

UNIT-4

MILLING MACHINE

Milling is a machining process of metal removal due to cutting action of a revolving cutter, when the work is fed past it. The revolving cutter is held on a spindle or arbor and the work clamped on the machine table, fed past the revolving cutter. In doing so, the teeth of the cutter remove the metal, in the form of chips, from the surface of the work to produce the desired shape.

It has a capability to perform large number of operations, which no other single machine tool can perform. It gives high production rate, with in very close limits of dimensions. That is why it has largely replaced other machine tools like shaper, planer, slotter etc for small and medium size jobs only. It is too slow for machining very long jobs. For small and medium jobs, the milling machine gives the fastest production with a very high accuracy. It has very wide application in mass production work.

Working Principle:

The metal removing operation on a milling machine, the work is rigidly clamped on the table of the machine and the revolving multi teeth cutter mounted on a spindle or an arbor. The cutter revolves at a 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.

Size and Specification:

Size of the milling machine is usually denoted by the dimensions (length and breadth) of the table of the machine. Different manufactures, denote these sizes by different numbers 0,1,2,3,4,5,6 etc. each of these numbers indicates a particular standard size. Other main specifications are the Horse power of driving motor, number of spindle speeds, feeds, drive, taper of spindle nose, required floor area etc.

Types of Milling Machines:

A large variety of different types of milling machines are available, the broad classification of these machines is as follows:

1. Column and knee type milling machines.
2. Fixed bed type or manufacturing type milling machines.
3. Planer type milling machines.
4. Production milling machines.
5. Special purpose machines.

1. Column and knee type Milling Machines

These machines are all general purpose machines and 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 vertical direction along a vertical column. These machines depending up on the spindle position and table movements are further classified as follows:

- a) Hand Milling Machine.
- b) Plain or Horizontal Milling Machine.
- c) Vertical Milling Machine.

- d) Universal Milling Machine.
- e) Omniversal Milling Machine.

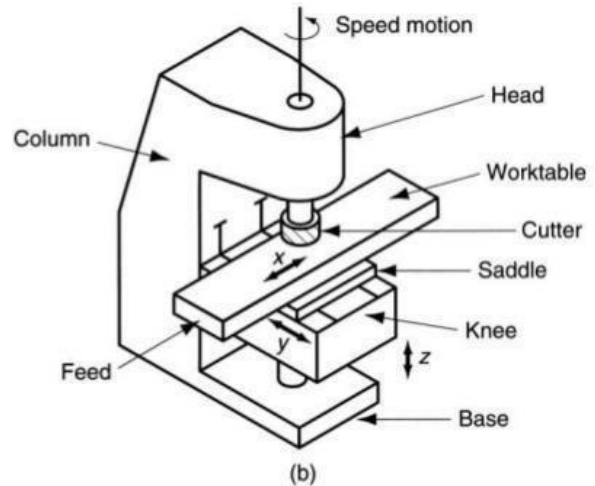
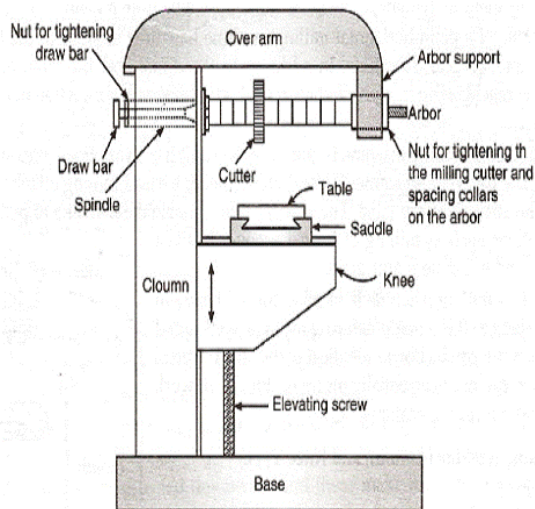


Fig. (b) vertical knee-and-column milling machine

2. Fixed bed type manufacturing type Milling Machines:

These machines, in comparison to the column and knee type, are more sturdy and rigid, heavier in weight and larger in size. They are not suitable for toolroom work. Most of these machines are either automatic or semi-automatic in operation. They may carry single or multiple spindles. The common operations performed on these machines are slot cutting, grooving, gang milling and facing. They facilitate machining of many jobs together, called multi-piece milling. Their further classification is as follows:

- a) Planer type (having single horizontal spindle)
- b) Duplex head (having double horizontal spindles)
- c) Triplex head (having two horizontal and one vertical spindle)
- d) Rise and fall type (for profile milling)

3. Planer type Milling Machines:

They are used for heavy work. Up to a maximum of four tool heads can be mounted over it, which can be adjusted vertically and transverse directions. It has robust and massive construction like a planer.

4. Production Milling Machines:

These are also manufacturing machines, but differ from the above machines in that they do not have fixed bed. They include the following machines.

- a) Rotary table or Continuous type.
- b) Drum type.
- c) Tracer controlled.

5. Special purpose machines:

These machines are redesigned to perform specific type of operation only

- a) Thread Milling Machine
- b) Profile Milling Machine
- c) Gear Milling or Gear hobbling Machine
- d) Cam Milling Machine
- e) Planetary type Milling Machine
- f) Double end Milling Machine
- g) Skin Milling Machine and
- h) Spar Milling Machine.

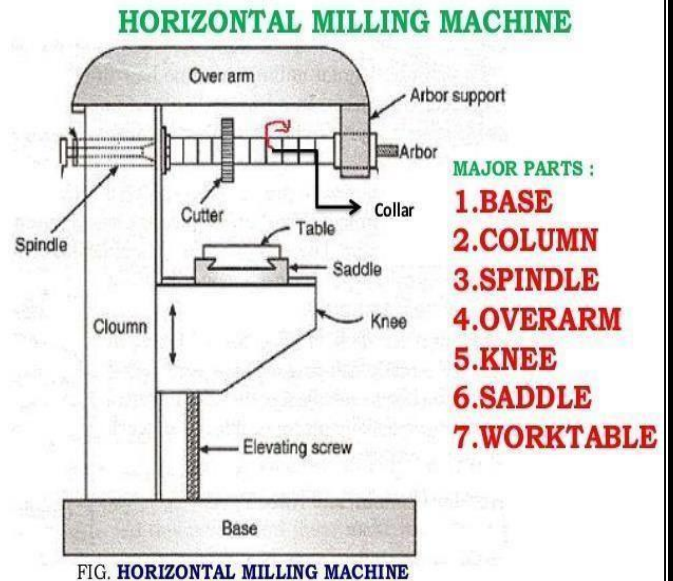
a) HandMillingMachine:

It is the simplest of all the milling machines and smallest in size. All the operations, except the rotation of arbor, are performed by hand. The table carrying the work over it is moved by hand to feed the work. This machine is especially useful in producing small components like hexagonal or square heads on bolts, cutting slots on screw heads, cutting keyways etc.

b) Plain or Horizontal Milling Machine:

The vertical column serves as a housing for electricals, the main drive, spindle bearing etc. The knee acts as a support for the saddle, work table and other accessories like indexing head etc. Over arm provides support for the yoke which in turn supports the free end of the arbor. The arbor carrying the cutter rotates about a horizontal axis. The table can be given straight motions in three directions, longitudinal, cross and vertical (up and down) but can't be swivelled. For giving vertical movement to the table the knee itself, together with the whole unit above it, slide up and down along the ways

provided in front of the column. For giving cross movement to the table the saddle is moved towards or away from the column along with the whole unit above it. A brace is employed to provide additional support and rigidity to the arbor, when a long arbor is used. Both hand and power feeds can be used for the work.



c) VerticalMillingMachine:

It derives its name from the vertical position of the spindle. This machine is available in both types, the fixed bed type as well as column and knee type.

It carries a vertical column on a heavy base. The over arm in this machine is made integral with the column and carries a housing at its front. This housing called head can be fixed type or swiveling type. In fixed type, the spindle always remains vertical and can be adjusted up and down. In swiveling type, the head can be swiveled to any desired angle to machine the inclined surfaces.

The knee carries an enclosed screw jack, by means of which it is moved up and down along the parallel vertical guide ways provided on the front side of the column.

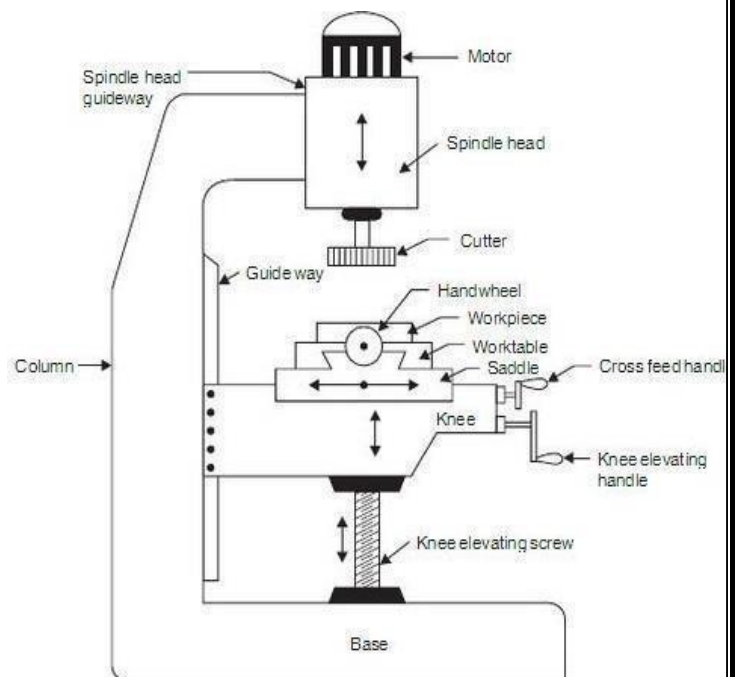


Fig. 4.10 Vertical milling machine

The saddle is mounted on the knee and can be moved, along the horizontal guide ways provided on the knee, towards or away from the column. This enables the table to move in cross-direction. The table is mounted on guide ways, provided on the saddle, which are in a direction normal to the direction of the guide ways on the knee. By means of the lead-screw, provided under the table, the table can be moved in the longitudinal direction. Thus the work gets up and down movement by the knee, cross movement by saddle and longitudinal movement by the table. Power feeds can be used to both the saddle and the table. Mostly face milling cutters and shell-end type cutters are used on these machines.

d) Universal Milling Machine:

It is the most versatile of all the milling machines and after lathe it is the most useful machine tool as it is capable of performing most of the machining operations. With its application the use of a large number of other machine tools can be avoided. It differs from the plain milling machine only in that, the tool can be given one more additional movement. Its table can be swivelled on the saddle in a horizontal plane. For this circular guide ways are provided on the saddle along which it can be swivelled. A graduated circular base is incorporated under the table, with a datum-mark on the saddle, to read directly the angle through which the table has been swiveled. This special feature enables the work to be set at an angle with the cutter for milling helical and spiral flutes and grooves. Its over arm can be pushed back or moved and a vertical milling head can be fitted in place of the arbor to use it as a vertical milling machine.

e) Omniversal Milling Machine: This is a modified form of plain milling machine and is provided with two spindles, of which one is horizontal, as in plain milling and the other is carried by a universal swiveling head and can be fixed in vertical position or can be set at any desired angle up to 90° on both sides of vertical i.e. in a plane parallel to the front face of the column, and up to 45° in a plane perpendicular to the former direction i.e. towards or away from the column. Another special feature of this machine is that it carries, in addition to all the possible adjustments provided in a universal milling machine, two more adjustments. These adjustments are of the knee which can be swiveled about a horizontal axis to tilt the table and can be moved horizontally also. These special features make it a very useful machine tool for tool room work as it facilitates various operations to be carried out in different planes and at different angles in a single setting of the work.

PRINCIPAL PARTS OF COLUMN AND KNEE TYPE MILLING MACHINES

Main parts of all the column and knee type milling machines are similar, the movements of the moving parts differ in them. All these machines essentially consist of the following main parts:

1. BASE: It is a heavy casting provided at the bottom of the machine. It is accurately machined on both the top and bottom surfaces. It actually acts as a load bearing member for all other parts of the machine. Column of the machine is secured to it carries the screw jack, which supports and moves the knee. It also serves as a reservoir for the coolant.

2. COLUMN: It is a very prominent part of a milling machine and is produced with enough care. Various parts and controls are fitted to this. On the front face of the column are made the vertical parallel ways in which the knee slides up and down. At its rear side, it carries the enclosed motor drive. A cover is provided on this side, which can be opened to enable accessibility to the drive. Top of the column carries dove-tail horizontal ways for the over arm.

3. KNEE: It is a rigid casting, which is capable of sliding up and down along the vertical ways on the front face of the column. This enables the adjustment of the table height. The adjustment is provided by operating the elevating jack provided below the knee, by means of a hand wheel or application of power feed. Machined 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 to ensure greater rigidity under heavy loads.

4. SADDLE: It is the intermediate part between the knee and the table and acts as a support for the table. It can be adjusted cross wise, along the ways provided on the top of the knee, to provide cross feed to the table. At its top, it carries horizontal ways along which table moves during longitudinal traverse.

5. TABLE: It acts as a support for the work. The work is mounted on it either directly or held in the dividing head. It is made of Cast Iron, with its top surface accurately machined and carries longitudinal T-slots to accommodate the clamping bolts for fixing the work. Longitudinal feed is provided to it by means of a hand wheel fitted on one side of the feed screw. Cross feed is provided by moving the saddle and vertical feed by raising or lowering the knee. Both hand feed and power feed can be employed the adjustable stops should be used to trip out the same at the correct movement.

Modern milling machines provide rapid traverse in all the three directions to effect saving in time. In universal milling machines, the table can be swiveled in horizontal plane and the graduations on circular base help in adjusting required swivel.

6. OVERARM: It is the heavy support provided on the top of both plain and universal milling machines. It can slide horizontally, along the ways provided on the top of the column, and is adjusted to a desired position in order to provide support to the projecting arbor, by accommodating its free end in yoke. If further support is needed, to have additional rigidity, braces can be employed to connect these when many cutters are used simultaneously.

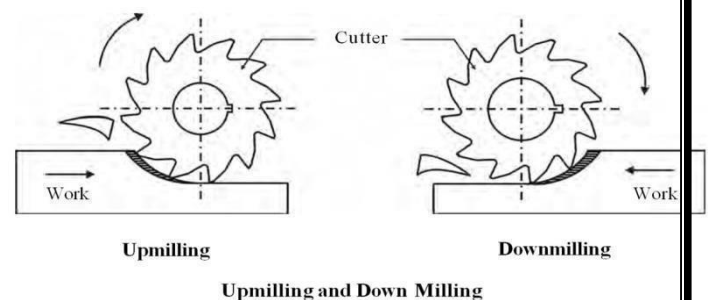
Milling Methods

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. Each tooth after taking a cut comes in operation again after some interval of time. This allows the tooth to cool down before the next cutting operation is done by it. This minimizes the effect of the heat developed in cutting on the cutting edge. With cylindrical cutters, the following two methods are commonly used for cutting operation.

1. Up or Conventional Milling: In this method of milling, the cutter rotates in a direction opposite to that in which work is fed.

2. Down or Climb Milling: In this method the direction of rotation of the cutter coincides with the direction of work feed.

The relative directions of movements of the cutter and work should be noted at the point of contact between the two. In the conventional milling the chip thickness increases as the cut proceeds and in case of climb milling the chip thickness decreases as the cut proceeds. I.e. the chip thickness is zero at start of the cut and maximum at the end of the cut in conventional milling whereas it is a reverse case in climb milling.



Upmilling and Down Milling

This section of a particular method of the above two, depends upon the nature of work. The conventional milling is commonly used for machining castings and forgings since this method enables the cutter to dig in and start the cut below the hard upper surface. The climb milling is particularly useful for finishing operations and small work, such as slot cutting, milling grooves, slitting etc. It gives a better surface finish if there is no backlash in feeding mechanism of the table and the work is rigidly held.

MILLING CUTTERS

The milling cutters may have either straight tooth i.e. parallel to the axis of rotation or in helical shape. The helix angle may be right hand or left hand and this will decide the direction of rotation of the cutter for performing the cutting operation. A milling cutter may be made of single piece of steel or having the cutting portion welded to a tough shank or having removable cutting teeth (bits) inserted in a solid body. The broad classification of milling cutter is according to the shape of the teeth they carry, such as plain, inserted, formed or saw teeth etc.

Common types of milling cutters are the following:

- | | |
|---|---------------------------|
| 1. Plain Milling Cutters | 2. Side Milling Cutters |
| 3. End Milling Cutters | 4. Face Milling Cutters |
| 5. Metal Slitting Cutters (Slitting Saws) | 6. Angle Milling Cutters |
| 7. Formed Milling Cutters | 8. T-slot Milling Cutters |
| 9. Woodruff-key Milling Cutters | 10. Fly Cutter |

1. PLAIN MILLING CUTTERS: These milling cutters may have the cutting teeth on their periphery and they may be either straight or helical. Their end faces are either ground square with the axis or slightly concave to reduce friction. Thus, no cutting action is provided by the side faces. These cutters are employed for milling flat surfaces parallel to the axis of rotation.

The milling cutters are made to have either fine pitch or coarse pitch. Fine pitch teeth cutters are used for light work and finishing work. The coarse pitch teeth cutters are called heavy duty slab milling cutters. They carry less number of teeth, having a steep helix angle. They are commonly used where very heavy cuts are to be used, since they are capable of removing more material with less power consumption.

2. SIDE MILLING CUTTERS: these cutters, apart from having teeth on the periphery, also have cutting teeth on one side or both sides. They are always provided with central hole for the purpose of mounting them on the arbor. They are also called staddle mills when used in pairs. The main types of side milling cutters are the following.

a) Plain side Milling Cutters: They are made to have cutting teeth on the periphery as well as on both sides. They are normally used for cutting slots or in face milling. These cutters are in different widths from 5mm to 25mm and dia up to 200mm.

b) Half side Milling: These cutters have teeth on the periphery and on one side only. They can be used for face milling. The teeth may be either straight or helical. Also they can be either left hand or right hand. Actual cutting action is performed by the teeth provided on the periphery while side teeth do the finishing and sizing work.

c) Staggered teeth side Milling Cutters: The cutters carry alternate teeth on the periphery only. These alternate teeth are of opposite helix angle, staggered from side to side, just as the teeth of wood saw, and cut alternately on one side and then on the other. They are commonly used for key-way cutting and slot cutting.

d) Interlocking side Milling Cutters: These cutters are similar in design to the side milling cutters but are used as a unit, consisting of two cutters joined together such that their teeth interlock. They can be adjusted to acquire the required width by inserting shims or spacers between them to make good the reduction in width of the cutters due to wear and frequent sharpening of the teeth. These cutters are used for milling wider slots to exact width.

3. END MILLING CUTTERS: These are solid circular cutters which are manufactured in two different varieties; those having shank and others which do not have shank. They carry teeth on the periphery as well as on the end. These teeth may be straight or helical. Helical teeth may be righthand and left hand. End milling cutters are used for milling slots, key ways, grooves and irregular shaped surfaces. Shank type end mills may have either taper shank or straight shank and diameters from 3mm to 50 mm.

4. FACE MILLING CUTTERS: These cutters are made in two common forms. The smaller type is known as shell-type-face milling cutter. It carries teeth on periphery as well as on end face. Maximum cutting is done by the teeth on the periphery and those on the end face perform finishing operation. The larger type of cutter, called the **built up face** milling cutter, consists of a steel body, along the periphery of which are inserted cutting teeth. The shell type face milling cutters are used for small work where a built up face milling for larger surfaces. The shell type cutter is usually held in a stub arbor and larger type can be mounted directly on the spindle.

5. METAL SLITTING CUTTERS: These cutters are also called metal slitting saws. They are used for cutting thin slots or parting off. They are very thin. They are in two varieties.

a) Plain Slitting Saws: They are plain milling cutters, which are very thin. Their teeth are provided with some side relief in order to prevent rubbing. They are made in different widths 1mm to 5mm.

b) Staggered teeth Milling Cutter (Saw): These saws are used for comparatively heavier work. They have their teeth staggered alternately and have side teeth also. These saws are in different widths, ranging between 4mm and 10mm.

6. ANGLE MILLING CUTTERS: These cutters carry sharp angular teeth which are neither parallel nor normal to their axes. Their specific use is in milling V-grooves, notches, dovetail slots, reamer teeth and other angular surfaces. The following two types of angular cutters are in common use:

a) Single Angle Cutter: these cutters may have their teeth either only on the angular face or on both, the angular face and side, which enables milling of both flank of the included angular groove simultaneously. Their teeth may have an included angle of 45° or 60°. ◻ ◻

b) Double angle cutters: These cutters differ from the single angle cutters in that they have two angular faces which join together to form V-shaped teeth. The included angle of this „V“ is either 45°, 60°, or 90°, though it is not necessary that the angle of both the faces should be equal.

7. FORM MILLING CUTTERS: These are also known as form relieved milling cutters or radius cutters. This category includes large variety of milling cutters used for producing different shaped contours. Their teeth are provided with a certain angle of relief, so that their form and size are retained even after resharpener. The common types of form relieved cutters are:

- a) Corner rounding cutters: For milling edges and corners of the jobs
- b) Concave and convex cutters: Concave cutter for milling convex surface and convex cutter for milling concave surface
- c) Gear cutters: For milling gear teeth
- d) Tap and reamer fluting cutters: For milling flutes on reamers and taps
- e) Gear hobs: For cutting teeth of worm wheels, helical and spur gears
- f) Thread milling cutters: For milling different types of threads.

8. WOOD RUFF-KEY MILLING CUTTER: It is a small type of end milling cutter, up to 50mm dia. are to have solid shank, to be fitted in the machine spindle, where as larger sizes are provided with a hole for mounting the same on an arbor. Smaller sizes have straight teeth on the periphery with the sides having little clearance. Larger sizes are usually made to have staggered teeth both on the periphery as well as the sides.

9. T-SLOT MILLING CUTTER: It is a single operation cutter, which is used only for cutting T-slots. In similar sizes it is made to have the shank integral with the cutter. 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 mill cutter. The T-slot milling cutter is then used for milling the wider groove.

10. FLY CUTTER: It is a single point tool, mounted on a cylindrical body, held in a stub arbor or held in a bar. Screws are used for tightly holding the tool in the holders. Cutting edge of the tool can be ground to any desired shape and is capable of producing a very accurate surface.

MATERIALS FOR MILLING CUTTERS

Materials used for manufacturing the milling cutters are the same as for lathe tools.

The common materials used are:

1. High Carbon Steel
2. High Speed Steel
3. Stellite
4. Cemented Carbides
5. Ceramics

High carbon steel is used for small scale production.

High speed steel is extensively used for solid type cutters.

Stellite is used for milling cutters for machining hard metals, forgings, castings etc.

Cemented Carbides are used in the form of bits for milling cutters when high speeds are used.

Ceramics are used for milling bronze and cast Iron. Twice the speed of Carbides.

ANGLES OF A PLAIN MILLING CUTTER:

A milling cutter can be considered as a built up unit of a number of single point cutting tools, such that each tooth of the cutter is a single point cutting tool. The relief angle α is the angle between the plain P_1 , which is normal to the axial plane PP at a point on the cutting edge, and the tangent to the relieved land of the outer tooth. This angle is measured in a plane perpendicular to the axis of the cutter. Higher the value of this angle, less will be the friction and hence less wear on the land.

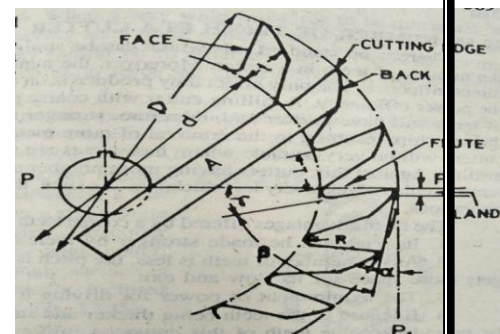


Fig. 12.62. Angles of plain milling cutter. D = Outside dia., d = Root dia., R = Fillet radius, t = Depth of tooth, γ = Rake angle, α = Relief angle, λ = Lip angle, T = Max. tooth thickness

A larger relief angle will increase the tool life between two grinds and ensure better surface finish, but at the same time, due to consequent reduction in the lip angle (β), it will make the tooth weak. Normally relief angle ranges between 10° to 30° .

The rake angle (γ) is the angle between the axial plane PP and the face of the cutter tooth, measure in a plane normal to the cutting edge. Rake angle facilitates free cutting by the tool by allowing the chip to flow smoothly. This ensures the less consumption of power, better surface finish, less wear on the tool face and consequently a greater life of the tool between two grinds. However, it should not be increased beyond 20° otherwise, the resulting smaller lip angle will again weaken the tool.

The angle between the face and the land of the cutter tooth is called lip angle (β). Its value depends upon the values of rake and relief angles. Larger lip angle ensures stronger tooth and helps in milling harder metals and when deeper cuts are used.

INDEXING OR DIVIDING HEADS:

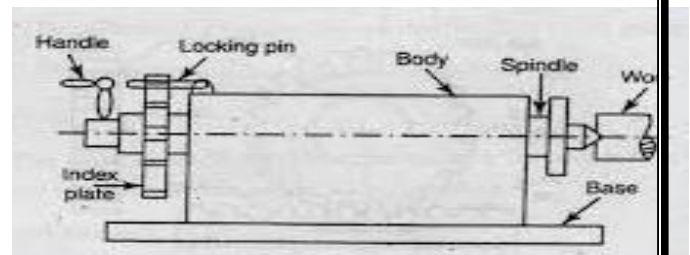
It helps in changing the angular position of the component in relation to the cutter. With their use, it is possible to divide the periphery of the work piece in to any number of equal parts. These heads are generally of the following three types.

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

Out of these, the optical dividing head is the most precision attachment and is therefore, used for very precision indexing work or for checking the indexing accuracy of the other types of dividing heads.

1. PLAIN DIVIDING HEADS: These dividing heads are mainly of two types. The first type carries the indexing plate directly mounted on its spindle and has no use of the worm and worm wheel. It is the simplest of all the dividing heads and is used in direct indexing. The index plate carries 12 or 24 equal spaced slots on its periphery. The job is held between two centers, one on the dividing head spindle and the other on the tail stock. The hand lever is used for locking the spindle in position. In operation, a lug engages the desired slot of the indexing plate. By means of this dividing head 2, 3, 4, 6, 8, 12 and 24 divisions can be obtained when 24 slots plate is used and 2, 3, 4, 6 and 12 divisions, when a 12 slot plate is used. The plate, tighter with the spindle, can be rotated by means of the handle provided on the left side of the dividing head.

Another useful form of the plain dividing head is the one used in simple indexing. It consists of a cast body, carrying the spindle. On the front end of the spindle are mounted the index



plate, having different hole circles on its face and teeth on its periphery. The plate gets movement through a worm by rotating the handle. The crank, carrying the pin, is mounted on a bolt about which it can be swung to any desired position to bring the pin in front of the desired hole. Usually, plates having 3 circles of 16, 42 and 60 or 24, 30 and 36 holes are provided on these heads. The job is held between the centers.

2. UNIVERSAL DIVIDING HEAD:

This type of dividing head is a very useful device for the purpose of indexing work. It essentially consists of a fairly robust body, enclosed in it is the worm drive, which consists of a worm wheel. The dividing head spindle carries a worm wheel.

The spindle carrying the worm, meshes with the worm wheel, carries a crank at its outer end. The index pin works inside the spring loaded plunger. This plunger can slide radially along a slot provided in the crank in order to adjust the pin position along a desired hole circle on the index plate. The index plate is also mounted on the same spindle as the crank, but on a sleeve such that the worm spindle, and hence the crank can move independent on the index plate. The sector arms provided on the index plate are usually of detachable type and can be set at a desired angle with one another in order to set a definite distance along a