MILLING MACHINE

INTRODUCTION

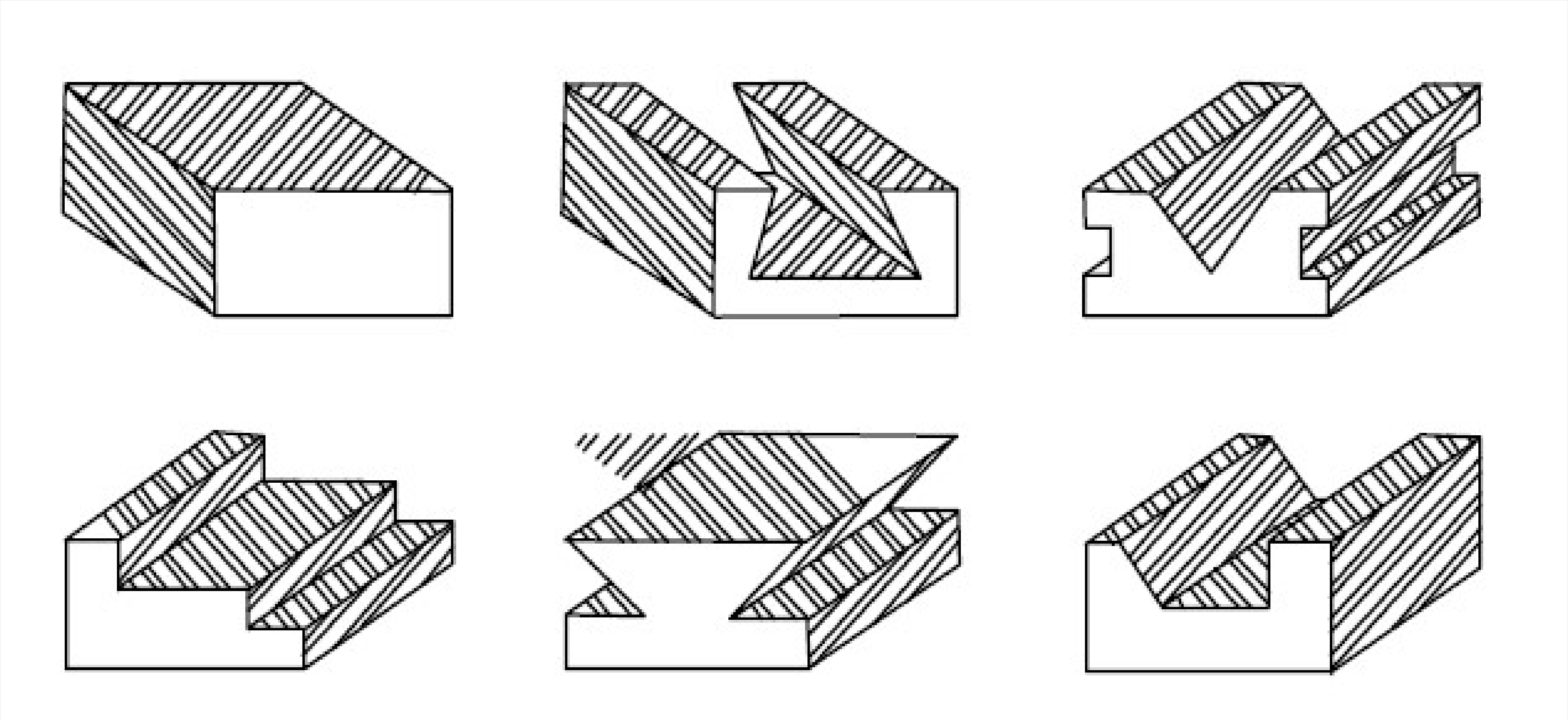
- A milling machine is a machine tool that removes metal as the work is fed against a rotating multipoint cutter.

- The milling cutter rotates at high speed and it removes metal at a very fast rate with the help of multiple cutting edges. One or more number of cutters can be mounted simultaneously on the arbor of milling machine.

- Milling machine is used for machining flat surfaces, contoured surfaces, surfaces of revolution, external and internal threads, and also used for drilling, slotting, making a circular profile, gear cutting or helical milling with good surface finish and accuracy.

- Typical components produced by a milling are given in Fig.

INTRODUCTION



Job surfaces generated by milling machine

PRINCIPLE OF MILLING

- In milling machine, the metal is cut by means of a rotating cutter having multiple cutting edges.
- For cutting operation, the workpiece is fed against the rotary cutter. As the workpiece moves against the cutting edges of milling cutter, metal is removed in form chips of trochoid shape.
- Machined surface is formed in one or more passes of the work. The work to be machined is held in a vice, a rotary table, a three jaw chuck, an index head, between centers, in a special fixture or bolted to machine table.
- The rotary speed of the cutting tool and the feed rate of the workpiece depend upon the type of material being machined

Milling Process

•Cutting action is carried out by feeding the workpiece against the rotating cutter. Thus, the spindle speed, the table feed, the depth of cut, and the rotating direction of the cutter become the main parameters of the process. Good results can only be achieved with a well balanced settings of these parameters.

Spindle Speed

•Spindle speed in revolution per minute (R.P.M.) for the cutter can be calculated from the equation

$$N = \frac{CS \times 1000}{\pi d}$$

:- where --

N = R.P.M. of the cutter,

CS = Linear Cutting Speed of the material in m/min.

d = Diameter of cutter in mm

Milling Process

Feed Rate

Feed rate (F) is defined as the rate of travel of the workpiece in mm/min. But most tool suppliers recommend it as the movement per tooth of the cutter (f). Thus,

$$F = f \cdot u \cdot N$$

Where , F = table feed in mm/min, f = movement per tooth of cutter in mm, u = number of teeth of cutter N = R.P.M. of the cutter where,

C.S. and feed rate for some common material :- Tool

Tool Material	High Speed Steel		Carbide	
Material	Cutting Speed	Feed (f)	Cutting Speed	Feed (f)
Mild Steel	25	0.08	100	0.15
Aluminium	100	0.15	500	0.3
Hardened Steel	---	---	50	0.1

Milling Process

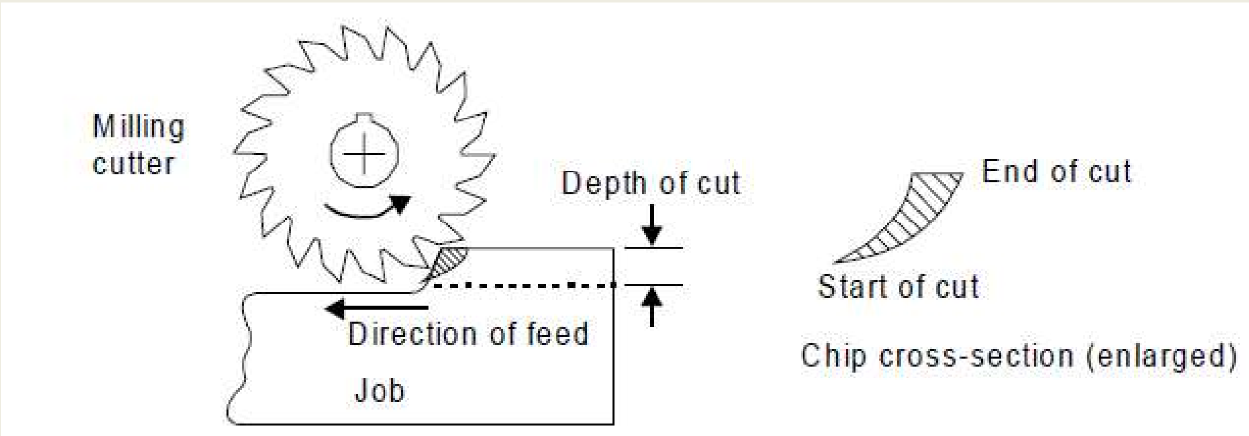
Depth of Cut

- Depth of cut is directly related to the efficiency of the cutting process. The deeper the cut the faster will be the production rate. Yet, it still depends on the strength of the cutter and the material to be cut.
- For a certain type of cutter, a typical range of cut will be recommended by the supplier. Nevertheless, it should be noted that a finer cut is usually associated with a better surface finish as well as a long tool life.

MILLING METHOD

- UP MILLING (Conventional milling)
- DOWN MILLING (Climb milling)

UP MILLING (Conventional milling)



•Cutter rotating against the direction of feed of the workpiece.

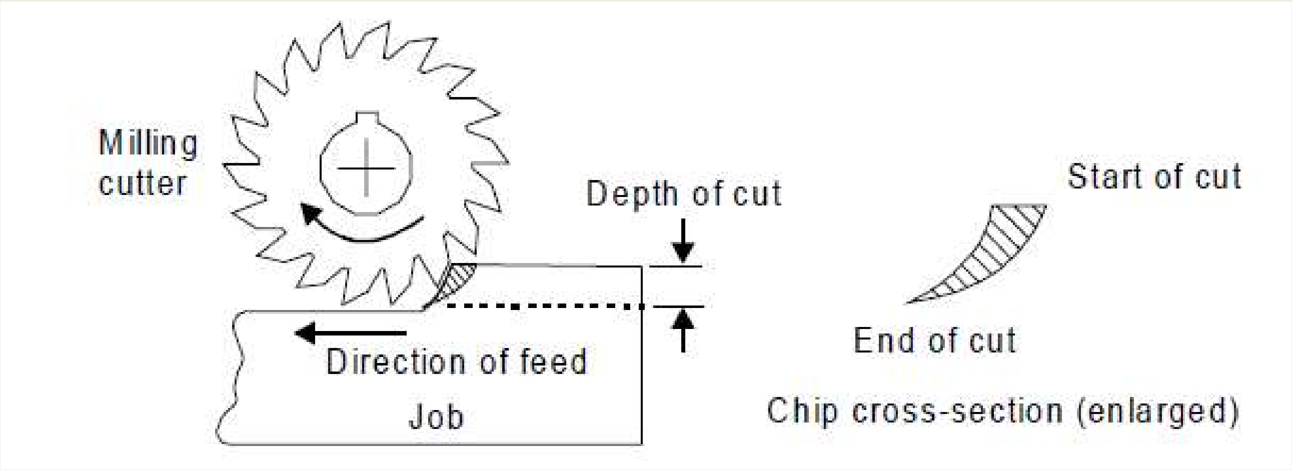
•Needs stronger holding of the job.

•Chip thickness is minimum at the start of the cut and maximum at the end of the cut.

❖ **Disadvantages**:-

- Tendency of the cutting force to lift the work from the fixtures.
- Poor surface finish obtained.

DOWN MILLING (Climb milling)



- Cutter rotating in the same direction of feed of the workpiece.
- Chip thickness is maximum at the start of the cut and minimum in the end.
- Cutting is more efficient, tool life is more and better surface finish is possible.
- less friction involved and consequently less heat is generated on the contact surface of the cutter and workpiece.

DOWN MILLING (Climb milling)

Advantage:

- Increased tool life (up to 50%)
  - -Chips pile up behind or to left of cutter
- Less costly fixtures required
  - -Forces workpiece down so simpler holding devices required
- Improved surface finishes
  - -Chips less likely to be carried into workpiece
- Lower power requirements
  - -Cutter with higher rake angle can be used so approximately 20% less power required

Disadvantage:

- Cannot be used for machining castings or hot-rolled steel
  - -Hard outer scale will damage cutter

CLASSIFICATION OF MILLING MACHINES

- Column and knee type milling machines
- Fixed bed type milling machines
- Planer type milling machines
- Special purpose milling machines

Column and Knee Type Milling Machine

- It is the most commonly used milling machine for general shop work.
- In this type of milling machine, the table is mounted on the knee casting which in turn is mounted on the vertical slides of the main column. The knee is vertically adjustable on the column so that the table can be moved up and down to accommodate work of various heights.
- The column and knee type milling machines are classified on the basis of various methods of supplying power to the table, different movements of the table and different axis of rotation of the main spindle.
- Column and knee type milling machine comprises of the following important parts-

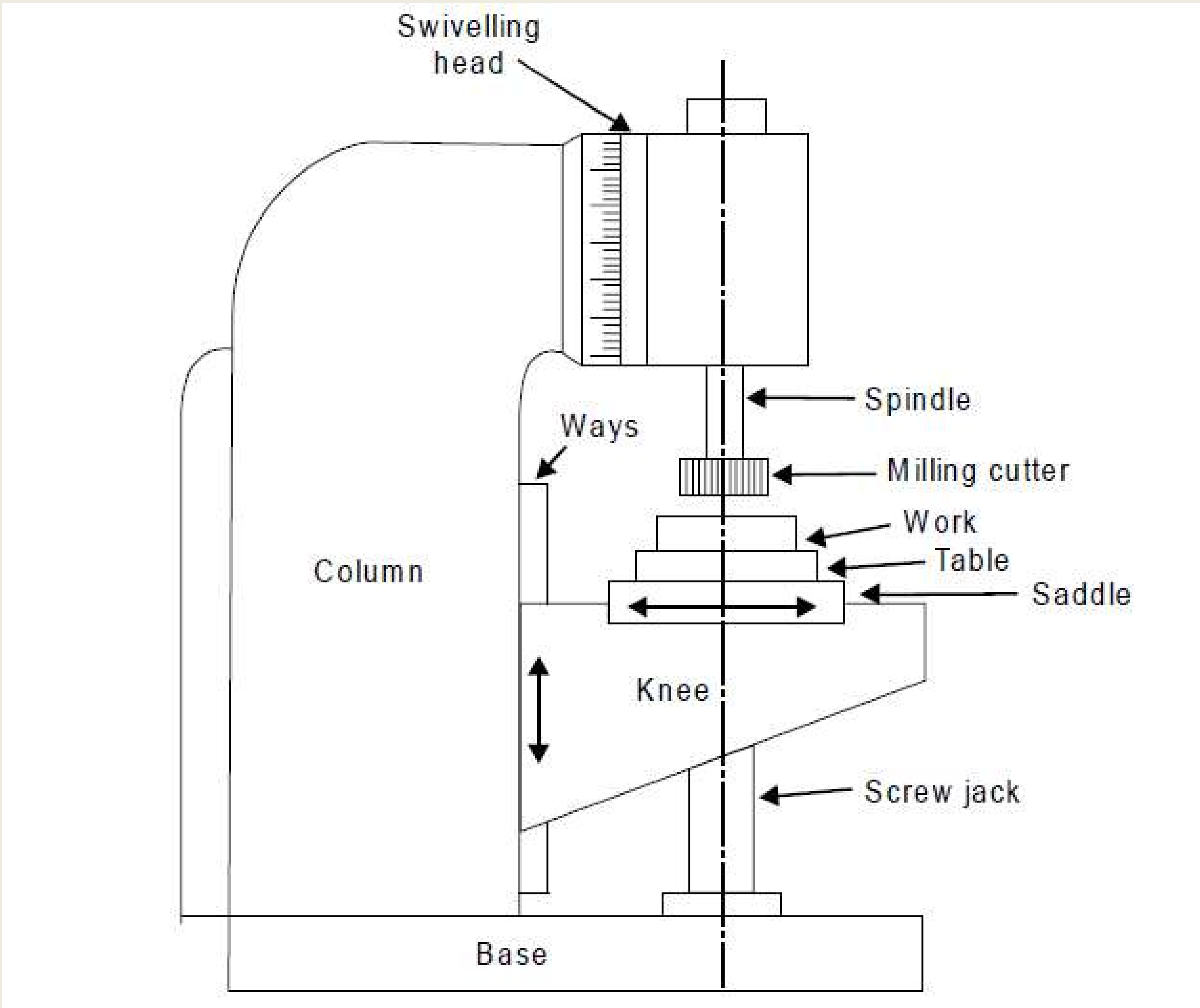
1. Base 2. Column 3. Saddle 4. Table

5. Elevating screw 6. Knee 7. Knee elevating handle 8. Cross feed handle

9. Front brace 10. Arbor support 11. Arbor 12. Overhanging arm

13. Cutter 14. Cone pulley 15. Telescopic feed shaft.

Column and Knee Type Milling Machine



column and knee type milling machine

Column and Knee Type Milling Machine

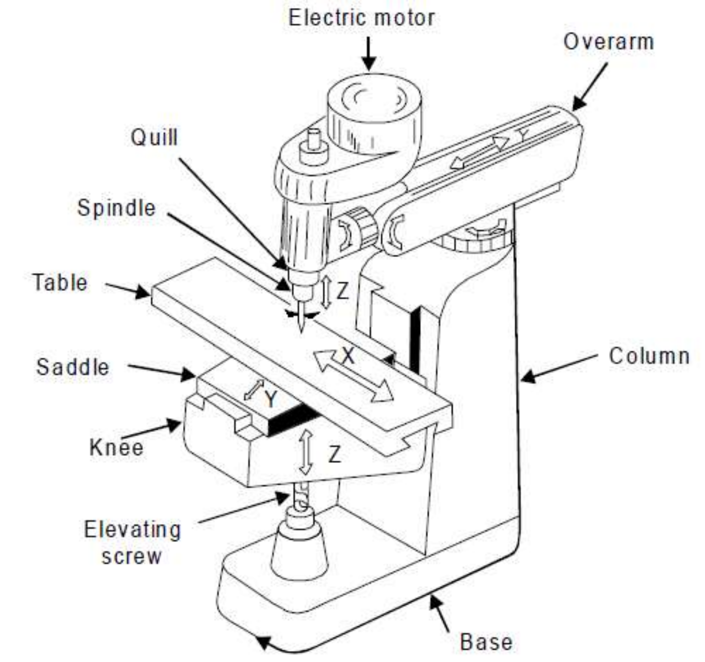
Column and knee type milling machines types

(a) Hand milling machine

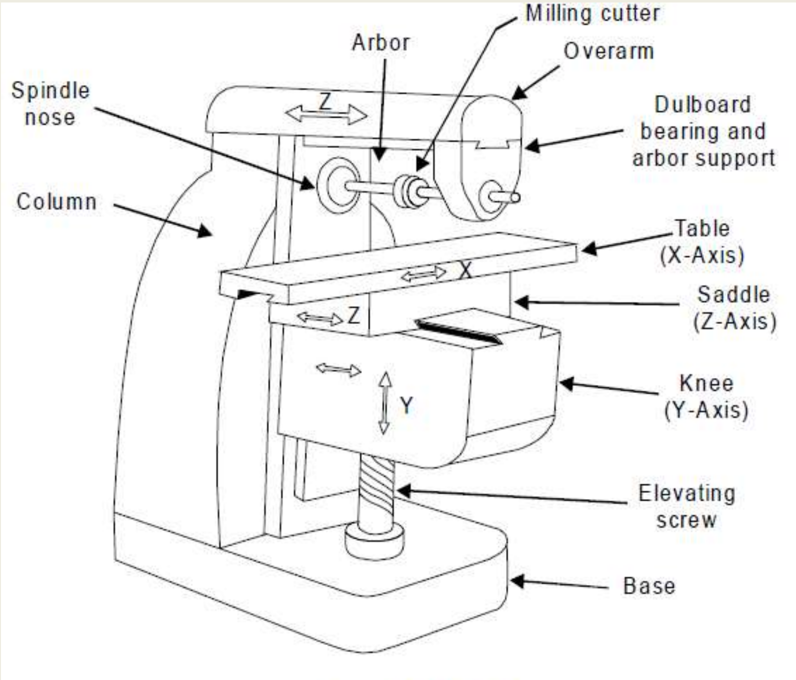
(b) Horizontal milling machine (Fig. 4)

(c) Vertical milling machine (Fig. 5)

(d) Universal milling machine



Horizontal Milling Machine



Vertical Milling Machine

Column and Knee Type Milling Machine

DIFFERENCES BETWEEN HORIZONTAL & VERTICAL MILLING MACHINES

SL. NO.	HORIZONTAL MILLING MACHINE	VERTICAL MILLING MACHINE
01	Spindle is horizontal & parallel to the worktable.	Spindle is vertical & perpendicular to the worktable.
02	Cutter cannot be moved up & down.	Cutter can be moved up & down.
03	Cutter is mounted on the arbor.	Cutter is directly mounted on the spindle.
04	Spindle cannot be tilted.	Spindle can be tilted for angular cutting.
05	Operations such as plain milling, gear cutting, form milling, straddle milling, gang milling etc., can be performed.	Operations such as slot milling, T-slot milling, angular milling, flat milling etc., can be performed and also drilling, boring and reaming can be carried out.

Column and Knee Type Milling Machine

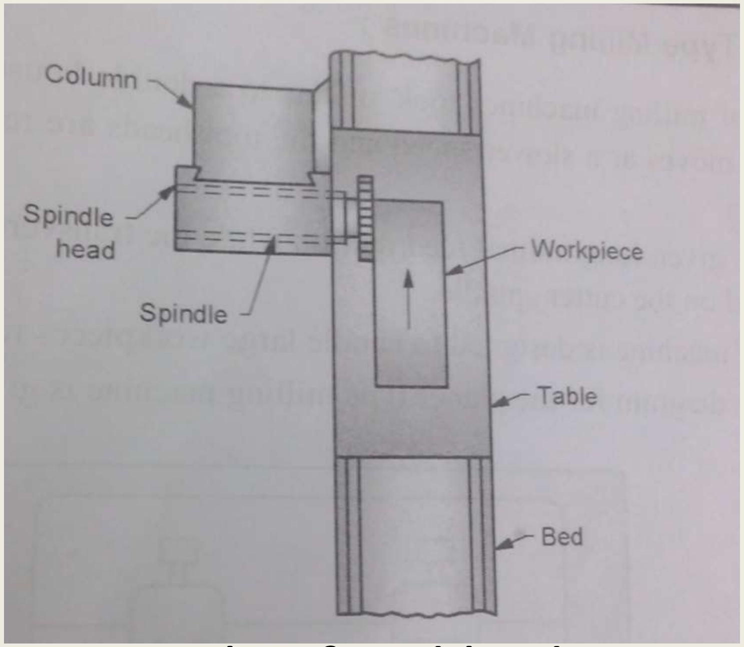
Universal milling machine

- The basic difference between a universal horizontal milling machine and a plain horizontal milling machine is the addition of a table swivel housing between the table and the saddle of the universal machine.
- This permits the table to swing up to 45° in either direction for angular and helical milling operations.

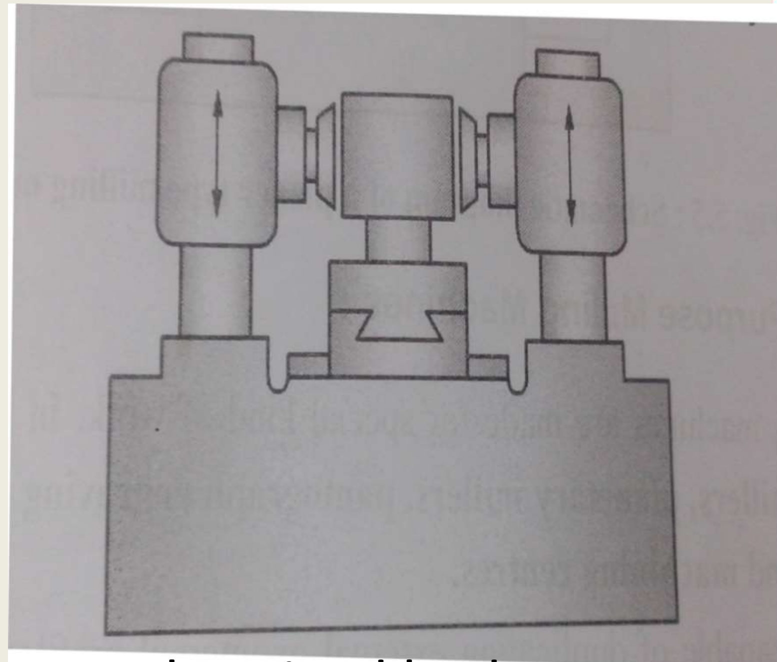
Fixed bed type milling machines

- Used for heavy cuts.
- The work table has only a longitudinal motion.
- The vertical motion is imparted to the spindle head instead of table.
- These machines are available as simplex, duplex or triplex.
- The Simplex Bed type has only one spindle head.
- The spindle head can be adjusted up and down on the column.
- After adjustment the spindle and spindle head they clamped in position for operation.
- The feed is then given to the table.
- A duplex fixed bed type machine has two opposed spindle on two columns, one on each side of the bed, so that both can operate simultaneously.
- A triplex machine has three spindle.

Fixed bed type milling machines



Simplex fixed bed type



Duplex Fixed bed type

Advantages and limitation :-

• Fixed bed type machines are designed to remove metal rapidly and to require minimum of attention from the operator.

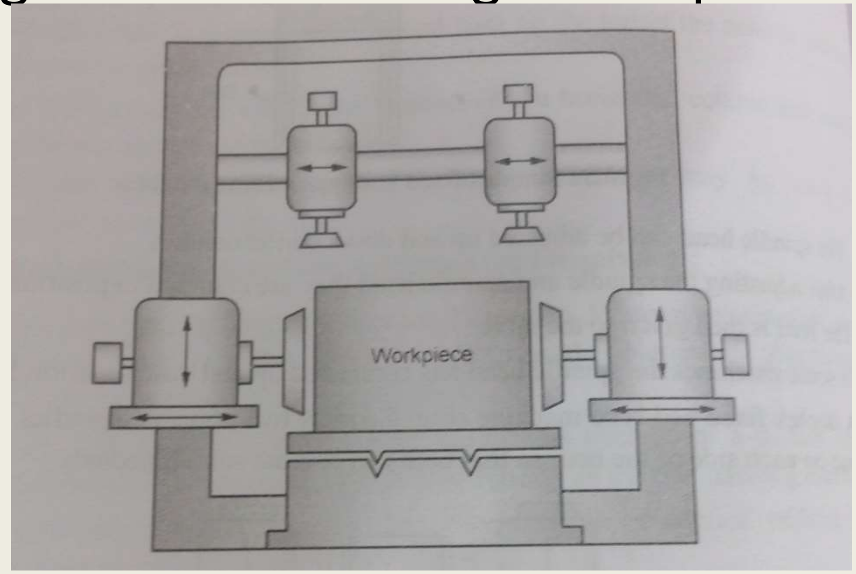
•Not as easy to adapt to various jobs as general purpose machines but are very useful for long run jobs where set up changes are not frequent and special fixtures are justified for holding the jobs.

Planer type milling machines

•This type of milling machines look similar to a double housing planer except that the table in this case moves at a slower speed and the tool heads are replaced by spindle carriers for rotating cutters.

•The work is given longitudinal feed motion while the transverse and vertical movements are provided on the cutter spindle.

•Designed to handle large work pieces requiring multiple cuts.



Special Purpose Milling Machines

- Used for special kind of work.
  - Profilers
  - Duplicators
  - Cam millers
  - Planetary millers
  - Pantograph engraving machines
  - Rotary table milling machines
  - Milling centre
- Profilers are capable of duplicating external or internal profiles.
- Duplicators produce forms in three dimensions.
- Cam millers produce disc cams.

SIZE OF MILLING MACHINE

The size of the column and knee type milling machine is specified by

(1) The dimensions of the working surface of the table, and

(2) Its maximum length of longitudinal, cross and vertical travel of the table.

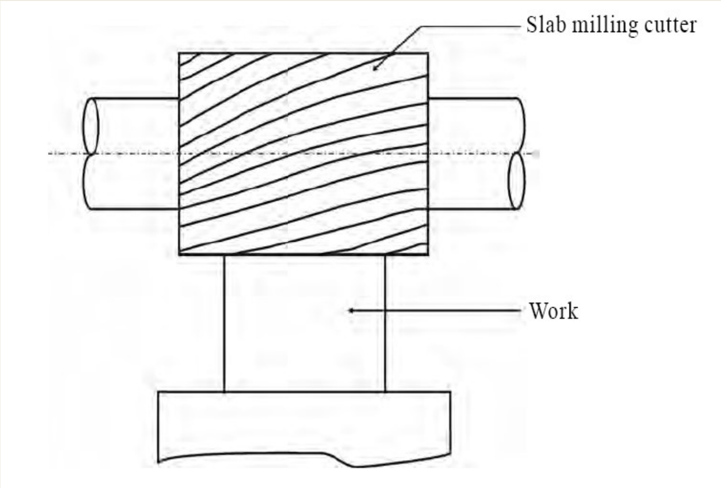
In addition to above, number of spindle speeds, number of feeds, spindle nose taper, power available, floor space required and net weight of machine will also be required for additional specification.

Milling machine operations

1. Plain milling
2. Face milling
3. Side milling
4. Straddle milling
5. Angular milling
6. Gang milling
7. Form milling
8. End milling
9. Keyway milling
10. Drilling & reaming
11. Boring
12. Gear cutting
13. Flute milling
14. Cam milling
15. Thread milling

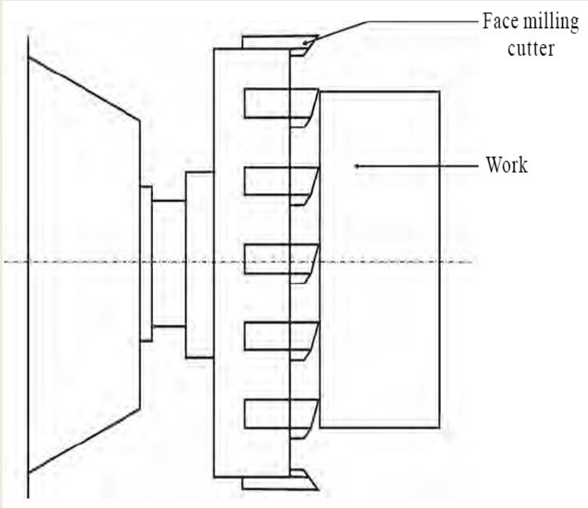
Milling machine operations

Plain milling



- It is the operation of production of a flat surface parallel to the axis of rotation of the cutter.
- It is also called as slab milling.
- Plain milling cutters or slab milling cutters are used to perform this operation.

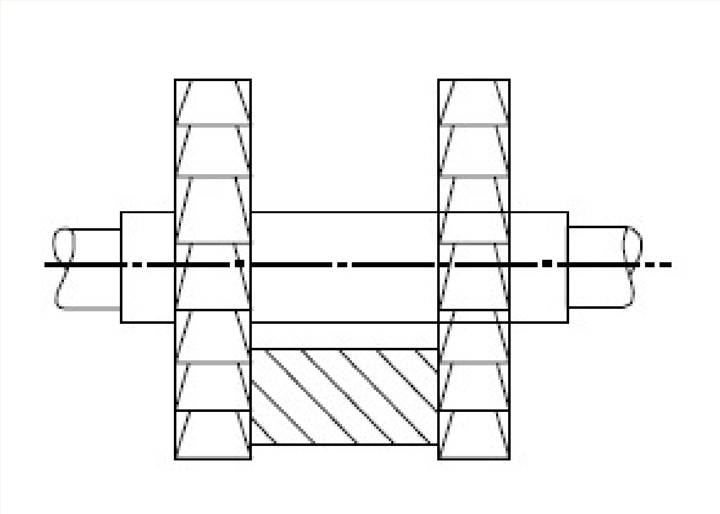
Face milling



- The face milling is the operation performed by the face milling cutter rotated about an axis at right angles to the work surface.
- The depth of cut is provided to the table.

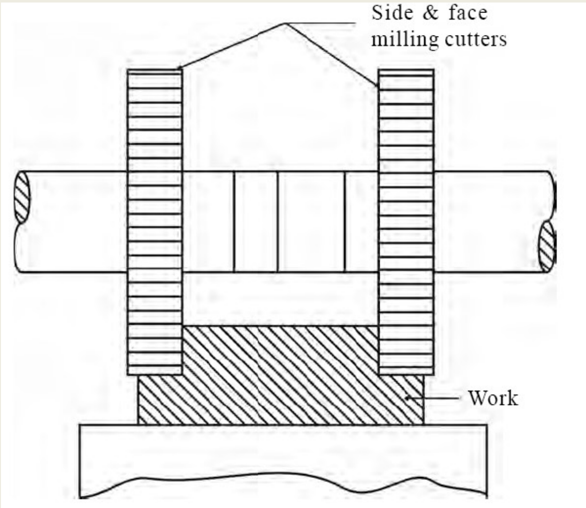
Milling machine operations

Side milling



•Side milling is the operation of machining a vertical surface on the side of a work piece by using a side milling cutter.

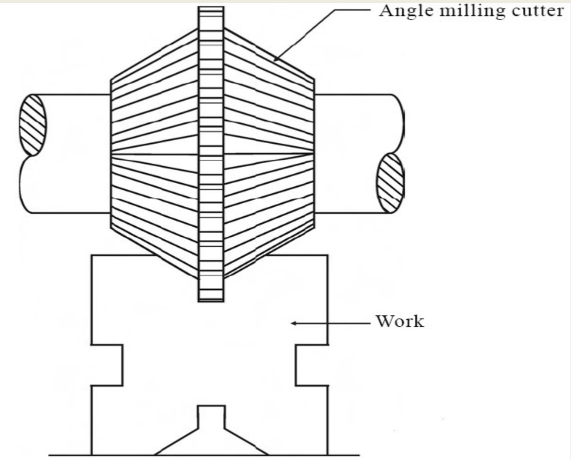
Straddle milling



- It is the operation of production of two vertical surfaces on both sides of the work by two side milling cutters mounted on the same arbor.
- Distance between the two cutters is adjustable.
- Commonly used to produce square or hexagonal surfaces.

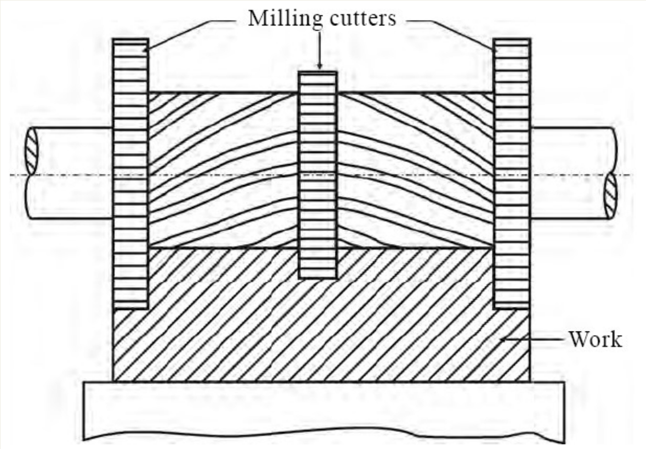
Milling machine operations

Angular milling



- Production of an angular surface on a work piece other than at right angles to the axis of the milling machine spindle is known as angular milling.
- Example of angular milling is the production of the 'V' blocks.

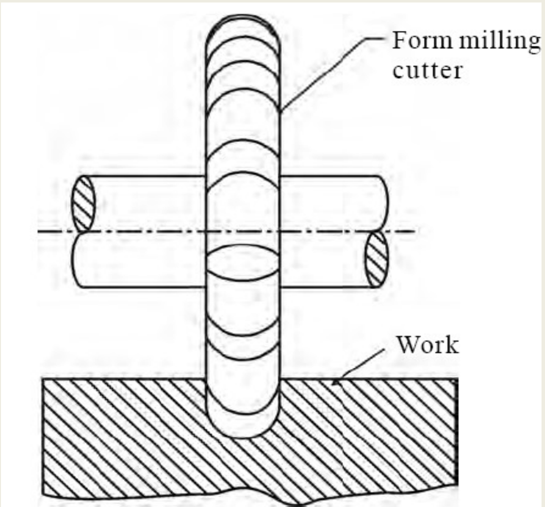
Gang milling



- It is the operation of machining several surfaces of work simultaneously by feeding the table against a number of cutters (either of same type or of different type) mounted on the arbor of the machine.
- This method saves much of machining time
- Mostly used in production work.

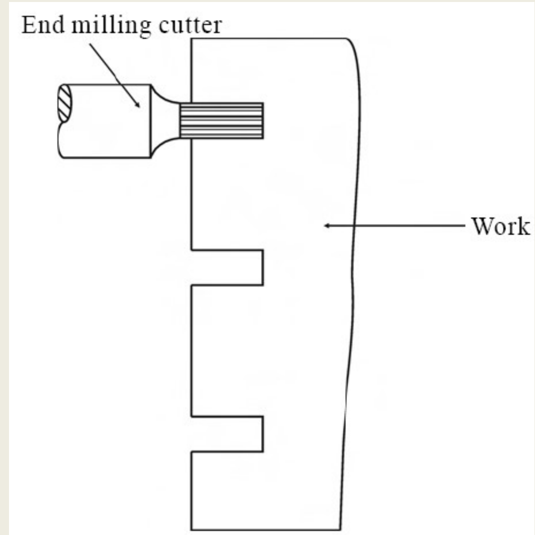
Milling machine operations

Form milling



- The form milling is the operation of production of irregular contours by using form cutters.
- Machining convex and concave surfaces and gear cutting are some examples of form milling.

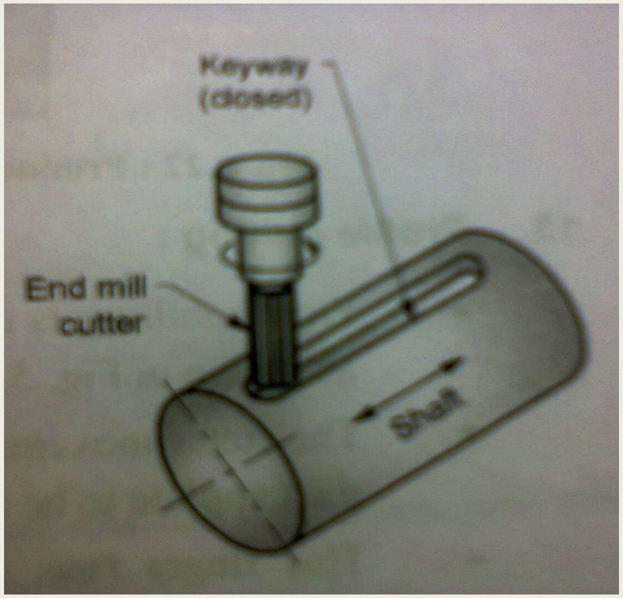
End milling



- It is the operation of producing a flat surface which may be vertical, horizontal or at an angle to the table surface.
- The end milling is performed by a cutter known as an end mill.
- End milling is mostly performed in a vertical milling machine.

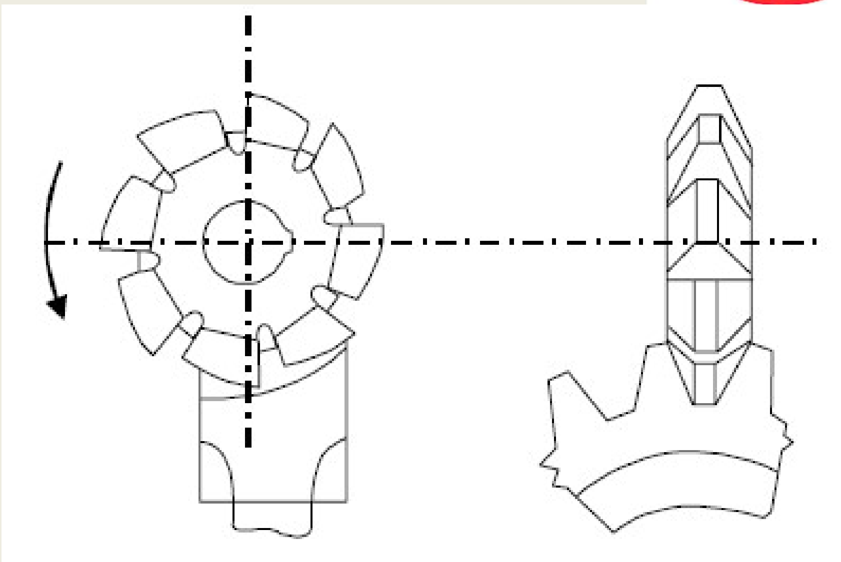
Milling machine operations

Keyway milling



- The operation of production of keyways, grooves and slots of different shapes and sizes can be performed in a milling machine by using a plain milling cutter, a metal slitting saw, an end mill or by a side milling cutter.

Gear cutting



- Gear cutting operation is performed in a milling machine by using a form cutter.
- The work is held between centers on a universal dividing head.

Milling machine operations

Drilling and reaming

- The operation of drilling and reaming are performed in a milling machine by mounting drills and reamers into the spindle of the machine.

Boring

- A single point cutting tool is mounted on the arbor to perform boring.
- By adjusting the single point cutting tool radially, different diameters of bores are machined.

Flute milling

- Flute milling is performed by selecting a suitable cutter in a milling machine.
- The flutes found on the drills, reamers and taps are machined by this method.

Milling machine operations

Cam milling

- Cam milling is the operation of producing cams in a milling machine with the use of a universal dividing head and a vertical milling attachment.
- It is performed by end mills on the cam blank.

Thread milling

- It is a method of milling threads on dies, screws, worms, etc. both internally and externally.
- As an alternative to the screw cutting in a lathe, this method is being more extensively introduced now a day in modern machine shops.

Milling Cutters

Milling cutters can be classified according to the:-

1) Method of mounting
2) Shape
3) Method used in grinding the teeth
4) Material
5) Construction

Milling Cutters

Method of mounting the cutters

❑**Arbor mounting cutter:**

• Have a central hole which closely fits the arbor of the machine.

•Collars and cutters are secured on the arbor with the help of the tightening nut.

❑**Shank-Mounting cutters:**

•Cutters of this type have either a straight or taper shank integral with the body of the cutter.

•Mounted on the spindle.

•If shank do not fit the spindle nose, adapters are available.

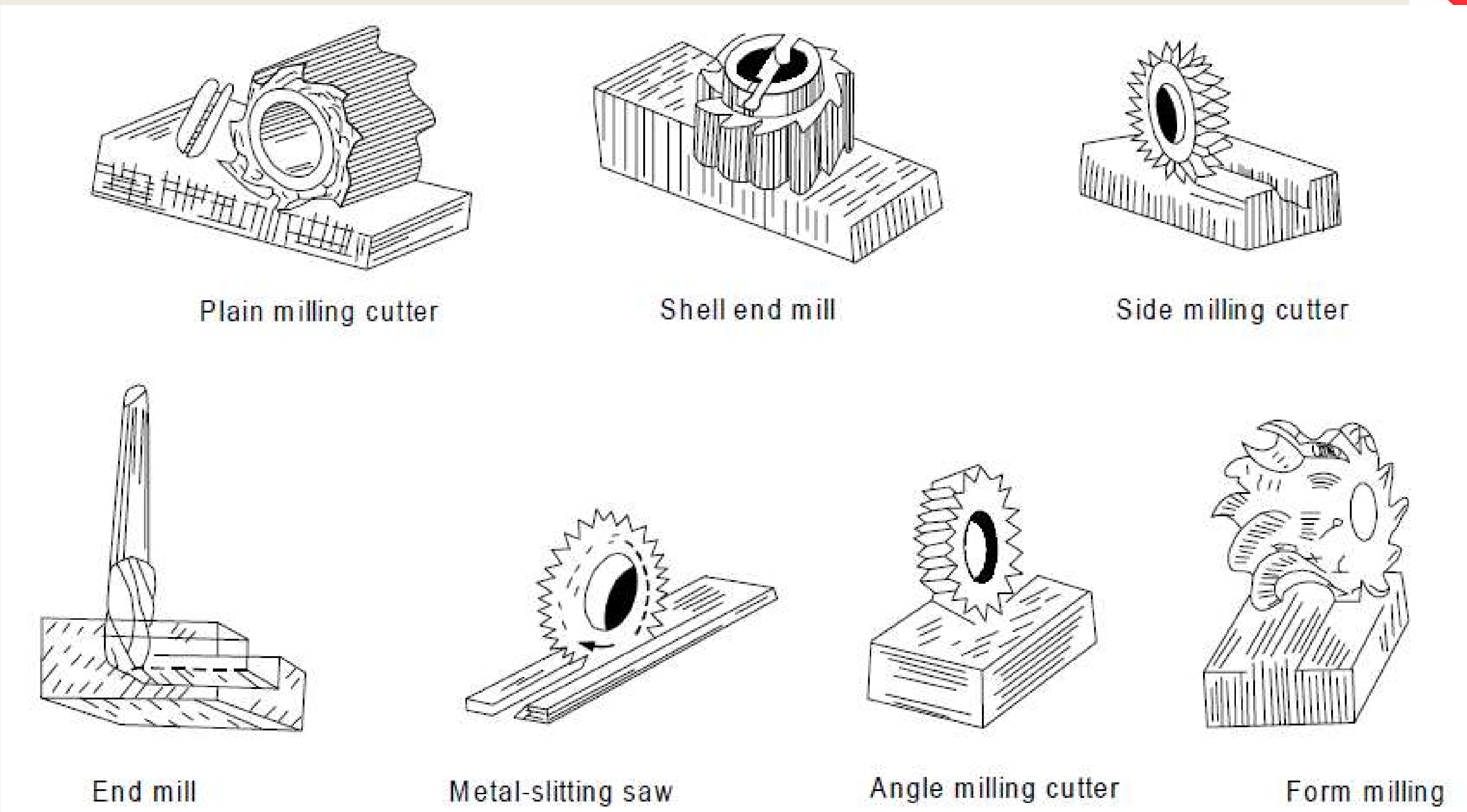
•Large shank mounting cutters are made with removable shank to reduce cost. Known as shell type cutters.

•End mills are the example of it.

❑**Cutters Mounting Directly on the spindle Nose:**

• Large diameter cutters of the face mill type are mounted directly on the spindle nose.

Milling Cutters



Types of Milling Cutters

Milling Cutters

Method Used in Grinding the Teeth

❑Teeth in milling cutters are made in two general styles according to the method used in sharpening them.

- Profile cutters
- Formed cutters

Milling Cutters

Cutter Material

- Milling cutters are made of high carbon steel, high speed steel, sintered carbide or cast non-ferrous alloys.
- High carbon steel cutters have a limited use since they dull quickly.
- Most general purpose cutters are made of HSS
- which may be used at temp 500 to 600° C and cutting speed 2 to 2.5 times than carbon steel cutters.
- Sintered carbide tipped cutters and cast non-ferrous alloys cutters have greater resistance to heat and used for heavy cuts and high cutting speed.
- Cutting speeds are 2 to 5 times greater than HSS.

Work Holding Method

- The vice jaws and the workpiece must be free from burrs, chips, and cutting fluid.
- Smaller workpiece should be supported by parallel bars to provide the supporting datum.
- Round bar must be placed between the workpiece and the movable jaw to ensure that the workpiece is in perfect contact with the fix jaw.
- The vice handle should be tightened by hand to avoid over clamping of the workpiece as well as the vice. Hide face hammer should be used to assure that the workpiece is in perfect contact with the supporting base.
- On completion of the milling of the first face, the workpiece should be unloaded, deburred, and cleaned before the next operation.
- To machine the second and the third faces, the workpiece should be clamped with its preceding machined surface facing against the fix jaw of the vice.
- Similar clamping method can be applied in the machining of the fourth face.
- Yet it can also be clamped on the vice without the round bar.
- Both ends of the workpiece can be machined with the periphery flutes of the cutter using up cut milling

Indexing of Milling Machine

•Indexing is the process of evenly dividing circumference of a circular work piece equally spaced division.

•It is used in cutting gear teeth, cutting splines, milling grooves in reamers and tap and spacing holes on a circle.

Indexing or Dividing head

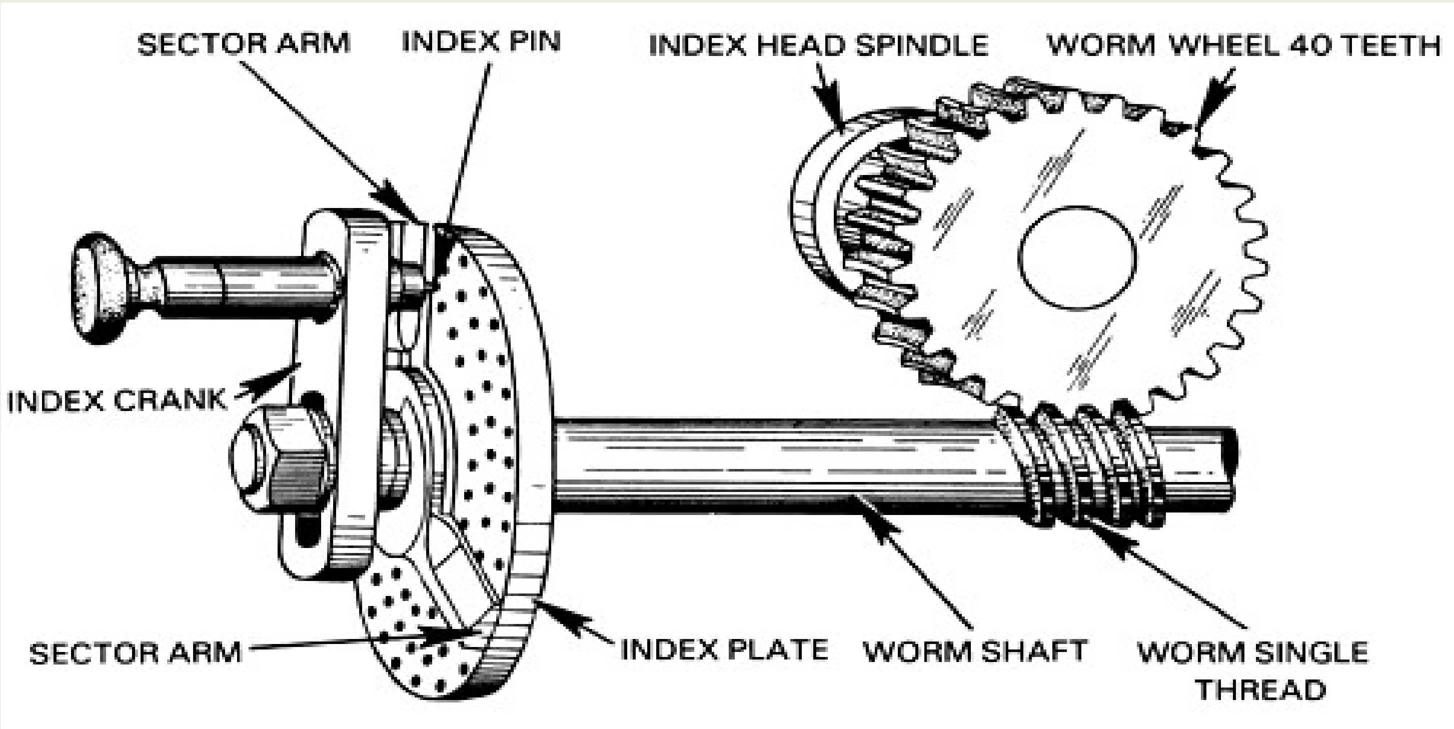
•The indexing head of the indexing fixture contains an indexing mechanism which is used to control the rotation of the index head spindle to space or divide a work piece accurately.

•A simple indexing mechanism consists of 40 teeth worm wheel fastened to the index head spindle, a single- cut worm, a crank for turning the worm shaft, an index plate and a sector.

Indexing of Milling Machine

•Since there are 40 teeth in worm wheel, one turn of the index crane causes the worm wheel, and the index head spindle to make 1/40 of a turn.

•So,40 turns of the index crane revolve the spindle one full turn.



Indexing of Milling Machine

Index Plate

- The indexing plate is a round plate with a series of six or more circles of equally spaced holes.
- The index pin on the crank can be inserted in any hole in any circle.
- With the interchangeable plates regularly furnished with most index heads, the spacing necessary for most gears, bolt heads, milling cutters, splines can be obtained.
- Three indexing plates are used. These plates have concentric circles of holes with their different numbers as described below :

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

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

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

Indexing of Milling Machine

Cincinnati type consists of one plate drilled on both side with circles divided as follows:

First side : 24,25,28,30,34,37,38,39,41,42,43 holes

Second side : 46,47,49,51,53,54,57,58,59,66 holes

Sector

The sector indicates the next hole in which the pin is to be inserted and makes it unnecessary to count holes when moving the index crank after each cut. It consists of two radial, beveled arms which can be set any angle.

Indexing of Milling Machine

Index Methods

Simple Indexing

- In simple indexing, an index plate selected for the particular application, is fitted on the worm shaft and locked through a locking pin.
- To index the work through any required angle, the index crank pin is withdrawn from the hole of the index plate than the work is indexed through the required angle by turning the index crank through a calculated no of whole revolution and holes on one of the hole circles, after which the index pin is relocated in the required hole.
- If the number of turns that the crank must be rotated for each indexing can be found from the formula

$N = 40/Z$

Indexing of Milling Machine

Where,

Z = No of division or indexing needed on the work

40 = No of teeth on the worm wheel attached to the indexing plate, since 40 turns of the index crank will turn the spindle to one full turn

•Suppose it is desired to mill a gear with eight equally spaced teeth. $1/8^{th}$ of 40 or 5 turns (Since 40 turns of the index crank will turn the spindle one full turn) of the crank after each cut, will space the gear for 8 teeth. It it is desired to space equally for 10 teeth. 1/1 of 40 or 4 turn would produce the correct spacing.

•The same principle applies whether or not the divisions required divide equally into 40. For example, if it is desired to index for 16 divisions, 16 divided into 40 equals 2 8/16 turns i.e. for each indexing we need two complete rotation of crank plus 8 more holes on the 16 hole circle of plate1 (Plate1 – 15,16,17,18,19,20 holes)

THANK YOU