MODULE – 2

LESSON CONTENTS:
Milling Machines: up milling & down milling, classification of milling machines, constructional features (Column and Knee and vertical milling machine), milling cutter nomenclature, various milling operations, calculation of machining time.
Indexing: Need of indexing Simple, compound and differential indexing calculations. Simple numerical on indexing.
Shaping, Slotting and Planning Machines Tools: Driving mechanisms of Shaper, Slotter and Planer. Operations done on Shaper, Planer & Slotter Difference between shaping and planning operations. **Drilling Machines**: Constructional features (Radial & Bench drilling Machines), operations, types of drill & drill bit nomenclature. Calculation of machining time.
Grinding: Grinding operation, classification of grinding processes: cylindrical, surface &centerless grinding

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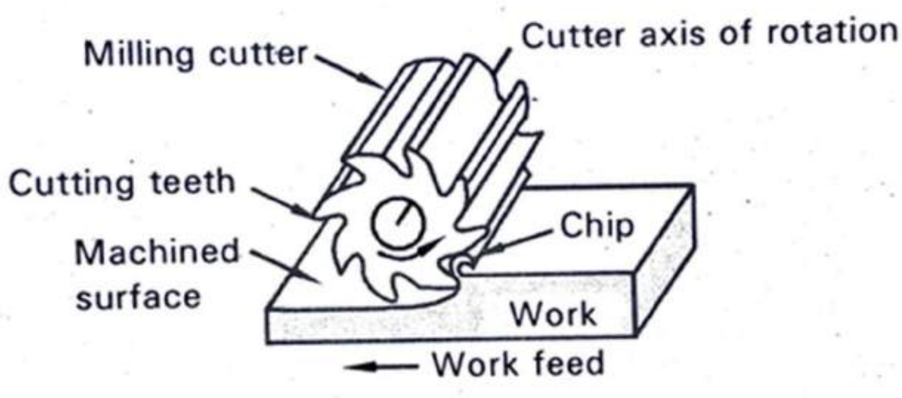
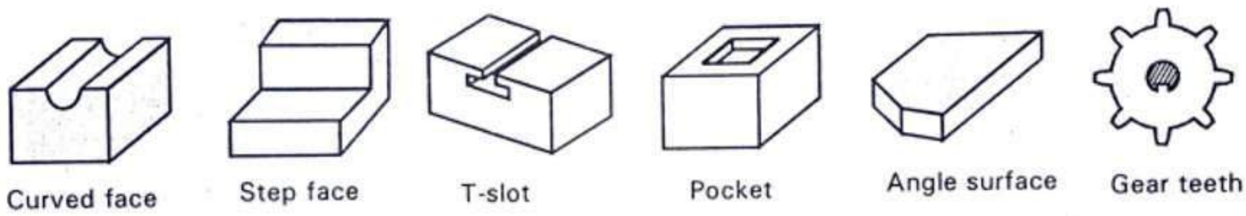
2.1 INTRODUCTION TO MILLING

- Milling is a process of shaping work materials by feeding the work material against a multipoint rotating cutter. As shown in figure 1(a).
- The machine used for the purpose is called milling machine. Milling can be used for producing flat, angular or curved surfaces, for cutting threads, toothed gears, keyways, slots, and a wide variety of other operations.
- The milling cutter is a multipoint cutting tool. The work piece is mounted on a movable worktable which will be fed against the revolving milling cutter to perform the cutting operation.
- A milling machine is a power operated machine tool in which the work piece mounted on moving table is machined to various shapes when moved under a slow revolving multipoint cutter.



(a) Milling process



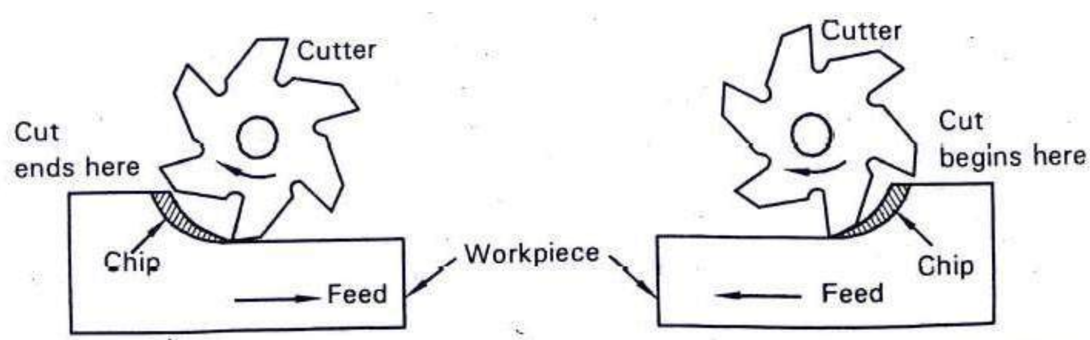
(b) Various shaped produced by milling

Fig. 1(a), 1(b).

- The difference between drilling and milling is that, in drilling a rotating drill is fed against a stationary work piece, while in milling the work piece is fed against a milling cutter which only revolves.
- Similarly, it also differs from the lathe operation because the lathe tool is fed against rotating work piece.
- It can also perform drilling and boring operations. The type of cutter used in milling depends on the shape desired on the workpiece. Figure 1 (b) shows the various shapes produced by milling. Milling is a metal cutting operation in which the operating tool is a slow revolving cutter having cutting teeth formed on its periphery

2.2 The Principle of Milling

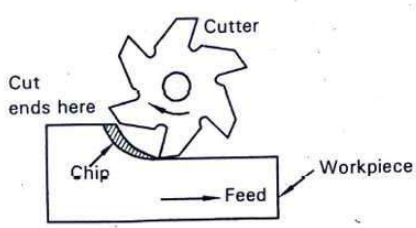
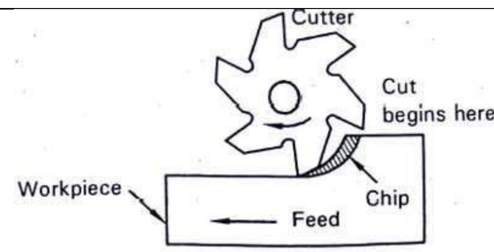
- In milling, the cutter is held in the spindle of the machine and made to rotate at suitable speeds.
- The workpiece is also held rigidly by a suitable device and is fed slowly against the rotating cutter.
- The workpiece can be fed in two different directions with respect to cutter rotation as shown in figure. below the process thus gives a means of classification of milling into two types known as up milling and down milling.
- In up milling process as shown in figure 2(a), the workpiece is fed in the direction opposite to that of the rotating cutter, while in down milling process as shown in figure 2(b), the workpiece is fed in the same direction as that of the rotating cutter. The various aspects related to the two types are tabulated in a comparison form in table.



(a) Up milling (Conventional milling) (b) Down milling (Climb milling)

Fig. 2(a), 2(b)

2.2.1 Comparison between Up Milling and Down Milling

Sl. No.	Up milling (Conventional milling)	Down milling (Climb milling)
1.	In up milling, the workpiece is fed in the direction opposite to that of the rotating cutter.	In down milling, the workpiece is fed in the same direction as that of the rotating cutter.
2.	The thickness of chip is minimum at the beginning of cut and reaches to a maximum when the cut ends.	The thickness of chip is maximum at the beginning of cut and reaches to the minimum when the cut ends.
3.	In up milling, the cutting force is directed upwards. This tends to lift the workpiece from the worktable. Hence, greater clamping force for the workpiece becomes necessary.	The cutting force is directed downwards, and this tends to keep the workpiece firmly on the worktable thereby permitting lesser clamping forces.
4.	During up milling, the chip gets accumulated at the cutting zone (tool-work interface). These chips interfere with the rotating cutter thereby impairing the surface finish on the work-surface.	In down milling, the chips do not interfere with the revolving cutter, since they are disposed easily by the cutter. Hence, there is no damage to the surface finish of the workpiece.
5.	In up milling, it is difficult for efficient circulation of coolant. The cutter rotating in the upward direction carries away the coolant from the cutting zone.	In down milling, the coolant can easily reach the cutting zone. Hence, efficient cooling of the tool and the workpiece can be achieved.
6.	Up milling is preferred for rough cuts, especially for castings and forgings, because this method enables the cutter to dig-in and start the cut below the hard upper surface.	Down milling produces better surface finish because there is no dig-in of the cutter. It is particularly used for finishing operations and small work like cutting slots, grooves etc.
	 (a) Up milling (Conventional milling)	 (b) Down milling (Climb milling)

2.3 TYPES OF MILLING MACHINES

The different types of milling machines are listed as follows.

i. Column and knee milling machines.
   a) Plain column and knee type milling machines

- Horizontal spindle type
- Vertical spindle type

b) Universal Column and knee type milling machine

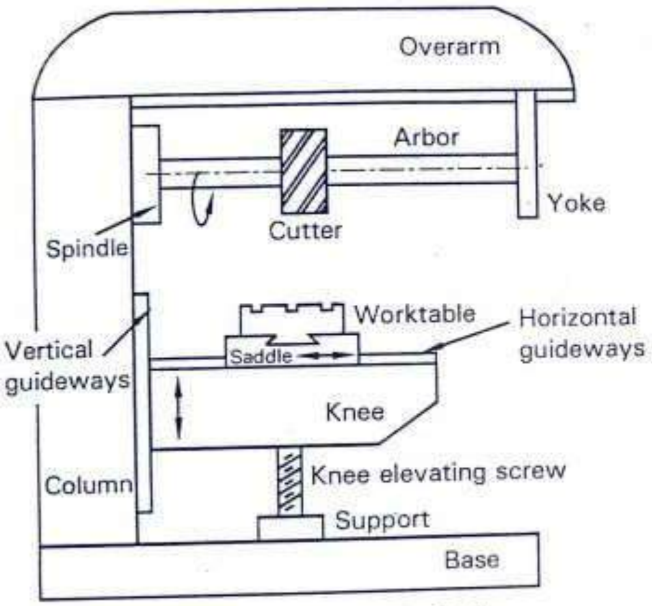
ii. Bed type milling machines
iii. Planer type milling machine
iv. Special purpose milling machines
   a) Tracer-controlled milling machine
   b) Thread milling machine.
   c) CNC milling machine.

2.3.1 Horizontal Spindle Column & Knee Milling Machine

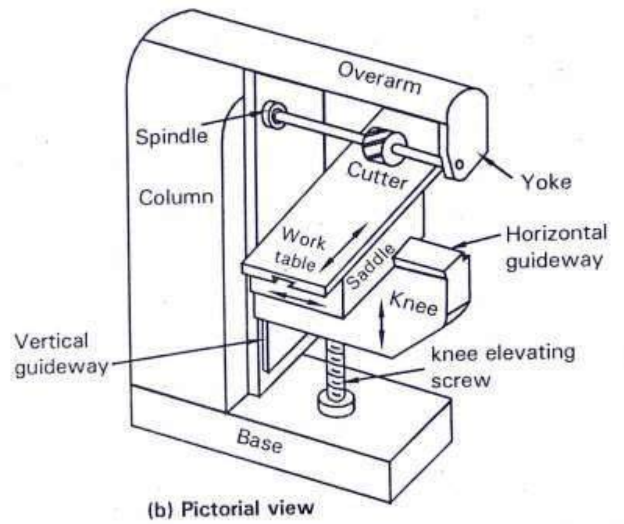
It is one of the most popular type of milling machine, and is commonly called horizontal milling machine, because of the horizontal position of the spindle. This type of machine is used to cut grooves, slots, keyways, gear teeth etc. figure (a) shows one of the principal views of a horizontal milling machine. Figure (b) shows the pictorial view of the same.

The machine consists of the following parts:

a) **Base** is usually a strong and a hollow part which forms the foundation of the machine and upon which all the other parts are mounted. The base also serves as a sump for the cutting fluid. A pump and filtration system can be installed in the base. The hole provided in the center of the base, houses the support for the elevating screw that raises and lowers the knee.
b) **Column** is a vertical hollow casting and is usually combined with the base to form a single casting. The column houses the spindle and bearings as well as the drive units (gears, clutches, shafts, and shifting mechanisms) for transmitting power from the electric motor to the spindle at desired speeds. The front face of the vertical column is provided With a square or dovetail type guideways on which the knee slides up and down.
c) **Spindle** is a hollow shaft supported by the column with suitable bearings that absorb both radial and thrust loads. The spindle is made hollow and tapered inside to accept standard arbors. The spindle obtains power from the motor and transmits it to the arbor. The arbor carrying the cutter rotates about a horizontal axis.
d) **Overarm** mounted on the vertical column supports the yoke, which in tum supports the free end of the arbor.
e) **Knee** is a casting that slides up and down on the vertical guideways provided on the column by means of an elevating screw. The knee supports the saddle.



(a) End view of a horizontal-spindle column and knee milling machine



(b) Pictorial view

Note: Hand wheel for providing motions to knee, saddle and table are not shown in figure.

Fig. Horizontal-spindle column and knee milling machine.

f) **Saddle** mounted on the knee is provided with two slides (guideways) on its top and bottom surfaces. The slides are machined at right angles to each other. The lower slide fits the slide provided on top of the knee and facilitates horizontal movement of the saddle. The upper slide provided on the saddle accepts the slide provided on the bottom surface of the worktable.

g) **Worktable** is larger in size and rests on the saddle. The bottom surface of the table has a dovetail slide that fits in the slide on the top surface of the saddle. This arrangement facilitates the worktable to be moved longitudinally or at right angles to the movement of the saddle. The worktable is provided with T-slots all along its length for mounting vice or other work holding devices. This enables the workpiece to be clamped rigidly on the table. The worktable may be manually controlled or power fed. A dial graduated in thousandths of an inch (not shown in figure) is provided to allow for accurate table movement and placement.

2.3.2 Vertical Spindle Column and Knee Milling Machine

- Vertical spindle milling machines are similar in construction to the horizontal milling machines, except that the spindle is held in a vertical position.
- This type of machine is generally used to perform end milling and face milling operations. Figure shows the principal parts of a vertical milling machine.

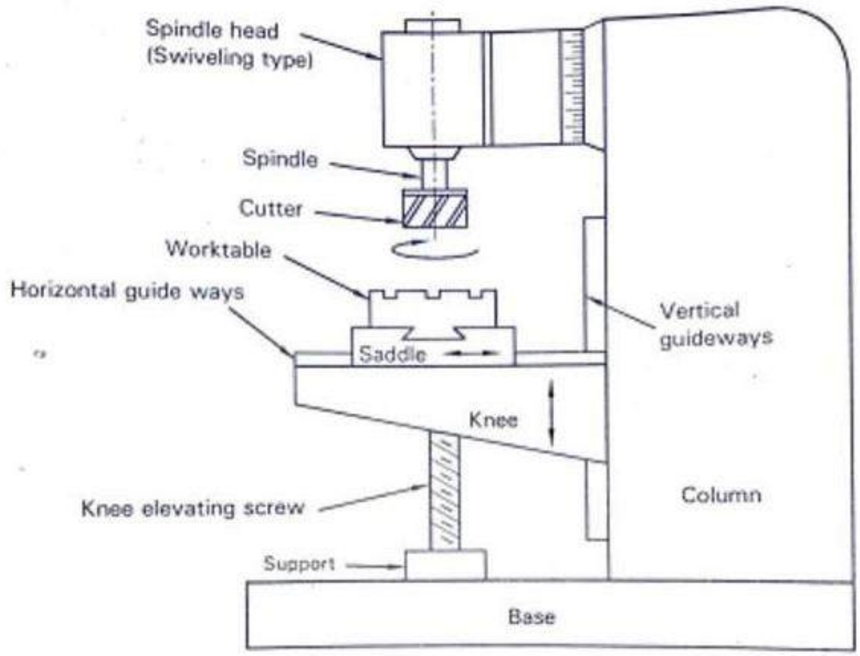


Fig. Vertical spindle column and knee type milling machine (swiveling type)

The machine consists of the following parts:

a) **Base** is usually a strong and a hollow part which forms the foundation of the machine and upon which all the other parts are mounted. The base also serves as a sump for the cutting fluid. A pump and filtration system can be installed in the base. The hole provided in the center of the base, houses the support for the elevating screw that raises and lowers the knee.

b) **Column** is a vertical hollow casting and is usually combined with the base to form a single casting. The column houses the spindle and bearings as well as the drive units (gears, clutches, shafts, and shifting mechanisms) for transmitting power from the electric motor to the spindle at desired speeds. The front face of the vertical column is provided With a square or dovetail type guideways on which the knee slides up and down.

c) **Spindle** is located vertically, parallel to the face of the column, and perpendicular to the top of the worktable. The spindle is mounted in the spindle head and .carries the cutter at its end. The spindle head houses the motor & feed controls & can be either fixed type or swiveling type.

In fixed type, the spindle head is fixed, and hence the spindle remains vertical. The spindle can be adjusted up and down to perform operations like grooving, slotting, facing, drilling and boring. While, in swiveling type, the spindle head can be swiveled to any angle to the surface of the worktable. This permit working on angular surfaces of workpieces.

d) **Overarm** mounted on the vertical column supports the yoke, which in tum supports the free end of the arbor,

e) **Knee** is a casting that slides up and down on the vertical guideways provided on the column by means of an elevating screw. The knee supports the saddle.

f) **Saddle** mounted on the knee is provided with two slides (guideways) on its top and bottom surfaces. The slides are machined atright angles to each other. The lower slide fits the slide provided on top of the knee and facilitates horizontal movement of the saddle. The upper slide provided on the saddle accepts the slide provided on the bottom surface of the worktable.

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2.4 Specification of Milling Machine

- The Milling machine is specified by one or more of the following criteria.
  - ✓ Type of spindle
  - ✓ Length & Breadth of the worktable
  - ✓ Power of driving motor
  - ✓ Number of spindle speeds
  - ✓ Spindle feed range
  - ✓ Taper of spindle nose, etc,

2.5 MACHINING PROCESSES ON MILLING MACHINE

A few machining processes on milling machine are discussed as follows.

a) Plain or Slab milling
b) Face milling
c) End milling
d) Slot milling
e) Angular milling
f) Form milling
g) Straddle milling
h) Gear cutting or Gear milling
i) Thread milling

a) Plain or Slab milling

- Plain milling, also called surface milling, peripheral milling or slab milling is a machining process for producing a plain horizontal surface with a milling cutter whose axis is parallel to the surface of-the workpiece being machined.

- Refer figure 1. The process is carried out on a horizontal milling machine with a cutter having straight or helical teeth* formed on the periphery of a cylindrical surface. The cutter is mounted on the arbor rotating at a suitable speed, while the workpiece is fed against the cutter causing material to be removed from the workpiece. A plain smooth surface can be produced with this process.

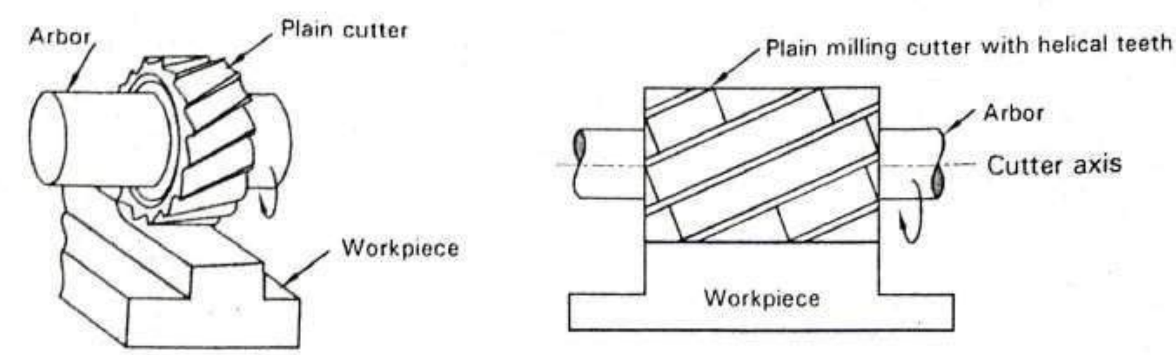


Fig.1 Plain/Slab milling

b) Face milling

Face milling is a machining process carried out for producing a flat surface, which is perpendicular to the axis of the rotating cutter. Refer figure 2. The process is carried out on a vertical milling machine with a cutter called face milling cutter, having diameter larger than the width of the workpiece being machined, so that the surface can be finished in a single pass.

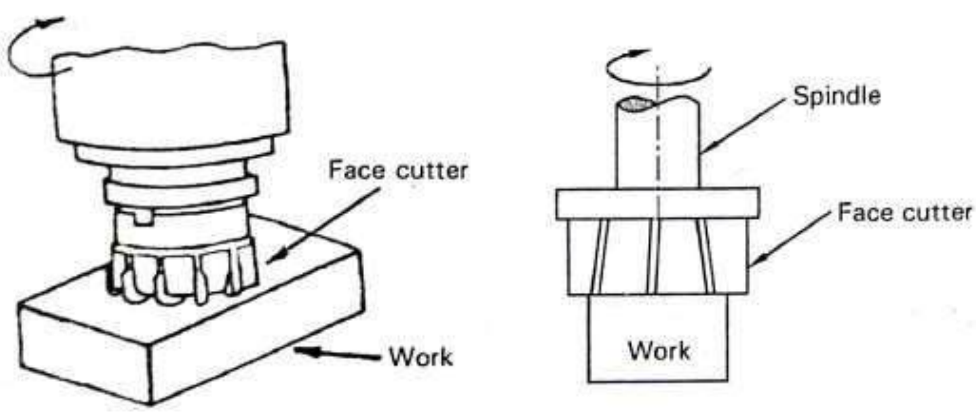


Fig.2 Face milling

c) End milling

End milling is a machining process carried out for producing flat surfaces, profiles, slots, grooves, or finishing the edges of the workpiece by means of a tool called end mill or end milling cutter. Figure 3 shows an end mining cutter having teeth on the end as well as the periphery (sides) for machining with both its end as well as its sides. The cutter usually rotates on an axis perpendicular to the work surface, although it can be tilted to machine tapered surfaces. End mills are also available with hemispherical ends (ball nose) for machining curved surfaces in metallic dies and moulds.

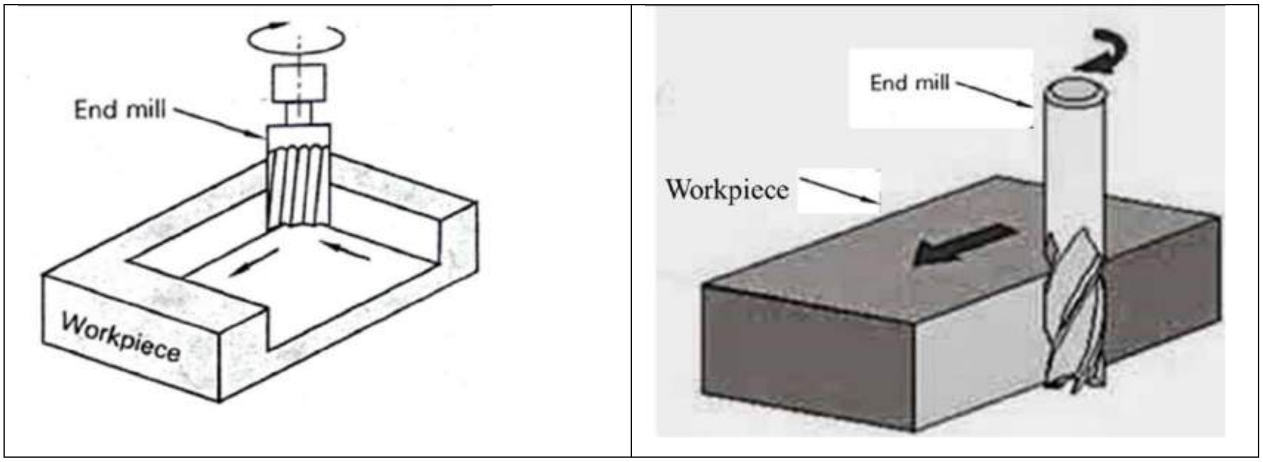


Fig.3 End milling

d) Slot milling

Slot milling is a machining process for producing slots like T-slots, plain slots, dovetail slots etc., in worktable fixtures and other work holding devices. The operation may be performed using either T-slot cutter end milling cutter, T-slot cutter, dovetail cutter, or side milling cutter. type of cutter selected depends on the shape of the slot to be produced, Figure 4. shows the operation of producing T-slot.

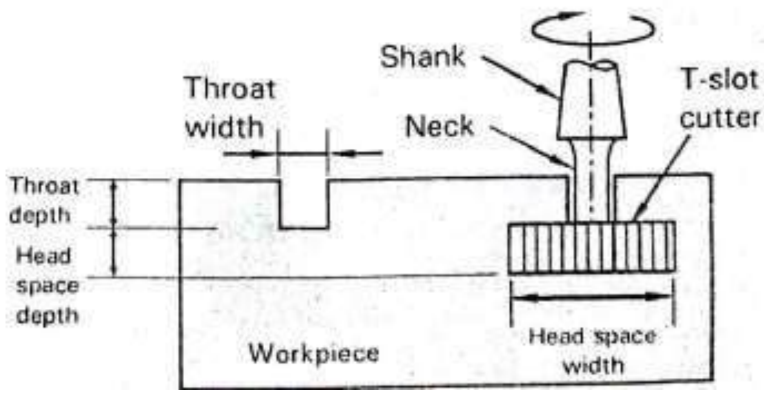


Fig.4 Slot milling

The separate milling cutters are required for milling T-slots. Initially, a plain cutter, side cutter or an end milling cutter is used to cut the throat (open slot) starting from one end of the workpiece to its other end. A T-slot milling cutter is then used to cut the headspace to the desired dimensions. Similar procedure is followed for cutting a dovetail slot , but a dovetail slot cutter is used in place of T-slot cutter.

e) Angular milling

Angular milling or angle milling is a machining process for producing all types of angular cuts like V-notches and grooves, serrations and other angular surfaces. Refer figure 5. The cutter, called angle milling cutter or angle cutter may be either single-angle type having teeth on its conical surface that can produce an angle or chamfer on the workpiece edge as shown in figure 5(a), or the cutter can be double-angle type having teeth on two conical surfaces that can double angle cuts as shown in figure 5(b). Angle cutters may also be used to produce dovetail slots in workpieces.

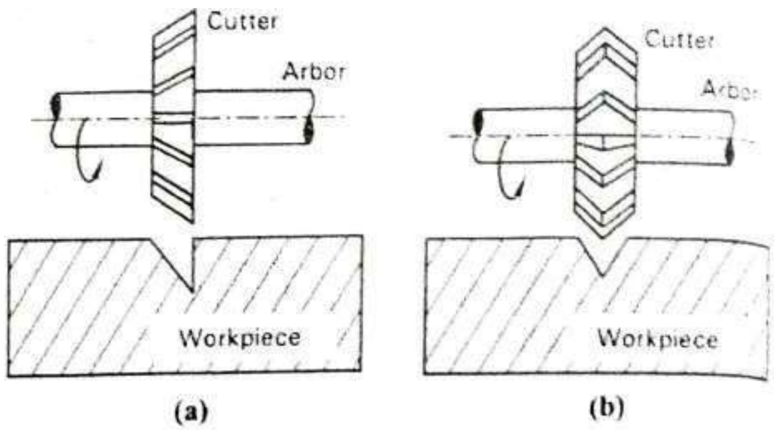


Fig.5 Slot milling

f) Form milling

Form milling is a machining process carried out for producing curved profiles with a variety of shapes like concave, convex, spline, etc., using cutters whose edge is shaped to produce a special configuration on the surface of the workpiece Refer figure 6. The cutter known as form mill has teeth on its periphery and is designed in various shapes to suit the type of surface to be machined.

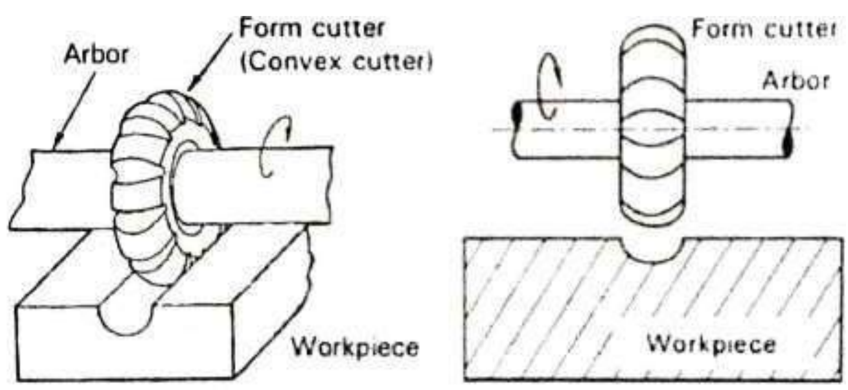


Fig.6 Slot milling

g) Straddle milling

Straddle milling is a machining process, in which a pair of side milling cutters is used for machining two parallel vertical surfaces simultaneously as shown in figure 7. The side milling cutter can have cutting edge on one or both sides as well as on the periphery.

Straddle milling is accomplished by mounting two side milling cutters on the same arbor, set apart at an exact spacing with the help of spacers, washers and shims, so that the distance between the cutting teeth of each cutler is exactly equal to the width of the workpiece area being machined.

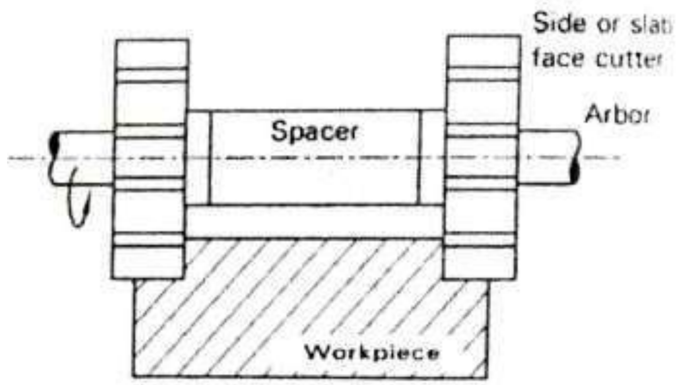


Fig.7 Slot milling

h) Gang milling

Gang milling is a machining process, in which two or more cutters are cutters are mounted on the same arbor, so that different profiles required on the workpiece can be machined simultaneously in a single pass as shown in figure 8. All the cutters used may be of the same type or of different types depending on the type of surface being machined.

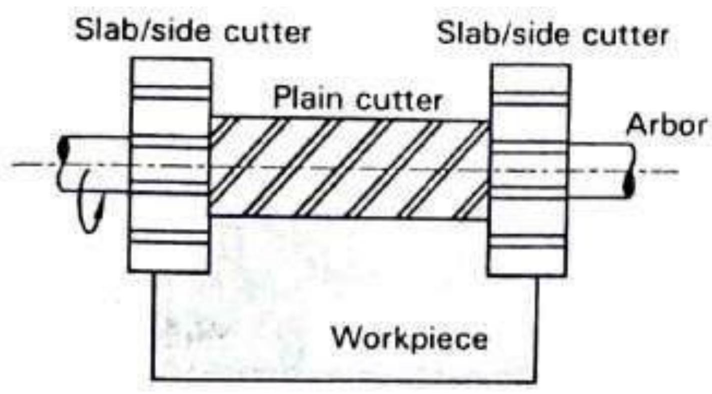


Fig.8 Gang milling

i) Gear cutting or Gear milling

Gear milling or gear cutting is a machining process carried out on a milling machine for cutting teeth of different shapes by using form milling cutters or involute gear cutters. The shape of the gear tooth profile depends on the shape of the cutter. Figure 9 shows the simplified diagram of a cutter in spur gear milling operation.

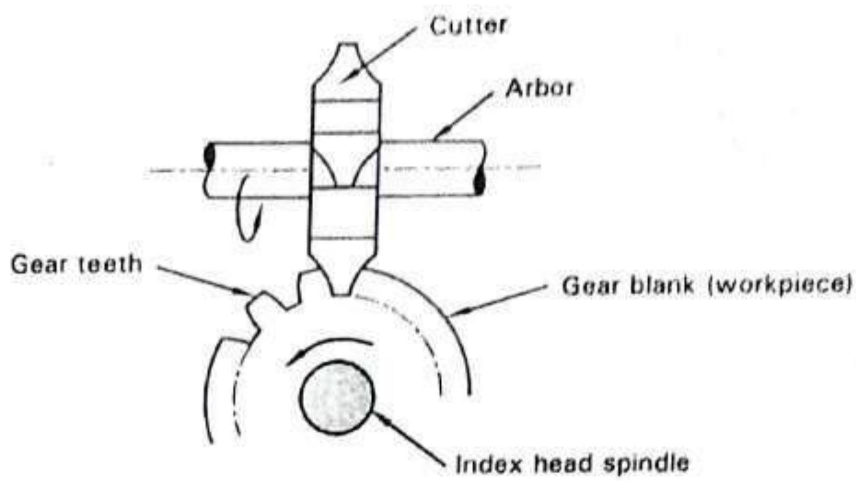


Fig.9 Gang milling

The workpiece is mounted rigidly on the index head spindle with the cutter touching the periphery of the workpiece. The vertical dial is then set to zero reading. The cutter is chosen according to the module and number of teeth to be cut. The cutter is mounted on the arbor of the horizontal milling machine rotating at a suitable speed. The worktable is fed vertically upwards to impart depth of cut. Teeth are cut of the workpiece by feeding it linearly against the rotating cutter. Depth of cut is increased slowly until it reached the full depth of the tooth. After one tooth is cut, the workpiece is indexed(rotated) by a suitable mechanism for cutting the next teeth.

j) Thread milling

Thread milling or Tread milling is the operation carried out on milling to cut threads and worms by means of suitable cutters. Two types of cutters are generally used for producing threads. The first type of cutter, called single cutter consists of a single row of teeth mounted on the periphery of a cylinder as shown in figure 10(a). Such cutters are generally used for cutting threads having coarse pitch and on long screwed parts like lead-screws and worms. The second type of cutter consists of teeth in a number of rows, spaced from one another at a distance equal to the pitch as shown in figure 10(b). this type of cutter is used for producing threads for comparatively shorter lengths.

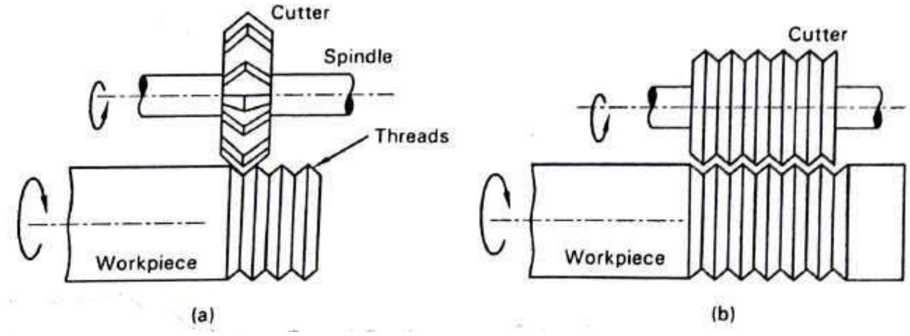


Fig.10 Thread milling

2.6 Indexing

- Milling operations sometimes require the rotation of work piece, correct to fractions of minutes, for each groove, slot, gear teeth, etc., to be cut evenly on the work surface.
- The accuracy of spacing between each cut becomes very important, and this is accomplished by means of a specialized attachment called indexing or dividing head. The process is referred as indexing.
- Indexing can be defined as the process of evenly dividing the circumference of a work piece into equally spaced divisions, in order to perform certain machining operations such as cutting gear teeth, splines, grooves in reamers and taps, etc. there are different types of indexing, however from the syllabus point of view, three types of indexing viz., simple indexing, compound indexing, and differential indexing are discussed herein.

2.7 Indexing mechanism

- A simple indexing mechanism as shown in figure (2.7). consists of a 40-tooth worm wheel fastened to the index head spindle, a single start threaded worm, a crank for turning the worm shaft and an index plate. Also, refer figure (2.10).
- The workpiece is secured to the index head spindle by means of a suitable holding device (not shown in figure).
- The goal of the indexing mechanism is to control the rotation of the index head spindle and hence the workpiece, so that the circumference of the workpiece can be divided into any desired number of equal divisions.
- The worm shaft carries the crank at its outer end, which in turn supports a spring loaded plunger as shown in the figure.
- The index pin (crank pin) works inside the plunger and can be adjusted to lock it into the desired hole circle on the index plate.
- By pulling the index pin outwards and rotating the plunger, the crank, and hence the worm shaft can be rotated.
- The index plate is also mounted on the same shaft (worm shaft) as the crank, but on a sleeve, in order to remain stationary while the crank and the worm shaft is being rotated.

- In operation, when the index pin (crank pin) is pulled outwards and the crank is rotated, the worm shaft rotates causing the worm to drive the worm wheel, and consequently the spindle head and the workpiece to turn.
- The distance or the angle through which the workpiece is rotated depends on the revolution given to the crank.

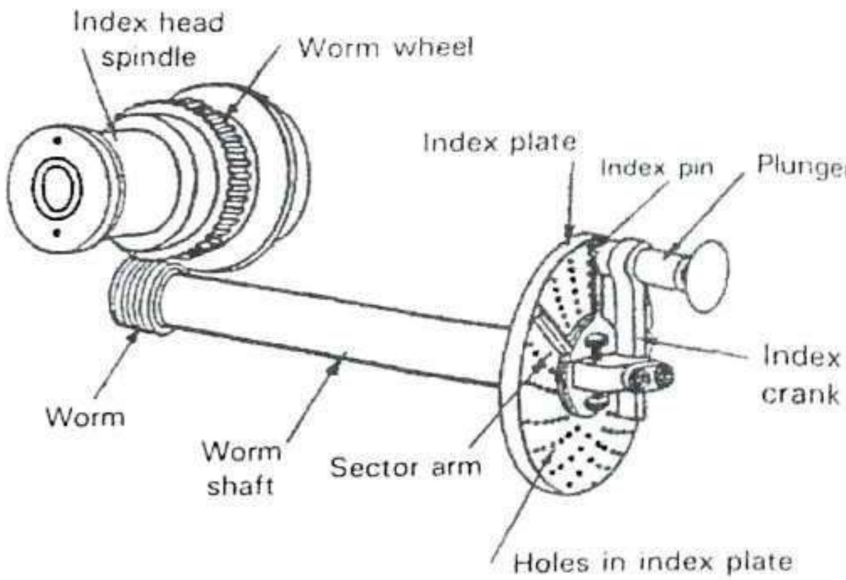


Fig. 2.7 Indexing mechanism

2.8 Use of Index Plate

- The index plate is a circular plate provided with a series of circles (six or more) of equally spaced holes.
- The index plate comes in three sets, each carrying different number of holes in them.
- The three standard plates of Brown and Sharp 1ype having different holes is given in table1. Figure 2.8 shows the index plate 1 of Brown and Sharp type.

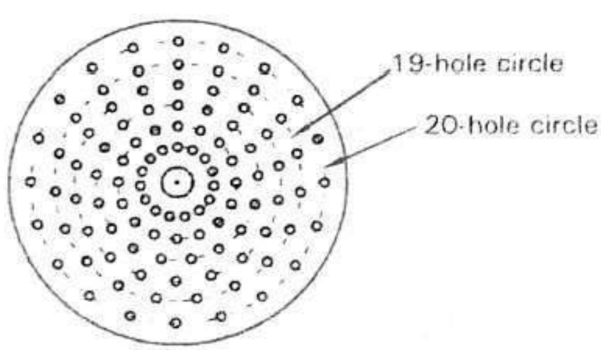


Fig. 2.8 Index plate 1 of Brown and Sharp type

Table 1. Index plates of Brown and[2]

Plate 1	15, 16, 17, 18, 19, 20 holes.
Plate 2	21, 23, 27, 29, 31, 33 holes.
Plate 3	37, 39, 41, 43, 47, 49 holes.

2.9 METHODS OF INDEXING

- There are different methods of dividing the circumference of a circular workpiece into equally spaced divisions.
- These include: Direct or Rapid indexing, Simple or Plain indexing. Compound indexing, Differential indexing and Angular indexing.
- From the syllabus point of view, the first three methods of indexing are discussed herein

2.10 SIMPLE OR PLAIN INDEXING

- In simple or plain indexing method, the workpiece is rotated by turning the crank as shown in figure 2.10. Also, refer figure 2.15.
- When the crank is rotated, the worm shaft rotates causing the worm to drive the wor1n wheel and consequently the spindle to turn.
- As the spindle rotates, the workpiece that is secured to the spindle by means of a suitable holding device (not shown in figure) also rotates.
- The angle through which the workpiece rotates for each revolution of the crank depends on the velocity ratio between the wor1n and the worm wheel.

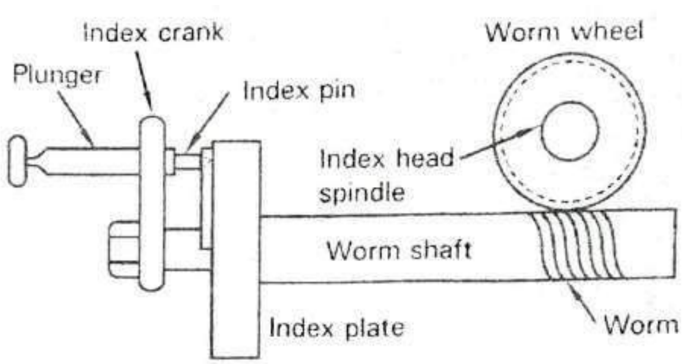


Fig. 10. Side view of the Indexing mechanism

To calculate velocity ratio

- Since the worm has a single start thread and the worm wheel 40 teeth, one revolution of the crank (i.e., of the worm) Causes the worm wheel to rotate through one pitch distance, i.e., equal to $1/40^{th}$ of a revolution.
- Similarly two turns of crank will make the workpiece to rotate through 2/40 or $1/20^{th}$ of a revolution, and so on.
- In other words, 40 revolutions of the crank will make the workpiece to complete one full turn or a 360° revolution thereby making the ratio 40:1
- Therefore, one turn of the index crank $= \frac{360°}{40} = 9°$
- Thus it is clear that, larger revolutions of the crank result in small rotation of the workpiece.
- Hence, we can divide the Circumference of the workpiece into any desired number of equal divisions.
- The following calculations shows the rotations required for the crank in order to divide the circumference of the workpiece into desired number of divisions.
- For 2 divisions on the workpiece, the crank has to rotate $\frac{40}{2} = 20$ turns for each division
- For 4 divisions on the workpiece, the crank has to rotate $\frac{40}{4} = 10$ turns for each division.
- Therefore, for N divisions on the workpiece, the crank has to be rotated $\frac{40}{N}$ for each division.
- In other words, the index crank movement is given by: Index crank movement = $\frac{40}{N}$ where, N = number of divisions required on the workpiece.

Numerical problems solved during class hours

2.11 COMPOUND INDEXING

- Compound indexing method is employed in those cases, when the number of divisions required on the workpiece cannot be obtained with simple or plain indexing method.
- This method involves two separate indexing movements that give the name compound indexing method. Compound indexing is performed in two stages:
    [1]. The first movement is obtained by turning the index crank, a definite amount in one direction in the same way as in simple indexing, i.e., the crank pin is rotated through a required number of spaces in one of the hole-circle of the index plate, and then the crank pin is engaged with the plate. Refer figure 2.11(a).

[2]. The second index movement is obtained by turning the index plate along with the crank as shown in figure 2.11(b).

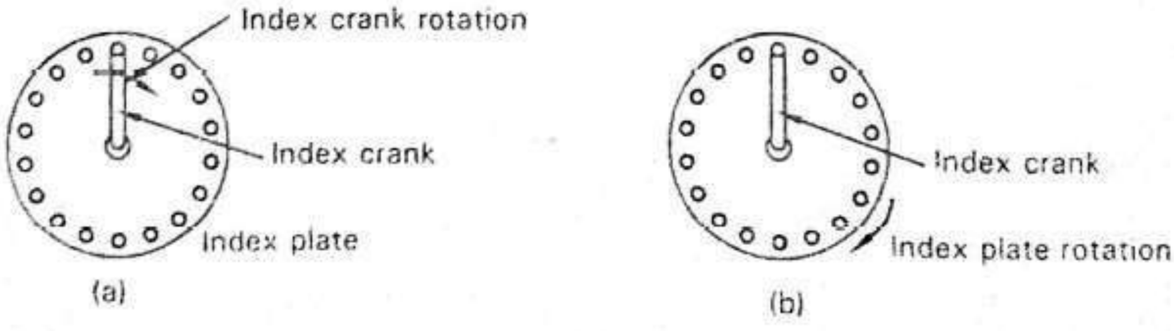


Fig 2.11 Movement of index crank in compound indexing

Turning of index plate

- Normally, the index plate is held stationary by a lock pin, which engages with one of the hole circles of the index plate from the back.
- While giving the second index movement, the lock pin at the back of the plate is removed and then the plate is rotated along with the index crank, either in the same direction or in the reverse direction through the calculated number of spaces of another hole-circle.
- The lock pin is engaged with the hole-circle at the back of the plate.
- The second movement is finally added or subtracted from that obtained in the first index movement

Rule for compound indexing

The rule for compound indexing is given by the formula $\frac{40}{N} = \frac{n_1}{N_1} \pm \frac{n_2}{N_2}$

Where,

- N = Number of divisions required on the workpiece
- N_1= The hole-circle used by the crank pin
- N_2 = The hole-circle used by the lock pin
- n_1 = The hole spaces moved by the crank pin in N_1 hole circle.
- n_2 = The hole spaces moved by the index plate and the crank pin in N_2 hole- circle.

2.12 DIFFERENTIAL INDEXING

- Differential indexing is similar to the compound indexing, wherein, the required division of the periphery of the job is obtained by the combination of two movements:
  a) The movement of the index crank through the required number of spaces in one of the hole circle of the index plate as in the case of simple indexing, and,
  b) The simultaneous movement of the index plate along with the crank, either in the same direction or reverse direction, thus adding (gain) further movement to, or subtracting (lost) from that obtained in the first movement.
- The only difference between compound and differential indexing is that the movement of the index plate is accomplished by moving the plate by means of a train of gears connecting the index head spindle to the worm shaft. Refer figure 2.12

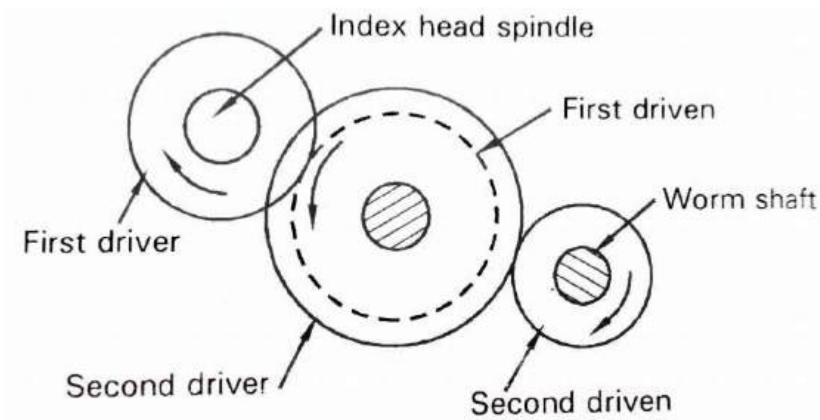


Fig. 2.12 Compound gear train

- As in compound indexing, the index plate locking-pin should be taken out to make the index plate free to rotate.
- The dividing head in differential indexing is supplied with change gears as follows:
  24, 24, 28, 32, 40, 44, 48, 56, 64, 72, 86, 100
- With these change gears and three sets of Brown and sharp Index head spindle plates, it is possible to index any number from 1 to 382 divisions.
- Differential method of indexing is employed when the number of divisions cannot be obtained by simple indexing.
- Both simple and compound gear train arrangements are used in differential indexing.
- In these gear trains, the first driver is always mounted on the spindle head, i.e., the spindle on which is mounted the worm wheel and the workpiece. Figure 2.12 shows the compound gear train arrangement for differential indexing.

2.13 DRILLING

- Drilling is a machining operation of producing a cylindrical hole in a solid workpiece by means of a revolving tool called drill bit.
- The tool is also called twist drill since it has sharp twisted edges formed around a cylindrical body. Figure 2.13 shows the drilling operation.
- In operation, the drill bit is held rigidly in the chuck of the machine and rotated by the spindle at high speeds.

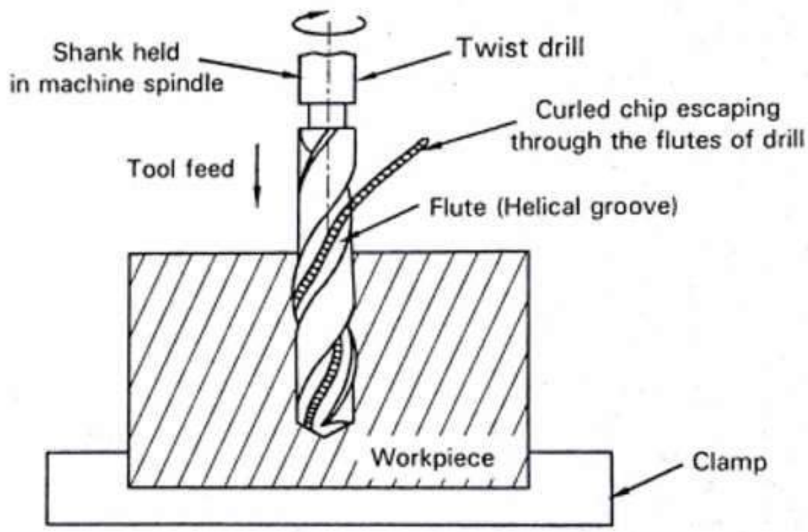


Fig. 2.13 Compound gear train

- With the help of a hand wheel or by automatic means, the drill bit is forced to move against the rigidly clamped workpiece.
- A hole is generated by the sharp cutting edges of the rotating drill bit and meanwhile, the excess material removed (chips) gets curled and escapes through the helical grooves provided in the drill bit.
- Although drilling seems to be a simple process, it is actually a complex one. The tool apart from performing the cutting action also extrudes the cut material (chips) from the workpiece.
- Since the cutting action takes place inside the workpiece, a lot of heat generated is minimized by circulating a suitable coolant.

2.13.1 DRILLING MACHINE OPERATIONS:

A number of operations that can be performed on a drilling machine using the various tools are as follows:

a) Drilling
b) Boring
c) Reaming
d) Counter-boring

e) Counter-sinking
f) Spot facing
g) Tapping

a) Drilling

- Drilling is defined as the metal removal process carried out by forcing a rotating drill bit against rigidly clamped solid work-piece to get a cylindrical hole.

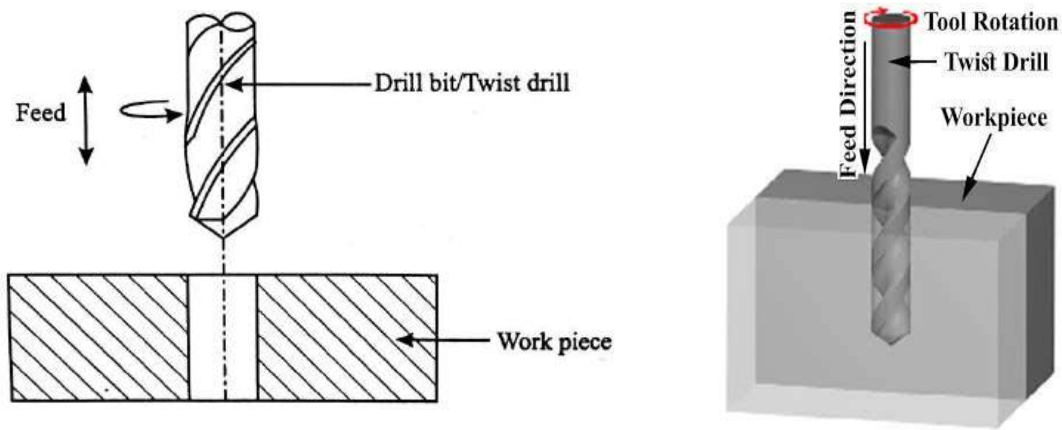


Fig. Drilling

- A typical drilling operation is shown in figure. Drilling is carried out by a rotating cutting tool to make circular holes in solid materials. The tool which makes the hole is called as twist drill, since it has a sharp twisted edge formed around a cylindrical tool provided with a helical groove along its length to allow the cut material to escape through it.
- The sharp edges of the conical surfaces ground at the lower end of the rotating twist drill cuts the material by peeling it circularly layer by layer when forced against a work-piece. The removed material chips get curled and escapes through the helical groove provided in the drill. A liquid coolant is generally used while drilling to remove the heat of friction and obtain a better finish for the hole.

b) Boring

- Boring is a machining process carried out for enlarging a previously drilled hole by means of an adjustable cutting tool having only one cutting edge. shown figure below.
- Boring is usually performed when a drill bit of the required dimension is not available.
- In such cases, a hole is first drilled to the nearest dimension and then a single point cutting tool is fastened and adjusted to a boring bar to enlarge the size of the existing hole to the required dimension.
- While boring, the tool is rotated at speeds slower than that of reaming. In addition to enlarging a previously drilled hole, boring operation corrects the hole location and out-of- roundness, if any, as the tool can be adjusted to remove Previously drilled hole more metal from one side of the hole than the other.

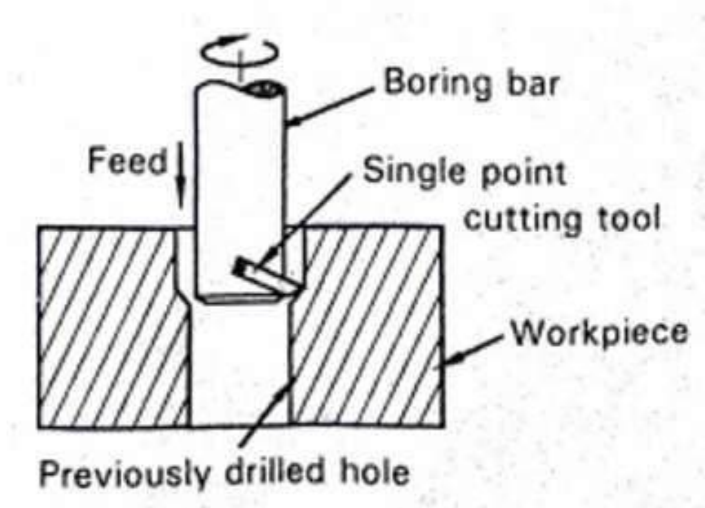


Fig. Boring

c) Reaming

- Reaming is a machining process carried out for finishing a previously drilled hole so as to bring it to a more exact size and to improve the surface finish of the hole. Refer figure below.

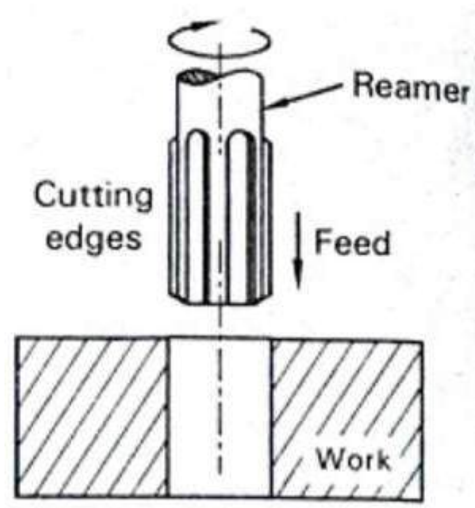
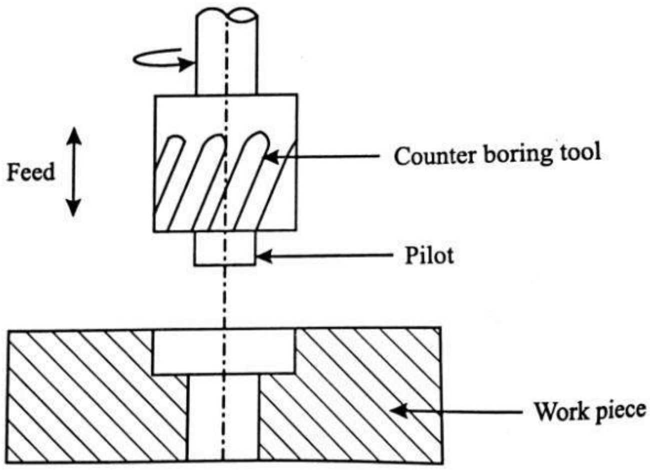


Fig. Reaming

- The operation is carried out using a multi-tooth revolving tool called **reamer,** which consists of a set of parallel straight or helical cutting edges along the length of the cylindrical body.
- While reaming, the speed of the spindle is reduced to nearly half of that of the drilling. The material is removed in small amounts, and hence the surface of the drilled hole is finished with high accuracy.

d) Counter-boring

- Counter-boring is to increase the size of a hole at one end only through a small depth.



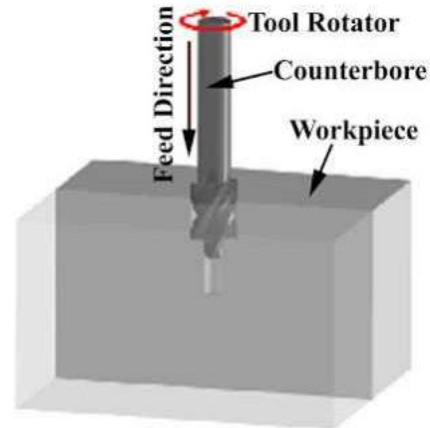
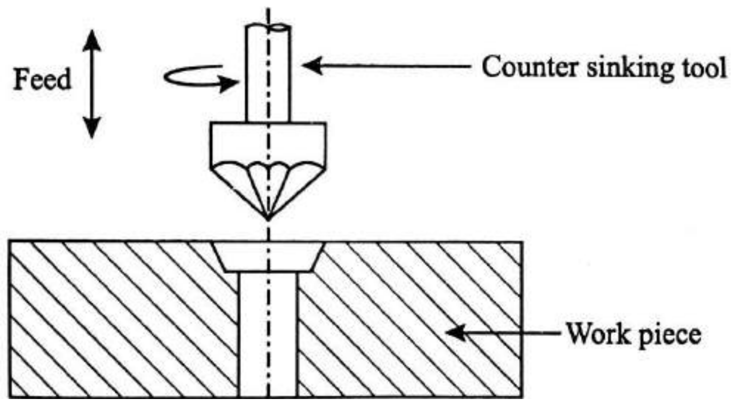


Fig. Counter-boring

- The counter-boring forms a larger sized recess or a shoulder to the existing hole.
- The cutting tool will have a small cylindrical projection known as pilot to guide the tool while counter-boring.
- The diameter of the pilot will always be equal to the diameter of the previously drilled hole. Interchangeable pilots of different diameters are also used for counterboring holes of different diameters.
- The speeds for counter-boring must be two-thirds of the drilling speed the corresponding size of the drilled hole.
- Generally, the counterboring is done on the holes to accommodate the socket head screws, or grooved nuts, or round head bolts.

e) Countersinking

- Countersinking is the operation of making the end of a hole into a conical shape. It is done using a countersinking tool shown in figure.
- The countersinking process may also be employed for deburring the holes. The cutting speeds for countersinking must be about one-half of that used for similar size drill.
- The countersunk holes are used when the countersunk screws are to be screwed into the holes so that their top faces have to be in flush with the top surface of the work-piece.



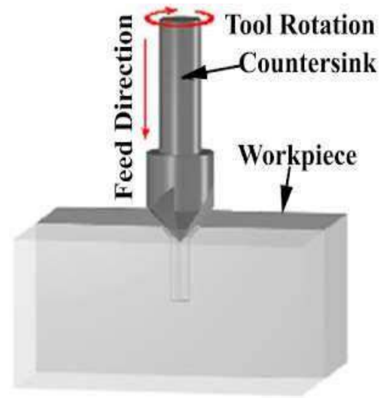


Fig. Countersinking

f) Spot Facing

- Spot facing is a finishing operation to produce a flat round surface usually around a drilled hole, to give a good bearing surface for the proper seating of a bolt head or a nut.
- The spot that is faced may be a circular raised pad on a casting or merely the surface around a bolt hole. Spot facing may be done with a counter-boring tool shown or using a special spot facing tool shown in Fig.

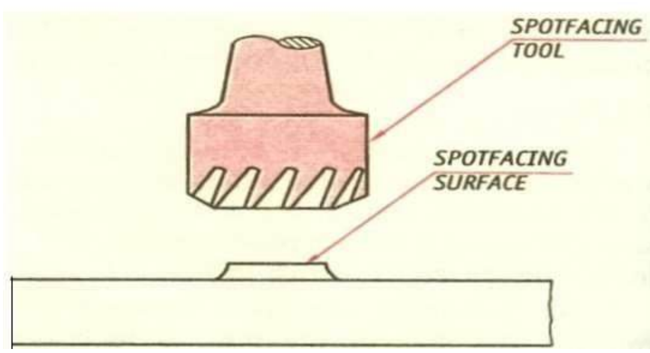


Fig. Spot facing

g) Tapping

- The tapping is the process of cutting internal threads with a thread cutting tool called tap.
- A tap is a fluted threaded tool used for cutting internal threads. Before tapping, a hole which is slightly smaller than the size of the tap is drilled.
- For cutting the threads, the tap is fitted in the tapping attachment which in turn is mounted in the drilling machine spindle, and the threads are cut in the same way as drilling.
- While tapping in a drilling machine the spindle has to rotate at very slow speeds. The tap will be held in a collapsible type of tapping chuck, which is inserted in the spindle of the drilling machine. Generally tapping is done on a drilling machine when identical threading is required on large number of parts.

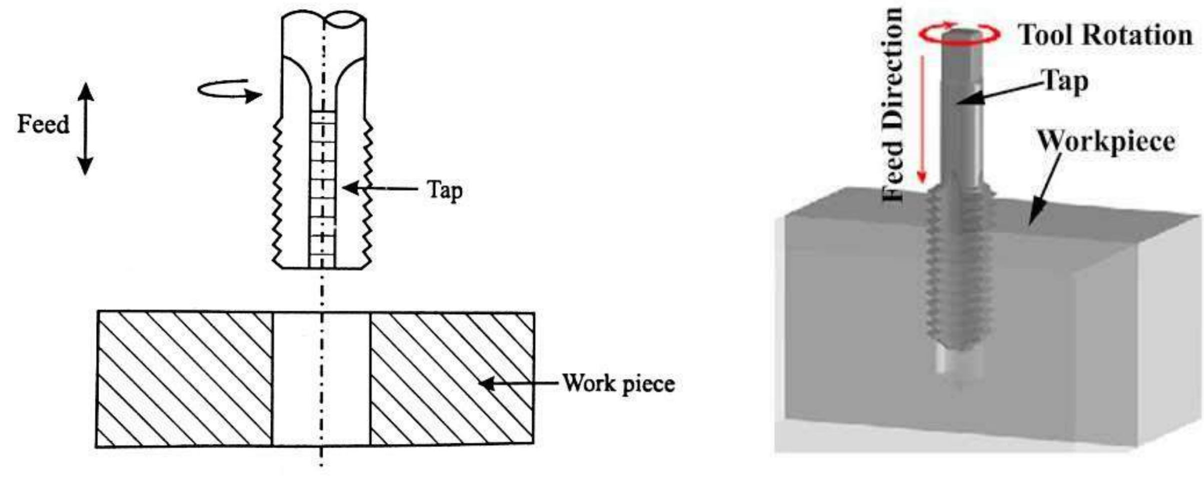


Fig. Tapping

2.14 CLASSIFICATION OF DRILLING MACHINES

- Drilling machines are classified according to their general construction and type of work they are required different to do. The types of drilling machines include:
  - a) Portable drilling machine
  - **b) Bench or Sensitive drilling machine**
  - **c) Radial drilling machine**
    - Plain radial drilling machine
    - Universal radial drilling machine
    - Semi-universal radial drilling machine
  - d) Upright drilling machine
    - Round column or Pillar drilling machine
    - Box column upright drilling machine
  - e) Multi-spindle drilling machine
  - f) Gang drilling machine
  - g) Automatic drilling machine
  - h) Deep hole drilling machine
  - i) Computer Numerical Control (CNC) drilling machine.

2.14.1 Bench (Sensitive) Drilling Machine

- Bench drilling machines are used for drilling small holes at high speeds in small sized work pieces. The diameter of the hole usually ranges from 1.5 mm to 15 mm.
- The machine is usually supported on a work-bench and hence the name bench drilling machine. Figure 2.14 shows the details of' a bench drilling machine. The machine consists of the following parts;

a) Base

- The base of the machine is made from cast iron material and supports the vertical column.
- The base is provided with holes to secure it firmly to the table or bench with the help of bolts shaft v-belt Stepped pulley and nuts.

b) Vertical column

- The column is a hollow steel pipe mounted rigidly on the base. It supports the drill head & worktable.

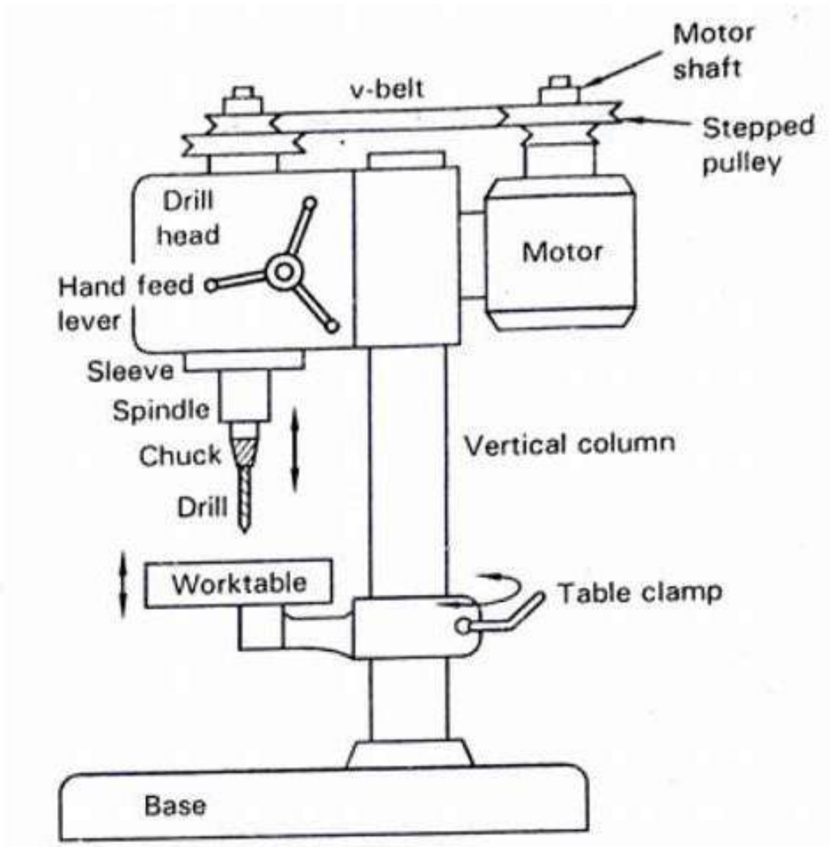


Fig. Bench or sensitive drilling machine

c) Worktable

- The worktable supports the work piece to be drilled.
- The table can be raised or lowered and can be clamped to the vertical column at any desired position.
- This helps to accommodate different sizes of workpiece on the table. The table can also be swiveled around the vertical column to any desired position, if need.

d) Drill head

- A fixed drill head located at the top end of the vertical column carries an electric motor and a mechanism through which the spindle can be made to rotate, as well as slide up and down.

- The top end of the spindle is connected to a stepped cone pulley which obtains power (rotary motion) from the motor shaft through a v-belt arrangement.
- The speed of the spindle can be varied by changing the belt position on the cone pulley. The lower end of the spindle carries a socket/drill chuck to hold the drill bit rigidly during operation. The vertical movement of the spindle and hence the drill bit, is controlled by the hand feed lever.

2.14.1.1 Specification of Bench (Sensitive) Drilling Machine

Bench or sensitive drilling machine is specified by one or more of the following criteria.

- Maximum diameter of the work that can be drilled.
- Power of motor
- Spindle speed and feed
- Weight of the machine, etc.

2.14.2 RADIAL DRILLING MACHINE

- Radial drilling machines are used for drilling medium or large diameter holes of up to 50 mm in heavy work pieces. Figure shows the principal parts of a radial drilling machine. The machine consists of the following parts:

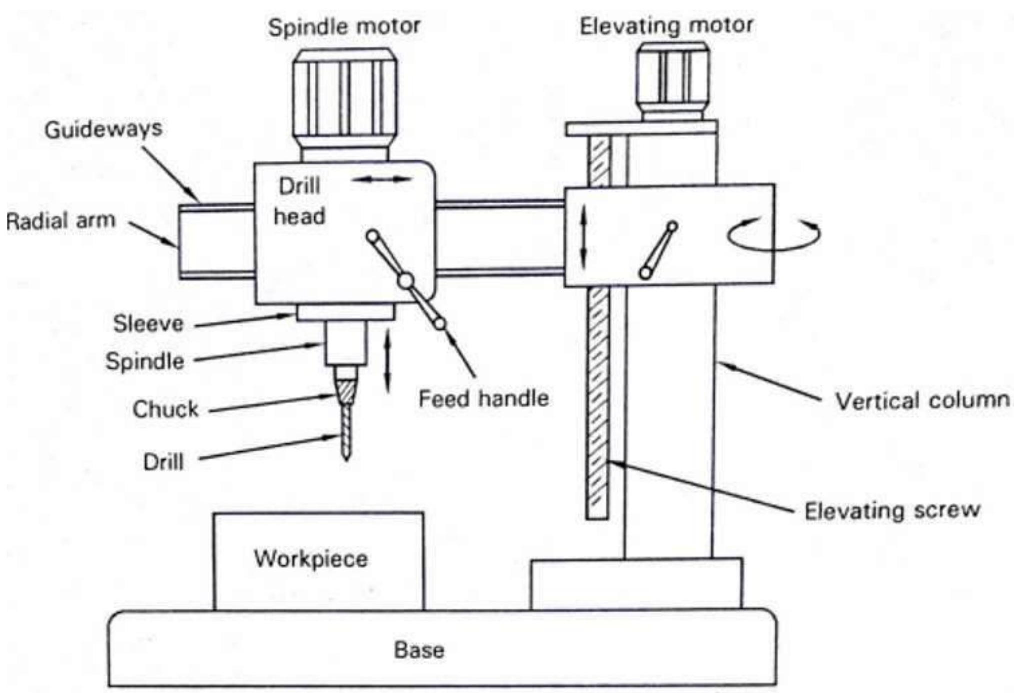


Fig. Radial drilling machine

a) Base

- The base of the machine is a large cast iron material on which is mounted a cylindrical vertical column.

- The base is provided with T-slots, which help the workpiece to be clamped rigidly to the base of the machine.

b) Vertical column

- The column is a long, cylindrical shaped part fastened rigidly to the base.
- The column carries a radial arm that can be raised or lowered by means of an electric motor and can be clamped to any desired position. The radial arm can also be rotated (swiveled) in a complete circle around the column.
- (A drill chuck holds the cutting tool of any size, whereas a socket is used to hold a tool of a particular shank size.)

c) Drill head

- The drill head is mounted on the radial arm and carries a driving motor and a mechanism for revolving and feeding (power feed) the drill bit into the work piece.
- The drill head can be moved horizontally on the guideways provided in the radial arm, and can be clamped to any desired position.
- With the combination of the movements of radial arm and the drill head, it is possible to move the drill bit and hence generate a hole at any desired position without moving the work piece.

2.14.2.1 Specification of Radial Drilling Machine

Radial drilling machine is specified by one or more of the following criteria.

- Length of arm
- Diameter of column
- Range of spindle speed and feed
- Motor power
- Drilling depth
- Weight of the machine, etc.

Cutting Speed, Feed and Depth of Cut

Cutting speed. It is the peripheral speed of a point on the surface of the drill in contact with the workpiece. It is usually expressed in metres per minute.

Mathematically, $$V_c = \frac{\pi D N}{1000}.$$

where, V_c = Cutting speed (surface), m/min,

D = Diameter of the drill, mm, and

N = Rotational speed of the drill, r.p.m.

The *cutting speed* depends upon the following factors :

(*i*) The type of material being drilled.

(*ii*) Cutting tool material.

(*iii*) The quality of hole desired.

(*iv*) The efficient use of cutting fluid.

(*v*) The way in which the work is set up or held.

(*vi*) The size and type of drilling machine.

FEED (*f*)

Feed (*f*). It is the distance the drill moves into the work at each revolution of the spindle. It is expressed in mm/rev. It may also be expressed as feed per minute.

The correct feeds for different sizes of drill are given below :

Drill size, mm	Feed, mm/rev
3.2 and less	0.025—0.050
3.2 to 6.4	0.050—0.10
6.4 to 12.7	0.10—0.18
12.7 to 25.4	0.18—0.38
25.4 and large	0.38—0.64

— A twist drill gives satisfactory performance if it is run at correct cutting speed and feed. The following factors help in running the drill at correct cutting speed and feed :

(*i*) The drill is correctly selected and ground for the material being cut. The selection of drill depends upon the following factors :

(*a*) Size of drill hole ;

(*b*) Material of workpiece ;

(*c*) Point angle of drill.

(*ii*) The work is rigidly clamped

(*iii*) The machine is in good condition

(*iv*) A coolant is used if required.

— The rates of feed and cutting speed for twist drill are lower than most other machining operation because of the following *reasons* :

(*i*) The twist drill is weak compared with other cutting tools.

(*ii*) It is relatively difficult for the drill to eject chips.

(*iii*) It is difficult to keep the cutting edges cool when they are enclosed in the hole.

Depth of Cut (d)

Depth of cut (d). It may be defined as the distance from the machined surface to the drill axis. That is,

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

- The choice of operating conditions in drilling operations becomes more critical with increase in the hole depth. As the depth of hole increases, (*i*) the chip ejection becomes more difficult, and (*ii*) the fresh cutting fluid is not able to reach to the cutting zone. These factors lead to overheating of the drill and shortens its life. Hence, for *machining of lengthy holes, reduced feeds are used.*

— For machining holes of very large length, a special type drilling process, known as *gun drilling* is used. By this process, it is possible to machine the holes having length greater than 300 times of the diameter.

Machining time in Drilling

Machining time, $$t_m = \frac{L_j + l_1 + l_2}{fN}, \text{ min}$$

where, L_j = Hole length or depth mm,

l_1 = Tool approach ≈ 0.29 D (with point angle of 118°), and

l_2 = Tool overtravel, 1 to 2 mm.

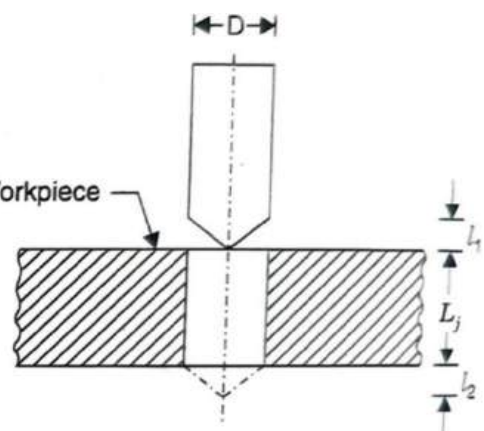


Fig. . Drilling operation.

Material Removal Rate

The material removal rate is indicated by the total volume of the material in the hole. In the case of a solid material without coring, the material removal rate *MRR* is given by the *area of cross-section of the hole times the tool travel rate through the material.* Thus

$$MRR = \frac{\pi D^2 f N}{4} \text{ mm}^3/\text{min}$$

where, D = Drill diameter, mm,
f = Feed, mm/rev, and
N = Rotational speed of the drill, r.p.m.

EXAMPLE 1)

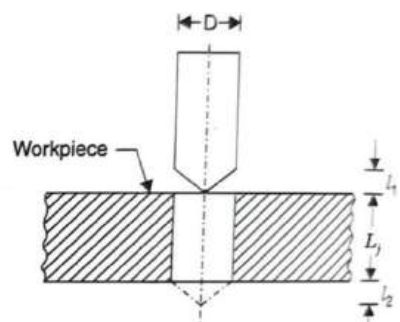
A hole of 30 mm diameter and 75 mm depth is to be drilled. The suggested feed is 1.3 mm per rev. and the cutting speed is 62 m/min. Assuming tool approach and tool overtravel as 6 mm, calculate;

(i) Spindle r.p.m.
(ii) Feed speed.
(iii) Cutting time.
(iv) Material removal rate.

Given data:

$D = 30$ mm ; $L_j = 75$ mm ; $f = 1.3$ mm/rev ;

$V_c = 62$ m/min ; $l_1 + l_2 = 6$ mm



Solution

(*i*) **Spindle r.p.m :**

$$V_c = \frac{\pi D N}{1000}$$

$$\text{Spindle r.p.m.} = \frac{1000 V_c}{\pi D} = \frac{1000 \times 62}{\pi \times 30}$$

$$= \mathbf{658 \text{ r.p.m.}}$$

(ii) **Feed speed :**

$$\text{Feed speed} = fN = 1.3 \times 658 = \mathbf{855.4\ mm/min.}$$

(iii) **Cutting time :**

$$t_m = \frac{L}{fN} = \frac{L_j + l_1 + l_2}{fN} = \frac{(75+6)}{1.3 \times 658} = \mathbf{0.095\ min.}$$

(iv) **Material removal rate :**

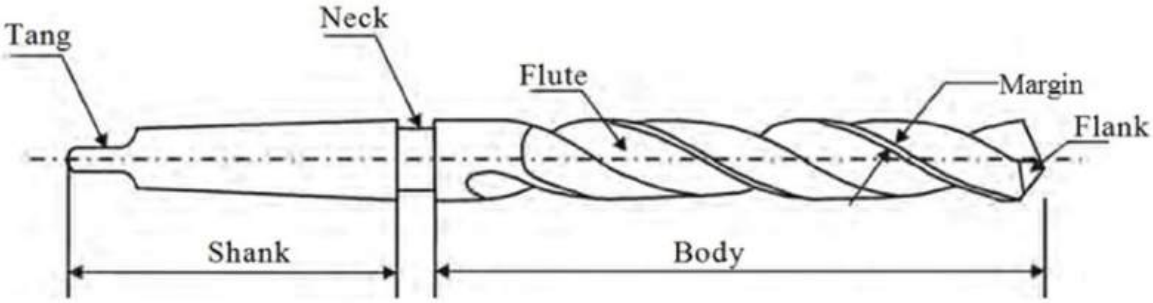
$$\text{MRR} = \frac{\pi D^2 \times f \times N}{4} = \frac{\pi \times (30)^2 \times 1.3 \times 658}{4} = \mathbf{60.4647 \times 10^4\ mm^3/min.}$$

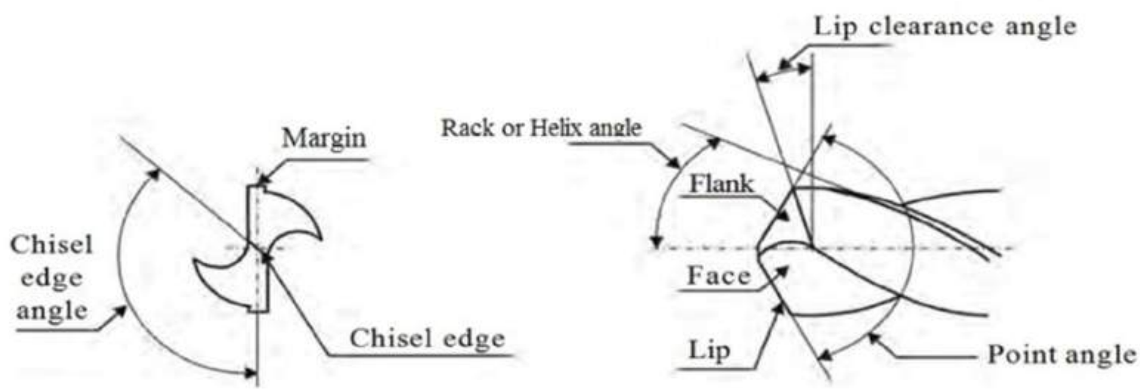
Example 2)

A hole of 40 mm diameter and 80 mm depth is to be drilled. The suggested feed is 1.3 mm per rev. and the cutting speed is 70 m/min. Assuming tool approach and tool overtravel as 6 mm, calculate;

- (i) Spindle r.p.m.
- (ii) Feed speed.
- (iii) Cutting time.
- (iv) Material removal rate.

TWIST DRILL NOMENCLATURE





- **Axis**: It is the longitudinal center-line of the drill.
- **Diameter:** Largest diameter measured across the top of the lands behind the point.
- **Back Taper**:
  - ✓ The diameter reduces slightly toward the shank end of the drill, this is known as "back taper".
  - ✓ Back taper provides clearance between the drill and work-piece preventing friction and heat.
- **Body**: It is the part of the drill from its extreme point to the commencement of the neck.
- **Neck :** The portion with reduced diameter in between body and shank.
- **Shank :** It is the part of the drill by which it is held and driven. The shank may be straight or taper.
- **Tang :** The flattened end of the taper shank is known as tang.
- **Point :** It is the conical sharpened end of the drill.
- **Flank :** Surface of drill which extends behind the lip to flute.
- **Flutes :** The grooves in the body of the drill are known as flutes.
- **Flute Length:**
  - ✓ The length of flute measured from the drill point to the end of the flute run out.
  - ✓ Flute length determines the maximum depth of drilling.
- **Margins:** The cylindrical portion of the land that is not cut away to provide clearance.

- **Helix Angle:** Angle formed between a line drawn parallel to the axis of the drill and the edge of the land. (30° or 45°)
- **Point angle :** This is the angle included between the two lips projected upon a plane parallel to the drill axis and parallel to the two cutting lips. (118°).
- **Chisel Edge :** it is the point where two cutting lips meets at extreme tip.
- **Chisel Edge Angle :** Angle between chisel edge and cutting lip measured plane normal to axis.

Classification of Drills

The tool used for drilling is called a drill. The commonly used drills may be classified in several ways as follows

1. *According to the type of shank* :
   (*i*) Parallel shank.
   (*ii*) Taper shank.
2. *According to the type of flutes* :
   (*i*) Flat or spade drills (parallel longitudinal flutes)
   (*ii*) Twist drills (spiral/helical fultes)
3. *According to length.*
   (*i*) Short series drills.
   (*ii*) Stub series drills.
   (*iii*) Long series drills.
4. *According to applications* :
   (*i*) Core drills.
   (*ii*) Drills for long hole drilling.
   (*iii*) Centre drills.
   (*iv*) Masonry drills.
5. *According to the tool material* :
   (*i*) High speed steel drills.
   (*ii*) Carbide tipped drills.

2.21 GRINDING

- Grinding is a process of removing excess material from the workpiece by the mechanical action of abrasive particles that are held together by an adhesive, generally in the form of a solid wheel.
- The wheel known as grinding wheel is rotated at high speeds, and when the surface of the rotating wheel is brought in contact with the workpiece, material is removed in the form of fine chips.
- The depth of cut is obtained by the downward movement of the grinding wheel, or in some machines the worktable carrying the workpiece is raised towards the grinding wheel. Figure 2.21(a) shows the grinding process.

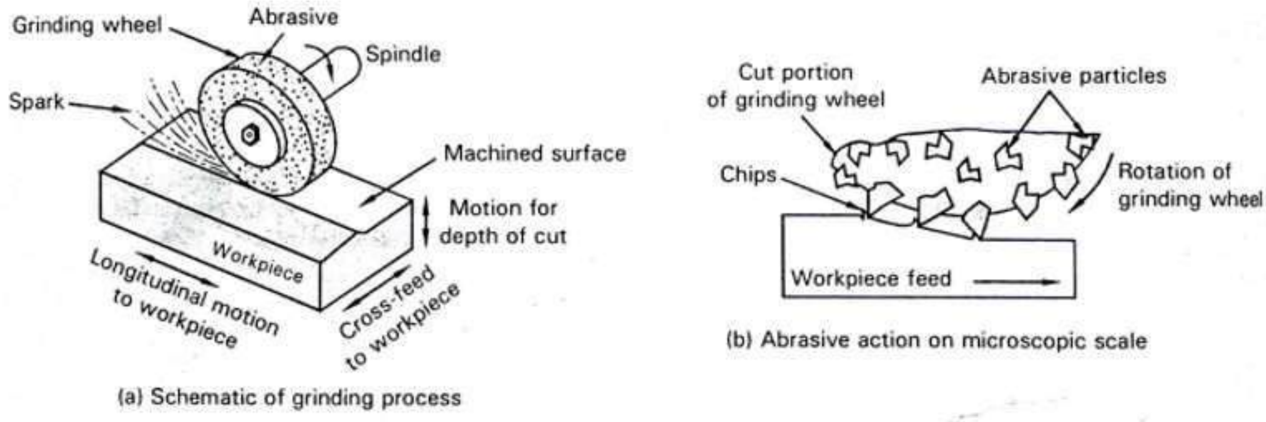


Fig. 2.21 Grinding process

- On a microscopic scale, the chip formation in grinding is similar to other manufacturing process like turning, milling etc. Refer figure 2.21(b).
- But, the process removes very little material in the form of fine chips when compared to that of turning, milling or drilling, and this makes it to be called a finishing process.
- Since the material from the workpiece is removed in the form of fine chips, the process tends to be slower towards achieving ne desired size and finish.
- For this reason, other manufacturing methods like turning, milling etc., are used to bring the workpiece close to its final size and then the workpiece is ground to achieve the desired surface finish and tolerance.

Reasons for selecting grinding process.

Grinding operation is selected when:

i. the workpiece material is too hard to be machined economically by other processes like turning, milling etc.

ii. the required surface finish and dimensional tolerance cannot be easily achieved by other manufacturing process.

Applications of Grinding

- Grinding is employed to produce a workpiece of high accuracy and surface finish.

- Automobile camshafts, jet engine rotors, bearings and various other parts are machined and finished to accurate size and shape.
- Materials from rubber hardest carbides and even composite materials can be machined by grinding process.
- Grinding is also used to cut steel and masonry block; sharpen knives, drill bits and many other tools; to clean and prepare surfaces for painting and plating.

2.22 GRINDING PROCESSES

The three common grinding processes, viz., surface grinding, cylindrical grinding & centerless grinding are briefed herein.

1) Surface grinding

- Surface grinding is a machining process primarily carried out for producing a flat surface of the desired finish as shown in figure 2.22.
- However, with the use of special fixtures and form dressing devices, angular and formed (curved) surfaces can also be finished.
- In operation, the work piece is secured firmly on the worktable by means of a magnetic chuck, vice, etc., and the grinding wheel is brought in contact with the surface of the workpiece.
- The abrasive action of the grinding wheel on the surface of the workpiece causes material to be removed from it in the form of fine chips.
- Longitudinal feed to the work piece is given by reciprocating the worktable, and after each longitudinal feed, cross-feed is given so as to finish the workpiece all along its width.
- Vertical downward movement of the wheel, or in some machines, upward movement of the workpiece gives the required depth of cut.

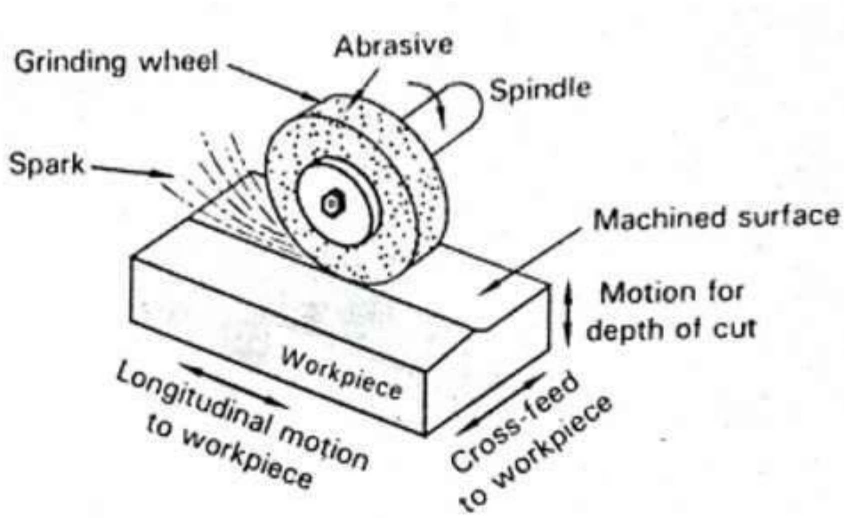


Fig. 2.22(a) Surface grinding (Isometric View)

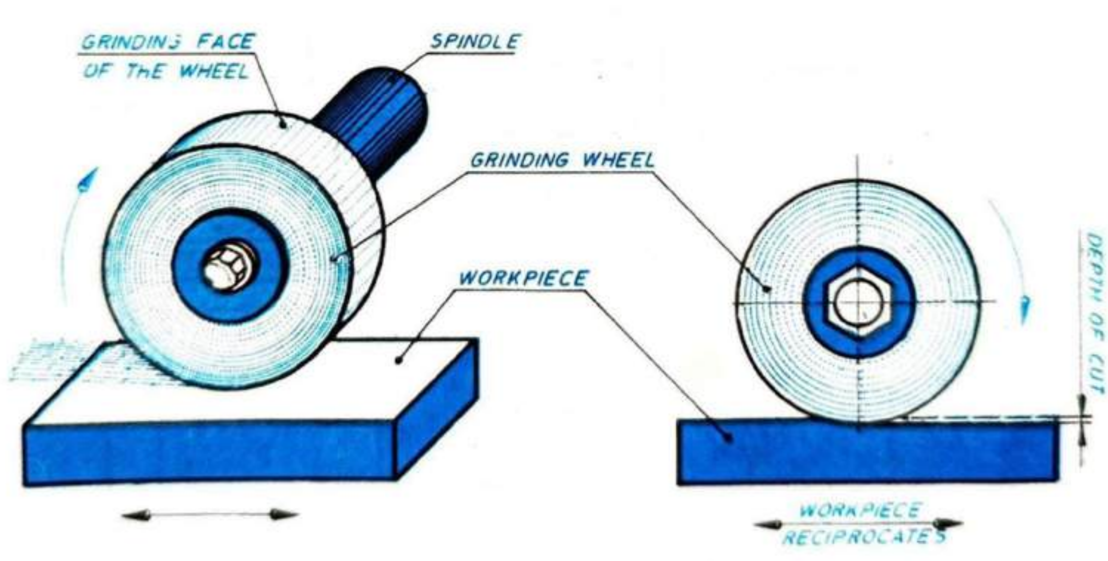


Fig. 2.22(b) Surface grinding

2) Plain cylindrical grinding

- Grinding wheel Plain cylindrical grinding is a machining process for grinding external cylindrical surfaces of single and multi-diameter shafts as shown in figure 2.23.
- The cylindrical workpiece to be ground is held and rotated between Support two centers of the machine.
- The grinding wheel is made to rotate at a comparatively higher speed, in a direction opposite to that of the workpiece.
- The workpiece is given longitudinal feed by reciprocating the worktable, while infeed is provided by moving the grinding wheel head at right angles to the longitudinal axis of the table resulting in depth of cut.

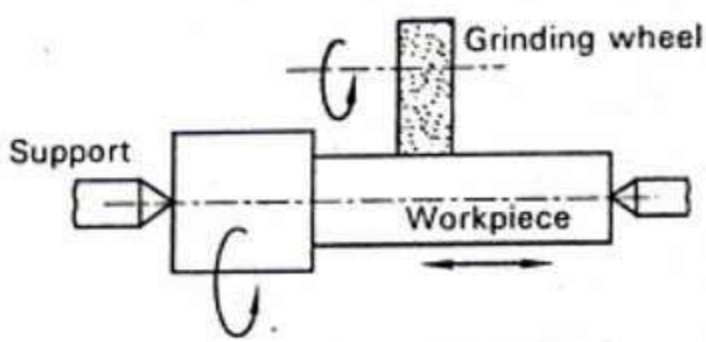


Fig. 2.23 Cylindrical grinding

3) Centerless grinding

- Centerless grinding is a machining process for grinding surfaces of long, slender rods that cannot be held and rotated between centers as is in the case of plain cylindrical grinding. As shown in figure 2.24, the workpiece is supported by the combination of grinding wheel, work rest blade, and the regulating wheel.

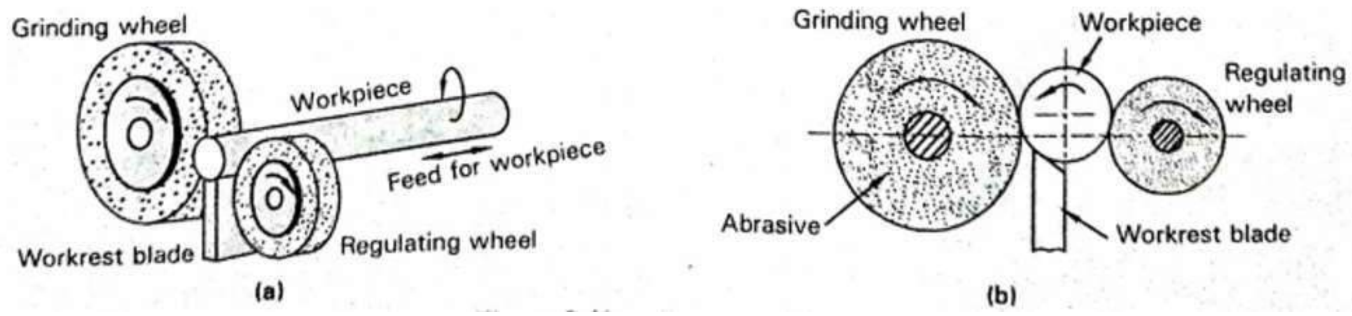


Fig. 2.24 Centerless grinding

- The grinding wheel is larger in diameter and rotates at higher speeds when compared to regulating wheel.
- Both the wheels rotate in clockwise direction, while the workpiece driven by the regulating wheel rotates in the counter-clockwise direction. The grinding operation is performed by the grinding wheel only.
- The function of the regulating wheel is to control (slow) the speed of rotation of the workpiece, so that it does not rotate at the same speed as the grinding wheel.
- The regulating wheel also controls the longitudinal motion of the workpiece, or rate of feeding of the workpiece past the grinding wheel.

Type of grinding Machine

The different type of grinding Machines are listed below

1) Surface Grinding Machine
2) Cylindrical Grinding Machine
3) Centreless Grinding Machine

1) Surface Grinding Machine

- The Surface Grinding Machine used to grind flat surfaces.
- Here, the job is mounted on a rectangular table which moves longitudinally as well as in the transverse direction below the rotating grinding wheel.
- The longitudinal and transverse feed movements can he accomplished either by manual feed or through power feed arrangement.

- The workpiece can he clamped in two ways; one is by clamping it to the work table by means of clamping elements; the other way is by using a magnetic chuck which holds the workpiece through its strong magnetic field.

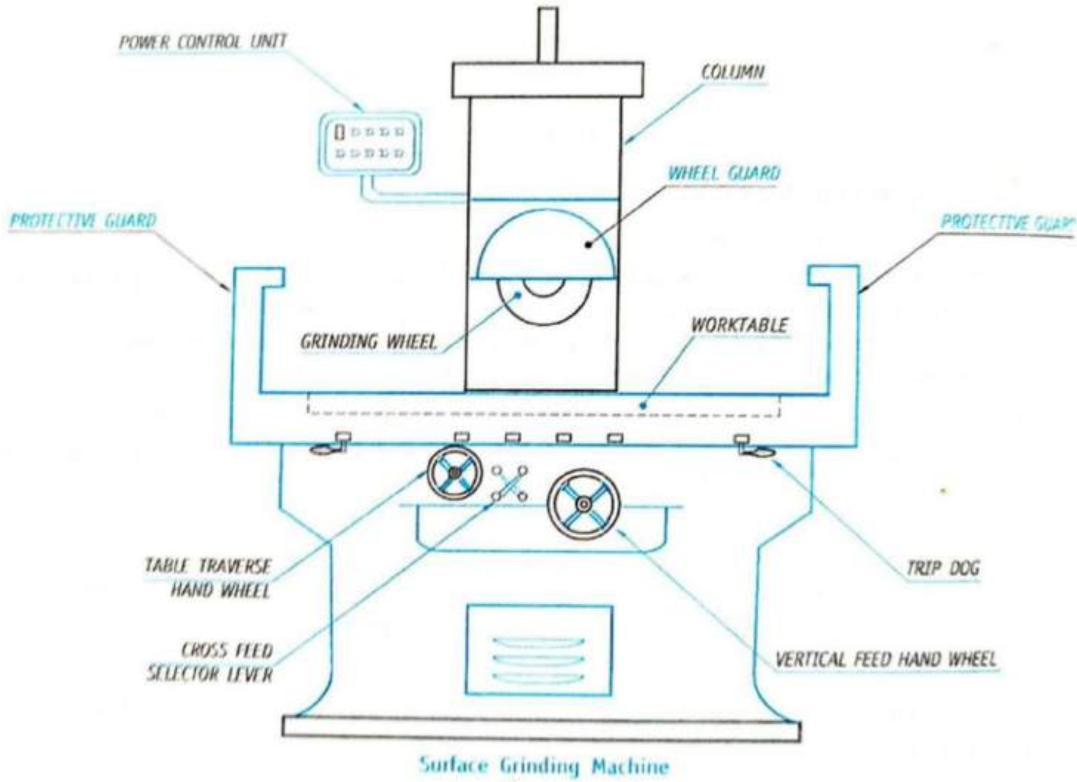


Fig. Surface Grinding Machine

- There is an internal pump and a piping arrangement to take care of automatic application and recirculation of the coolant.
- There is a protective safety guard at the end of the table to prevent the wheel from hitting any person or object.
- Fig. shows a typical surface grinding machine

2) Cylindrical Grinding Machine

- Cylindrical grinding is the process of grinding the curved surfaces of cylindrical pieces.
- These surfaces may be straight, tapered or contoured. Fig shows a typical Cylindrical grinding machine.
- The workpiece is mounted on the two centres , one is the tailstock centre and the other is the headstock centre.
- The tailstock centre is the dead centre and the headstock centre may or may not revolve during grinding.

- When high accuracy is required the two supporting centres must remain stationary when the workpiece revolves.

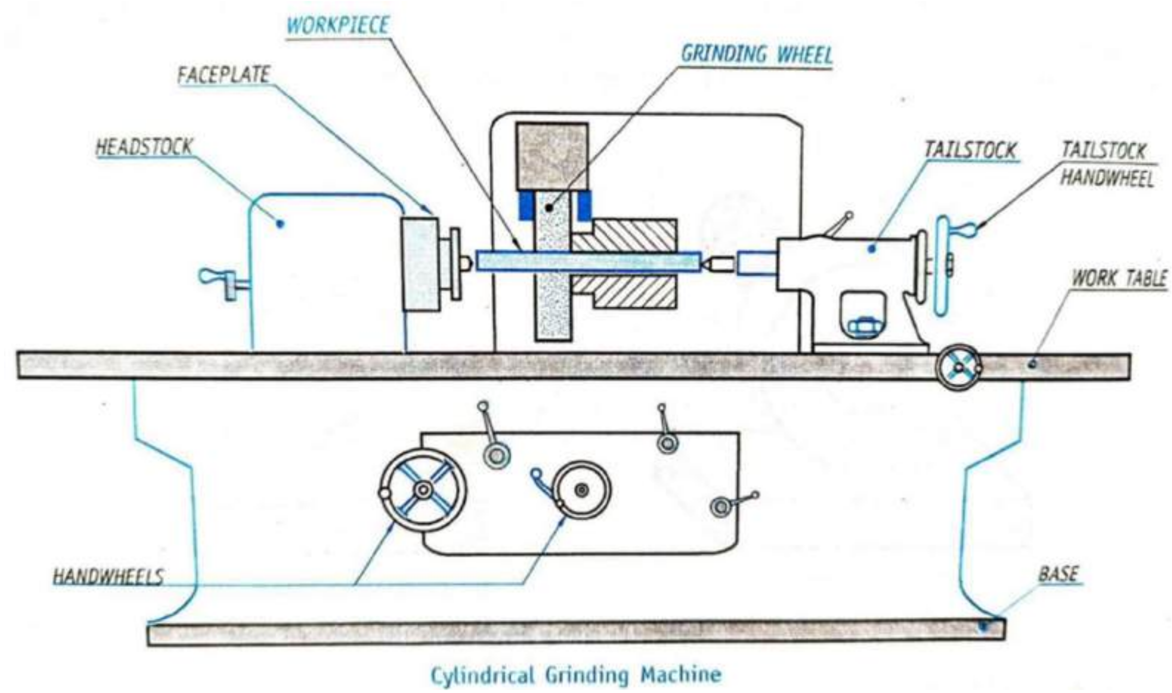


Fig. Cylindrical grinding Machine

- When both centres are dead, precision sizes and good finish can be obtained, because there is no possibility of runout from the headstock spindle.
- As the workpiece revolves, the grinding wheel rotating much faster in the opposite direction is brought into contact with the workpiece.
- The workpiece and the table reciprocate while the grinding wheel in contact with the workpiece removes the material.

3) Centreless Grinding Machine

- Centreless grinding method also employed for grinding the curved surfaces of long slender rods which cannot be ground by cylindrical grinding due to the lateral thrust of the wheel on the workpiece.
- Centreless grinding method also employed for grinding the curved surfaces of long slender rods which cannot be ground by cylindrical grinding due to the lateral th rust of the wheel on the workpiece.
- In the centreless grinding, shown in Figure. the workpiece rests on a work-rest blade, and is backed up by a second wheel, called the regulating wheel.
- The rotation of the grinding wheel pushes the workpiece down on the work-rest blade and against the regulating wheel.

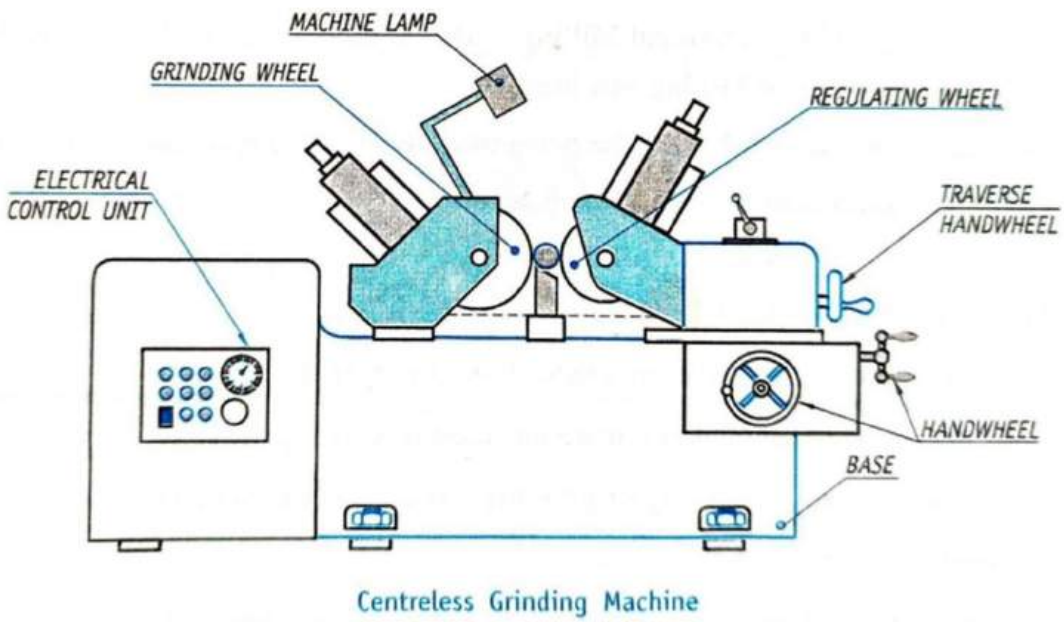


Fig. Centreless Grinding Machine

- The regulating wheel, usually made up of a rubber bonded abrasive, rotates in the same direction as the grinding wheel and controls the longitudinal feed of the workpiece. A typical centerless grinding machine is shown in Fig.

2.16 SHAPING MACHINE

- Shaping is a machining process of removing the excess material from the workpiece by means of a single-point cutting too held in a reciprocating ram.
- The process is employed to produce flat surfaces (horizontal, vertical, or inclined), grooves, T slots, dovetails, and may also be used to produce contoured surfaces with the use of copying attachments.
- The machine used for performing the operation is called shaping machine or shaper. Figure shows the principle of operation on a shaping machine.
- In operation, the workpiece is clamped rigidly on the machine table, and a single-point cutting tool is held in the tool post mounted on the ram of the shaping machine.
- The ram reciprocates the tool to and fro across the workpiece as shown in figure (a). Hence, the ram makes two strokes during the cutting process. These two strokes are called cutting stroke and return stroke as shown in figure (b) and (c).

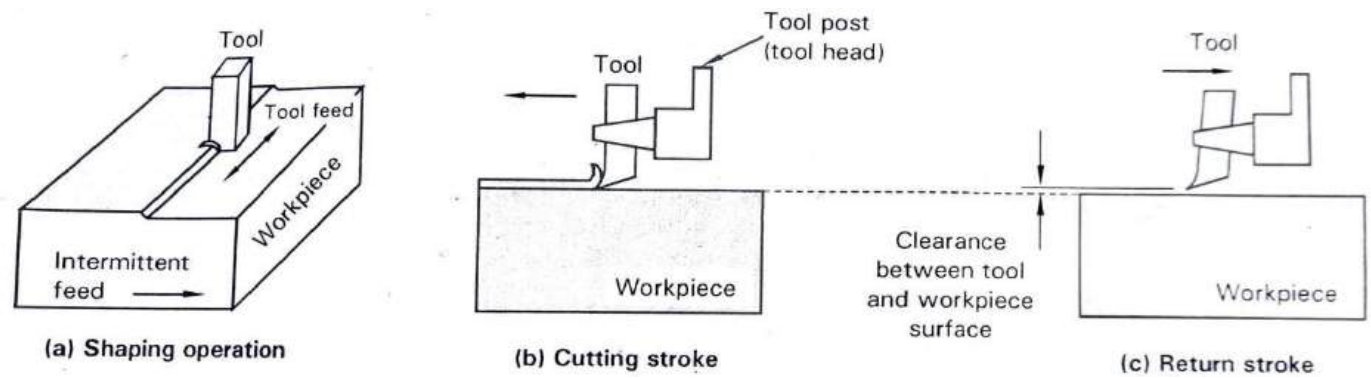


Fig. Principle of shaping

- During cutting stroke, the tool moves in the forward direction, during which it cuts a small thin strip of metal from the workpiece as shown in figure (b).
- No cutting of material takes place during the return stroke* of the ram and hence, this stroke is also called idle stroke.
- During return stroke, the tool is lifted clear of the workpiece, reducing the cutting action to one direction only. Refer figure (c).
- The workpiece is given an indexed feed (equal amount after each cut) in a direction perpendicular to the line of action of the cutting tool.
- Shaping is a relatively simple process used often in the tool room, or for machining one or two pieces for prototype work. Tooling is simple, and the machine does not always require operator attention while cutting.

  (* In draw-cut type of shaping machine, cutting operation takes place during the return stroke of the ram.)

CLASSIFICATION OF SHAPING MACHINE (SHAPER)

Shapers may be classified according to:

a) Design of work table
   - Standard shaper
   - Universal shaper

b) Driving mechanism
   - Crank shaper
   - Geared shaper
   - Hydraulic shaper

c) Design of travel of ram
   - Horizontal shaper
   - Vertical shaper
   - Traveling head shaper

d) Nature of cutting stroke

- Push cut shaper
- Draw cut (pull type) shaper

2.16.1 Constructional Features of Horizontal Shaper

Below Figure shows the principal parts of a horizontal shaper. It consists of the following parts:

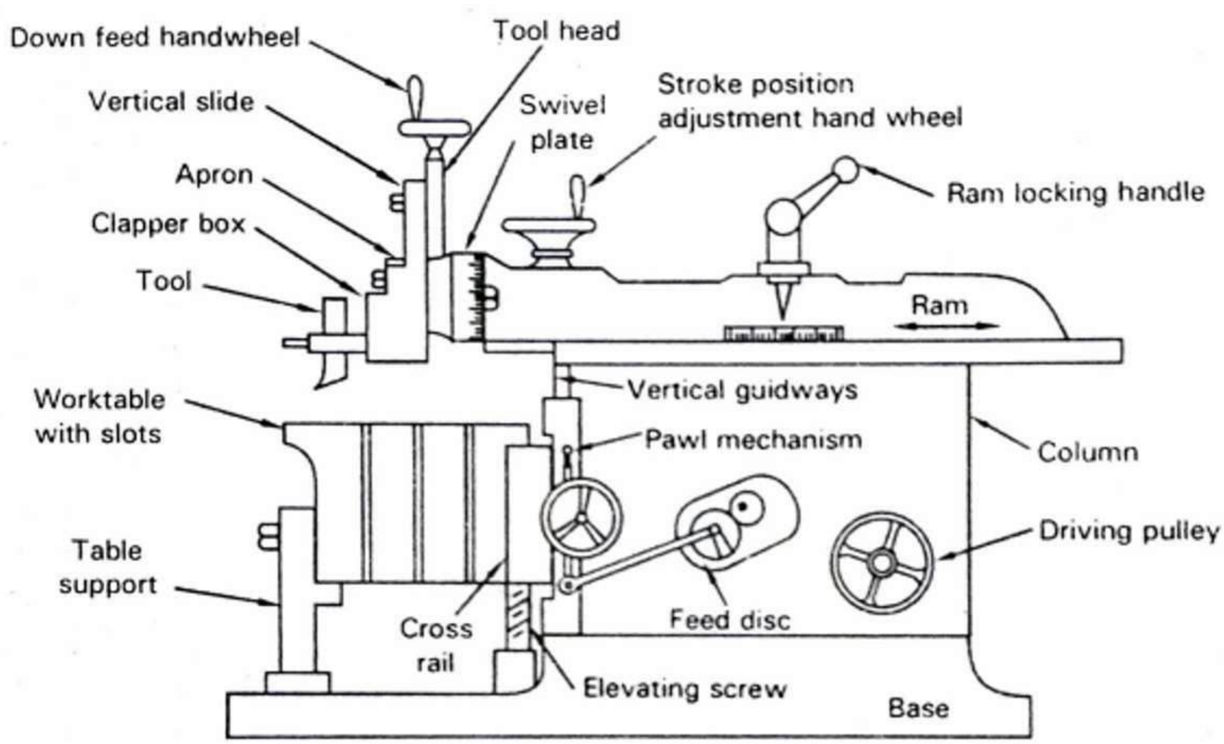


Fig. Horizontal shaping machine

a) Base

- The base is a heavy cast iron body that supports the entire weight of the machine parts, and also the forces generated during the machining process.
- The base is secured rigidly to the floor with the help of foundation bolts and nuts.

b) Column

- The column is a rigid hollow casting mounted on the base.
- It houses the driving motor, control devices, and the mechanism for driving the ram & the worktable.
- The column carries horizontal guideways at its top on which the ram reciprocates, and vertical guideways at its front face on which the cross-rail slides.

c) Cross-rail

- The cross-rail mounted on the front vertical guideways of the column can be raised up and down by means of an elevating screw to accommodate workpiece of different heights,

- The cross-rail is provided on its front face with horizontal guideways, which is perpendicular to the ram movement.

d) Worktable

- The worktable is a box shaped casting that can slide on the horizontal and vertical guideways of the cross-rail.
- The front face of the table is supported by an adjustable table support to withstand the weight of the workpiece and the cutting action during operation.

e) Ram

- The ram is a rigidly braced casting, and of semi-cylindrical form located on the top of the column.
- The ram reciprocates on the guideways provided on top of the column by means of a slotted link mechanism. The cutting tool is attached to the ram via a tool holder and head.

f) Tool head

- The tool head mounted at the front end of the ram, holds the tool and imparts the tool, the necessary vertical and angular feed movements.
- Vertical movement of tool that provides the depth of cut is achieved by moving the vertical slide downwards by means of tool feed handle, and angular movement for machining angular surfaces is achieved by unbolting and tilting the swivel plate to the desired angle.
- The apron carries the clapper box. which allows the cutting tool to be lifted upwards* during the return stroke of the ram, thereby preventing the scratching of the tool on the job.

(*Cutting action takes place when the ram moves in the forward direction only. When the ram moves in the backward direction the tool is lifted slightly upwards by means of clapper box in order to prevent cutting action.)

SPECIFICATION OF SHAPER

<u>The size of the shaper is specified by one of the following criteria:</u>

- ✓ Maximum stroke length of ram
- ✓ Maximum travel of worktable in horizontal and vertical direction
- ✓ Dimensions of table working surface
- ✓ Distance between table surface and ram
- ✓ Motor power
- ✓ Overall dimensions, etc.

Shaper Operations

Steps in making a block square & parallel

1. Remove all dirt and burrs from the work piece and the vise.
2. Vise jaws should be perpendicular to the line of motion of ram.
3. Tool should be vertical.
4. Set the work piece in the vise with parallel blocks at the bottom.
5. All cutting force should be against the fixed jaw of the vise.
6. Machine the side 1. (It is the surface having the largest area)
7. Machine side 2, with side 1 resting against the fixed jaw.
8. Machine side 3, opposite to side 2 with side 1 resting against the fixed jaw.
9. Machine side 4, opposite to side 1.
10. Then machine the two edges side 5 & 6.