3.15 DRILLING&BORINGMACHINES

DRILLING

Drilling is the process of originating holes in the work piece by using a rotating cutter called drill. The machine used for this purpose is called drilling machine. Although it was primarily designed to originate a hole, it can perform a number of similar operations. In a drilling machine holes may be drilled quickly and at a low cost. As the machine tool exerts vertical pressure to originate a hole it is also called drill press. Holes were drilled by the Egyptians in 1200 B.C. by bow drills. The bow drill is the mother of present day metal cutting drilling machine.

Types of drilling machine

The different types of drilling machine which are most commonly used are:

- ✓ Portable drilling machine.
- ✓ Sensitive drilling machine (Bench mounting table top and Floor mounting
- ✓ Upright drilling machine (Pillar or Round column section and Box column section)
- ✓ Radial drilling machine (Plain, Semi-universal and Universal)
- ✓ Gang drilling machine.
- ✓ Multiple spindle drilling machine.
- ✓ Deep hole drilling machine.
- ✓ Turret type drilling machine

But in working principle all are more or less the same.

3.10.1.1 Portable drilling machine or hand drilling machine

Unlike the mounted stationary drilling machines, the hand drill is a portable drilling device which is mostly held in hand and used at the locations where holes have to be drilled. The small and reasonably light hand drilling machines are run by a high speed electric motor. In fire hazardous areas the hand drilling machine is often rotated by compressed air. The maximum size of the drill that it can accommodate is not more than 12 to 18 mm. Fig. 3.109 illustrates a hand drilling machine.

Fig. 3.109 Hand drilling machineFig. 3.110 Table top sensitive drilling machine

Bench mounting or table top sensitive drilling machine

This small capacity (≤ 0.5 kW) upright (vertical) single spindle drilling machine is mounted on rigid table and manually operated using usually small size (ϕ ≤ 10 mm) drills. Fig. 3.110 illustrates a table top sensitive drilling machine.

Floor mounting sensitive drilling machine

The floor mounting sensitive drilling machine is a small machine designed for drilling small holes at high speed in light jobs. The base of the machine is mounted on the floor. It consists of a vertical column, a horizontal table, a head supporting the motor and driving mechanism, and a vertical spindle for driving and rotating the drill. There is no arrangement for any automatic feed of the drill spindle. The drill is fed into the work by purely hand control. High speed is necessary for drilling small holes. High speeds are necessary to attain required cutting speed by small diameter drill. Hand feed permits the operator to feel or sense the progress of the drill into the work, so that if the drill becomes worn out or jams on any account, the pressure on the drill may be released immediately to prevent it from breaking. As the operator senses the cutting action, at any instant, it is called sensitive drilling machine. Sensitive drilling machines are capable of rotating drills of diameter from 1.5 to 15.5 mm. Super sensitive drilling machines are designed to drill holes as small as 0.35 mm in diameter and the machine is rotated at a high speed of 20,000 r.p.m. or above. Fig. 3.111 illustrates a floor mounting sensitive drilling machine.

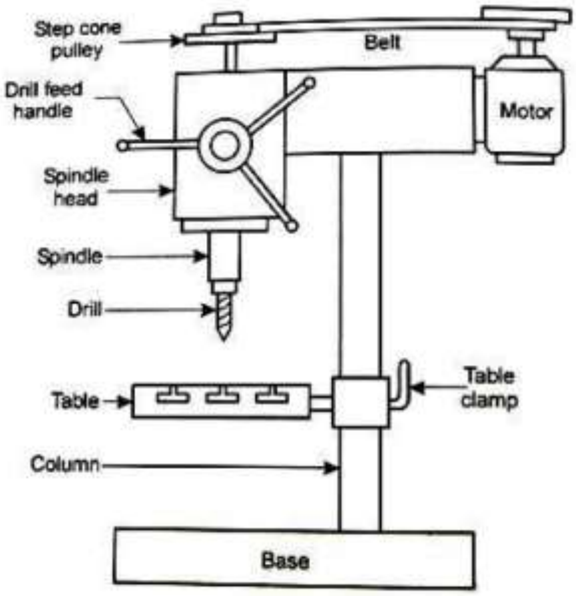


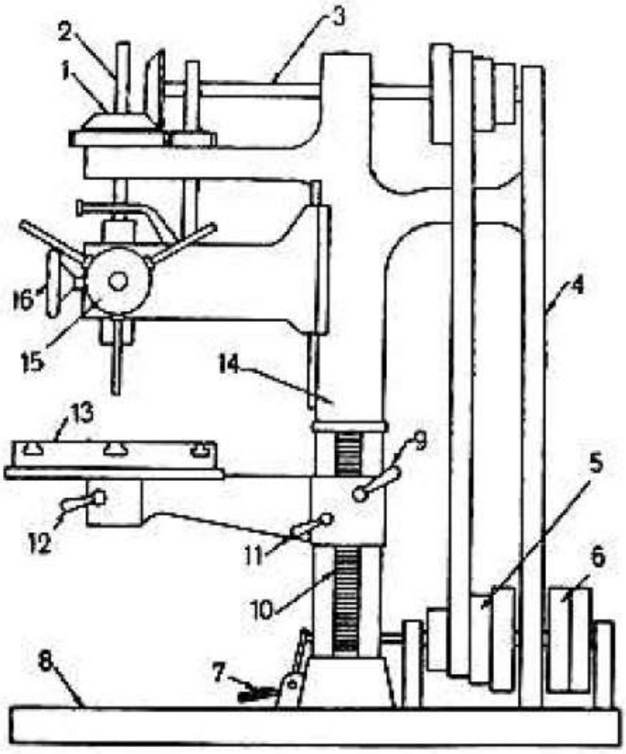
Fig. 3.111 Floor mounting sensitive drilling machineFig. 3.112 Pillar drilling machine

Pillar or Round column section upright drilling machine

Fig. 3.112 illustrates a pillar or round column section upright drilling machine. This machine is usually called pillar drilling machine. It is quite similar to the table top drilling machine but of little larger size and higher capacity (0.55 ~ 1.1 kW) and are mounted on the floor. In this machine the drill feed and the work table movements are done manually. This low cost drilling machine has a base, a tall tubular column, an arm supporting the table and a drill head assembly. The arm may be moved up and down on the column and also be moved in an arc up to 1800 around the column. The table may be rotated 3600 about its own centre independent of the position of the arm. It is generally used for small jobs and light drilling. The maximum size of holes that can be drilled is not more than 50 mm.

Box column section upright drilling machine

Fig. 3.113 illustrates a box column section upright drilling machine. The major parts are:



1. Bevel gear drive to spindle
2. Spindle
3. Overhead shaft
4. Back stay
5. Counter shaft cone pulley
6. Fast and loose pulley
7. Foot pedal
8. Base
9. Table elevating handle
10. Rack on column
11. Table elevating clamp handle
12. Table clamp
13. Table
14. Column
15. Handwheel for quick hand feed
16. Handwheel for sensitive hand feed

Base: It is a part of the machine on which vertical column is mounted. The top of the base is accurately machined and has T-slots on it so that large work pieces and work holding devices may be set up and bolted to it.

Column It is the vertical member of the machine which supports the table and the head containing all the driving mechanism. The column should be sufficiently rigid so that it can take up the entire cutting pressure of the drill. The column may be made of box section or of round section. Box column is a more rigid unit. In box column type, the front face of the column is accurately machined to form guide ways on which the table can slide up and down for vertical adjustment.

Table It is mounted on the column and is provided with T-slots for clamping the work directly on its face. The table may be round or rectangular in shape. The table may have three types of adjustments: vertical adjustment, radial adjustment about the column, and circular adjustment about its own axis. After the required adjustments have been made the table and the arm are clamped in position.

Drill head It is mounted on the top of the column and houses the driving and feeding mechanism for the spindle. In some of the machines the drill head may be adjusted up or down for accommodating different heights of work in addition to the table adjustment.

Spindle Holds the drill and transmits rotation and axial translation to the tool for providing cutting motion and feed motion - both to the drill.

Radial drilling machine

Fig. 3.114 illustrates a radial drilling machine. The major parts are:

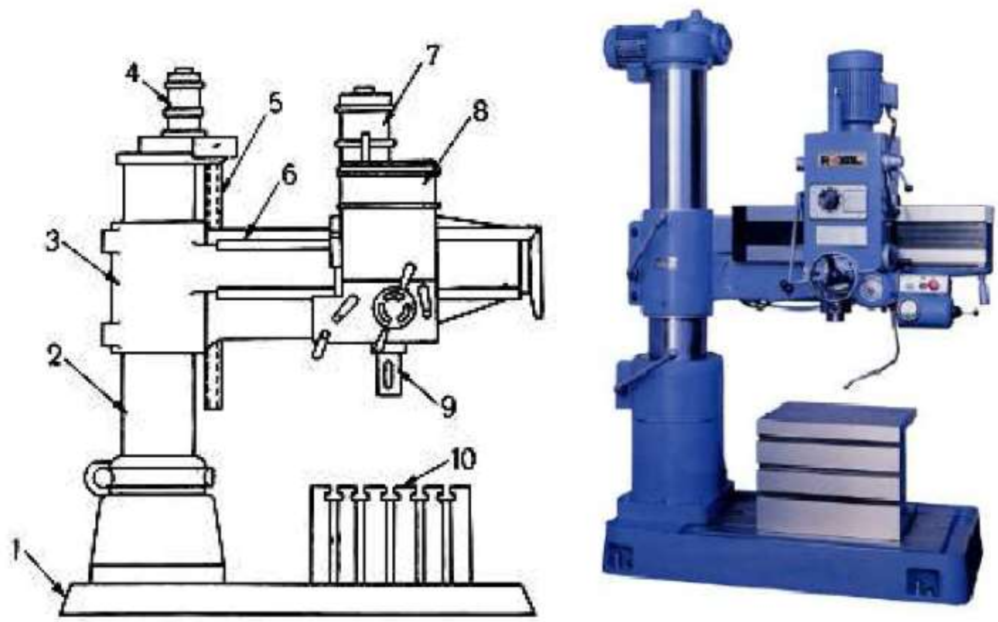


Fig. 3.114 Radial drilling machine

Base: It is a large rectangular casting that is finished on its top to support a column on its one end and to hold the work table at the other end. In some machines T-slots are provided on the base for clamping work when it serves as a table.

Column The column is a cylindrical casting that is mounted vertically at one end of the base. It supports the radial arm which may slide up or down on its face. An electric motor is mounted on the top of the column which imparts vertical adjustment of the arm by rotating a screw passing through a nut attached to the arm.

Radial arm: The radial arm that is mounted on the column extends horizontally over the base. It is a massive casting with its front vertical face accurately machined to provide guide ways on which the drill head may be made to slide. The arm may be swung round the column. In some machines this movement is controlled by a separate motor.

Drill head: The drill head is mounted on the radial arm and drives the drill spindle. It encloses all the mechanism for driving the drill at multiple speeds and at different feed. All the mechanisms and controls are housed within a small drill head which may be made to slide on the guide ways of the arm for adjusting the position of drill spindle with respect to the work.

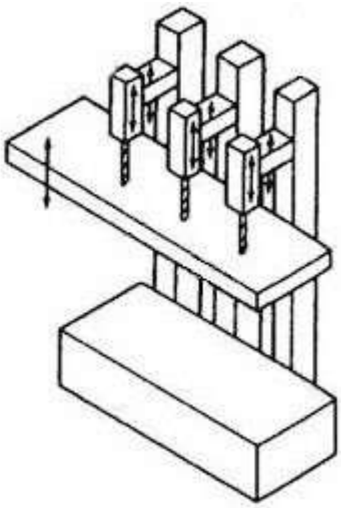
Spindle drive and feed mechanism

There are two common methods of driving the spindle. A constant speed motor is mounted at the extreme end of the radial arm. The motor drives a horizontal spindle which runs along the length of the arm and the motion is transmitted to the drill head through bevel gears. By the gear train within the drill head, the speed of the spindle may be varied. Through another gear train within the drill head, different feeds of the spindle are obtained. In some machines, a vertical motor is fitted directly on the drill head and through gear box multiple speed and the feed of the spindle can be obtained.

Working principle: The work is mounted on the table or when the work is very large it may be placed on the floor or in a pit. Then the position of the arm and the drill head is altered so that the drill may be pointed exactly on the location where the hole is to be drilled. When several holes are drilled on a large work piece, the drill head is moved from one position to the other after drilling the hole without altering the setting of the work. This versatility of the machine allows it to work on large work pieces. There are some more machines where the drill spindle can be additionally swiveled and / or tilted.

Gang drilling machine

In this almost single purpose and more productive drilling machine a number of spindles (2 to 6) with drills (of same or different size) in a row are made to produce number of holes progressively or simultaneously through the jig. Fig. 3.115 illustrates a typical gang drilling machine.



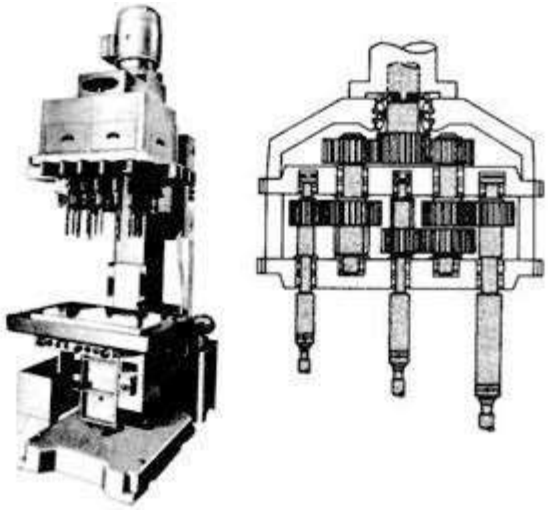


Fig. 3.115 Gang drilling machine Fig. 3.116 Multiple spindle drilling machine

Multiple spindle drilling machine

Fig. 3.116 schematically shows a typical multiple spindle drilling machine. In this high production machine a large number of drills work concurrently on a blank through a jig specially made for the particular work. The entire drilling head works repeatedly using the same jig for batch or lot production. The rotations of the drills are derived from the main spindle and the central gear through a number of planetary gears in mesh with the central gear and the corresponding flexible shafts. The positions of those parallel shafts holding the drills are adjusted depending upon the locations of the holes to be made on the job. Each shaft possesses a telescopic part and two universal joints at its ends to allow its change in length and orientation respectively for adjustment of location of the drills of varying size and length. In some heavy duty multi spindle drilling machines, the work-table is raised to give feed motion instead of moving the heavy drilling head.

Deep hole drilling machine

Very deep holes of L/D ratio 6 to even 30, required for rifle barrels, long spindles, oil holes in shafts, bearings, connecting rods etc, are very difficult to make for slenderness of the drills and difficulties in cutting fluid application and chip removal. Such drilling cannot be done in ordinary drilling machines and by using ordinary drills. It needs machines like deep hole drilling machine such as gun drilling machines with horizontal axis or vertical axis.

These machines are provided with:

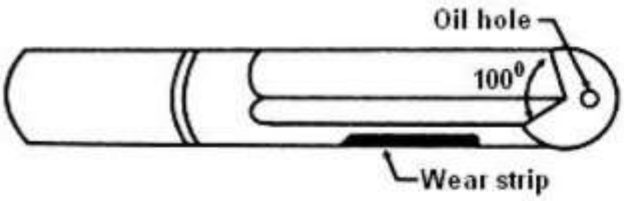
High spindle speed.

High rigidity.

Tool guide.

Pressurized cutting oil for effective cooling, chip removal and lubrication at the drill tip.

Fig. 3.117 schematically shows a deep hole drill tool used in the deep hole drilling operation.



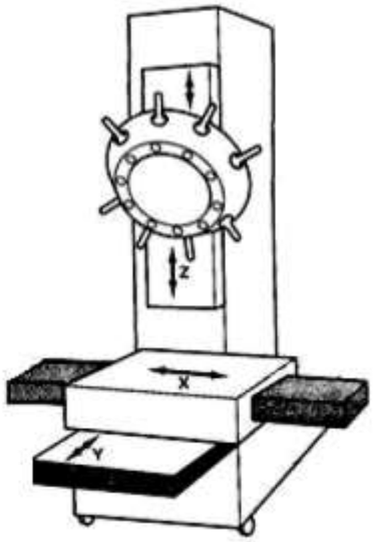


Fig. 3.117 Deep hole drill Fig. 3.118 Turret type drilling machine

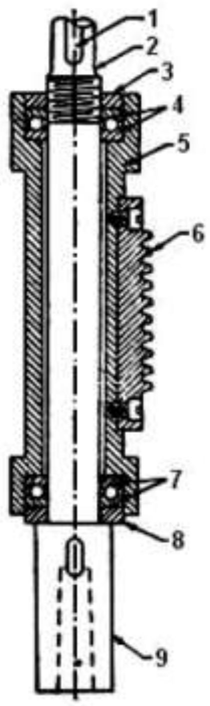
Turret type drilling machine

Fig. 3.118 schematically shows a typical turret type drilling machine. Turret drilling machine is structurally rigid column type drilling machine but is more productive like gang drill machine by having a pentagon or hexagon turret. The turret holds a number of drills and similar tools, is indexed and moved up and down to perform quickly the desired series of operations progressively. These drilling machines are available with varying degree of automation both fixed and flexible type.

Spindle and drill head assembly

The spindle is a vertical shaft which holds the drill. It receives its motion from the top shaft though bevel gears. A long key-way is cut on the spindle and the bevel gear is connected to it by a sliding key. This construction is made to allow the spindle to be connected with the top shaft irrespective of its position when the spindle is raised or lowered for feeding the drill into the work piece. The spindle rotates within a non-rotating sleeve which is known as the quill. Rack teeth are cut on the outer surface of the sleeve. The sleeve may be moved up or down by rotating a pinion which meshes with the rack and this movement is imparted to the spindle to give the required feed.

The downward movement of the spindle is effected by rotating the pinion which causes the quill to move downward exerting pressure on the spindle through a thrust bearing and washer. The spindle is moved upward by the upward pressure exerted by the quill acting against a nut attached to the spindle through the thrust bearing. The lower end of the spindle is provided with Morse taper hole for accommodating taper shank drill.. A slot is provided at the end of the taper hole for holding the tang of the drill to impart it a positive drive. The drill spindle assembly is illustrated in Fig. 3.119.



1. Key way on the spindle
2. Spindle
3. Nut
4. Thrust beatings
5. Quill or Sleeve
6. Rack
7. Washer
8. Lower end of the spindle

Fig. 3.119 Drill spindle assembly

Spindle drive mechanism

The spindle drive mechanism of a drilling machine incorporates an arrangement for obtaining multiple speed of the spindle similar to a lathe to suit to various machining conditions.Multiple speed of the spindle may be obtained as follows:

By step cone pulley drive.

By step cone pulley drive with one or more back gears.

By gearing.

Step cone pulley drive

Fig. 3.113 shows the schematic view of a spindle driving mechanism incorporating a step cone pulley. The motion is transmitted from an overhead line shaft to the countershaft mounted on the base of the machine. The countershaft may be started or stopped by shifting the belt from loose pulley to fast pulley or vice versa by operating the foot-pedal 7. The step cone pulley mounted on the head of the machine receives power from the countershaft step cone pulley 5 through the belt. The drill spindle 2 receives power from the overhead shaft 3 through bevel gears 1 and the speed of the spindle may be varied by shifting the belt on different steps of the cone pulley 5. The number of spindle speeds available is dependent upon the number of steps on the cone pulley.

Step cone pulley drive with back gear

In order to obtain larger number of spindle speeds back gears are incorporated in the machine in addition to the step cone pulley.

Spindle drive by gearing

Modernheavydutydrilling machinesaredrivenby individual motor mounted on the frame of the machine. The multiple speeds may be obtained by sliding gear or sliding clutch mechanism or by the combination of the above two methods.

Feed mechanism

In a drilling machine, the feed is effect by the vertical movement of the drill into the work. The feed movement of the drill may be controlled by hand or power.

The hand feed may be applied by two methods:

Quick traverse hand feed.

Sensitive hand feed.

The quick traverse feed is used to bring the cutting tool rapidly to the hole location or for withdrawing the drill when the operation is completed. Quick hand feed is obtained by rotating the hand wheel pivoted to the pinion. One turn of the hand wheel will cause the pinion to rotate through one complete revolution giving quick hand feed movement of the spindle.

The sensitive hand feed is applied for trial cut and for drilling small holes. The sensitive feed hand wheel is attached to the rear end of the worm shaft. Rotation of the hand wheel will cause the worm and worm gear to rotate and a slow but sensitive feed is obtained.

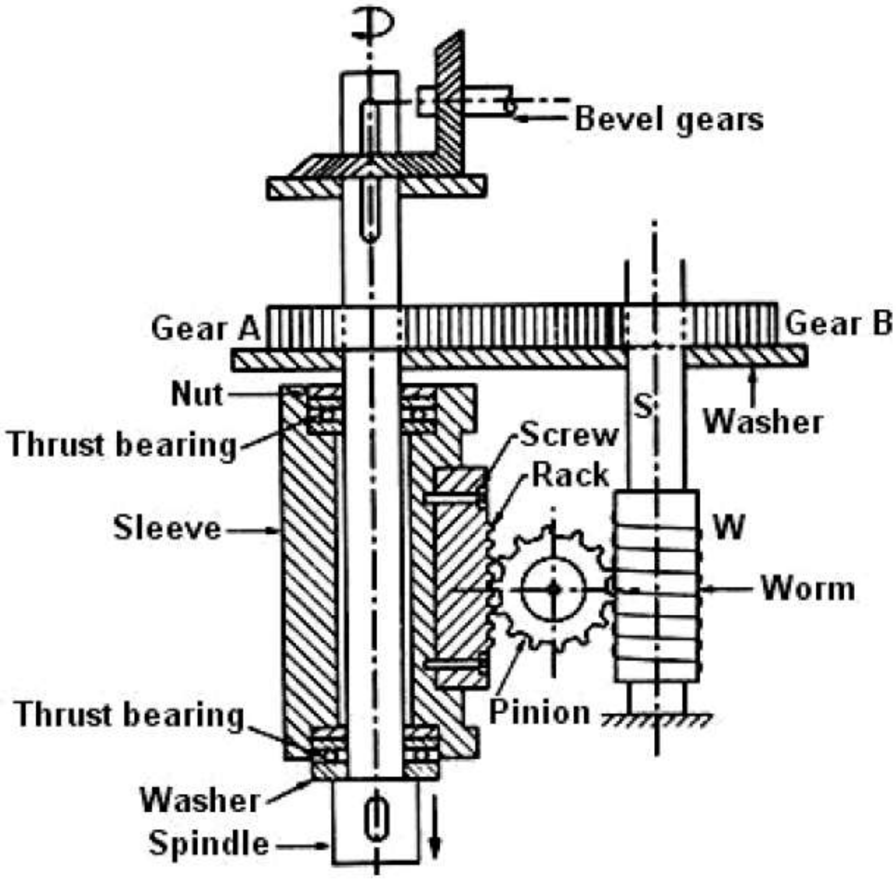


Fig. 3.120 Automatic feed mechanism

The automatic feed is applied while drilling larger diameter holes as the cutting pressure required is sufficiently great. Fig.3.120 illustrates the automatic feed mechanism. The gear A rotates with the spindle as the spindle passes through it. Gear B is connected with gear A, so it also rotates. The shaft S rotates with the gear B as it connected to it. At a suitable distance under the shaft, there is a worm which drives a pinion. The pinion is connected with the rack on the non rotating sleeve (quill) fitted over the spindle. The rotation of the worm rotates the pinion. The rotation of the pinion moves the quill up and down through the rack cut on it. The quill moves the drill spindle up and down. Thus the automatic feed of the drill spindle is achieved. Different ranges of feed can be obtained by means of feed gearbox.

3.10.3 Work holding devices used in drilling machines

Before performing any operation in a drilling machine it is absolutely necessary to secure the work firmly on the drilling machine table. The work should never be held by hand, because the drill while revolving exerts so much of torque on the work piece that it starts revolving along with the tool and may cause injuries to the operator. The work holding devices commonly used for holding the work piece in a drilling machine table are: T-bolts and clamps, machine vises, step blocks, V-blocks, angle plate and drill jigs. All of them except drill jig have been described in Article 3.2.6 and

Page 110. When the work is heavy and / or of odd shape and size, it is directly clamped on the drilling machine table.

Drill jigs

These are used for holding the work in a mass production process. A drill jig can hold the work securely, locate the work and guide the tool at any desired position. The work may be clamped and unclamped quickly. Jigs are specially designed for each type of work where quantity production is desired. The work is clamped below the jig and the holes are located. The drill is guided by the drill bush. Fig. 3.121 schematically shows some types of drill jigs used in mass production.

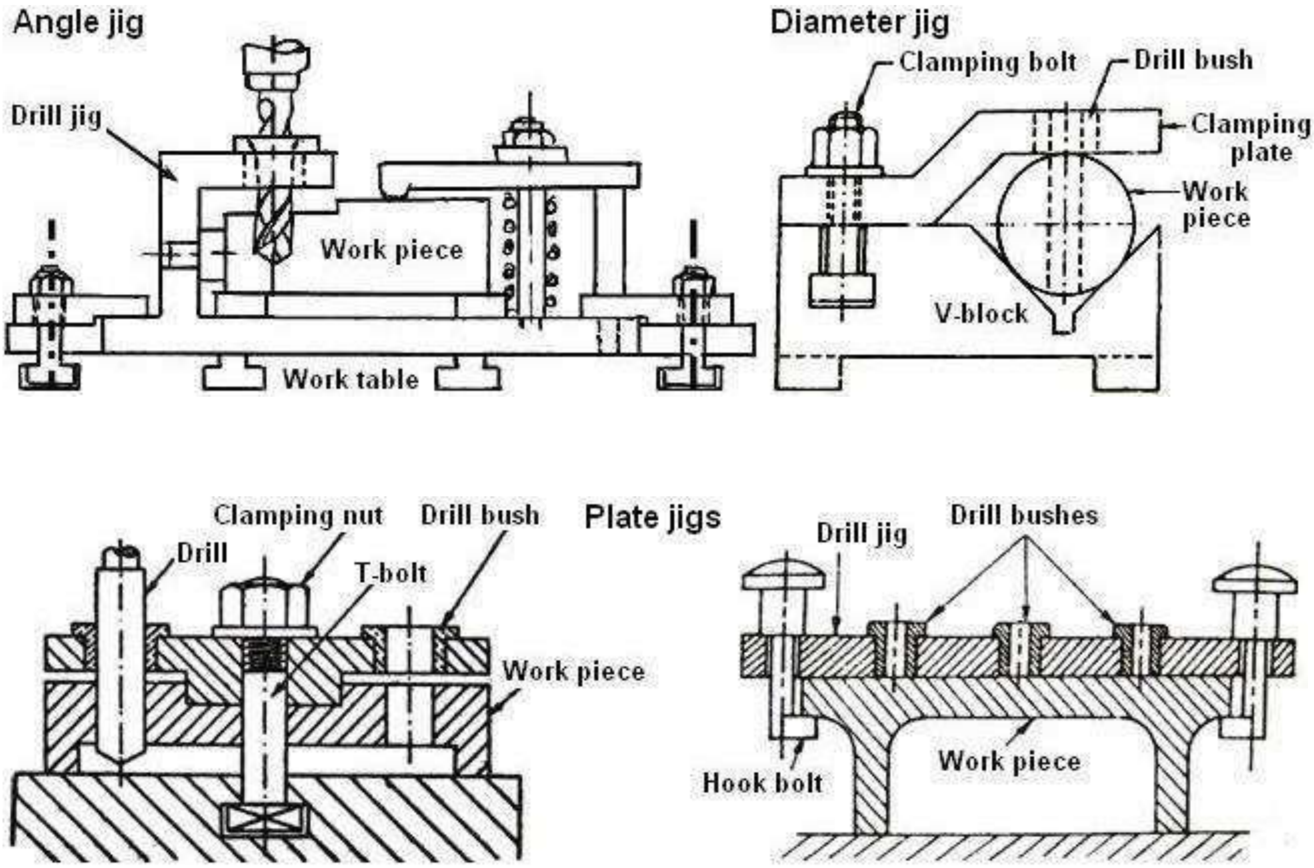


Fig. 3.121 some types of drill jigs

Shaping Machine	Planer Machine	Slotter Machine
1. It is a multipurpose machine, used for producing flat surfaces.	1. It is similar to shaper and is used 'Or producing large surfaces	1. It is similar to vertical shaping machine and used for producing regular or irregular surfaces.
2. The cutting tool reciprocates against the stationary workpiece, during machining.	2. The workpiece is clamped on table, which reciprocates against the stationary cutting tool.	2. The cutting tool reciprocates against the stationary workpiece, during machining. Working Principle
3. The cutting tool is held in tool post, mounted on ram.	3. The cutting tools is held stationary on tool post, mounted on the cross-rail.	3. The cutting tool is held in tool post, mounted on ram.
4. The tool moves in horizontal direction, to	4. The table reciprocates in horizontal direction, to	4. The tool reciprocates in transverse or vertical axis,

remove the material from the workpiece	remove material from the - workpiece.	to remove the material from the workpiece.
5. The cutting action takes place in forward stroke of tool and returns stroke remains idle.	5. The cutting action takes place in forward stroke of table and return stroke remains idle.	5. The cutting action takes place in downward stroke of tool and upward stroke remains idle.
6. The feed is given by movement of table.	6. The feed is given by the linear movement of tool.	6. The cutting feed is given by the movement-of table.
7. It is used for machining flat surfaces like horizontal, vertical or inclined.	7. It is used for machining large flat surfaces.	7. It is used for machining slots, grooves, keyways etc.

3.16 Tool holding devices used in drilling machines

In drilling machines mostly drills of various type and size are used for drilling holes. Often some other tools are also used for enlarging and finishing drilled holes, counter boring, countersinking, tapping etc. The different methods used for holding tools in a drill spindle are:

By directly fitting in the spindle.

By a sleeve.

By a socket.

By chucks.

Drill directly fitted in the spindle

All drilling machines have the spindle bored out to a standard Morse taper (1:20) to receive the taper shank of the tool. While fitting the tool the shank is forced in the tapered hole and the tool is gripped by friction. The tool may be rotated with the spindle by friction between the tapered surface and the spindle; but to ensure a positive drive the tang or tongue of the tool fits into a slot at the end of the taper hole. The tool is removed by pressing a tapered wedge known as the drift or key into the slotted hole of the spindle. Fig. 3.122 (a) shows a drill directly fitted in the spindle. Fig. 3.122 (b) shows a drift.

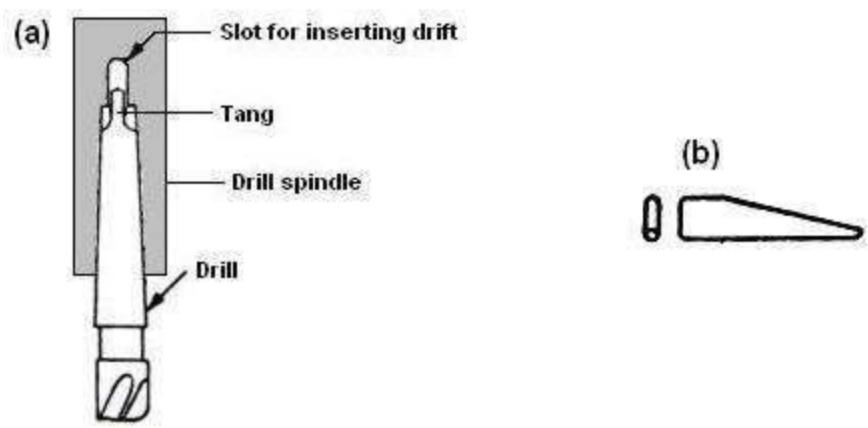


Fig. 3.122 (a) Drill directly fitted in the spindle and (b) Drift or key

Drill sleeve

The drill spindle is suitable for holding only one size of shank. If the taper shank of the tool is smaller than the taper in the spindle hole, a taper sleeve is used. The outside taper of the sleeve conforms to the drill spindle taper and the inside the taper holds the shanks of smaller size tools or smaller sleeves. The sleeve fits into the taper hole of the spindle. The sleeve has a tang which fits into the slot of the spindle. The tang of the tool fits into a slot provided at the end of the taper hole of the sleeve. The sleeve with the tool may be removed by forcing a drift within the slot of the spindle and the tool may be separated from the sleeve by the similar process. Different size of the tool shanks may be held in the spindle by using different sizes of sleeves. Fig. 3.123 (a) shows a drill sleeve. Fig. 3.123 (b) shows a drill sleeve holding a drill fitted in the drill spindle. Fig. 3.123 (c) shows different sizes of drill sleeves.

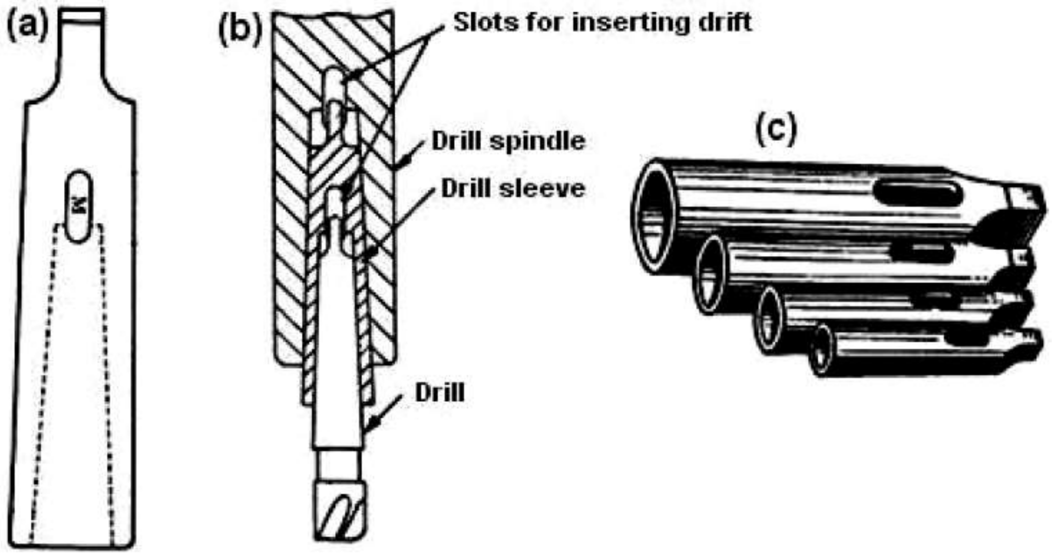


Fig. 3.123 (a) Drill sleeve (b) Drill sleeve holding a drill fitted in the drill spindle and

(c) Different sizes of drill sleeves.

Drill socket

When the tapered tool shank is larger than the spindle taper, drill sockets are used to hold the tool. Drill sockets are much longer in size than the drill sleeves. A socket consists of a solid shank attached to the end of a cylindrical body. The taper shank of the socket conforms to the taper of the drill spindle and fits into it. The body of the socket has a tapered hole larger than the drill spindle taper into which the taper shank of any tool may be fitted. The tang of the socket fits into the slot of the spindle and the tang of the tool fits into the slot of the socket. Fig. 3.124 shows a drill socket.

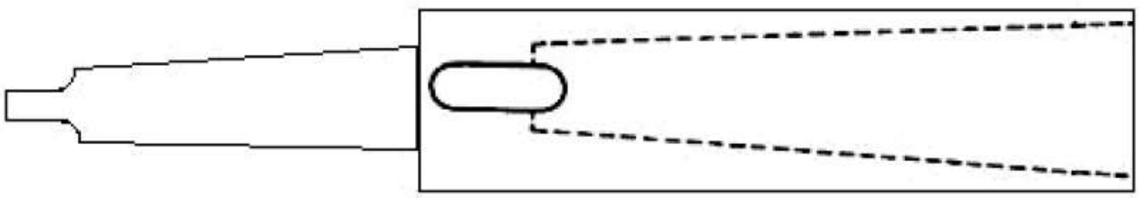


Fig. 3.124 Drill socket

Drill chucks

The chucks are especially intended for holding smaller size drills are any other tools. A sleeve or socket can hold one size of tool shank only; but a drill chuck may be used to hold different sizes of tool shanks within a certain limit.Drill chucks have tapered shanks which are fitted into the drilling machine spindle. Different types of drill chucks are manufactured for different purposes. The most common type of drill chuck used is three jaw self centering drill chuck.

This type of chuck is particularly adapted for holding tools having straight shanks. Three slots are cut 1200 apart in the chuck body which houses three jaws having threads cut at the back that meshes with a ring nut. The ring nut is attached to the sleeve. Bevel teeth are cut all round the sleeve body. The sleeve may be rotated by rotating a key having bevel teeth cut on its face which meshes with the bevel teeth on the sleeve. The rotation of the sleeve causes the ring nut to rotate in a fixed position and all the three jaws close or open by the same amount from the centre holding or releasing the shank of a tool. Fig. 3.125 shows a three jaw self centering drill chuck

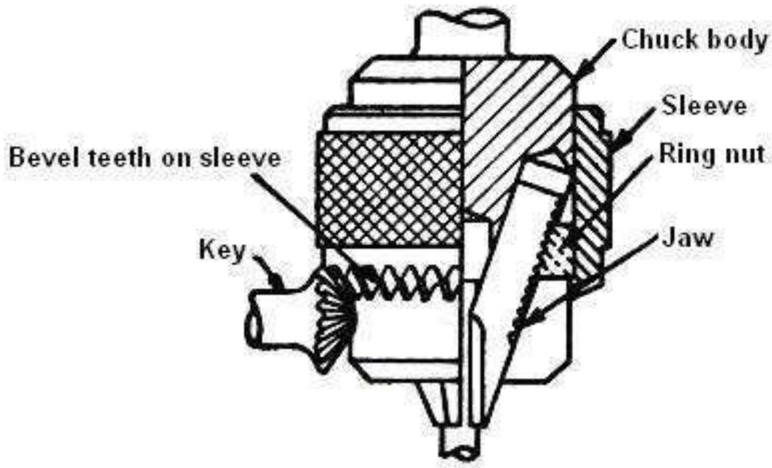


Fig. 3.125 Three jaw self centering drill chuck

Work Holding Devices

1. Machine Table Vice

   The machine vice is equipped with jaws which clamps the work piece. The vice can be bolted to the drilling table or the tail can be swung around swung around. Fig. 13 shows the standard and swivel vice.

   The swivel vice is a machine wise that can be swivel through 360° on a horizontal plane.

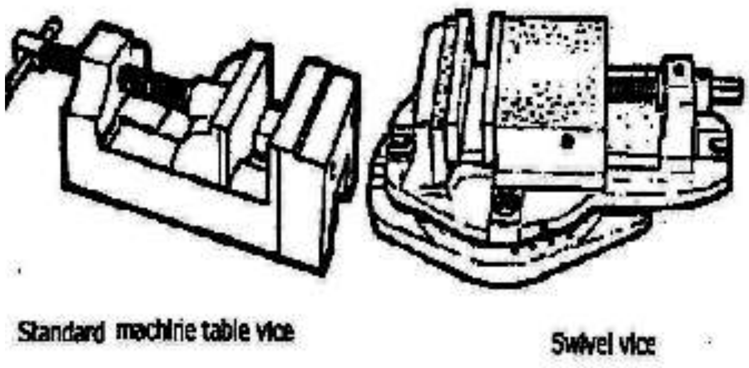


Fig. 13 Machine Table vice.

2. Step Blocks

These are built to allow height adjustment for mounting the drilling jobs and are used with strap clamps and long T-slot bolts.

3. Clamps

These are small, portable vises , which bears against the work piece and holding devices. Common types of clamps are C-clamp, Parallel clamp, machine strap clamp, U-clamp etc.. Fig. 14 shows the correct and incorrect methods of mounting the work piece.

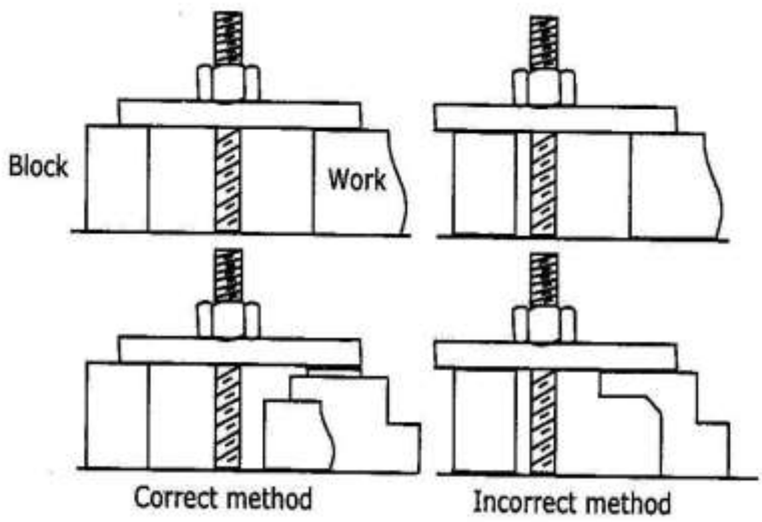


Fig. 14 Correct and incorrect methods of clamping the work piece.

4. V-Blocks

These are designed to hold round work pieces.

5. Angles

Angle plates are made in a 90°angle with slots and bolt holes for securing work to the table.

6. Jigs

The jig guides the drill through a bushing to locate and drill holes accurately.

7. T- Slots Bolt

These are special bolts which has a T shaped head, which slides into the T slots of drilling machine work table.

Drilling tools

Different types of drills are properly used for various applications depending upon work material, tool material, depth and diameter of the holes. General purpose drills may be classified as:

According to material:

High speed steel - most common.Cemented carbides.

Without or with coating.

In the form of brazed, clamped or solid.

According to size:

Large twist drills of diameter around 40 mm.

Micro drills of diameter 25 µm to 500 µm.

Medium range diameter ranges between 3 mm to 25 mm (most widely used).

According to number of flutes:

Two fluted - most common.

Single flute - e.g., gun drill (robust).

Three or four flutes - called slot drill.

According to helix angle of the flutes:

Usual: 200 to 350 - most common.

Large helix: 450 to 600 - suitable for deep holes and softer work materials. Small helix: for harder / stronger materials.

Zero helix: spade drills for high production drilling micro-drilling and hard work materials.

According to length to diameter ratio:

Deep hole drill; e.g. crank shaft drill, gun drill etc. General type: $L/\phi \cong 6$ to 10.

Small length: e.g. centre drill.

According to shank:

Straight shank - small size drill being held in drill chuck.

Taper shank - medium to large size drills being fitted into the spindle nose directly or through taper sockets and sleeves.

According to specific applications:

Centre drill [Fig. 3.126 (a)] for small axial holes with 600 taper ends to hold the lathe centre. Step drill and sub land drill [Fig. 3.126 (b and c)] for small holes with 2 or 3 steps.

Half round drill, gun drill and crank shaft drill [Fig. 3.126 (d, e and f)] for making oil holes. Ejector drill for high speed drilling of large diameter holes.

Taper drill for batch production.

Trepanning tool [Fig. 3.126 (g)] for large holes in soft materials.

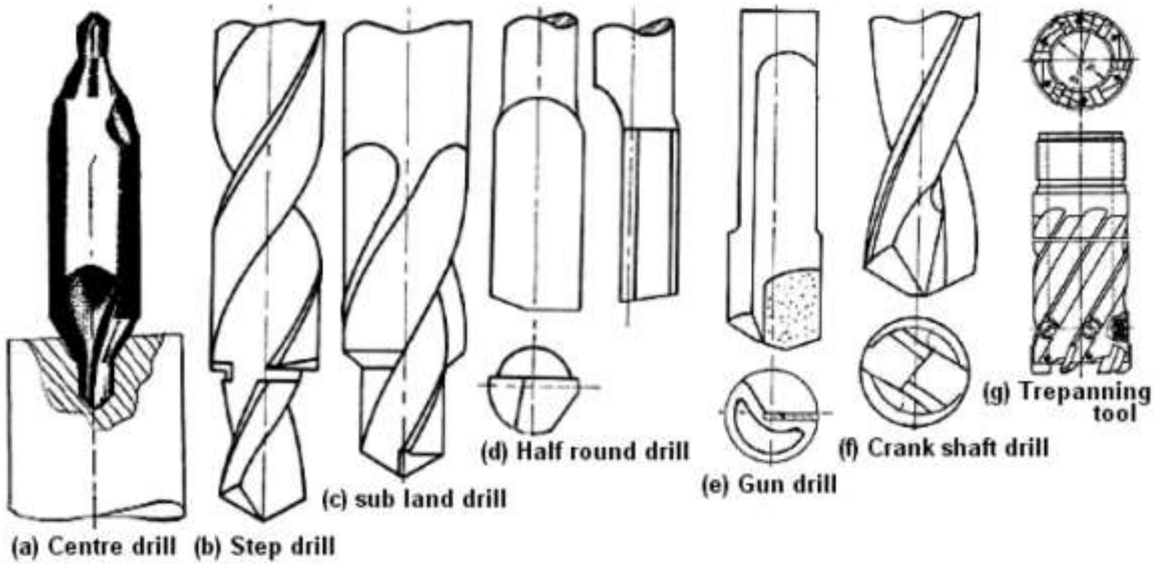
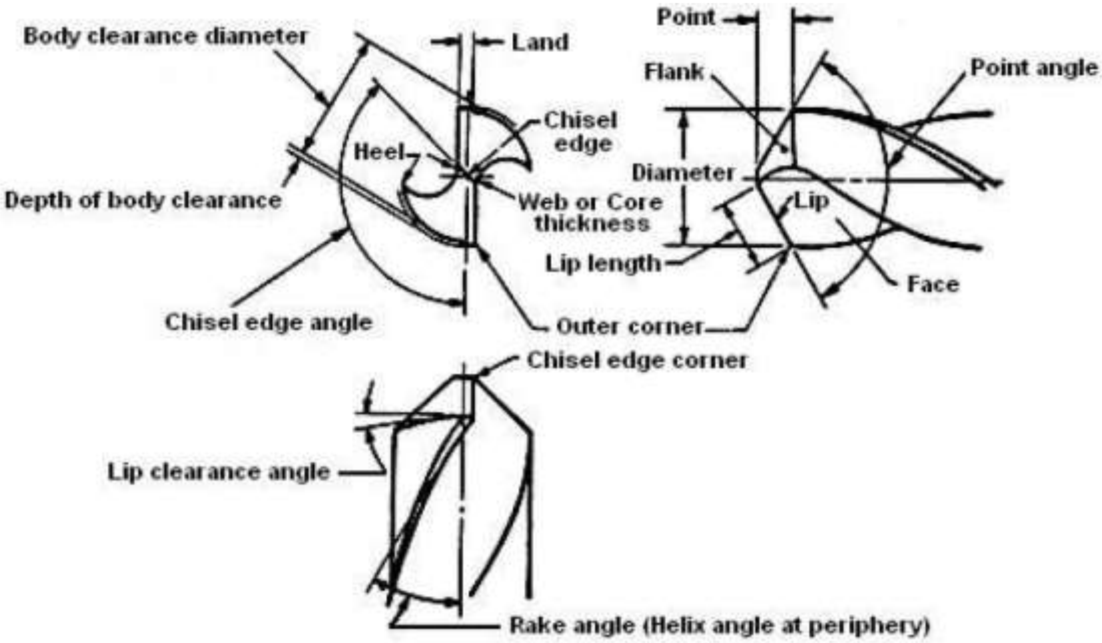


Fig. 3.126 Different types of drills used in various applications

Twist drill nomenclature

The following are the nomenclature, definitions and functions of the different parts of a drill illustrated in Fig. 3.127.



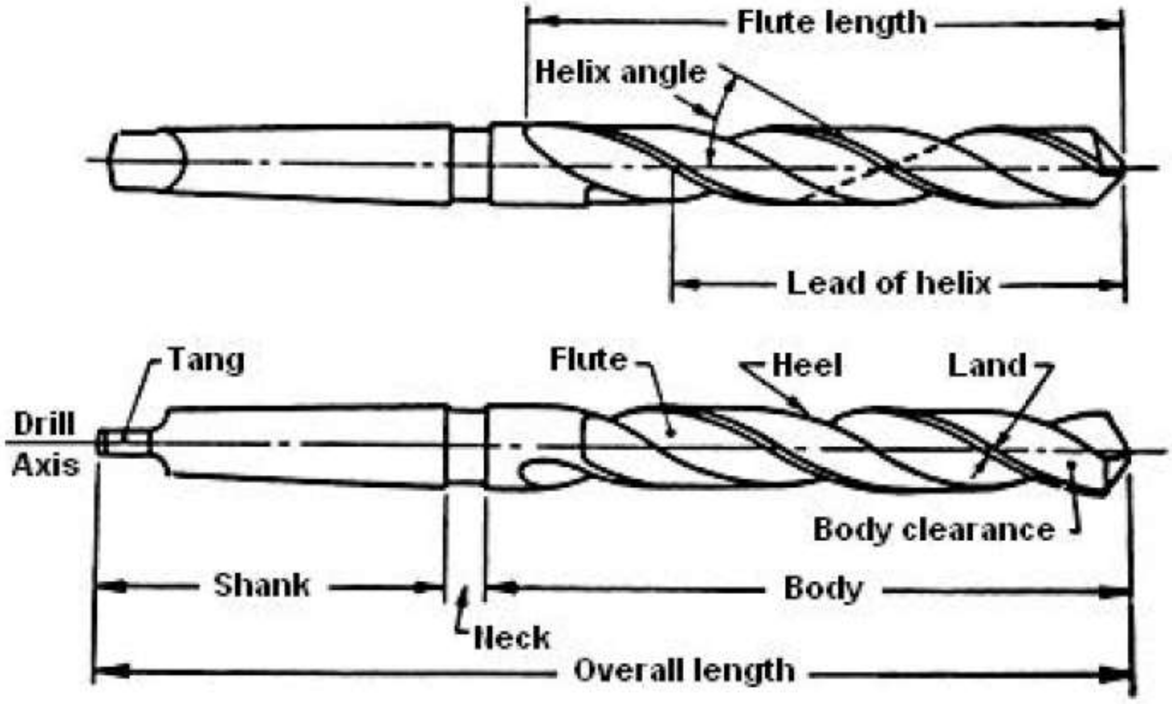


Fig. 3.127 Twist drill nomenclature

Twist drill elements

AxisThe longitudinal centre line of the drill.

Body That portion of the drill extending from its extreme point to the commencement of the neck, if present, otherwise extending to the commencement of the shank.

Body clearance: That portion of the body surface which is reduced in diameter to provide diametral

clearance.

Chisel edge The edge formed by the intersection of the flanks. The chisel edge is also sometimes called dead centre.

Chisel edge corner: The corner formed by the intersection of a lip and the chisel edge.

Face: The portion of the flute surface adjacent to the lip on which the chip impinges as it is cut from the work.

Flank: That surface on a drill point which extends behind the lip to the following flute.

Flutes The groove in the body of the drill which provides lip.

The functions of the flutes are:

To form the cutting edges.

To allow the chips to escape.

To cause the chips to curl.

To permit the cutting fluid to reach the cutting edges.

HeelThe edge formed by the intersection of the flute surface and the body clearance.

Lands The cylindrically ground surface on the leading edges of the drill flutes. The width of the land is measured at right angles to the flute helix.

Lip (cutting edge) The edge formed by the intersections of the flank and face.

The requirements of the drill lip are:

Both lips should be at the same angle of inclination (590) with the drill axis.

Both lips should be of equal length.

Both lips should be provided with the correct clearance.

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

Outer corner The corner formed by the intersection of the flank and face.

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

Shank That part of the drill by which it is held and driven. The most common types of shank are the taper shank and the straight shank.

Tang The flattened end of the taper shank intended to fit into a drift slot in the spindle, socket or drill holder. The tang ensures positive drive of the drill from the spindle.

Web The central portion of the drill situated between the roots of the flutes and extending from the point toward the shank; the point end of the web or core forms the chisel edge.

Linear dimensions

Back taper (longitudinal clearance) It is the reduction in diameter of the drill from the point towards the shank. This permits all parts of the drill behind the point to clear and not rub against the sides of the hole being drilled. The taper varies from 1:4000 for small diameter drills to 1:700 for larger diameters.

Body clearance diameter The diameter over the surface of the drill body which is situated behind the lands.

Depth of body clearance: The amount of radial reduction on each side to provide body clearance.

Diameter The measurement across the cylindrical lands at the outer corners of the drill.

Flute length: The axial length from the extreme end of the point to the termination of the flute at theshank end of the body.

Lead of helix The distance measured parallel to the drill axis between the corresponding points on the leading edge of the flute in one complete turn of the flute.

Lip length: The minimum distance between the outer corner and the chisel edge corner of the lip.

Overall length The length over the extreme ends of the point and the shank of the drill.

Web (core) taper The increase in the web or core thickness from the point of the drill to the shank end of the flute. This increasing thickness gives additional rigidity to the drill and reduces the cutting pressure at the point end.

Web thickness The minimum dimension of the web or core measured at the point end of the drill.

Drill angles

Chisel edge angle The obtuse angle included between the chisel edge and the lip as viewed from the end of the drill.

Helix angle or rake angle This is the angle formed by the leading edge of the land with a plane having the axis of the drill.

Point angle This is the angle included between the two lips.

Lip clearance angle The angle formed by the flank and a plane at right angles to the drill axis.

3.17 Operations performed

The wide range of applications of drilling machines includes:

Drilling machines are generally or mainly used to originate through or blind straight cylindrical holes in solid rigid bodies and/or enlarge (coaxially) existing holes:

Of different diameters up to 40 mm.

Of varying length depending upon the requirement and the diameter of the drill.

In different materials excepting very hard or very soft materials like rubber, polythene etc. Originating stepped cylindrical holes of different diameter and depth. Making rectangular section slots by using slot drills having 3 or 4 flutes and 1800 cone angle. Boring, after drilling, for accuracy and finish or prior to reaming Counter boring, countersinking, chamfering or combination using suitable tools. Spot facing by flat end tools.Trepanning for making large through holes and or getting cylindrical solid core.

If necessary Reaming is done on drilled or bored holes for accuracy and good surface finish. Different types of reamers of standard sizes are available for different applications.

Also used for cutting internal threads in parts like nuts using suitable attachment.

The different operations that can be performed in a drilling machine are shown in Fig. 3.128.

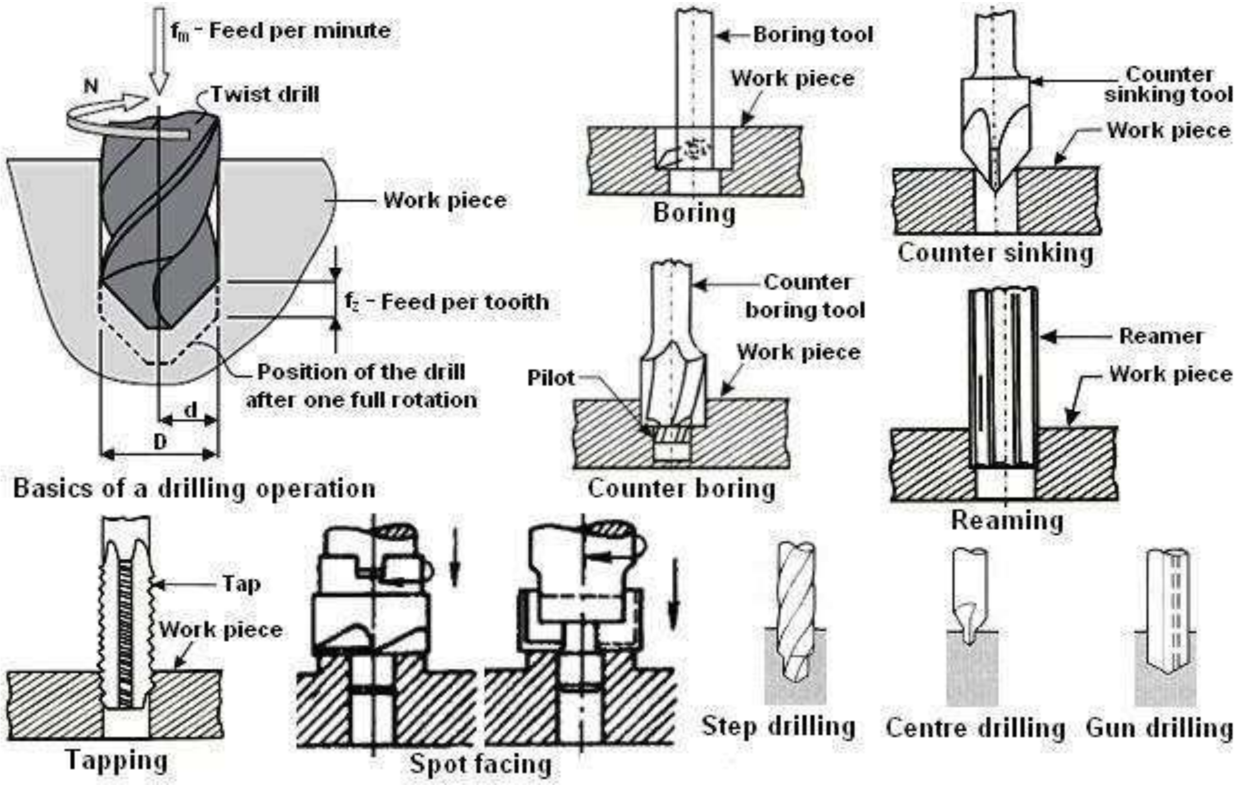


Fig. 3.128 Different operations performed in a drilling machine

REAMING

Reaming is an operation of finishing a hole previously drilled to give a good surface finish and an accurate dimension. A reamer is a multi tooth cutter which rotates and moves axially into the hole. The reamer removes relatively small amount of material. Generally the reamer follows the already existing hole and therefore will not be able to correct the hole misalignment. Fig. 3.129 illustrates the elements of a reamer. Fig. 3.130 shows the different types of reamers of standard sizes.

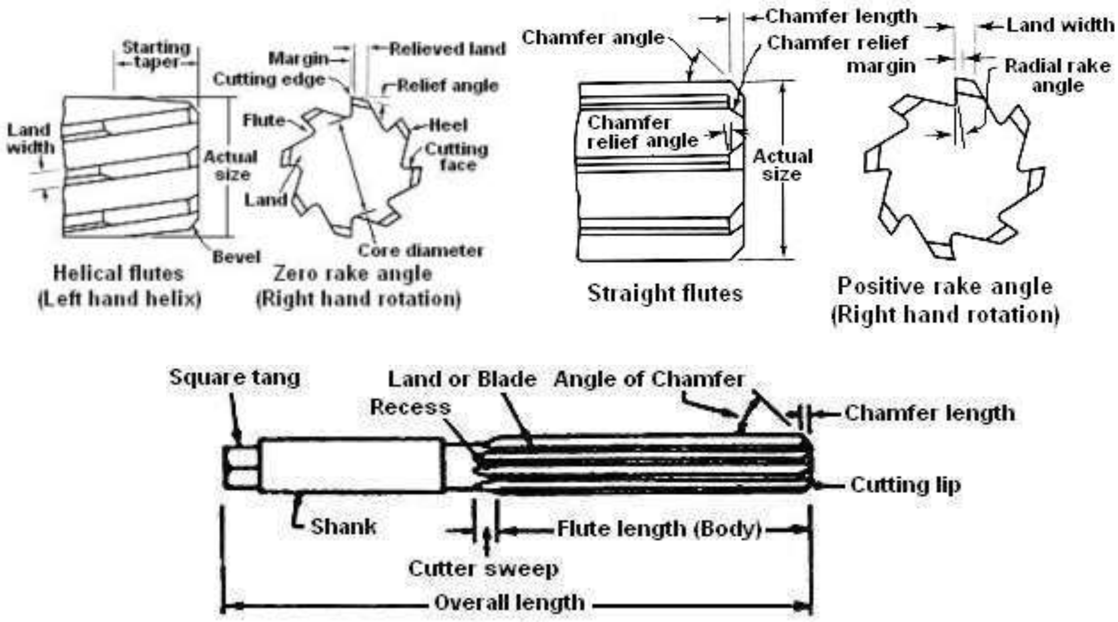
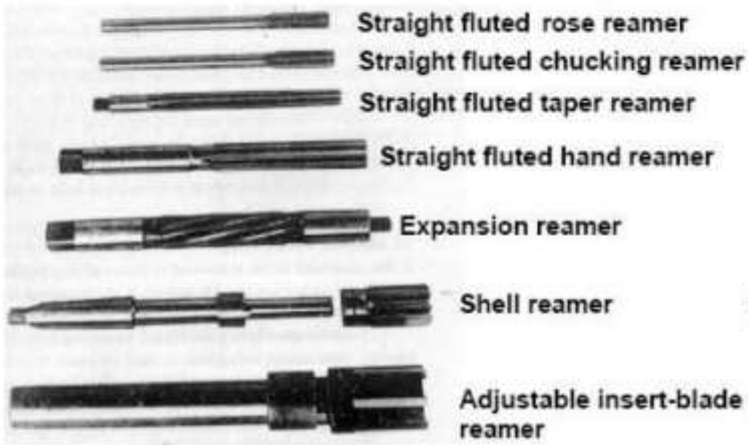


Fig. 3.129 Elements of a reamer



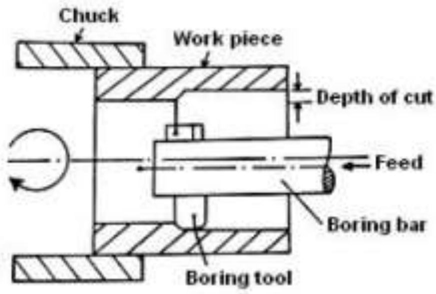


Fig. 3.130 Different typesofreamersFig. 3.131 Principle of boring operation

Reaming

Reaming has been defined as a machining process that uses a multi-edged fluted cutting tool to smooth, enlarge or accurately size an existing hole. Reaming is performed using the same types of machines as drilling.

A reamer is a rotary cutting tool with one or more cutting elements used for enlarging to size and contour a previously formed hole. Its principal support during the cutting action is obtained from the workpiece.

Reamer nomenclature

Here's the basic construction and nomenclature of reamers. The illustration shows the most frequently used style for holes up to 1", called a chucking reamer.

Solid reamers do almost all their cutting with the 45-degree chamfered front end. The flutes guide the reamer and slightly improve the finish. Therefore, reamers should not be used for heavy stock removal.

Axis: The axis is the imaginary straight line that by rotating the reamer between centers.

Back taper: The back taper is a slight decrease in diameter, from front to back in the flute length of reamers.

Body: The body is: 1) The fluted full diameter portion of a reamer, inclusive of the chamfer, starting taper and bevel; 2) the principal supporting member for a set of reamer blades, usually including the shank.

Chamfer: The chamfer is the angular cutting portion at the entering end of a reamer.

Chamfer length: The chamfer length is the length of the chamfer measured parallel to the axis at the cutting edge.

Chamfer relief angle: The chamfer relief angle is the axial relief angle at the outer corner of the chamfer. It is measured by projection into a plane tangent to the periphery at the outer corner of the chamfer.

Clearance: Clearance is the space created by the relief behind the cutting edge or margin of a reamer.

Cutting edge: The cutting edge is the leading edge of the land in the direction of rotation for cutting.

Flutes: The flutes are longitudinal channels formed in the body of the reamer to provide cutting edges, permit passage of chips, and allow cutting fluid to reach the cutting edges.

Flute length: Flute length is the length of the flutes not including the cutter sweep.

Land: The land is the section of the reamer between adjacent flutes.

Margin: The margin is the unrelieved part of the periphery of the land adjacent to the cutting edge.

Neck: The neck is a section of reduced diameter connecting shank to body, or connecting other portions of the reamer.

Overall length: The overall length is the extreme length of the complete reamer from end to end, but not including external centers or expansion screws.

Shank: The shank is the portion of the reamer by which it is held and driven.

Straight shank: A straight shank is a cylindrical shank.

Taper shank: A taper shank is a shank made to fit a specified (conical) taper socket.

Types of reamers

Reamers are made with three shapes of flutes and all are standard.

Straight flute: Straight flute reamers are satisfactory for most work and the least expensive, but should not be used if a keyway or other interruption is in the hole.

Right-hand spiral: Right-hand spiral fluted reamers give freer cutting action and tend to lift the chips out of the hole. They should not be used on copper or soft aluminum because these reamers tend to pull down into the hole.

Left-hand spiral: Left-hand spiral fluted reamers require slightly more pressure to feed but give a smooth cut and can be used on soft, gummy materials, since they tend to be pushed out of the hole as they advance. It is not wise to use these in blind holes, because they push the chips down into the hole.

All reamers are used to produce smooth and accurate holes. Some are turned by hand, and others use machine power.

1: Hand Reamer:

These reamers are operated by hand with a tap wrench fitted on the sequence of the reamer. The work is hold in a vice. The flutes may be straight or helical. Shank is straight with a square tang for the wrench.

2: Machine Reamer;

These are similar to hand reamer, except that the shank is tapered.

3: Chucking Reamers:

These are machine reamers with shorter flutes. These may be either of the type known as rose reamers or fluted reamers. These are using for heavy roughing cuts.

4: Fluting Reamers:

There the holder are not rigid but are fluting this permits the reamer. To flow the previously made hole naturally and without restrained resulting in a better hole.

5: Expanding Reamers:

These reamers allow slight increase in their size to allow for wear to remove an extra amount of material. For this the body of the reamers is bored tapered and is slitted. A taper plug runs through the hole end is operated by a screw so that it acts as the expander.

6: Adjustable Reamers:

In these reamers separate blades are inserted in the grooves provided in the body of the reamer. The blades can be moved up or down of the reamer.

7: Tapered Reamers:

These reamers are used to finish the taper holes for cutting the taper things used to secure the collars, pulleys etc to the shaft.

8: Shell Reamers:

Solid reamers (upto about 20mm diameter or usually made of Hss) to reduce the cost of larger reamers the cutting portion is made as separate shell which are mounted on standard shanks made of lower cost steel. These reamers are however do not very rigid and accurate inserted tooth or plates in shells in further reduced the cost of reamers can tip with cemented carbides.

Operating conditions

In reaming, speed and feed are important; stock removal and alignment must be considered in order to produce chatter-free holes. Reaming speeds Speeds for machine reaming may vary considerably depending in part on the material to be reamed, type of machine, and required finish and accuracy. In general most machine reaming is done at about 2/3 the speed used for drilling the same material.

Reaming feeds: Feeds for reaming are usually much higher than those used for drilling, often running 200 to 300 percent of drill feeds. Too low a feed may result in excessive reamer wear. At all times it is necessary that the feed be high enough to permit the reamer to cut rather than to rub or burnish.

Too high a feed may tend to reduce the accuracy of the hole and may also lower the quality of the finish. The basic idea is to use as high a feed as possible and still produce the required finish and accuracy.

Stock to be removed: For the same reason, insufficient stock for reaming may result in a burnishing rather than a cutting action. It is difficult to generalize on this phase as it is tied in closely with type of material, feed, finish required, depth of hole and chip capacity of the reamer.

Alignment: In the ideal reaming job, the spindle, reamer, bushing, and hole to be machined are all in perfect alignment. Any variation from this tends to increase reamer wear and detracts from the accuracy of the hole. Tapered, oversize, or bell-mouthed holes should call for a check of alignment. Sometimes the bad effects of misalignment can be reduced through the use of floating or adjustable holders. Quite often if the user will grind a slight back taper on the reamer it will also be of help in overcoming the effects of misalignment.

Chatter: The presence of chatter while reaming has a very bad effect on reamer life and on the finish in the hole. Chatter may be the result of one of several causes, some of which are listed:

- Excessive speed;
- Too much clearance on reamer;
- Lack of rigidity in jig;
- Insecure holding of work;
- Excessive overhang of reamer or spindle;
- Too light a feed.

Reaming operations can be performed on lathes, drills and machining centers.

3.12BORING

Boring is an operation of enlarging and locating previously drilled holes with a single point cutting tool. The machine used for this purpose is called boring machine. The boring machine is one of the most versatile machine tools used to bore holes in large and heavy parts such as engine frames, steam engine cylinders, machine housings etc. Drilling, milling and facing operations also can be performed in this machine. Screw cutting. Turning, planetary grinding and gear cutting operations also can be done by fitting simple attachments. The principle of boring operation is illustrated in Fig. 3.131.

3.12.1 Horizontal boring machines

In horizontal boring machine, the tool revolves and the work is stationary. A horizontal boring machine can perform boring, reaming, turning, threading, facing, milling, grooving, recessing and many other operations with suitable tools. Work pieces which are heavy, irregular, unsymmetrical or bulky can be conveniently held and machined. This machine has two vertical columns. A headstock slides up and down in one column. It may be adjusted to any desired height and clamped. The headstock holds the cutting tool. The cutting tool revolves in the headstock in horizontal axis. A sliding type bearing block is provided in the other vertical column. It is used to support the boring bar. The work piece is mounted on the table and is clamped with ordinary strap clamps, T-slot bolts and nuts, or it is held in a special fixture if so required. Various types of rotary and universal swiveling attachments can be installed on the horizontal boring machines table to bore holes at various angles in horizontal and vertical planes.Fig. 3.132 schematically shows the basic configuration of a horizontal boring machine.

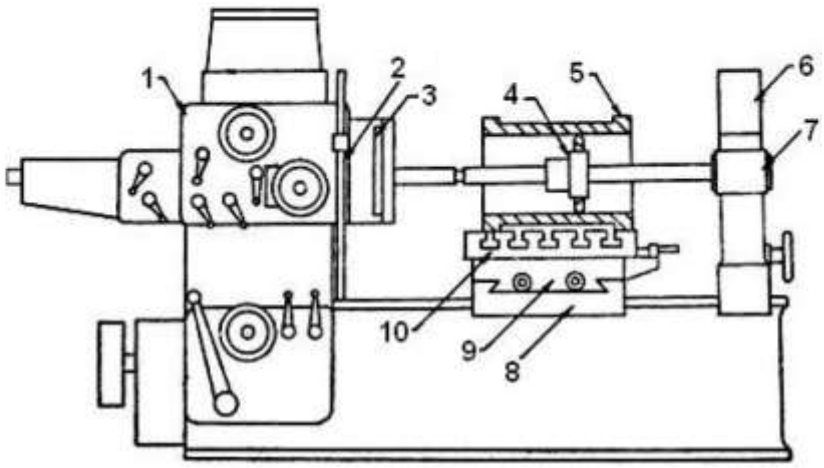


Fig. 3.132 Basic configuration of a horizontal boring machine

1. Head stock
2. Head stock elevating screw
3. Boring head
4. Boring tool on boring bar
5. Work piece
6. End supporting column
7. Bearing block
8. Saddle
9. Coss slide
10. Work table

3.12.2 Types of horizontal boring machine

Different types of horizontal boring machines have been designed to suit different purposes.

They are:

3.12.2.1 Table type horizontal boring machine

The work is held stationary on a coordinate work table having in and out as well as back and forth movements that is perpendicular and parallel to the spindle axis. The spindle carrying the tool can be fed axially. Alternatively, the table travels parallel to the spindle axis (longitudinal feed). This method of boring with longitudinal feed of the table is employed when holes are of considerable length and being bending of the boring bar is possible. Fig. 3.133 shows the table type horizontal boring machine.

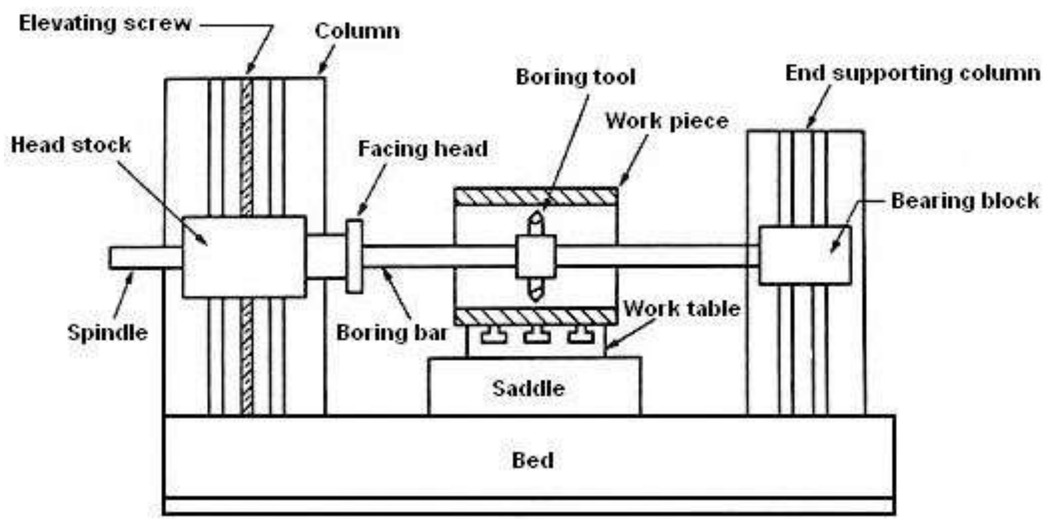


Fig. 3.133 Table type horizontal boring machine

3.12.2.2 Planer type horizontal boring machine

This machine is similar to the table type horizontal boring machine except that the work table has only in and out movements that is perpendicular to the spindle axis. Other features and applications of this machine are similar to the table type horizontal boring machine. This type of machine is suitable for supporting a long work. Fig. 3.134 shows the planer type horizontal boring machine.

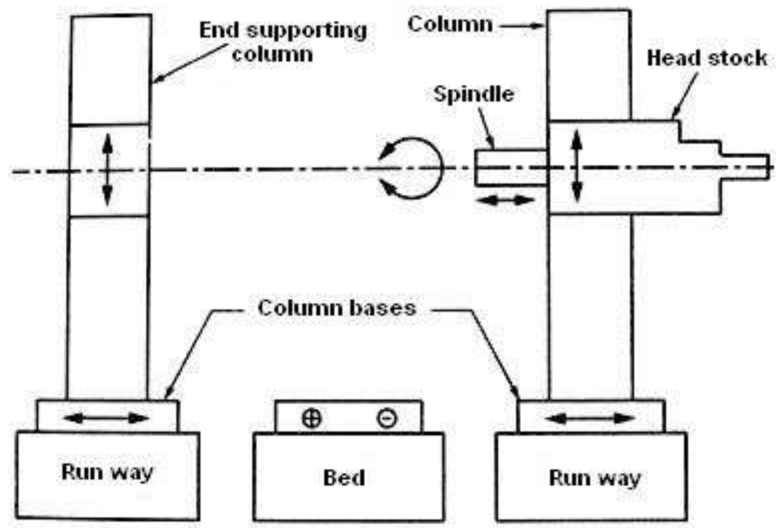


Fig. 3.134 Planer type horizontal boring machine

3.12.2.3 Floor type horizontal boring machine

Here, there is no work table and the job is mounted on a stationary T-slotted floor plate. This design is used when large and heavy jobs can not be mounted and adjusted on the work table. Horizontal movement perpendicular to the spindle axis is obtained by traversing the column carrying the head stock, on guide ways. Fig. 3.135 shows the floor type horizontal boring machine.

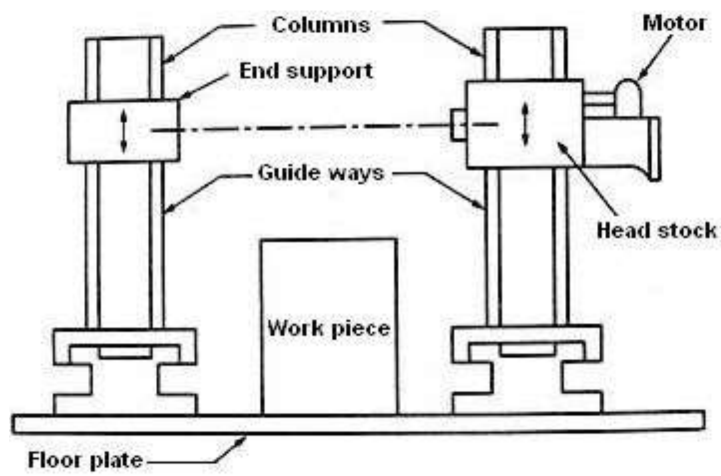


Fig. 3.135 Floor type horizontal boring machine

3.12.2.4 Multiple head type horizontal boring machine

The machine resembles a double housing planer or a Plano-miller and is used for boring holes of large diameter is mass production. The machine may have two, three or four headstocks. This type of machine may be used both as a horizontal and vertical machine. Fig. 3.136 shows the multiple head type horizontal boring machine.

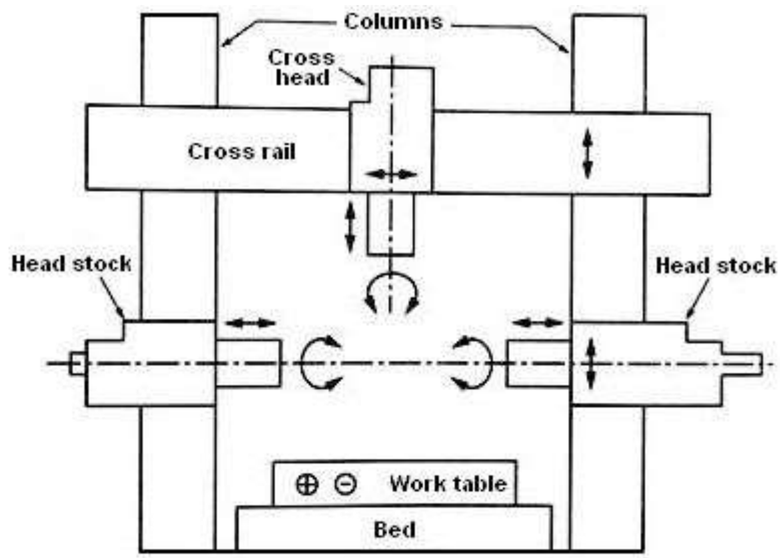
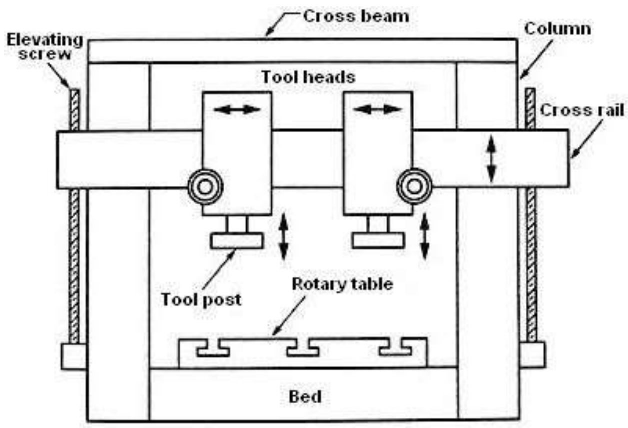


Fig. 3.136 Multiple head type horizontal boring machine

3.12.3 Vertical boring machines

For convenience, parts whose length or height is less than the diameter are machined on vertical boring machines. The typical works are: Large gear blanks, locomotive and rolling stock tires, fly wheels, large flanges, steam and water turbine castings etc. On a vertical boring machine, the work is fastened on a horizontal revolving table, and the cutting tool(s) which are stationary, advance vertically into it are as the table revolves.

There are two types of vertical boring machine: Single column vertical boring machine and double column vertical boring machine. The single column vertical boring machine looks like a drilling machine or a knee type vertical milling machine. Guide ways are employed on the column to support the spindle head in the vertical direction. A double column vertical boring machine is shown in Fig. 3.137. The work is accommodated on the horizontal revolving table at the front of the machine. The circular work can be clamped on to the table with the help of jaw chucks whereas the T-slots can be used with bolts and clamps for setting up and holding irregular work. A horizontal cross rail is carried on vertical slideways and carries the tool holder slide(s). On machines designed for working on large batches of identical parts, a single slide with turret may be employed. Fig. 3.138 shows the turret boring machine.



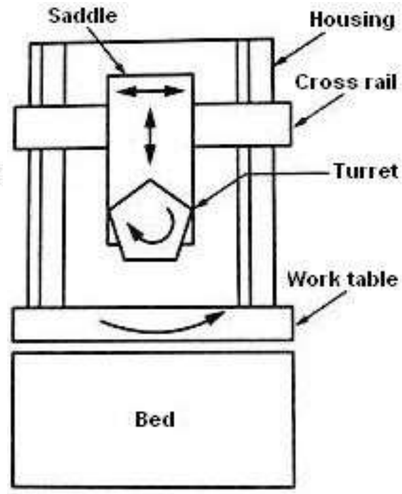


Fig. 3.137 Double column vertical boring machineFig. 3.138 Turret boring machine

3.12.5 Boring tools

A boring tool consists of a single point cutting tool (boring bit) held in a tool holder known as boring bar. The boring bit is held in a cross hole at the end of the boring bar. The boring bit is adjusted and held in position with the help of set screws. The material of the boring bit can be: Solid HSS, solid carbide, brazed carbide, disposable carbide tips or diamond tips. Boring tools are of two types: fixed type and rotating type. Fixed type boring tools are used on working rotating machines such as lathes, whereas rotating type boring tools are used on tool rotating machines such as drilling machines, milling machines and boring machines. Fig. 3.140 shows the different types of boring tools (bars).

3.13 TAPPING

Tapping has been defined as: A process for producing internal threads using a tool (tap) that has teeth on its periphery to cut threads in a predrilled hole. A combined rotary and axial relative motion between tap and workpiece forms threads.

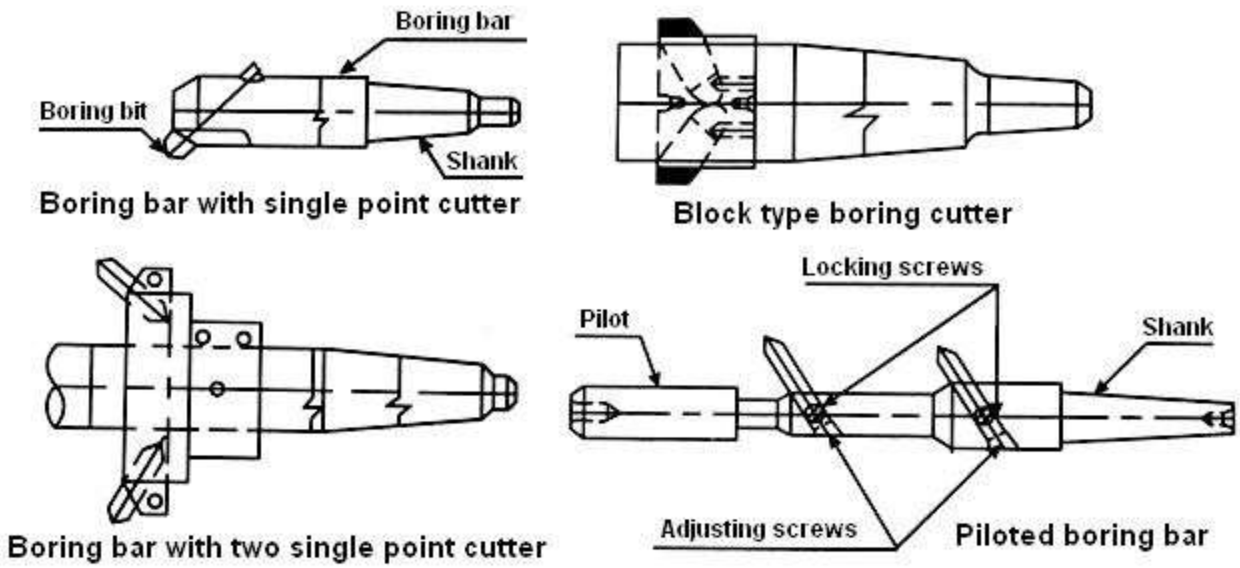


Fig. 3.140 Different types of boring tools (bars)

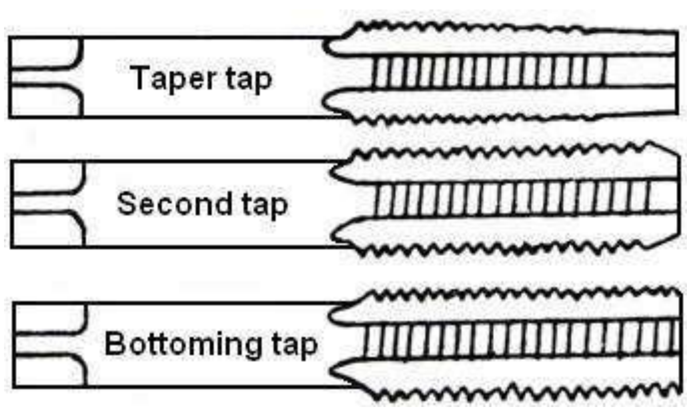


Fig. 3.141 Hand (solid) taps

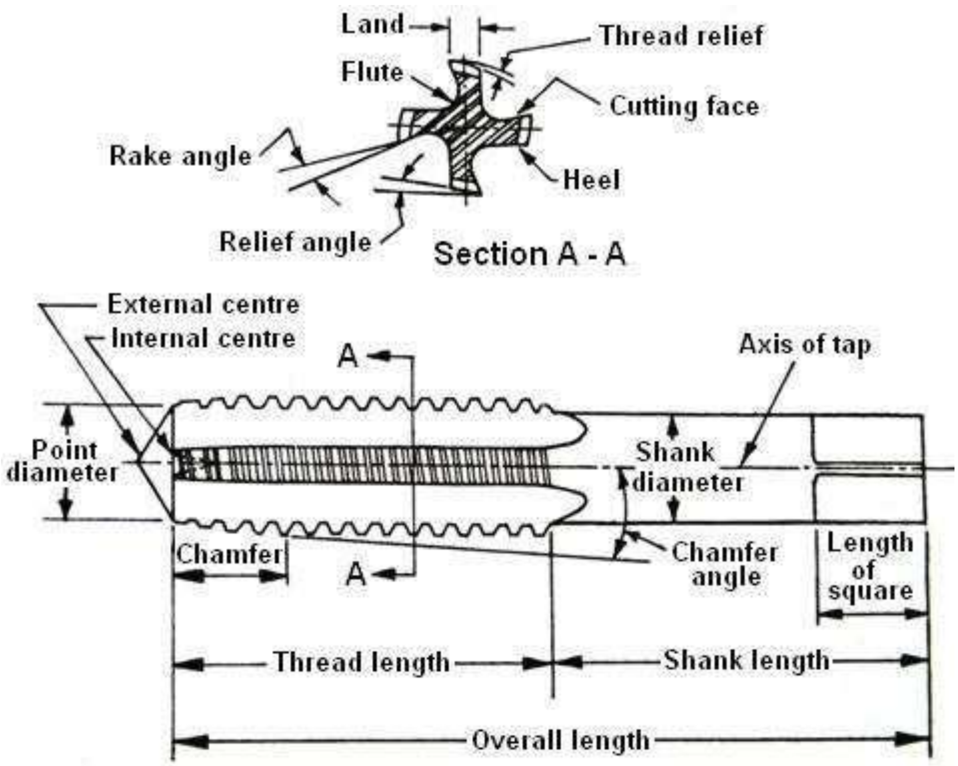


Fig. 3.142 Elements of a solid tap

Screw threads have many dimensions. It is important in modern manufacturing to have a working knowledge of screw thread terminology. A "right-hand thread" is a screw thread that requires right-hand or clockwise rotation to tighten it. "Thread fit" is the range of tightness or looseness between external and internal mating threads. "Thread series" are groups of diameter and pitch combinations that are distinguished. from each other by the number of threads per inch applied to a specific diameter. The two common thread series used in industry are the coarse and fine series, specified as UNC and UNF.

Tap nomenclature

Chamfer: Chamfer is the tapering of the threads at the front end of each land of a chaser, tap, or die by cutting away and relieving the crest of the first few teeth to distribute the cutting action over several teeth.

Crest: Crest is the surface of the thread which joins the flanks of the thread and is farthest from the cylinder or cone from which the thread projects.

Flank: Flank is the part of a helical thread surface which connects the crest and the root, and which is theoretically a straight line in an axial plane section.

Flute: Flute is the longitudinal channel formed in a tap to create cutting edges on the thread profile and to provide chip spaces and cutting fluid passage.

Hook angle: The hook angle is the angle of inclination of a concave face, usually specified either as "chordal hook" or "tangential hook."

Land: The land is one of the threaded sections between the flutes of a tap.

Lead of thread: The lead of thread is the distance a screw thread advances axially in one complete turn. On a single start tap, the lead and pitch are identical. On a multiple start tap the lead is the multiple of the pitch.

Major diameter: This is the diameter of the major cylinder or cone, at a given position on the axis that bounds the crests of an external thread or the roots of an internal thread.

Minor diameter: Minor diameter is the diameter of the minor cylinder or cone, at a given position on the axis that bounds the roots of an external thread or the crests of an internal thread.

Pitch diameter: Pitch diameter is the diameter of an imaginary cylinder or cone, at a given point on the axis of such a diameter and location of its axis, that its surface would pass through the thread in a manner such as to make the thread ridge and the thread groove equal and, as such, is located equidistant between the sharp major and minor cylinders or cones of a given thread form. On a theoretically perfect thread, these widths are equal to one half of the basic pitch (measured parallel to the axis).

Spiral point: A spiral point is the angular fluting in the cutting face of the land at the chamfered end. It is formed at an angle with respect to the tap axis of opposite hand to that of rotation. Its length is usually greater than the chamfer length and its angle with respect to the tap axis is usually made great enough to direct the chips ahead of the tap. The tap may or may not have longitudinal flutes.

Square: Square is the four driving flats parallel to the axis on a tap shank forming a square or square with round corners.

Types of taps

Hand Taps: Today the hand tap is used both by hand and in machines of all types. This is the basic tap design: four straight flutes, in taper plug, or bottoming types. The small, numbered machine screw sizes are standard in two and three flutes depending on the size.

If soft and stringy metals are being tapped, or if horizontal holes are being made, either two- or three-flute taps can be used in the larger sizes. The flute spaces are larger, but the taps are weaker. The two-flute especially has a very small cross section.

The chips formed by these taps cannot get out; thus, they accumulate in the flute spaces. This causes added friction and is a major cause of broken taps.

Spiral point tap: The spiral point or "gun" tap is made the same as the standard hand tap except at the point. A slash is ground in each flute at the point of the tap. This accomplishes several things:

• The gun tap has fewer flutes (usually three), and they are shallower. This means a stronger tap.

• The chips are forced out ahead of the tap instead of accumulating in the flutes, as they will with a plug tap.

• Because of these two factors, the spiral point tap can often be run faster than the hand tap, and tap breakage is greatly reduced.

This tap has, in many cases, replaced the "standard" style in industry, especially for open-ended trough holes in mild steel and aluminum. Both regular and spiral-point taps are made in all sizes including metric.

Spiral flute tap: The spiral flute-bottoming tap is made in regular and fast spirals, that is, with small or large helix angle. They are sometimes called "helical-fluted" taps. The use of these taps has been increasing since they pull the chip up out of the hole and produce good threads in soft metals (such as aluminum, zinc, and copper), yet also work well in Monel metal, stainless steel and cast steel. They are made in all sizes up to 1 1/2" and in metric sizes up to 12 mm.

While the "standard" taps will efficiently do most work, if a great deal of aluminum, brass, cast iron or stainless steel is being tapped, the manufacturer can supply "standard" specials that will do a better job.

Pipe taps: General Purpose Pipe Taps are used for threading a wide range of materials both ferrous and non-ferrous. All pipe taps are supplied with 2 1/2 to 3 1/2 thread chamfer. The nominal size of a pipe tap is that of the pipe fitting to be tapped, not the actual size of the tap. Ground Thread Pipe Taps are standard in American Standard Pipe Form (NPT) and American Standard Dryseal Pipe Form (NPTF). NPT threads require the use of a "sealer" like Teflon tape or pipe compound. Dryseal taps are used to tap fittings that will give a pressure tight joint without the use of a "sealer."

Fluteless taps: Fluteless taps do not look like taps, except for the spiral "threads." These taps are not round. They are shaped so that they "cold form" the metal out of the wall of the hole into the thread form with no chips. The fluteless tap was originally designed for use in aluminum, brass, and zinc alloys. However, it is being successfully used in mild steel and some stainless steels. Thus, it is worth checking for use where BHN is under 180. They are available in most sizes, including metric threads.

Collapsing Taps: These taps collapse to a smaller diameter at the end of the cut. Thus, when used on lathes of any kind, they can be pulled back rapidly. They are made in sizes from about 1 inch up, in both machine and pipe threads. They use three to six separate "chasers" which must be ground as a set. The tap holder and special dies make this assembly moderately expensive, but it is economical for medium and high production work.

Operating options

Some threads, both external and internal, can be cut with a single-point tool as previously shown. However, most frequently a die or tap of some type is used because it is faster and generally more accurate.

Taps are made in many styles, but a few styles do 90 percent of the work. The cutting end of the tap is made in three different tapers.

The "taper tap" is not often used today. Occasionally, it is used first as a starter if the metal is difficult to tap. The end is tapered about 5 degrees per side, which makes eight partial threads.

The "plug tap" is the style used probably 90 percent of the time. With the proper geometry of the cutting edge and a good lubricant, a plug tap will do most of the work needed. The end is tapered 8 degrees per side, which makes four or five incomplete threads.

The "bottoming tap" is used only for blind holes where the thread must go close to the bottom of the hole. It has only 1 1/2 to 3 incomplete threads. If the hole can be drilled deeper, a bottoming tap may not be needed. The plug tap must be used first, followed by the bottoming tap.

All three types of end tapers are made from identical taps. Size, length, and all measurements except the end taper are the same.

Material used for taps is usually high-speed steel in the M1, M2, M7 and sometimes the M40 series cobalt high-speed steels. A few taps are made of solid tungsten carbide.

Most taps today have ground threads. The grinding is done after hardening and makes much more accurate cutting tools. "Cut thread" taps are available at a somewhat lower cost in some styles and sizes.

Just like reaming operations, tapping can be performed on lathes, drills and machining centers.

George Schneider, Jr., is the author of Cutting Tool Applications, a handbook to machine tool materials, principles, and designs. He is the Professor Emeritus of Engineering Technology at Lawrence Technological University, and former Chairman of the Detroit Chapter of the Society of Manufacturing Engineers

3.18 Fine Boring Machines

3.19 Jig boring machine

It is very precise vertical type boring machine. The spindle and spindle bearings are constructed with very high precision. The table can be moved precisely in two mutually perpendicular directions in a plane normal to the spindle axis. The coordinate method for locating holes is employed. Holes can be located to within tolerances of 0.0025 mm. Jig boring machines are relatively costlier. Hence, they are found only in the large machine shops, where a sufficient amount of accurate hole locating is done. Jig boring machines are basically designed for use in the making jigs, fixtures and other special tooling.Fig. 3.139 shows the block diagram of a jig boring machine.

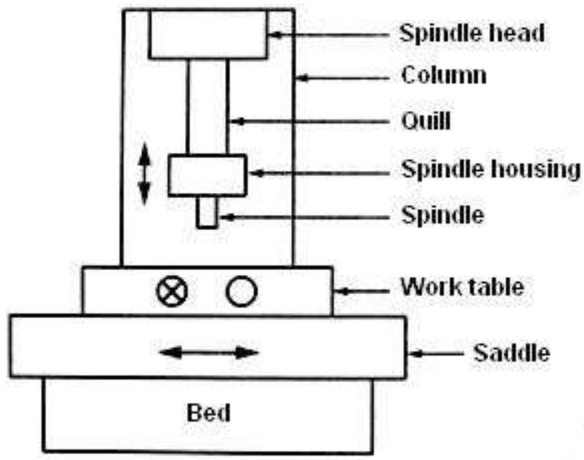


Fig. 3.139 Block diagram of a jig boring machine

Definitions

1. Cutting Speed (v):-

It's the peripheral speed of the drill.The cutting speed depends upon the properties of the material being drilled, drill material, drill diameter, rate of speed, coolant used etc…

$v = \Pi * D * N$ where

D =dia of the drill in m

N = Speed of rotation in rpm

2. Feed Rate (f):-

It's the movement of drill along the axis (rpm)

3. Depth of Cut (d):-

The distance from the machined surface to the drill axis.

$d = D / 2$

As the depth of hole increases,the chip ejection becomes more difficult and the fresh cutting fluid is not able to cutting zone. Hence for machining the lengthy hole special type of drill called 'gun drill' is used.

4. Material Removal Rate:-

It's the volume of material removed by the drill per unit time

$MRR = (\Pi D2 / 4) * f * Nmm3 / min$

5. Machining Time (T) :-

It depends upon the length (l) of the hole to be drilled , to the Speed (N) and feed (f) of the drill

$t = L / f N$ min

Precautions for Drilling machine

- Lubrication is important to remove heat and friction.
- Machines should be cleaned after use
- Chips should be removed using brush.
- T-slots, grooves, spindles sleeves, belts, and pulley should be cleaned.
- Machines should be lightly oiled to prevent from rusting

Safety Precautions

- Do not support the work piece by hand – use work holding device.
- Use brush to clean the chip
- No adjustments while the machine is operating
- Ensure for the cutting tools running straight before starting the operation.
- Never place tools on the drilling table
- Avoid loose clothing and protect the eyes.
- Ease the feed if drill breaks inside the work piece.

Problems

1. Calculate the speed of thedrill bit to drill a hole of dia 20mm where the cutting speed is 25mts/min.

$N\ [rpm] = (\pi * D * N)/1000$

$= (25 * 1000) / (\pi * 20)$

$= 397.8$rpm

2. The dia of one end of a taper plug is 150mm and dia of the other end is 80mm and the length is 300mm.Calculate its taper.

Taper per mm = $(D-d)/L$

$= (150-80)/ 300$

$= 0.233$mm

3. . The dia of one end of a taper plug is 150mm and dia of the other end is 80mm and the length is 300mm.Calculate its taper angle.

$\tan \alpha/2 = (D-d)/2L$

$= (150-80)/2*300$

$= 6.65°$

Review Questions:

Part – A

1. What is meant by drilling?
2. Which tool is commonly used for drilling?
3. Name the different types of drilling machine?
4. What is meant by hand feed?
5. What is meant by power feed?
6. What are the salient features of radial drilling machine?
7. What are the different ways to mount the drilling tool?
8. Name the different types of drilling operations?
9. What is meant by reaming?
10. What is boring?
11. What is the difference between reaming and boring?
12. What is counter boring?
13. What is countersinking?
14. What is the purpose of tapping operation?
15. Name some work holding devices?

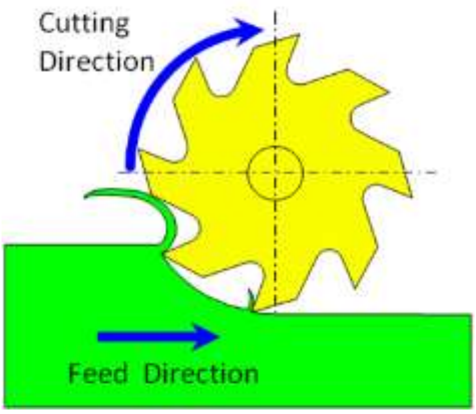
Part – B

1. Explain with neat sketch the salient features of radial drilling machine?
2. Draw and explain the working principle of upright drilling machine?
3. With neat sketch describe the nomenclature of twist drill?
4. Discuss is detail with diagram the various operations that can be performed in drilling machine

MILLINGMACHINES:

4.1 Principles of working

The working principle, employed in the metal removing operation in a milling machine, is that the job or work-piece is rigidly clamped on the table of the machine or in a chuck or an index head or held between centers and multiteeth cutter mounted either on a spindle or an arbor. The cutter revolves at a fairly high speed and the work fed slowly past the cutter. The work can be fed in a vertical, longitudinal or cross direction. As the work advances, the cutter-teeth remove the metal from the work surface to produce the desired shape.



4.2 Size and Specifications of milling machine

Generally the size of a milling machine is denoted by the dimension i.e. length and breadth of the table. Other main specifications of the machine or placing an order are the horse power of the driving motor, number of spindle speeds and feeds, the taper of spindle nose required floor area, gross weight of the m/c etc.

Milling methods:

Milling is a process of metal cutting by means of a multi-teeth rotating tool called cutter. The form of each tooth of the cutter is the same as that of a single point tool.

Up milling or conventional milling: Here, the cutter rotates in the opposite direction to the work table movement. In this, the chip starts as zero thickness and gradually increases to the maximum. The cutting force is directed upwards and this tends to lift the work piece from the work holding device. Each tooth slides across a minute distance on the work surface before it begins to cut, producing a wavy surface. This tends to dull the cutting edge and consequently have a lower tool life. As the cutter progresses, the chip accumulate at the cutting zone and carried over with the teeth which spoils the work surface.

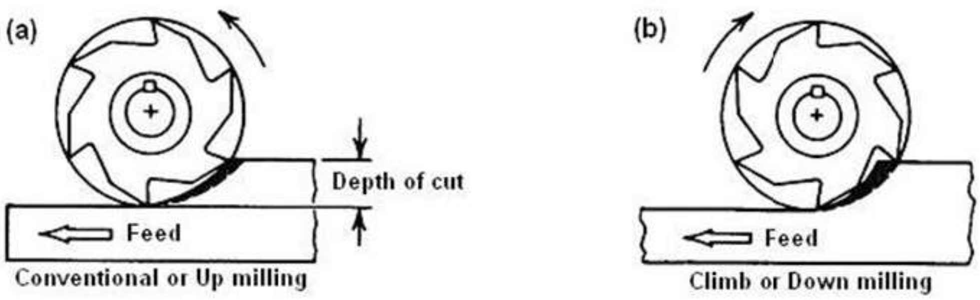


Fig. 3.94 Schematic views of (a) Up milling process and (b) Down milling process

Down milling or climb milling: Here, the cutter rotates in the same direction as that of the work table movement. In this, the chip starts as maximum thickness and gradually decreases to zero thickness. This is suitable for obtaining fine finish on the work surface. The cutting force acts downwards and this tends to seat the work piece firmly in the work holding device. The chips are deposited behind the cutter and do not interfere with the cutting. Climb milling allows greater feeds per tooth and longer tool life between regrinds than up milling. Fig. 3.94 (b) schematically shows the down or climb milling process.

4.3 Classification of Milling Machines

Milling machines can be classified into different categories depending upon their construction, specification and operations. The choice of any particular machine is primarily determined by nature of the work to be done, its size, geometry and operations to be performed. The typical classification of milling machines on the basis of its construction is given below.

The broader classification has three categories and each category has its sub-classifications given below:

Types of Milling Machine

The usual classification according to the general design of the milling machines is as follows: -

a. Column and knee type milling machine
   i. Horizontal milling machine (Plain)
   ii. Universal milling machine
   iii. Omniversal milling machine
   iv. Vertical milling machine
b. Bed or manufacturing type milling machine
   i. Simplex milling machine
   ii. Duplex milling machine
   iii. Triplex milling machine
c. Special type
   i. Rotary table milling machine
   ii. Drum milling machine
   iii. Tracer controlled milling

In addition to above three types there is one more type of milling machine named as planner type milling machine which is rarely used.

Column and Knee Type Milling Machine

Main shape of column knee type of milling machine is shown in the figure. This milling machine consists of a base having different control mechanisms housed there in. The base consists of a vertical column at one of its end. There is one more base above the main base and attached to the column that serves as worktable equipped with different attachments to hold the workpiece. This base having worktable is identified as "knee" of the milling machine. At the top of the column and knee type milling machines are classified according to the various methods of supplying power to the table, different movements of the table and different axis of rotation of the main spindle. These are described in brief as below.

Head Milling Machine

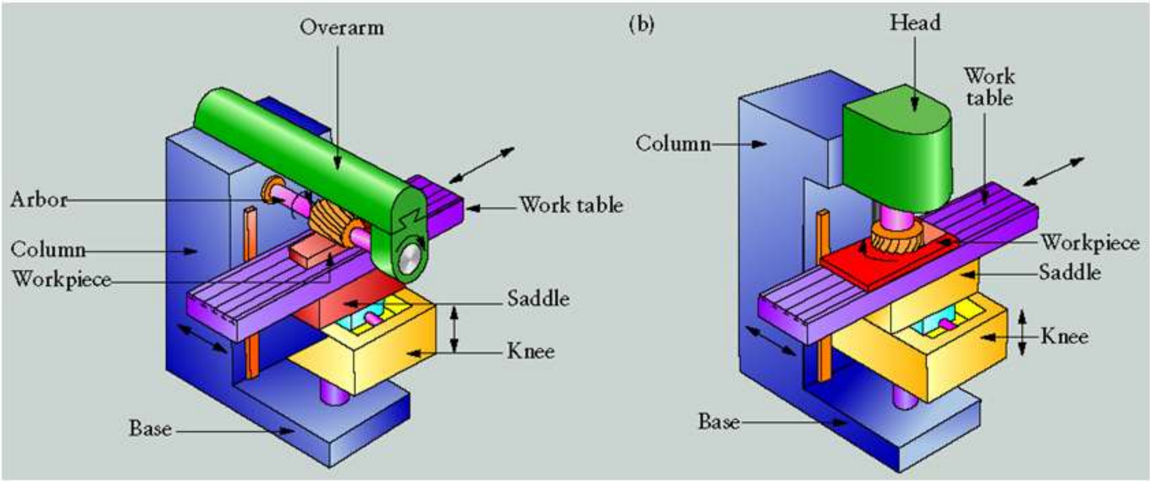
In case of head milling machine feed motion is given by hand and movements of the machine are provided by motor. This is simple and light duty milling machine meant for basic operations.

Plain Milling Machine

Plain milling machine is similar to hand milling machine but feed movement can be powered controlled in addition to manual control.

4.4 Principle features of horizontal

PRINCIPAL PARTS OF A MILLING MACHINE



Generally columns and knee type milling machine is considered as typical milling machine. Principal parts of a typical milling machine are described as below.

Base

It provides rest for all parts of milling machine including column. It is made of grey iron by casting.

Column

It is a type of rigid vertical long box. It houses driving mechanism of spindle, table knee is also fixed to the guide ways of column.

Knee

Knee can be adjusted at a height on the column. It houses the feed mechanism of the table and other controls.

Saddle

Saddle is placed at the top of the knee. Saddle provides guide ways for the movement of the table.

Table

Table rests on the saddle. It consists of „T" shaped slots for clamping the workpiece. Movements of the table (feed motions) are given in very controlled manner be lead screw.

Overhanging Arm

Overhanging arm is mounted on the column and serves a bearing support for the arbor. This arm is adjustable so that the bearing support may be provided near to the milling cutter. There can be more than one bearing supports to the arbor.

Arbor

It holds rotating milling cutters rigidly and mounted on the spindle. Sometimes arbor is supported at maximum distance from support of overhanging arm like a cantilever, it is called stub arbor. Locking provisions are provided in the arbor assembly to ensure its reliability.

Front Brace Milling

Front base is used to adjust the relative position of knee and overhanging arm. It is also an extra support fixed between the knee and overhanging arm for rigidity.

Spindle

Spindle is projected from the column face and provided with a tapered hole to accommodate the arbor. Performance of a milling machine depends on the accuracy, strength and rigidity of the spindle. Spindle also transfer the motive power to arbor through belt or gear from column.

Column and Knee Type Milling Machine

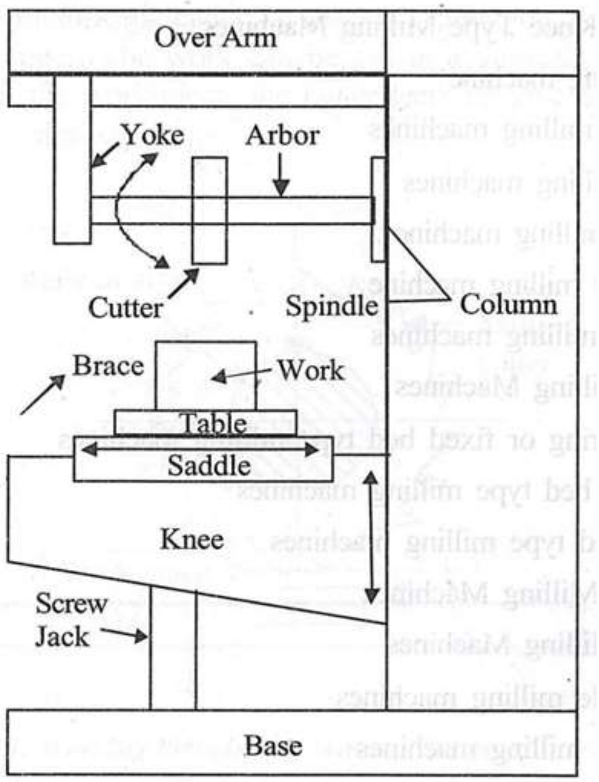
For general workshop the most commonly used is the column and knee type. These machines have a single spindle only. They derive their name “Column and Knee” type from the fact that the work table is supported on a knee like casting which can slide in a vertical direction along a vertical column. The up and down movement of the table can accommodate work of various heights.

Main Parts

Main parts of column and knee milling machine are as follows.

(a) **Base** - The base of machine is a grey cast iron casting provided at the bottom of the machines. It is accurately matching on both top and bottom of the machine surface. Column of the machine is secured to its base and serves as a reservoir for the coolant.

(b) **Column** - It is a very prominent part of milling machine. The column is box shaped heavily ribbed in side and houses all the driving mechanism for the spindle and table feed. The front vertical face of the column is accurately machined and is provided with dovetail guide ways for supporting the knees. Top of the column carries dovetail in horizontal ways for the over arm.



Column and Knee Type Milling Machine

(c) **Knee** - It is the rigid casting which is capable of sliding up and down along the vertical ways on the front face of the column. The adjustment of the height is affected by elevating screw mounted on the base that also supports the knee. The knee houses the feed mechanism of the table and different controls to operate it. The machine horizontal ways are provided on the top surface of the knee for the cross traverse of the saddle and hence the table. For efficient operation of the machine, rigidity of the knee and accuracy of its ways play an important role. On the front face of the knee two bolts are usually provided for securing the braces to it ensure greater rigidity under heavy loads.

Plain Milling Machine

These machines are of the column and knee type and consist of a rigid frame or box structure. It consists of a table, a saddle and a knee. This gives three straight-line movements perpendicular to each other. The arbor is fixed in position, and the tool rotates while the work is fed past the cutter in a straight line. It is a useful machine for manufacturing operation involving simple, straight line cut.

Omniversal Milling Machine

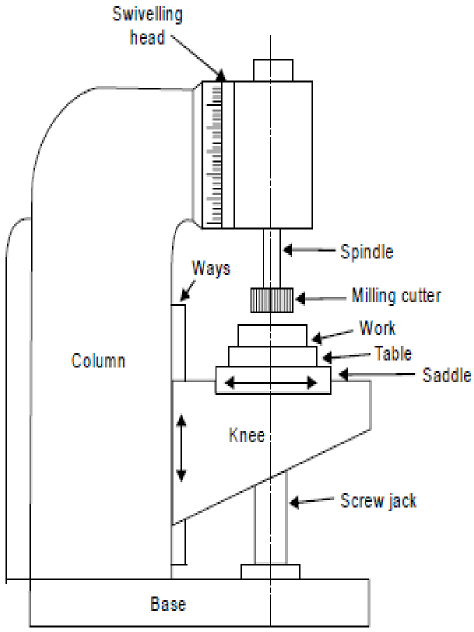
4.5 Vertical and universal Milling Machine

Vertical Milling Machine

There are two types of vertical spindle milling machines.

a. Fixed bed type
b. Column and knee type.

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 work table. The machine may be a plain or universal type and has all the movements of the table for proper setting and feeding the work. The spindle head which is clamped to the vertical column may be swivelled at an angle, permitting the milling cutter mounted on the spindle to work on angular surfaces. In some machine the spindle can be adjusted up or down relative to the work.



Vertical Milling Machine **Universal Milling Machine**

Universal Milling Machine

A universal milling machine is so named because it may be adapted to a very wide range of milling operation. A universal milling machine can be distinguished from a plain milling machine that the table of a universal milling is mounted on a circular swivelling base which has degree graduations and the table can be swivelled to any angle up to 450 on either side of the normal position. This is advantageous when milling spirals. Thus in a universal milling machine in addition to three movement as incorporated in a plain milling machine, the table may have a fourth movement when it is fed at an angle to the milling cutter.

Omniversal Milling Machine

In this machine, the table having all the movements of a universal milling machine, and can be tilted in a vertical plane by providing a swing arrangement at the knee. The entire knee assembly is mounted in such a way that it may be fed in longitudinal direction horizontally. The additional swivelling arrangement of the table enables it to machine taper spiral grooved in reamers, bevel gears etc it is essentially a tool room and experimental shop machine

Fixed Bed Type Milling Machine

(a) **Horizontal Simplex Milling Machine** - These types of machines are production type machines and are of rigid structure which yields high production of interchangeable jobs. It has got one spindle head.

(b) **Horizontal Duplex Milling Machine** - Milling machines using the two spindles. For finishing two surfaces of casting at a time.

(c) **Triplex Milling Machine** - Milling machines using the three spindles, two horizontal and one vertical for finishing three surfaces of casting at a time.

Planner type Milling Machine

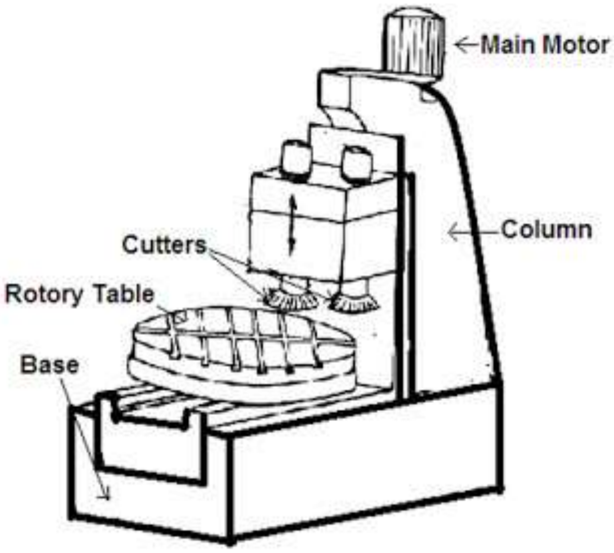
They are used for heavy work. Upto a maximum of four tool heads can be mounted over it, which can be adjusted vertically and traverse directions. It has a robust and constructions like a planer.

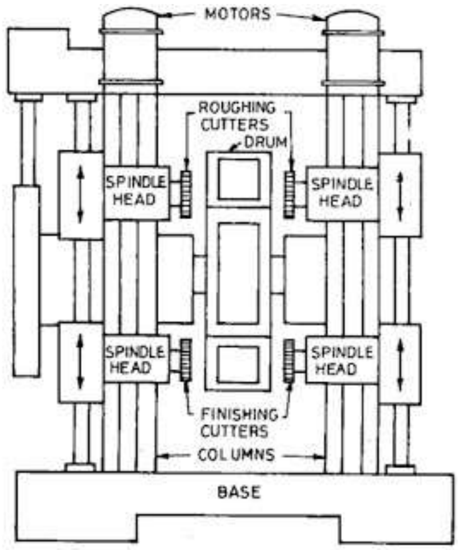
B ed Type Milling Machine **Bed or Manufacturing Type Milling Machine**

Special type Milling Machine

(a) **Continuous Feed Rotary Milling Machine** - The construction of the machine is a modification of a vertical milling machine and adapted for machining flat surfaces at production rate. The face milling cutters are mounted on two or more vertical spindles and a number of work pieces are clamped on the horizontal surface of a circular table which rotates about vertical axis. The cutters may be set at different heights relative to the work so that when one of the cutters is roughing the pieces the other is finishing them. Operator may carry out a continuous loading and unloading of the work pieces, while the milling is in progress.

(b) **Drum Type Milling Machine** - The drum type milling machine is similar to rotary table milling machine in that its work supporting table which is called a drum, rotates in a horizontal axis. The cutters are face mills and are usually roughing and finishing cutters similar to those of a rotary table miller. Fixture is mounted to the drum either on each face or on the periphery. When the work is mounted on the periphery, the operation is usually facing the two ends of the work piece to the precise length. The finished machined parts are removed after one complete turn of the drum and then new ones are mounted on it.





Continuous Feed Rotary Machine **Drum Type Machine**

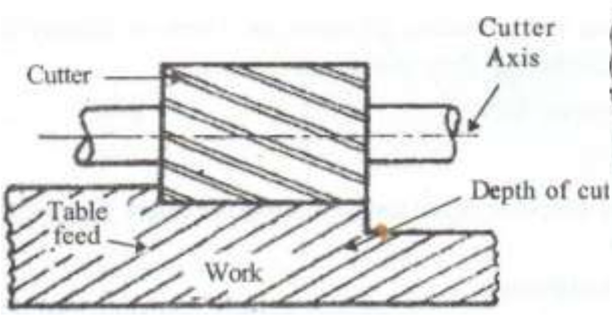
4.6 Machining operations

Milling Operations

Milling machines can perform various operations on different jobs by using different cutters. The main operations are as follows:

1. Plain milling
2. Face milling
3. Side milling
4. Straddle milling
5. Angular milling
6. Gang milling
7. Form milling
8. Profile milling
9. End milling
10. Saw milling
11. Milling keyways, grooves and slots
12. Gear cutting
13. Helical milling
14. Cam milling
15. Thread milling

1. Plain Milling: The plain milling is the operation of production of a plain, fiat, horizontal surface parallel to the axis of rotation of a plain milling cutter. The operation is also called slab milling. To perform the operation, the work and the cutter are secured properly on the machine. The depth of cut is adjusted by rotating the vertical feed screw of the table and the machine is started after selecting proper speed and feed. The plain milling operation is illustrated in Fig. 1.54.



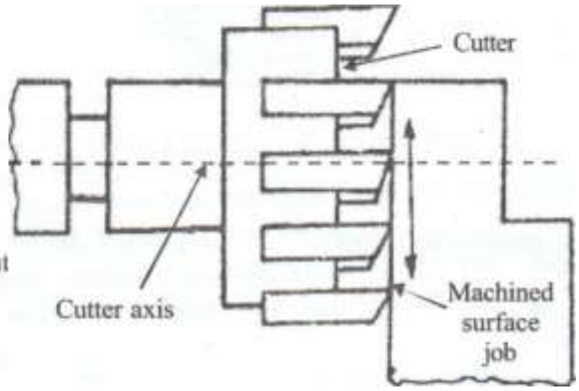
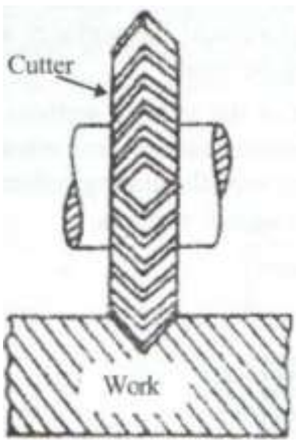


Fig. 1.54: Plain Milling

Fig. 1.55: Face Milling

Face Milling: The face milling operation is performed by a face milling cutter rotated about an axis perpendicular to the work surface. The operation is carried in a plain milling machine, and the cutter is mounted on a stub arbor to produce a flat surface. The depth of cut is adjusted by rotating the cross feed screw of the table. The face milling operation is illustrated in Fig. 1.55.

Angular Milling: This operation is for the production of flat surface which is at an angle to the cutter. In this operation angular surfaces (V-slots) are produced. V-grooves of different included angles are produced and the angular surfaces may be machined at any angle other than 90° to the machine spindle.



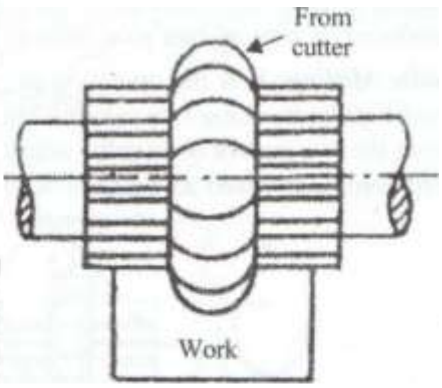


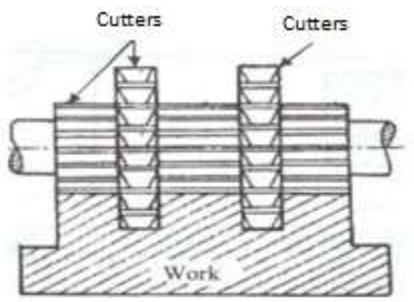
Fig. 1.56: Angular Milling

Fig. 1.57: Form Milling

Form Milling: It is the operation of production of irregular contours by using form cutters. The irregular contours may be convex, concave, or of any other shape. The cutting speed of form milling is about 25% less than that of the plain milling. The cutter used called form milling cutter, will have the shape of its cutting teeth confirming to the profile of the surface to be produced (Fig. 1.57). After machining, the formed surface is checked by a template gauge.

Side Milling: It is the operations of production of a flat vertical surface on the side of a work-piece by using side milling cutter. The depth of cut is adjusted by rotating the vertical feed screw of the table. When two parallel vertical flat surfaces are required to be produced, a pair of two side milling cutter may be used.

Straddle Milling: It is the operation of production of flat vertical surfaces on both sides of a work-piece by using two side milling cutters mounted on the same arbor. The distance between the two cutters is correctly adjusted by using suitable spacing collars. This process is very commonly used to produce square and hexagonal surfaces.



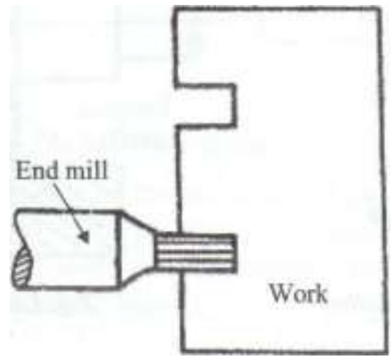


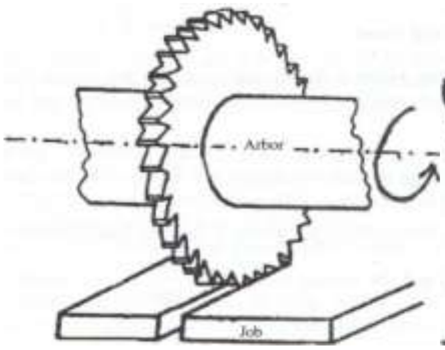
Fig. 1.60: Gang Milling

Fig. 1.61: End Milling

Gang Milling: It is the operation of machining several surfaces of a work-piece simultaneously by feeding the table against a number of revolving cutters having same or different diameters mounted on the arbor, of the machine. This method saves much of the machining time and is widely used in repetitive work. The combination of cutters may consist of only side milling cutters or of plain and side milling cutters both. Fig. 1.60 shows Gang milling operation.

End Milling: It is the operation of production of a flat surface which may be vertical, horizontal or at an angle in reference to the table surface. The cutter used is an end mill: The end milling cutters may be used for milling of slots, grooves and key ways etc. A vertical milling machine is most suitable for end milling operation.

Saw Milling: It is the operation of production of narrow slots or grooves on a work-piece by using a saw milling cutter. The saw milling can also be performed for complete parting-off operation (Fig. 1.62). The cutter and the work-piece are set in a manner so that the cutter is directly placed over one of the T-slots of the table.



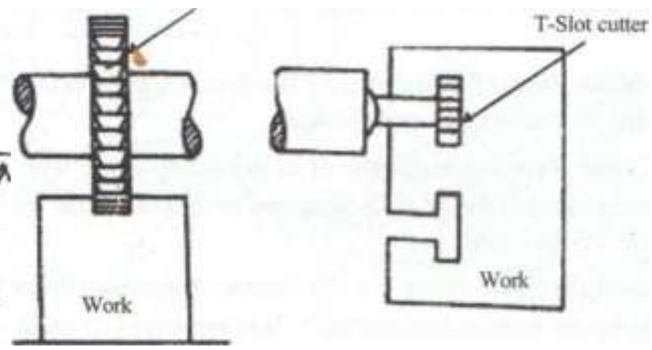


Fig. 1.62: Saw MillingFig. 1.63: Keyway Milling

Milling Keyways, Grooves and Slots: The operation of production of keyways, grooves and slots of varying shapes and sizes can be performed on a milling machine by using a plain milling cutter, a metal slitting saw, an end mill, and by a side milling cutter. The closed slots are produced by using end mills. A dove tail slot or a T-slot is manufactured by using special type of cutters designed to give the required shape on the work-piece. The T-slot is produced by first milling a plain slot on the work-piece and then the shank of the T-slot milling cutter is introduced through the first machined slot .The second slot is cut at right angles to the first slot by feeding the work past the cutter. Figure 1.64 shows a T-slot milling operation.

A wood-ruff key is produced by using a woodruff key slot cutter. Standard keyways are cut on shafts by using side milling cutters or end mills. The cutters are exactly, at the center line of the work-piece and then the cut is taken. Fig. 1.63 shows the operation of cutting keyways by side milling cutter.

Cutting Speed and Feed

Cutting speed of a milling cutter is the distance travelled pgr minute by the cutting edge of the revolving cutter. It is measured at the circumference of the cutter and is expressed in meters per minute.

If d mm is the diameter of the cutter and it makes N revolutions per minute, then the distance travelled by its cutting edge in each revolution will be equal to the circumference of the cutter, i.e.,= p d mm.

If it makes N r.p.m. (revolutions per minute), then the total distance travelled per minute will

be equal to pdN mm, and the cutting speed, v = pdN/1000m per minute.

Hence, v = pDN/1000 m/min

From the expression 1.1 it is clear that the cutting speed various directly as the diameter and r.p.m. of the cutter.

Example 1.1:A milling cutter, 100 mm diameter, runs at 280 r.p.m. calculate its cutting speed. Solution: Given — d= 100 mm, N= 280 rp.m, then, v= ?

pdN 22 100 280

\ Required cutting speed, v = — 88m/min.Ans.

1000 7 1000

Feed: For the milling machine, the feed is defined as the rate with which the work-piece advances under the cutter. For the milling machine the feed is expressed in the following three ways:

Feed Per Minute (Sm): It is defined by the distance the work advances in one minute.; It is expressed in millimeters per minute.

Feed Per Cutter Revolution (Srev): It is the distance the work advances in the time when the cutter turns through one complete revolution. It is expressed in millimeters per revolution of the cutter.

Feed Per Tooth (Sz): It is defined by the distance the work advances in the time between engagements by the two successive teeth. It is repressed in millimeters per tooth of the cutter.

The feed per tooth, the feed per cutter revolution, and the feed per minute are related following by the g formula:

Sm=nxSrev=Szxzxn

where, Z = Number of teeth in the cutter, and

N = The cutter speed in rp.m.

Depth of Cut: In the milling operation, the depth of cut is the thickness of the material removed in one pass of the work under the cutter. It is the perpendicular distance measured between the original and the final surface of the work-piece and is expressed in mm.

4.7 Types of cutters

The milling cutters are revolving tools having one or several cutting edges of identical form equally spaced on the circumference of the cutter. The cutting elements are called teeth which intermittently engage the work-piece and remove material by relative movement of the work-piece and cutter. Milling cutters may be classified as:

1. According to the constructional features of the cutter:
   (a) Solid cutter
   (b) Tipped solid cutter
   (c) Inserted teeth cutter
2. According to the relief characteristics of the cutter teeth:
   (a) Profile relieved cutter
   (b) Form relieved cutter
3. According to the methods of mounting the cutter:
   (a) Arbor type cutter
   (b) Shank type cutter
   (c) Facing type cutter
4. According to the direction of rotation of the cutter:
   (a) Right hand rotational cutter
   (b) Left hand rotational cutter
5. According to the direction of helix of the cutter teeth:
   (a) Parallel or straight teeth cutter
   (b) Right hand helical cutter
   (c) Left hand helical cutter
   (d) (d) Alternate helical teeth cutter
6. According to purpose or use of the cutter:
   (a)Standard milling cutter
   (b)Special milling cutter

Solid Cutter: A solid cutter has teeth integral with the cutter body. The cutters are of smaller diameter and width and made of one piece material usually of high speed steel.

Tipped Solid Cutter: A tipped solid cutter is similar to a solid cutter, except that the cutter teeth are made of cemented carbide or satellite tips which are brazed on the tool shanks of an ordinary tool steel cutter body to reduce the cost of the cutter.

Inserted Teeth Cutter: In large milling cutters, the teeth or blades are inserted or secured in a body of less expensive materials. The blades are usually held in the cutter body by mechanical means. This arrangement reduces the cost of the cutter and enables economy in maintenance, as a single tooth if broken can be readily replaced

Profile Relieved Cutter: In this category of milling cutters, a relief to the cutting edges is provided by grinding a narrow land at the back of the cutting edges. The profile relieved cutters generate flat, curved or irregular surfaces.

Form Relieved Cutter: In this category of milling cutters a curved relief is provided at the back of the cutting edges. The cutters are sharpened by grinding the faces of the teeth. The form relieved cutters are mainly used for generating formed or contoured surfaces.

Arbor Type Cutter: The arbor type cutter is provided with a central hole having a keyway for mounting them directly on the milling machine arbor. Milling cutters having tapered or threaded holes are also available. They are mounted on arbors of different designs.

Shank Type Cutter: The shank type cutters are provided with straight or tapered shank integral with the cutter body. The straight or tapered shanks are inserted into the spindle nose and are clamped to it either by friction or by a draw bolt.

Facing Type Cutter: The facing type cutters are either bolted or attached directly to the spindle nose, or secured on the face of a short arbor called stud arbor. The facing type cutters are mainly used to produce flat surface.

Right Hand Cutter: A milling cutter is designated as a right hand cutter which rotates in an anticlockwise direction when viewed from the end of the spindle. Fig.1.23 shows a right hand.

Standard Milling Cutters: There are many different types of standard milling cutters. They are classified below:

1. Plain milling cutters
2. Side milling cutters
3. Metal slitting saws
4. Face milling cutters
5. Angle milling cutters
6. End milling cutters
7. T-slot milling cutters
8. Woodruff key slot milling cutter
9. Fly cutter
10. Formed cutters
    (a) Convex and concave milling cutters
    (b) Corner rounding milling cutters
    (c) Gear cutter
    (d) Thread milling cutter
11. Tap and reamer cutter

1. *Plain Milling Cutters:* Plain milling cutters are cylindrical in shape and have teeth on the circumferential surface only. The cutters are intended for the production of flat surfaces parallel to the axis of rotation of the spindle. The cutter teeth may be straight or helical according to the size of the cutter. Fig.l.24 illustrates a straight teeth plain milling cutter. Very wide plain milling cutters are termed as slabbing cutter Fig. 1.25. These cutters have nicked teeth. The nicks are uniformly distributed on the entire periphery of the cutter. The object of the nicks is to break the chips and enable the cutter to take a coarse feed. The plain milling cutters are available in diameters from 16 to 160 mm and the width of the cutters range from 20 to 160 mm. Fig.1.26 illustrates a helical plain milling cutter.

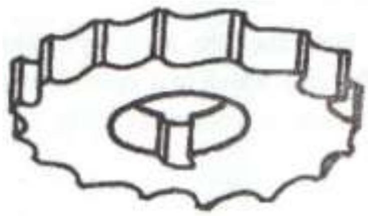


Fig. 1.24: Plain Milling Cutter

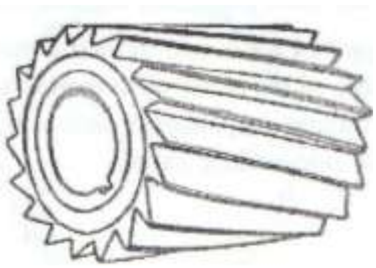


Fig. 1.25: Slab Milling Cutter

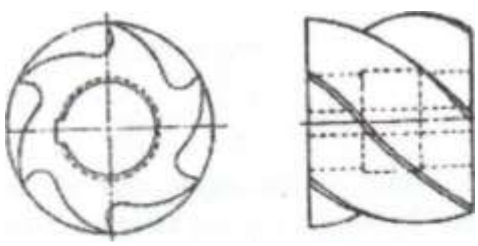


Fig. 1.26: Helical Plain Milling Cutter

The light duty plain milling cutters have face width less than 20 mm and are made with straight teeth parallel to the axis. The wider cutters are made with helical teeth, with helix angle of less than 25°. These are relatively fine tooth cutters.

The heavy duty plain milling cutters are wider cutters and are used for heavy duty work. The helix angle of the teeth ranges from 25 to 45°. The cutters have fewer teeth on the periphery and that increases chip space permitting them to take deeper cuts. They are also sometimes called coarse tooth milling cutters.

The helical plain milling cutters Fig. 1.26 have further coarse pitch and the helix angle of the teeth ranges from 45 to 60°. The cutter is useful in profile milling work due to its smooth cutting action and is adapted for taking light cuts on soft steel or brass and where wide surfaces are to be maintained.

2. ***Side Milling Cutter:*** Side milling cutters have teeth on its periphery and also on one or both of its sides. The side milling cutters are intended for removing metals from the side of a work. Figure 1.27, illustrates a side milling cutter. The side milling cutters are available from 50 to 200 mm in diameter and the width of the cutter ranges from 5 to 32 mm.

Plain side milling cutters have straight circumferential teeth and have side teeth on both of its sides. Two or more such cutters may be mounted on the arbor and different faces of the work-piece may be machined simultaneously.

Staggered teeth side milling cutters have alternate teeth with opposite helix angle. This design of the cutter teeth increases the chip space to a great extent. The cutter is suitable for milling deep, narrow slots or key ways on work-pieces. Fig. 1.28 illustrates a staggered teeth side milling cutter.

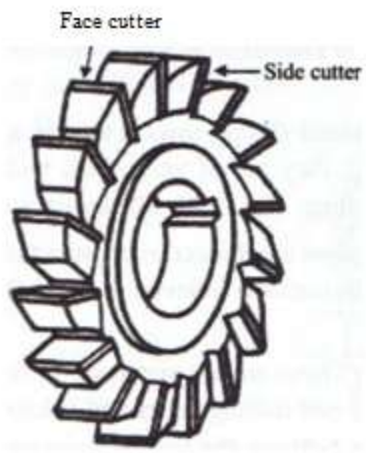


Fig. 1.27: Side Milling Cutter

Half side milling cutters have straight or helical teeth **on its circumferential surface and** on one of its sides only. The peripheral teeth do the **actual cutting, whereas the side teeth** size and finish the work. While straddle milling, when **two half side milling cutters are** mounted on the arbor at a fixed distance apart to mill **the two end faces of the work** simultaneously, the cutter are chosen with one having **right hand helical teeth and the other** having left hand helix to counter— balance the end **thrust on the arbor.**

Interlocking side milling cutters are formed out of two **half side milling cutters or two** staggered teeth side milling cutters which are made to **interlock to form one unit. The teeth** of the two cutters may be plain or of alternate helix. **The paths of the teeth overlap when** the cutters are used for milling wider slots of accurate **width. The width of the cutter may** be varied by inserting spacers of suitable thickness between **the two halves of the cutter.** This feature enables the cutter to maintain an accurate width even after repeated sharpening. The width of the cutter ranges from 10 to 32 mm with a possible adjustment to the maximum of 4 mm. The cutters are available in diameters **ranging from 50 to 200 mm.**

Fig. ***1.28: Staggered Teeth Side Milling Cutter***

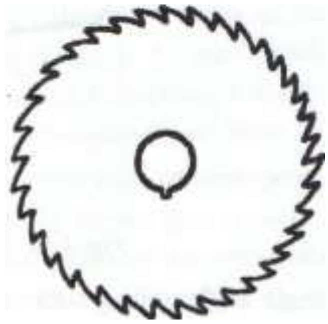


Fig. 1.29: Metal Slitting Saw

The staggered teeth metal slitting saws resemble a staggered teeth side milling cutter, but the width of the cutter is limited to 6.5 to 7 mm. The cutter is used for heavy sawing in steel.

3. ***Metal Slitting Saws:*** Metal slitting saws resemble a plain milling cutter or a side milling cutter in appearance but they are of very small width. The cutters are used for parting-off operation or for slotting. Fig. 1.29. illustrated a metal slitting saw.

The plain metal slitting saws are thinner in construction and the width of the cutter is limited to 5 mm. The side of the cutter is relieved in order that the side faces may not rub against the work.

4. ***Face Milling Cutters:*** These cutters are made in two common forms. The smaller type almost resembles a shell end milling cutter and is known as *Shell-type face milling cutter* (See Fig.1.30) it carries teeth on the periphery as well as the end face. Maximum cutting is done by the teeth on the periphery and those on the end face perform a type of finishing operation. The larger type of cutter, called the built-up face milling cutter, consists of a steel body, along the periphery on which are inserted the cutting teeth. The former type is used for small work whereas the latter for larger surfaces. The shell-type cutter is usually held in a stub arbor and the larger type can be mounted directly on the spindle nose.

5. ***Angle Milling Cutters:*** Angle milling cutters are made as single or double angle cutters and are used to machine angles other than 90°. The cutting edges are formed at the conical surface around the periphery of the cutter.

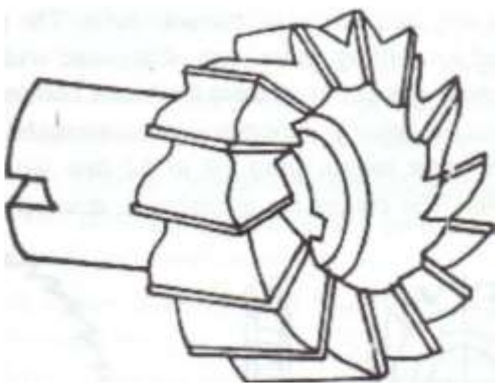


Fig. 1.30: Shell Type Face Milling Cutter

The single angle milling cutter illustrated in Fig. 1.31 has teeth on the conical or angular face of the cutter and also on the large flat side. The angle of the cutter is designated by the included angle between the conical face and the large flat face of the cutter. The cutters having different included angles of 30°, 45°, 60°. 65°, 70°, 75°, 80° and 85° degrees are available with diameter of 50 mm and width of 12 mm. There are another set of cutters having the same range of included angle, but the diameter of the cutters is 63 mm and width 28mm. There is a third set of cutters having included angle of 78,75 and 80 degrees, all having 63 mm in diameter and 28 mm in width.

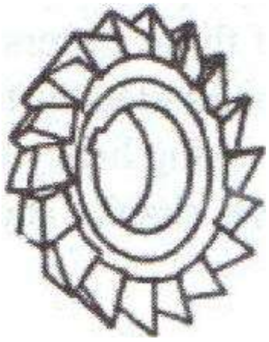


Fig. 1.32: Double Angle Cutter

Fig. 1.31: Single Angle Cutter

The double angle milling cutters (Fig. 1.32), teeth with both conical surfaces at an angle to their end faces. The angle of teeth may not be symmetrical with respect to a plain a right angles to the cutter axis. The unsymmetrical double angle cutters are available in diameters of 50, 63, 80, and 100 mm and their width varies from 12 to 36 mm. The cutters are available in different included angles of 55°, 60°, 65°, 70°, 75°, 80°, 85°, 90°, and 100° degrees. The equal angle cutters are available in diameters from 56 to 100 mm having width ranging from 10 to 28 mm. The included angle of the cutter may be 45°, 60° or 90°. The double angle milling cutters are mainly used for cutting spiral grooves on a piece of blank.

6. ***End Milling Cutters:*** These are solid circular cutters which are manufactured in two different varieties; those having shank and the others which do not have the shank. They carry teeth on the periphery as well as on the end. These teeth may be straight *i.e.,* parallel to the axis of rotation, or helical as in slab milling cutters. Helical teeth may be right hand or left hand. End milling cutters are used for milling slots, keyways, grooves and irregular shaped surface. Shank type end mills may have either taper shank or straight shank and are available in a wide range of diameters from 3 mm to 50 mm. Shank type end mills are either mounted directly on the spindle, or held in collets (straight shank type mills only) or in an adaptor. The following are the main classifications of these mills:

Common type: These milling cutters carry multiple teeth on their periphery and also on the end. The teeth may be straight or helical; the former type is, however, available in small sizes only, say below 8 mm dia. A typical design of this type is shown in Fig. 1.33

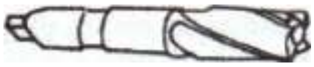


Fig. 1.33: Common Type End Milling Cutter

Two-lipped end mill: These milling cutters are also known as slotting mills. These cutters **have two straight or helical** teeth on the periphery and the corresponding two teeth on **the end, which meet at the end** centre. The main advantage of these cutters is that they **can be fed straight into the** metal like a drill and then fed longitudinally to produce a **groove of desired length and depth.** Also, they can be used for taking heavy cuts in solid **stock. These cutters may have either** a straight shank or a taper shank. The latter type **is however, more commonly used** Fig. 1.34

Fig. 1.34: Two-lipped Taper Shank End Milling Cutter

Shell end milling cutters: **These cutters** are larger and heavier than most of the other **types of end mills. They have teeth on the periphery and the end both.** Generally they **are made in over 50 mm size (diameter). The end** face of these cutters is provided with **a recess to receive a cap screw. They are held in**

a stub arbor, shown in Fig. 1.35. Two **slots are made across the back of the cutter,** which engage the collar keys of the arbor **to get the drive. Generally helical teeth are provided** on these cutters. These teeth may **be right *hand or left hand.* These cutters** are **employed** for heavy duty work. Milling **of flat surfaces, using the end or face, and cutting** slots, etc. are the common operations **performed by them. The former operation** is called facing.

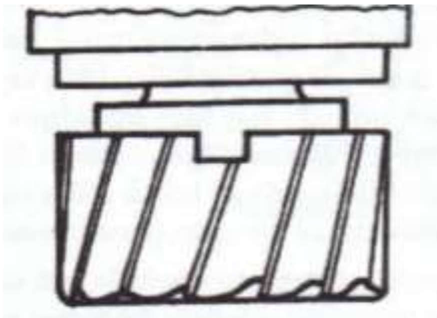


Fig. 1.35: Shell-end Milling Cutter

7. T-slot-Milling Cutter: It is a single operation cutter which is used only for cutting T-slots. In smaller sizes it is made to have the shank integral with the cutter, as shown in Fig. 1.36. Large size cutters are mounted on a separate shank. In operation, the narrow groove at the top is first milled by means of a slotting cutter or end milling cutter. The T-slot milling cutter is then employed for milling the wider grooye. The thin neck provided between the shank and the cutter. It facilitates an unhindered movement of the cutter through the upper groove as the cut proceeds.

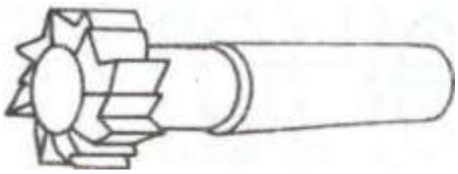
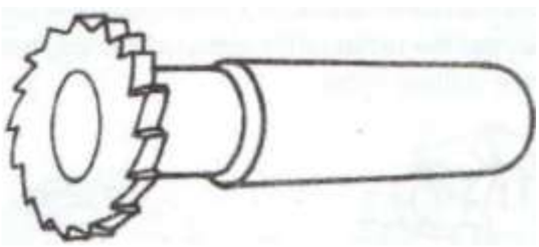


Fig. 1.36: T-slot Milling Cutter

8. ***Woodruff-key Slot Milling Cutter:*** It is a small type of end milling cutter which resembles with plain and side mills. Smaller sizes, say up to 50 mm diameter, and are made to have solid shank, to be fitted in the machine spindle, whereas the larger sizes are provided with a hole for mounting the same on an arbor. Smaller sizes generally have straight teeth on the periphery with the sides having a little clearance. Larger sizes are usually made to have staggered teeth both on the periphery as well as the sides. A small size woodruff-key milling cutter is illustrated in Fig. 1.37.



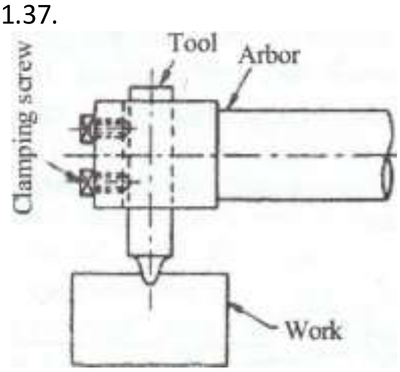


Fig. 1.37: Woodruff Key-seat Cutter Fig. 1.38: Fly Cutter

9. Fly Cutter: The fly cutters are simplest form of cutters and are mainly used in experimental shops or in tool room works. The cutter consists of a single point cutting tool attached to the end of an arbor. The cutting edge may be formed to reproduce contoured surface. The cutter may be considered as an emergency tool when the standard cutters are not available. A fly cutter is shown in Fig. 1.38.

10. Formed Cutter: Formed cutters have irregular profiles on the cutting edges in order to generate an irregular outline of the work. The different types of standard formed cutters are described below:

i. **Convex milling cutter:** The convex milling cutters have teeth curved outwards on the circumferential surface to form the contour of a semicircle. The cutter produces a concave semicircular surface on a work-piece. The diameter of the cutter ranges from 50 to 125 mm and the radius of the semicircle varies from 1.6 to 20 mm. Fig. 1.40 illustrates a convex milling cutter.

ii. **Concave milling cutter:** The concave milling cutters have teeth curved inwards on the circumferential surface to form the contour of a semicircle. The concave milling cutters produce a convex semicircular surface on a work-piece. The diameter of the cutter ranges from 56 to 110 mm and the radius of the semicircle varies from 1.5 to 20 mm. Fig. 1.39 illustrates a concave milling cutter.

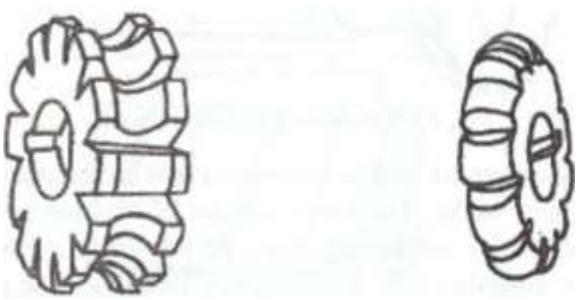


Fig. 1.39: Concave utter Fig. 1.40: Convex cutter

iii. **Corner rounding cutters:** These cutters are used for milling the edges and corners of the jobs to a required radius. They are manufactured separately as single cutters or double cutters. Single cutters may be right hand (Fig. 1.41) or left hand (Fig. 1.42) The double cutter (Fig. 1.43) has a combination of both right hand and left hand in a single unit.

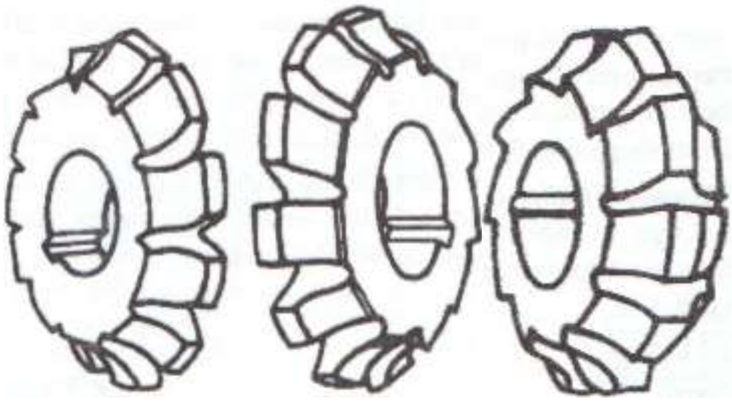


Fig. 1.41: R.H. Corner Rounding Cutter Fig. 1.42: L.H. Corner Rounding Cutter Fig. 1.43: Double Rounding Cutter

iv. ***Gear cutters:*** They are also designed as involute gear cutters. They are used for milling gear teeth on a milling machine. The *two common grades are roughing and finishing, shown in Figs.1.44 and 1.45* respectively.

The gear cutters have formed cutting edges which reproduce the shape of the cutter teeth on the gear blank. The shape of the cutter teeth may be involute or cycloid, according to the gear tooth profile. The cutter tooth profile should be differently.

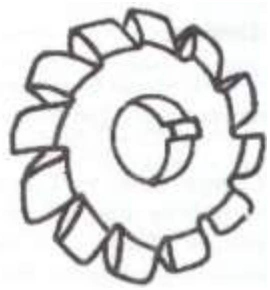
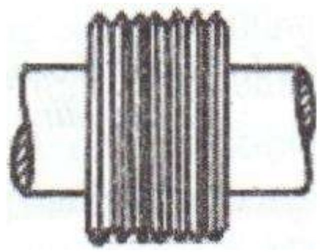


Fig. 1.44: Form Relieved Gear Cutter (roughing)Fig. 1.45: Form Relieved Gear Cutter (Finishing

v. *Thread milling cutters:* These are also formed cutters used for milling different types of threads, mostly for worms and acme type threads. These cutters can be single or multi-teeth. The included angle of the cutting teeth will correspond to the angle of the threads to be produced. Generally, worms and acme threads are produced by thread milling cutters. The cutters may have parallel or taper shanks. The parallel shank thread milling cutters shaped for each pitch of the gear and also for each change in number of teeth on the gear which it is going to cut. But in practice a compromise is affected by using one cutter to cover a range of gear sizes. Thus for cutting gear teeth of involute profile, 8 numbers of cutters are required to cut f om a pinion of 12 teeth to a rack and for cycloidal tooth profile 24 cutters are used for cutting different numbers of gear teeth.

***11.*Tap and Reamer Fluting Cutters:** These formed cutters are used for milling flutes on reamers and taps. In appearance, they look like double angle cutters, such that their two inclined faces meet to form a rounded corner. A typical tap and reamer fluting cutter is shown in Fig. 1.47.



(i) Single Cutter(ii) Multi Teeth-Cutter

Fig. 1.46: Thread Milling Cutter ***Fig. 1.47: Tap and Reamer Flutting Cutter.***

4.8 Geometry of milling cutters

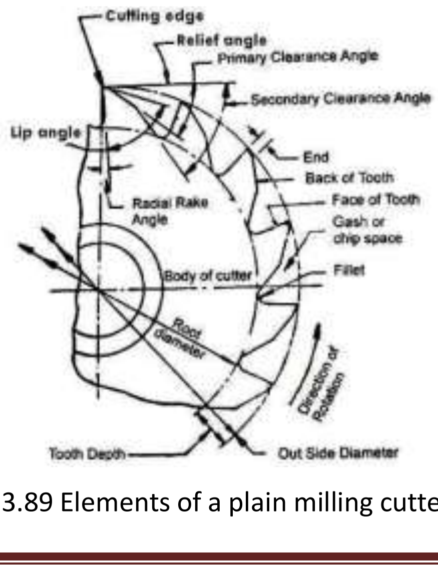


Fig. 3.89 Elements of a plain milling cutter

Small end mill with ball like hemispherical end is often used in CNC milling machines for machining free form 3-D or 2-D contoured surfaces. These cutters may be made of HSS, solid carbide or steel body with coated or uncoated carbide inserts clamped at its end as can be seen in the Fig. 3.88.

4.9 Elements of a plain milling cutter

The major parts and angles of a plain milling cutter are illustrated in Fig. 3.89.

Body of cutter: The part of the cutter left after exclusion of the teeth and the portion to which the teeth are attached.

Cutting edge: The edge formed by the intersection of the face and the circular land or the surface left by the provision of primary clearance.

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

Fillet: The curved surface at the bottom of gash that joins the face of one tooth to the back of the tooth immediately ahead.

Gash: The chip space between the back of one tooth and the face of the next tooth.

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.

Outside diameter: The diameter of the circle passing through the peripheral cutting edge.

Root diameter: The diameter of the circle passing through the bottom of the fillet.

Cutter angles: Similar to a single point cutting tool, the milling cutter teeth are also provided with rake, clearance and other cutting angles in order to remove metal efficiently.

Relief angle: The angle in a plane perpendicular to the axis. The angle between land of a tooth and tangent to the outside diameter of cutter at the cutting edge of that tooth.

Lip angle: The included angle between the land and the face of the tooth, or alternatively the angle between the tangent to the back at the cutting edge and the face of the tooth.

Primary clearance angle: The angle formed by the back of the tooth with a line drawn tangent to the periphery of the cutter at the cutting edge.

Secondary clearance angle: The angle formed by the secondary clearance surface of the tooth with a line drawn tangent to the periphery of the cutter at the cutting edge.

Rake angle (Radial): The angle measured in the diametral plane between the face of the tooth and a radial line passing through the tooth cutting edge. The rake angle which may be positive, negative or zero is illustrated in Fig. 3.90.

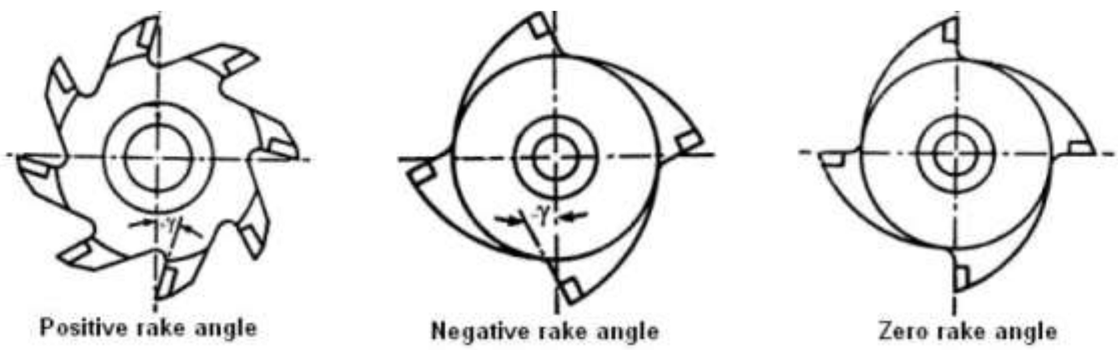


Fig. 3.90 Three types of rake angle of a plain milling cutter

4.10 Indexing

Indexing is the operation of dividing the periphery of a workpiece into any number of equal parts. The indexing operation can be adapted for cutting gears, ratchet wheels, keyways, fluted drills, taps and reamers. The indexing head serves as an attachment for holding and indexing the work in doing the above tasks.

For example if we want to make a hexagonal bolt. Head of the bolt is given hexagonal shape. We do indexing to divide circular workpiece into six equal parts and then all the six parts are milled to an identical flat surface. If we want to cut "n‟ number of teeth in a gear blank. The circumference of gear blank is divided into „n‟ number of equal parts and teeth are made by milling operation one by one.

4.10.1 Indexing heads

The main component used in indexing operation is universal dividing head.

There are three different types of indexing heads namely

1. Plain or simple dividing head
2. Universal dividing head
3. Optical dividing

4.10.1.1 Plain Dividing Head

A plain dividing head has a fixed spindle axis and the spindle rotates only about a horizontal axis.

4.10.1.2 Universal Dividing Head

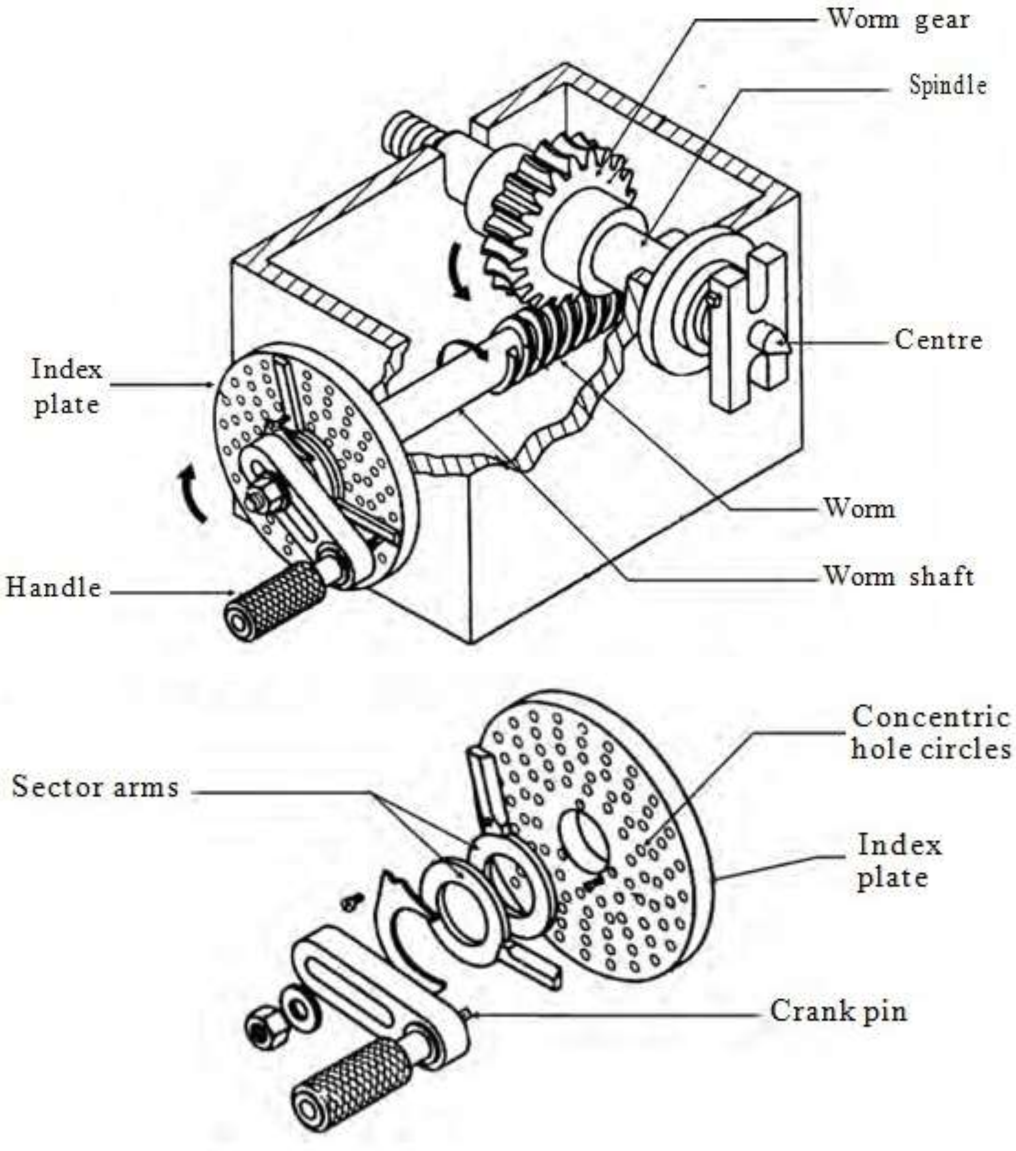
It is most popular and common type of indexing arrangement. As indicated by its name "universal", it can be used to do all types of indexing on a milling machine. Universal dividing head can set the workpiece in vertical, horizontal, or in inclined position relative to the worktable in addition to working principle is explained below with the help of illustration in Figure. The worm gear has 40 teeth and the worm has simple thread. Crank is directly attached with the worm. If we revolve crank by 40 revolutions the spindle attached with worm gear will revolve by only one revolution and one complete turn of the crank will revolve the spindle only by 1/40th revolution (turn). In order to turn the crank precisely a fraction of a revolution, an indexing plate is used. An indexing plate is like a circular disc having concentric rings of different number of equally spaced holes. Normally indexing plate is kept stationary by a lock pin. A spring loaded pin is fixed to the crank which can be fixed into any hole of indexing plate. The turning movement of the workpiece is stably controlled by the movement of crank as explained below.

4.10.1.3 Optical indexing head

These models are used for high precision angular setting of the work piece with respect to the cutter. For reading the angles, an optical system is built into the dividing head.

4.10.2 Index Head Parts

4.10.2.1 Construction of Indexing Head



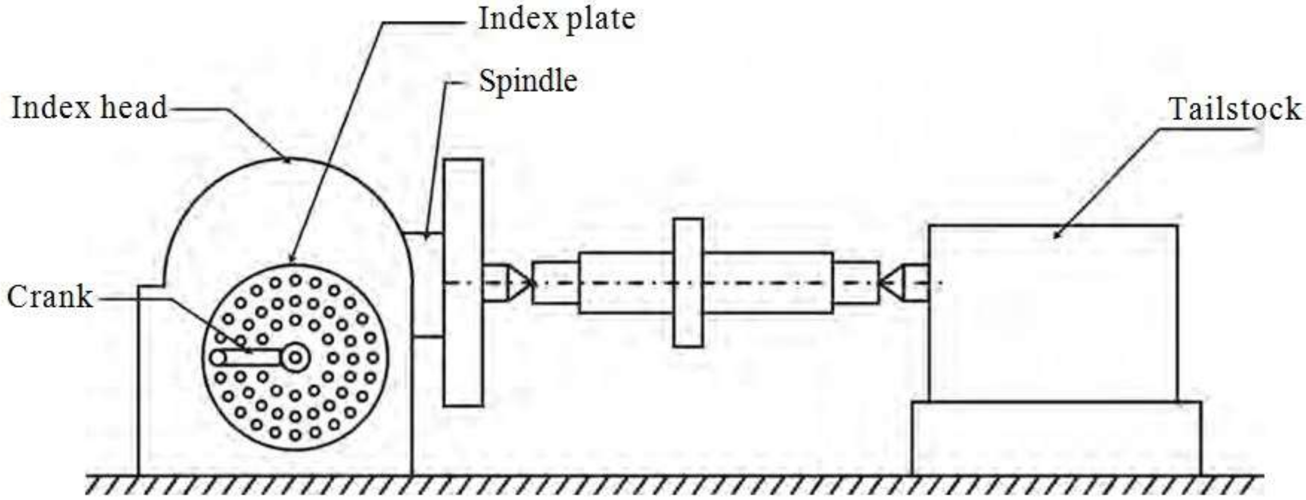
Construction of Index Head

Base – The base of the indexing head is fitted in the 'T' – slots of the milling machine table. It supports all the other parts of dividing head.

Spindle – The spindle is situated at the centre of the dividing head. It has a taper hole to receive a live center. The spindle is supported on a swiveling block, which makes the spindle to be tilted through any angle from 5º below horizontal to 10º beyond vertical. A worm wheel is mounted on the spindle. While doing direct or rapid indexing, the index plate is directly fitted on the front end of the spindle nose.

Worm shaft – It is situated at right angles to the main spindle of the dividing head. A single threaded worm is mounted on the worm shaft, which meshes with the worm wheel. An index plate is fitted on the front end of the worm shaft and with the help of a handle the worm shaft can be rotated to a predetermined amount.

Index plate – It is mounted on the front end of the worm shaft. It is a circular disk having different numbers of equally spaced holes arranged in concentric circles. The crank is positioned in the required hole circle and rotated through a calculated amount while indexing. The sector arm is used to eliminate the necessity of counting the holes on the index plate each time the index crank is moved.



Index Head

Driven shaft – It is parallel to the spindle and perpendicular to the worm shaft.

Dead center – The work is held between the center of the spindle and the dead center. It can be made to slide and positioned at the required location.

Working Principle of Dividing Head

When the crank is rotated with help of a handle through the required number of holes in the index plate, the work is rotated to required amount. This is possible because of the worm and worm wheel mechanism.

A gear train is arranged between the main spindle and the driven shaft when indexing is done by differential indexing method. The work is rotated as usual when the handle is rotated. At the same time, the index plate is also made to rotate a small amount through the gear train. When indexing is by this differential indexing method, the index plate is released from the lock pin.

4.10.3 Methods of indexing

There are several methods of indexing and they are

1. Direct or rapid indexing
2. Plain or simple indexing
3. Compound indexing
4. Differential indexing
5. Angular indexing

4.10.3.1 Direct Indexing

It is also named as rapid indexing. For this direct indexing plate is used which has 24 equally spaced holes in a circle. It is possible to divide the surface of workpiece into any number of equal divisions out of 2, 3, 4, 5, 6, 8, 12, 24 parts. These all numbers are the factors of 24.

In this case first of all worm and worm wheel is disengaged. We find number of holes by which spring loaded pin is to be moved. If we want to divide the surface into 6 parts than number of holes by which pin is to be moved= **24/N** for 6 parts N = 6.

4.10.3.2 Simple Indexing

It is also named as plain indexing. It over comes the major limitation of direct indexing that is possibility of dividing circumference of workpiece into some fixed number of divisions. In this case worm and worm gear is first engaged. So one milling complete turn of indexing crank revolves the workpiece by $1/40^{th}$revolution.

Three indexing plates are used. These plates have concentric circles of holes with their different numbers as described below:

Plate No.1	15	16	17	18	18	19
Plate No.2	21	23	27	29	31	33
Plate No.3	37	39	41	43	47	49

Indexing Procedure

Divide 40 by the number of divisions to be done on the circumference of work piece. This gives movement of indexing crank.

Indexing crank movement = 40/N

N is the number of divisions to be made on the circumference of work piece.

(b) If the above number is a whole number, then crank is rotated by that much number of revolutions after each milling operations, till the completion of the work.

For example, if we want to divide the circumference into 10 number of parts.

Indexing crank movement =40/4=4 revolutions.

That is the indexing crank is given 4 revolutions after each of milling operation for 9 more milling operations.

(c) If indexing crank movement calculated by 40/N is not whole number, it is simplified and then expressed as a whole number and a fraction.

(d) The fractional part of the above number is further processed by multiplying its denominator and numerator by a suitable common number so that the denominator will turn to a number equal to any number of holes available on the any of indexing plates.

(e) That particular holes circle is selected for the movement of crank pin.

(f) The numerator of the process fraction stands for the number of holes to be moved by the indexing crank in the selected hole circle in addition to complete turns of indexing crank equal to whole number part of 40/N

4.10.3.3 Compound indexing

When the available capacity of the index plates is not sufficient to do a given indexing, the compound indexing method can be used. First, the crank is moved in the usual fashion in the forward direction. Then a further motion is added or subtracted by rotating the index plate after locking the plate with the plunger. This is termed as compound indexing. For example, if the indexing is done by moving the crank by 5 holes in the 20 hole circle and then the index plate together with the crank is indexed back by a hole with the locking plunger registering in a 15 hole circle as shown in Fig. 3.68.

Then the total indexing done is = i.e., 11 holes in a 60 hole circle. Unfortunately the 60 hole circle is not available in the range of index plates. Similarly it is possible to have the two motions in the same direction as well. In this, the total indexing will be + = i.e., 19 holes in a 60 hole circle.

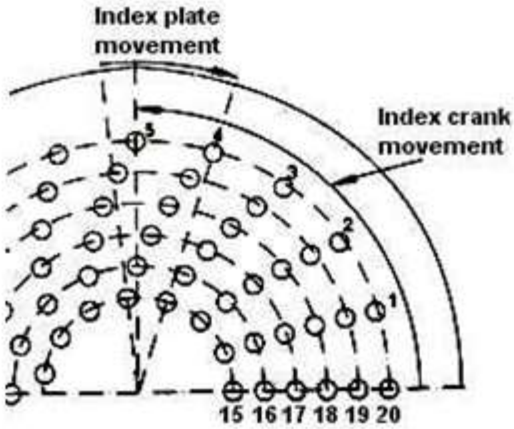


Fig. 3.68 An example of compound indexing

4.10.3.4 Differential indexing

This is an automatic way to carry out the compound indexing method. In this the required division is obtained by a combination of two movements. The movement of the index crank is similar to the simple indexing. The simultaneous movement of the index plate, when the crank is turned. Fig. 3.69 schematically shows the arrangement for differential indexing.

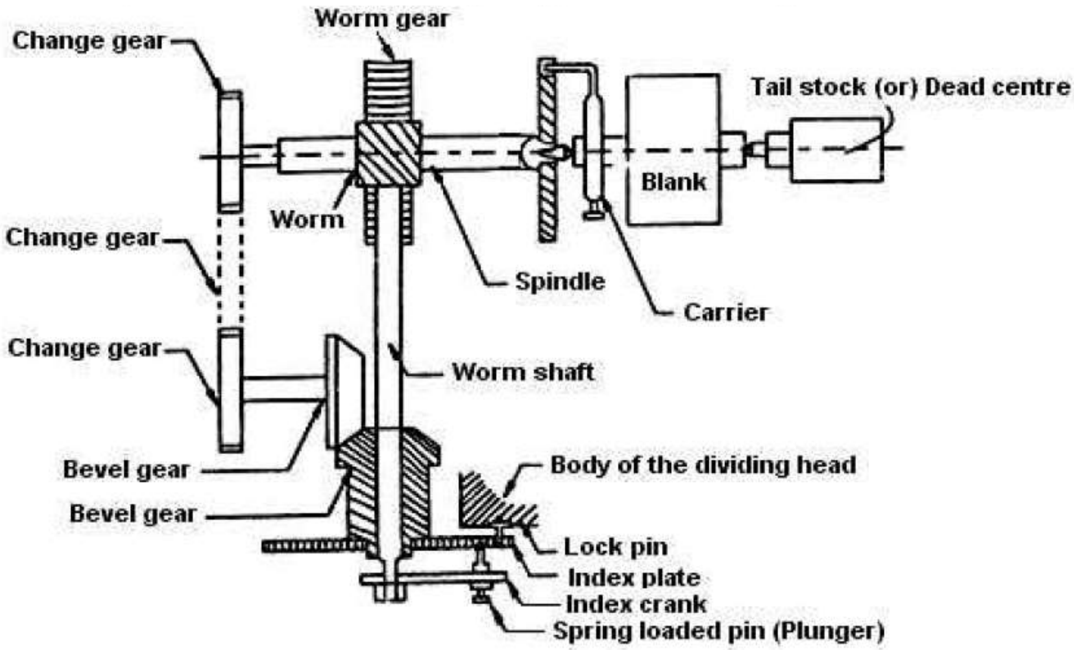


Fig. 3.69 Arrangement for differential indexing

In differential indexing, the index plate is made free to rotate. A gear is connected to the back end of the dividing head spindle while another gear is mounted on a shaft and is connected to the shaft of the index plate through bevel gears as shown in Fig.3.69. When the index crank is rotated, the motion is communicated to the work piece spindle. Since the work piece spindle is connected to the index plate through the intermediate gearing as explained above, the index plate will also start rotating. If the chosen indexing is less than the required one, then the index plate will have to be moved in the same direction as the movement of the crank to add the additional motion. If the chosen indexing is more, then the plate should move in the opposite direction to subtract the additional motion.

The direction of the movement of the index plate depends upon the gear train employed. If an idle gear is added between the spindle gear and the shaft gear in case of a simple gear train, then the index plate will move in the same direction to that of the indexing crank movement. In the case of a compound gear train an idler is used when the index plate is move in the opposite direction. The procedure of calculation is explained with the following example.

The change gear set available is 24 (2), 28, 32, 40, 44, 48, 56, 64, 72, 86 and 100.

4.10.3.5 Angular indexing

Sometimes it is desirable to carry out indexing using the actual angles rather than equal numbers along the periphery. Here, angular indexing would be useful. The procedure remains the same as in the previous cases, except that the angle will have to be first converted to equivalent divisions. Since 40 revolutions of the crank equals to a full rotation of the work piece, which means 3600, one revolution of the crank is equivalent to 90. The formula to find the index crank movement is given below.

Index crank movement = Angular displacement of work (in degrees) / 9

= Angular displacement of work (in minutes) / 540

= Angular displacement of work (in seconds) / 32400

Example 3.5: Calculate the indexing for 41^0.

Indexing required = $\frac{41}{9} = 5\,\frac{4}{9}$

This can be done as follows using the Brown and Sharpe plates.

Four full rotations + 10 holes in 18 hole circle in plate No. 1.

Example 3.6: Calculate the indexing for 190 40'.

19^0 40' = (19 x 60) + 40 = 1140 + 40 = 1180

Indexing required = $\frac{1180}{540} = \; = \frac{59}{27} == \frac{41}{9} = 2\,\frac{5}{9}$

This can be done as follows using the Brown and Sharpe plates.

Two full rotations + 5 holes in 27 hole circle in plate No. 2

4.11 Accessories to milling machines

1.5 Milling Machine Accessories: Cutter Holding Devices

There are several methods of supporting and rotating milling cutters with the machine spin depending on the different designs of the cutters. The following are the different devices for holding and rotating cutters.

Arbor is an accurately made shaft. One end has a taper which fits into a corresponding taper the machine spindle (Fig. 1.9a) Arbor is designed to hold rotary milling cutters. Arbor is held y in place by tightening the drawbar.

The arbors used on milling machines are mainly of two types: (1) the long supported arbor; and (2) the stub arbor. The former is also known as standard arbor and is relatively larger than the latter type (Fig. 1.9d) It is provided with a set of spacing collars, which help in adjusting the position of the cutter or the distance between cutters when more than two cutters are mounted simultaneously.

A large number of such collars, usually ranging from 1 mm to 50 mm in width, are supplied with the machine, In addition to these, two or three collars of relatively larger diameter are also supplied, which act as bearing sleeves when the arbor is supported in the yokes or arbor supports. The slots provided on the flange of the arbor engage the driving dogs of the spindle. A key runs for the whole length of the arbor, which fits in the corresponding key-way in the cutter to provide a positive drive. Rear end of the shank carries internal threads in which enters the threaded front end of the draw bar. Stub arbors are used to hold face and side milling cutters, which do not need a large overhang.

Collets: A milling machine collet is a form of sleeve bushing for reducing the size of the taper hole at the nose of the milling machine spindle so that an arbor or a milling cutter having a smaller shank than the spindle taper can be fitted into it; Fig. 1.10 illustrated a milling machine collet.

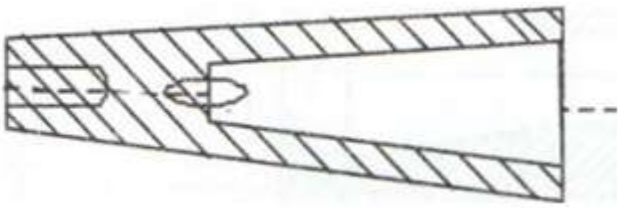


Fig. 1.10: Milling Machine Collet

Adapter: An adapter is a form of collet used on milling machine having standardized spindle end. Cutters having shanks are usually mounted on adapters. An adapter can be connected with the spindle by a draw bolt or it may be directly bolted to it. Fig.1.11 illustrates a milling machine adapter.

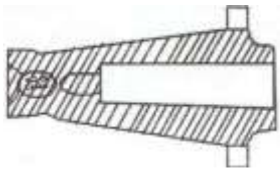


Fig. 1.11: Milling Machine Adapter

Spring Collets: Straight shank cutters are usually held on a special adapter called "spring collet" or "spring chuck". The nose end of the adapter is tapered and threaded for a small distance and also split by three equally spaced slots. The cutter shank is introduced in the cylindrical hole provided at the end of the adapter and then the nut is tightened. This causes the split jaws of the adapter to spring inside, and grip the shank firmly. Fig. 1.12 shows a spring collet.

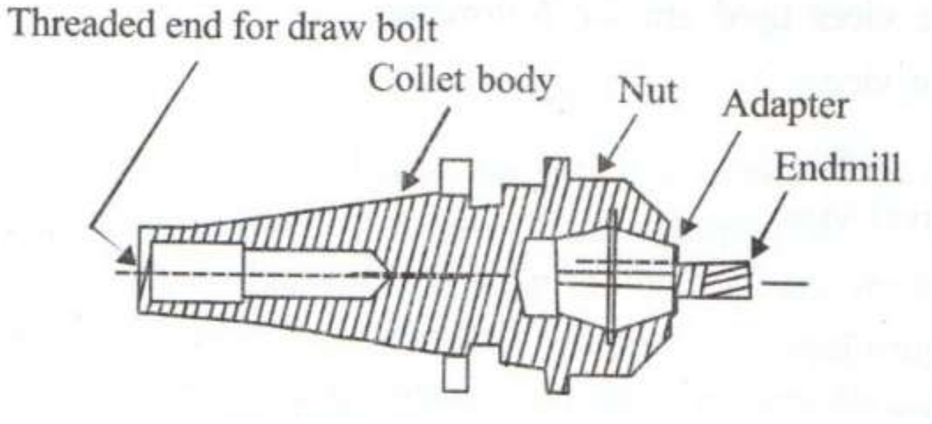


Fig. 1.12: Spring Collet

Bolted Cutters: The face milling cutters of larger diameter having no shank are bolted directly on the nose of the spindle. For this purpose four bolt holes are provided on the body of the spindle. This arrangement of holding cutter ensures utmost rigidity. Fig. 1.13, illustrates a face milling cutter bolted on the spindle. The face milling cutter can also be mounted on the spindle by a face milling arbor or a quick change adapter.

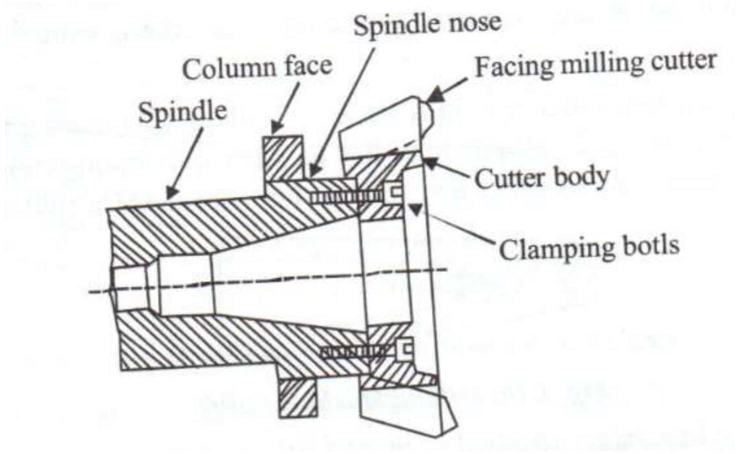


Fig. 1.13: Bolted Cutter

Screwed on Cutters: The small cutters having threaded holes at the centre are screwed on the threaded nose of an arbor which is mounted on the spindle in the usual manner. The cutter threads may be right hand or left hand depending on the direction of rotation of the cutter so that the cutter may not come off the arbor during the cut. Fig. 1.14 shows a screwed on cutter.

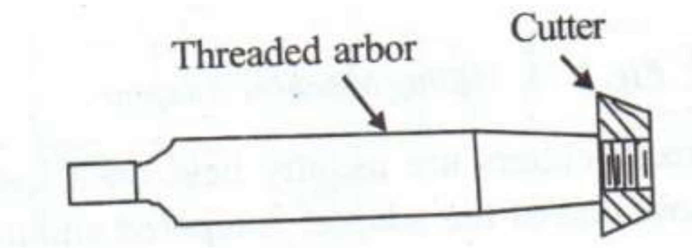


Fig. 1.14: Screwed on Cutter

Vices: Vices are the common devices used for holding the work on milling machines. The common types of the vices used are the following:

1. Plain Machine vice
2. Swivel vice
3. Universal swivel vice
4. Vertical vice
5. Precision angle vice
6. Compound vice

1. **Plain Machine Vice**: Shown in Fig. 1.15, it is the most widely used form of all the above six. It consists of a solid cast base, carrying a fixed jaw at one end and an elevated projection at the other. The latter carries internal threads and acts as a nut for the screwed spindle which, while rotating in it, moves the movable jaw. It is commonly employed for holding the work in all plain milling operations, which involve heavy cuts, such as in slab milling. Its especially low construction enables the work to remain quite close to the table and, thus, reduces the chances of vibrations to a minimum. The base carries slots to accommodate T-bolts to fix the vice on the table.

2. **Swivel Vice:** It consists of a swivel base, on which is mounted the body, which can be clamped in any angular position by means of the clamping bolts. The graduated plate provided on the swivel base helps in adjusting the body at any desired angle relative to the base. The upper construction is similar to that of a plain vice. A vice of this type is shown in Fig. 1.16. This vice facilitates milling of an angular surface on the work- piece without distributing its setting. The clamping bolts operate in a circular T-slot provided in the base.

3. **Universal Machine** Vice: Shown in Fig.1.17, it enables milling of various surfaces, at an inclination to one another, without removing the work-piece from the same. The vice, apart from being swiveled in a horizontal plane, can also be tilted vertically to be set at a desired angle and can,

thus, be adopted for milling of compound angles. It is vastly used in tool room work and should not be used where heavy cuts are to be employed as it does not have required clamping rigidity.

Circular Table

It is also called the circular milling attachment and is employed for indexing as well, as providing continuous rotary motion to the work. It can be either manually operated or power driven. It consists of a heavy base which is secured to the machine table by means of T-bolts.

Rotary motion to the table is provided by rotating the hand wheel (Fig. 1.18), which operates the worm wheel at the bottom of the circular table, through a worm provided on the shaft on which this hand wheel is mounted. The work-piece can be mounted on the table either directly by means of clamps and bolts or held in a vice clamped to the table.

Dividing or Indexing Head

The dividing heads are used for dividing the periphery of the work-piece into a desired number of equal parts, *i.e.* indexing the work-piece through a certain angle automatically after every operation, thus enabling the setting of job in a new angular position in relation to the cutter. The two common types of dividing heads are:

1. Plain dividing head.
2. Universal dividing head.
3. Optical Dividing head

Detailed description of these attachments will be given later on in the article or indexing, hence omitted here.

Milling Machine Attachments: The attachments are standard or special auxiliary devices intended to be fastened to or joined with one or more components of the milling machine for the purpose of augmenting the range, versatility, productivity or accuracy of operation. Some classes of milling machine attachments are used for positioning and driving the cutter by altering the cutter axis and speed, whereas other classes are used for positioning, holding and feeding the work along a specified geometric path. The following are the different attachments used on standard column and knee type milling machine.

Circular Milling Attachment: A circular milling attachment or a rotary table is a special work holding device which is bolted on the top of the machine table. It provides rotary motion to the work-piece in addition to the longitudinal, cross and vertical movements of the table. The attachment consists of a circular table having T-slots mounted on a graduated base. The circular table maybe rotated by hand, and in special cases by power by linking the rotary table driving mechanism with the machine lead screw. The driving mechanism of a circular milling attachment consists of a vertical shaft which is keyed to a worm gear fitted with the circular table. A horizontal worm meshes with the worm gear and imparts rotary movement to the table when the worm is rotated. The surface of any profile of a work-piece can be generated by combining three or four movements of the table and rotary movement of the attachment. In some of the circular milling attachments an index plate is provided on the horizontal worm shaft for milling equally spaced slots or grooves on the periphery of a work-piece.

Dividing Head Attachment: A dividing head attachment is also a special work holding device which is bolted on the machine table. The work may be mounted on a chuck fitted on the dividing head spindle or may be supported between a live and a dead centre. The dead center is mounted on a foot stock as in a lathe tail stock that is bolted on the machine table after correctly aligning its spindle axis with the dividing head spindle. The attachment is principally used for dividing the periphery of a work-piece in equal number of divisions for machining equally spaced slots or grooves. The worm and worm gear driving mechanism of the attachment can be linked with the table lead-screw for cutting equally spaced helical grooves on the periphery of a cylindrical work-piece. The actual construction and operation of a dividing head has been described in Art 1.10.

Vertical Milling Attachment: A vertical milling attachment can convert a horizontal milling machine into a vertical machine by orienting the cutting spindle axis from horizontal to vertical for performing specific operations. The attachment consists of a right angle gear box which is attached to the nose of the horizontal milling machine spindle by bolting it on the column face. The speed of the vertical spindle is same as that of the machine spindle. The attachment with the spindle can also be swiveled at any angle other than at right angles to the table for machining angular surfaces.

Slotting Attachment: A slotting attachment converts the rotary motion of the spindle into the reciprocating motion of the ram by means of an eccentric or crank housed within the attachment. Thus a milling machine can be converted into a slotter by accepting a single point slotter tool at the bottom end of the ram and is conveniently used for cutting internal or external keyways, splines, etc. The attachment is bolted on the face of the column and can also be swivelled at an angle of machining angular surfaces. The length of stroke of the ram can also be adjusted.

Universal Milling Attachment: The attachment is similar to the vertical milling attachment but it has an added arrangement for swivelling the spindle about two mutually perpendicular axes. This feature of the attachment permits the cutting spindle axis to swivel at practically any angle and machine any compound angular surface of the work. The attachment is supported by the over arm and operates at either the same speed or at higher speed than the machine spindle.

High Speed Milling Attachment: The attachment consists of a gearing arrangement enclosed within its casting to increase the regular spindle speeds by four to six times. This is for operating smaller diameter of milling cutters efficiently and at the proper cutting speed. The attachment is bolted to the face of the column and enables the cutters to be operated at speeds beyond the scope of the machine.

Universal Spiral Milling Attachment: The universal spiral milling attachment may be used in a plain milling machine or in a universal milling machine for cutting a spiral groove on a cylindrical work-piece. The attachment is bolted on the face of the column and its spindle head may be swivelled in a vertical or horizontal plane. While using on a plain milling machine, the cutter mounted on the attachment may be swivelled to the required helix angle for cutting a spiral similar to the swivelling of the table of a universal milling machine. The attachment is used in a universal milling machine for cutting spiral grooves having a helix angle of more than 45°, which is the maximum limit of swivelling the table.

Rack Milling Attachment: A rack milling attachment is bolted to the face of the column and is used for cutting rack teeth on a job mounted on the table. The attachment consisting of a gear train enables the spindle axis to be oriented at right angles to the machine spindle in a horizontal plane. The successive rack teeth are cut by using a rack indexing attachment. The slanted rack teeth or a skew rack may be machined where the table may be swivelled to the required helix angle.