



milling machine :-

16.1 Introduction :-

Milling is the process of removing metal by feeding the work past a rotating multi point cutter. In milling operation the rate of metal removal is rapid as the cutter rotates at a high speed and has many cutting edges. Thus the jobs are machined at a faster rate than with single point tools and the surface finish is also better due to multicutting tools and the surface finish is also better due to multicutting point tools and the surface finish is also better due to multicutting edge.

Milling machine is one of the most important machine tools in a tool room as nearly all the operations can be performed on it with high accuracy. The indexing head makes the machine suitable for so many purposes by exact rotation of the workpiece. The indexing head augments the work of a lathe and can produce the plain and curved surfaces and also helical grooves etc. The milling machine may be arranged so that the several cutters are mounted on the arbors at the same time thus increasing the metal removal rate and allowing several surfaces to be machined at the same time.

16.2 Classification of milling machines :-

There are many types of milling machines from the simple hand mills to the complex tape controlled machines each has a particular field in which it performs best. Many are special single purpose machines which can do only one job or may even be designed to do one operation on one workpiece.

1. column and knee milling machine :

- (a) horizontal milling machine.
- (b) vertical milling machine
- (c) universal milling machine
- (d) Ram-type universal milling machine.

(e) Bed type milling machine:

- (a) simplex milling machine
- (b) Duplex milling machine

(c) Triplex milling machine

3. Plano-type milling machine

4. Special purpose milling machine.

(a) Rotary table milling machine

(b) drum milling machine

(c) Profile milling machine

(d) Duplicating milling machine

(e) planetary milling machine

16.3 Principal Parts :-

The Principal parts of the

column and knee type milling machine are described

below

Base. It is the foundation of the machine and is that part upon which all other parts are mounted it gives the machine rigidity and strength sometimes it also serves as a reservoir for cutting fluid.

→ Knee The knee projects from the column and slides up and down on its face it supports the saddle and table and is partially supported by the elevating screw which adjusts its height.

→ Table The table rests on ways on the saddle and 90° Travels longitudinally on ways on top of the knee it is provided with graduations for exact movement and can be operated by hand or power

→ over-arm The over arm is mounted on and guided by the top of the column.

→ spindle The spindle obtains its power from the motor through belts gear and clutch and Transmits it to an arbor or sub arbor cutters are mounted directly in the spindle nose.

→ Arbor The Arbor is an accurately machined shaft for holding and driving the arbor type cutter it is tapered at one end to fit the spindle nose and has two slots to fit the nose keys for locating and driving it.

Q.6 Ram-type universal machine :-

In place of ordinary type of over arm there is ram which can slide forward and backward for the adjustment of tool position or for shifting the cutter position quickly. The cutter head is pivoted to the face of the arm and is capable of any angle adjustment b/w vertical and horizontal positions. These range of adjustment often make it possible to complete jobs with one set up without having to change the job to some other machine.

Figure :-

16.7 Universal milling machine :-

it is similar to the plan milling machine with the difference that the table is placed on the swivel and the swivel is placed on the saddle. Because of the swivel the table and hence the job can be fixed at desired angle so that inclined cuts can be taken and hence the helical gear and drilling fixtures are easily cut by the machine. This type of machine is essentially a tool - shop machine used for very accurate work.

16.8 Bed Type milling machine :-

machines of this type are essentially production machines and are of rigid structure which yield high production of interchangeable parts. The solid base provides inherent rigidity in this type of machines. The table is directly mounted on the main body of the machine in place of knee so that it becomes more stout and rigid. The table moves longitudinally over bed ways if they can withstand heavy cutting loads for long time in production work. This type of machine can have more than one spindle so that different operations can be performed simultaneously.

→ These machines are usually used with carbide cutters and require huge power for cutting. Generally their actions are automatic and hence need lesser attention of the operator.

16.9 Planer-type milling machine :-

The usual features of this planer adopted for doing milling machine operation on very big jobs. Table movement is slightly slower than the actual planer. Rotating cutting of the milling machine heads do milling operation on the jobs. The variable table feeding movement and the rotation cutter of the principle feature that distinguish this machine from the planer. Transverse and vertical movements are provided on the cutter spindle.

Figure :-

16.10 Special milling machines :-

Special milling machines are those which are adapted to and equipped for a particular job.

- (i) Rotatory Table milling machine it is an adaptation

To the vertical milling machine it consists of two vertical spindles each equipped with a facing mill. cylinder heads are roughed at one station and finish milled as they pass the second station.

(ii) Drum milling machine. Drum-milling machine are used for production work only. This type of machine has a like a Ferris wheel. The cutters are of face mill type and usually both roughing and finishing cutters similar to those of a rotary table miller are employed in operation.

(iii) Profile milling machine in appearance it resembles the vertical spindle machine. It has one to four cutter spindles. The cutter is small diameter shank type end mill. Its movement is controlled either by hand or automatically by the path of a stylus or tracer which has the same diameter and shape as the cutter.

(iv) Tracer milling machine. This machine is best suited for very complicated part like embossing and forging die and moulds and for die sinking and contour milling. The cutting tool is traversed across the work by means of a tracer mechanism.

16.11 machine size:-
The size of the milling machine is given by the dimension of the table in cm the length and width or by the manufacturer's number. A prospective buyer of a milling machine would also go into details of horse-power of the driving motor, spindle speeds and feed of a part of the specifications of the machine to see if they meet his requirement.

16.11. work performed:-

next to the lathe milling machine performs a versatile role in the production of variety of components. here are some of the most common operation which can be performed on milling machine

All kinds of grooves; straight spiral vertical and formed
Spiral and key ways on shafts
slots for inserting teeth in milling cutter.

Flat surfaces of all kinds at any angle
contours of infinite variety with straight and spiral element
concave and convex surfaces

Facing operations of all kinds.

Plate and barrel cams

cavities for plastic glasses or die casting moulds

Forging and press die

jet and steam-turbine buckets root and bucket surface

Indenting operations of all kinds : gear teeth slots flutes.
in twist drills and hole etc.

16.12 method of milling:-

Following variations of milling method are possible
depending upon the set up of job and tool

(i) single piece milling this the simplest method of
milling in which a single workpiece is milled in a
single machine cycle.

(ii) string milling in this case two or more parts are
fixed on the table and milled one after the other

- (ii) abreast milling In this case two or more parts are fixed on table and are milled simultaneously
- (iv) Gang milling In this case a number of cutters are fixed rigidly in combination to produce the desired shape on the workpiece
- (v) Progressive milling In this method two or more similar or different operations are performed either simultaneously or one after the other on separate workpieces on the same machine work pieces are progressively moved from one station to next to complete all operations.

16.12.1 setting up the milling machine:-

The selection of proper cutter for doing a job is very important aspect in milling operation. Depending on the cutter and workpiece suitable feeds and speed are calculated and set on the machine. Depth of cut is dependent on the amount of material to be removed usually two cuts one roughing and one finishing are taken to achieve better surface finish and higher dimensional accuracy. Depth of roughing cut is limited by horse power of machine or rigidity of set up and is usually 2.5 to 5 mm. Finishing cut is usually 0.4 to 0.8 mm.

For setting up the machine the knee locking clamp and the cross slide lock are loosened. The spindle is turned on and its rotation checked. The table is positioned so that the workpiece is under the cutter.

provided with four ball bearing drawery of which two ~~are~~^{q3} are equipped as simple drawery and two as double drawery which in turn can be fitted out with different inserts.

16.14 milling cutter :- milling cutter is the cutting tool used in milling machine it has a cylindrical body rotates on its own axis and is provided with equally spaced teeth which engage the work piece intermittently. The cutter teeth are machined to give cutting edge on the periphery. They may be grazed either axially or spirally. The material from workpiece is removed by relative movement of workpiece and cutters. There are a variety of cutters available depending upon the type and location of teeth. of cutters available depending parallel to the axis of rotation or at an angle known as helix angle. They may be on the cylindrical surface or the flat. Further the helix may be right or left or left handed. The cutter may be of the solid type with teeth and body on one piece or of the inserted type the body being of low carbon steel and the teeth of any kind of tool steel. In the integral tooth cutters the teeth are formed by cutting away material integral projections to which blocks of some cutting material are attached by brazing or welding. Inserted blade cutters have forged steel bodies with slots or grooves machined in the body periphery.

adjustable from 0° to 90° it can be swivelled through 360° inside its axial fitting housing according to a graduated scale and axially shifted by 60 mm. This adjustability permits facing.

Right-angle milling head :- This head can be swivelled through 360° inside its axial fitting housing according to the same graduated scale and shifted by 60 mm. The right-angle milling head is specially suited for producing keyways, oil grooves and internal pockets.

This accessory eliminates expensive set up time and alignment problems of multiple operations are carried out in one set-up only. All the parts subject to heavy loading spindles and bevel gears are hardened and ground.

measuring and centering instrument :-

Indispensable for the centering of workpiece angles and bore as well as for the checking of concentricity and parallelism. Dial indicator can pivot through 360° for accurate reading with the instrument in any position.

universal cross-slide milling head :-

This head was developed as an auxiliary attachment for milling machines. The design presents a most versatile range of possible applications.

Economic production of complicated parts is made possible by the cross slide and rotary motion features of this milling head.

Tool cabinet :- The steel tool cabinet is suitable for the careful storage of tools and accessories. The cabinet is

16.13.1 Special Accessories for the universal milling and boring machine :-

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Hydraulic clamping vice :- Accurate and easily adjustable vice simple and rapid operation by hydraulication. The clamping pressure can be adjusted and controlled mechanical coarse adjustment and hydraulic clamping operation.

Mechanically operated high pressure clamping vice :- Robust and strong design head and clamping slide can be shifted and positioned on the lower slide section by means of adjustable pins. Basic slides of different lengths can be used and combined to give a double acting vice.

Universal Precision vice :- special fine grained gray cast iron.

Swivelling of the vice on its cradle through 360° .
Swivelling of the cradle on the base plate through 360° .
Inclination of the vice surface 90° in one direction 30° in the other direction.

Semi universal indexing device :- semi-universal indexing device for direct or indirect indexing as well as indexing by degrees on a scale. The workpiece can be clamped by centre collets or three jaw chucks completely enclosed design.

Helical milling device :- The device combined with the vertical milling head and the spindle slide. Permits the manufacture of pieces with helical grooves it is mounted on the fixed table and consists of a universal indexing device which enables direct indirect and differential indexing. The tailstock of the indexing device can be adjusted in its height and angularity.

vertical indexing device :- with overarm and swivel angle. Plate to be directly fixed in the vertical position on the vertical table slide of the milling machine. It is used for direct or indirect indexing and indexing by degrees on a scale.

The workpiece can be clamped by centrefix three jaw chuck face plates or collets

Punch milling attachment :- important economic attachment for tool manufacture. It enables a considerably simpler quicker and more accurate work like manufacture of blanking punches. Extent range of application with broaching device.

Rotary table :- For indexing by degrees on a scale and indirect indexing. Fast change over from one system to the other by tightening or releasing a ring nut. High accuracy.

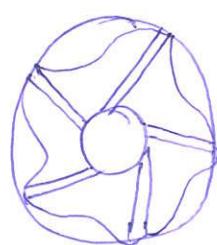
Confocal microscope :- with built-in illumination magnification 20x, with eye eyepiece angle 70°. Focal length approx 30 mm. Built-in graticule with cross wire and 12 concentric circles. With fine adjustment from all sides shock and tamper proof eyepiece.

Precision high speed spindle :- Built of special steel hardened and ground mounted on ball bearings. Quiet and free from vibrations. Increase the speed range.

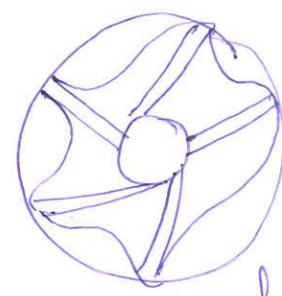
Adjustable multi-angle milling head :- The adjustable multi-angle milling head is especially suitable for the accurate machining of internal angles and inner edge of workpiece parts which are not easily accessible. The milling head is.

16.14.1 material of milling cutters :- All important tool materials like carbon steel high speed steel cast as non ferrous cutting alloys sintered carbide etc are used for milling cutters solid type of cutters may be made of carbon steel or generally of HSS. Bodies of milling cutter having blade of hard cutting materials are made of carbon steel or generally made of HSS or a cast non-ferrous cutting alloy like satellite carbide are mechanically locked.

16.14.2 hand of milling cutter Rotation :- In order to determine the hand of rotation of any milling cutter lock at is from the front or cutter end of the spindle if the spindle rotates clockwise the rotation is left hand rotation or left hand cut and if it rotates counter clockwise then it is right hand or a right hand cut



left hand cut



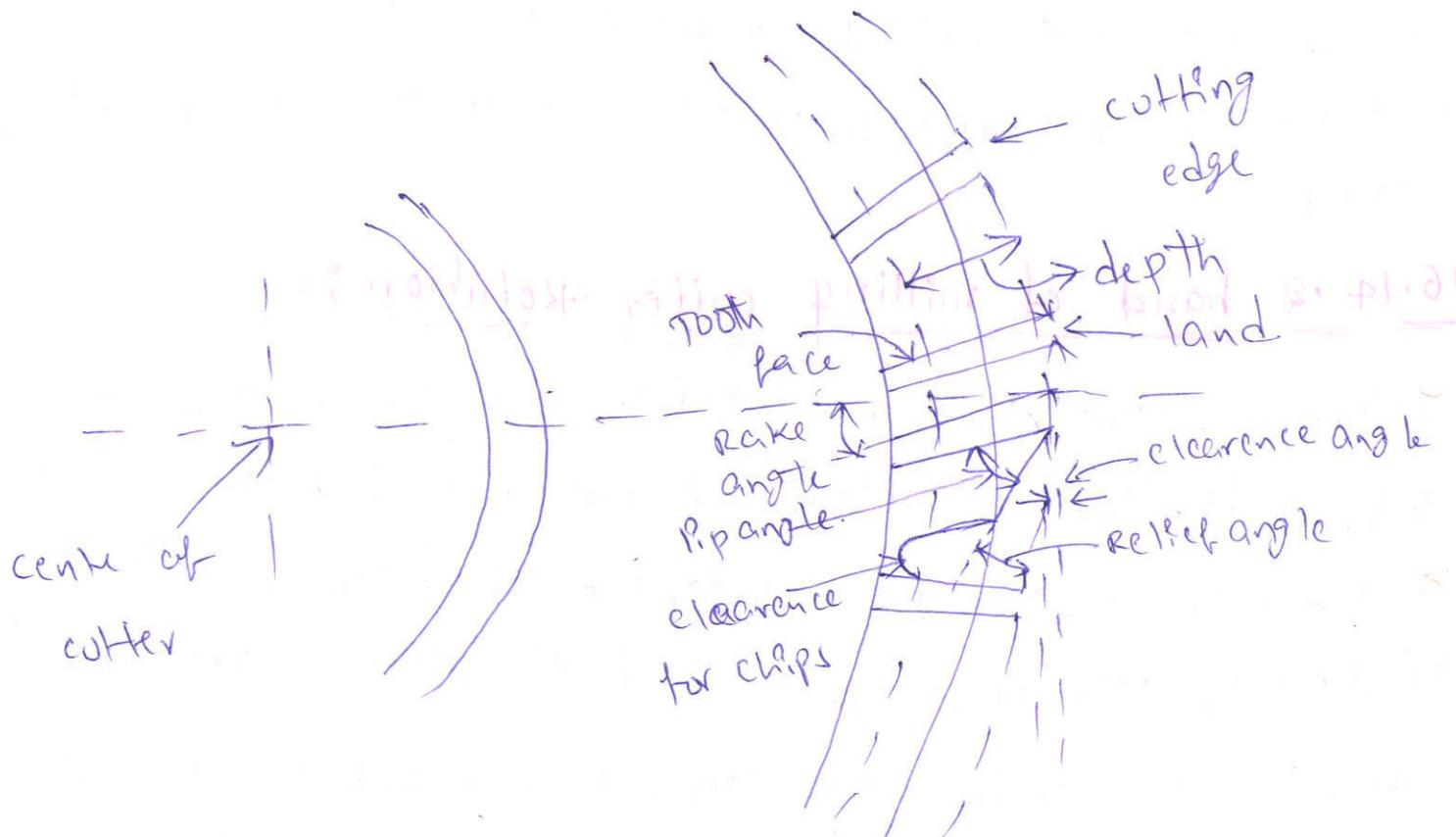
Right hand cut

→ The hand of helix can also be judged the same way if from front or cutting end of a cutter the helix appears to have a clockwise contour it is right helix and if counter clockwise then it is left helix.

16.15 elements of fluted milling cutter :-

The teeth of fluted cutters are designed to cut on the periphery and in many case on the side as well.

A typical milling cutter with various angles and cutter nomenclature is shown in Fig 16.30.



Arbor:- It is the shaft on which the milling cutter is mounted and driven.

shank:- It is the cylindrical tapered extension along the axis of the cutter employed for holding and driving.

cutter body:- This is the main frame body the cutter on which the teeth are brazed or mechanically held or are integral with it. It has either a hole for mounting on an arbor or a solid shank for mounting in the spindle or collet.

MILLING MACHINE AND MILLING WORK

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* Milling cutters:-

The milling cutters may have either straight teeth 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 from performing the cutting operation. The broad classification of milling cutters is according to the shape of teeth they carry, such as plain, inserted, formed or sawteeth, etc. Under this classification are converted a large number of milling cutters.

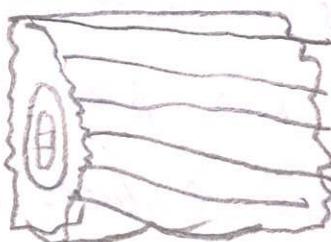
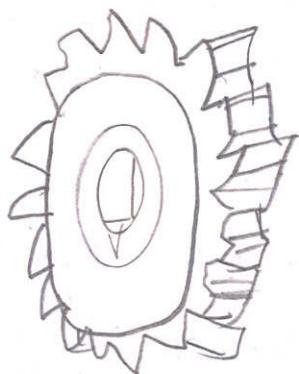
Common types of milling cutters are the following:

- plain milling cutters
- end milling cutters
- metal slitting cutters
- formed milling cutters
- T-slot milling cutters
- side milling cutters
- face milling cutters
- Angle milling cutters
- woodruff milling cutters
- fly cutters.

* plain Milling cutters:-

These milling cutters may have the cutting teeth on their periphery. The teeth may be either straight i.e., parallel to the axis, or helical. Thus, no cutting action is provided by the side faces. These cutters are employed for milling flat surfaces parallel to the axis of rotation.

These cutters include the light duty plain milling cutter or key way cutter and the helical or slab milling cutters. The former type is available up to 20mm in width and carries straight teeth. It is usually employed for key way and slot cutting. The latter type, i.e., slab milling cutters are enough long and carry helical teeth. These cutters are made to have eight fine pitch & coarse pitch fine pitch teeth cutters are used for light work and finishing work. They are commonly used where very heavy cuts are to be employed, since they are capable for removing more materials with less power consumption. It has a very big length cutters with their teeth running alternately right and left hand to neutralize the end thrust.

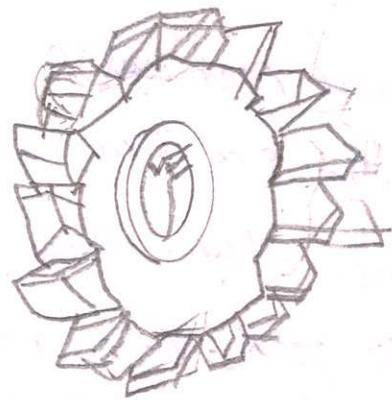


→ Side Milling cutters:-

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

1. plain side milling cutters:-

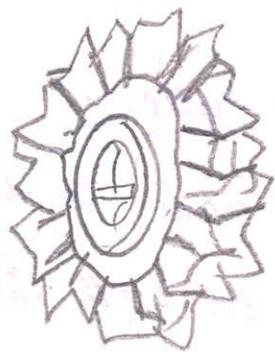
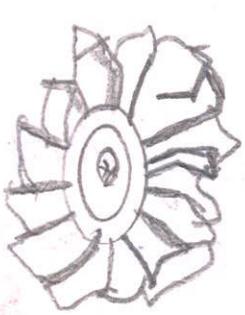
They are made to have cutting teeth on the periphery as well as on both sides, as shown in the figure. They are normally used for cutting slots or in face milling. These cutters are available in different widths ranging from 5mm to 25mm and diameters up to 200mm.



2. Half side milling cutters:- The cutters have teeth on the periphery and on one side only. They can be used for face milling. Actual cutting operation is performed by the teeth provided on the periphery while the side teeth do the finishing and sizing work. They are frequently used in pairs for milling two parallel surfaces simultaneously, the operation being known as straddle milling.

3. staggered teeth side milling cutters:-

These cutters carry alternate teeth on the periphery only. These alternative teeth are of opposite helix-angle, staggered from side to side, just as the teeth of a wood saw, and cut alternately. They prove very efficient in milling deep slots but narrow in width. A typical teeth type of staggered tooth side milling cutter is shown in the figure.



4. Interlocking side milling cutters:-

These cutters are similar in design to the side milling cutters but used as a unit. They can be adjusted to acquire the required width by inserting shims or spaces between them. These shims or spacers are also used to make good the reduction width. These cutters are used for milling relatively wider slots to exact width. Also, they find a wide use in Gang milling.

→ End milling cutters:-

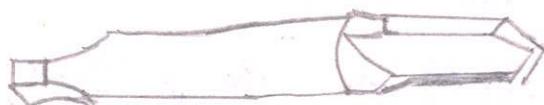
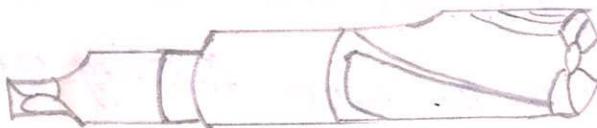
These are solid cutters which are manufactured in two different varieties. Those having the shank and the others which do not have the shank. These teeth may be big straight i.e., parallel to the axis of rotation.

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Helical Teeth may be right hand & left hand. End milling cutters are used for milling slots. shank type end mills may have lighter types shank and are available in a wide diameter from 3mm to 50mm. The following are the main classifications of these end mills.

1. 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 8mm dia.



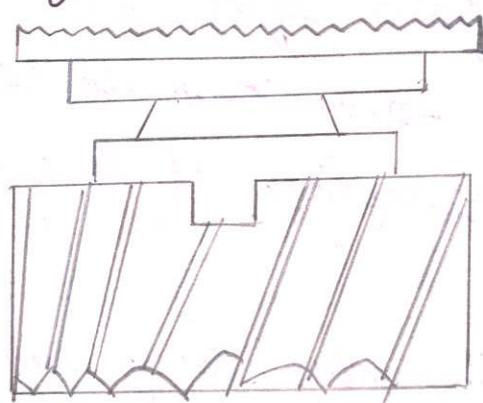
2. Two-lipped end mill:

These milling cutters are also known as slotting mills. These 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.

3. shell end milling cutters:

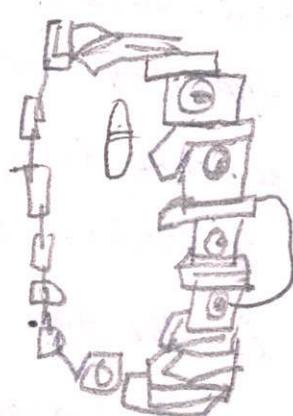
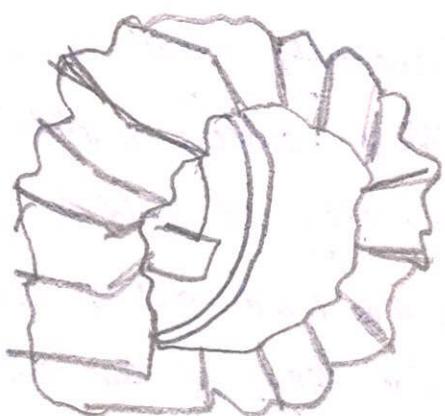
These cutters are larger and heavier than most of the other type of end mills. Generally they are made in over 50mm size. The end face of these cutters is provided with a recess to receive a cap-screw. They are held in a stub arbor, shown in the fig. Two slots are made across the back of the cutter, which engage the collar keys of the arbor to get the drive. Milling of flat surfaces, using the end

3 face, and cutting slots, etc. are operations called facing.
A shell end milling cutter is shown in the fig.



→ 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. It carries teeth on the periphery as well as the end face. Maximum cutting is done by the teeth on the cutter. Finishing operation on larger type of cutter called the Built-up face milling cutter, consists of a steel body, along the periphery of 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.



→ Metal slitting cutters:-

The cutters are also frequently called metal slitting saws. They are used for cutting thin slots or for parting off.

They are commonly manufactured in the following two varieties:

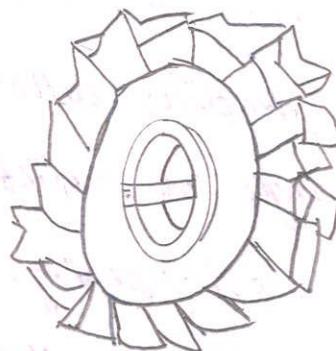
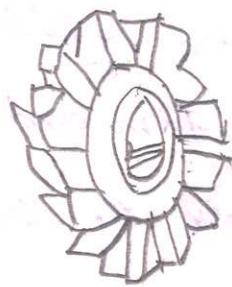
1. plain slitting saws:-

They are plain milling cutters which are very thin as compared to other types of milling cutters. Their teeth are provided with some side relief in order to prevent chattering. They are made in different widths, ranging between approximately 4 mm and 5 mm. A plain slitting saw is shown in the fig.



2. staggered teeth milling cutter:

These saws are used for comparatively heavier work. They have their teeth staggered alternatively and have side teeth also. These saws are generally made in different widths, ranging between 4 mm and 10 mm.



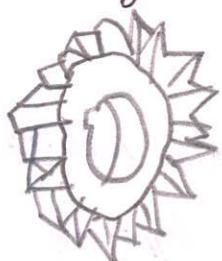
→ Angle milling cutters:-

These cutters carry sharp angular teeth which are neither parallel nor normal to their axes.

The following types of angle cutters are in common use:

1. Single angle cutters:-

These cutters may have their teeth either only on the angular face or both the angular face and the side. The latter type enables milling of both the flanks of the included angular groove simultaneously. The teeth may have an included angle of 45° or 60° .



2. Double angle cutters:-

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

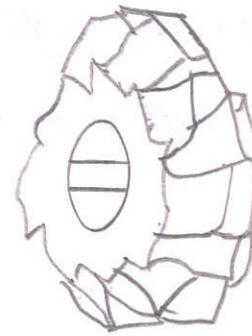
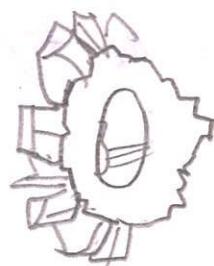
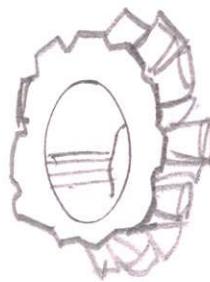
→ Form Milling Cutters:-

They are also known as form relieved milling cutters or radius cutters. Their teeth are provided with a certain angle of relief so that their form and size is retained even after resharpening. The following are the common types of form relieved cutters.

1. Corner Rounding cutters:-

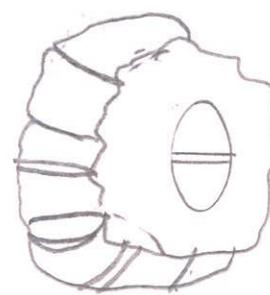
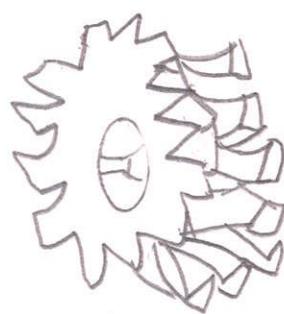
These cutters are used for milling the edges and corners of the jobs to a required radius. They are manufactured separately as single cutters or double cutters. Single cutters be right hand or left hand. The double

cutter has combination of both right hand and left hand in a single unit.



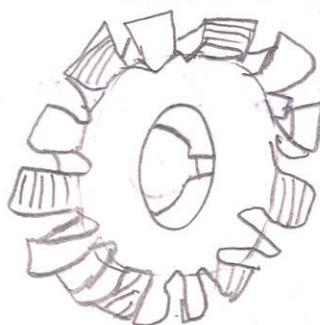
2. Concave and convex cutters:-

These cutters are very commonly used types of form relieved cutters. They are used to milling convex and concave surface or circular contours of half circles less. As such a concave cutter will be used for milling a concave surface and a convex cutter for milling a convex surface.



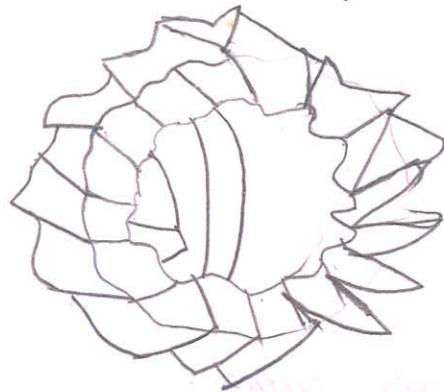
3. Gear cutters:-

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.



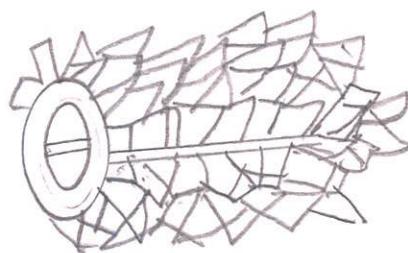
4. Tap and Reamer fluting cutters:-

These formed cutters are used for milling flutes on reamers and taps. In appearance, they look like double angle cutters. A typical Tap and Reamer fluting cutter is shown in the fig.



5. Gear Hobs:-

A Gear hob is a formed milling cutter which carries helical cutting teeth on its periphery. It is used for a number of different milling operations. A standard form of such a cutter is shown in the fig.



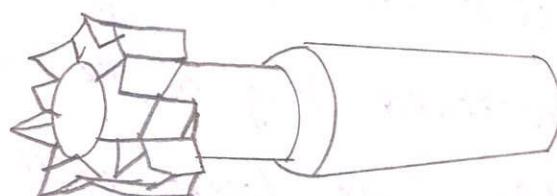
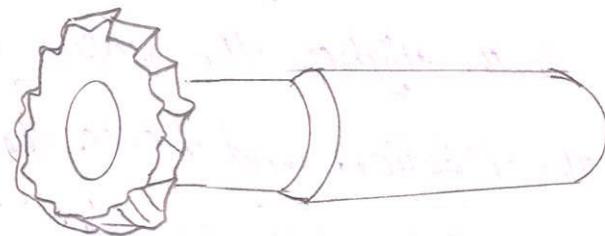
6. Thread Milling Cutters:-

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 type threads. The included angle of the cutting teeth will correspond to the angle of the threads to be produced. These cutters have already been described in detail in Art.

→ Woodruff - Key Milling Cutter:-

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It is a small type of end milling cutter which resembles with plain and side mills. Smaller sizes, say up to 50 mm diameter, are made to have solid shank, to be fitted on the machine spindle, whereas the larger sizes are provided with a hole for mounting the same on an arbor. 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 shown in the fig.



→ T-slot Milling cutter:-

It is single operation cutter which is used only for cutting T-slots. In smaller sizes made to have the shank integral with the cutter. The T-slot milling the wider groove. It facilitates an unhindered movement of the cutter through the upper groove as the cut proceeds.

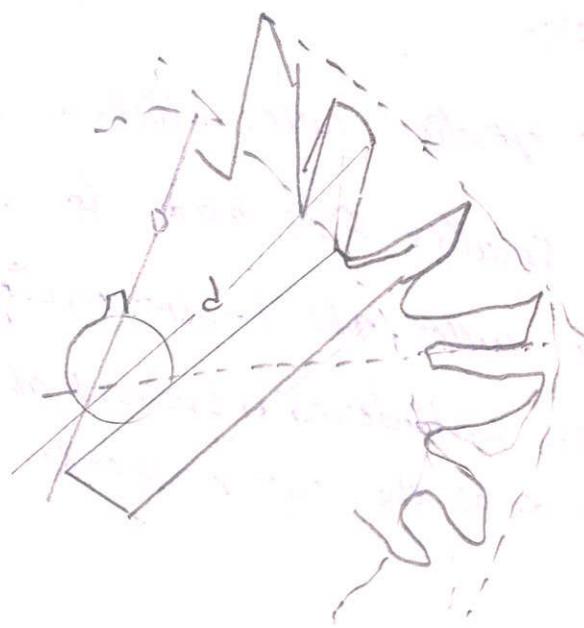
→ Fly cutter:-

It is actually a single point tool. It is either mounted on a cylindrical body, held on a stub arbor & held in a bar exactly in the same way as a boring tool in a Boring bar. It is generally used for experimental purposes since such a cutter, if properly designed, is capable very accurate surface.

→ Angles of Plain Milling cutter:-

A milling cutter can be considered as a built up unit of a number of a single point cutting tools such that each tooth of the cutter is a single point cutting tool, as shown by 'A' in fig. Before proceeding on to the study of tool angles, note the names of various parts of the cutter teeth, such as Face, cutting edge, Back, flute, fillet, land etc.

The relief angle (α) is the angle between the plane P_1 , which is normal to the axial plane pp at the point on the cutting edge, and the tangent to the relieved land of the cutter tooth. Higher the value of this angle lesser will be the friction and hence the wear on the land. Normally relief angle ranges between 10° and 30° .



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The Rake angle (r) is the angle between the axial plane PP and the face of the cutter tooth measured in a plane normal to the cutting edge. Rake angle facilitates free cutting by the tool by allowing the chips to flow smoothly. 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. As such, the endeavour should be to keep it as large as feasible, taking into consideration the factors explained in the foregoing paragraphs.

This is particularly important while milling harder metals and when deeper cuts are to be employed. The recommended values of principal angles are given in the Table.

→ Number of teeth in cutter:-

There is no standard rule which can be straightway applied to determine the number of teeth in a cutter. Moreover, the number of teeth do not have any direct influence. A milling cutter with coarse pitch, i.e., having less number of teeth, have thicker and, therefore stronger teeth. As such, these cutters will be very suitable where heavy cuts are to be employed i.e., in rough milling. Against this, cutters having more

number of teeth etc i.e., of fine pitch, will remove chips of relatively less thickness.

The main advantages offered by a coarse teeth are summarised below:

- Its teeth can be made stronger by increasing their cross-section.
- As the number of teeth is less, the pitch is wider and, therefore, the chip gets more space for its flow and exit.
- The required of power of driving it is less.
- Because of the teeth being thicker and stronger a bigger rake angle can be provided on the teeth of this cutter.
- Lesser heat is developed at the metal cutting area due to smaller sliding friction.

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→ Milling operations:-

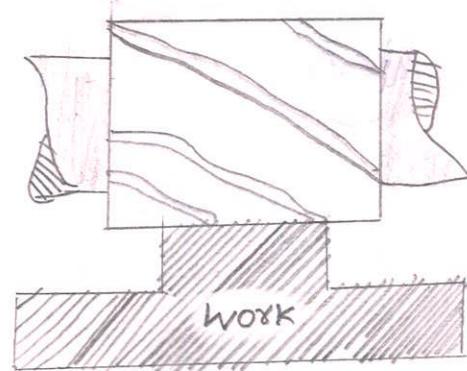
A large variety of components are machined on a milling machine involving various types of operations. These operations are broadly classified as follows:

- plain or slab milling → Face milling
- Angular milling. → form milling.
- straddle milling → Gang milling.

1. plain & slab Milling:-

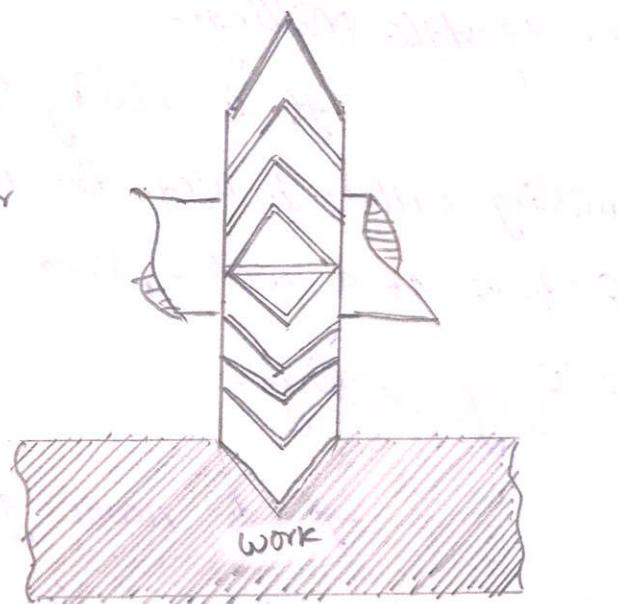
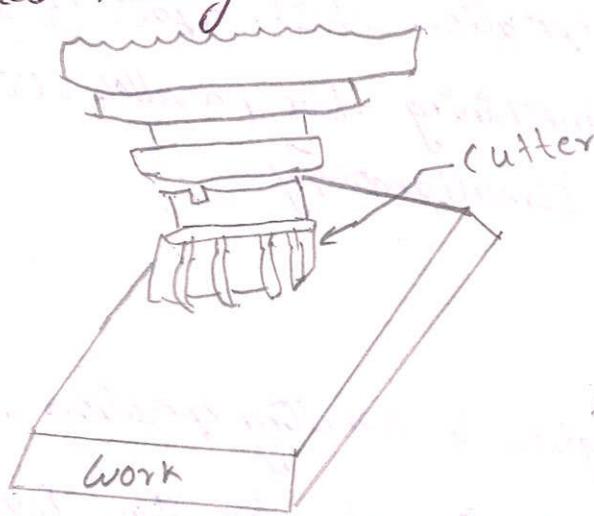
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It is the process which is employed for machining a flat surface, parallel to the axis of the cutter as shown in fig. when a very wide surface is to be machined, it is advisable to use the interlocking teeth plain milling cutters. each other so as to force the cutters closer as the operation proceeds.



2. Face Milling:-

This milling process is employed for machining a flat surface which is at right angles to the axis of the rotating cutter. The cutter used in this operation is the face milling cutter.



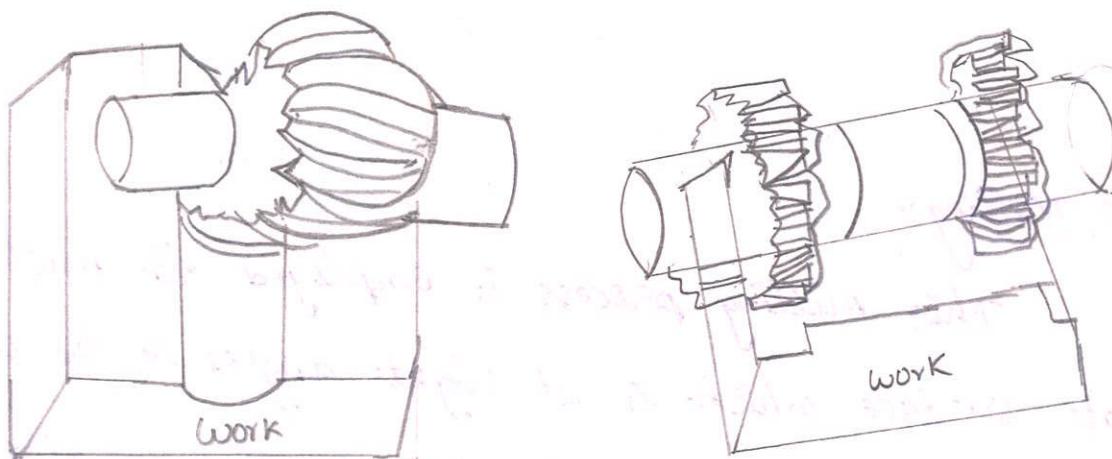
3. Angular milling:-

It is a milling process which is used for machining a flat surface at an angle, other than a right angle to the axis of the revolving cutter. The cutter used may be a single or double angle cutter, depending upon whether

a single surface is to be machined or two mutually perpendicular surfaces simultaneously.

4. Form milling:-

The milling process is employed for machining those surfaces which are of irregular shapes. The cutter used, called a form milling cutter, will have the shape of its cutting teeth conforming to the profile of the surface to be produced.



5. Straddle Milling:-

It is a milling operation which a pair of side milling cutters is used for machining two parallel vertical surfaces of a work-piece simultaneously.

6. Gang Milling:-

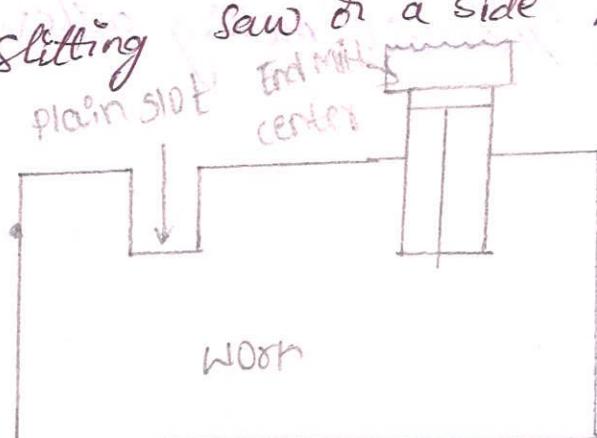
It is name given to a milling operation which involves the use of a combination of more than two cutters, mounted on a common arbor, for milling a number of flat horizontal and vertical surfaces of a work-piece simultaneously. This combination may consist of only side milling cutters & of plain and side milling cutters both.

A part from this, a number of other operations are named either after the name of the cutter used for them or some other factors like the shape or use of the surface produced. These operations are:

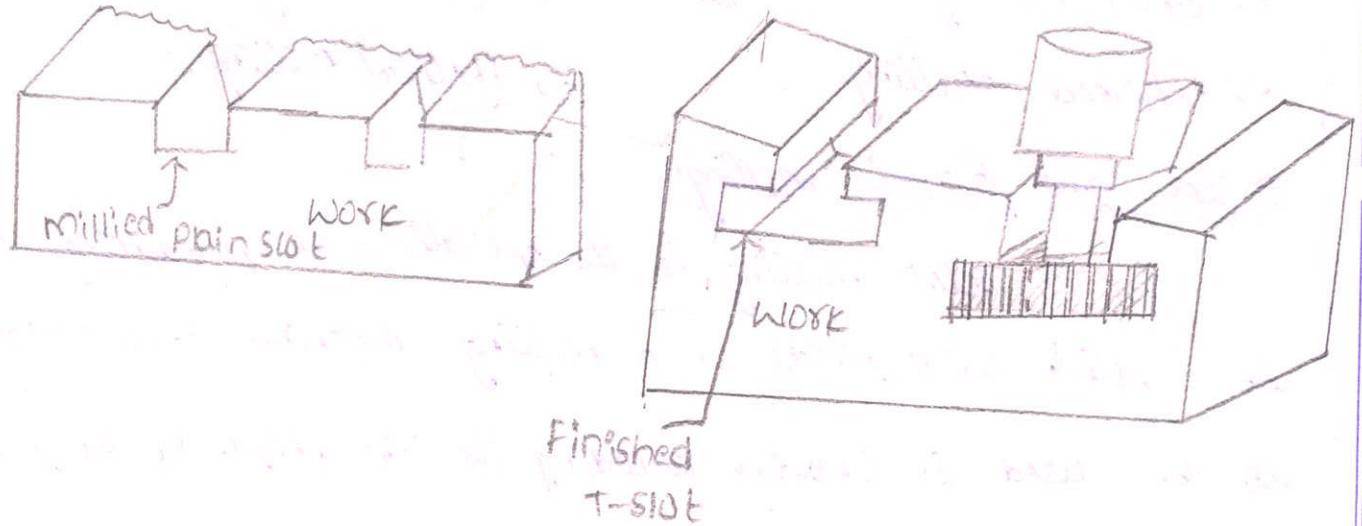
- slot and Groove milling → keyway milling
- Slitting or Saw milling. → side milling
- End milling → profile milling
- Gear milling → Cam milling
- Threaded milling → Helical Milling.

Slot and Groove Milling:-

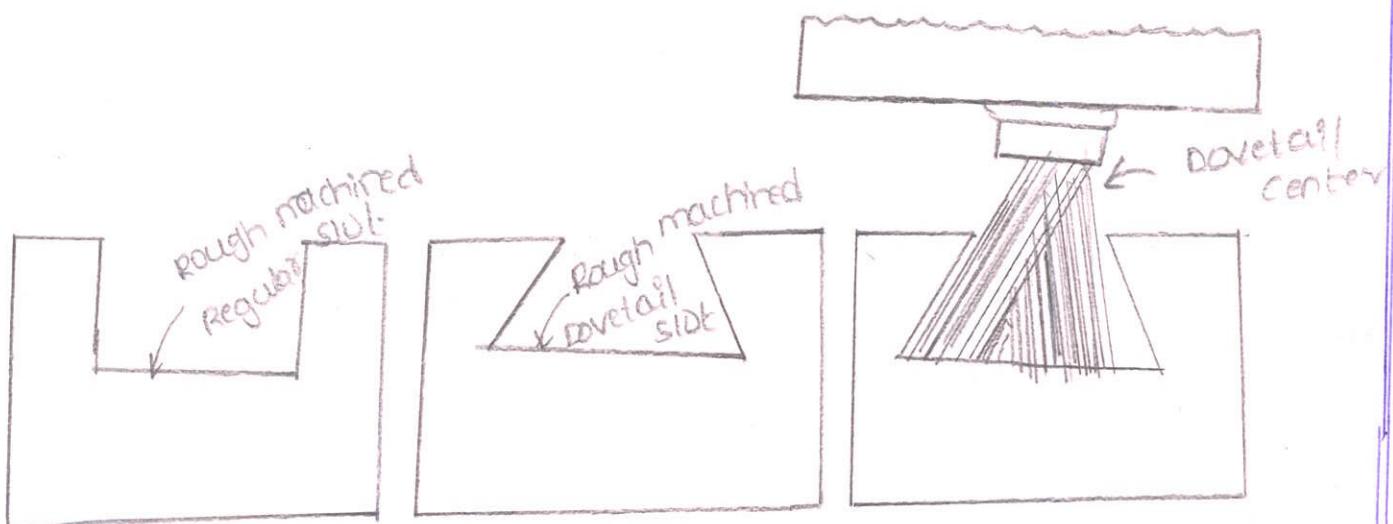
Slot milling is the operation of producing slots in solid work pieces on a milling machine. The cutter to be used is chosen according to the shape of the groove. To slot to be produced milling of a V-groove, using a double angle cutter. The same result can be obtained with two single angle cutters of opposite angles, used one after the other. Similarly, plain milling cutter, an end mill, a slitting saw or a side milling cutter.



Milling of T-slot and dovetail slot is carried out in two or three stages. In the first stage an open slot, from one end of the solid workpiece to its other end. When the slot is milled to the required shape by using a special cutter - a T-slot cutter & T-slot and dovetail milling cutter for dovetail slots.



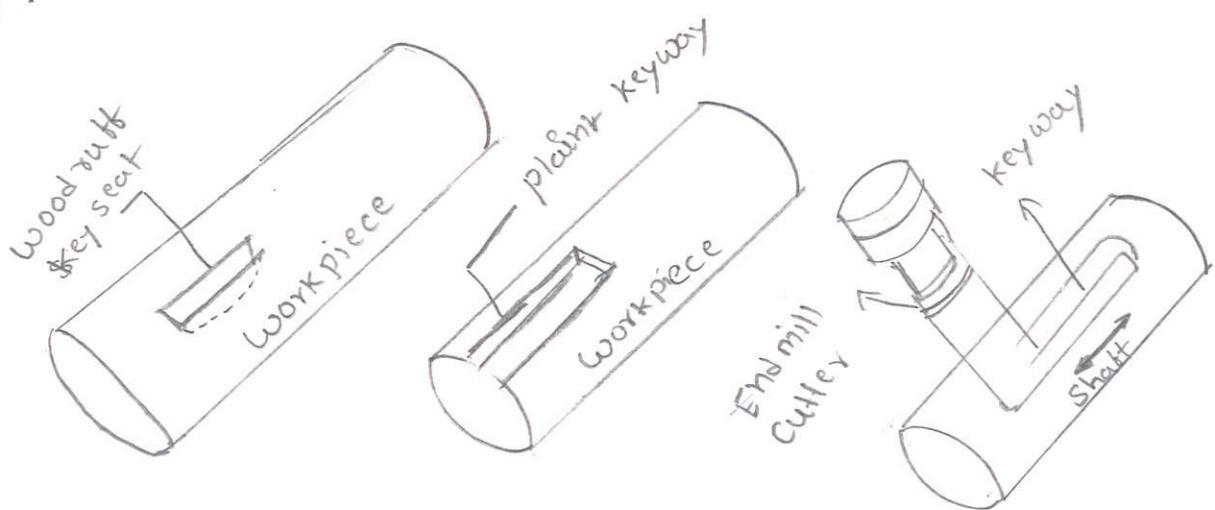
Production of a dovetail slot in three stages shown in the fig. is shown a rectangular slot produced through rough machining by means of form angle cutter. The slot is finally finished by machining the base and sides of the slot help of dovetail milling cutter.



→ keyway milling:-

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Milling of a keyway is a commonly performed operation on a milling machine in which a groove is milled, usually the shafts and spindles. The groove is known as key seat. It is closed groove with a rounded bottom. In the fig. is shown a plain key seat milled with a single plain or side milling cutter. It is an open groove. It is a closed groove with rounded ends. Same is the case with woodruff key seat.

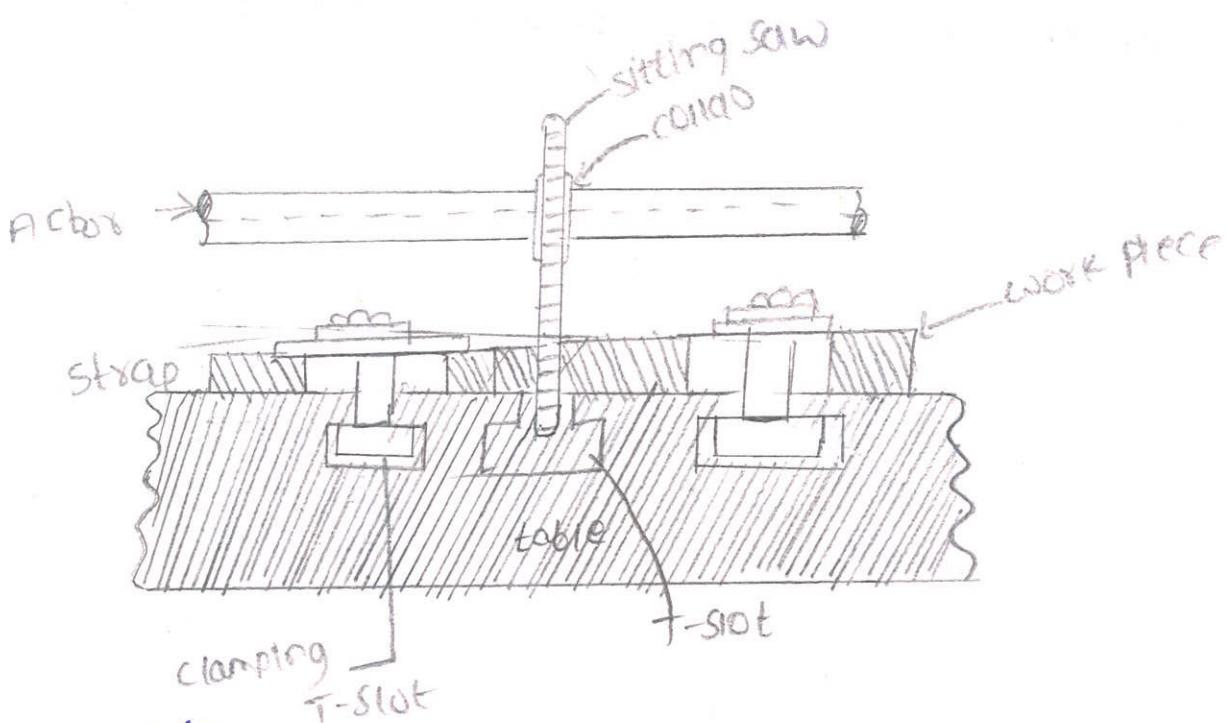


→ slitting & saw milling:-

A slitting saw or slitting cutter is used for many purposes on a milling machine, such as parting off a solid work piece into two, cutting of narrow slots and groove, etc. An important factor in any slitting operation is the rigidity of the workpiece. In other cases the workpiece may be clamped directly on the machine table using suitable job holding.

unit-3, pg-33 | 25

devices. An important precaution is this case is to keep the line of cutting in the centre of a T-slot and running along its length. This will allow the slitting saw to project safely into the free space in the slot. A parting off operating, being performed by means of a slitting saw, is shown in fig.

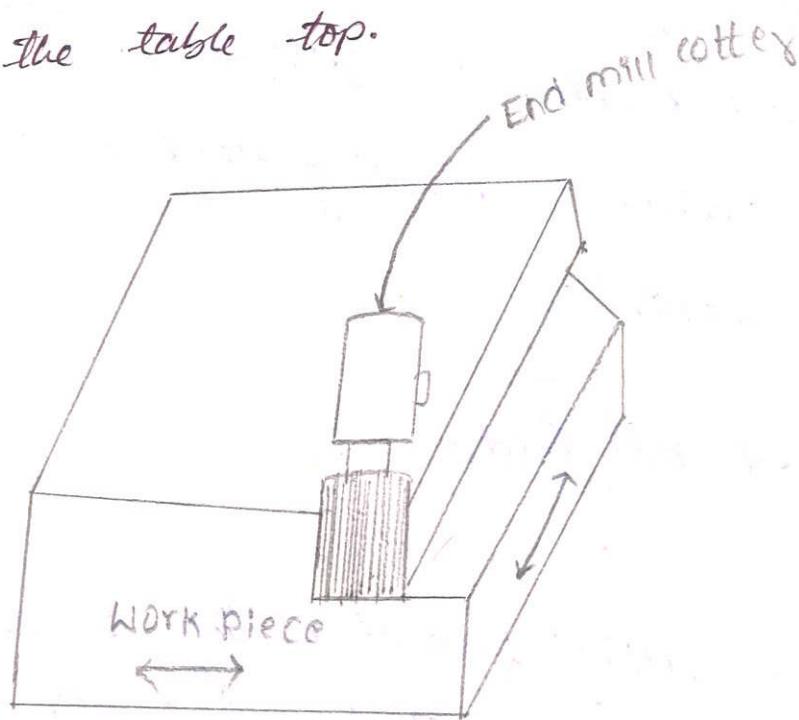


→ side milling:-

In this operation, a side milling cutter is used to machine a flat vertical surface on a side of the workpiece. When two parallel vertical flat surfaces are required to be machined, the usual time saving practice is to use a pair of two side milling cutters to machine both the surfaces simultaneously. The space between the two cutters can be easily adjusted as per requirement by using the spacers. This operation is then known as 'straddle milling' and is already explained.

→ End Milling:-

In this operation an end mill cutter is used to machine and produce a flat surface or a pair of parallel flat surfaces. When the operation is performed at the end of a workpiece, as produced. The surface produced may be horizontal, vertical or inclined with respect to the top of the machine table. For producing a horizontal surface, the axis of rotation of the cutter has to be horizontal, for vertical surface it remains vertical and for inclined surface it is to be set at proper inclination with the table top.



→ profile Milling:-

It is operation in which the profile of a template or the shape of the cavity of a master-die is duplicated on the work surface. The movement of the cutter is guided by a Traces control unit which carries a contact finger. This finger runs in contact with the outline to be duplicated and the Traces unit-3, pg-35/25

mechanism guides the tool movement accordingly

⇒ Gear Milling:-

This operation, often referred to as Gear cutting, involves cutting of different types of gears on a milling machine. For this, either an end-mill cutter or a form relieved cutter is used, which carries the profile on its cutting teeth corresponding to the required profile of the gap between gear teeth. For dividing the periphery of the gear blank into required number of equispaced parts or indexing mechanism or dividing head is used, which is described later.

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⇒ Cutting speed and feed:-

⇒ Cutting speed:-

The cutting speed of milling cutter is the distance travelled per minute by the cutting edge of the cutter. It is measured at the circumference of the cutter and is expressed in meters per minute of feed per minute, depending upon the units that are adopted.

Now suppose that 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 is equal to the circumference of the cutter i.e., $= \pi D \text{ mm}$

Since it makes $N \text{ rpm}$, therefore the total distance travelled per minute $= \pi DN \text{ mm}$.

$$\text{∴, the cutting speed} = \frac{\pi DN}{1000} \text{ m/min} \quad \text{--- (1)}$$

$$\text{∴, the cutting speed} = \frac{\pi DN}{12} \text{ ft/min} \quad \text{--- (2)}$$

From expressions 1 and 2 you will find the cutting speed varies directly as the diameter and rpm of the cutter. A few examples below will show the method of computing the cutting speed.

Example 1:-

A milling cutter, 100 mm dia., runs at 200 rpm. Calculate the cutting speed.

Solution:-

$$\begin{aligned}\text{Cutting speed} &= \frac{\pi DN}{1000} \\ &= \frac{22 \times 100 \times 200}{7 \times 1000} \\ &= 66 \text{ m/min.}\end{aligned}$$

Example 2:-

A milling cutter 4" in diameter revolves at 70 rpm. Find the cutting speed.

Solution:-

$$\text{Required speed} = \frac{\pi DN}{12}$$

$$= \frac{22 \times 4 \times 70}{7 \times 12}$$

$$= 73 \frac{1}{3} \text{ ft/min.}$$

However, it will be standard recommendation with regard to the cutting speed and what we are actually required to find out is either the diameter of the cutter or the rpm. Corresponding values for finishing will be 25% to 100% higher than these and may be suitably adopted.

→ Feed:-

It represents the table travel in any direction, measured in millimeters, whatever may be the mode of feeding. It can be expressed in the following three ways.

1. Feed per minute: i.e., the table travel in millimeters in 1 minute in any direction. It is expressed as mm/min.

2. Feed per tooth: i.e., the table travel in millimeters during the period when the cutter revolves through an angle corresponding to the distance between the cutting edges of two adjacent teeth.

3. Feed per revolution: i.e., the table travel in millimeters during the period when the cutter makes one full revolution. It is expressed in mm/rev.

It will be interesting to note that:

$$\text{feed per revolution} = \text{Feed per tooth} \times T$$

where, T = no. of teeth in the cutter

$$\text{and Feed per min} = \text{feed per revolution} \times N$$

where, N = no. of revolutions per min of the cutter.

$$\text{i.e., Feed per min} = \text{feed per tooth} \times T \times N.$$

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⇒ INDEXING OR DIVIDING HEADS:-

These heads, as already described, help in changing the angular position of the component in relation to the cutter. These Heads are generally of the following three types:

→ plain dividing head.

→ universal dividing head

→ optical dividing head.

out of these the last one i.e., the optical

is the most precision attachment.

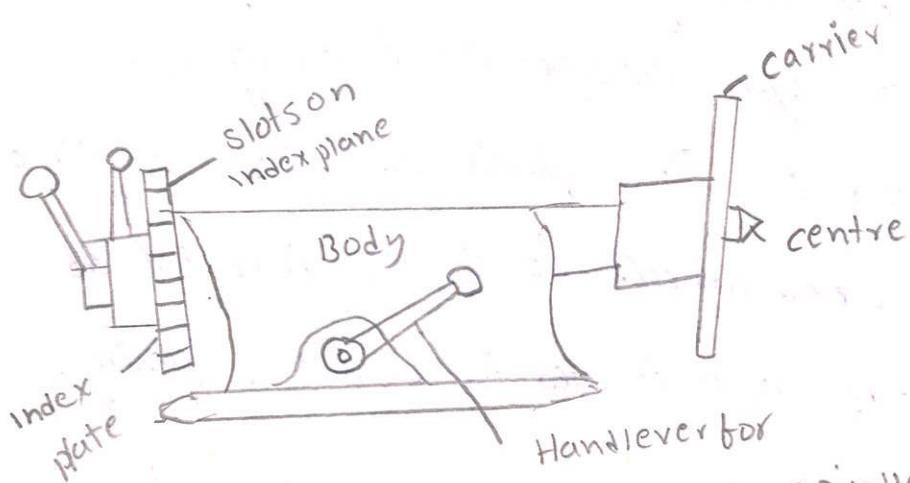
Dividing head

+ 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 hand lever is used for locking the simple in position. In operation, a lug engages the desired slot of the indexing plate. By means of the dividing heads 2, 3, 4, 8, 12 and 24 divisions can be obtained when 24 slots plate is used and 2, 3, 4, 6 and 12 divisions when 12 slot plate.

Another useful form of the plain dividing head is the one used in simple indexing. The plate gets movement through a worm by rotating the head handle. The crank, carrying the pin, is mounted on a bolt about which it can be swung to any desired position. Usually plates having 3 circles at 16, 42 and 60 or 24, 30 and 36 holes are provided on these heads. Other plates of different table circles may also be available in the market. The job is held between centres are usual.



→ Using the dividing head:-

As described above, the dividing head provides support to the job, holds it position and rotates it through a desired angle after each cut is over. When the crank is rotated, the worm rotates which, in turn, rotates the worm wheel. Since this wheel is mounted directly on the spindle the latter rotates along with former. The angle through which the job will rotate, for each revolution of the crank, depends upon the velocity ratio between the worm and worm-wheel. This ratio is usually 40 to 1. i.e., for 40 revolution of the worm, or of the crank, the job will make one revolution. However some dividing heads carry different velocity ratios of these two and the same should be known before performing the actual indexing operation.

A set of change gears can be incorporated to connect the worm shaft and the spindle. Each of these circles carries a definite number of holes on them. The standard Brown and Sharp index plates have the following circles.

No. 1. 15, 16, 17, 18, 19, 20.

No. 2. 21, 23, 27, 29, 31, 33.

No. 3. 37, 39, 41, 43, 47, 49.

Some German made dividing heads, which are now quite commonly supplied with a large number of milling machines manufactured in our country, are supplied with a set of 3 index plates carrying hole circles are follows.

	one side	13, 16, 18, 20, 23
Plate No. 1	other side	15, 17, 19, 21, 24
Plate No. 2	one side	27, 28, 31, 37, 37, 41, 47
	other side	29, 33, 39, 43, 44, 49
Plate No. 3.	one side	18, 19, 20, 23, 29, 33, 39, 43, 49
	other side	15, 17, 19, 21, 31, 37, 41, 47

This obviously, provides a much wider range for indexing as compared to the Brown and carries sharp type.

Some dividing heads, used for simple indexing, are providing with a single plate only. It carries holes on its both sides as follows:

Front: 24, 25, 28, 30, 34, 37, 38, 39, 41, 42, 43

Back: 46, 47, 49, 51, 53, 54, 57, 58, 59, 62, 66.

There is however no standard practice followed internationally for this purpose. As such, you may come across several other combinations of hole circles. The only thing to remember is that whatever may be the number of plates, or that of the hole circles on them, the principles of indexing remain the same. Also, higher the number of plates and wider will be the edge of indexing obtained through that dividing head.

For using the dividing head, first it is calculated as to how many full turns the crank has to rotate through and how many holes on which circle it has to cross further in order to give the required rotation to the work. Before rotating the crank, the crank pin is withdrawn by pulling the plunger. It rotates, as described above, independent of the index plate. In differential indexing, where the plate has also to rotate, the same is unlocked.

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→ universal Dividing Head:-

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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 device, which consists of a worm and worm wheel. Details of this internal mechanism are shown in the fig. The dividing head spindle carries a worm wheel as shown.

The spindle carrying the worm, which meshes with the worm wheel, carries a crank at its outer end. The index pin works inside the spring loaded plunger. The index plate is also mounted on the same spindle as the crank, but on a sleeve such that the work spindle, and hence the crank, can move independent on the index plate. The sector arms provided on the index plates 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 desire hole circle. On the back side of the dividing heads is provided a bracket which carries a slot along its length. One or two studs, according to required, can be fitted in this slot and predetermined set of change gears can be mounted them. The universal dividing head performs the following operations:

1. It sets the work piece in desired position in relation to the machine table.
2. After each cut, it rotates the job through a desired angle and, thus indexes the periphery of the work.
3. It provides a continuous rotary motion to the job during milling of helical grooves.
4. It, in conjunction with a tailstock, acts both as a holding as well as device for the operation.

INDEXING METHOD

→ The indexing is the operation of dividing the periphery of a work-piece into any number of equal parts. Indexing operation rotates the workpiece through a required angle between two successive cuts. The indexing operation is used for cutting gears of spur gear, providing hexagonal & square headed bolts, cutting splines on shafts, fluting drills, taps and reamers and many other jobs, all required equally and accurately. Indexing performed by using a special attachment known as (Dividing or index head).

→ There are three types of Indexing method. They are :- * plain or simple dividing head
* universal dividing head.
* optical dividing head.

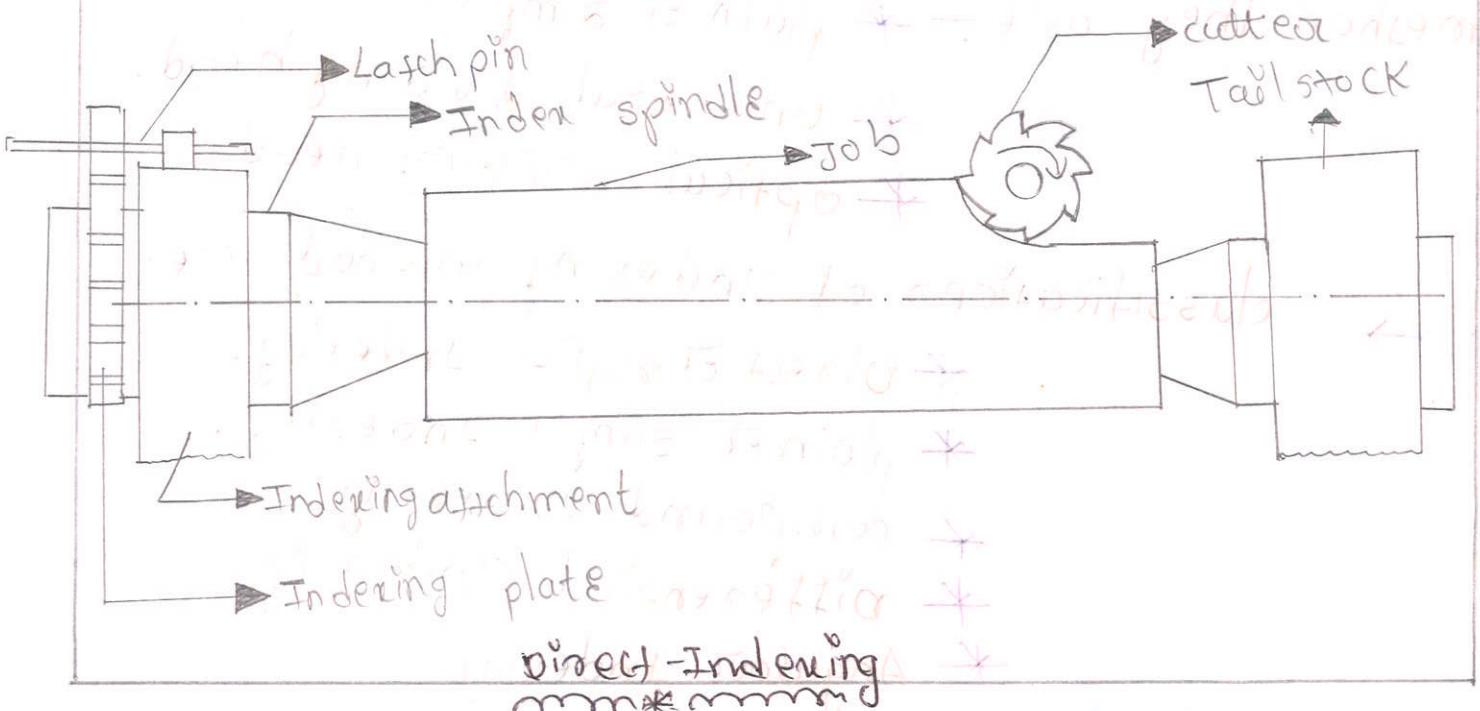
→ classifications of Indexing method are.

- * direct or rapid indexing.
- * plain or simple indexing.
- * compound indexing.
- * differential indexing.
- * Angular indexing.

Direct (or) Rapid Indexing:

Rapid or direct indexing is the simplest method of indexing and is used only on work that requires a small number of divisions, such as square or hexagonal nuts, etc. In this indexing method, the spindle is turned through a given angle without interposition of gearing. The spindle is rotated through a given angle by turning the spindle by hand.

The indexing plate is fastened directly to the spindle, so that one complete revolution of the index plate rotates the spindle one complete revolution. During indexing, the latch pin is first taken out & the spindle is rotated by hand, & after the required position is reached it is again locked by the latch pin.



revolutions of the crank turn the spindle one-eighth (one-fourth) & one-half revolutions.

If the number of divisions on job circumference needed is "N_{div}" then the number of turns that the crank must be rotated for each indexing can be found from the following relationship.

$$\text{Eqn: } N_{cr} = \frac{40}{N_{div}}$$

Index plates with circles of hole patented by the brown & sharpe manufactured company

plate No. 1 - 15, 16, 17, 18, 19, 20.

plate No. 2 - 21, 23, 27, 29, 31, 33.

plate No. 3 - 37, 39, 41, 43, 47, 49.

The no. of holes in each circular row of holes is as follows.

First side - 24, 25, 28, 30, 34, 37, 38, 39, 41, 42, 43.

Second side - 46, 47, 49, 51, 53, 54, 57, 58, 59, 62, 66.

An indexing method 24 holes can be used for any number of equal division divisible into 24 i.e., the work can be dividing into "2, 3, 4, 6, 12 & 24" parts directly.

$$\text{No. of holes to be moved} = \frac{N}{N_{\text{div}}}$$

where $N \rightarrow$ No. of slots on periphery of index plate

$N_{\text{div}} \rightarrow$ No. of divisions required on the job.

Simple Indexing :-

Simple or plain indexing is carried out using any of the indexing plates in conjunction with the worm. Simple indexing is employed when it is required to divide a circle into more number of parts than is possible by rapid indexing.

The gearing usually consists of worm on the index crank shaft which meshes with worm-wheel on the spindle. 40 turns of the index crank are required to rotate the index head spindle. In other word one complete turn of index crank will cause the spindle to make $\frac{1}{40}$ of a revolution. Like wise 5, 10 & 20

COMPOUND INDEXING

The compound indexing method is employed when the no. of divisions required is out-side the range that can be obtained by simple indexing.

The effective indexing movement will be the summation of two-movements.

The rule for compound indexing is given by the formula

$$\frac{40}{N_{\text{div}}} = \frac{n_1}{N_1} + \frac{n_2}{N_2}$$

where $N_{\text{div}} \rightarrow$ No. of divisions required.

$N_1 \rightarrow$ The hole of circle used by the crank

$n_1 \rightarrow$ The hole space moved by the crank in N_1 hole circle

$N_2 \rightarrow$ The hole circle used by the lock pin

$n_2 \rightarrow$ The hole spaces moved by the index plate & the crank in N_2 hole circle.

Differential Indexing:

Through compound indexing as explained is a convenient way to get any indexing required, it is fairly cumbersome to use in practice. It is used to index almost all numbers not obtainable by simple & compound indexing.

The change gear set available is: 24, 24, 28, 32, 40, 44, 48, 56, 64, 72, 86 & 100.

The following relation is used for calculating the necessary gears to be placed between the spindle & the worm shaft,

$$\text{Gear ratio} = \frac{\text{Driver.}}{\text{Driven.}}$$

$$= \frac{\text{Gear on spindle}}{\text{Gear on Index plate}}$$

$$(A - N_{\text{div}}) \times 40$$

$$\text{Gear ratio} = \frac{(A - N_{\text{div}}) \times 40}{A}$$

$$\text{Gear Moment} = \frac{40}{A}$$

To make sure that the calculations made for change gears & the crank movement are correct, apply the following crank.

(i) if $(A - N_{\text{div}})$ is positive, the solution will be

correct if

$$N_{\text{div}} = 40M - R \cdot M$$

(iii) If $(A - N_{div})$ is negative, the solution will be correct if

$$N_{div} = 40M + R \cdot M$$

where

N_{div} → No. of divisions to be indexed on the job.

$M \rightarrow \frac{\text{hole circle chosen}}{\text{No. of holes taken in the circle}}$

$R \rightarrow \frac{\text{Driver}}{\text{Driven}}$

Angular Indexing:

The angular indexing is the process of dividing the periphery of a work in angular measurements & not by the number of divisions. The crank the work will rotate through

$\frac{360}{40} = 9^\circ$. To find the index crank movement, divide the angle the angle by 9 if it is expressed in degrees, by 540 if it is expressed in minutes, & by 32,400 if it is expressed in seconds. The formula is

Index Crank-Movement

= $\frac{\text{Angular displacement of work in degrees}}{9}$

= Angular displacement of work in minute

540

60 * 60 = 3600

1440 - 1140 = 300

= Angular displacement of work in seconds

32,400

3600

32,400 / 3600 = 9

32,400 / 3600 = 9

32,400 / 3600 = 9

32,400 / 3600 = 9

32,400 / 3600 = 9

To calculate one of following undergoes at
Falling down when in the building site probably
different from the other because construction
work done in the same time.

Falling down in construction site is 20-30% of
falling down in the building site
in building site it is 10-15% of the total time 20%

falling down in the building site is 10-15% of the total time 20%

falling down in the building site is 10-15% of the total time 20%

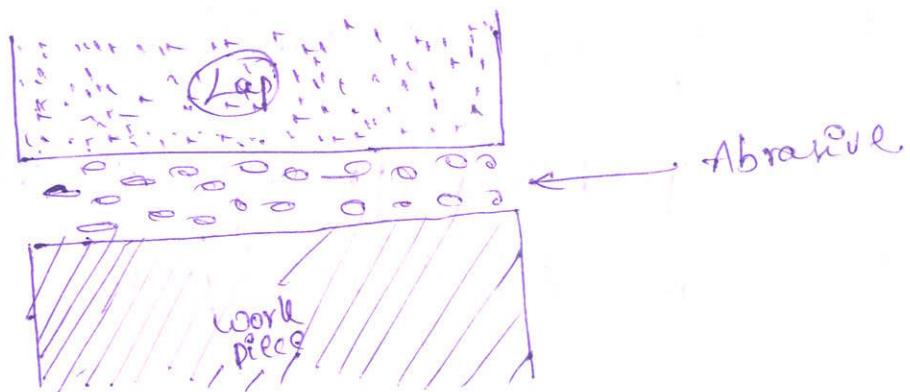
falling down in the building site is 10-15% of the total time 20%

* Lapping

Lapping is a finishing operation of producing an extremely accurate highly finished. Lapping is used to.

- produce geometrically true surfaces.
- correct minor surface imperfections.
- improve dimensional accuracy.
- provide a very close fit b/w two contact surfaces.

* Lapping is carried out by means of lapping shoes called laps. The laps are made up of soft cast iron, copper, brass, lead or soft steel. Chasing a lap means embedding the abrasive grain into its surface.



In machine lapping, the abrasives used may be bonded or loose abrasives or cloth or paper - packed abrasive belts. Three important types of lapping machines are in common use.

Vertical axis lapping Machine consists of two flat abrasive laps - upper and lower lap. Work holder holding a number of work pieces is fed to the two laps. Only the lower lap rotates and upper just floats over the work pieces. unit-3, pg:54/25

⑤ ~~Centre~~ Centreless Lapping Machine is used for lapping piston pins, shafts, valve supports and bearing races. The machine is actually a centre less grinding machine adopted for lapping round work pieces.

⑥ Abrasive belt Lapping machine is mostly used for lapping crank shaft, crank pin and cam etc. and employs an abrasive coated cloth belt.

→ In lapping, the quality of surface finish and extent of dimensional accuracy depends on the following factors.

i) Type of lapping medium or abrasive material.

ii) Type of lap material.

iii) Speed and pressure of lapping motion.

iv) material to be lapped.



HONING:

Honing is an abrading process used for finishing internal cylindrical such as drilled or bored holes of metallic and non-metallic surfaces.

Removed material by honing involves the use of a number of bonded abrasive stones called "hones".

Honing stones are formed by bonding abrasives like aluminium oxide or silicon carbide in nitrided or reinforced bond. Honing stones are loosely held on a mandrel or holders at regular interval surface. This action produces a cross hatched pattern. The stones can be adjusted radially for different hole sizes.

Honing is also done on external cylinder or flat surfaces and to remove sharp edges on cutting tools and inserts.

Honing is primarily used for

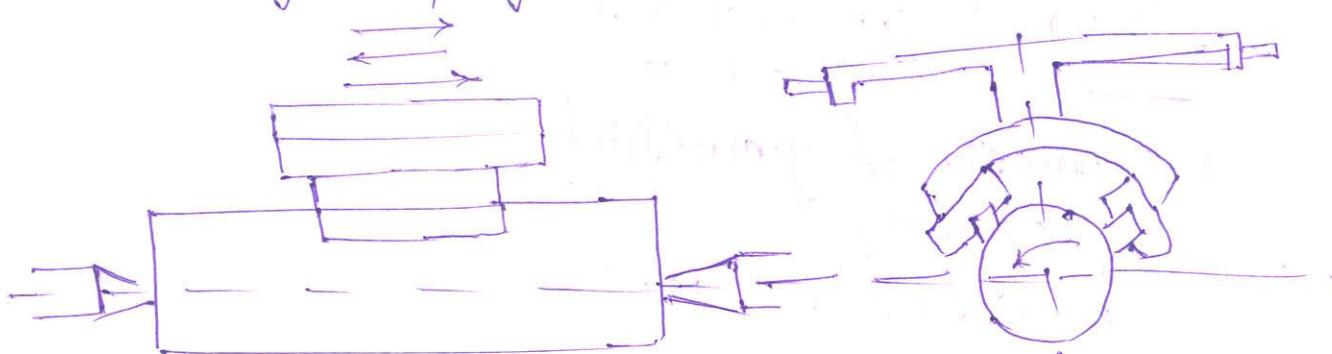
1. Correction of geometrical accuracy.
- * out of roundness.
- * Tapers.
- * axial distribution.
- d. Dimensional accuracy.

There are two general types of honing machines: horizontal and vertical. A honing machine rotates and reciprocates the hone inside holes being finished. Vertical honing machines are probably more common. Horizontal honing machines are often used for guns and large bores. The amount of metal removed in honing is usually less than 0.0125 mm.

Super Finishing

The super finishing is an abrading process, to produce an extremely high quality of surface finish in conjunction with an almost complete absence of defects in the surface layer using bonded abrasive stones. It is most commonly used for obtain a very fine surface finish.

In super finishing a very fine grit (grain size 400 to 600) abrasive stick is retained in a suitable holder and applied to the surface of the workpiece with a light spring pressure.



Finger shaft Superfinishing

The low tensile materials such as cast iron, aluminum, brass and brake lining materials.

Surface Coating methods

a part is mainly lacquered some of its surfaces may have to be processed further in order to acquire certain properties and characteristics, before the parts are processed further and are assembled. These methods are called "Surface coating methods". The following are the common process used for providing metallic coatings.

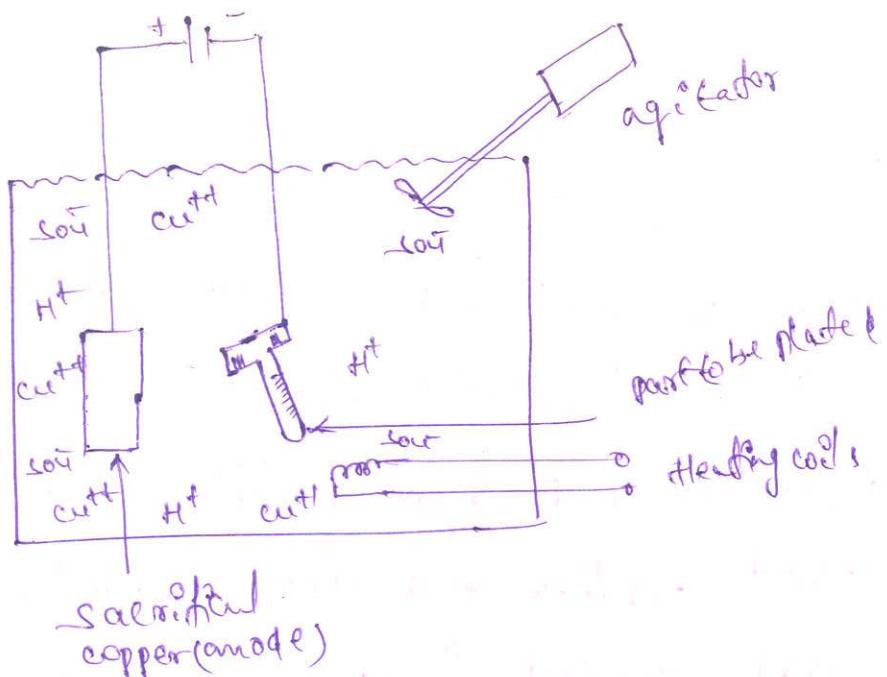
1. Electroplating,
2. Hot dipping → galvanizing, tin coating.
3. Anodizing
4. metal spraying → wire method,
→ powder method.
5. organic.

Electroplating

Electroplating is the most popular process of providing metallic coatings on the surface of metals and sometimes on non-metals by means of electrolysis.

In electroplating the work piece is plated with a different metal while both are suspended in a bath containing a water-bar electrolyte soln.

- * an electric current (dc) is passed through an electrolyte b/w the anode and cathode.
- * the metal ions from the anode are discharged using the potential energy from the dc supply - 3 pg: 58/25



→ hot dipping

Hot dipping is a rapid, inexpensive process which allows to form a coating on corrosion-resistant metals a base metal by dipping them in molten bath, at less cost than by electroplating. Al, lead, and zinc are the commonly used coating metals.

For the success of hot dipping it is necessary that,

- * the base metal i.e. the metal to be provided with the coating.
- * For the formation of a well adhering and uniform coating the surface of the base metal should be thoroughly cleaned.

1. galvanizing 2. washing 3. passivating.

~~Broaching~~ Broaching and Broaching Machines

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* Broaching :

- Broaching is a machining operation in which a tool, having a series of cutting teeth, is called broach.
- the broaching machine post the surface of a work piece.

* Types of broaching :

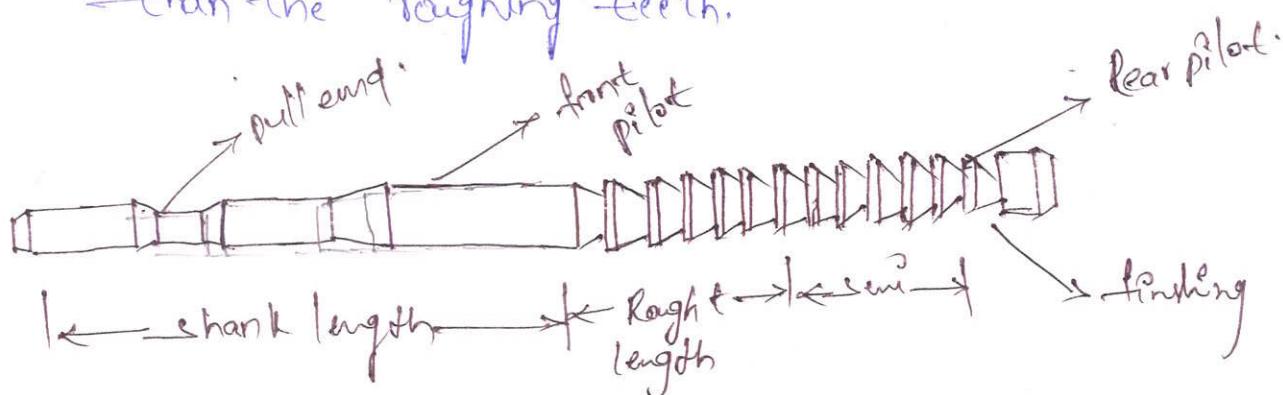
- there is a fairly large variety of broaches in use in industry, but all of them can be classified as follows.
 - 1) According to the method of operation — push, pull or stationary.
 2. Acc to the kind of operations they perform — internal and external.
 3. Acc to their construction — solid, built up, rotor cut, inserted both etc.
 4. Acc to their use — single purpose (or) combination
 5. Acc to the functions — keyway, spline, burnishing, reaming, lifting, serration, surface, etc.

* Details of broach construction :

- it illustrates the details of a pull type hole or internal broach for producing a cylindrical hole.
→ the puller grips the broach at the shank end.

The first set of cutting teeth, called roughing teeth does most of the cutting.

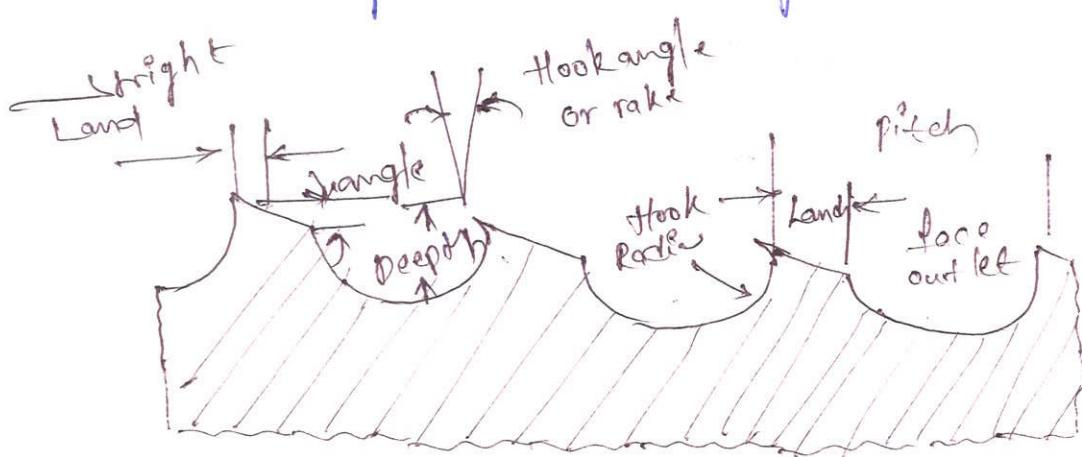
→ the variation in their sizes will obviously be smaller than the roughing teeth.



They bring the size of the hole to roughly the required size. The finishing teeth, which follow after the semi-finishing teeth, do not practically remove any appreciable amount of stock. When the first finishing teeth are worn out, those behind them start doing the finishing operation. The rear pilot supports the broach and keeps it aligned after the cut is over.

Elements of a Broach

Ans^o The principle elements of a common type of broach are following, as shown in figer.



1. pull end: that end of the pull broach, which contains shank. Is the pull end. The broaching machine's puller heads grips this end of the broach.
2. Front pilot: It guides the broach into the hole and keeps it concentric with the latter.
3. Rear pilot: its size and shape conforms to those of the finished hole and provides support to the broach after the cutting process is over.
4. Land: It is extreme top part of the tooth and is normally ground slightly to provide clearance.
5. Pitch: the linear distance measured b/w the cutting edge of one tooth and the corresponding point on the next tooth is called "pitch".
6. Cut per tooth: It corresponds to the depth of the gullet, which varies gradually from the first tooth near the shank to finishing teeth.
7. back of angle: It is also known as clearance angle and ground on the land to provide relief.
8. hook radius: It is the radius contained by the bottom of the gullet.

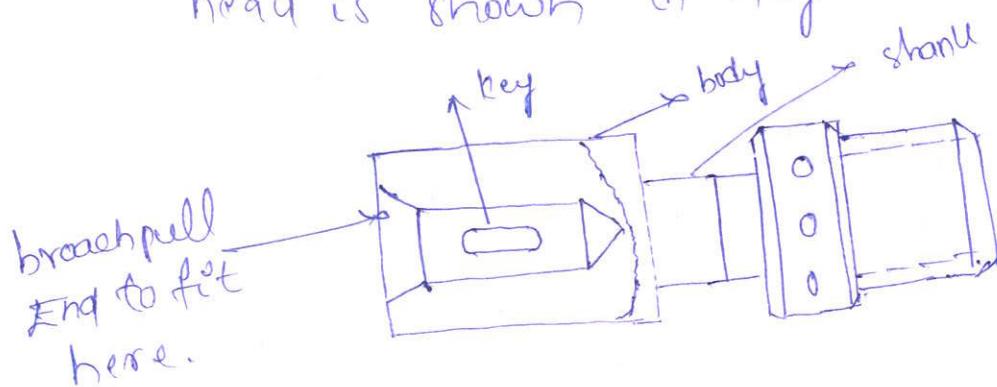
* Pulling heads

All pull type broaches, irrespective of the fact as to whether they are for external or internal broaching need a device to connect their pull end to the ram of the machine. This device is known as "pulling head".
→ They are 3 types of pulling head and commonly used.

1. Key type

It is a very simple design consisting of cylindrical body and threaded shank. The shank is fitted into the ram of the machine. The body carries a hole normal to the axis of the former, through which a key can be fitted.

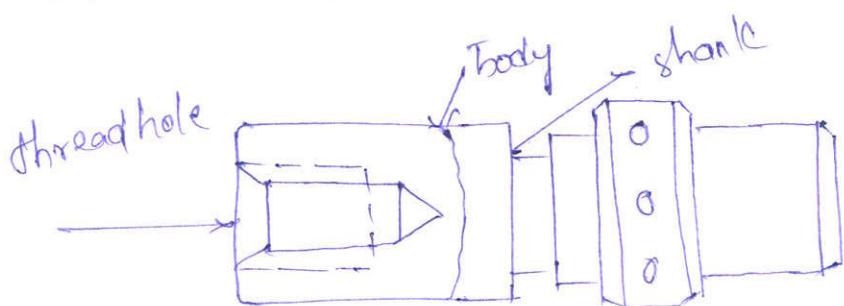
A simple design of this type of pulling head is shown in figure.



Threaded type:

Ans. It is another simple design of pulling head, consisting of a body and shank, quite similar to the former type, but the body instead of having a key hole carries a threaded hole.

If the pull end of the broach is provided with external threads and two are fastened together by means of screwing the threaded pull end into the threaded hole of the body, the shown in fig.



* Automatic type:

It is more popular and efficient type of pulling head, but it is also more complicated in design than the former two. In this body is provided with a sleeve outside and a collar at the rear end.

The pull end of the broach enters the slot of the body of the pulling head and the pins project on the shank of the pull end.

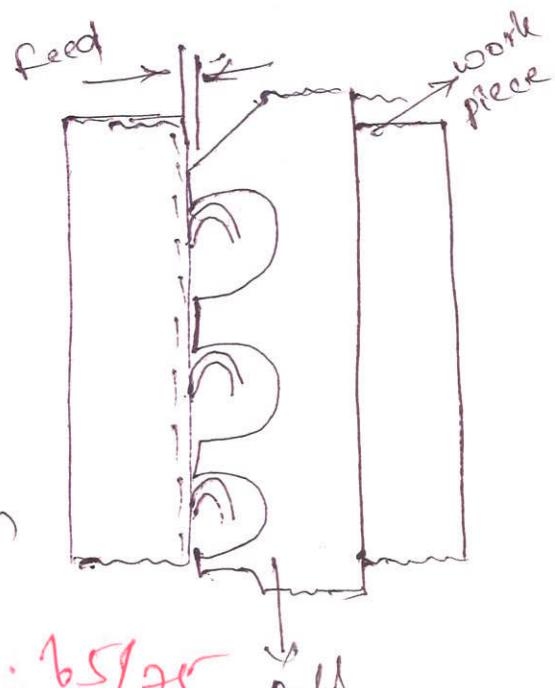
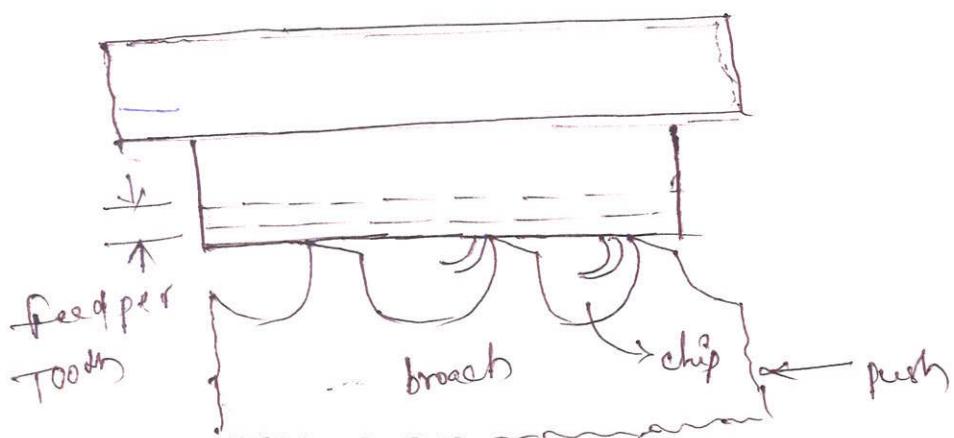
* Use of fixtures

Ans: Use of properly designed fixtures is more pronounced and almost an unavoidable feature in broaching. The workpiece always needs a proper supporting and clamping device. The following are the functions of all broaching fixture.

- to locate the work in correct position
- to support and hold work rigidly during the operations.
- to guide the broach during operation.
- to move the work piece in the correct position.

** Principle of Broaching

In the operation of broaching, it makes use of a multi-tooth cutter called broach. The teeth of the broach are so designed that the height of the cutting edge of the following cutting tooth is slightly more equal to the feed per tooth, than that of the preceding tooth.



4. Acc to the condition of movement of the tool relative to the work — moving or stationary broach.
 5. Acc to the type of drive — mechanical (or) hydraulic drive.
 6. Acc to the number of pull heads — single or multi pull head.
- brief description of construction and working of some common type of Broaching Machine are given in the following articles.

* Broaching Presses

Ans: The various type of presses have been developed which are used for Broaching. This is simple and lighted of all the presses used in broaching work and is manually operated. Shown in figer.

The usually carry a hydraulic Drive push type broaches are commonly used on the machine.

The machine are made in various different sizes ranging in capacity from 250 kg to 35 tonnes pressure.

The machine are generally available in the vertical type.

The work piece is placed on the machine table and the vertical ram of the machine.

the sum of thickness of all the layers taken together ~~is~~¹²² is called the depth of cut. During operation.

the surface produced carries an inverse profile so that the feed is equal to the chip thickness. This aspect is amply clear in the given diagram.

The figure shows a push type of broach being fed past the stationary work on a horizontal broaching machine.

The figure shows a pull type of broach being fed into a hollow work piece on a vertical pull-down type machine.

* Types of Broaching Machines

Ans: There are a number of different designs a variable of broaching machines in different sizes and capacities. The common type of broaching machine can be classified as follows.

1. Acc to the power employed : manually operated or power driven
2. Acc to the direction of broach movement in cutting - horizontal (or) vertical.
3. Acc to the method of cutting - pull and push or continuous.

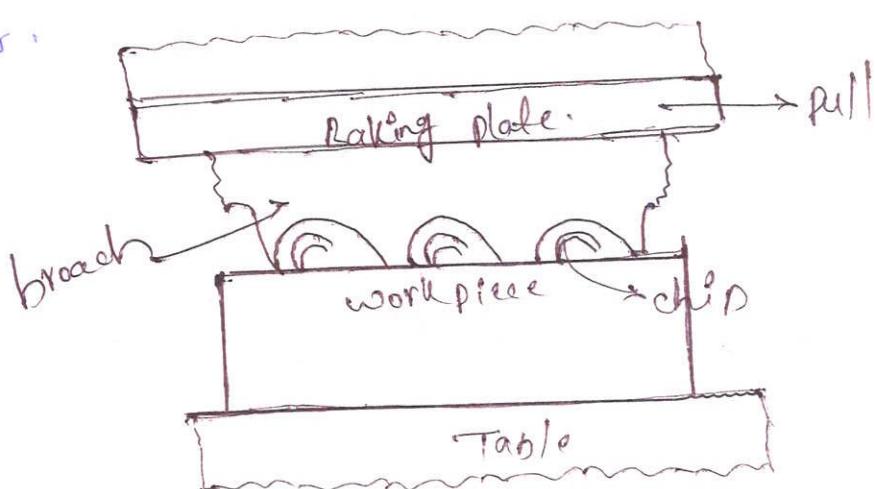
* Horizontal pull type broaching machine

Ans. The almost all the modern horizontal pull-type broaching machines carry a hydraulic drive for reasons of getting the required power and efficient driven. These machines are used both of internal as well as external broaching. The lathe and the broach moves like the tailstock on the bed ways.

These machines are manufactured in both fully automatic and semi-automatic type. In both the type automatic stops or limit switches are provided to control the length of the ram.

Principle of both surface broaching and internal broaching operations, as performed on a horizontal pull-type broaching machine, are shown in the figure.

Figure:



* Vertical broaching machine

Ans. Vertical broaching machine using the method of pull-broaching are two types:-

1. Pull down type.
2. Pull up type (unit-4, pg 68) 25

→ pull down type

The pull down type machine carries an elevator at the top from which the broaches are suspended in an upside down position. The work piece is mounted over the table and broach lowered to pass it front pilot through the work. The principle of internal broaching is shown in fig.

→ pull up type

The pull up type machine is ram is provided at the top which carries the pulling heads at bottom. The elevators are provided inside the bed to hold the broach in vertical position.

The rear ends of broaches are grown gripped by the elevators and the form is brought back to the starting position.

* Duplex - Head broaching machine

Ans: These machines carry two rams instead of one. They are made in both horizontal type as well as vertical type. These machines generally used push method of broaching and are commonly employed and vice-versa. For external or surface broaching, same thing happens in case of loading and unloading of jobs that while one fixture is being unloaded and reloaded with fresh job the other is holding the other job in operation and vice-versa.

* Continuous broaching Machine 124

Ans. These machines are manufacture in both horizontal as well as vertical type. Horizontal machine mainly differs from other types of machines in that the broach remains stationary while the work piece move continuously past it to perform the cutting.

→ A series of fixtures are mounted on this chain to travel along with it. The broache are rigidly held at the machine in a horizontal position over the chain.

→ The principle of operation of this type of machine is shown in figure. The vertical type carries a number of planfens and continuous chain.

→ The broaches are moved and the work remaining stationary. The another used type of continuous broaching machine is the rotary table horizontal continuous broaching machine. In this machine, a rotary type of table is provided which continuously rotates about vertical axis. The broach held rigidly in the broach holder above the table.

* Machine Size

Ans: The size of a broaching machine is given by the length of stroke of ram in millimetres and the pressure on the broach in kilograms or tonnes.

* Range of speeds and feeds.

* Type of driven.

* Power rating of electrical motor.

* Methods of Broaching

Ans: Different broaching methods can be broadly classified as follows.

1. Internal or hole broaching: In this normally the work remains stationary and the broach is either pushed or pulled through the same to produce a hole of desired shape and size.

2. External Surface of broaching: In this either the work or the broach is moved past the other to produce a groove or surface of desired shape and size on the external surface of the work.

3. Pull broaching: mostly adopted for internal broaching. In this, the work remains stationary and the broach is pulled through the same to produce the hole of desired shape and size.

4. Push broaching: Adopted mostly for internal broaching of relatively job. the workpiece is stationary and the broach is pushed through the same.

Q. continuous Broaching? It is a method suitable

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and largely adopted for broaching of identical components on large scale, while the work pieces move continuously past the same along a horizontal or circular path.

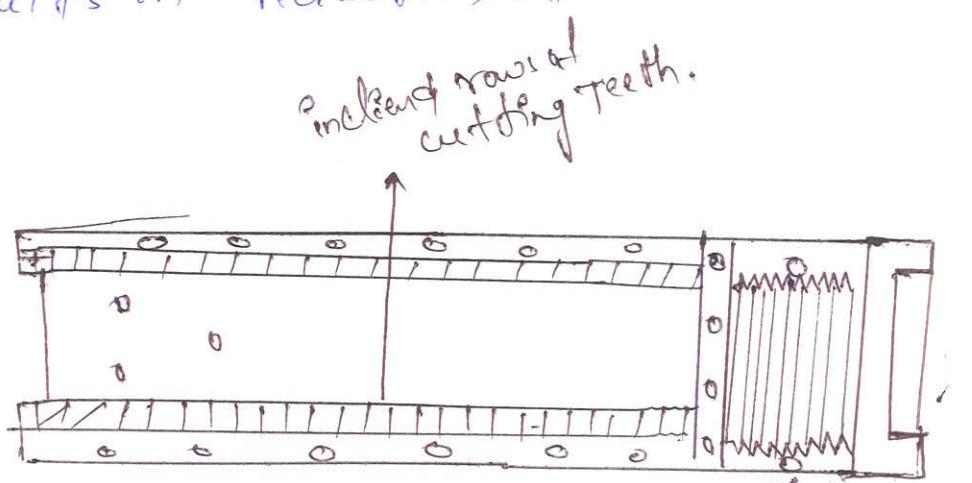
* Progressive broaching

Ans It is a surface broaching operation used mainly for broaching wide flat surfaces and hard skin.

It employs the use of a special type of broach is called "progressive broach" as shown in fig.

In this broach, the cutting teeth are arranged in a staggered fashion. The first few parallel teeth perform the main cutting operation centrally.

These teeth progressively machine the remaining surface of the work piece. The complete operation of course is completed in a single pass as usual but such an arrangement of cutting teeth results in reduction of tooth loads.



Teeth of
general cutting.

unit-3, Pg: 72/75

* Tooth Load on a broach

calculation of the load on a broach helps in ascertaining whether the broach will stand during the operation or fail. If the broach is strong enough is strong enough to bear this load on its weakest section, it is considered suitable. The machine for pulling or pushing the broach. This load (F) is calculated as follows.

$$F = \pi d \cdot T \cdot f \cdot p$$

where

d = diameter of machine hole.

T = Total number of feeds cutting at time.

f = Rise per tooth.

p = force required to cut 1 mm^2 of metal at the given rise/ tooth.

$$F = \pi d \cdot T \cdot f \cdot p$$

L = machine length of one side of the square hole.

* Broaching speed

Ansⁿ Broaching operation employs relatively lower cutting speed. Selection of proper speed for broaching a part of component will be governed by the following factors.

* Hardness of work piece material.

* Length of broaching

* Type of material to be broached.

* Rigidity of the component to be broached.

* Economics considerations for the broached.

material	cutting speed m/min.	material	cutting speed m/min.
carbon steel	3-8	Free machining steel	10-12
cast iron	6-30	magnesium alloys	10-18
copper alloys	8-16	Aluminum alloys	10-20

* Machining Time \rightarrow

Ans: In broaching operation the machining time depends on the effective length of broach.
i.e. length of tooth system of the broach.

$$\text{Machine time} = \frac{\text{Effective length of broach in meter}}{\text{cutting speed in m/min.}}$$

$$= \frac{\text{Effective length in mm}}{100 \times \text{cutting speed in m/min.}}$$

* Broaching Versus Other Machining Operations \rightarrow

Ans: The work that is done by broaching can also be done by machining operation, as such it is necessary to compare its merits and demerits with other operations.

Merits: * Broaching is faster than other machine operation.

* It enables a higher rate of production with more accuracy and better finish in comparison to other operation.

* Owing to the above reason, the tool cost per work piece is low. Unit-3, Pg: 74/75

- * a single tool above performs both roughing and finishing operation.
- * cutting fluid can be applied more easily and effectively than in other operation.

Demerits → * broach is a single purpose tool that can produce only one type of surface.

- * the initial cost of a broach is very high as compared to other tools.
- * the broaching machine if set is probably the most costly of all the machine tools.
- * surfaces which lie in separate planes cannot be machined in single setting of job.
- * blind holes cannot be easily produced through the broaching.