Drilling

Introduction

Drilling machine is one of the most important machine tools in a workshop. It was designed to produce a cylindrical hole of required diameter and depth on metal workpieces. Though holes can be made by different machine tools in a shop, drilling machine is designed specifically to perform the operation of drilling and similar operations. Drilling can be done easily at a low cost in a shorter period of time in a drilling machine. Drilling can be called as the operation of producing a cylindrical hole of required diameter and depth by removing metal by the rotating edges of a drill. The cutting tool known as drill is fitted into the spindle of the drilling machine. A mark of indentation is made at the required location with a centre punch. The rotating drill is pressed at the location and is fed into the work. The hole can be made upto a required depth.

Construction of a drilling machine

- The basic parts of a drilling machine are a base, column, drill head and spindle. The base made of cast iron may rest on a bench, pedestal or floor depending upon the design. Larger and heavy duty machines are grounded on the floor. The column is mounted vertically upon the base. It is accurately machined and the table can be moved up and down on it. The drill spindle, an electric motor and the mechanism meant for driving the spindle at different speeds are mounted on the top of the column. Power is transmitted from the electric motor to the spindle through a flat belt or a ‘V’ belt.

Types of drilling machines

Drilling machines are manufactured in different types and sizes according to the type of operation, amount of feed, depth of cut, spindle speeds, method of spindle movement and the required accuracy. The different types of drilling machines are:

1. Portable drilling machine (or) Hand drilling machine
2. Sensitive drilling machine (or) Bench drilling machine
3. Upright drilling machine
4. Radial drilling machine
5. Gang drilling machine
6. Multiple spindle drilling machine
7. Deep hole drilling machine

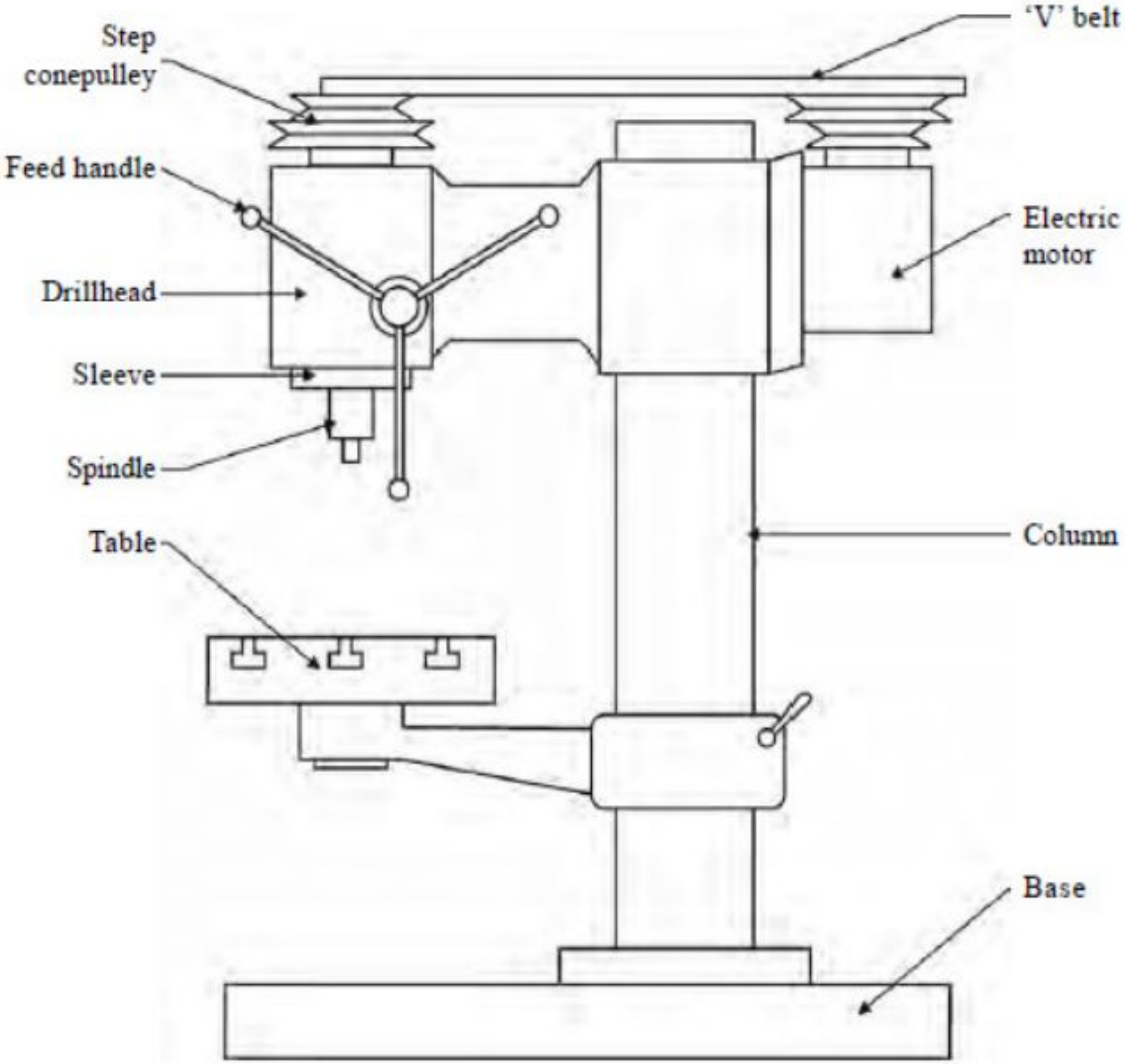
Portable drilling machine

- Portable drilling machine can be carried and used anywhere in the workshop. It is used for drilling holes on workpieces in any position, which is not possible in a standard drilling machine.
- The entire drilling mechanism is compact and small in size and so can be carried anywhere. This type of machine is widely adapted for automobile built-up work.
- The motor is generally universal type. These machines can accommodate drills from 12mm to 18 mm diameter. Portable drilling machines are operated at higher speeds.

Sensitive drilling machine

- It is designed for drilling small holes at high speeds in light jobs. High speed and hand feed are necessary for drilling small holes. The base of the machine is mounted either on a bench or on the floor by means of bolts and nuts. It can handle drills upto 15.5mm of diameter. The drill is fed into the work purely by hand. The operator can sense the progress of the drill into the work because of hand feed. The machine is named so because of this reason. A sensitive drilling machine consists of a base, column, table, spindle, drill head and the driving mechanism

Sensitive drilling machine



Sensitive drilling machine

- Base

The base is made of cast iron and so can withstand vibrations. It may be mounted on a bench or on the floor. It supports all the other parts of the machine on it.

- Column

The column stands vertically on the base at one end. It supports the work table and the drill head. The drill head has drill spindle and the driving motor on either side of the column.

- Table

The table is mounted on the vertical column and can be adjusted up and down on it. The table has ‘T’-slots on it for holding the workpieces or to hold any other work holding device. The table can ` Study of Machine Tools – Drilling Machine Page 3 be adjusted vertically to accommodate workpieces of different heights and can be clamped at the required position.

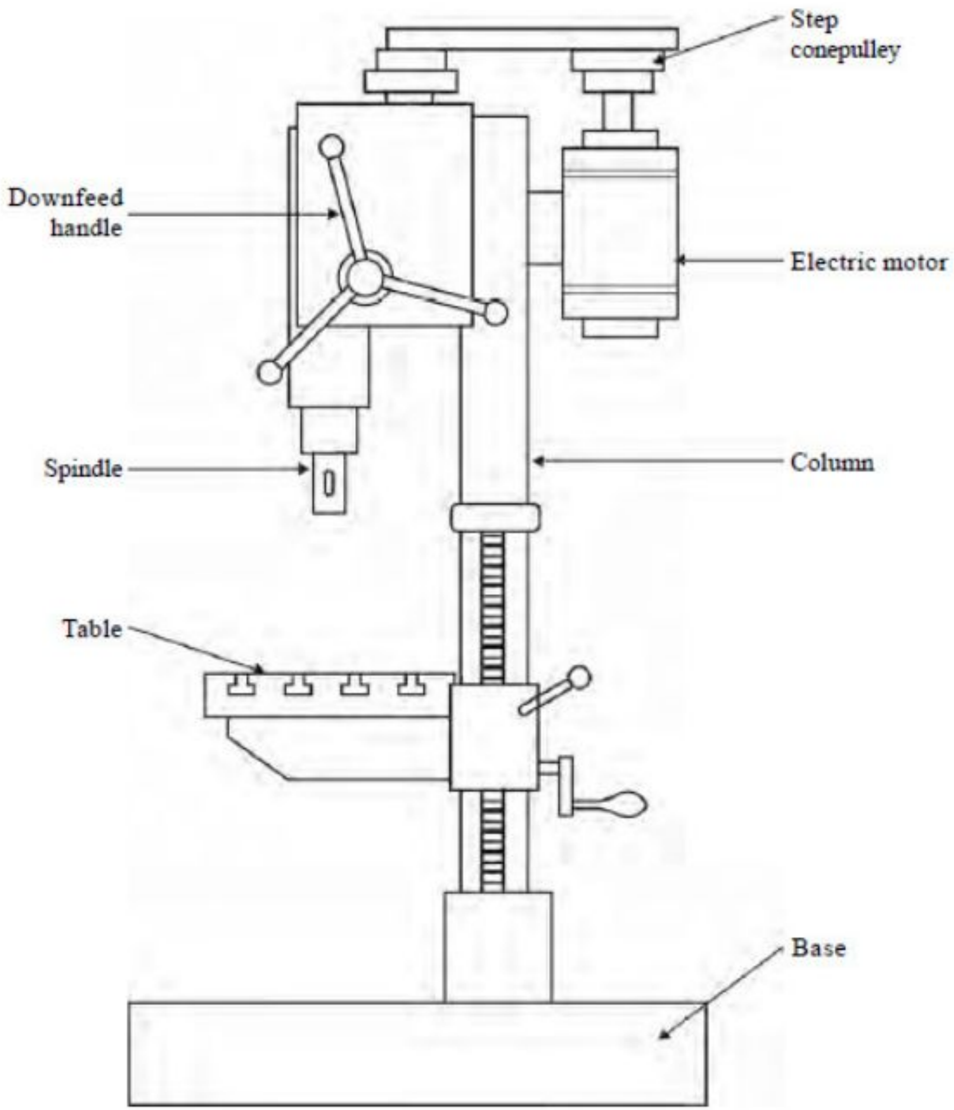
- Drill head

Drill head is mounted on the top side of the column. The drill spindle and the driving motor are connected by means of a V-belt and cone pulleys. The motion is transmitted to the spindle from the motor by the belt. The pinion attached to the handle meshes with the rack on the sleeve of the spindle for providing the drill the required down feed. There is no power feed arrangement in this machine. The spindle rotates at a speed ranging from 50 to 2000 r.p.m.

Upright drilling machine

The upright drilling machine is designed for handling medium sized workpieces. Though it looks like a sensitive drilling machine, it is larger and heavier than a sensitive drilling machine. Holes of diameter upto 50mm can be made with this type of machine. Besides, it is supplied with power feed arrangement. For drilling different types of work, the machine is provided with a number of spindle speeds and feed.

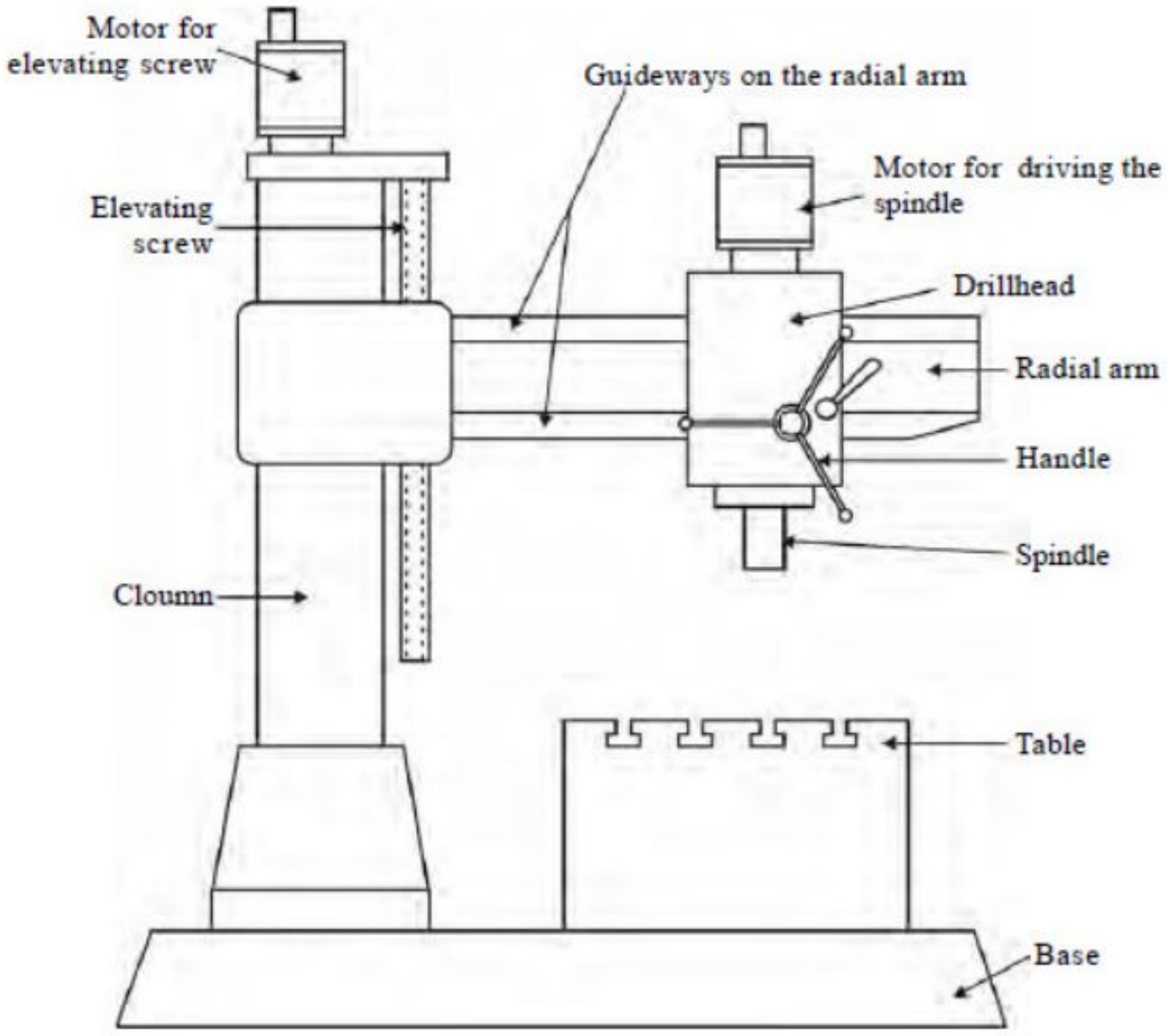
Upright drilling machine



Radial drilling machine

The radial drilling machine is intended for drilling on medium to large and heavy workpieces. It has a heavy round column mounted on a large base. The column supports a radial arm, which can be raised or lowered to enable the table to accommodate workpieces of different heights. The arm, which has the drill head on it, can be swung around to any position. The drill head can be made to slide on the radial arm. The machine is named so because of this reason. It consists of parts like base, column, radial arm, drill head and driving mechanism.

Radial drilling machine



Gang drilling machine

Gang drilling machine has a long common table and a base. Four to six drill heads are placed side by side. The drill heads have separate driving motors. This machine is used for production work.

A series of operations like drilling, reaming, counter boring and tapping may be performed on the work by simply shifting the work from one position to the other on the work table. Each spindle is set with different tools for different operations.

Multiple spindle drilling machine

This machine is used for drilling a number of holes in a workpiece simultaneously and for reproducing the same pattern of holes in a number of identical pieces. A multiple spindle drilling machine also has several spindles. A single motor using a set of gears drives all the spindles. All the spindles holding the drills are fed into the work at the same time. The distances between the spindles can be altered according to the locations where holes are to be drilled. Drill jigs are used to guide the drills

Deep hole drilling machine

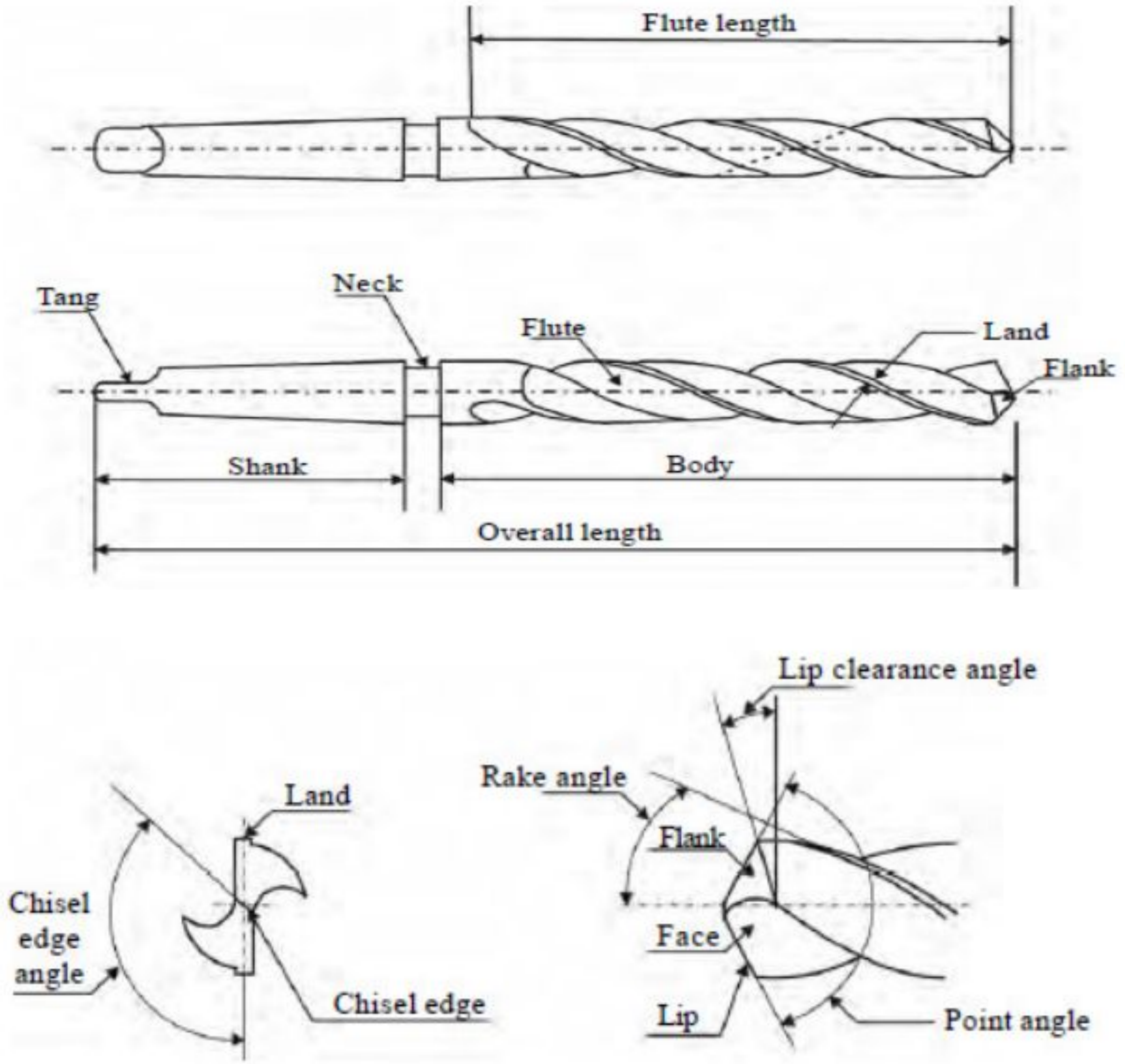
A special machine and drills are required to drill deeper holes in barrels of gun, spindles and connecting rods. The machine designed for this purpose is known as deep hole drilling machine. High cutting speeds and less feed are necessary to drill deep holes. A non rotating drill is fed slowly into the rotating work at high speeds. Coolant should be used while drilling in this machine. There are two different types of deep hole drilling machines

Size of a drilling machine (Specification)

To specify the machine completely the following factors are considered:

1. the maximum diameter of the drill that it can handle
2. the size of the largest workpiece that can be centred under the spindle
3. distance between the face of the column and the axis of the spindle
4. diameter of the table
5. maximum travel of the spindle
6. numbers and range of spindle speeds and feeds available
7. Morse taper number of the drill spindle
8. floor space required
9. weight of the machine
10. Power input is also needed to specify the machine completely.

Twist drill nomenclature



Twist drill nomenclature

- Axis : It is the longitudinal centre line of the drill running through the centres of the tang and the chisel edge.
- Body: It is the part of the drill from its extreme point to the commencement of the neck, if present. Otherwise, it is the part extending upto the commencement of the shank. Helical grooves are cut on the body of the drill.
- Shank: It is the part of the drill by which it is held and driven. It is found just above the body of the drill. The shank may be straight or taper. The shank of the drill can be fitted directly into the spindle or by a tool holding device.
- Tang :The flattened end of the taper shank is known as tang. It is meant to fit into a slot in the spindle or socket. It ensures a positive drive of the drill.
- Neck: It is the part of the drill, which is diametrically undercut between the body and the shank of the drill. The size of the drill is marked on the neck.

Twist drill nomenclature

- Point: It is the sharpened end of the drill. It is shaped to produce lips, faces, flanks and chisel edge.
- Lip : It is the edge formed by the intersection of flank and face. There are two lips and both of them should be of equal length. Both lips should be at the same angle of inclination with the axis (59°).
- Land : It is the cylindrically ground surface on the leading edges of the drill flutes adjacent to the body clearance surface. The alignment of the drill is maintained by the land. The hole is maintained straight and to the right size.
- Flutes: The grooves in the body of the drill are known as flutes. Flutes form the cutting edges on the point. It allows the chips to escape and make them curl. It permits the cutting fluid to reach the cutting edges.

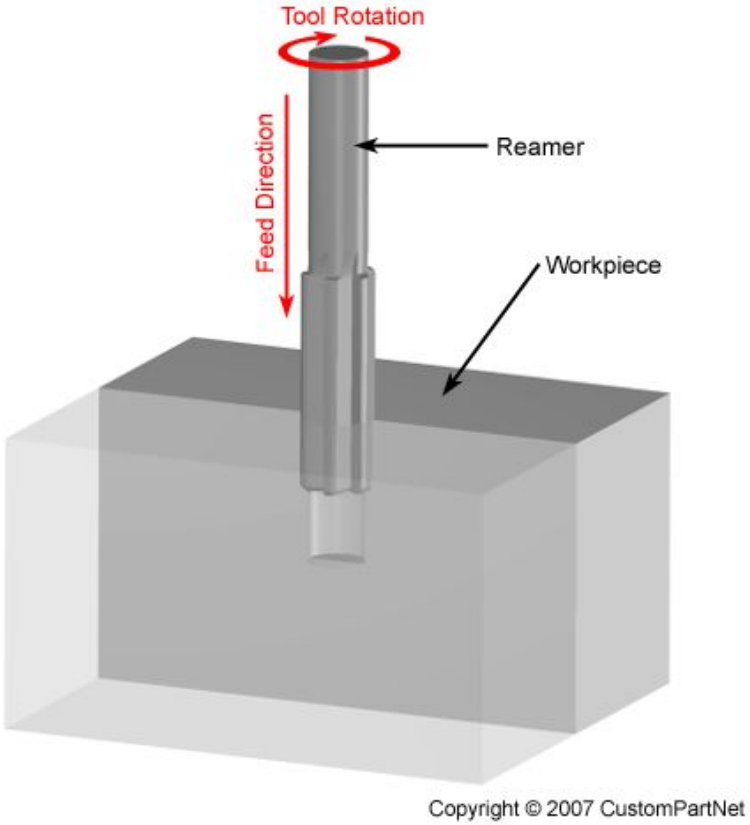
Drilling machine operation

- Reaming
- Boring
- Counter boring
- Counter sinking
- Spot facing
- Tapping

Reaming

- It is a process of *smoothing* the surface of drilled holes with a tool.
- Tool is called as reamer.
- Initially a hole is drilled slightly smaller in size.
- Drill is replaced by reamer.
- Speed is reduced to half that of the drilling.

Reaming


Tool Rotation
Feed Direction
Reamer
Workpiece
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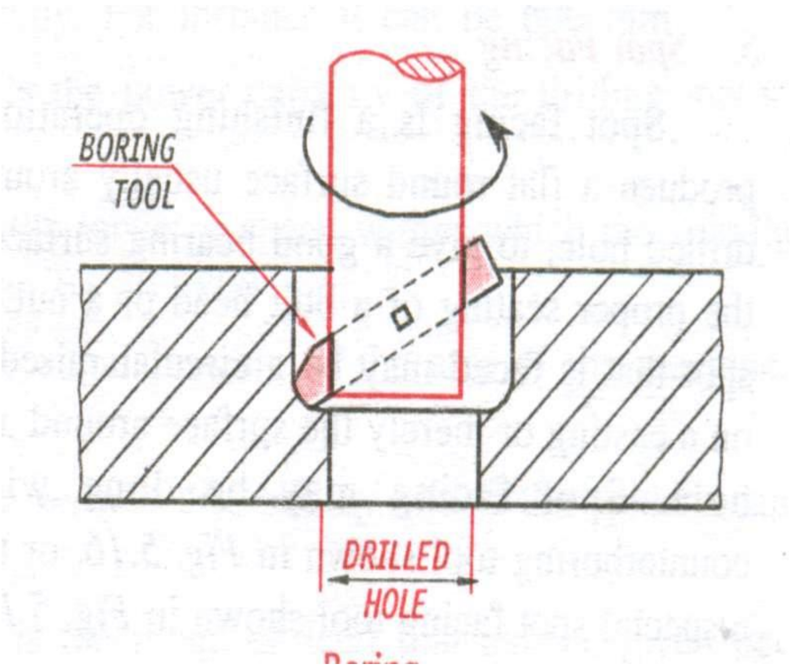
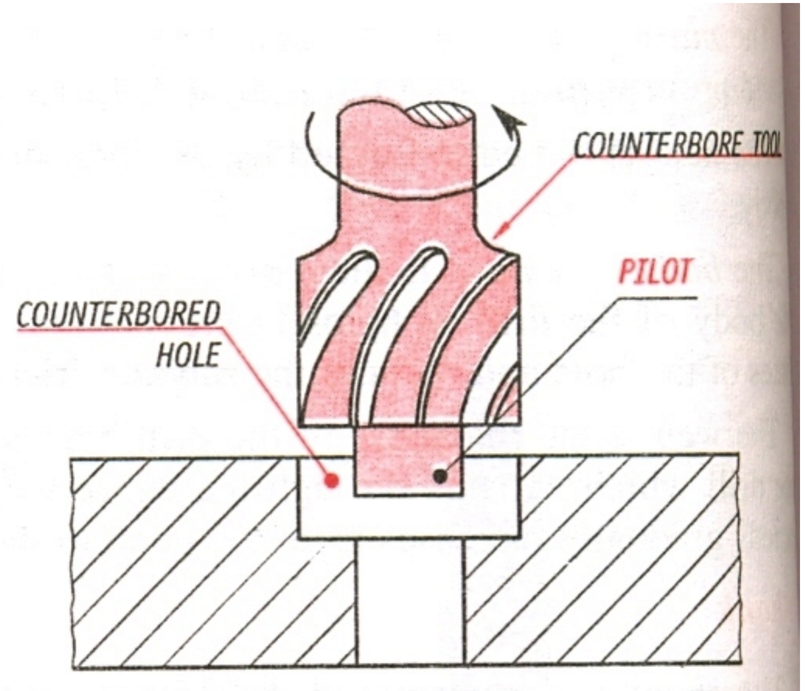
Boring

- It is process carried on a drilling machine to increase the size of an already drilled hole.
- Initially a hole is drilled to the nearest size and using a *boring* tool the size of the hole is increased.



Counter boring

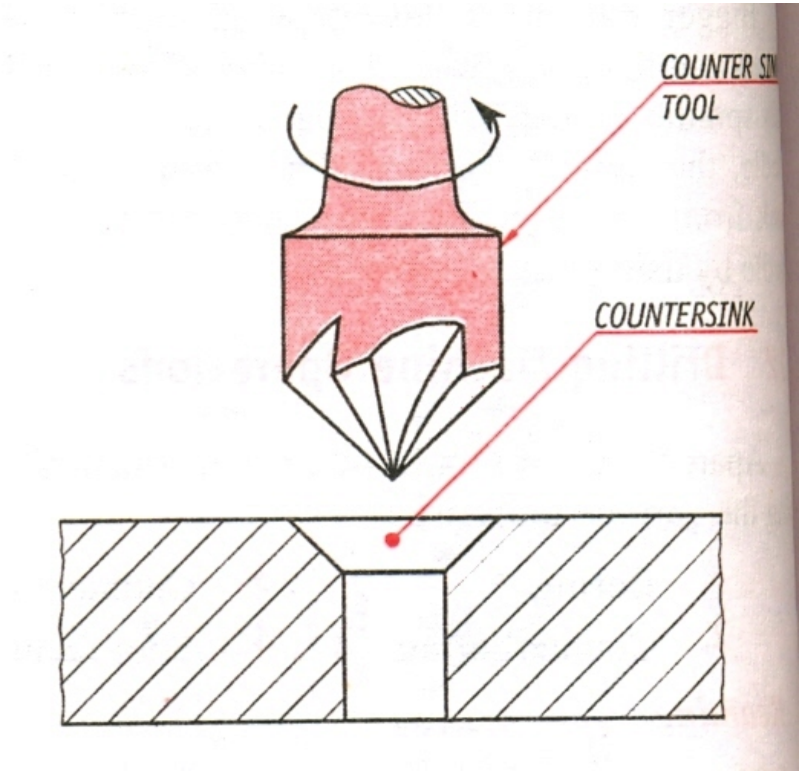
- This process involves increasing the size of a hole at only one end.
- Cutting tool will have a small cylindrical portion called *pilot.*
- Cutting speed = two-thirds of the drilling speed for the same hole.

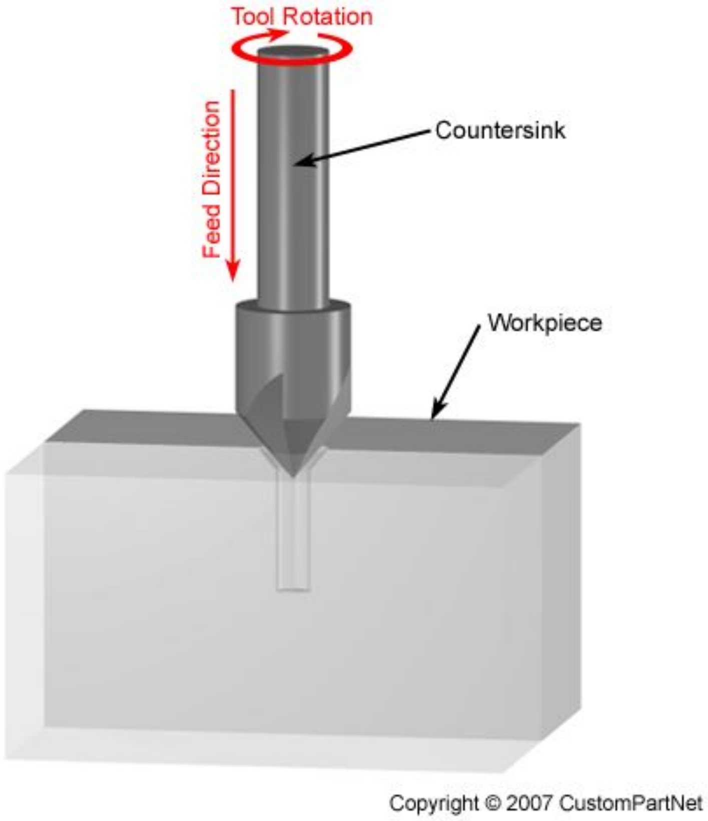


Counterboring

Counter sinking

- This is an operation of making the end of a hole into a *conical shape.*
- Cutting speed = half of the cutting speed of drilling for same hole.




Tool Rotation
Feed Direction
Countersink
Workpiece
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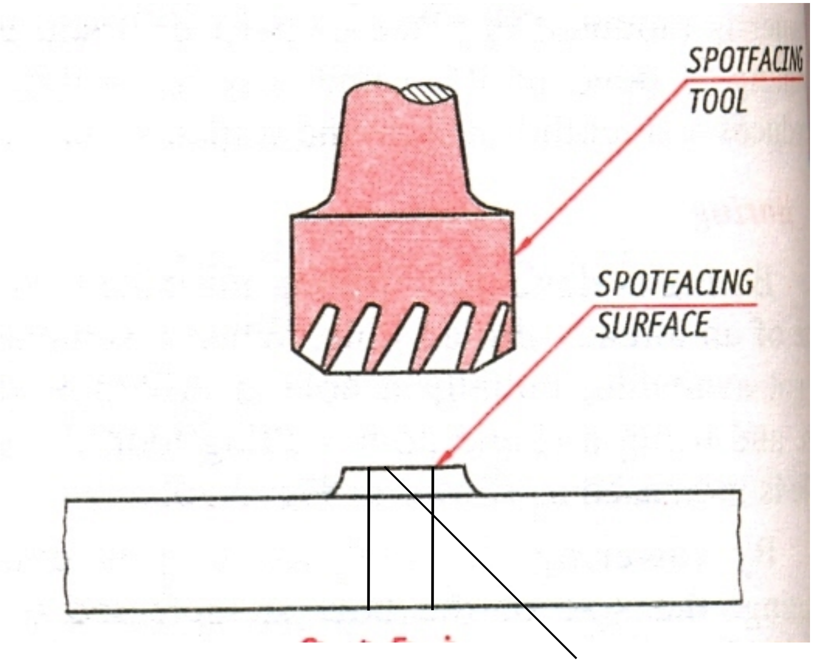
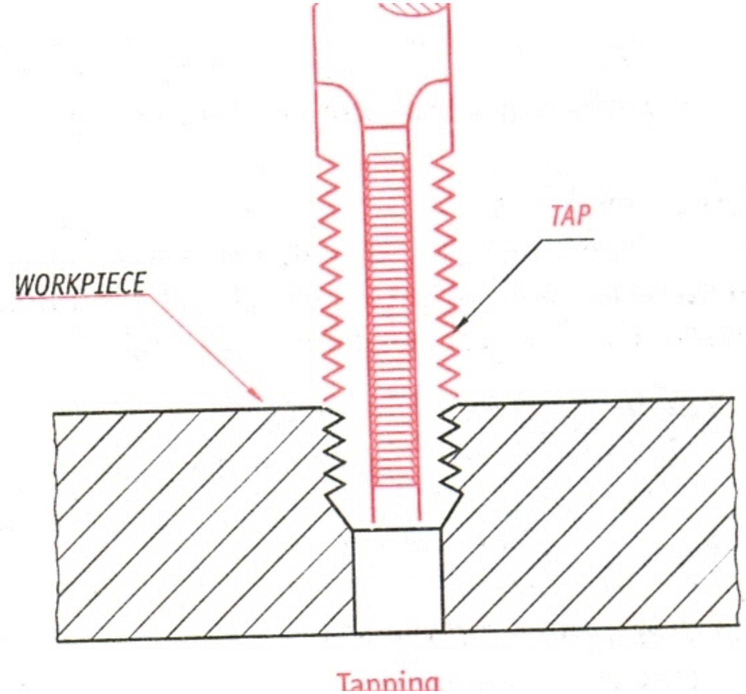
Spot facing

- It is a finishing operation to produce flat round surface usually around a drilled hole, *for proper seating of bolt head or nut.*
- It is done using a special spot facing tool.



Tapping

- Process of cutting internal threads with a thread tool called as *tap*.
- Tap is a fluted threaded tool used for cutting internal thread
- Cutting speed is very slow.



Determination Of Machining Time Requirement For Particular Operations.

The major aim and objectives in machining industries generally are;

i. reduction of total manufacturing time, T

ii. increase in MRR, i.e., productivity

iii. reduction in machining cost without sacrificing product quality

iv. increase in profit or profit rate, i.e., profitability.

Cutting Speed:

- The cutting speed can be defined as the speed of the periphery of the cutting tool in meters per minute.
- The cutting speed depends upon the material to be drilled. Generally, the cutting speed varies from 10 to 90 meters/minute.
- The cutting speed for the highspeed drill should be double than that of the carbon steel drill.
- Mathematically it can be expressed as:

$$Cutting\ speed = \frac{\pi \times Diameter\ of\ the\ drill\ in\ mm\ \times r.p.m}{1000}$$

Feed

- The feed can be defined as the distance moved by each rotation of the drill bit into the workpiece.
- It is mostly measured in millimeters. The feed range varies from 0.05 to 0.35mm.
- The amount of the metal removed is a function of the cutting speed and the feed.
- By using the highest possible feed rate the best tool life for a given tool can be obtained.

Machining Time

The machining time in drilling can be calculated by the following equation:

$T=L/(N \times f)$ minutes.

Where,

N= r.p.m of the drill.

f= feed per revolution of the drill.

L=Length or depth of the hole in mm.

T= Drilling time in a minute.

Problems

Estimate the time taken to drill a 25 mm dia × 10 cm deep hole in a casting. First a 10 mm dia drill is used and then the hole is enlarged by a 25 mm diadrill. Assume: Cutting speed = 15 m/min. Feed for f 10 mm drill= 0.22 mm/rev. Feed for f 25 mm drill= 0.35 mm/rev.

Solution :

(*i*) To calculate the time to drill f 10 mm hole — 10 cm deep

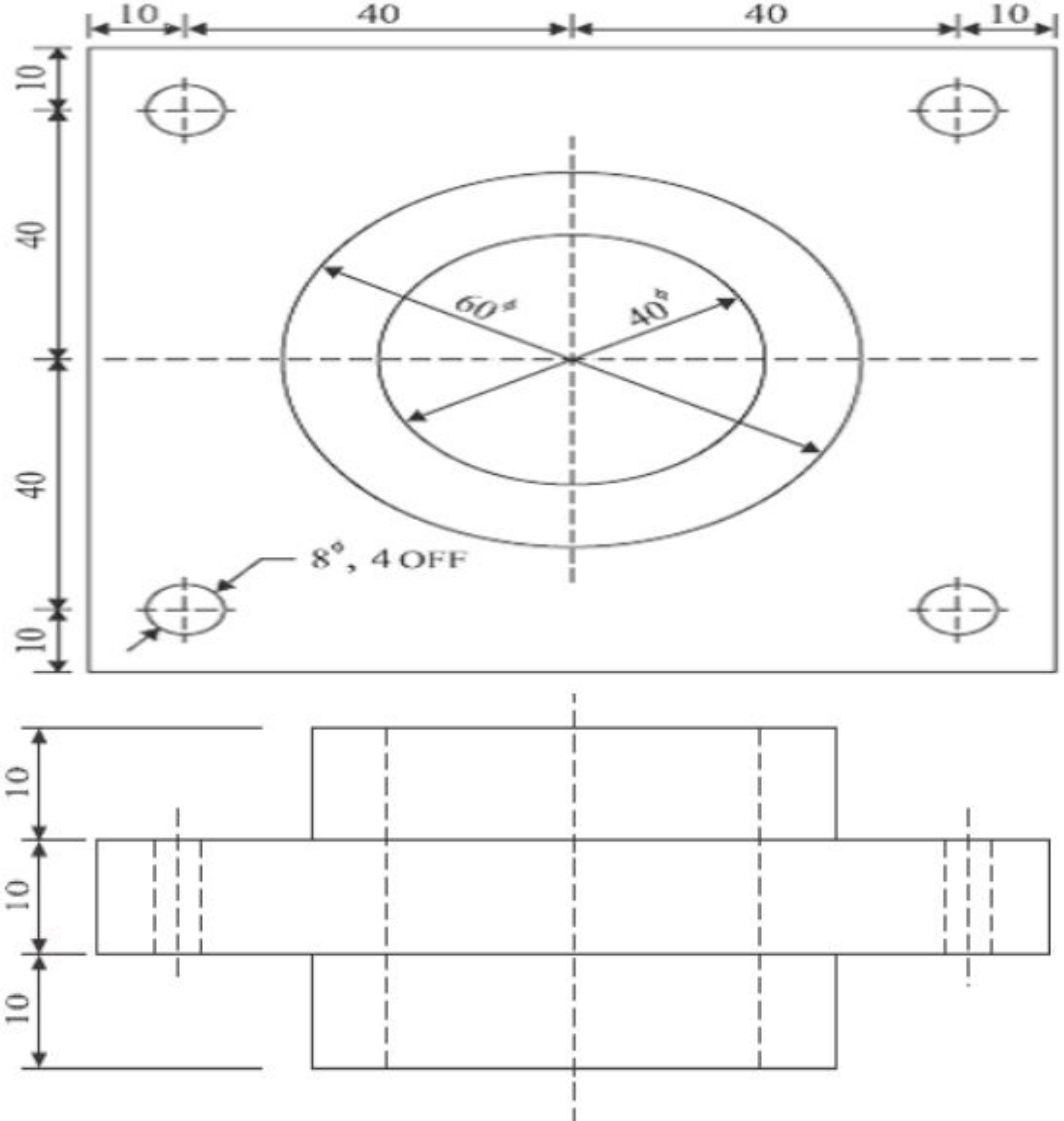
$$S = 15 \text{ m/min.}$$
$$f = 0.22 \text{ mm/rev.}$$
$$\text{Dia of drill } D = 10 \text{ mm}$$
$$\text{Length of cut} = 10 \text{ cm} = 100 \text{ mm}$$
$$\text{r.p.m. of drill N} = \frac{15 \times 1{,}000}{\pi \times 10} = 478$$
$$\text{Time taken} = \frac{\text{Length of hole}}{\text{Feed/rev.} \times \text{r.p.m.}}$$
$$= \frac{100}{0.22 \times 478} = 0.95 \text{ min.}$$

(*ii*) To calculate time for enlarging 10 mm dia hole to 25 mm dia hole

$$\text{Dia of drill} = 25 \text{ mm}$$
$$f = 0.35 \text{ mm/rev.}$$

$$N = \frac{15 \times 1{,}000}{\pi \times 25} = 190 \text{ r.p.m.}$$
$$\text{Time taken} = \frac{100}{0.35 \times 190} = 1.5 \text{ min.}$$
$$\text{Total time to drill the hole} = 0.95 + 1.5 = 2.45 \text{ min.}$$

Example 2: Calculate the machining time to drill four 8 mm dia holes and one 40 mm dia central hole in the flange shown in Fig. 5.26.



20 mm dia hole is drilled first and then enlarged to 40 mm f hole. Take cutting speed 10 m/min, feed for 8 mm drill 0.1 mm/rev, for 20 mm drill feed is 0.2 mm/rev.and for 40 mm f drill feed is 0.4 mm/rev

(*i*) Time to drill four 8 mm dia holes

S = 10 m/min.

Dia of drill D = 8 mm.

$$L = 10 \text{ mm}$$

$$f = 0.1 \text{ mm/rev.}$$

$$N = \frac{S \times 1{,}000}{\pi D} = \frac{10 \times 1{,}000}{\pi 8}$$

$$= 398 \text{ r.p.m.}$$

$$\text{Time taken to drill one hole} = \frac{L}{f \times N} = \frac{10}{0.1 \times 398}$$

$$= 0.25 \text{ min.}$$

$$\text{Time to drill 4 holes} = 0.25 \times 4 = 1 \text{ minute.}$$

(*ii*) Time to drill one hole of 40 mm diameter :

This hole is made in two steps :

(*a*) Drill 20 mm f hole — 30 mm long

$$N = \frac{10 \times 1{,}000}{\pi \times 20} = 159 \text{ r.p.m.}$$

$$\text{Time taken} = \frac{30}{0.2 \times 159} = 0.95 \text{ min.}$$

(*ii*) Enlarge 20 mm f hole with 40 mm f drill

Here
$$N = \frac{10 \times 1{,}000}{\pi \times 40} = 80 \text{ r.p.m.}$$
$$f = 0.4 \text{ mm/rev.}$$
$$\text{Time taken} = \frac{30}{0.4 \times 80} = 0.94 \text{ min.}$$

Total time taken to drill all the holes $= 1.0 + 0.95 + 0.94 = 2.9$ min.

Milling

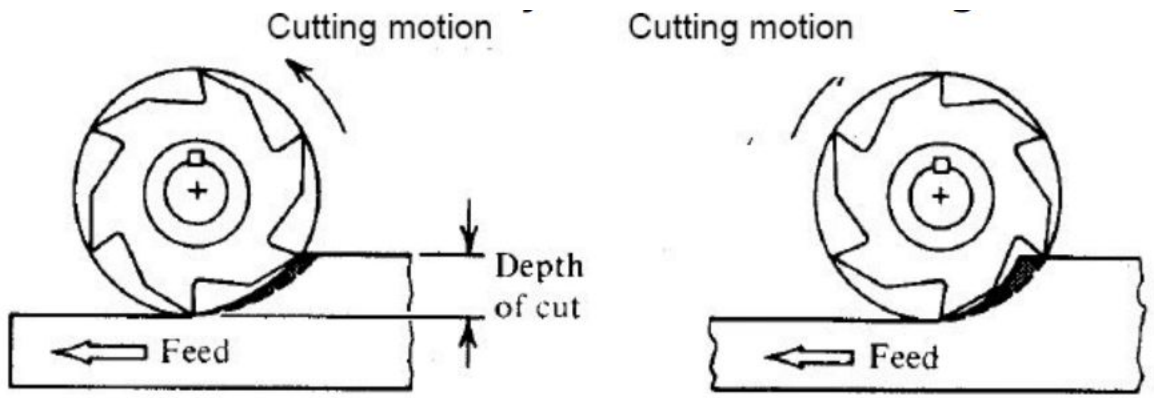
Milling

Milling machine is one of the important machining operations. In this operation the workpiece is fed against a rotating cylindrical tool. The rotating tool consists of multiple cutting edges (multipoint cutting tool). Normally axis of rotation of feed given to the workpiece. Milling operation is distinguished from other machining operations on the basis of orientation between the tool axis and the feed direction, however, in other operations like drilling, turning, etc. the tool is fed in the direction parallel to axis of rotation.

Milling machines

Basic functions and purposes of using milling machines

The basic function of milling machines is to produce flat surfaces in any orientation as well as surfaces of revolution, helical surfaces and contoured surfaces of various configurations. Such functions are accomplished by slowly feeding the workpiece into the equispaced multiedge circular cutting tool rotating at moderately high speed as indicated in Fig. Upmilling needs stronger holding of the job and downmilling needs backlash free screw-nut systems for feed



Conventional, or up milling

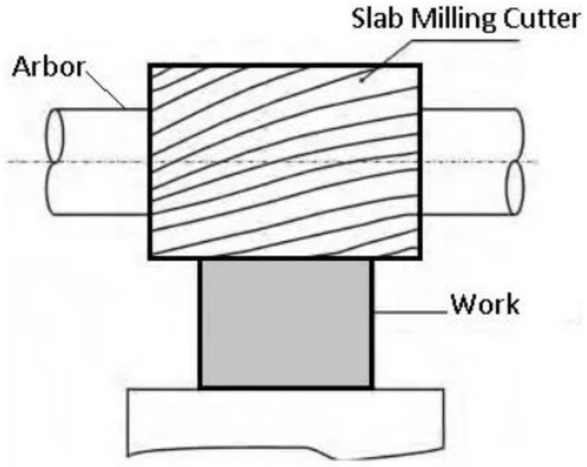
Climb, or down milling

Milling Machine Operations

- Plain Milling Operation
- Face Milling Operation
- Side Milling Operation
- Straddle Milling Operation
- Angular Milling Operation
- Gang Milling Operation
- Form Milling Operation
- Profile Milling Operation
- End Milling Operation
- Saw Milling Operation
- Milling Keyways, Grooves, and Slot
- Gear Milling
- Helical Milling
- Cam Milling
- Thread Milling

Plain Milling

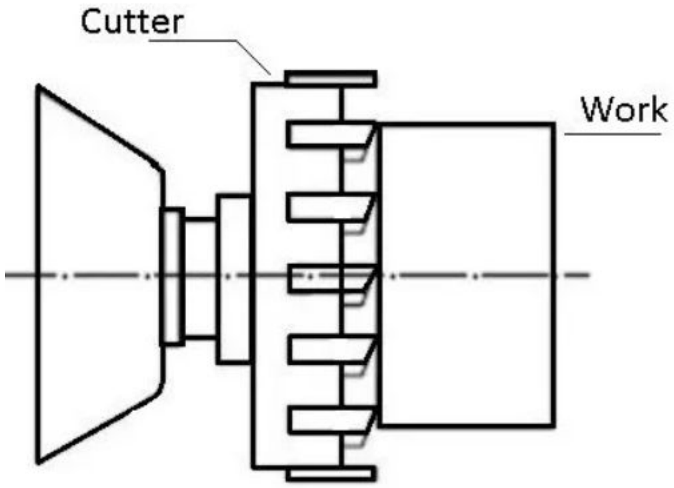
- The plain milling is the most common types of milling machine operations.
- Plain milling is performed to produce a plain, flat, horizontal surface parallel to the axis of rotation of a plain milling cutter.
- The operation is also known as slab milling.
- To perform the operation, the work and the cutter are secured properly on the machine.
- The depth of cut is set by rotating the vertical feed screw of the table. And the machine is started after selecting the right speed and feed.



Plain Milling Operation

Face Milling

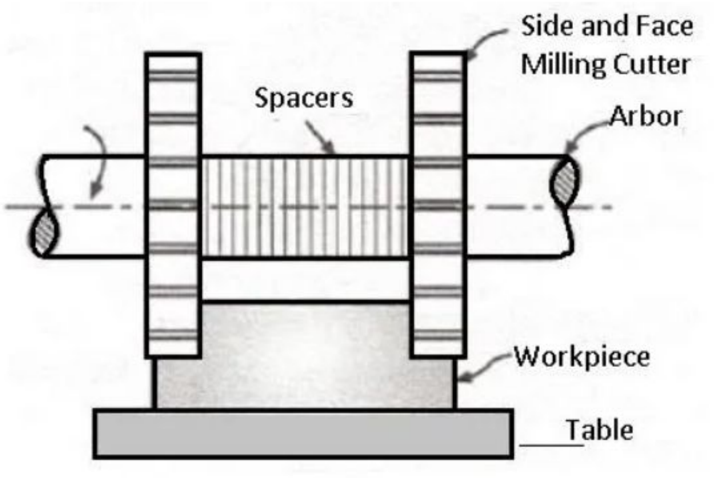
- The face milling is the simplest milling machine operations.
- This operation is performed by a face milling cutter rotated about an axis perpendicular to the work surface.
- The operation is carried in plain milling, and the cutter is mounted on a stub arbor to design a flat surface.
- The depth of cut is adjusted by rotating the crossfeed screw of the table.



Face Milling Operation

Straddle Milling

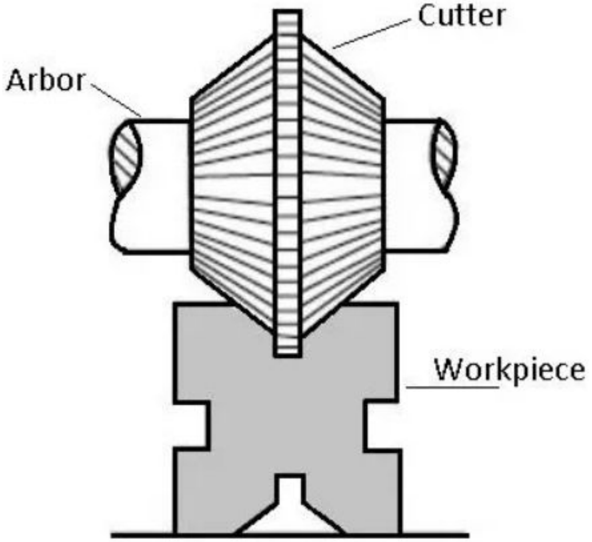
- The straddle milling is the operation of producing a flat vertical surface on both sides of a workpiece by using two side milling cutters mounted on the same arbor.
- Distance between the two cutters is adjusted by using suitable spacing collars.
- The straddle milling is commonly used to design a square or hexagonal surfaces.



Straddle Milling Operation

Angular Milling

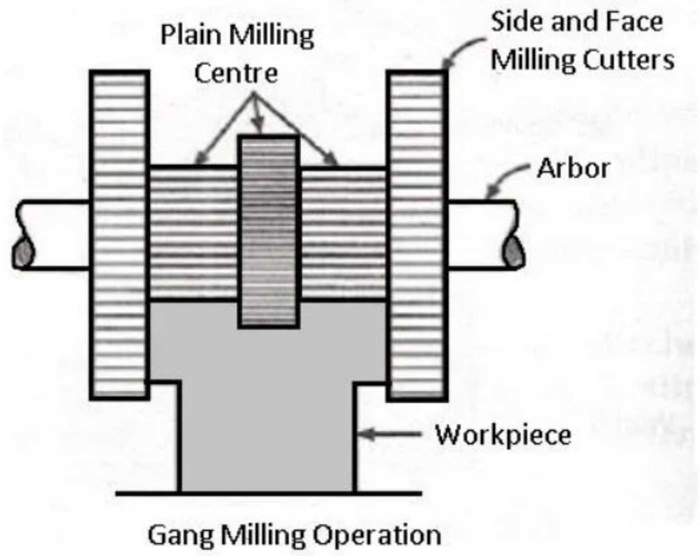
- The angular milling is the operation of producing an angular surface on a workpiece other than at right angles of the axis of the milling machine spindle.
- The angular groove may be single or double angle and may be of varying included angle according to the type and contour of the angular cutter used.
- One simple example of angular milling is the production of V-blocks.



Angular Milling

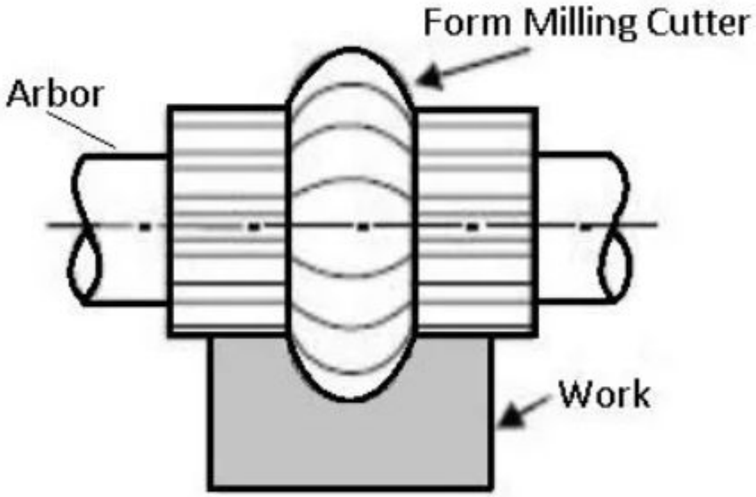
Gang Milling

- The gang milling is the operation of machining several surfaces of a workpiece simultaneously by feeding the table against a number of cutters having the same or different diameters mounted on the arbor of the machine.
- The method saves much of machining time and is widely used in repetitive work.
- Cutting speed of a gang of cutters is calculated from the cutter of the largest diameter.



Form Milling

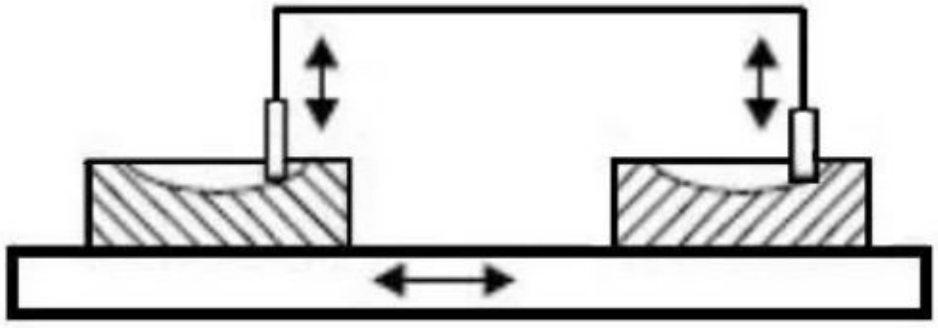
- The form milling is the operation of producing the irregular contour by using form cutters.
- The irregular shape may be convex, concave, or of any other shape. After machining, the formed surface is inspected by a template gauge.
- Cutting rate for form milling is 20% to 30% less than that of the plain milling.



Form Milling Operation

Profile Milling

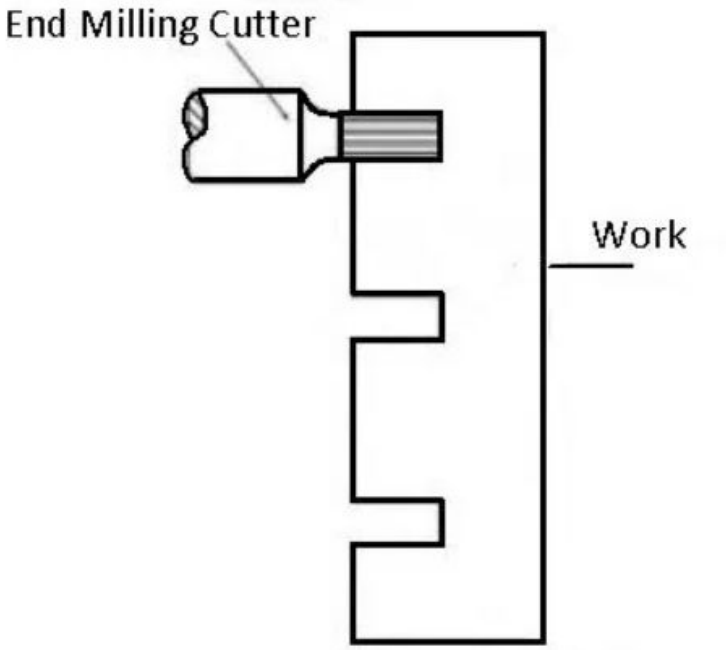
- The profile milling is the operation of reproduction an outline of a template or complex shape of a master dies on a workpiece.
- Different cutters are used for profile milling. An end mill is one of the widely used milling cutters in profile milling work.



Profile Milling Operation

End Milling

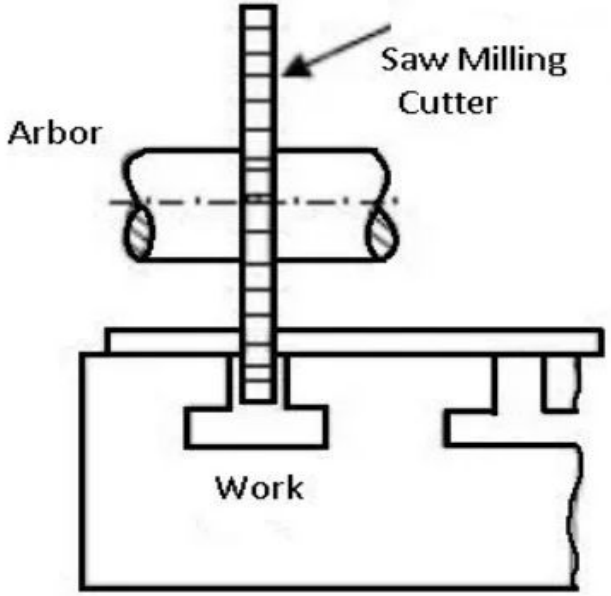
- The end milling is the operation of producing a flat surface which may be vertical, horizontal or at an angle in reference to the table surface.
- The cutter used is an end mill. The end milling cutters are also used for the production of slots, grooves or keyways.
- A vertical milling machine is more suitable for end milling operation.



End Milling Operation

Saw Milling

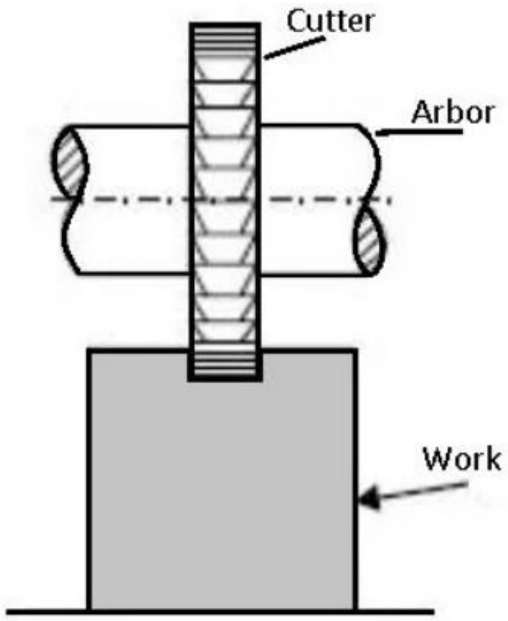
- Saw-milling is the operation of producing narrow slots or grooves on a workpiece by using a saw-milling cutter.
- The saw-milling also performed for complete parting-off operation.
- The cutter and the workpiece are set in a manner so that the cutter is directly placed over one of the T-slots of the table.



Saw Milling Opeartion

Milling Keyways, Grooves and Slots

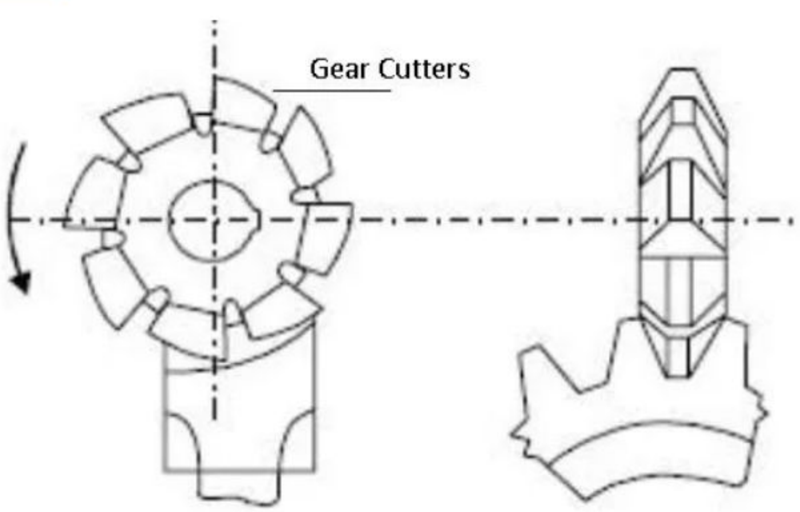
- The operation of producing of keyways, grooves and slots of varying shapes and sizes can be performed in a milling machine.
- It is done by using a plain milling cutter, a metal slitting saw, an end mill or by a side milling cutter.
- The open slots can be cut by a plain milling cutter, a metal slitting saw, or by a side milling cutter. The closed slots are produced by using endmills.



Keyway Milling Operation

Gear Cutting

- The gear cutting operation is performed in a milling machine by using a form-relieved cutter. The cutter may be a cylindrical type or end mill type.
- The cutter profile fits exactly with the tooth space of the gear.
- Equally spaced gear teeth are cut on a gear blank by holding the work on a universal diving head and then indexing it.



Gear Cutting Milling Operation

Cam Milling

- The cam milling is the operation of producing cams in a milling machine by the use of universal dividing head and a vertical milling attachment. The cam blank is mounted at the end of the dividing head spindle and an end mill is held in the vertical milling attachment.
- The axis of the cam blank and the end mill spindle should always remain parallel to each other when setting for cam milling. The dividing head is geared to the table feed screw so that the cam is rotated about its axis while it is fed against the end mill. The axis of the cam can be set from 0 to 90° in reference to the surface of the table for obtaining a different rise of the cam.

Thread Milling

- The thread milling machine operations are used to produce threads by using a single or multiple thread milling cutter. Thread milling operation is performed in special thread milling machines to produce accurate threads in small or large quantities.
- The operation requires three driving motions in the machine. One for the cutter, one for the work and the third for the longitudinal movement of the cutter.
- When the operation is performed by a single thread milling cutter, the cutter head is swivelled to the exact helix angle of the thread. The cutter is rotated on the spindle and the workpiece is revolved slowly about its axis. The thread is completed in one cut by setting the cutter to the full depth of the thread and then feeding it along the entire length of the workpiece.

Indexing

- Indexing is an **operation of dividing a periphery of a cylindrical workpiece into equal number of divisions by the help of index crank and index plate**
- There are five methods of indexing.
  - Direct indexing,
  - Simple or plain indexing,
  - Compound indexing,
  - Differential indexing,

Direct Indexing

Direct Indexing: is the simplest of four methods. The dividing head has a circular plate attached to its main spindle and has a circle of 24 equally spaced holes struck behind it. A locking pin operated by the handle engages with any one of the holes, and locks the plateand spindle in position. Since the plate has 24 holes, then any number of divisions which divide evenly into 24 can be indexed by this method.

- To find the indexing movement, divide the number of divisions required into 24.

Simple Indexing

Simple Indexing: is achieved by using index plates while the main spindle is rotated by turning the index crank. The choice and use of suitable index plates generally extends the range of indexing and the majority of divisions can be obtained in this way.

The rule for simple indexing is:

1. Divide 40 by the number of divisions required.

2. The quotient obtained gives the number of turns or parts of a turn of the index crank required for the given number of divisions.

3. The circle of holes chosen must be a multiple of the denominator of the fraction obtained.

4. Turns of index = (40crank/N)

Where, N = Number of divisions or cuts required.

Compound Indexing

Compound Indexing: When a number of divisions required is outside the range of that secured by simple indexing, a method known as compound indexing may be employed. The process of compound indexing aims at securing a required division by using two separate simple indexing movements. This is done in two stages:

1. By turning the crank a definite amount in the usual way.

2. By turning the index plate itself in such a way that a further movement is added to, or subtracted from, that obtained in the first operation. The index plate locking pin is withdrawn and the plate turned the necessary amount in the same direction as, or the opposite direction to, that of the crank.

Differential Indexing

- A very useful method of indexing, one by which almost any number of divisions can be obtained, is known as “differential Indexing”.
- In principle, it is the same as compound indexing, except that the index plate is rotated by means of a train of gears connected to the divided head spindle.
- With the correct combination of gears, turning the index crank causes the index plate to move automatically in the right direction, and through the amount required to give the desired movement in the dividing head spindle.