.
- The nose of tool projects slightly beyond the shank.
- This is to give clearance for cutting

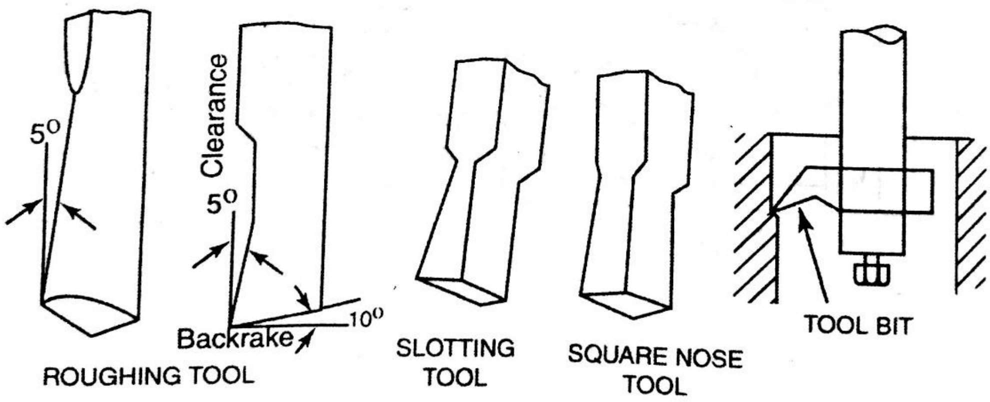


Figure 28 Types of tools

- Fig 28 illustrates the different slotter tools.
- Keyway cutting tools are thinner at the cutting edge.
- Round nose tools are used for machining contoured surface.
- Square nose tools are for machining flat surfaces.

SLOTTER OPERATIONS

The different operations done in a slotter are

1. Machining flat surface.
2. Machining grooves, slots, keyways.
3. Machining cylindrical surface.
4. Machining irregular surface.

1. Machining flat surface.

- The work is clamped on the table or vice.
- The work is set parallel to the column.
- Rotary movement of table is locked.
- Depth of cut is given by moving the saddle.
- Feed is given by moving cross slide.
- In this method, internal and external flat surfaces can be machined.

2. Machining keyway

- The work piece may be fixed by using vice or on table as shown in fig 29.
- For cylindrical work pieces, the center of job must be aligned with center of table.
- The length and position of stroke is adjusted.
- The slot is finished giving rough and finish cuts.

3. Machining cylindrical surface

- The work piece may be clamped in a vice or in the table or in a fixture.
- The center of job must be aligned with the center of table.
- The rotary table is set at centre.
- Then only the cutting takes place in radial direction.
- This is done by adjusting the saddle and cross slide.
- Then the paddle and cross slide are locked.
- Work is finished by giving circular feed.

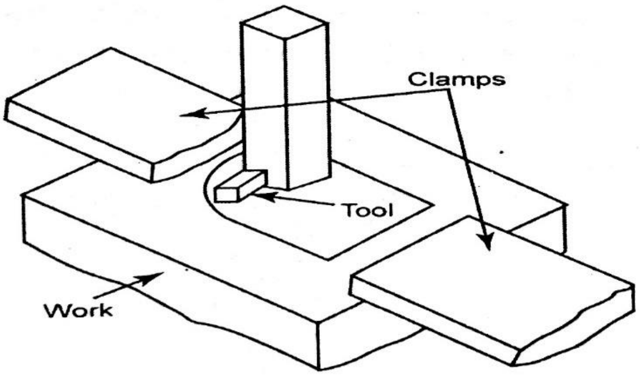


Figure 29 Machining curved surface

UNIT - IV: ADVANCED MACHINING OPERATIONS

- Milling is the process of removing metal by feeding the work past rotating multipoint cutter.
- The metal is removed in the form of small chips.
- In milling operation, the ratio of metal removal is rapid as the cutter rotates at a high speed and has many cutting edges.
- Thus, the jobs are machined at a faster rate than with single point tools and the surface finish is also better due to multi cutting edges.
- It is used for machining flat and irregular surface.

PRINCIPLE OF OPERATION

- The action of a milling cutter is vastly different form that of drill or lathe tool.
- The milling machine has a rotating cutter.
- The multi-point cutter is mounted on a rotating spindle or arbor.
- The cutter rotates at the required cutting speed.
- The work piece is clamped on the table.
- The work piece is fed slowly past the cutter.
- As the work advances, the cutting edges remove the metal in the form of chips.
- The feed may be longitudinal, cross wise or vertical.
- Angular feed can also be given in certain milling machines.
- During machining, when one cutting edge performs the cutting, the other edges will be idle.
- So, these edges are cooled.
- Also the stress on the cutting edge is not continuous.
- This gives more life to the cutting edge.
- Fig 1 illustrates the principle of operation of milling process.

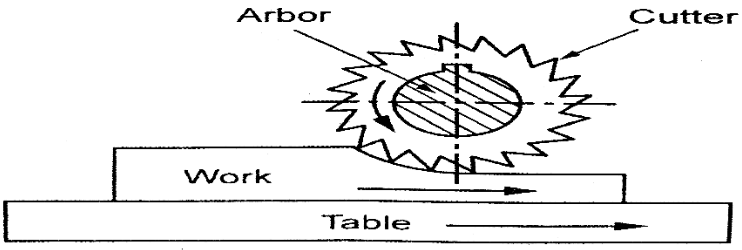


Figure 1

SPECIFICATIONS OF MILLING MACHINE

A typical milling machine is specified by the following

1. The table length and width.
2. Maximum longitudinal cross and vertical travel of the table.
3. Number of spindle speeds and feeds.
4. Power of driving motor.
5. Floor space and net weight.
6. Spindle nose taper size.
7. Type of milling machine

CLASSIFICATION OF MILLING MACHINE

Milling machine are classified in a variety of ways. The broad classification of these machines can be done as follows.

1. Column and knee types
   a. Plain milling machine
   b. Vertical milling machine
   c. Universal milling machine.
   d. Ram-type milling machine.
   e. Omniversal milling machine.
2. Bed-Type milling machine
   a. Simplex milling machine.
   b. Duplex milling machine.

c. Triplex milling machine.
3. Piano-type milling machine
4. Special purpose milling machine
    a. Rotary table milling machine
    b. Drum milling machine.
    c. Profile milling machine.

Column and Knee Type Milling Machines

- Column and Knee type milling machines are most commonly used for general shop floor work, maintenance work, tool room work, etc.
- It has a vertical column on its base.
- The column has machined guide ways on its front face.
- A knee slides up and down on these ways.
- The column serves as housing for speed and feed mechanisms.
- The Knee carries the saddle and worktable.
- There are two types of column and knee type milling machines.
    1. Horizontal type.
    2. Vertical type.
        - In horizontal type, the axis of rotation of arbor is horizontal.
        - In vertical type, the axis of rotation of arbor is vertical.

1. Plain or Horizontal milling machine

- It is a horizontal column and knee type-milling-machine otherwise simply a horizontal milling machine.
- A description of the principle parts of a milling machine is as follows:

♣***Base:***
- It is the foundation of the machine made of grey cast iron.
- All other parts are mounted on it. It also serves as reservoir for cutting fluid.

♣***Column:***
- It is the main support of the machine.
- The motor and other driving mechanisms are housed in it.
- It supports and guides the knee in its vertical travel.

♣***Knee:***
- The knee projects from the column and slides up and down through dove tail guides.
- It supports saddle and the table.
- Elevating screw provides its vertical movement (up and down).

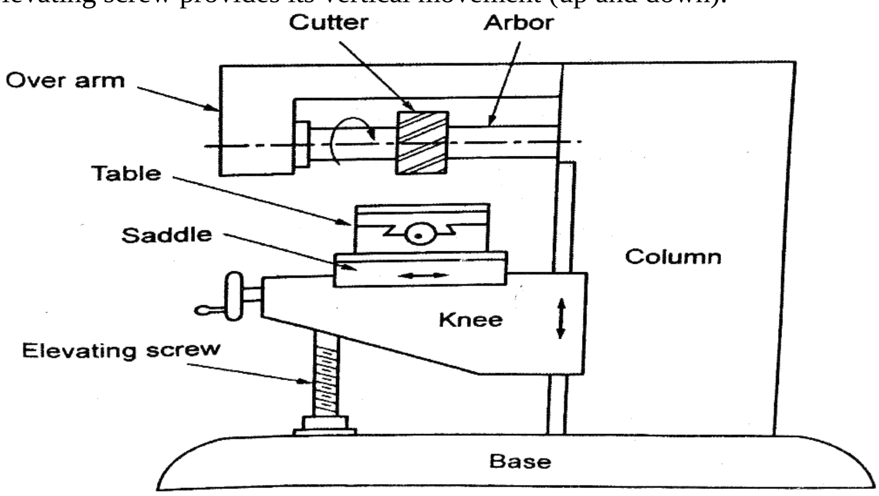


Figure 2 Horizontal milling machine

♣***Saddle:***
- The saddle supports and carries the table and provides traversed movement.

♣***Table:***
- The top surface of the table is accurately machined.
- There are T-slots along the length of the table for holding the work.
- The table rests on the guide ways of the saddle and travels longitudinally in a horizontal plane.
- It supports the work piece, fixtures etc.

♣***Over arm:***

- It is mounted on and guided by the top of the column.
- The over arm is used to hold the outer end of the arbor to prevent it from bending.

♣***Arbor:***

- Arbor is an accurately machined shaft.
- Cutters are mounted on the arbor which is rigidly supported by the over arm, spindle and end braces.
- It is tapered at one end to fit the spindle nose and has two slots to fit the nose keys for locating and driving it.

2. ***Vertical milling machine***

- A vertical milling machine can be distinguished from a horizontal milling machine by the position of its spindle which is vertical or perpendicular to the worktable.
- It carries a vertical column on heavy base.
- The spindle head which is clamped to the vertical column may be swivelled at an angle permitting to work on angular surfaces.
- The over arm in this machine is made integral with the column and carries a housing at its front.
- The machine is used for machining grooves, slots and flat surfaces.
- Generally, vertical milling machine is used to perform end milling and face milling operations.
- The fig. 3 illustrates the vertical milling machine.
- The Knee carries an enclosed screw jack by means of which it is moved up and down along the parallel Vertical guide ways provided on the front side of the column.
- The saddle is mounted on the knee and can be moved along the horizontal guide ways provided on the knee towards or away from the column.
- This enables the table to move in cross direction.
- The table is mounted on guide ways, provided on the saddle; which is in a direction normal to the direction of the guide ways on the knee.
- By means of a lead screw provided under the table, the table can be moved in the longitudinal direction.
- Thus, the work gets up and down movement by the knee, cross movement by saddle and longitudinal movement by the table.
- Power feeds can be employed to both the saddle and the table.
- Mostly face milling cutters and shell-end type cutters are used on these machines.

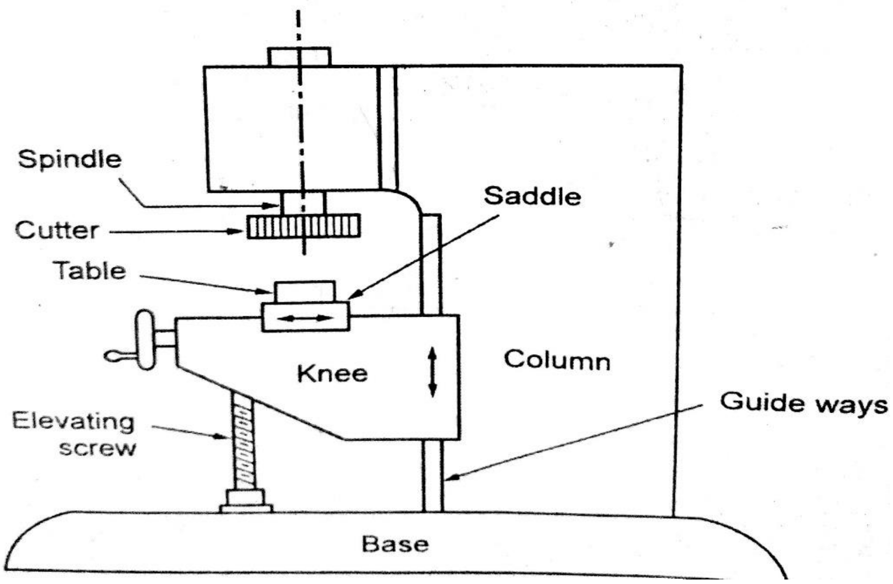


Figure 3 Vertical milling machine

3. ***Universal Milling machine***

- It is the most versatile of all milling machines with its application.
- The use of large number of other machine tools can be avoided.
- In appearance, a universal milling machine is similar to a horizontal milling machine.
- The worktable of this machine is provided with another extra swivel movement with an index or dividing head located at the end of the table.
- Thus, the universal milling machine table has the following movements:
    1. Vertical movement-through the knee.
    2. Cross wise movement-through the saddle.

3. Longitudinal movement of the table.
4. Angular movement of the table-by swivelling the table on the swivel base.

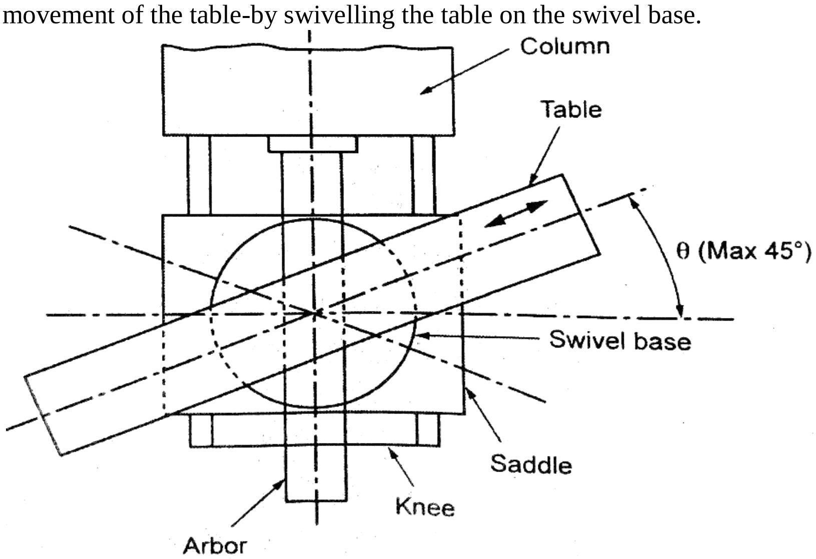


Figure 4 Universal Milling machine

- The swivelling attachments provided on these machines help in cutting spirals, gears and cams in addition to normal milling operations.
- These machines are very accurate and used mainly for tool room work.
- Various controls of a universal milling machine are shown in fig 4.

Comparison between Plain and Universal milling machine

1. In plain milling machine, the table is provided with three movements, longitudinal, cross and vertical. In universal milling machine in addition to these three movements, there is a fourth movement to the table. The table can be swivelled horizontally and can be fed at angle to the milling machine spindle.
2. The universal milling machine is provided with auxiliaries such as dividing head, vertical milling attachment, rotary table etc. Hence, it is possible to make spiral, bevel gears, twist drills, reamers etc. on universal milling machine.
3. The plain milling machine is more rigid and heavier in construction than a universal milling machine.
4. The plain milling machine is used for manufacturing operations whereas universal milling machine is used for tool room work and for special machining operations. Hence generally universal milling machine is used in tool room.

4. Omniversal milling machine

- This is a modified form of a plain (horizontal) milling machine.
- It is provided with two spindles, one of which is in the horizontal plane while the other is carried by a universal swivelling head.
- The latter can be fixed in vertical position or can be set at any desired angle up to 90° on both sides of the vertical plane.
- The knee of this machine can also be swivelled in the horizontal plane.
- Thus, it enables to carry out a large number of operations like spiral grooves in reamers, bevel gears etc.
- Fig 5 shows this type of machine.

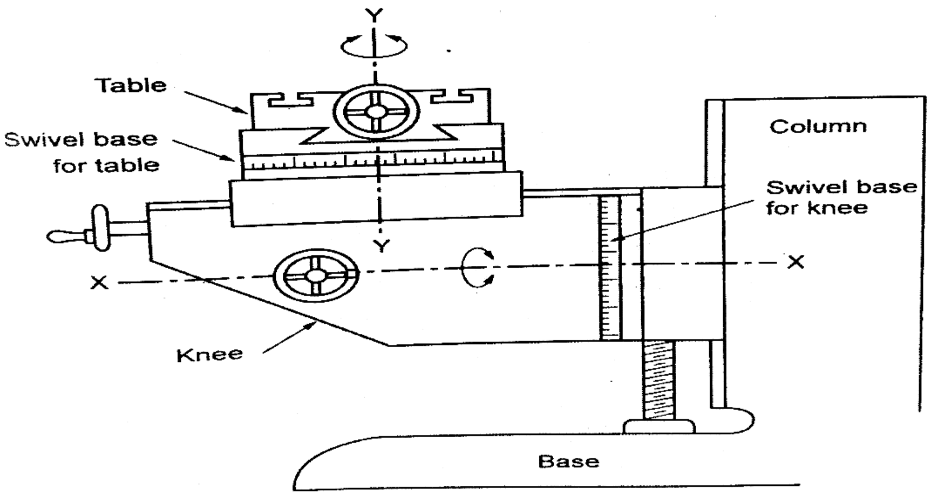


Figure 5 Omniversal milling machine

Bed Type Milling Machine

- These are comparatively large, heavy and rigid in construction.
- The vertical motion is imported to the spindle head instead of the table.
- Depending upon the number of spindle, these are classified as simplex, duplex and triplex machine.

1. ***Fixed bed type simplex milling machine***
    - In a fixed bed plain milling machine, the table is mounted on a fixed bed instead of a saddle and knee as in the case of a plain milling machine.

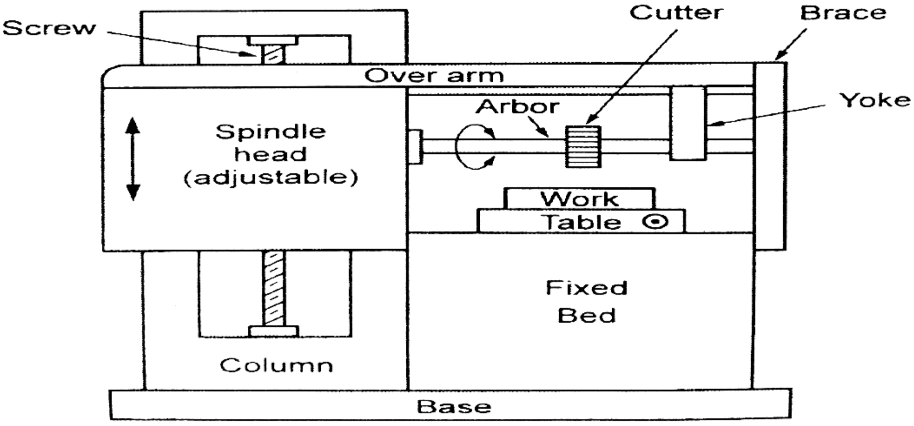


Figure 6 Fixed bed type simplex milling machine

- Since the bed is fixed, it cannot move up, down or crosswise.
- The machine consists of an adjustable spindle head spindle carrier fixed rigidly to the column with parallel vertical ways.
- The spindle head carries the spindles which can be moved up and down along the column ways to adjust the tool in the proper position for carrying out different milling operations.

2. ***Duplex head fixed bed type milling machine***
    - It is another useful form of the fixed bed type milling machine.
    - In appearance, it is similar to the fixed bed type simplex milling machine, except that it carries two vertical column instead of one.
    - The columns are one each on both sides of the fixed bed as shown in fig 7.
    - Both the columns carry parallel vertical ways on which two adjustable spindle heads or spindle carriers are mounted as shown.
    - Both these carriers carry a horizontal spindle each on which cutters can be mounted.
    - The spindle carriers can be adjusted vertically up and down to adjust the cutters to the work.
    - The table has a longitudinal movement only and cannot be moved in any other direction.
    - This machine enables machining of two surfaces simultaneously.

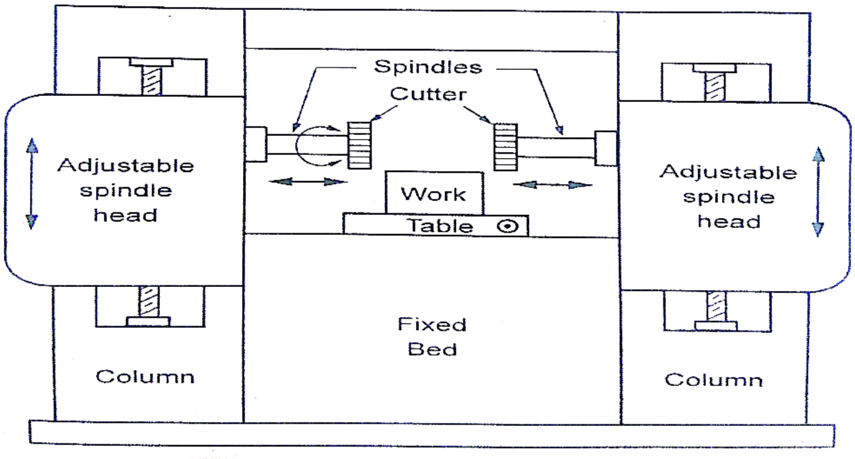


Figure 7 Duplex head fixed bed type milling machine

3. ***Triplex-head fixed bed type milling machine***
    - It is similar in construction and operation to the duplex head- milling machine described above.
    - The only difference lies in the number of spindles.
    - It carries in addition to the two horizontal spindles, one vertical spindle also.
    - Thus, three surfaces can be simultaneously machined on this type of machine.

Planer-Type Milling Machine

- It is similar in appearance and construction to a double housing planer.
- The working principle is also similar to the planing machine.
- The essential difference between a planer and Piano-miller lies in the table movement.
- In planer, the table moves to give the cutting speed but in piano-miller the table movement gives the feed.
- Hence, the table movement in Piano-miller is much slower than that of a planer. The line diagram of Piano-miller is shown in fig 8.
- The machine has a fixed bed.
- The bed has longitudinal guide ways.
- The table reciprocates longitudinally over these guide way.
- There are two vertical columns each provided on each sides of the bed.
- A cross rail slide vertically along the column guide ways.
- The cross rail carries vertical cutter heads.
- These cutter heads can slide along the cross rail.
- There are two cutter heads mounted on the vertical columns.
- These can slide over vertical guide ways on the column.
- The work can be machined in four different ways according to requirements as follows:
    a. By moving the table and rotating the cutters in position.
    b. By keeping the table stationary and feeding the cutters by moving the milling heads.
    c. By moving the table and the milling heads simultaneously.
    d. By keeping the table stationary and moving the cross-rail downwards and also the side cutters up and down.
- All the four cutter heads can be used to machine the work surfaces at a time.
- The cutter heads can also be swivelled for machining angular surfaces.
- This machine is used for heavy duty production work such as lathe bed ways, other machine bed ways etc. table can be given the longitudinal and cross feeds simultaneously or independently as desired.
- The simultaneous feeding enables the diagonal motion.
- A template which is the replica of the shape to be produced is fitted to the machine.
- The contact finger or hydraulic tracer unit or tracer head makes a light contact with the contours of the template and guides the cutter movement, synchronizing with the table movement, to produce a similar machined surface as on the template.

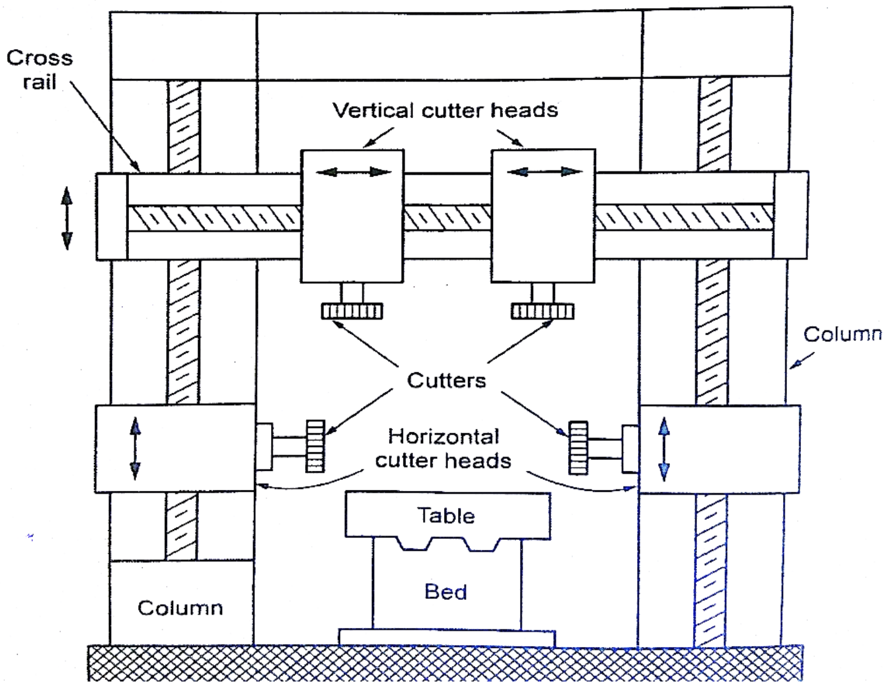


Figure 8 Planer-Type Milling Machine

WORK HOLDING DEVICES

The following work holding devices are used for clamping the work in the milling machine.

1. ‘T’ bolts and clamps
2. Angle plates.
3. ‘V’ blocks
4. Machine vises.
5. Milling fixture.
6. Dividing heads.

Clamping the work piece by using ‘T’ bolts and clamps, angle plate and ‘V’ block is already explained in the shaper. Machine vise (plain type) is also explained in planner.

1. ***Swivel vise***

- This vise has a circular base graduated in degrees.
- The base is clamped on the table by using 'T' bolts.
- The vise is swivelled over the swivel base after loosening the clamping bolt.
- After setting the vise to the required angle, the clamping bolts are tightened.

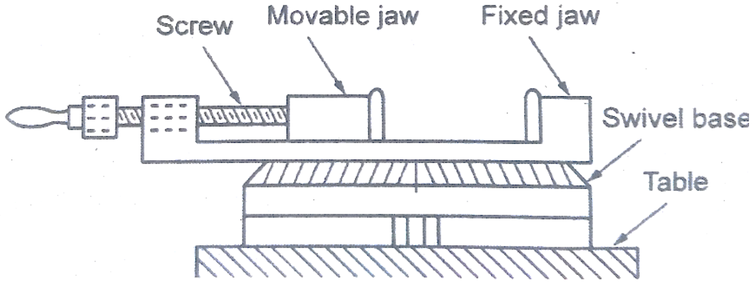


Figure 9 Swivel vise

2. ***Universal vise***

- The universal vise can be tilted in a horizontal and vertical plane.
- There is a horizontal swivel base on the base of the vise which is used for tilting the vise in a horizontal plane.
- Over the horizontal swivel base, a vertical swivel arrangement is provided.
- It is used to tilt the vise body to a certain degrees.
- This vise is not rigid in construction.
- It is mainly used in tool rooms.

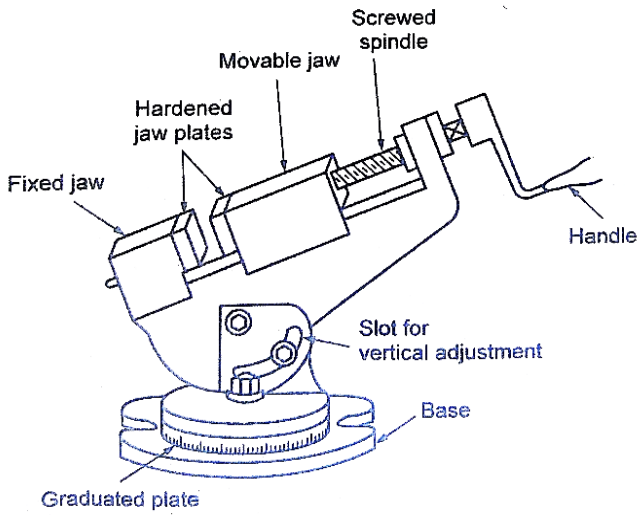


Figure 10 Universal vise

3. ***Indexing or dividing head***

- It is a device which is used for dividing the periphery at the work pieces into any number of equal divisions.
- The process of dividing the periphery of work is called indexing.
- Indexing is essential for cutting gears, splines, equally spaced grooves, hexagonal heads etc.
- The indexing bead has a headstock arid a tailstock.
- The work piece is held between the centres of headstock and a tailstock.
- Short work pieces are held in a chuck fitted to the head stock spindle.
- The work piece can be indexed by rotating the crank in the headstock.
- The crank movement is transmitted to the work piece through a worm and worm wheel.
- The indexing plate is used to rotate the crank to a required angle.

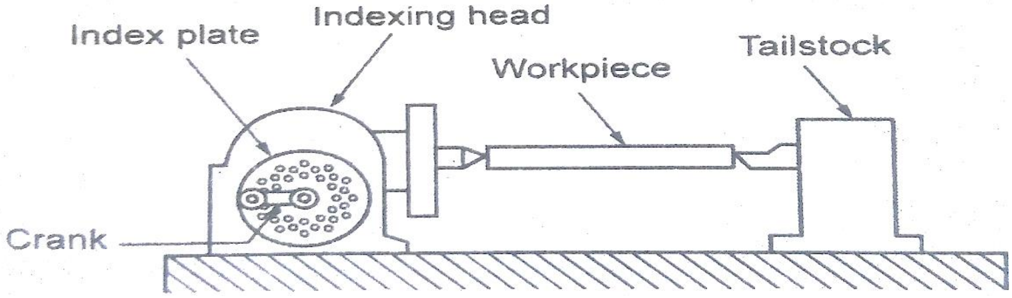


Figure 11 Indexing or dividing head

4. *Milling fixture*

- The milling fixtures are used when the above discussed holding devices are not suitable for production work, mass production and for accurate location of jobs.
- These are especially useful when a large number of identical parts are to be produced.
- The use of fixtures minimizes loading, locating, clamping and unloading time.
- Depending upon the design requirement, different types of fixtures are used on milling machine.

TOOL OR CUTTER HOLDING DEVICES

Depending upon the design of the cutter, the following cutter holding devices are used on milling machines:

1. Arbors.
2. Adaptors.
3. Collets.

1. *Arbors*

- There are two types of arbors used in milling machines.

(a) <u>Standard arbor:</u>

- o Cutters having a central bore are mounted on the standard arbor of a milling machine.
- o It is a long slender shaft. It has a taper shank at one end.
- o The shank has internal thread.
- o A draw bolt holds the arbor in position.
- o The draw bolt is introduced into the spindle bore from the back of the milling machine column.
- o The draw bolt is screwed in the threaded hole 6f the arbor.
- o The draw bolt is used to pull in or push out the arbor from the spindle.
- o The slots on the flange of the arbor engage the driving lugs of the spindle.
- o A key runs for the whole length of the arbor.
- o It is to fix the cutter and to get positive drive of the cutter.
- o The arbors are provided with a set of spacing collars.
- o The spacing collets are used to set the cutter in the required position.
- o The arbor is supported at the other end by the yoke of the milling machine.
- o The yoke can be adjusted on the over arm.
- o At the end of the arbor, a bearing bush is inserted. It rests on the yoke.

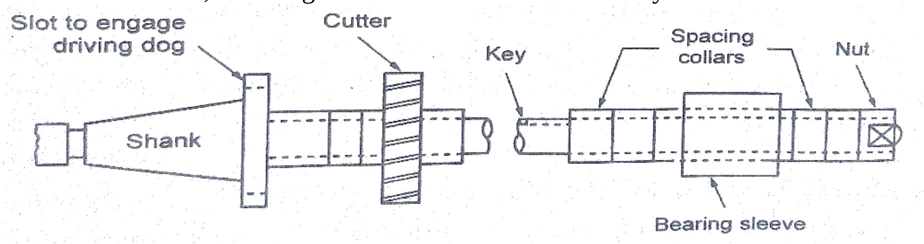


Figure 12 Standard arbor

(b) <u>Stub arbors:</u>

- o It is a short arbor.
- o Its construction is Similar to standard arbor.
- o But it is has a short shaft to hold the cutter.
- o Its taper shank fits in to the taper hole of the spindle.

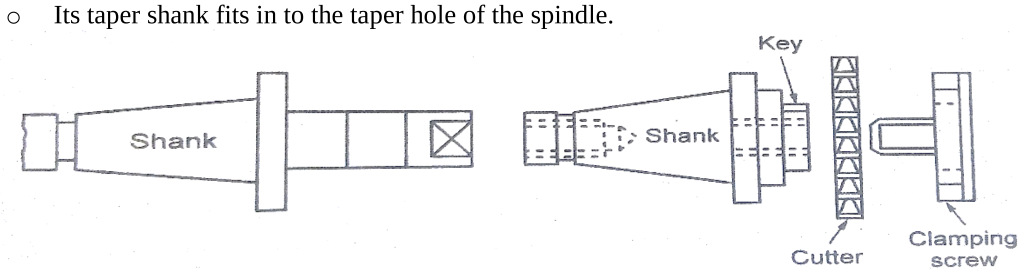


Figure 13 Stub arbors

- o The draw bolts are used to pull the arbor tightly and hold the arbor in position.
- o The flange of the arbor is clamped to the spindle nose to give positive drive.
- o One or two spacing collets are used to set the cutter in position.
- o A clamping screw may be used to fit the cutter in the arbor, when face and side milling cutters are used.

2. *Adaptor*

- Many cutters have tapered shank.
- If the size of the shank is smaller than that of the hole in the spindle nose, adaptors are used to hold these cutters.

- It has internal taper hole to receive the taper shank of the cutter, it has external taper corresponding to the spindle nose hole taper.
- Flange of the adaptor is made to have two slots to engage the driving dogs of the spindle.
- The rear end of the adaptor carries internal threads to engage the threaded front end of the draw bar.
- It is held in the spindle in the same way as the arbor.

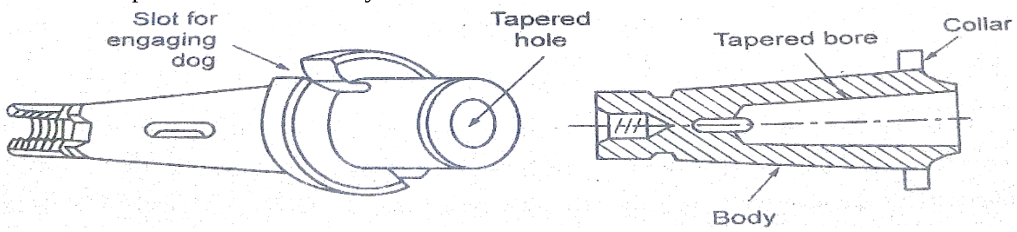


Figure 14 Adaptor

3. ***Spring collet***
   - Milling cutters which carry straight shanks held in a collet chuck carrying a spring collet.
   - Fig 15 illustrates the construction of a spring collet and collet chuck.
   - The collet chuck has a taper shank to fit in to the milling machine spindle.
   - It has internal threads for tightening it with the spindle by means of draw bolt.
   - It has an external threaded body.
   - The body has a taper hole to receive the collet.
   - The tapered portion of the spring collet is splitted by three equally spaced slots.
   - The collet has a cylindrical hole to receive the straight shank of the cutter.
   - A special nut fits over the taper of the collet and the threaded portion of the chuck.
   - When this nut is tightened, the split jaws of the collet close over the straight shank of the cutter.
   - Thus, the tool is held firmly on the collet.

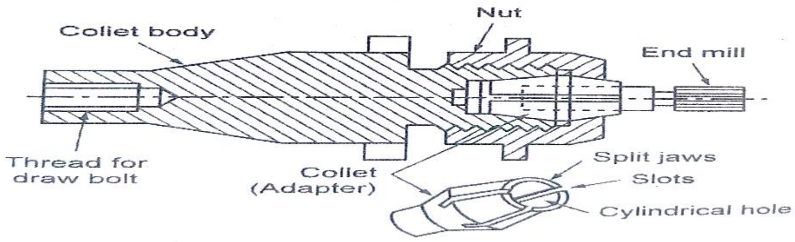


Figure 15 Spring collet

MILLING MACHINE ATTACHMENTS

- Many standard or special auxiliary devices are used on a milling machine for augmenting the range, versatility, productivity and accuracy of operation.
- Some milling attachments are used for positioning and driving the cutter by altering the axis of rotation.
- Other devices are used for positioning, holding and feeding the work.
- We now discuss various attachments used on milling machines.

1. ***Vertical Milling Attachment***
   - It is an attachment used for converting a horizontal.
   - Milling machine into a vertical milling machine by orienting the cutting spindle axial from the horizontal to the vertical position.
   - A vertical milling attachment is used for vertical milling operations with large end mills and face mills.
   - The spindle head can be swivelled to any degree for milling operations.

2. ***Universal Milling Attachment***
   - The spindle of a universal milling attachment can be swivelled about two mutually perpendicular axes and set at any angle in both planes.
   - In other respects it is similar to a vertical milling attachment.
   - This attachment is especially useful when the spindle needs to be set at an angle to the table for angular milling.

3. ***High Speed Milling Attachment***
   - A high speed milling attachment consists primarily of a number of gears (4 to 6) enclosed in a casing for increasing the normal speed of the milling machine spindle.
   - It is used to obtain the correct cutter speed for small milling cutters.

4. ***Rotary Attachment***
   - A rotary attachment is also known as a circular milling attachment.

- It is used for a variety of circular milling operations such as segment outlines, spline slotting segmental milling and die making jobs.
- The attachment consists of a rotary table which is mounted on top of the machine table and provides rotary motion to the work piece.
- The circular table may be rotated by hand or with the help of power by linking the rotary table mechanism with the lead screw.
- The circumference of the table is graduated in degrees for accurate work.

5. ***Slotting Attachment***
   - The slotting attachment consists of a tool slide and an eccentric or crank housed within the attachment.
   - It converts rotary motion into reciprocating motion making the machine operate like a slotter.
   - It is largely used for making tools, keyways and splines.
   - The attachment can be set at any angle from 0 to 90°.

6. ***Rack Milling Attachment***
   - The attachment consists of a gear train and enables the spindle axis to be oriented at right angles to the machine spindle.
   - It is used for cutting rack teeth but can also be used in conjunction with the universal spiral index for cutting worms and other miscellaneous operations.

7. ***Universal Spiral Milling Attachment***
   - It is a device used principally for milling helical and spiral gear teeth.
   - The attachment is used on a plain or universal milling machine by bolting on the face of the column.
   - It is suitable for vertical and angular milling for cutting worms and grooves on milling cutters and twist drills.

MILLING CUTTERS

Classification of Cutters

These are multi tooth rotary cutting tools generally made of high speed steel or sintered carbides. Milling cutters are classified into different ways.

According to the shape of the tooth, milling cutters are classified as

i) Milled tooth cutters.
ii) Form relieved cutters.

According to the type of operation.

i) Plain milling cutters.
ii) Side milling cutters.
iii) End mill cutters.
iv) Angle milling cutters.
v) T-slot milling cutters.
vi) Slitting saws.
vii) Form milling cutters.
viii) Fly cutters.
ix) Wood ruff key slot milling cutter.

According to the way of mounting on the machine.

i) Arbor cutters.
ii) Shank cutters.
iii) Face cutters.

1. ***Plain milling cutter***
   - This is also known as a mill cutter.
   - It is a disc or cylindrical shaped cutter having teeth on its circumference.
   - If is used to machine flat surface parallel to its axis.
   - There are two types of plain milling cutters commonly used.
     i) Plain straight teeth cutter.
     ii) Plain milling helical teeth cutter.
   - The plain milling cutters having the width more than its distance is called slab mill cutter.
   - This is used for rough machining with coarse feed.
   - The cutter has less number of teeth.

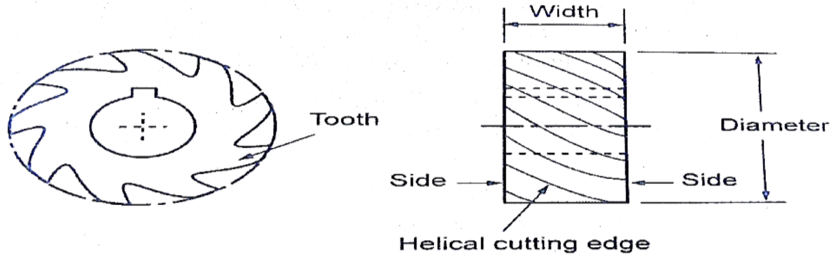


Figure 16 Plain milling cutter

- Straight teeth plain milling cutters are used for light operations.
- Helical teeth cutters are used for heavy cut operations.
- Cutters of various diameters arid widths are available.
- Roughing cutters will have less number of teeth.
- Finishing cutters will have more number of teeth for the same diameter.

2. *Side milling cutter*

- It has cutting edges on its periphery and also on the sides.
- This cutter is used for removing metal from the side of the work pieces.
- It is also used for cutting slots.
- These cutters may have plain, helical or staggered teeth.
- Among these three, helical cutters are preferred on milling machines since they require less power for machining.
- And also it provides smoother operation as more than one tooth performs a milling operation at a time.

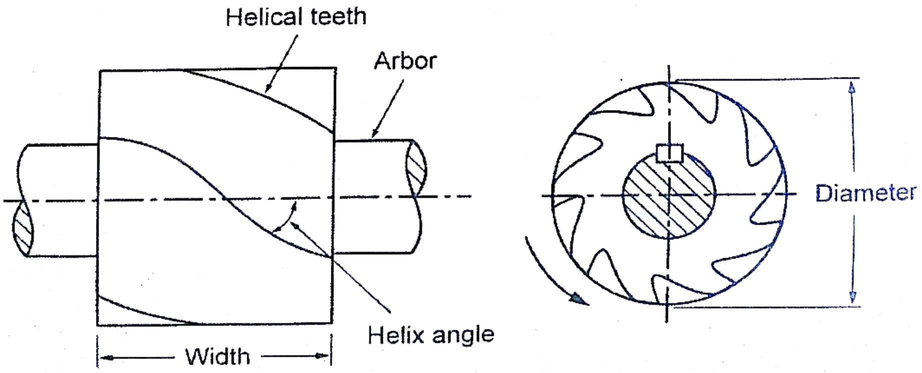


Figure 17 Side milling cutter

3. *End milling cutters*

- The end milling cutters have cutting teeth on the end as well as on the periphery of the cutter.
- The peripheral teeth may be straight or helical.
- It is similar in construction to a twist drill or reamer.
- These cutters are generally provided with a shank on one end.
- The shank may be of straight or tapered.
- Tapered shank cutters are fitted to the spindle using adapters.
- Straight shank cutters are fitted to the spindle using collets.
- End mills are commonly used for vertical milling operations.
- They are used for light milling operations like cutting slots, machining accurate holes and profile milling.

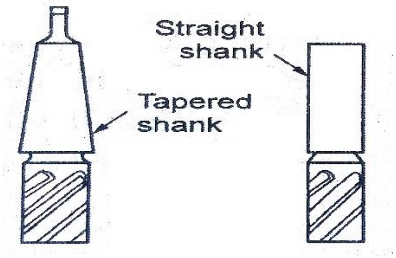


Figure 18 End milling cutters

4. *Angle milling cutters*

- All cutters which have their cutting teeth at an angle to the axis of rotation are known as angular cutters.
- Their specific use in milling V - grooves, notches, dove tail slots, reamers teeth and other angular surfaces.
- Angular cutters are classified as single angle cutters and double angle cutters.
- Single angle cutters may have their teeth either only on the angular face or on both, the angular face and the side.
- The later type enables milling of both the flanks of the inclined angular groove simultaneously.
- Their teeth may have an included angle of 45° to 60°.
- Double angle cutters differ from single angle cutters in such a way that they have two angular faces which join together to form V-shaped tooth.
- The included angle of this 'V' is either 45°, 60° or 90°. Angle of both sides should be equal.

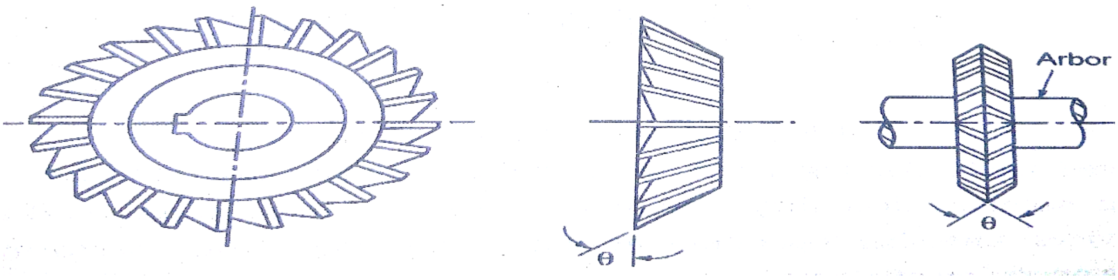


Figure 19 Angle milling cutters

5. ***T-slot milling cutter***

- It is a single operation cutter which is used only for cutting T- slots.
- The arrangement of cutting teeth is similar to that of a side-lining cutter.
- But this cutter has a tapered shank.
- A neck is formed between, the cutting face and the shank.
- The cutter has cutting edges on its periphery and on its sides.

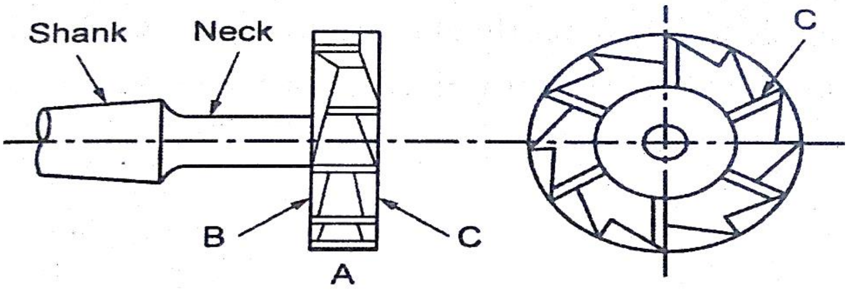


Figure 20 T-slot milling cutter

6. ***Slitting saws***

- These are very thin cutters in varying in thickness from 0.5 to 5mm.
- They are used for cutting deep slots and parting off materials into pieces.
- These cutters are thinner at the centre than at the edges to provide clearance and reduce friction.

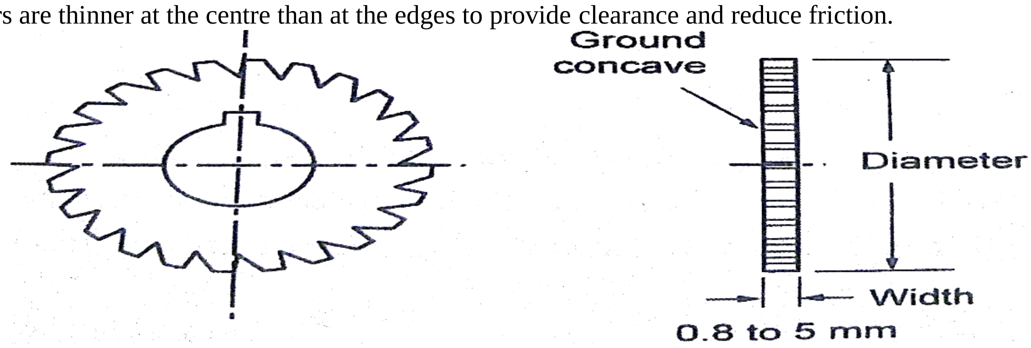


Figure 21 Slitting saws

7. ***Form milling cutter***

- Concave milling cutter has teeth curved inwards on its periphery.
- The cutter will produce a convex semi-circular surface on the work piece.
- Convex milling cutter has teeth curved outward on its periphery.
- The cutter will produce a concave semi-circular surface on the work piece.
- Gear cutters have formed cutting edges.
- The shape of the cutter teeth is involute.
- The cutter will produce groove of involute shape.
- The involute gear tooth is formed between two grooves milled by the cutter.
- The profile of the gear tooth depends upon the module and the number of teeth on the gears.
- Therefore, for cutting different number of gear teeth of same module, different cutters are required.
- Corner rounding cutters are used for milling the edges and corners of the jobs to a required radius.

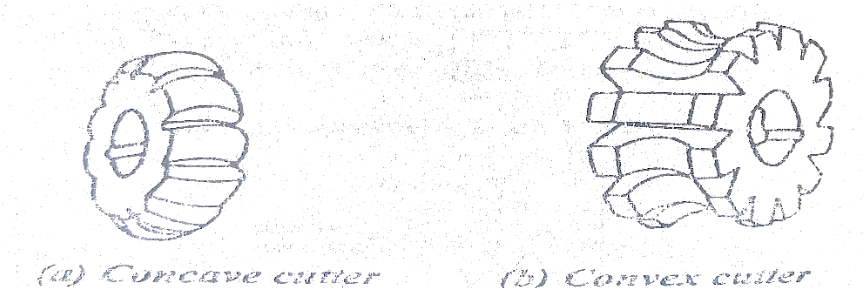


Figure 22 Form milling cutter

8. ***Fly cutters***
   - It is, actually a single point tool which is used in milling machine when standard cutters are not available.
   - It is either mounted, on a cylindrical body held in a stub arbor or held in a bar.
   - Screws are used for tightly holding the tool in the above holders.
   - The cutting edge of the tool is ground to the required shape.
   - The cutter removes metal when it rotates.

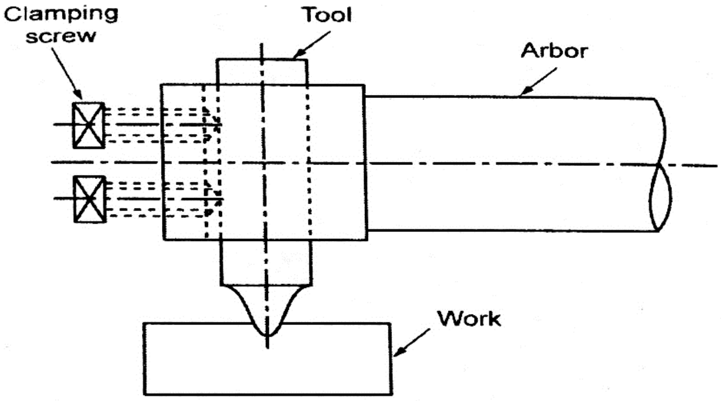


Figure 23 Fly cutters

9. ***Woodruff key slot milling cutter***
   - It is a small type of end milling cutter which is similar to plain and bide mills.
   - It has a taper shank and a neck.
   - The cutter may have straight or staggered teeth.
   - The sides of the cutter are ground concave.
   - This provides clearance for the cutter movement.
   - It is used to cut woodruff key slot in a shaft.

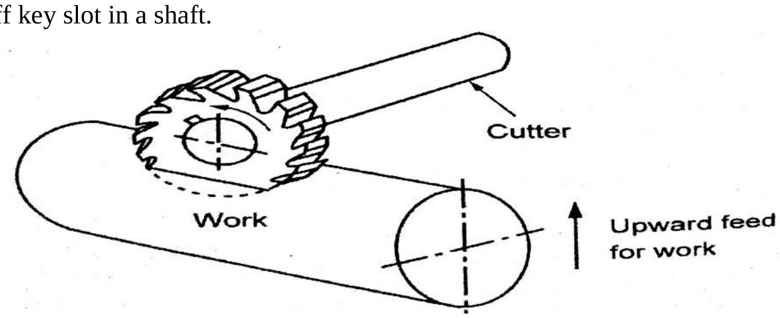


Figure 24 Woodruff key slot milling cutter

Nomenclature of Plain Milling Cutter

- Fig 25 shows the principle parts and angles of a plain milling cutter. The various elements of a plain milling cutter are as follows:

1. ***Body of cutter***
   - The main frame of the cutter on which the teeth rests to form an integral part is' known as body of the cutter.

2. ***Cutting edge***
   - The edge formed by the intersection of the teeth and the circular land of the surface left by the provision of primary clearance is known as cutting edge.

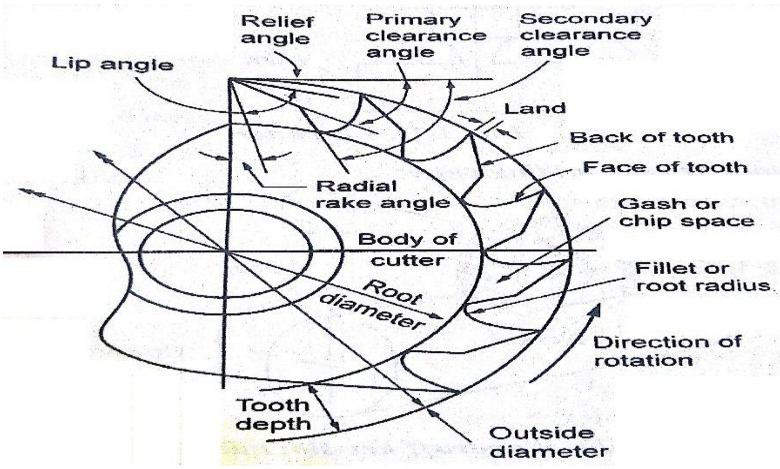


Figure 25 Nomenclature of Plain Milling Cutter

3. ***Face***
   - The portion of the gash adjacent to the cutting edge on which the chip impinges as it is cut from the work.

4. ***Fillet***
   - The curved surface at the bottom of gash which joins the face of one tooth to the back of the tooth immediately ahead.

5. ***Gash***
   - The chip space between the back of one tooth and the face of the next tooth.

6. ***Lead***
   - The cutter advances the distance in one complete revolution or turn.

7. ***Land***
   - The part of the back of tooth adjacent to the cutting edge which is relieved to avoid interference between the surface being machined and the cutter.

8. ***Outside diameter***
   - The diameter of the circle passing through the peripheral cutting edge.

9. ***Root diameter***
   - The diameter of the circle passing through the bottom of the fillet.

10. ***Cutter Angles***
    - A milling cutter is provided with a rake, clearance and other putting angles for the efficient removal of chips. The different angles provided on cutters are now discussed.

    i) Clearance Angle:
    - There are two types of clearance angles on a milling cutter-primary clearance and secondary clearance angle.

    (a) <u>Primary clearance angle:</u>
    - ⇒ This is the angle between the surface of a land and a tangent to the periphery at the cutting edge.
    - ⇒ It is provided on the cutter to prevent the back of the tooth from rubbing against the job.
    - ⇒ Depending upon the size of the cutter, the primary clearance angle varies from 3° to 12°.

    (b) <u>Secondary clearance angle:</u>
    - ⇒ This is the angle formed by the secondary clearance surface of the tooth and the tangent to the periphery at the cutting edge.
    - ⇒ It is usually 3° greater than the clearance angle.

    ii) Relief angle:
    - The angle between the land of a tooth and the tangent to the outside diameter at the cutting edge is known as relief angle.

    iii) Rake:
    - A milling cutter so ground that the surface against which the chips bear while being served. The inclination is in such a way that the keenness of the cutting edge increases. Rake angles are classified as zero, positive or negative.

    (a) <u>Zero Rake:</u>
    - ⇒ When the radial line and tooth face coincide, the cutter is said to have a zero rake.

    (b) <u>Positive rake:</u>
    - ⇒ If the face and tooth of a cutter are on the same side of the radial line, the cutter is said to have a positive rake,

    (c) <u>Negative rake:</u>
    - ⇒ If the face of the tooth and the tooth body are on opposite sides, the cutter is said to have a negative rake.

iv) Helix angle:
- The inclination of a helical curve relative to its axis.

v) Axial Rake Angle:
- The line between the line of the peripheral cutting edge and the axis of the cutter.

vi) Lip Angle:
- The included angle between the land and the face of the tooth.

MILLING PROCESSES

- Milling processes can be broadly grouped into peripheral milling and face milling.
- In peripheral milling, the milled surface is parallel to the cutter axis.
- In the face milling, the milled surface is at right angles to the cutter axis.

Peripheral Milling

- In peripheral milling, the appearance of the surface and the type of chip formation are affected by the direction of cutter rotation relative to the movement of the work piece.
- The peripheral milling process is classified into two types.
  i) Up milling or Conventional milling, and
  ii) Down milling or climb milling.

1. Up milling or Conventional milling

- Fig 26 illustrates the conventional or up milling of milling process where the cutter rotates opposite to the direction of feed of the work piece.
- In up milling, the chip thickness is minimum at the beginning of the cut.
- It reaches the maximum at the end of the cut.
- So the stress on the teeth is minimum at the beginning of the cut and it increases gradually to the maximum at the end of the cut.
- In up milling, friction and rubbing occur as the insert enters into the cut thereby resulting chip welding and heat dissipation into the insert and work piece.
- The cutting forces in up milling are generally directed upwards as shown in fig 26 and this tends to lift the work piece from the table.
- Conventional milling is preferred over climb milling in stich cases where backlash or clearance exists in the feed mechanism or in machining situations where the depth of cut varies excessively.
- For example milling of castings or forgings with very rough surfaces due to sand inclusion or with scale.

  Advantages
  1. It does not require a backlash eliminator.
  2. Safer operation due to separating forces between cutter and work
  3. Less wear on feed screw and nut due to the absence of pre- load.
  4. Milled surface does not have built up edge.

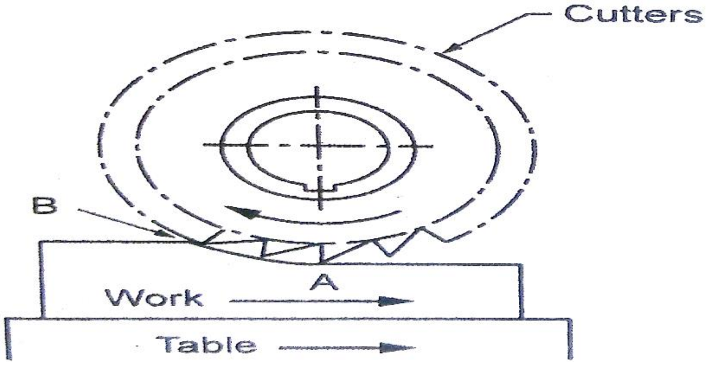


Figure 26 Up milling

2. Down or Climb milling

- In this method of milling, the cutter rotates in the same direction of travel of the work piece as shown in fig 27.
- The thickness of the chip is maximum at the beginning of the cut. The chip thickness decreases to the minimum at the end of the cut.
- So, the stress, is maximum at the beginning of the cut. This gives the shock load to the teeth, the cutting [action of the teeth presses the work piece downwards.
- Therefore, the Mixture design becomes easier as the force tends to seat the work firmly in the work holding devices.
- The chips are also disposed off easily and do not interfere with the cutting.
- The coolant can be poured directly at the cutting zone.
- It results in improved surface finish and diminishes the heat generated.

  Further advantages
  a. Cutter with higher rake angles can be used. This reduces power requirements.
  b. Cutter wear is less because chip thickness is maximum at the start of the cut.

c. Finishing is generally good because the rubbing action with chip, is eliminated.

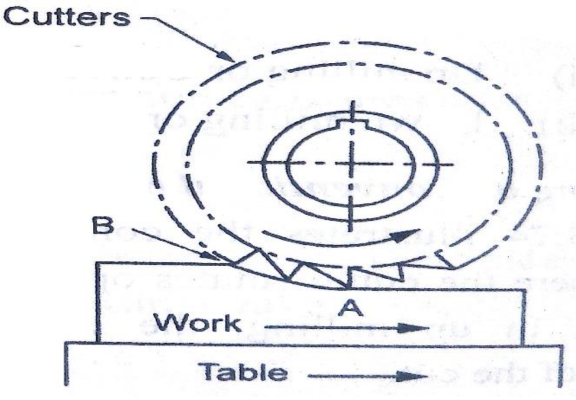


Figure 27 Climb milling

Face Milling

- Face milling is the operation performed by a milling cutter to produce flat-machined surfaces perpendicular to the axis of rotation.
- The peripheral cutting edges of the cutter do the actual cutting whereas the face milling cutting edges finish up the work surface by removing a very small amount of materials.

MILLING OPERATIONS

- A large variety of components are machined on a milling machine involving various types of operations.
- These operations are broadly classified as:
    1. Plain or slab milling.
    2. Face milling.
    3. Angular milling.
    4. Straddle milling:
    5. Gang milling.
    6. Form milling.
    7. End milling.
    8. T-slot milling.
    9. Gear cutting.

1. ***Plain or Slab Milling***
    - Plain or slab milling is the operation of producing flat horizontal surface parallel to the axis of the cutter using a plain or slab milling cutter as shown in fig 28.

    .

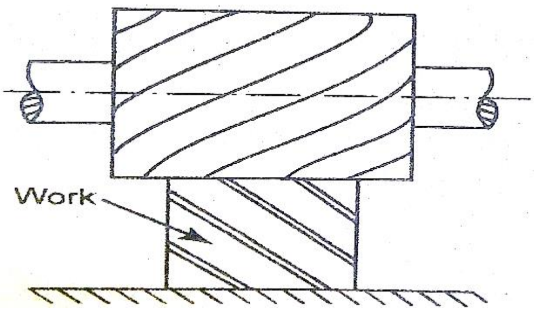


Figure 28 Plain or Slab Milling

2. ***Face Milling***
    - Face milling is the operation of producing flat surface on the face of the work piece which is at right angle to the axis of rotation of the face milling cutter.

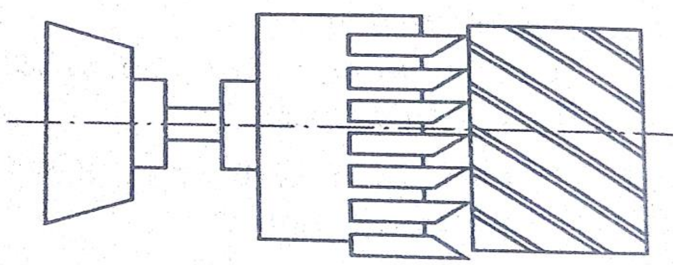


Figure 29 Face Milling

3. Angular or Bevel Milling

- It is the operation of machining a flat surface at an angle, other than right angle to the axis of the revolving cutter.
- The cutter used may be a single or double angle cutter, depending upon whether a single surface is to be machined or two mutually inclined surfaces simultaneous.

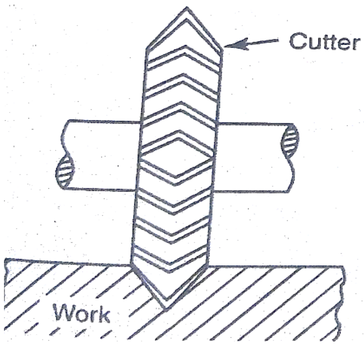


Figure 30 Bevel Milling

4. Straddle Milling

- Straddle milling operation is the production of two vertical flat surfaces on the both sides of the job by using two side milling cutters which are separated by collars.
- Straddle milling is very commonly used for milling square and hexagonal surfaces.

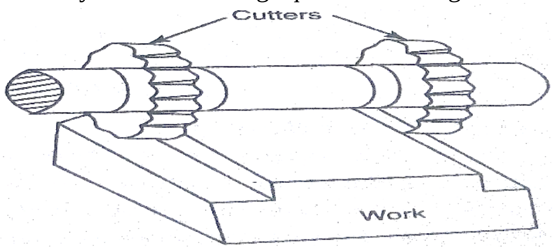


Figure 31 Straddle Milling

5. Gang Milling

- Gang milling is the production of many surfaces of a job simultaneously by feeding the table against a number of required cutters.
- Fig 32 shows a gang of three side milling cutters and two plain milling cutters which are fitted to the arbor.
- The two plain milling cutters have helical teeth of opposite hands.
- This method of operation saves machining time and hence is widely used in mass production.

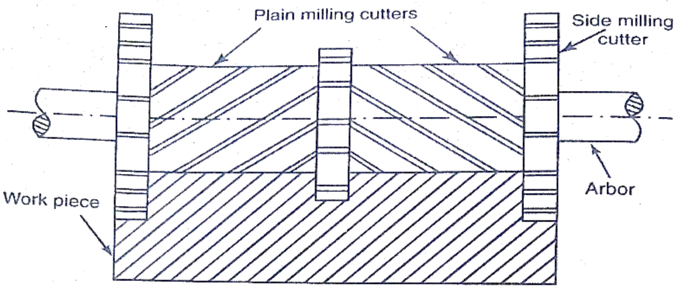


Figure 32 Gang Milling

6. Form Milling

- It is the operation of producing irregular surfaces or contours by using required form cutters.
- The irregular contour may be convex, concave or any other shape. The form milling operation is illustrated in fig 33.

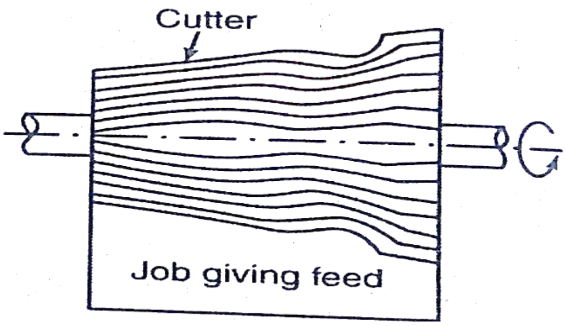


Figure 33 Form Milling

7. ***End Milling***

- It is the operation of producing both peripheral and face milling operations simultaneously, generates vertical, horizontal or angular surfaces by using an end milling cutter.
- It is used for milling slots, grooves, keyways etc.

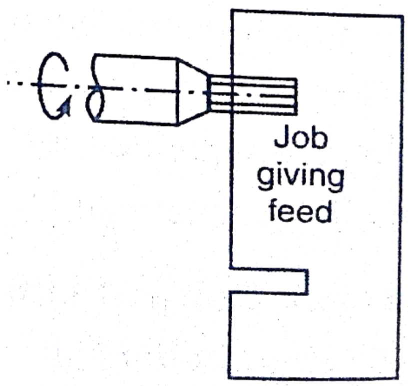


Figure 34 End Milling

8. ***T-Slot Milling***

- Milling of T-slot is produced in two or three stages.
- In the first operation, the end milling operation or a plain slot is made by using an end-milling cutter.
- In second operation, T-slot is made by using the T-slot cutter to enlarge the slot and to mill the bottom face of the slot as shown in fig 35.

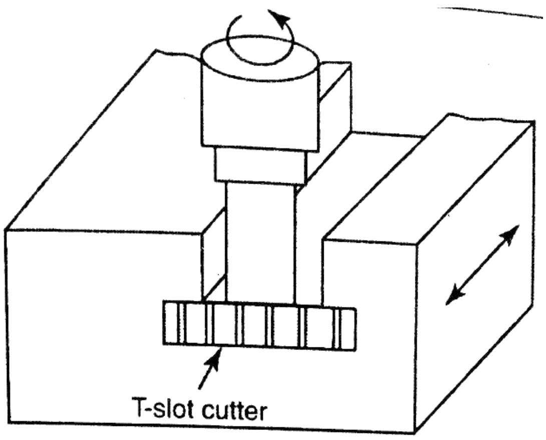


Figure 35 T-Slot Milling

9. ***Gear Cutting***

- The gear cutting operation involves cutting of different types of gears on a milling machine.
- It is performed.by using a form relieved cutter which is having the profile corresponding to the required tooth space of the gear.
- Equally spaced gear teeth are cut on a gear blank by holding the work on a universal dividing head and then indexing it.
- The detailed description of gear cutting is discussed in further articles.
- Fig 36 illustrates the gear cutting process.

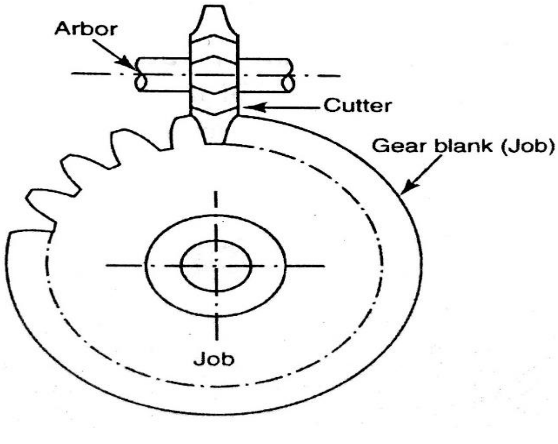


Figure 36 Gear Cutting

UNIT V

❖ METAL CUTTING AND CUTTING TOOLS

- ✓ Metal cutting or traditional machining processes are also known as conventional machining processes.
- ✓ These processes are commonly carried out in machine shops or tool room for machining cylindrical or flat jobs to a desired shape, size and finish on a rough block of job material with the help of a wedge shaped tool.
- ✓ The cutting tool is constrained to move relative to the job in such a way that a layer of metal is removed in the form of a chip.
- ✓ General metal cutting operations are shown in fig.
- ✓ These machining processes are performed on metal cutting machines, more commonly termed as machine tools using various types of cutting tools (single or multi-point).
- ✓ A machine tool is a power driven metal cutting machine which assist in managing the needed relative motion between cutting tool and the job that changes the size and shape of the job material.
- ✓ In metal cutting (machining) process, working motion is imparted to the workpiece and cutting tool by the mechanisms of machine tool so that the work and tool travel relative to each other and machine the workpiece material in the form of shavings (or swarf) known as chips.

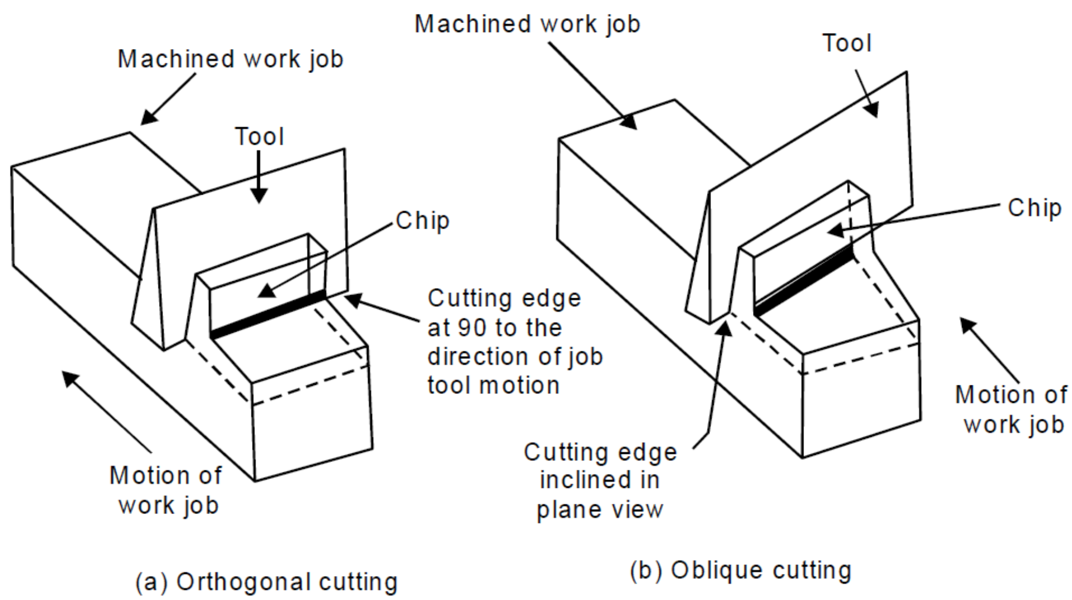


Fig. Metal cutting operation

- ✓ The machine tools involve various kinds of machines tools commonly named as lathe, shaper, planer, slotter, drilling, milling and grinding machines etc.
- ✓ The machining jobs are mainly of two types namely cylindrical and flats or prismatic.
- ✓ Cylindrical jobs are generally machined using lathe, milling, drilling and cylindrical grinding whereas prismatic jobs are machined using shaper, planner, milling, drilling and surface grinding.

- ✓ In metal cutting operation, the position of cutting edge of the cutting tool is important based on which the cutting operation is classified as
- ✓ Orthogonal cutting and
- ✓ Oblique cutting.
- ✓ Orthogonal cutting (fig.) Is also known as two dimensional metal cutting in which the cutting edge is normal to the work piece.
- ✓ In orthogonal cutting no force exists in direction perpendicular to relative motion between tool and work piece.
- ✓ Oblique cutting (fig.) Is the common type of three dimensional cutting used in various metal cutting operations in which the cutting action is inclined with the job by a certain angle called the inclination angle.

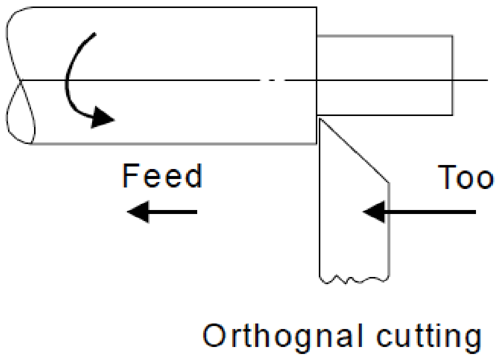


Fig. Orthogonal cutting

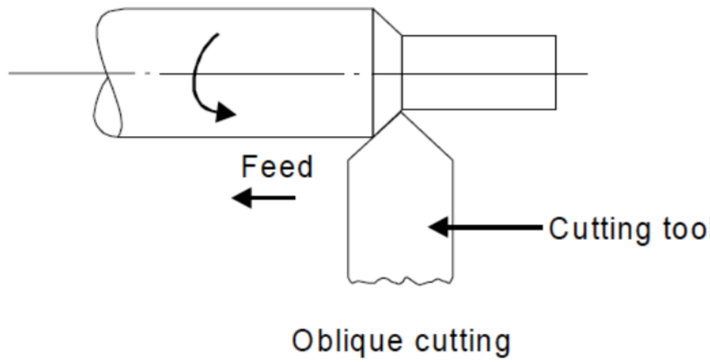


Fig. Oblique cutting

Cutting tool

- ✓ Cutting tools performs the main machining operation.
- ✓ They comprise of single point cutting tool or multipoint cutting tools.
- ✓ It is a body having teeth or cutting edges on it.
- ✓ A single point cutting tool (such as a lathe, shaper and planner and boring tool) has only one cutting edge, whereas a multi-point cutting tool (such as milling cutter, milling cutter, drill, reamer and broach) has a number of teeth or cutting edges on its periphery.

Mechanics of metal cutting

- ✓ The work piece is securely clamped in a machine tool vice or clamps or chuck or collet.
- ✓ A wedge shape tool is set to a certain depth of cut and is forced to move in direction as shown in figure.
- ✓ All traditional machining processes require a cutting tool having a basic wedge shape at the cutting edge.
- ✓ The tool will cut or shear off the metal, provided
- ✓ The tool is harder than the metal
- ✓ The tool is properly shaped so that its edge can be effective in cutting the metal

- ✓ The tool is strong enough to resist cutting pressures but keen enough to sever the metal, and
- ✓ Provided there is movement of tool relative to the material or vice versa, so as to make cutting action possible.
- ✓ Most metal cutting is done by high speed steel tools or carbide tools.
- ✓ In metal cutting, the tool does not slide through metal as a jack knife does through wood, not does the tool split the metal as an axe does a log.
- ✓ Actually, the metal is forced off the work piece by being compressed, shearing off, and sliding along the face of the cutting tool.
- ✓ The way a cutting tool cuts the metal can be explained as follows.
- ✓ All metals in the solid state have a characteristic crystalline structure, frequently referred to as grain structure.
- ✓ The grain or crystals vary in size from very fine to very coarse, depending upon the type of metal and its heat-treatment.
- ✓ The cutting tool advances again in the work piece.
- ✓ Heavy forces are exerted on the crystals in front of the tool face.
- ✓ These crystals, in turn exert similar pressures on crystals ahead of them, in the direction of the cut or force applied by the cutter.

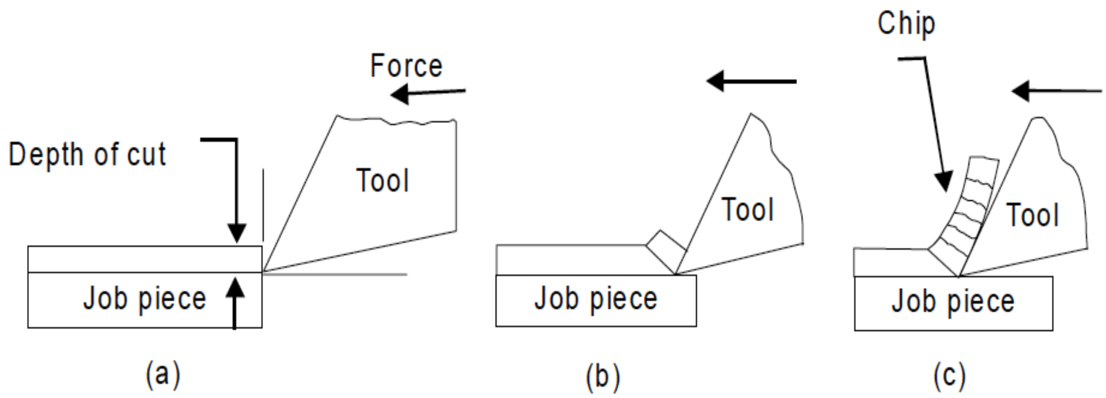


Fig. Metal cutting operation

- ✓ As the tool continues to advance, the material at sheared point is sheared by the cutting edge of the tool or it may be torn loose by the action of the bending chip which is being formed.
- ✓ As the tool advances, maximum stress is exerted along sheared line, which is called the shear plane.
- ✓ This plane is approximately perpendicular to the cutting face of the tool.
- ✓ There exists a shear zone on both sides of the shear plane, when the force of the tool exceeds the strength of material at the shear plane, rupture or slippage of the crystalline grain structure occurs, thus forming the metal chip.
- ✓ The chip gets separated from the work piece material and moves up along the tool face.
- ✓ In addition, when the metal is sheared, the crystals are elongated, the direction of elongation being different from that of shear.

- ✓ The circles which represent the crystals in the uncut metal get elongated into ellipses after leaving the shearing plane.

Types of chips

- ✓ In a metal cutting operation is carried out in machine shop.
- ✓ Chips are separated from the workpiece to impart the required size and shape to the workpiece.
- ✓ The type of chips edge formed is basically a function of the work material and cutting conditions.
- ✓ The chips that are formed during metal cutting operations can be classified into four types:
    - Discontinuous or segmental chips
    - Continuous chips
    - Continuous chips with built-up edge
    - Non homogenous chips
- ✓ The above three common types of chips are shown in fig.

Continuous chips

- ✓ Fig. (a) shows continuous chips coming out during machining in machine shop.
- ✓ These types of chips are obtained while machining ductile material such as mild steel and copper.
- ✓ A continuous chip comes from the cutting edge of a cutting tool as a single one piece, and it will remain as one piece unless purposely broken for safety or for convenience in handling.
- ✓ Formation of very lengthy chip is hazardous to the machining process and the machine operators.
- ✓ It may wrap up on the cutting tool, work piece and interrupt in the cutting operation.
- ✓ Thus, it becomes necessary to deform or break long continuous chips into small pieces.
- ✓ It is done by using chip breakers.
- ✓ Chip breaker can be an integral part of the tool design or a separate device.

Discontinuous or segmental chips

- ✓ Fig. (b) shows discontinuous chips coming out during machining in machine shop.
- ✓ In this type, the chip is produced in the form of small pieces.
- ✓ These types of chips are obtained while machining brittle material like cast iron, brass and bronze.
- ✓ Fairly good surface finish is obtained and tool life is increased with this type of chips.

Continuous chips with built-up edge

- ✓ Fig. (c) shows continuous chip with built-up edge.
- ✓ During cutting operation, the temperature rises and as the hot chip passes over s the face of the tool, alloying and welding action may take place due to high pressure, which results in the formation of weak bonds in microstructure and weakened particles might pullout.
- ✓ Owing to high heat and pressure generated, these particles get welded to the cutting tip of the tool and form a false cutting edge.this is known as built-up edge

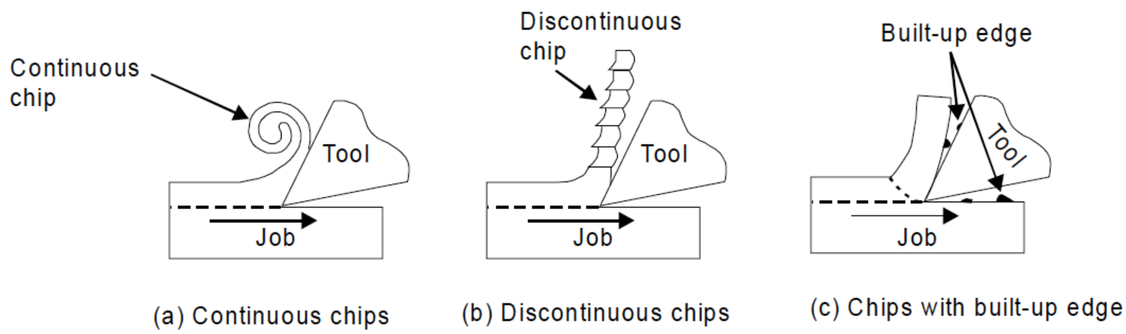


Fig. Common types of chips

Non homogenous chips

- ❖ Non homogenous chips are developed during machining highly hard alloys like titanium.
- ❖ It suffers a marked decrease in yield strength with increase in temperature

TOOL MATERIALS

- ❖ In order to remove chips from a work piece, a cutting tool must be harder than the work piece and must maintain a cutting edge at the temperature produced by the friction of the cutting action.

carbon steel

- ❖ Steel with a carbon content ranging from 1 to 1.2 percent was the earliest material used in machine tools.
- ❖ Tools made of this carbon steel are comparatively inexpensive but tend to lose cutting ability at temperatures at about 400° f (205° c).

High-speed steel

- ❖ In 1900 the introduction of high-speed steel permitted the operation of tools at twice or three times the speeds allowable with carbon steel, thus doubling or trebling the capacities of the world’s machine shops.
- ❖ One of the most common types of high-speed steel contains 18 percent tungsten, 4 percent chromium, 1 percent vanadium, and only 0.5 to 0.8 percent carbon.

Cast Alloys

- ❖ A number of cast-alloy cutting-tool materials have been developed; these nonferrous alloys contain cobalt, chromium, and tungsten and are particularly effective in penetrating the hard skin on cast iron and retaining their cutting ability even when red hot.

Cemented tungsten carbide

- ❖ This material was first used for metal cutting in germany in 1926.
- ❖ Its principal ingredient is finely divided tungsten carbide held in a binder of cobalt; its hardness approaches that of a diamond.

- Tungsten carbide tools can be operated at cutting speeds many times higher than those used with high-speed steel.

Oxides

- Ceramic, or oxide, tool tips are one of the newest developments in cutting-tool materials.
- They consist primarily of fine aluminum oxide grains, which are bonded together.

Diamonds

- Diamonds have been used for many years for truing grinding wheels, in wire-drawing dies, and as cutting tools.
- For cutting applications they are used largely for taking light finishing cuts at high speed on hard or abrasive materials and for finish-boring bronze and babbitt-metal bearings.

Single point cutting tools

- It involves the removal of metal from a work piece using cutting tools that only have one primary cutting edge.
- There are mainly two types of single point tools namely
    1. The solid type (as shown in fig.) And
    2. The tipped tool (fig.).
- The solid type single point tool may be made from high speed steel, from a cast alloy.
- Brazed tools (fig.) Are generally known as tool bits and are used in tool holders.
- The tipped type of tool is made from a good shank steel on which is mounted a tip of cutting tool material.
- Tip may be made of high speed steel or cemented carbide.
- In addition to this, there are long index-able insert tools and throwaway.
- The insert type tool throwaway refers to the cutting tool insert which is mechanically held in the tool holder.
- The inserts are purchased which are ready for use.
- When all cutting edges are used, the insert is discarded and not re-sharpened.
- These tools can be further classified depending upon the operations for which they are used and the type of the shank (straight or bent shank type).
- Tools may be of the types planning tools, turning tools, facing tool, boring tools, parting and slotting tools etc.
- Different types of carbide tips are generally used on tipped tool.
- In general the straight shank type tools are cheaper to manufacture as compared to bent shank type.
- But bent shank type can be used for turning either longitudinal or cross feed without resetting and for turning, facing and chamfering operations. Boring tools usually quite long and the cross section is small.

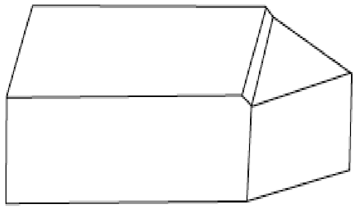


Fig. Solid type of single point cutting tool

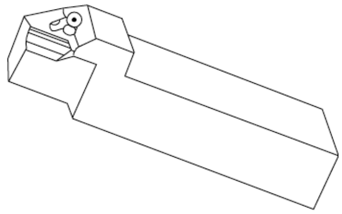


Fig. Tipped type single point cutting tool

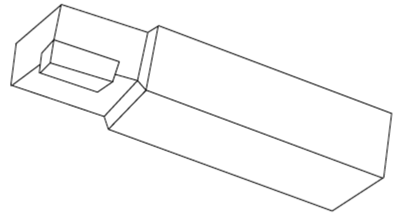


Fig. Index-able insert type single point cutting tool

- ❖ A single point cutting tool can be understood by its geometry (fig.).
- ❖ Geometry comprises mainly of nose, rake face of the tool, flank, heel and shank etc.
- ❖ The nose is shaped as conical with different angles.
- ❖ The angles are specified in a perfect sequence as american society of tool manufacturer for recognizing them as under.

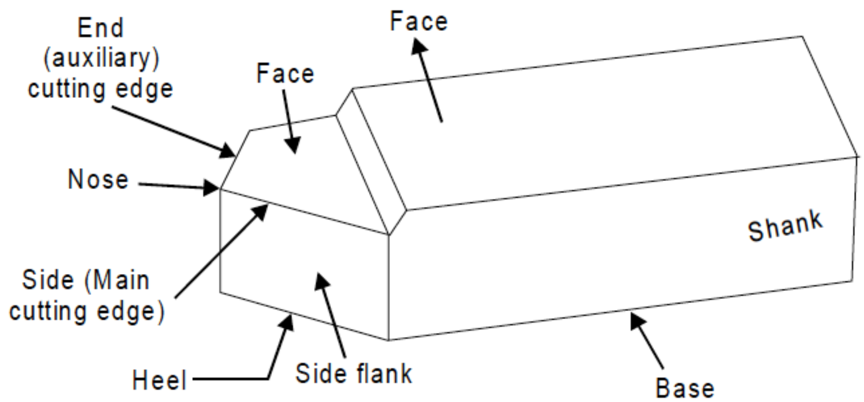


Fig. Single point cutting

Nomenclature of single point tool

- ❖ The elements of tool signature or nomenclature single point tool is illustrated in fig.

(*i*) Back rake angle

- ❖ It is the angle between the face of the tool and a line parallel with base of the tool measured in a perpendicular plane through the side cutting edge.
- ❖ If the slope face is downward toward the nose, it is negative back rake angle and if it is upward toward nose, it is positive back rake angle.
- ❖ This angle helps in removing the chips away from the work piece.

(*ii*) Side rake angle

- ❖ It is the angle by which the face of tool is inclined sideways.
- ❖ This angle of tool determines the thickness of the tool behind the cutting edge.

- It is provided on tool to provide clearance between work piece and tool so as to prevent the rubbing of work- piece with end flake of tool.
- It is the angle between the surface the flank immediately below the point and the line down from the point perpendicular to the base.

(*iii*) End relief angle

- It is the angle that allows the tool to cut without rubbing on the work- piece.
- It is defined as the angle between the portion of the end flank immediately below the cutting edge and a line perpendicular to the base of the tool, measured at right angles to the flank.
- Some time extra end clearance is also provided on the tool that is also known as end clearance angle.
- It is the secondary angle directly below the end relief angle

(*iv*) Side relief angle

- It is the angle that prevents the interference as the tool enters the material.
- It is the angle between the portion of the side flank immediately below the side edge and a line perpendicular to the base of the tool measured at right angles to the side.
- It is incorporated on the tool to provide relief between its flank and the work piece surface.
- Some time extra side clearance is also provided on the tool that is also known as side clearance angle.
- It is the secondary angle directly below the side relief angle.

(*v*) End cutting edge angle

- It is the angle between the end cutting edge and a line perpendicular to the shank of the tool.
- It provides clearance between tool cutting edge and work piece.

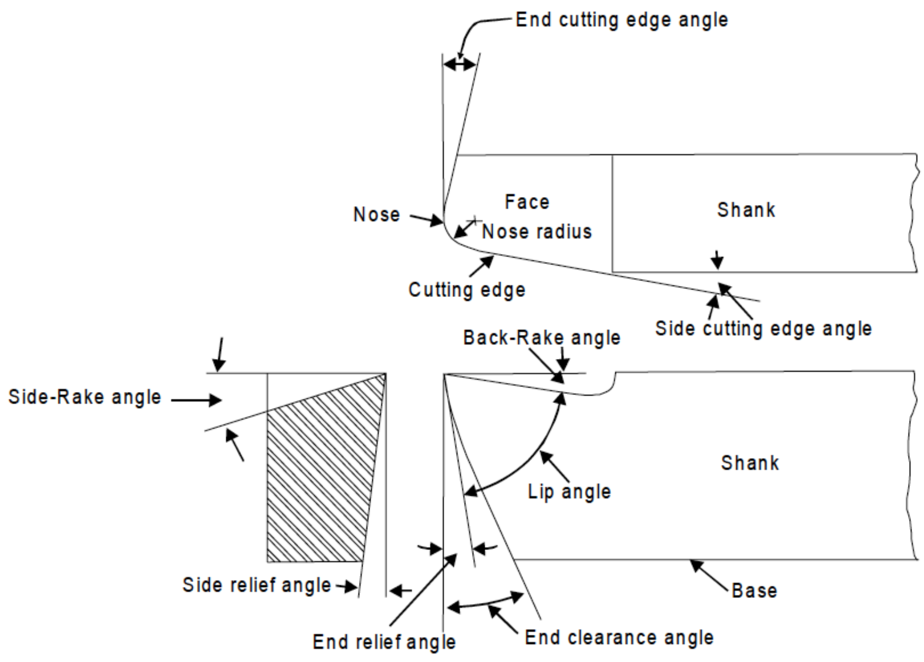


Fig. Elements of tool signature or nomenclature of single point tool

(*vi*) side cutting edge angle

- It is the angle between straight cutting edge on the side of tool and the side of the shank.
- It is also known as lead angle.
- It is responsible for turning the chip away from the finished surface.

(*vii*) nose radius

- It is the nose point connecting the side cutting edge and end cutting edge.
- It possesses small radius which is responsible for generating surface finish on the work-piece

***(viii)* shank**

- It is that portion of the tool bit which is not ground to form cutting edges.
- It is rectangular in cross - section

***(ix)* flank**

- It is that surface which faces the work piece.

***(x)* heel**

- It is the lowest portion of the side-cutting and end-cutting edge.

***(xi)* face**

- It is that surface against which the chip slides upwards

***(xii)* nose**

- It is the conjunction of the side and end-cutting edges.

***(xiii)* rake**

- It is the slope of the top away from the cutting slope.
- Each tool has a side and back rake.

***(xiv)* base**

- It is the under-side of the shank.

***(xv)* lip or cutting angle**

- It is included angle when the tool has been ground wedged-shaped.

TOOL SIGNATURE

- Convenient way to specify tool angles by use of a standardized abbreviated system is known as tool signature or tool nomenclature.
- It indicates the angles that a tool utilizes during the cut.
- It specifies the active angles of the tool normal to the cutting edge.
- This will always be true as long as the tool shank is mounted at right angles to the work-piece axis.
- The seven elements that comprise the signature of a single point cutting tool can be stated in the following order:

  Tool signature 0-7-6-8-15-16-0.8

  1. Back rake angle (0°)

2. Side rake angle (7°)
3. End relief angle (6°)
4. Side relief angle (8°)
5. End cutting edge angle (15°)
6. Side cutting edge angle (16°)
7. Nose radius (0.8 mm)

NOMENCLATURE OF MULTI POINT TOOL

Back taper

- A slight taper resulting in the shank end of the cutting diameter being smaller than the cutting end.
- This condition aids not only the plunging or drilling condition but also tends to compensate for deflection.

Clearance

- Space created by the removal of additional tool material from behind the relief angle.

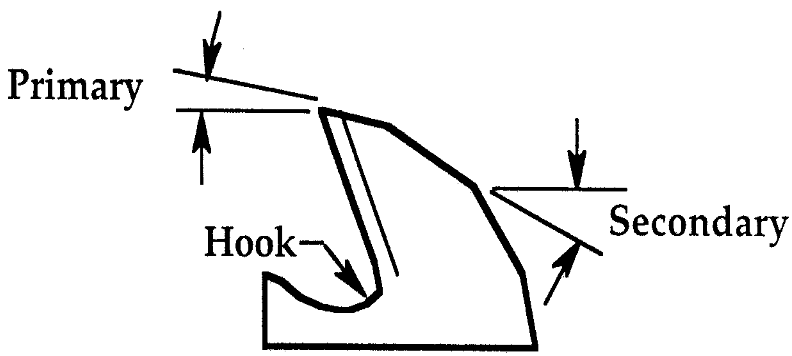


Fig. Cutting edge of end milling tool

Clearance angle

- The angle formed by the cleared surface and line tangent to the cutting edge.
  - **Clearance:** primary (1st angle, 5°-9°) - relief adjacent to the cutting edge.
  - **Clearance:** secondary (2nd angle, 14°-17°) - relief adjacent to cutting edge
  - **Clearance:** tertiary (3rd) - additional relief clearance provided adjacent to the secondary angle.

Concave

- Small hollow required on the end face of an end mill.
- This feature is produced by a dish angle produced on the cutter.

Convex

- An outward projection radius feature on the end face of a ball mill.

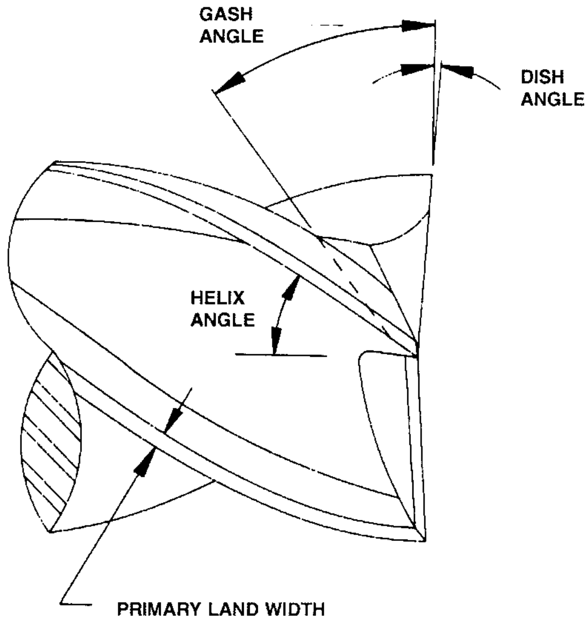
Dish angle

- The angle formed by the end cutting edge and a plane perpendicular to the cutter axis.
- Dish ensures that a flat surface is produced by the cutter.

Gash (notch)

❖ The secondary cuts on a tool to provide chip space at corners and ends.

❖ The space forming the end cutting edge, which is used when feeding axially.



Gash angle

❖ The relief angle of the gash feature.

Gash width

❖ The width of the gash feature.

❖ The space between cutting edges, which provides chip space and re-sharpening capabilities.

❖ Sometimes gash width is called as the flute.

Heel

❖ The back edge of the relieved land.

❖ It is the surface of the tooth trailing the cutting edge.

Helical

❖ A cutting edge or flute which progresses uniformly around a cylindrical surface in an axial direction.

❖ The normal helical direction is a right direction spiral.

Helix angle

❖ The angle formed by a line tangent to the helix and a plane through the axis of the cutter or the cutting edge angle which a helical cutting edge makes with a plane containing the axis of a cylindrical cutter.

Hook

❖ A term used to refer to a concave condition of a tooth face.

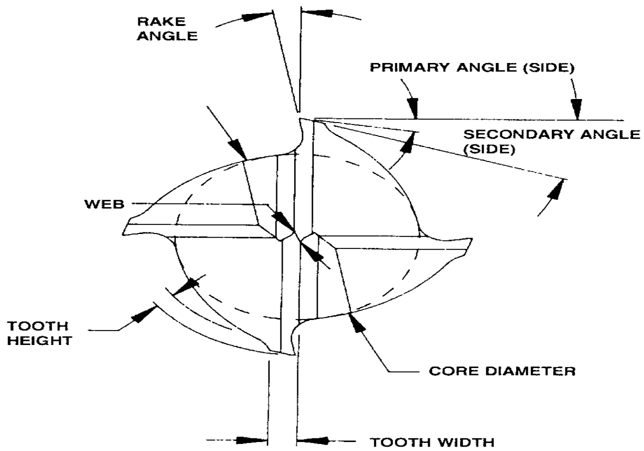
❖ This term implies a curved surface rather than a straight surface.

❖ Hook must be measured at the cutting edge, making measurement difficult.

Land

❖ The narrow surface of a profile sharpened cutter tooth immediately behind the cutting edge,

- (a) cylindrical - a narrow portion of the peripheral land, adjacent to the cutting edge, having no radial relief.
- (b) relieved - a portion of the land adjacent to the cutting edge, which provides relief.



Lead

❖ The axial advance of a helical cutting edge in one revolution.

Lead = (cutter diameter x pi) / tangent helix angle

Length of cut (flute length)

❖ The effective axial length of the peripheral cutting edge which has been relieved to cut.

Radial rake angle

❖ The angle made by the rake face and a radius measured in a plane normal to the axis.

Rake

❖ The angular relationship between the tooth face or a tangent to the tooth face at a given point and a reference plane or line.

❖ An angular feature ground onto the surface of an end mill.

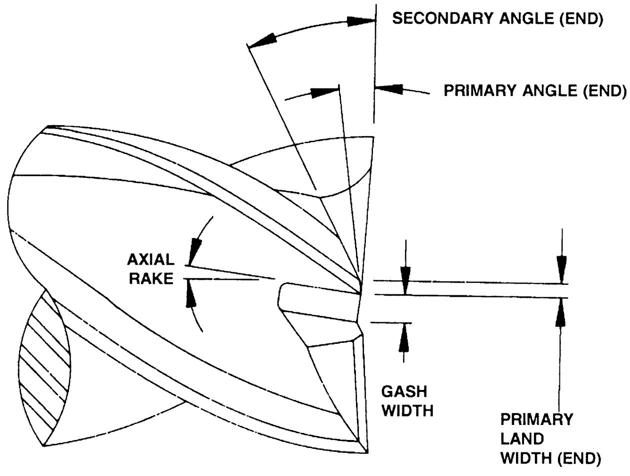
✓**Axial rake -** the angle formed by a plane passing through the axis and a line coinciding with or tangent to the tooth face.

✓**Effective rake -** the rake angle influencing chip formation most is that measured normal to the cutting edge. The effective rake angle is greatly affected by the radial and axial rakes only when corner angles are involved.

✓**Helical rake -** for most purposes the terms helical and axial rake can be used interchangeably. It is the inclination of the tooth face with reference to a plane through the cutter axis.

✓**Negative rake -** exists when the initial contact between tool and work piece occurs at a point or line on the tooth other than the cutting edge. The rake surface leads the cutting edge.

✓ **Positive rake -** exists when the initial contact between the cutter and the work piece occurs at the cutting edge. The cutting edge leads the rake surface.



Relief-space

- Provided by removing material immediately behind the cutting edge.
- Done to eliminate the possibility of heeling or rubbing.
  - **Axial angle relief -** the angle made by a line tangent to the relieved surface at the end cutting edge and a plane normal to the axis.
  - **Axial relief -** the relief measured in the axial direction between a plane perpendicular to the axis at the cutting edge and the relieved surface. Helps to prevent rubbing as the corner wears.
  - **Concave relief -** the relieved surface behind the cutting edge having a concave form. Produced by a grinding wheel set at 90 degrees to the cutter axis.
  - **Eccentric relief -** the relieved surface behind the cutting edge having a convex form. Produced by a type i wheel presented at an angle to the cutter axis.
  - **End relief -** relief on the end of an end mill. Needed only for plunging cutters and to relieve rubbing as the result of corner wear.
  - **Flat relief -** the relieved surface behind the cutting edge having a flat surface produced by the face of a cup wheel.
  - **Radial relief -** relief in a radial direction measured in the plane of rotation. It can be measured by the amount of indicator drop at a given radius in a given amount of angular rotation.

Tangential rake angle

- The angle made by a line tangent to a hooked tooth at the cutting edge and a radius passing through the same point in plane normal to the axis.

TOOL FAILURE

- The failure of cutting tools may be the result of
  1. Wear on the flank of the tool
  2. Wear at the tool-chip interface

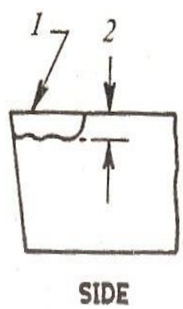
3. combination of flank wear and cratering
4. Spalling or crumbling of the cutting edge
5. Loss of hardness
6. Fracture by a process of mechanical breakage

I. Wear on the flank of the tool

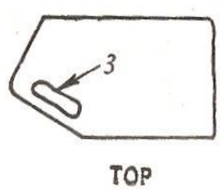
- ❖ Flank wear is a flat portion worn behind the cutting edge which eliminates some clearance or relief.
- ❖ Flank wear takes place when machining brittle materials like c.i. Or when feed is less than less than 0.15 mm/rev.
- ❖ The worn region at the flank is called the wear land.
- ❖ The wear land width is measured accurately with brinell microscope.

II. Wear at the tool-chip interface

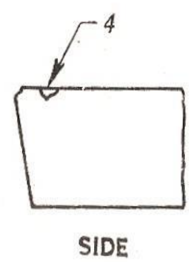
- ❖ It occurs in the form of a depression or crater.
- ❖ This is caused by the pressure of the chip as it slides up the face of the cutting tool.
- ❖ Both flank and crater wear take place when feed is greater than 0.15 mm/rev at low or moderate speeds.
- ❖ This type of failure cause when high speed steel, satellite, or sintered-carbide tools turn ductile metals.



(a) flank wear and wear land



(b) crater



(c) chipping

TOOL LIFE

- ❖ The tool life is an important factor in a cutting tool performance since considerable time is lost whenever tool is ground and re-set.
- ❖ A tool cannot cut for an unlimited period of tie.
- ❖ It has its definite life
- ❖ If the cutting tool is to have a long life it is essential that the face of the tool be as smooth as possible.
- ❖ Tool life is the time a tool will operate satisfactorily until it is dulled.
- ❖ A blunt tool causes chatter in machining, poor surface finish, increase in cutting forces and power consumption, and overheating of the tool.

Coolants or cutting fluids or emulsions

- During any machining or metal cutting process, enough heat is evolved in cutting zone.
- To remove this heat from cutting zone, soluble oils are used as cutting fluid during machining.
- Emulsions (also known as soluble oil) cool the work-piece and tool and thus relieved them from overheat.
- Air circulation is required so as to remove the heat by evaporation.
- The remaining oil forms a protecting layer over the machined work piece and save it from rust and corrosion.
- Such coolants decrease adhesion between chip and tool, provides lower friction and wear and a smaller built up edge.
- They remove chips and hence help in keeping freshly machined surface bright.
- They also protect the surface from corrosion.
- They decrease wear and tear of tool and hence increase tool life.
- They improve machinability and reduce machining forces.
- Chemical cutting fluids possess a good flushing action and are non-corrosive and nonclogging.
- Since they are non-clogging, they are widely used for grinding and sawing.
- The most efficient method of applying cutting fluids is to use a pump, tray and reservoir, to give a slow continuous stream over the cutting action.
- Chemical cutting fluids are replacing straight and emulsifiable cutting oils for many applications.
- If chemical concentrates are mixed in correct proportion with deionized water, chemical cutting fluids provide longer life at less cost than oil base cutting fluids.
- Other coolants and cutting fluids are cutting wax and kerosene.
- Cutting fluids may also be used on aluminium, aluminium alloys and brass for machining operations of low severity.
- It may be used as a coolant and for removing chips when machining cast iron.
- Some commonly used machining materials require following cutting fluids:
    1. Steel soluble oil straight
    2. Water base mainly grinding
    3. Aluminium and alloys paraffin dry
    4. Cast iron dry   5. Brass, copper and bronze dry

Functions or uses of coolants or cutting fluids

The important functions of cutting fluids are given as under.

(i) Cutting fluid washes away the chips and hence keeps the cutting region free.

(ii) It helps in keeping freshly machined surface bright by giving a protective coating against atmospheric, oxygen and thus protects the finished surface from corrosion.

(iii) It decreases wear and tear of cutting tool and hence increases tool life.

(iv) It improves machinability and reduce power requirements

(v) It prevents expansion of work pieces.

(vi) It cools the tool and work piece and remove the generated heat from the cutting zone.

(vii) It decreases adhesion between chip and tool; provide lower friction and wear, and a smaller built-up edge.

CUTTING FLUIDS

During metal cutting, heat is generated due to plastic deformation of metal, friction of the tool work piece interface. This will increase the temperature of both work piece and the tool. Hence, the hardness of the tool decreases. This leads to tool failure. Cutting fluids are used to carry away the heat produced during machining. At the same time, it reduces the friction between the tool and chip. Cutting fluids usually in the form of a liquid are applied to the chip formation zone to improve the cutting conditions.

Functions of Cutting Fluid

i) Cutting fluid cools the cutting tool and work piece. The heat produced during machining is carried away by the fluid. It is done by supplying adequate quantity of cutting fluid. It is necessary to cool the tool to prevent metallurgical damage and to assist in decreasing friction at the tool - chip interface. When the friction is decreased, the tool life will increase and surface finish will also increase. It prevents the work piece from excessive thermal distortion.

ii) It lubricates the cutting tool and thus reduces the coefficient of friction between tool and work. This property reduces the energy or power consumption in removing metal. So, wear on the cutting tool is reduced and hence it increases the tool life.

iii) It improves the surface finish as stated earlier.

iv) It causes the chips to break up into small parts. It protects the finished surface from corrosion. II It washes away the chips from the tool. It prevents the tool from fouling.

v) It prevents corrosion of work and machine.

Properties of Cutting Fluid

A cutting fluid should have the following properties

❖ It should have good lubricating properties to reduce frictional forces and to decrease the power consumption.

❖ High heat absorbing capacity.

❖ It should have a high specific heat, high heat conductivity and high film coefficient

❖ High flash point.

❖ It should be odorless

❖ It should be non-corrosive to work and tool

❖ It should have low viscosity to permit free flow of the liquid

❖ It should be harmless to operators and the bearings

It should be stable so that it should not get oxidized or decomposed when left in air.

❖ It should be transparent so that the cutting action of the tool may be observer. It is especially desirable in precision work.

❖ It should not stain or leave residues on the work piece surface.

❖ It should be economical to use.

Types of Cutting Fluids

There are various types of cutting fluids used depending upon the work material and the characteristic of machining process.

There are basically two main types of cutting fluid.

(a) Water based cutting fluids

(b) Straight or heat oil based cutting fluids.

1. Water based cutting fluids

To improve the cooling and lubricating properties of water, the soft soap or mineral oils are added to it. These oils are known as soluble oils. Soluble oils are emulsions composed of around 80% of water remaining soap and mineral oils. The soap acts as an emulsifying agent which breaks the oil into minute particles to disperse them throughout water. Water based cutting fluids are quite commonly used. This has excellent cooling properties at low cost and there is also some lubricating effect between tool and chip which reduces tool wear. By mixing various proportions of water with soluble oils and soaps, cutting fluids with a wide range of cooling and lubricating properties can be obtained. Modern soluble oil contains corrosion inhibiler and a biocide to keep down the growth of bacteria. Less frequently used forms of water-based cutting fluids are based on chemical solutions. Soda solutions are often used on grinding operations as it has good flushing action and cooling effect. Water is also used as coolant but it causes rust and corrosion.

2. Straight or heat oil based cutting fluids

Straight oil based cutting fluids means undiluted or pure oil based fluids. Most of the oils are not directly used but mixed with other oils or oils with chemicals such as sulphur and chlorine. It is classified into the following subgroups.

(i) Mineral oils

(ii) Straight fatty oils

(iii) Mixed oils or compounded oils

(iv) Sulphurised oils

(v) Chlorinated oils

(i) Mineral oils:

These oils are primarily composed of hydrocarbons of different structures and molecular weights. Some of the examples of such type are straight mineral (petroleum) oils, kerosene, and paraffin low- viscosity petroleum fractions such as mineral seal or higher viscosity mineral oils. These oils are normally used for light machining operations such as turret and capstan lathes and single spindle automatics where free cutting brasses and steels are being machined.

(ii)Straight fatty oils or fixed oils:

These oils consist of animal, fish and vegetable oils. Some commonly used mineral oils are lard oil, olive oil, whale oil, cotton seed and linsed oil. The most important variety of straight fatty oil is lard oil. These oils are not stable and rapidly loose their lubricating properties. Lard oil is mainly used during thread cutting operations. These oils are more expensive and less available than mineral oil.

(iii)Mixed or compound oils:

It is the mixture of straight fatty and mineral oils. The film strength of fatty oils is retained even when diluted with 75% mineral oil. Therefore they are much cheaper and more fluid than straight fatty oils. This oil has excellent lubrication and cooling properties. It is used for automatic screw machine work, heavy duty operations such as threading on capstan and turret lathes, thread milling etc.

(iv)Sulphurised oils:

This is one type of chemical additive oil. When sulphur (about 5%) is mixed with lard oil. It will give good lubricating and cooling qualities. This oil is called sulphurised oil It is used for heavy-duty lathe work, gear cutting and thread grinding.

(v) Chlorinated oils:

It is another type of chemical additive oil. To prepare chlorinated oils, chlorine about 3% is added in mineral oils. These oils are particularly effective in promoting anti-weld characteristics.

If we use both chlorine and sulphur with mineral oil, they give the extreme pressure property to oil and are suitable for severe cutting operations on strong and tough materials such as stainless steels and nickel alloys.

The selection of cutting fluid depending on the following factors

(i)Cutting speed

(ii)Feed rate

(iii)Depth of cut

(iv)Tool and work piece material

(v)Velocity of cutting fluid

(vi)Tool life to be expected

(vii)Economical aspects