

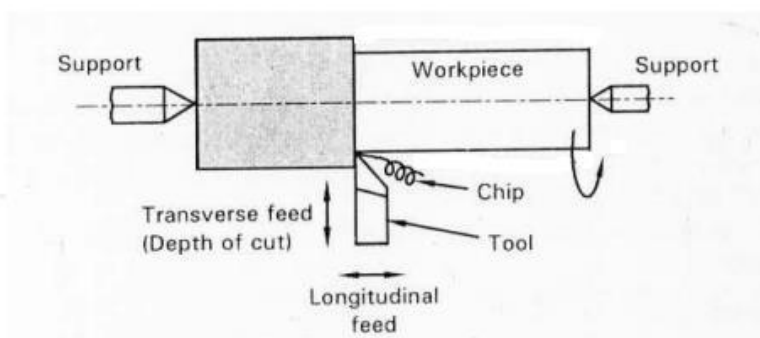
MODULE-3

LATHE, DRILLING MACHINE , MILLING MACHINE , JOINING PROCESSES

LATHE

Lathe is the oldest of all machine tools and perhaps the most basic tool used in industries. A lathe is used to remove excess material by forcing a cutting tool against a rotating cylindrical work piece. They are primarily used to produce cylindrical, plain and tapered surfaces, and also used for knurling and thread cutting on metal parts. Besides these, they can also perform operations such as drilling, boring, reaming, etc. Lathes are also called *turning machines*, since the work piece is turned or rotated between two centers; the *live center* and *dead center* of the machine.

PRINCIPLE OF WORKING OF LATHE



Lathe works on the principle that, a cutting tool can remove material, when it is moved against a rotating workpiece. This is accomplished by rotating the workpiece between two rigid and strong supports, while the cutting tool is fed against it. Basically three types of surface can be produced depending on the movement of the cutting tool with respect to the rotating workpiece.

PARTS OF CENTER LATHE

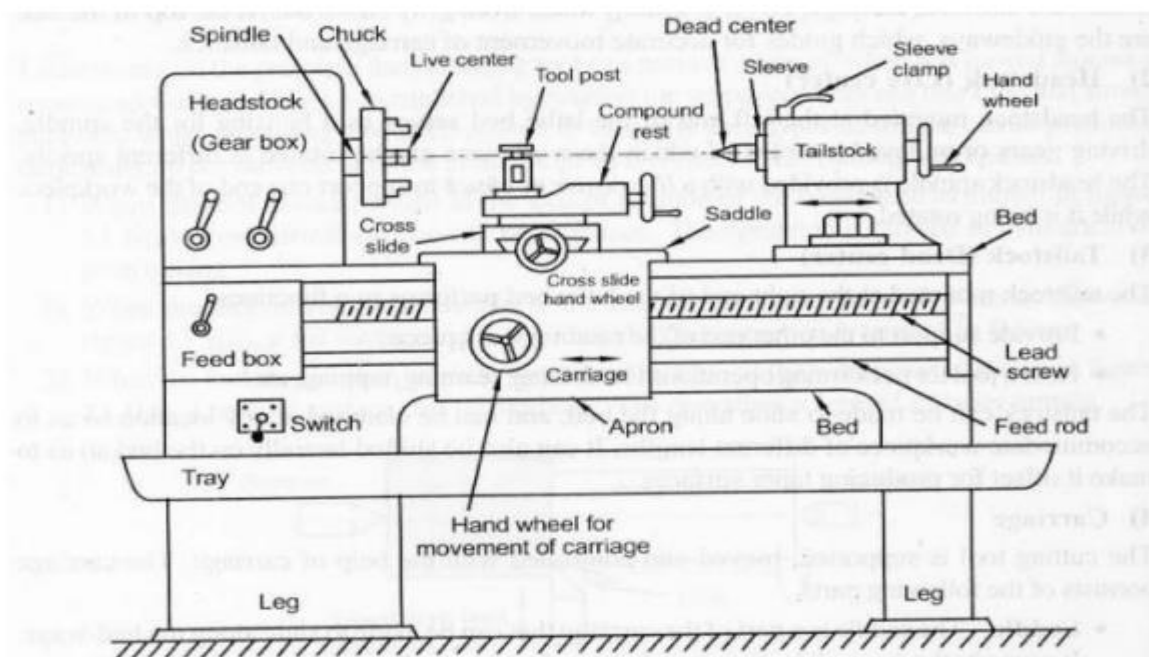


Figure Parts of Center Lathe

1) Bed

It is a rigid structure which forms the base or foundation to support all the other parts such as headstock, tailstock, carriage, etc. It is usually made from *gray cast iron*. At the top of the bed are the guideways, which guides for accurate movement of carriage and tailstock.

2) Headstock (Live center)

The headstock mounted at the left end of the lathe bed serves as a housing for the spindle, driving gears or pulleys by means of which the workpiece can be rotated at different speeds. The headstock spindle is provided with a *live center* or *chuck* to support one end of the workpiece while it is being rotated.

3) Tailstock (Dead center)

The tailstock mounted at the right end of the lathe bed performs two functions:

- Provide support to the other end of the rotating work piece
- Hold a tool for performing operations like drilling, reaming, tapping, etc.

The tailstock can be made to slide along the bed, and can be clamped at any location so as to accommodate workpiece of different lengths. It can also be shifted laterally on the bed so as to make it offset for producing taper surfaces.

4) Carriage

The cutting tool is supported, moved and controlled with the help of carriage. The carriage consists of the following parts.

- **Saddle** – The saddle is a part of the carriage that can be made to slide along the bed-ways. It supports the cross-slide, compound rest and tool post.
- **Cross-slide** – The cross-slide is mounted on the saddle. It can be made to move in a direction perpendicular to the saddle movement, or perpendicular to the lathe axis thereby providing the necessary depth of cut to the workpiece
- **Compound rest** – It is mounted on the cross-slide and supports the tool post. The compound rest has a circular base graduated in degrees. This helps the cutting tool to be swivelled at any angle to obtain taper surfaces.
- **Tool-post** – It is mounted on the compound rest, and is used to hold/support the cutting tool firmly in position during machining.
- **Apron** – It is fitted beneath the saddle facing the operator. It houses the gears, levers, hand-wheels and clutches to operate the carriage by hand or by automatic power feed.
- **Feed rod** – The feed rod is a long shaft that gives automatic feed to the carriage for various operations namely boring, turning etc., *except thread cutting*.
- **Lead screw** – It is a long shaft with square threads cut on it. The rotation of the lead screw facilitates the movement of carriage during thread cutting operations.

5) Legs

Legs are the supports which carry the entire load of the machine over them. They are firmly secured to the floor by means of foundation bolts in order to prevent vibrations of the machine during operation.

Specification of Center Lathe

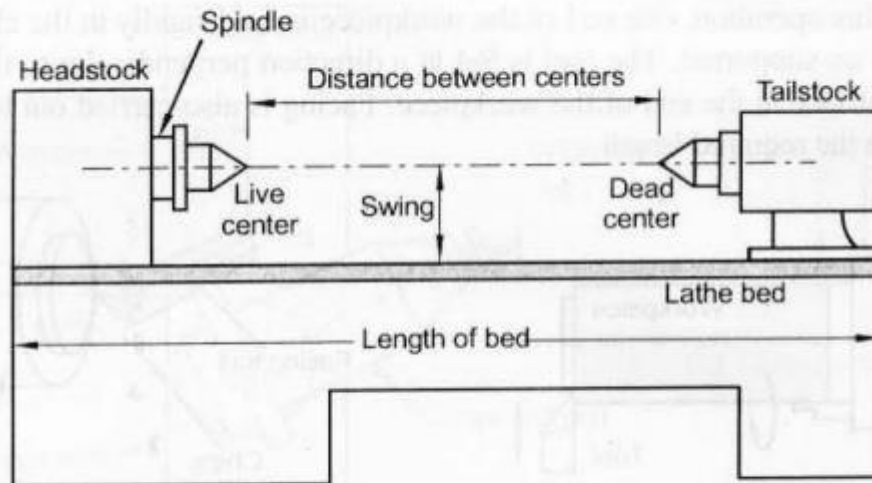


Figure Specification of Center Lathe

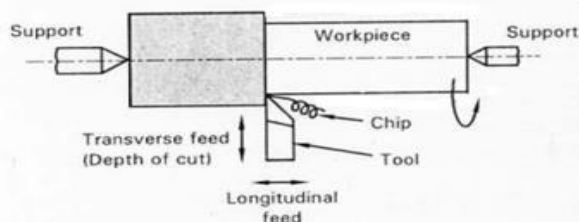
The size of center lathe is specified by one or more of the following criteria.

- **Distance between centers** It is the maximum length of the job that can be held between the *live center* and *dead center*.
- **Swing diameter** It is the maximum diameter of the workpiece that can revolve without touching the guide ways. Some manufacturers specify *Height of centers* instead of swing diameter.
- **Height of centers** It is the height measured from the bed to the lathe center axis.
- **Length of bed** It indicates the approximate floor space occupied by the lathe.
- **Range of spindle speeds**

LATHE OPERATIONS

A variety of operations can be performed on a lathe. These include; turning, facing, knurling, thread cutting, drilling, taper turning, boring, etc. A few of them are discussed briefly below.

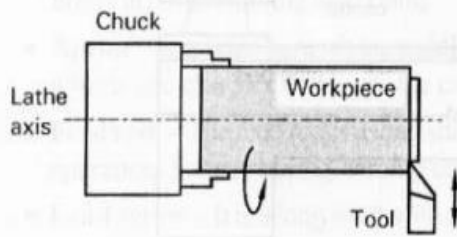
a) Cylindrical Turning



Cylindrical turning, also called plain turning or straight turning is the operation of removing excess material from the workpiece to produce a cylindrical surface. Refer Figure

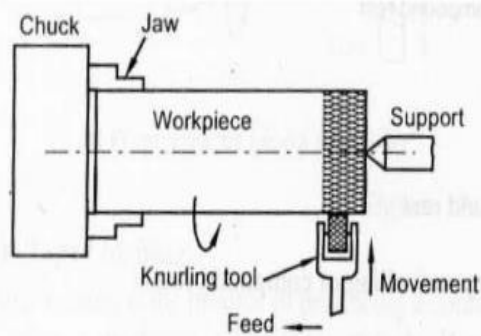
The workpiece is held rigidly and rotated between the two centers; *live center* and *dead center*. The cutting tool is fed against the revolving workpiece, in a direction *parallel* to the lathe axis so as to produce a cylindrical surface. Cylindrical turning can be done through rough turning and

b) Facing



Facing is the operation for generating a flat surface at the end of the workpiece as shown in figure. In this operation, one end of the workpiece is held rigidly in the chuck, while the other end is left un-supported. The tool is fed in a direction perpendicular to the lathe axis to produce a flat surface at the end of the workpiece. Facing is also carried out to reduce or cut the workpiece to the required length.

(c) Knurling



Knurling is a process carried out on a lathe, whereby a visually-attractive criss-cross pattern is cut or rolled on the surface of metallic parts.

In operation, the lathe is set, so that the workpiece revolves at a slow speed. The knurling tool is pressed against the rotating workpiece and pressure is slowly increased until the tool produces a pattern on the workpiece. Sometimes more than one pass may be required to get a deep cut.

(d) Thread cutting

Thread cutting or threading is a operation for cutting screw threads on metallic parts. Figure shows a thread cutting operation.

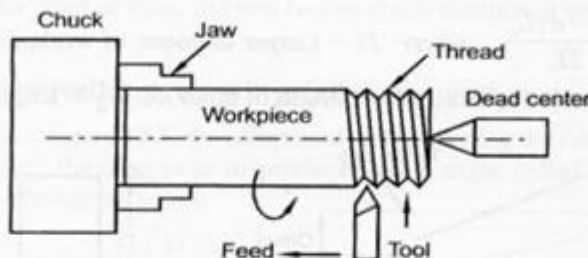


Figure Thread Cutting

In operation, a suitable tool which gives the required thread profile (*Example* V-thread, square thread, etc.) is mounted on the tool post. The carriage is connected to the lead screw with the help of a split nut. The rotation of the lead screw gives the required motion to the carriage relative to the rotation of the workpiece. The speed of the spindle in thread cutting is much lower than that used in turning. Hence the speed of the workpiece should be initially adjusted.

(e) Taper turning

Taper turning is the process of producing a conical surface from a cylindrical shaped workpiece. A taper is produced, when the cutting tool moves at an angle to the axis of rotation of the workpiece. Taper can be produced by any one of the following methods.

- By swivelling (rotating) of compound rest
- By off-setting the tailstock
- By using a taper turning attachment
- By form tool method

Taper turning by swivelling (rotating) of compound rest

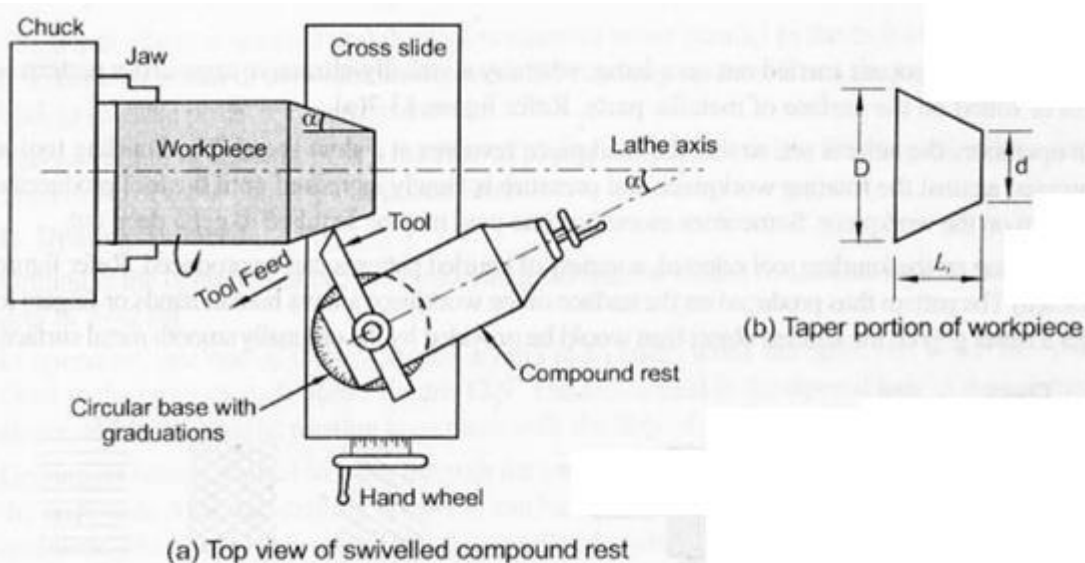


Figure Taper turning by swivelling of compound rest

In this method as shown in figure , the compound rest supporting the cutting tool is swivelled to the desired angle at which the taper is to be produced. This angle, called *half-taper angle* (α) is calculated using the equation given below.

$$\text{half-taper angle } \alpha = \tan^{-1} \left(\frac{D-d}{2L_t} \right)$$

where D = larger diameter of taper in mm

d = smaller diameter of taper in mm & L_t = Length of taper in mm

The compound rest has a circular base graduated in degrees. The rotation of the compound rest to the calculated taper angle, will cause the tool to be fed at that angle, thereby producing the corresponding taper on the workpiece. This method is more suitable for producing steep taper with short lengths.

Drilling Machine

Drilling is a metal cutting process carried out by a rotating cutting tool to make circular holes in solid materials. The tool which makes the hole is called a *drill*. It is generally called as *twist drill*, since it has a sharp twisted edges 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 workpiece. 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.

Drilling Machine

A power operated machine tool, which holds the drill in its spindle rotating at high speeds and when manually actuated to move linearly simultaneously against the workpiece produces a hole, is called *drilling machine*. In a drilling machine the holes can be produced to the sizes as small as *thousandth of a centimetre and upto 7.5 cm diameter*. The various other operations that can be performed on a drilling machine are : reaming, counterboring, countersinking, spot facing, thread tapping, etc.

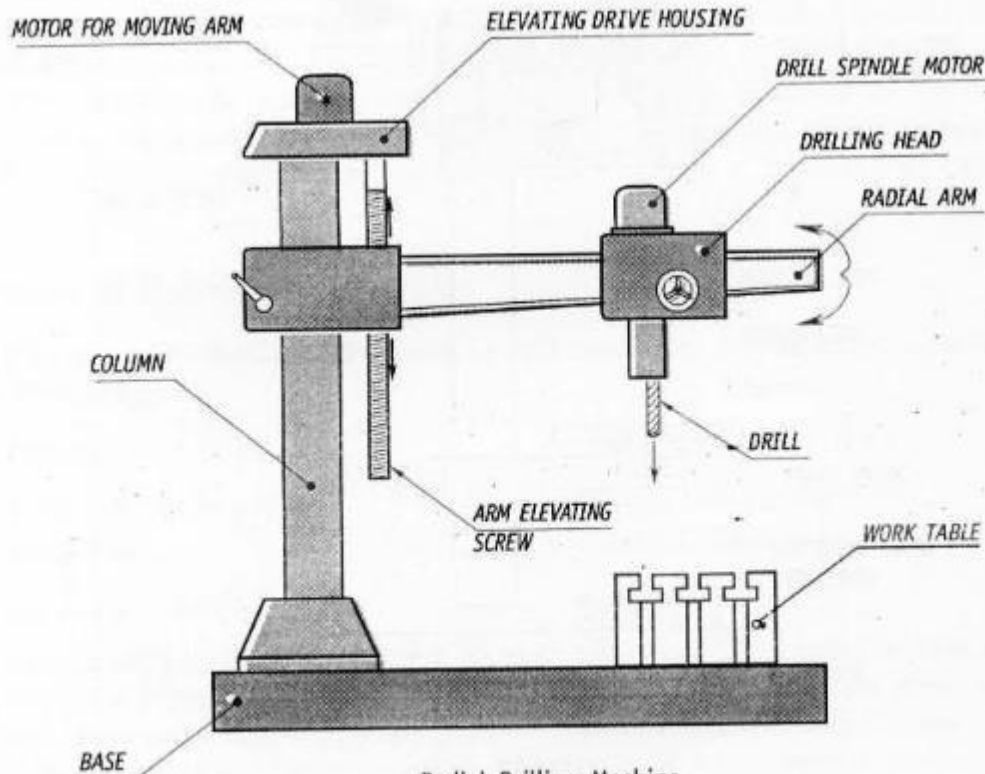
Types of Drilling Machines

Drilling machines are manufactured in different sizes for different classes of work and classified as follows :

- | | |
|------------------------------|------------------------------|
| 1. Portable Drilling Machine | 2. Bench Drilling Machine |
| 3. Pillar Drilling Machine | 4. Radial Drilling Machine |
| 5. Gang Drill | 6. Multiple Drilling Machine |

Radial Drilling Machine

A radial drilling machine shown in Fig is used to perform the drilling operations on the workpieces which are too heavy and also may be too large to mount them on the work table of the vertical spindle drilling machine. It consists of a heavy *base* and a *vertical column* with a long *horizontal arm* extending from it and can be rapidly raised, lowered and swung in the horizontal plane about the main column to any desired location. The *drilling head* can move to and fro along the arm and can be swiveled only in the universal radial drilling machines, to drill holes at an angle. The combination of motions of the radial arm and drilling head offers a great deal of flexibility in moving the drill to any position. The main advantage of the radial drilling machine is that the drilling can be carried out on heavy work pieces in any position without moving them.



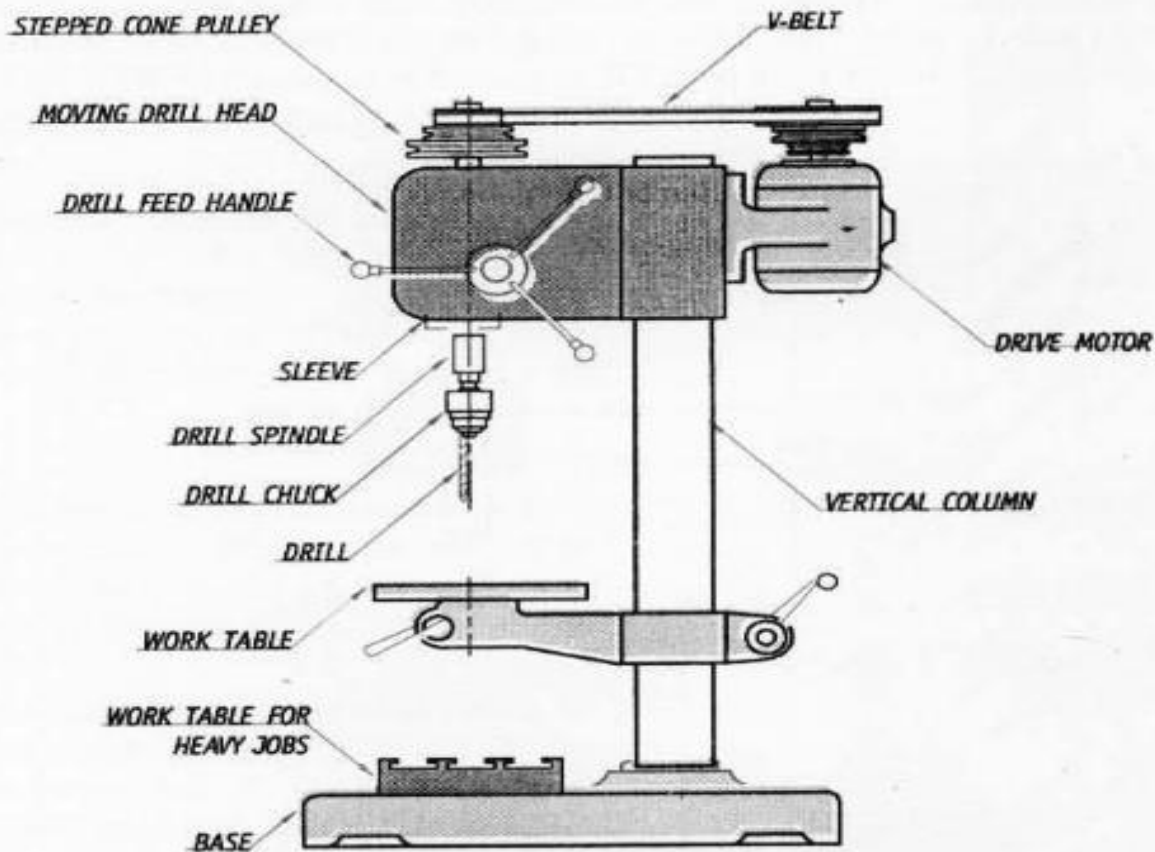
Radial Drilling Machine
Fig.

Bench Drilling Machine

Bench drilling machines are light duty drilling machines widely used in small workshops. They are usually placed on workbenches, hence the name. This type of drilling machines are also called *sensitive drilling machines* because of its accurate and well balanced spindle, which enable the operator to sense or feel the cutting action and apply the required pressure while drilling. Generally holes of sizes upto 15 mm are drilled in these machines.

Parts of a Bench Drilling Machine

Fig. shows a bench drilling machine. It consists of a *vertical main column* mounted over a *base*. The vertical column carries a *moving head* housing in it a *speed gear box* and *spindle feeding mechanism*, and a job mounting table, called *work table* which can also be raised or lowered. An *electric motor* is mounted at the top end of the vertical column on its rear side. The power is transmitted to the main spindle through the stepped cone pulley drives and gearing systems. A drill chuck for small size drills is fitted in the spindle at its lower end. For bigger sizes the drill itself will be fitted directly in the spindle. The workpiece will be mounted on the work table and is clamped to it.



Bench Drilling Machine

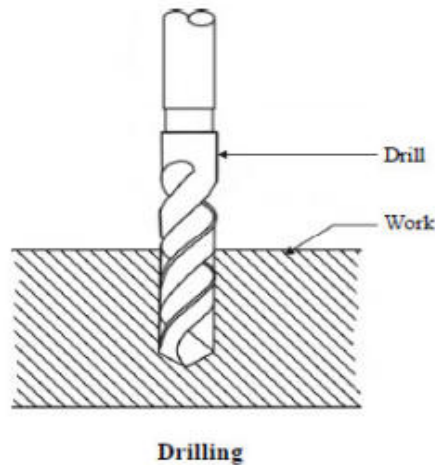
Fig.

Drilling machine operations

Though drilling is the primary operation performed in a drilling machine, a number of similar operations are also performed on holes using different tools. The different operations that can be performed in a drilling machine are:

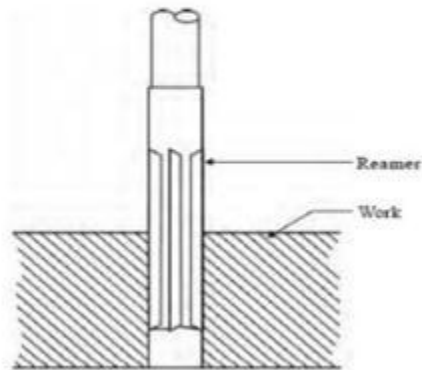
1. Drilling
2. Reaming
3. Boring
4. Counter boring
5. Countersinking
6. Spot facing
7. Tapping
8. Trepanning

1. Drilling



This is the operation of making a circular hole by removing of metal from the workpiece by a rotating cutting tool called drill as shown in Fig. Drilling removes solid metal from the work piece to produce a circular hole. Before drilling, the hole is located by drawing two lines at right angle and a center punch is used to make an indentation for the drill point at the center to help the drill in getting started.

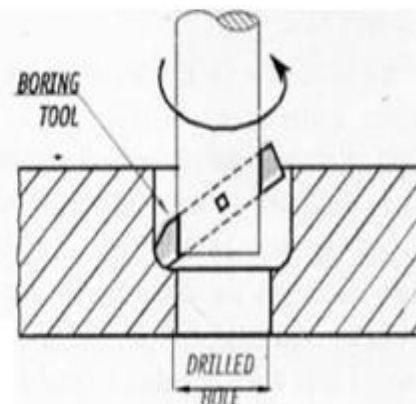
2. Reaming



Reaming is the process of smoothing the surface of the drilled holes with a reamer. A reamer is similar to the twist drill, but has straight flutes. After drilling the hole to a slightly smaller size, the reamer is mounted in place of twist drill and with the speed reduced to half of that of the drilling, reaming is done in the same way as drilling. It removes only a small amount of material and produces a smooth finish on the drilled surfaces.

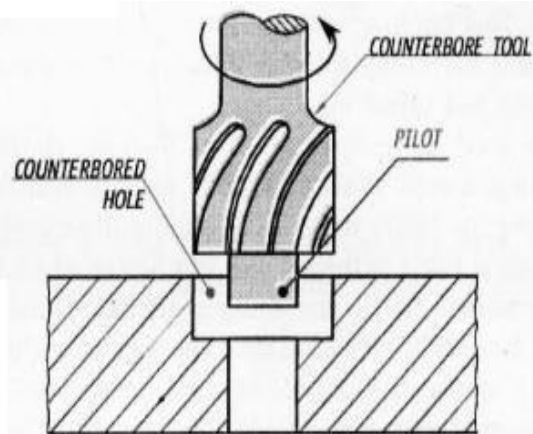
3. Boring

Boring is done on a drilling machine to increase the size of an already drilled hole. When a suitable size drill is not available, initially a hole is drilled to the nearest size and using a single point cutting tool, the size of the hole is increased as shown in Fig.



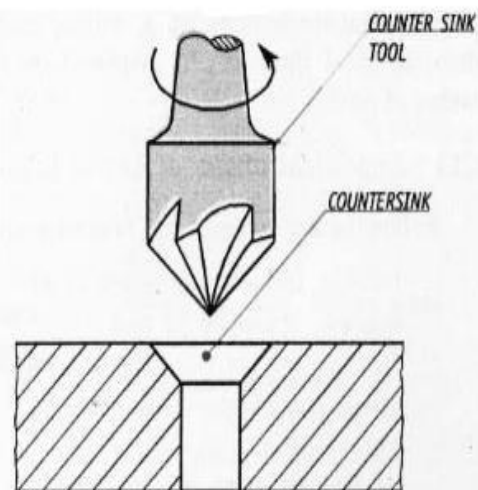
4. Counterboring

Counterboring is to increase the size of a hole at one end only through a small depth as shown in Fig. The counterboring forms a larger sized recess or a shoulder to the existing hole.



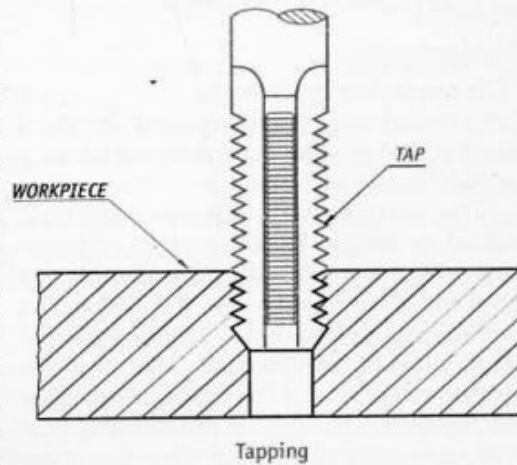
5. Countersinking

Countersinking shown in Fig. 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.



6) Tapping

The tapping, shown in Fig. 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.



Specifications of a Drilling Machine

A Drilling machine can be specified by the following Specifications :

1. Drilling Capacity in Steel :

This denotes the capacity of the drilling machine to drill into jobwork made of steel. It is usually expressed by the depth upto which drilling is done. Drilling machines capable of drilling upto a depth of 20 mm are available in the market.

2. Spindle Traverse :

This is the extent by which the rotating spindle of the drilling machine can traverse vertically from its home position of position of rest to the maximum vertical distance downwards. This is expressed in mm.

3. Spindle Speed Range :

This is the range of speed by which the Spindle of the drilling machine is able to rotate. This is expressed in revolutions per minute or RPM. For example, the range can be from 500 – 2000 rpm.

4. Table Overall Size :

This is the area on the work table where the targeted jobs are to be clamped to the table. They are usually expressed as Length X width (mm × mm) of the table for instance, the table size is 280 × 280 sq.mm.

5. Table Working Surface

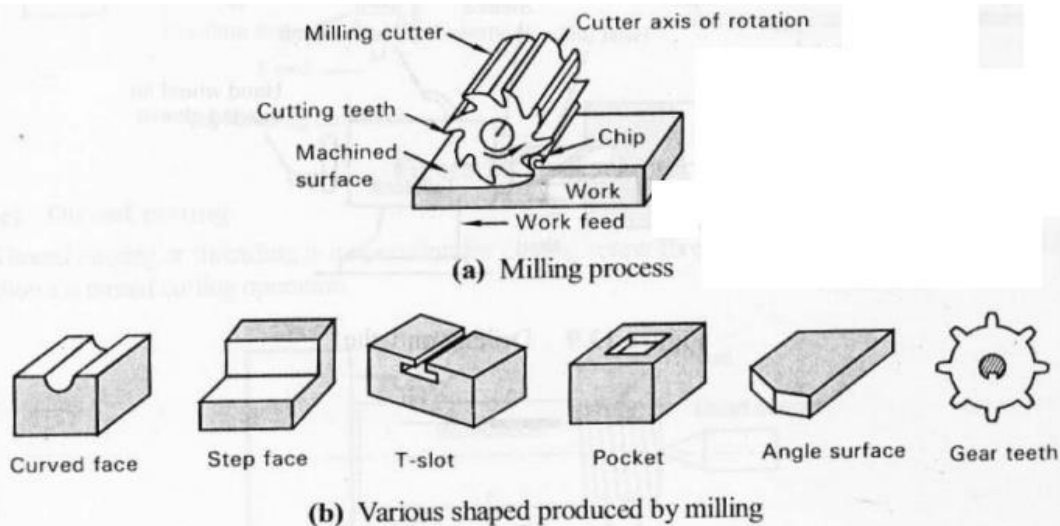
This is the area available out of the overall size of the table for carrying out the desired work. For instance, as shown in the above figure, the Working surface is 200 × 200 sq.mm out of 280 × 280 sq.mm

6. Power and Speed of the Motor :

Power, usually expressed in kW (or HP) and its speed in RPM is helpful in power calculations and cost calculations. For instance, the power and speed can be 1 HP/ 1440 rpm in Standard Bench Drilling Machines.

MILLING MACHINES

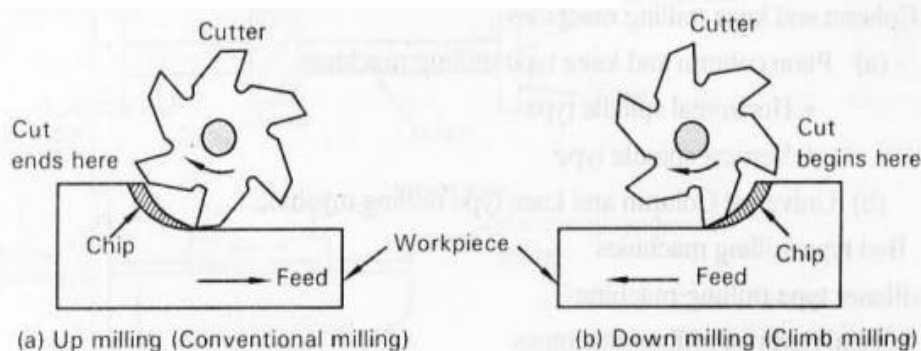
Milling is a process of shaping work materials by feeding the work material against a multipoint rotating cutter. Refer figure (a). The machine used for the purpose is called *milling machine*. Milling can be used for producing flat, angular or curved surfaces, for cutting threads, toothed gears, keyways, slots, and a wide variety of other operations. It can also perform drilling and boring operations. The type of cutter used in milling depends on the shape desired on the workpiece. Figure (b) shows the various shapes produced by milling.



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 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 (a), the workpiece is fed in the direction opposite to that of the rotating cutter, while in down milling process as shown in figure (b), the workpiece is fed in the same direction as that of the rotating cutter.



**Up milling
(Conventional milling)**

V/s

**Down milling
(Climb milling)**

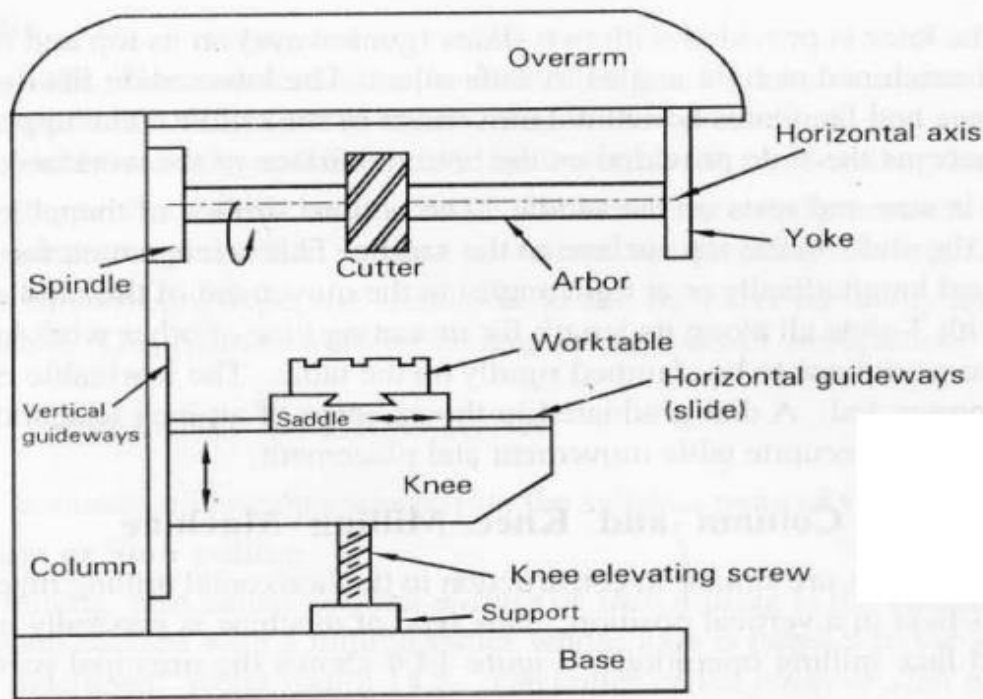
Sl. No.	Up milling (Conventional milling)	Down milling (Climb milling)
1.	Workpiece is fed in the direction <i>opposite</i> to that of the rotating cutter.	Workpiece is fed in the <i>same</i> direction as that of the rotating cutter.
2.	Thickness of chip is <i>minimum</i> at the beginning of cut and reaches to a <i>maximum</i> when the cut ends.	Thickness of chip is <i>maximum</i> at the beginning of cut and reaches to the <i>minimum</i> when the cut ends.
3.	Cutting force is directed upwards that tends to lift the workpiece from the worktable. Hence, greater clamping force for the workpiece is necessary.	The cutting force is directed downwards, which tends to keep the workpiece firmly on the worktable, permitting lesser clamping forces.
4.	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.	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.

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, etc

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.

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 turn 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.

Vertical Spindle Column and Knee Milling Machine

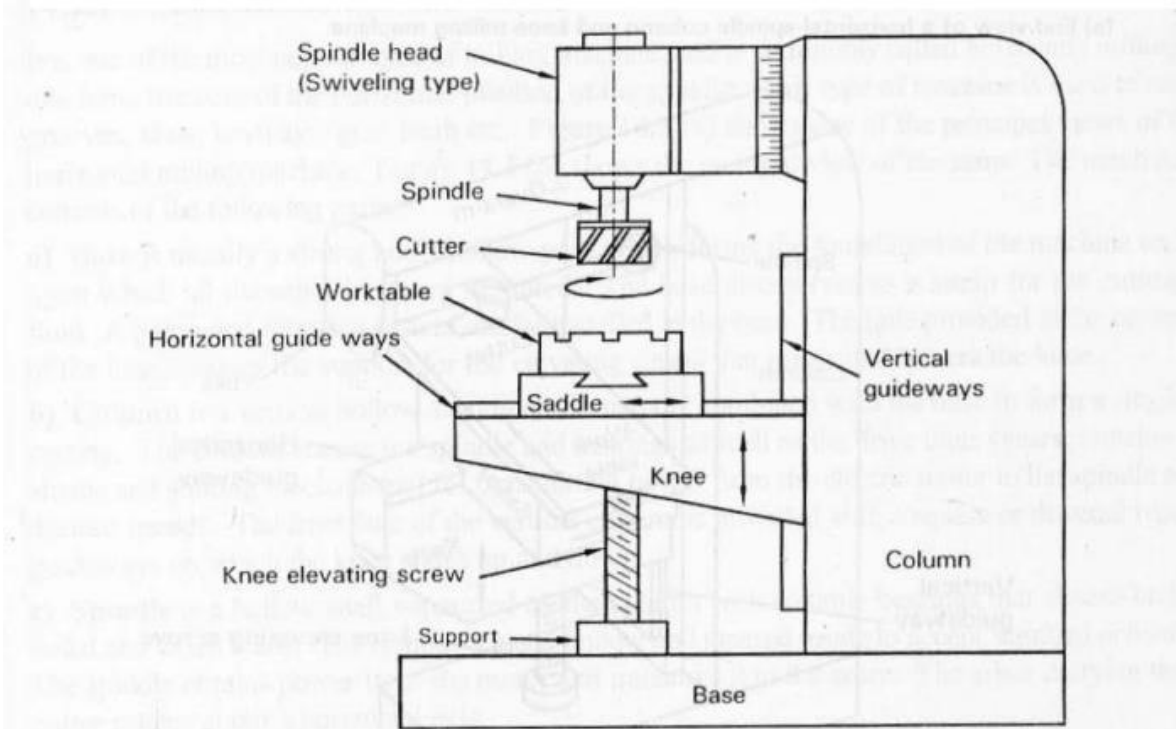


Figure Vertical spindle column and knee type milling machine (swiveling type)

Spindle

The 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 permits working on angular surfaces of workpieces.

Milling Machine Specifications :

Just as any other machine tool, milling machine should also be specified by some general Specifications. It is only through these specifications that the milling machines can be selected to optimally suit the applications or jobs. These specifications act as guidelines for expressing the capacity of the Milling machine.

The following are the general specifications of a milling machine.

1. *Clamping Area* : This is the area on the work table where the targeted jobs are to be clamped to the table. They are expressed as length X width of the table.
2. *Longitudinal Movement* : This is the distance along the X-axis by which the table along with the job moves longitudinally. This is expressed in mm.
3. *Transverse Movement* : This is the distance along the Y-axis by which the table travels in the transverse direction expressed in mm.
4. *Vertical Movement* : This is the distance vertically along the Z-axis by which the spindle travels. It is expressed in mm.
5. *Speed* : This is the speed of the spindle rotation expressed in revolutions per minute (rpm).
6. *Power of the Milling Spindle motor* : This is the power capacity of the motor of the spindle expressed in kW.
7. *Power of the Feed Motor* : This is the power capacity of the feed motor expressed in kW.

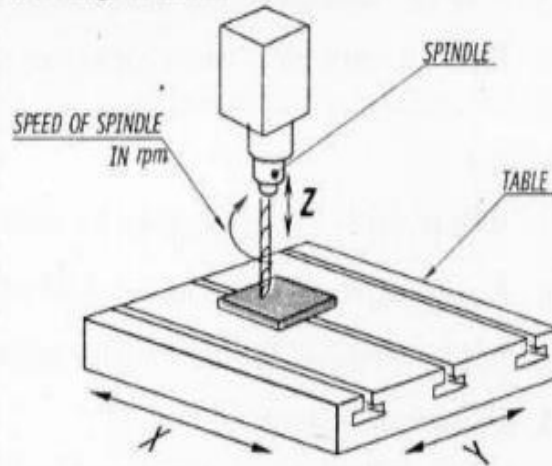


Fig. Axes Interpretation in Milling

MILLING OPERATIONS

A few common milling operations from the syllabus point of view has been discussed herein.

a) Plain or Slab milling

Plain milling, also called *surface milling* or *slab milling* is the operation of producing a plain horizontal surface with a milling cutter whose axis is parallel to the surface of the workpiece being machined. Refer figure The cutter called *plain or slab milling cutter* is mounted on the arbor of a horizontal milling machine to carry out the machining operation. The cutter has straight or helical teeth formed on the periphery of a cylindrical surface. Helical tooth cutter removes greater amount of material and produces a smooth surface finish when compared to the straight tooth cutters.

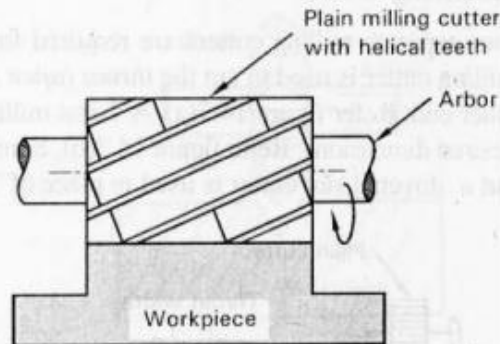
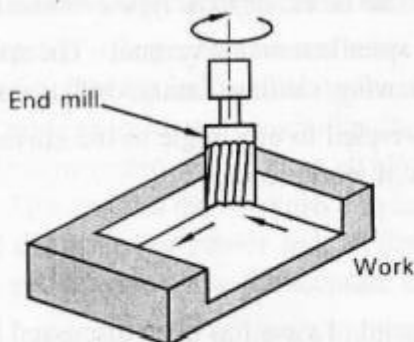


Figure Plain or slab milling

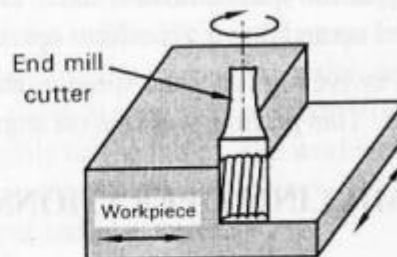
b) End milling

End milling is the operation performed for producing flat surfaces, slots, grooves or finishing the edges of the workpiece by means of a tool called *end mill* or *end milling cutter*. The cutter has teeth on the *end* as well as the *periphery (sides)*, and hence can be configured to cut with both its end and the sides as shown in figure (a).

Figure (b) shows a flat surface produced by the end side of the cutter only. The cutter is typically mounted vertically and may have straight or spiral flutes. Straight flute cutters are used for milling both soft and tough materials, while spiral flutes are used mostly for cutting steel. The surface produced by end milling may be horizontal, vertical or inclined with respect to the top of the machine table.



(a) Cutting with both sides of end mill cutter



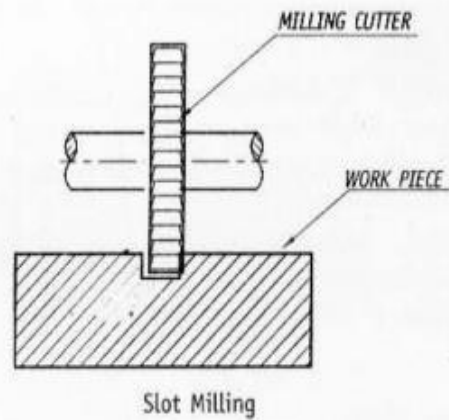
(b) Producing single flat surface

Figure End milling

c) Slot Milling

Slot Milling is the process of milling slots using a different type of cutter called "Slot drill" which has the capacity to cut into solid material. Slot drill is used majorly in cases where it takes a lot of time to pre-drill a hole for an end mill and there is not enough room for the end mill to plunge using a helical motion.

A typical slot milling operation is shown in Fig.

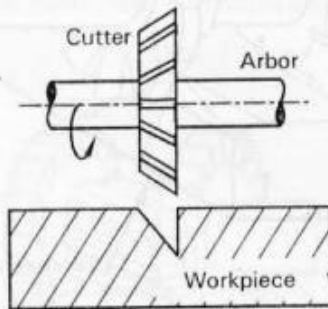


d) Angular milling

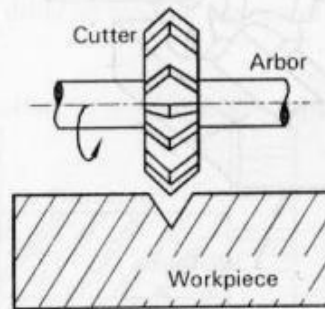
Angular milling or angle milling is the operation of producing all types of angular cuts like V-notches and grooves, serrations and other angular surfaces.

The cutter, called *angle milling cutter* or *angle cutter* has peripheral teeth, which are neither parallel nor perpendicular to the cutter axis. The cutter may be either single-angle or double-angle type, and its selection depends on the type of surface to be machined.

Single-angle cutters are angled on one side to produce an angle or chamfer on the workpiece edge as shown in figure (a), while double angle cutters are angled on both the sides of the cutter, and hence can produce double angle cuts as shown in figure (b). Angle cutters may also be used to produce dovetail slots in workpieces.



(a) Angular milling with single-angle cutter



(b) Angular milling with double-angle cutter

Figure

Angular milling

JOINING PROCESSES

INTRODUCTION TO JOINING PROCESSES

There are various processes by which two or more parts can be joined together. The joints obtained by these processes may be temporary or permanent. Joints obtained by processes like brazing, soldering, bolts and nuts, studs and nuts, screws, etc., are temporary in nature. In other words, the connected parts can be separated easily without damage to them. Whereas processes like welding, riveting, etc., produce permanent joints. The joints obtained by these processes will be such that the connected parts have to be broken in order to separate them.

Of all the various processes, welding, brazing, and soldering are different from others, in the sense that, in these processes, the parts are joined by the application of heat. Following sections deals with the fundamentals of soldering, brazing, and welding processes.

SOLDERING

The details regarding soldering process are briefed as follows:

Principle of soldering

Soldering is a group of joining process used for joining similar or dissimilar metals by means of a *filler metal* whose melting temperature is *below* 450°C. The filler metal usually called *solder* is an alloy of tin and lead in various proportions.

Soldering involves melting the filler metal (solder) and allowing it to flow into the gap between the two workpieces. The solder cools down and solidifies forming a joint. Refer figure . The principle by which the filler metal is drawn throughout the joint is by *capillary action* . The resulting joint although not as strong as the base metal (workpiece metal), still has adequate strength, electrical conductivity, and water-tightness that makes it suitable for many uses.

Surface preparation in soldering

Surface preparation includes thoroughly cleaning the workpiece surfaces to remove contaminants like oil, rust, scale, paint, and other impurities either mechanically by wire brushing, abrasion techniques, etc., or chemically by means of soaking, cleaning, or acid etching. Once the contaminants are removed, the next step is to apply a suitable *flux*.

A flux is a substance, either in a liquid or semi-liquid state performing the following functions:

- The flux primarily helps the base metals from oxidizing while they are being heated to the soldering temperature. The flux covers the surface to be soldered, shielding it from oxygen and thereby preventing oxidation during heating.
- The flux acts as a wetting agent in the soldering process, reducing the surface tension of the molten solder and causing it to better wet out the parts to be joined.
- Flux cleans the surface, dissolving the metal oxides.

Different types of flux include rosin-alcohol, zinc chloride, aniline phosphate etc. The flux may be applied on to the metal surface by brushing, dipping, spraying, or by other methods.

Advantages of Soldering

- Low power requirements.
- Low temperature process. Hence, no thermal distortions and residual stresses in the joint parts.
- Dissimilar parts can be easily soldered.
- Thin parts can be joined easily.

Disadvantages of Soldering

- Flux residues should be removed after soldering, otherwise which causes corrosion.
- Thick parts cannot be *efficiently* joined.
- Since soldering temperatures are low, a soldered joint cannot be used in high temperature applications.
- Strength of joint is low. Hence cannot be used for load-bearing members.

Applications of Soldering

One of the most common applications of soldering is assembling *electronic components to printed circuit boards* (PCB's). Another common application is making connections between copper pipes in plumbing systems.

Joints in sheet metal objects such as food cans, metal containers, and rain gutters are made by soldering. The process can also be used as a semi-permanent patch for a leak in a container, or cooking vessel.

TYPES OF SOLDER

A solder is an alloy, which melts at low temperatures. There are two types of solder: *soft solder* and *hard solder*, discussed as follows.

(i) Soft solder

- These are alloys of tin and lead. *Example* Lead = 37 % and Tin = 63 %.
- They have low melting points ranging from 150°C – 190°C.

- A very small amount of antimony, usually less than 0.5% is sometimes added to improve the mechanical properties of the solder. But, its addition should be controlled, otherwise which might impair soldering characteristics.
- Soft solders are used in those applications, where the joint is not subjected to heavy loads and high temperatures.

(ii) Hard solder

- Silver alloyed with lead (lead = 97.5 % & silver = 2.5 %) or silver alloyed with copper and zinc (Silver = 50 %, copper = 34 %, & zinc = 16 %) are the widely used type of hard solder.
- The melting point of hard solder ranges from 300 - 600°C depending on the type and alloy composition.
- Hard solder is used to make strong joints that can resist high temperatures.

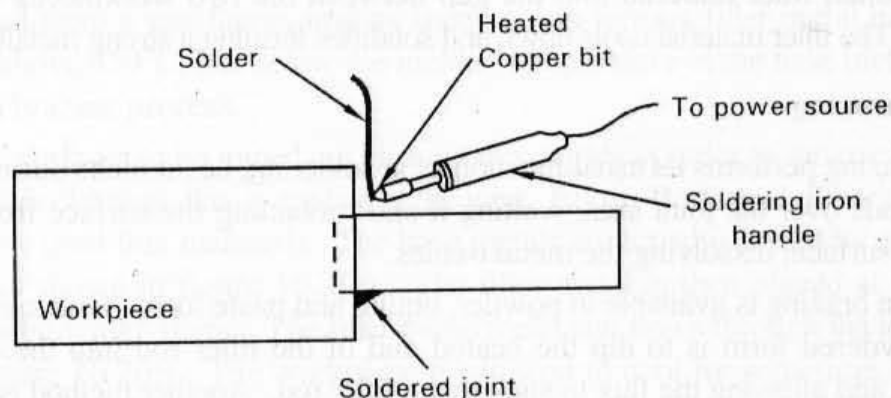
Note In practice, solder (soldering filler materials) are available in many different alloys for different applications. Some examples of solder types and their applications include tin-lead (general purpose), tin-zinc for joining aluminum, lead-silver for strength at higher than room temperature, applications, cadmium-silver for strength at high temperatures, zinc-aluminum for corrosion resistance, and tin-silver and tin-bismuth for electronics applications.

TYPES OF SOLDERING

Soldering methods are classified based on the mode of heat application. The heat applied should be such that it should melt the solder and permit the molten solder to flow quickly into the joint. The various soldering methods are briefed as follows.

(a) Soldering iron method

It is the most common and widely used method of soldering. The tool used in this method is a *soldering iron* with a copper coated tip, which may be heated electrically, or by oil/gas flame. The tip of the soldering iron stores and conducts heat from the heat source to the components being joined. Figure 10.1 shows the soldering process.



Figure

Soldering

The surface of the workpieces to be joined are cleaned thoroughly to remove the contaminants. A suitable flux is applied at the joint. Zinc chloride, hydrochloric acid and alcohol-rosin are some of the fluxes used in soldering. The soldering iron is heated to a suitable temperature and a little solder is melted at the tip of the soldering iron. The tip of the soldering iron, called the *bit*, is brought at the joint and the molten solder is deposited. The molten solder flows into the joint by the capillary force. The solder cools down and solidifies forming a joint. The joint is cleaned to remove flux residues in order to prevent corrosion.

(b) Torch soldering

Torch soldering utilizes the heat of a flame issued from an oxy-fuel gas torch. The *torch* mixes a fuel gas like acetylene with oxygen in suitable proportions, and burn the mixture at its tip. The flame generated at the torch tip is directed at the workpieces with a flux applied on their surfaces. When the workpieces are heated to a suitable temperature, the solder is fed into the joint region to melt and flow into the gap between the two workpieces. The solder cools down and solidifies forming a joint.

(c) Wave soldering

Wave soldering is a very popular approach for soldering through-hole components on printed circuit boards. This method uses a tank filled with a molten solder. The solder is pumped, and its flow forms a wave of a predetermined height. The printed circuit boards pass over the wave touching it with their lower sides.

BRAZING

The details regarding brazing process are briefed as follows:

Principle

Brazing is a method of joining similar or dissimilar metals by means of a filler metal whose melting temperature is above 450°C, but below the melting point of the base metal (workpiece). The filler metal called *spelter* is a non-ferrous metal or alloy. Copper and copper alloys, silver and silver alloys, and aluminum alloys are the most commonly used filler metals for brazing.

The flow of molten filler material into the gap between the two workpieces is driven by the capillary force. The filler material cools down and solidifies forming a strong metallurgical joint.

Flux used in brazing

Flux used in brazing performs its usual function as in soldering, i.e., it melts during the preheating stage and spreads over the joint area, wetting it and protecting the surface from oxidation. It also cleans the surface, dissolving the metal oxides.

The flux used in brazing is available in powder, liquid, and paste form. One method of applying the flux in powdered form is to dip the heated end of the filler rod into the container of the powdered flux, and allowing the flux to stick to the filler rod. Another method is to heat the base metal slightly and sprinkle the powdered flux over the joint, allowing the flux to partly melt and

stick to the base metal. Sometimes, it is desirable to mix powdered flux with clean water (distilled water) to form a paste. Flux in either the paste or liquid form can be applied with a brush to the joint. Better results occur when the filler metal is also given a coat.

The most common type of flux used is borax, or a mixture of borax with other chemicals. Some of the commercial fluxes contain small amounts of phosphorous and halogen salts of iodine, bromine, fluorine, chlorine, or astatine.

Advantages of Brazing

- Much heat is not involved in the process. Hence, low thermal distortions and residual stresses in the joints.
- Easily automated process.
- Dissimilar parts can be joined.

Disadvantages of Brazing

- Flux residues must be removed after brazing, otherwise which may cause corrosion.
- Large and thick sections cannot be brazed efficiently.
- Relatively expensive filler materials.

Applications of Brazing

Brazing is employed in areas such as automotive, aerospace and tool industries, where high demands exist for strength and fatigue-, corrosion- and oxidation resistance. Brazing is used for fastening pipe fittings, tanks, carbide tips on tools, radiators, heat exchangers, electrical parts, axles, parts of bicycle such as frame and rims, etc. It can be used to join cast metals to wrought metals, dissimilar metals and also porous metal components.

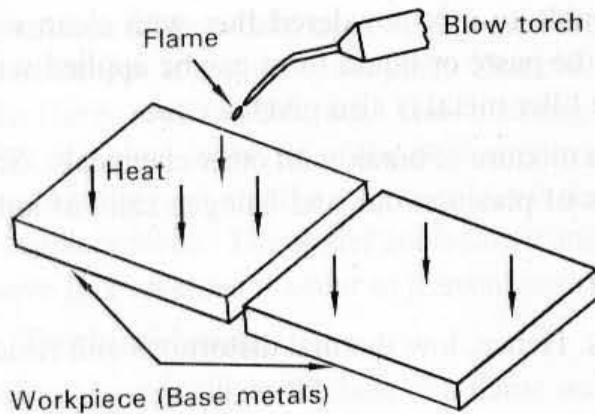
TYPES OF BRAZING

Brazing methods are classified based on the mode of application of heat. A few common methods are briefed as follows.

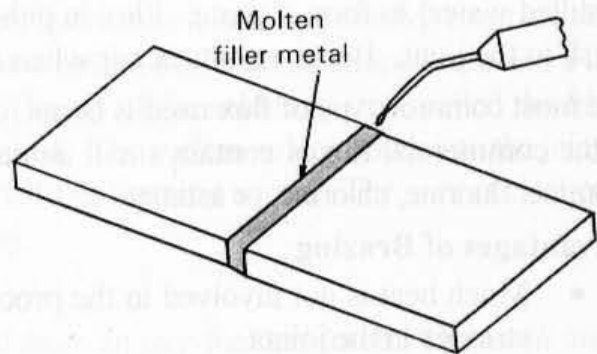
(a) Torch brazing

Torch brazing is the most commonly used brazing process wherein the two metals are joined by the heat obtained from a gas flame, and by using a non-ferrous filler metal having a melting temperature of above 450°C, but below the melting temperature of the base metal. Figure shows the torch brazing process.

In operation, the surfaces to be joined are cleaned thoroughly in order to remove dirt, grease and other oxides. After cleaning, flux is applied at the joint. Borax, Boric acid, Fluorides, or chlorides are the commonly used flux materials. The base metals are broadly heated by an oxy-acetylene welding torch as shown in figure (a). The filler metal is then placed at the joint and is heated with a carburizing flame. The filler metal melts and flows through the joint by capillary action. Refer figure (b). The workpiece is allowed to cool for sometime, and the joint is then cleaned to remove flux residues in order to prevent corrosion.



(a) Broad heat to base metals



(b) Filler metal placed at the joint & melted

Figure

Brazing

(b) Furnace brazing

Furnace brazing is a process in which bonding is produced by using the furnace heat and a non-ferrous filler metal having a melting temperature of above 450°C , but below the melting temperature of the base metal. The filler metal is distributed in the joint by capillary attraction. Furnace brazing is suited for fabricating complete brazements, and does not require a highly skilled operator. Pre-fluxed or pre-cleaned parts with filler metal pre-placed at the joints are heated in furnaces. Brazing can be done in an *air furnace* with a flux, though a protective atmosphere usually is needed. The type of atmosphere required depends on the materials being brazed and the filler metals being used. Base metals with readily reducible oxides can be brazed in an atmosphere of combusted natural gas or cracked ammonia. Dry hydrogen, a powerful reducing agent can be used for brazing stainless steels nickel, cobalt and iron-base alloys.

(c) Dip brazing

Dip brazing is used on aluminum assemblies, since the temperature of the molten flux bath can be controlled. The molten bath serves as both heating medium and fluxing agent. Uniform heating to brazing temperature is achieved rapidly. Parts are cleaned, assembled and held together in fixtures during brazing. Parts are normally preheated before immersion, and residues are removed after brazing in order to prevent corrosion.

(d) Resistance brazing

Resistance brazing is suited for special joints where heat must be restricted to a localized area without overheating surrounding parts. The heat required for brazing is produced due to the electrical resistance offered by the joint members to the flow of current through them.

(e) Induction brazing

Induction brazing utilizes alternating electromagnetic field of high frequency for heating the workpieces together with the flux and the filler metal placed in the joint region. The technique is used only in those applications, where the entire assembly would be adversely affected by heat. Since the workpiece is heated selectively by the coil, induction brazing reduces unwanted part distortion or annealing. Induction heating brings the joint rapidly to brazing temperatures.

BRAZING v/s SOLDERING

Table shows a brief comparison between brazing and soldering.

Sl. No.	Brazing	Soldering
1.	Filler metal used in Brazing is called <i>spelter</i>	Filler metal is called <i>solder</i>
2.	Melting point of filler metal is above 450°C but below the melting point of the workpiece metal.	Melting point of filler metal is below 450°C
3.	Stronger joints can be obtained in brazing	Strength of the joint obtained in soldering is comparatively low.
4.	Brazed joints resist corrosion.	Soldered joints do not resist corrosion to the same extent as that of brazed joints.
5.	Brazing is slightly costlier	Cheaper

Table Comparison between brazing and soldering

WELDING

Welding is a fabrication process in which two or more workpieces, usually metals, (or even thermoplastics) are joined permanently to form a single component. The process is carried out by heating the edges of the workpieces to a suitable temperature and then fused together with or without the application of pressure. Since a slight gap usually exists between the edges of the workpieces, a *filler metal* is used to supply additional material to fill the gap. However, welding can also be carried out without the use of filler metal.

The filler metal is melted in the gap, combines with the molten metal of the workpiece, and upon solidification forms an integral part of the weld.

Advantages of Welding

- The strength of the joint obtained in welding is much stronger than the workpiece metal.
- Metals with different chemical compositions can be welded easily.
- Welding equipments are portable. Hence, the parts can be fabricated at the relevant location instead of transporting the entire assembly to its destination.
- Complex shapes that are difficult to cast or machine can be easily assembled in parts by welding.
- Parts can be fabricated at reasonable costs.
- Welding process can be automated.

Disadvantages of Welding

- a) The process gives out harmful radiations, fumes and spatter. Hence, care should be taken during welding.
- b) Skilled operator is required to produce a good joint.
- c) The high heat involved in the process causes changes in the structure of metal thereby lowering its properties (strength, ductility, etc.).

Applications of Welding

Welding finds application in ship building, automobiles, aircraft, power plants, building and bridge constructions, storage tanks, pressure vessels, refrigerators, machine tools, and almost in all sectors, where parts are fabricated as per the needs.

Apart from fabrication work, welding is also used in repair and maintenance work; for example joining broken parts and rebuilding worn out components.

CLASSIFICATION OF WELDING PROCESSES

In general, welding processes are classified into two types: *Plastic welding* and *Fusion welding*.

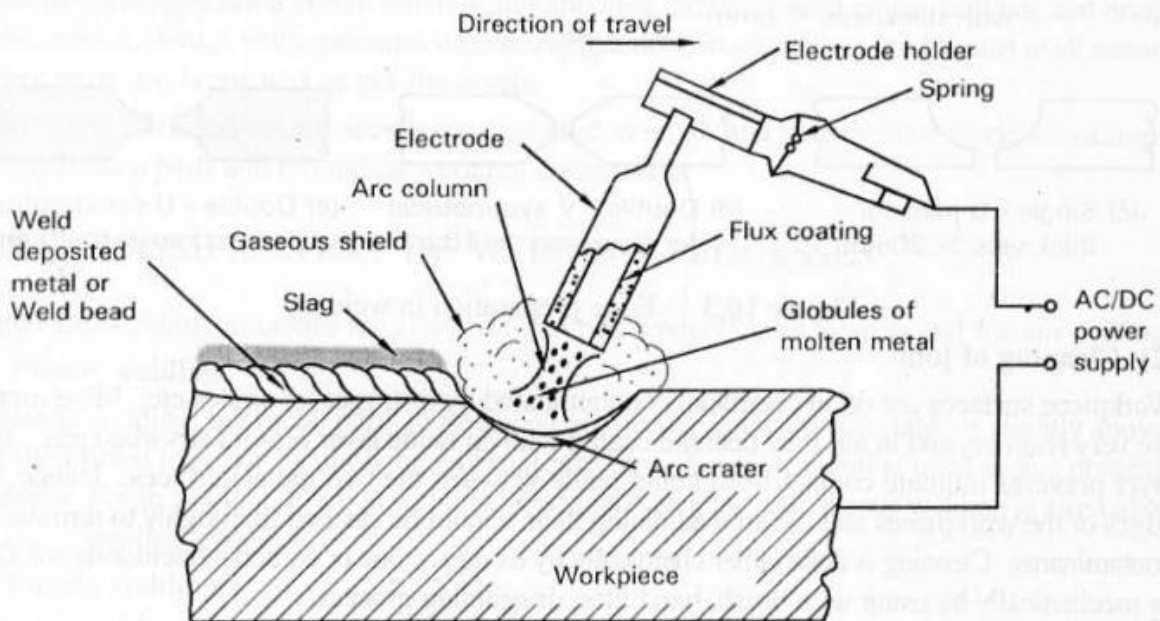
1) Plastic welding

In plastic welding, the metal parts to be joined are heated to the plastic state, or slightly above, and then fused together by applying external pressure. No filler metal is used in this process. *Example* Forge welding, Friction welding, Resistance welding, etc. Plastic welding is also called *pressure welding process*.

2) Fusion welding

In fusion welding, the parts to be joined are heated above their melting temperatures and then allowed to solidify by cooling. A filler metal may or may not be used during the welding process. *Example* Arc welding, gas welding, Laser welding, etc.

ARC WELDING PROCESS



Arc welding process is a fusion method of welding that utilizes the high intensity of an electric arc to melt the workpiece metals. A solid continuous joint is formed upon cooling. Either AC (alternating current) or DC (direct current) can be used to supply the required current for welding.

Figure shows the arc welding process. In this process, the electrode holder holding the electrode firmly forms one pole of the electric circuit, while the workpiece to be welded forms the other pole. The electrode serves both to carry the arc and also acts as a filler rod to deposit the molten metal into the joint.

The electrode used in arc welding process is a metallic wire, which is made of the same material or nearly the same chemical composition as that of the workpiece material. The metallic wire is coated with a suitable flux material like rutile (titania), calcium fluoride, cellulose, iron oxide, etc., which gives off gases as it decomposes thereby preventing oxidation of the molten metal during welding process.

In operation, an arc is struck by touching the tip of the electrode on the workpiece (similar to striking a match stick), and instantaneously the electrode is separated by a small distance of

2–4 mm such that the arc still remains between the electrode and the workpiece. The temperature of the arc ranges from 5000 – 6000°C. The high heat at the tip of the arc melts the workpiece metal forming a small molten metal pool. At the same time, the tip of the electrode also melts. The molten metal of the electrode is transferred into the molten metal of the workpiece in the form of globules of molten metal. The deposited metal fills the joint and bonds the joint to form a single piece of metal. The electrode is moved along the surface to be welded to complete the joint. The arc is extinguished by increasing the arc length, i.e., by widening the gap between the workpiece and the electrode.

Advantages

- The process is simple and inexpensive. Hence, suitable for shop jobs and field work.
- Eliminates skilled labour.
- The process dominates other welding processes in maintenance and repair industry.
- Used to weld ferrous & few non-ferrous metals like aluminum, nickel, copper alloys etc.

Disadvantages

- Weld times are rather slow, since the consumable electrode must be frequently replaced.
- Weld spatter, poor fusion, shallow penetration, and cracking are a few major problems associated with the process. However, by proper welding practice, they can be minimized.

Applications

Arc welding finds applications in building and bridge construction, ship building, boiler and pressure vessel fabrication, joining of large pipes and penstock, and in almost all repair and maintenance work.