Module 3

3.1. Basic description of manufacturing processes

Production of a component involves transforming a blank or raw material from its original state to a finished state by changing its shape, size and properties in a series of steps, each step is called a production process. When no further changes are required , the component is known as a finished component or finished part. The subject manufacturing process deals with various aspects of production of a finished part. The selection of the best process for a given part requires a knowledge of all possible production methods. Hence the subject has become increasingly important to the engineer, supervisor, or worker engaged in the production field connected with all branches of engineering.

Manufacturing process can be broadly classified into five groups, as:

1. Shaping processes.
2. Machining processes.
3. Joining processes.
4. Finishing processes.
5. Property changing processes.

Shaping processes are those processes in which the shape and size of the metal is changed without removal of the material. The common processes which fall under this category are; casting , forging, rolling, extruding, drawing etc. In certain cases, the shaping process gives parts which are suitably finished for commercial use. But in certain other cases, after the shaping process, some other processes are required to obtain a finished part.

Machining processes are those processes in which the shape and size of the metal is changed by removing the material from the unwanted portions of the workpiece. Generally these processes are carried out after completing the shaping process. These processes require one or more machines and cutting tools to remove the material. The common processes which fall under this category are turning, drilling, grinding, milling etc.

Joining processes are those processes in which two or more parts are joined together , generally for fabrication work. The common processes, which fall under this category, are ; welding , brazing, soldering, bolting, riveting, shrink fitting etc.

Finishing processes are those processes by which the required surface finish or protective coating is provided to the part. It is not treated as a metal removing process even though very small amount of metal removal or addition may take place. Some of the processes, which fall under this category, are honing, lapping, electroplating, galvanizing etc.

Property changing processes are those processes in which certain properties of a part are changed so as to make it suitable for a particular application. The common processes which fall under this category are annealing , normalizing , hardening, tempering etc.

3.2. Sand casting

Casting is the process of producing metallic parts of desired shape and size by pouring molten metal into a mould having a cavity of the part to be cast and then allowing the molten metal to solidify. The resulting solid will have the shape of the cavity and is called casting. The mould into which the molten metal is poured, is made of some heat resistant material. Sand is most often used as it is readily available, easily packed to shape , is somewhat porous and resists high temperature, Moulding is the process of making a mould using a pattern. A pattern is the model or replica of the part to be cast. Wood is the most common material used for pattern, since it is easy to work and readily available. The main disadvantage of wood as pattern material is that it changes its size due to effect of moisture in the moulding sand. Also it wears out quickly and hence wood is used for making pattern when the number of castings to be produced are few. Patterns are made of metals when a large number of castings are required. Metallic patterns are more durable and produce mould of good dimensional accuracy and better surface finish. Cast iron, brass, aluminium and its alloys etc are some common metals used for pattern making.

Plastic are now finding their place as a modern pattern material because they do not absorb moisture, are strong and dimensionally stable, resistant to wear , have a very smooth surface and are light in weight. Gypsum cement known as plaster of paris, waxes etc are also used as pattern materials.

Properties of moulding sand

A good moulding sand must fulfill various requirements like porosity, cohesiveness, adhesiveness, plasticity, refractoriness, flowability and chemical stability.

Porosity or permeability

The property that allows passage of gases through the mould is termed as porosity or permeability. The moulding sand must be sufficiently porous to allow the gases and steam generated to escape.

Cohesiveness or strength

The ability of sand particles to stick together is termed as cohesiveness or strength. Moulding sand must have sufficient strength to prevent the collapse of the mould during conveying, turning over and closing.

Adhesiveness

The property of sand particles to stick on to other bodies is termed as adhesiveness. Moulding sand must have sufficient adhesiveness to hold the sand mass in the moulding box and to prevent its falling out from the box when it is turned over or conveyed.

Plasticity

The property of acquiring predetermined shape under pressure and to retain it when the pressure is removed is termed as plasticity. Moulding sand must have sufficient plasticity to get a good impression of the pattern. It depends upon the content of clay , moisture and grain size of sand etc.

Refractoriness

The property of sand to withstand high temperature without breaking down or fusing is termed as refractoriness. Moulding sand must have sufficient refractoriness to withstand the high temperature of molten metal.

Flowability

The property of sand to behave like a fluid is termed as flowability . Moulding sand must have sufficient flowability so that it can flow to all portions of a moulding box and around the pattern when it is rammed. This property enables the mould to pick up the correct contour of the pattern.

Chemical stability

The property of sand to resist chemical reaction with molten metal is termed as chemical stability. A good moulding sand must have sufficient chemical stability to withstand chemical reaction with molten metal so that it can be used again and again.

Sand moulds are prepared in a specially made box called moulding box or moulding flask, which is open at the top and bottom. It is made in two parts and held in alignment by pins. The top part is called the cope and lower part the drag. These flasks are made of wood or metal.

Gating system

The passage for bringing the molten metal to the mould cavity is known as gating system. It consists of a pouring basin, sprue and gate. Pouring basin is made at the top of the mould. The main purpose of the pouring basin is to help to maintain the required rate of flow of molten metal into the mould cavity. It also prevents slag from entering the mould cavity.

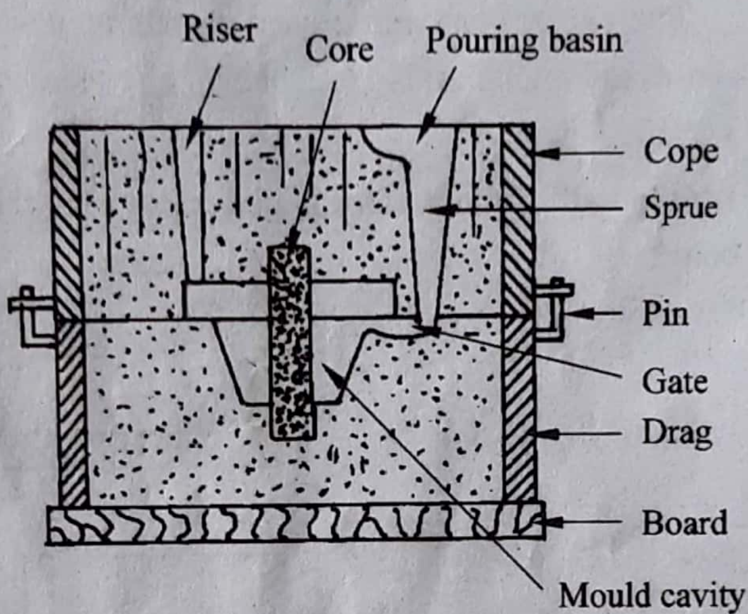


Fig. 3.1. Sectional view of a sand mould

Sprue is the vertical passage that passes through the cope and connects the pouring basin with the gate. Gate is the passage through which molten metal flows from the sprue base to the mould cavity. Riser is the passage made in the cope to permit the molten metal to flow after the mould cavity is filled up. If the molten metal does not appear in the riser , it indicates that mould cavity is not filled up completely. The riser also acts as a reservoir and feed molten metal into the mould cavity to compensate for the soildification shrinkage of castings. Riser also serves as a vent for steam and gases generated as the mould cavity is being filled up with the molten metal.

Core

Core is a prepared solid mass of dry sand, having the shape of the internal cavity or hole in the casting. Cores are made separately using core boxes and are kept in the mould after the pattern is removed. It is used to obtain the desired hole or recess in the casting which otherwise could not be obtained by normal moulding process. The projections on the pattern intended to get impressions in the mould which support and hold the core are known as core prints.

Casting procedure

The general procedure used in making a sand mould for the casting shown in Fig. 3.2 (a) is given below. The required pattern is shown in Fig. 3.2 (b).

1. One half of the pattern is placed with its flat surface on a moulding board.

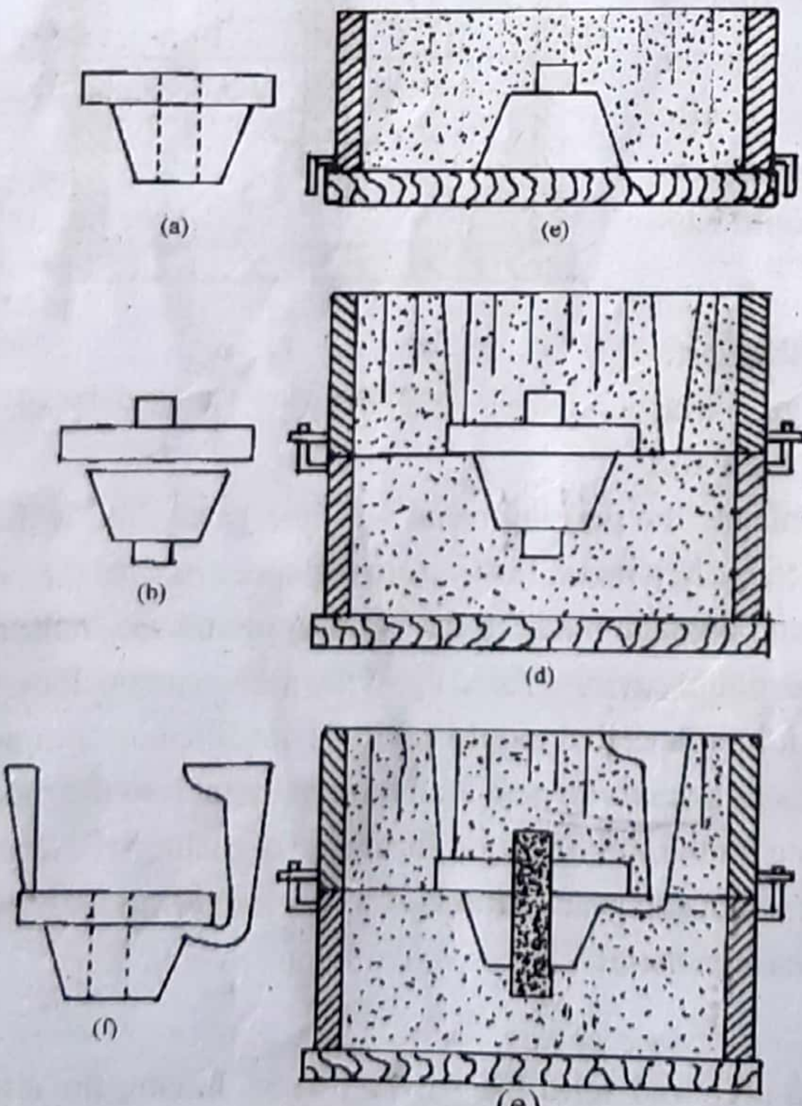


Fig. 3.2. Making a sand mould

2. The drag is placed on the board with the pins downward.

3. The drag is filled with moulding sand and properly rammed.

4. Excess sand above the top level of drag is removed and levelled with the top of the drag. Fig. 3.2 (c)

5. The drag is turned over and placed on another board.

6. The other part of the pattern is kept over the first half and parting sand is prinkled over the surface . Now the cope is placed over the drag.

7. Runner and riser pins are placed at appropriate places and cope is filled with moulding sand, rammed properly.

8. Excess sand above the top level of cope is removed and levelled with the top of cope. Vent holes are made to ensure the escape of gases which are formed when molten metal is poured .

9. Runner and riser pins are removed (Fig. 3.2 (d)) and pouring basin is cut at the top of the sprue.

10. The cope is turned over and kept on a board

11. Pattern halves are carefully removed from the cope and drag.

12. Passage for the molten metal into the mould cavity known as gate is prepared on the top surface of the drag.

13. Repairs, if any, and cleaning of the mould cavity is carried out.

14. Surface of the mould cavity is sprinkled with fine graphite powder in order to get a good surface finish.

15. Core is kept in position.

16. The cope is kept back, carefully in position on the drag and clamped. The mould is now ready for pouring the molten metal. Fig. 3.2 (e).

17. After pouring the molten metal sufficient time is allowed for solidification. Once the solidification is over, the casting is taken out by breaking the mould. Fig. 3.2 (f).

18. The unwanted projections on the casting due to runner and riser are removed by cutting them off and the casting is cleaned.

Casting defects

A large number of defects occur in sand castings due to various reasons such as high moisture content, uneven ramming of sand, improper design of pattern etc. These defects can be eliminated or minimized by adopting suitable techniques . The following are some of the major casting defects.

1. Blowholes

Smooth , round holes below the surface of castings, which are not visible from outside are known as blowholes. Blowholes are formed by the entrapped bubbles of gases in the metal. It is caused due to excess moisture in the moulding sand , low porosity of sand , hard ramming of sand , inadequate venting, etc.

2. Inclusions

Any separate non-metallic foreign material present in the casting is called an inclusion. The inclusions may be in the form of oxides, slag, dirt and sand. Oxide, slag and dirt tend to float on the top of the metal and should be prevented from entering the mould cavity.

3. Swell

It is a localized or overall enlargement of the casting. It is caused due to loose ramming of the sand . Mould cavity enlarges under the pressure of molten metal at the places where the ramming is loose, resulting swelling of casting in those places.

4. Scab

It is the erosion or breaking down a portion of the mould and the recess filled with metal . The main cause is the uneven ramming of sand.

5. Honey combing

Number of small cavities present on the casting surface is called honey combing. It is caused by dirt held in suspension in the molten metal.

Shift

Mismatching of casting section is known as shift. It is caused due to isalignment of pattern, misalignment of cope and drag, movement of ould box during pouring the molten metal etc.

Misrun

An incomplete casting is produced. If the molten metal fails to reach ll the sections of the mould. Such a defect is termed as misrun.It happens due to low fluidity of metal caused by low temperature, slow and intermit-ent pouring of molten metal, presence of very thin sections, etc.

8. Cold shut

A cold shut is an external defect formed when two streams of molten metal of low temperature approach within the mould cavity, from opposite directions. The two streams of metal establish a physical contact between them, but fail to fuse together. It is caused due to low fluidity of molten metal, slow and intermittent pouring of molten metal , presence of thin sections etc.

9. Rattails and buckles

When molten metal having very high temperature is poured into the mould cavity, a thin outer layer of sand expands. If the molten metal fails to compress back this layer of sand, it gets separated from the remaining sand and remains over the surface of the casting. A slight compression failure of a thin layer of mould sand is known as rattail and severe compression failure of the sand surface is known as buckles

10. Fin

A thin projection of metal, which is not a part of the required casting is called fin. Fins usually occur at the parting surface of the cape and drag, mould cavity and core sections. It is caused due to insufficient weight of mould , improper clamping of moulding boxes, high pressure of molten metal, incorrect position of the core in the mould cavity etc.

18.

3.3. Forging

The process of changing the shape of metals when it is in the plastic state, by applying compressive force, is called hot forging or simply forging. When the shape of the metal is changed while it is at room temperature, by applying large compressive force, is called cold forging. A forged product always has better mechanical properties than a cast one and hence it is generally employed for those components which require high strength and other better mechanical properties. The components that are produced by forging are: nails, bolts, spanners, crane hooks, axles, crankshafts, connecting rods etc.

The different methods of forging are hand forging (smith forging) drop forging, press forging and machine forging.

1. Hand forging

This is the traditional forging operation carried out by blacksmith in a section of a workshop called smithy. Heating of metal is done in an open fire and hand tools are used for forging . To get the required shape , the operator has to manipulate the component in between the blows. Smith forging requires a lot of skill on the part of the operator and also is time consuming. Hence this method is not suitable for mass production. However for small lots and for trial production this method is highly used.

2. Drop forging

This is the operation done in closed impression dies and the force for shaping the component is applied in a series of blow by using drop hammers. The die is made in two halves, which contains the shape of the component to be produced , in the form of a cavity . This process can be used for mass production of small and medium sized products of simple to somewhat complex shapes.

3. Press forging

This process is similar to drop forging but for the method of application of force. In this case the force is applied by a continuous squeezing operan by means of a hydraulic press. This is also a mass production technique . Small to medium sized components are made using this method.

Machine forging

This process makes use of forging machines, also known as up setters for the application of force. In this process also the shaping of the product is done by using two halves of a die which contains the impression of the required product. Some of the examples are bolt heads, rivets, small shafts etc.

Hand forging operations

A number of operations are to be performed to change the shape of material to the desired form. The commonly used forging operations are:

1. Upsetting also called jumping
2. Drawing down also called necking down
3. Setting down
4. Bending
5. Welding
6. Cutting
7. Punching
8. Swaging
9. Drifting

1. Upsetting

It is a process of increasing the cross sectional area of a bar at any desired portion at the expense of length of the bar. The portion to be upset is heated and then hammered axially .

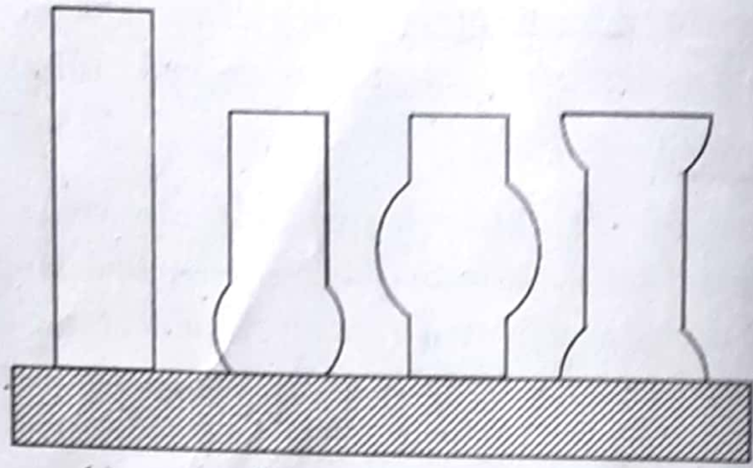


Fig. 3.3. Upsetting

Fig. 3.3 shows the effect on a round billet (a), when hammering it by healing only at one end (b), only at the centre (c), and at both ends keeping the centre portion unheated (d).

2. Drawing down

It is the process of reducing the cross section of a bar by increasing its length

Fig. 3.4 shows a typical drawing down process

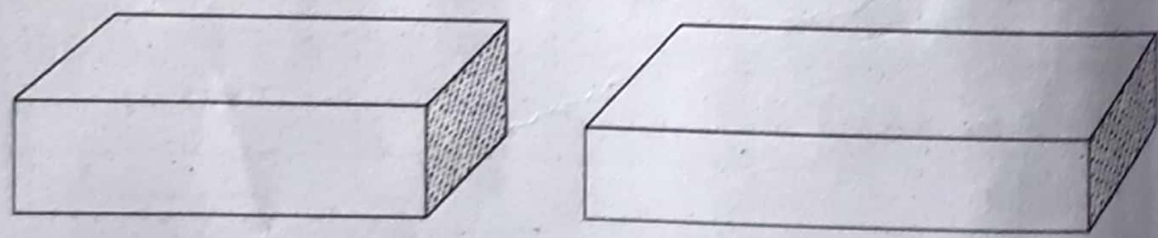


Fig. 3.4. Drawing down

3. Setting down

Setting down is the local thinning down operation using a set of hammer.

4. Bending

Bending is an operation by which bars and rods are bent to form rings, hooks etc. Fig. 3.5 shows the operation of bending a plate.

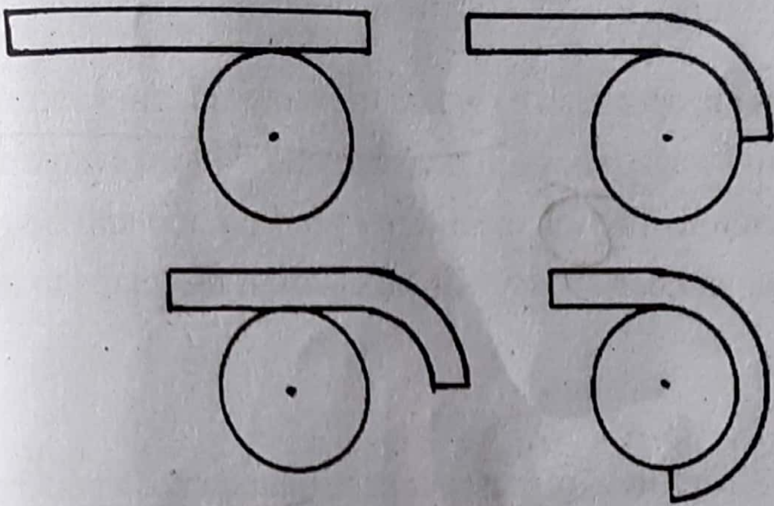


Fig. 3.5. Bending of a plate

5. Forge welding

Forge welding is the process of joining two metallic surfaces without using filler materials. The surfaces to be joined are heated to a temperature higher than the ordinary forging temperature and then joined together by hammering Fig. 3.6.

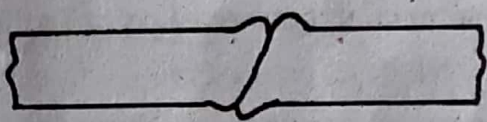


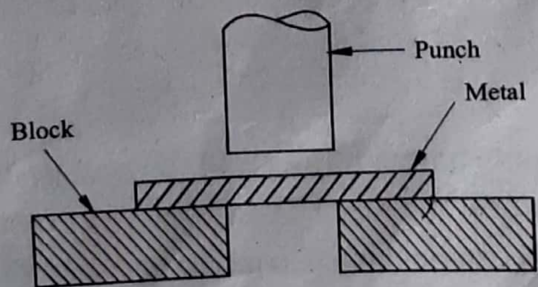
Fig. 3.6. Forge Welding

6. Cutting

Cutting is the process of removing pieces of metal from a billet by means of a chisel.

7. Punching

Punching is the process in which a punch is forced through a job to produce a hole. The job is heated and supported on a block. The block has a hole in it slightly larger than the hole to be made. Fig. 3.7.



-job

Fig. 3.7. Punching

8. Swaging

Swaging is the operation by which the required cross sectional shape is obtained. Two swage blocks, top swage and bottom swage are used for swaging operation. The job is held between the top and bottom swages and is hammered. Each swage will have half of the shape to be produced on the job.

9. Drifting

Drifting is the process of increasing the diameter of a punched hole. In this a drift which has tapered end is made to pass through the punched hole to produce a finished hole of the required size.

3.4. Rolling

Rolling is the process of forming metals into desired shapes by passing the metal in between a pair of rolls. The rolls in general squeeze the metal to reduce its cross section while increasing its length. Rolling is more economical than forging when metal is required in long lengths of uniform cross section. Bars, plates, sheets, rails, and other structural sections are made by rolling. Hot rolling is the process in which metal is fed to the rolls after being heated above the recrystallization temperature. In cold rolling metal is fed to the rolls when it is below the recrystallization temperature. The process of rolling basically consists of passing metal between two rolls rotating in opposite directions at the same speed.

The arrangement of rolls for a rolling operation constitute a rolling mill. The rolling mills are classified, on the basis of number of rolls and their arrangement, are two high rolling mill, three high rolling mill, four high rolling mill and cluster mill. The different types of rolling mills are described below.

1. Two high mill

Fig. 3.8 shows a two high rolling mill. It consists of two heavy rolls placed exactly one over the other. Mostly the lower roll will be fixed in position. Upper roll can be moved to adjust the space between the rolls. Both rolls rotate at the same speed but in opposite directions.

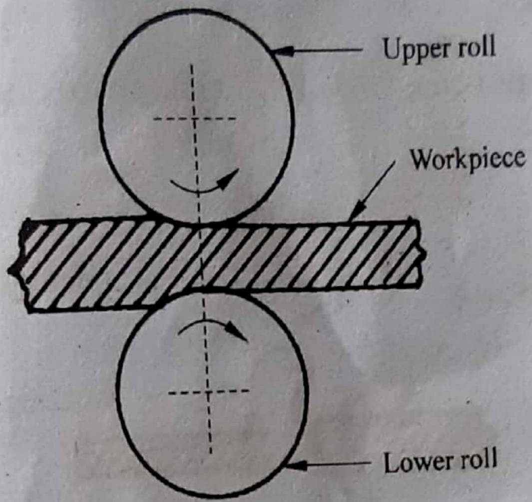


Fig. 3.8. Two high mill

Three high mill

It consists of three rolls positioned one over the other as shown in Fig. .9. The upper and lower rolls rotate in the same direction, while the middle oll rotates in the opposite direction. The work piece is made to pass in one direction between the upper and the middle rolls in the first pass and then

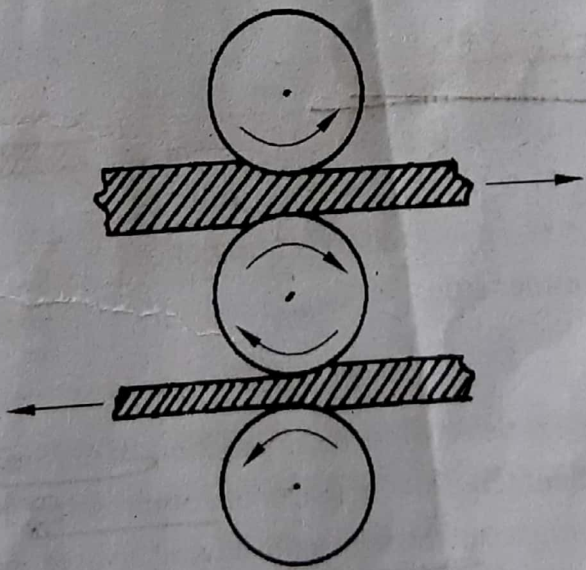


Fig. 3.9. Three high mill

between the middle and the lower rolls in the opposite direction during the second pass. In this, the middle roll is kept fixed and the upper and lower rolls are moved to adjust the roll gap.

3. Four high mill

It consists of four rolls, two of which are working rolls and the other two back up rolls.

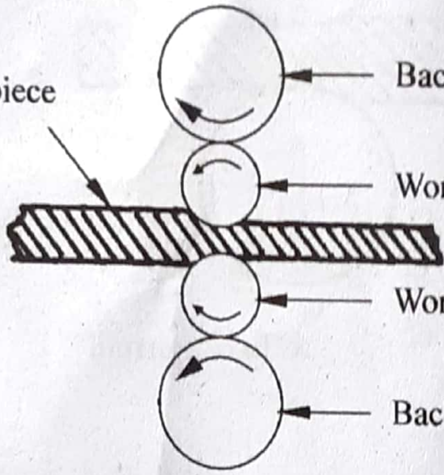


Fig. 3.10. Four high mill

The back up rolls have larger and are used for preventing the deflection of the working rolls. This arrangement is shown in Fig. 3.10.

4. Cluster mill

For rolling very thin sheet or foils, an arrangement known as cluster mill shown in Fig. 3.11 is used. It consists of a pair of working rolls of very small diameter, supported by a number of back up rolls on either side.

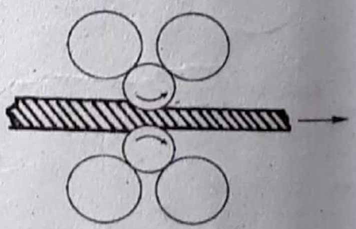


Fig. 3.11. Cluster

3.5. Extrusion

Extrusion is the process of forming products of uniform cross sectional shapes in convenient length. It consists of compressing the metal inside a chamber and forcing it out through a die having an opening in the shape of the cross sectional of the product. The compression of metal can be achieved either by hydraulically or mechanically. When extrusion is carried out at elevated temperatures it is known as hot extrusion. If the extrusion is caried out at low temperatures, it is known as cold extrusion. If the extrusion is carried out at low temperatures, it is known as cold extrusion.

Some metals such as lead, in tin and aluminium are extruded at room temperature. rods, tubes, structural shapes, etc. are some common products of extrusion.

Extrusion process can be classified as direct extrusion and direct extrusion and indirect extrusion.

1. Direct extrusion (forward extrusion)

In this process the metal (called billet) is placed in the die chamber and the metal is forced through the die opening by applying pressure on the ram. The extruded part coming out through the die is then cut into the required length. (Fig. 3.12)

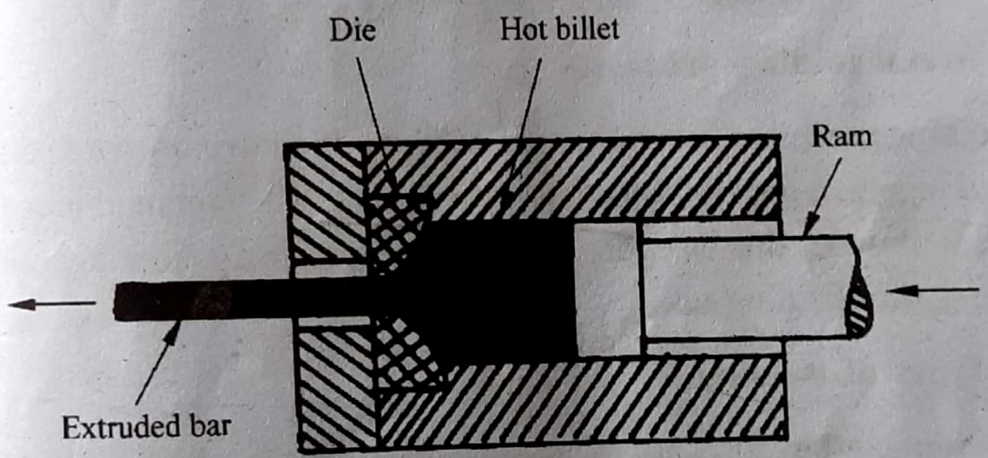
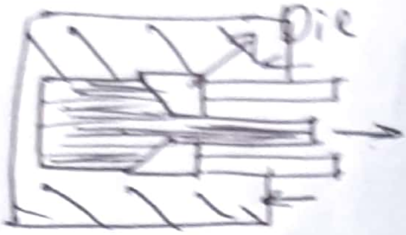


Fig. 3.12. Direct extrusion

2. Indirect extrusion (Backward extrusion)

In this process the extruded part which is forced out of the die is taken out through the ram (plunger), which is made hollow. In this case, the extruded part moves out in a direction opposite to that of the ram movement. This process requires less force than the direct method since there is no frictional force between the metal and the die chamber wall. The weakening of the ram when it is made hollow and the difficulty of providing adequate support for the extruded parts are the limitations of this process. (Fig. 3.13)



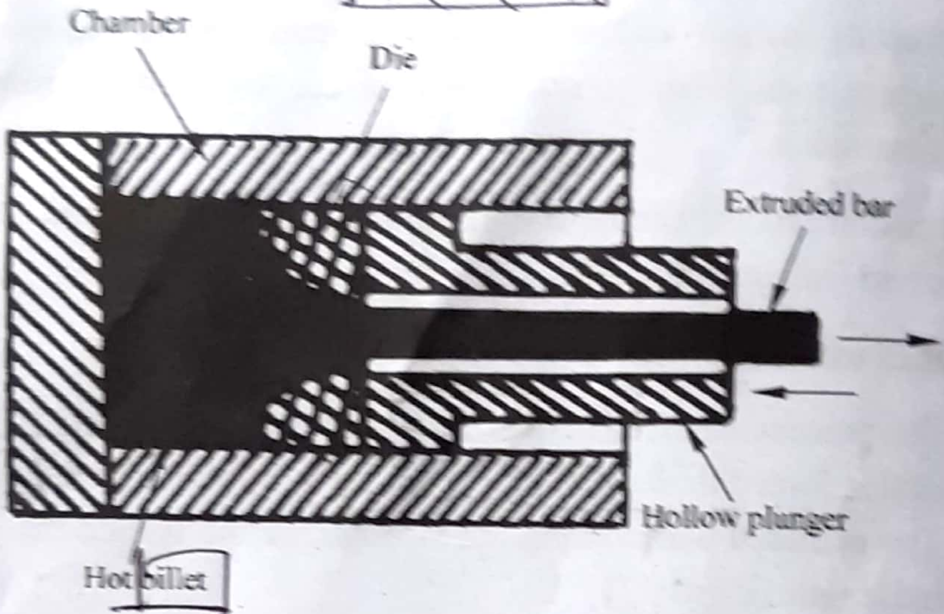


Fig. 3.13. Indirect extrusion

3.6. Metal joining processes

Joining processes are those processes in which two or more parts are joined together, generally for fabrication work. The common processes, which fall under this category are; welding, brazing, soldering, bolting, riveting, shrink fitting etc.

3.7. Types of welding

Welding is the process of joining two metals by the application of heat. Heat for welding process can be obtained from many sources such as smith's hearth for forge welding, electric current for resistance welding, gas flames for gas welding, chemical reaction for thermit welding and electric arc for arc welding etc.

Welding is done with the help of a welding machine. The welding machine raises the temperature of the required portions of the work pieces so that it can fuse them. Depending upon the type of heat production welding processes are classified as, (i) electrical resistance welding, (ii) gas welding and (iii) thermit welding and (iv) Arc welding

(i) Electrical resistance welding

In this process the work piece to be joined are held together and a strong electric current of low voltage (6 to 10 volts) and high amperage (60 to 4000 amperes) is passed through them. When the current passes through the metal, the high resistance at the point of contact raises the temperature at the junction. The mechanical pressure applied at this moment completes the weld.

(ii) Gas welding

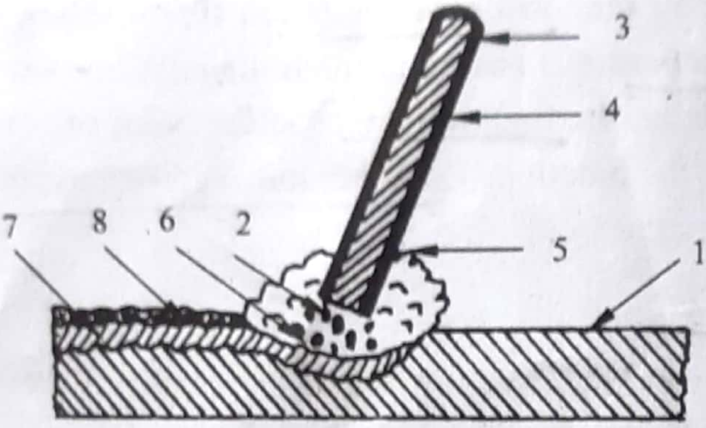
It is fusion welding process in which the required heat is obtained by a combustion of a fuel gas. The heat is used to melt the ends of the work pieces to be joined and also to melt the filler metal rod known as welding rod. The weld is obtained as the molten metal solidifies. Several gas mixtures like oxygen and acetylene, oxygen and hydrogen, natural gas are used for producing the gas flame

(iii) Thermit welding

It is a fusion welding process in which the required heat is obtained by an exothermal chemical reaction.

3.8. Arc welding

In arc welding, the surfaces to be joined are fused by the heat produced from an electric arc. A metal electrode is used for obtaining the electric arc between the work piece and the electrode, together an electric current is established. Separating electrode from the workpiece by a short distance, an electric arc is formed in which the electrical energy is converted into heat. The intense heat so produced melts the work piece under the arc forming a pool of molten metal which if forced out of the pool by the blast from the arc as shown in Fig. 3.14. The electrode end is also melted by the heat and it is transferred across the arc to the molten metal pool. The arc is maintained by uniformly moving the electrode towards the workpiece and hence keeping constant gap between the electrode and the workpiece. At the same time the electrode is moved along the desired line of welding.



1. Workpiece 2. Arc 3. Electrode 4. Coating
5. Gas shield 6. Molten metal 7. Weld metal 8. Slag

Fig. 3.14. Arc welding

Generally the electrodes are coated with slagging or fluxing materials. It is to provide a gas shield around the arc to prevent direct contact of oxygen and nitrogen in the air with the deposited metal. It also covers the weld metal with a protective slag coating which prevents oxidation of the weld metal during cooling. The slag is brushed off after the joint has cooled.

3.9. Soldering

It is a form of joining metals, by using another metal or alloy heated to its melting point. The heated metal, called solder, flows between the metals to be joined and solidifies. The mechanical and physical properties of the solder should be near to those of the metal to be joined. There are two types of solders, soft solder and hard solder. Soft solder is an alloy of tin and lead with some additives. Hard solder is an alloy of copper and zinc. Soft solder will melt at a temperature of about 320°C and hard solder at 600°C. The method of heating the solder is by using a soldering iron which is heated by electric current. The parts to be joined are first cleaned and are coated with flux . The soldering iron is then heated to red hot. The joints are placed in a clamp. A few pieces of solder are then put on the tip of the soldering iron and a few drops of the molten solder are applied over the joint. The spots of solder in the joint are spread evenly over the entire length of the joint.

Soldered joints can be easily separated and hence are useful only for semi permanent work. It cannot withstand high temperature and pressure. Soldering process is applied in the fabrication works on drain water pipes, radiator tubes of motorcars, copper pipes of automobiles, wiring joints etc.

3.10. Brazing

Brazing is the process of making joints which can with stand temperatures upto 800°C and moderately high pressure. A filler material called brazing solder or spelter is heated to its melting point and allowed to flow between the metals to be joined. On solidification, a moderately strong joint is formed. The filler material is generally a mixture of copper, zinc and tin. In operation, the ends of the metal pieces to be joined are initially cleaned. Spelter is then spread over the surface together with the flux. The parts are then clamped together and are heated. On cooling it solidifies and the joint is formed.

Normally a brazing mixture is prepared in the form of a paste. This will be applied to the surfaces to be joined instead of spreading the spelter. This paste is made by mixing the spelter and flux in equal parts and then adding water to it. The applications of brazing are found in parts of bicycle, pipe joints subjected to vibrations, suction pipes in automobiles, stove burners, steel tips of lathe tools, saw blades etc.

3.11. Basic manufacturing operations

Machining processes are those processes in which the shape and size of the metal is changed by removing the material from the unwanted portions of the workpiece. Generally these processes are carried out after completing the shaping process. These processes require one or more machines and cutting tools to remove the material. The common processes which fall under this category are surfacing, turning, shaping, drilling, grinding, milling etc.

3.12. Turning

Turning is the removal of material from the periphery of a work piece to obtain a cylindrical surface. It is one of the major machining operations that can be performed in a lathe. Turning can be carried out by holding the work in a chuck or by supporting the work in between lathe centres as shown in Fig. 3.15. A cutting tool, fed either parallel or perpendicular to the axis of the work, removes material from the rotating work to give the required size and shape.

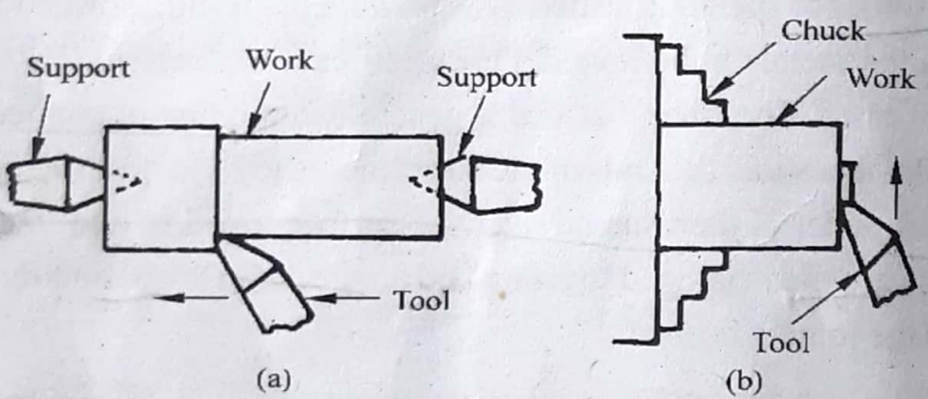


Fig. 3.15. Turning

If the tool is moved parallel to the axis of rotation of the work then a cylindrical surface is produced as shown in Fig. 3.15 (a). If the tool is moved perpendicular to the axis of rotation of the work, then a flat surface is produced at the end of the workpiece as shown in Fig. 3.15 (b).

The following procedure is adopted for turning.

(i) Hold the workpiece in a chuck with a short length projecting out. Rotate it at a constant speed.

(ii) Face the end of the work by feeding the tool perpendicular to the axis of rotation

(iii) Drill a small hole at the centre of this faced surface. This can be done by fixing the drillbit in the tailstock and feeding it into the rotating workpiece.

(iv) Remove the drillbit from the tailstock and fix the dead centre.

(v) Set the workpiece between the chuck and the dead centre.

(vi) Fix a tool in the tool post in such a way that the tip of the tool is in level with the axis of rotation of workpiece.

(vii) Adjust the depth of cut by moving the tool perpendicular to the axis of work. After giving the depth of cut, the tool is moved parallel to the axis of the rotating work. For further reduction in diameter of the work, apply further depth of cut and traverse the tool again. For final finish the speed of rotation must be increased and a fine depth of cut must be given. The traversing of tool must also be slow and steady.

Taper turning

Some machine elements and other parts are required to be turned with a taper. Taper is expressed as the ratio of the difference in the end diameters to the length of tapered job, measured parallel to the axis. Taper turning means producing a conical surface by gradual reduction in diameter from a cylindrical workpiece. The following methods are used for taper turning.

(i) Forming tool method

Fig. 3.16. shows the method of taper turning by a forming tool. The tool having a straight cutting edge is set at correct angle and is fed straight into work to generate the tapered surface. This method is limited to turn short external tapers only.

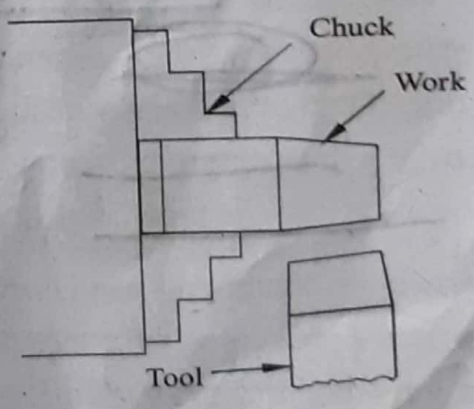
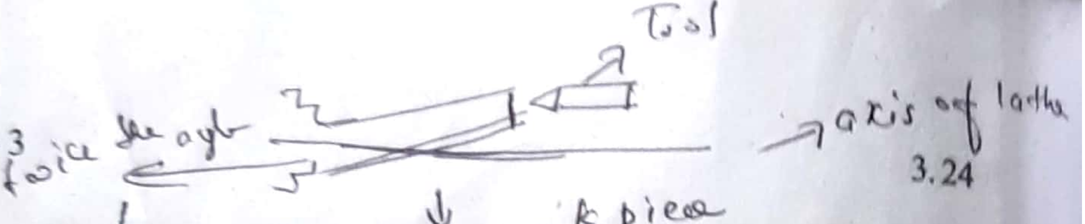


Fig. 3.16. Forming tool method

(ii) Tailstock set over method.

The principle of turning taper by this method is to shift the axis of rotation of the workpiece at an angle to the lathe axis and feeding the tool parallel to the lathe axis. The tool will cut a taper on the work, the angle



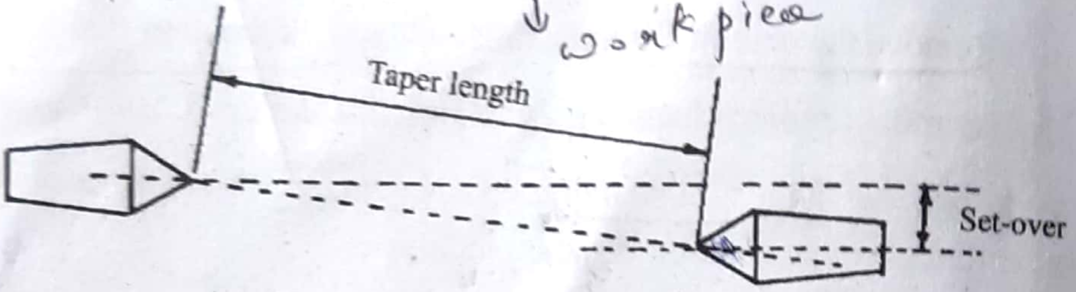


Fig. 3.17. Tail stock set over method.

of which will be twice the inclination of the axes as shown in Fig. 3.17. This method is limited to the production of small taper on long jobs.

(iii) Compound rest method

The principle of turning taper by this method is to rotate the workpiece on the lathe axis and feeding the tool at an angle to the axis of rotation of the workpiece. The compound rest, on which the tool is mounted, has a circular base graduated in degrees. By swiveling compound rest, it can be set at any desired angle. For taper turning this angle must be half the taper angle.

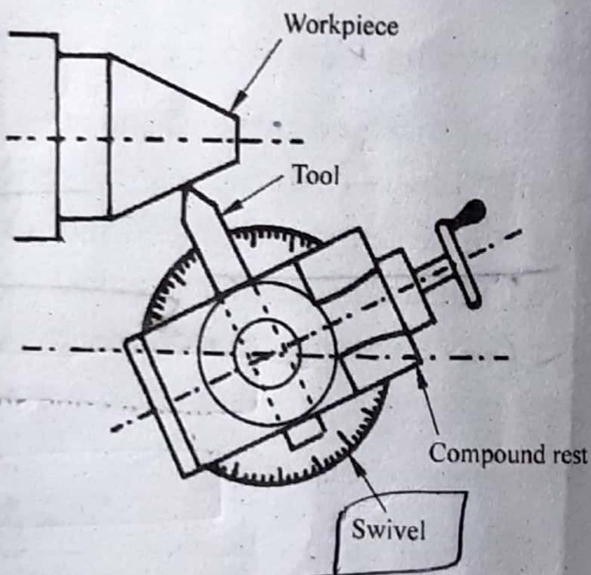


Fig. 3.18. Compound rest method.

Once the compound rest is set at the desired angle, rotation of the compound slide screw will cause the tool to be fed at that angle and generate a corresponding taper. This method shown in Fig. 3.18 is limited to turn a short taper owing to the limited movement of the cross slide.

3.13. Drilling

It is the operation of producing a circular hole using a drill by removing metal from the workpiece. Fig. 3.19 (a) shows this operation. Drilling is generally followed by some other operations like, Reaming

Reaming is the operation of sizing and finishing a hole by means of a reamer (reaming tool) having several cutting edges. The reamer does not originate a hole. It merely follows a drilled hole and removes a very small amount of metal. Reaming operations is shown in Fig. 3.19 (b).

2. Boring

Boring is the operation of enlarging a hole by means of an adjustable single point tool.

3. Counter boring

It is the operation of increasing the diameter of a hole for a certain distance down. It is done with a special cutter as shown in Fig. 3.19 (c).

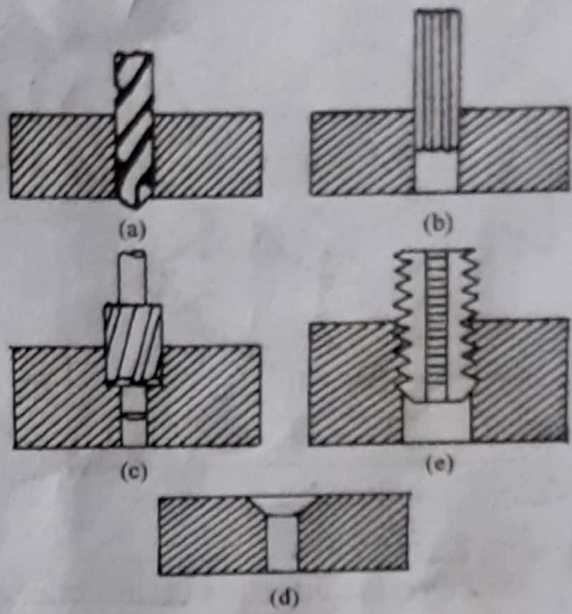


Fig. 3.19. Drilling

4. Counter sinking

It is the operation by which a cone shaped enlargement is made at the end of a hole. Fig. 3.19 (d).

5. Spot facing

It is the operation of smoothening and squaring the surface around a hole drilled in a rough surface. It provides a flat seating for nut and washer.

6. Taping

It is the operation of cutting internal threads by means of a tool called tap. When a tap is screwed into the hole it removes metal and cuts internal threads as shown in Fig. 3.19 (e).

3.14. Milling

Milling is the process of removing metal by feeding the workpiece against a rotating multipoint cutter. As the cutter rotates, each cutting edge removes a small amount of material from the advancing workpiece for each rotation of the cutter. The rate of metal removal is rapid as the cutter rotates at very high speed and has many cutting edges. The difference of milling and other machining processes are interrupted cutting, relatively small size of chips and variation of chip thickness in a single chip itself.

Figure Imp sem

for compare

up milling

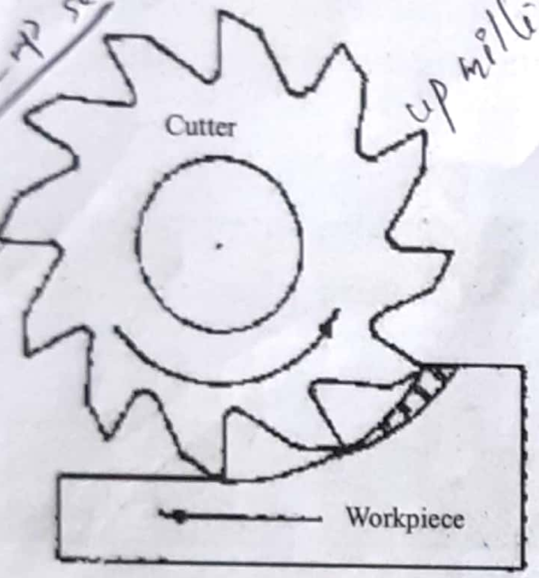


Fig. 3.20

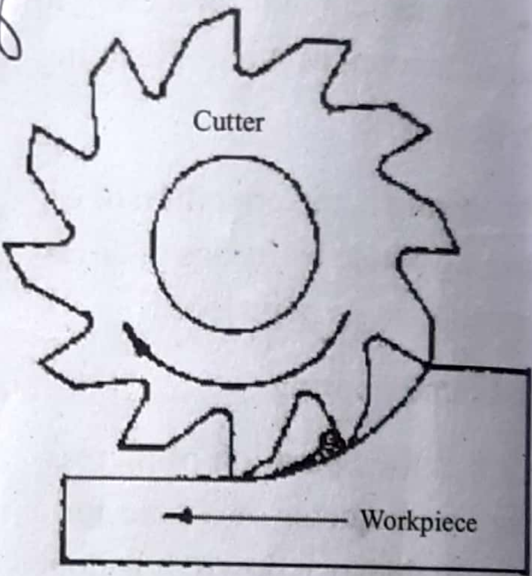


Fig. 3.21

Based on the direction of the cutter motion and workpiece feed, milling can be classified into conventional milling or up milling and climb milling or down milling. In conventional milling (up milling) the work piece which is mounted on a table is fed in the opposite direction of that of the rotating cutter as shown in Fig 3.20. In down milling the work piece which is mounted on the table is fed in the same direction of that of the rotating cutter as shown in Fig 3.21.

In conventional milling the chip thickness varies from minimum at the start of cut to a maximum at the end of cut. The load on each cutting edge is gradually increased. Since the cutting force is directed upwards at an angle, the cutter tends to lift the work piece from the worktable. While taking heavy cuts this results in poor surface finish.

In climb milling the chip thickness varies from a maximum at the start of cut to a minimum at the end of cut. If the workpiece has a hard surface the cutter has to cut through the hard surface which reduces the life of the cutter. The cutting force is directed downwards at an angle, forcing the up milling , down milling.

work piece towards the table. This is advantage for milling of such work piece which cannot be easily held on the table. Down milling produces surface of higher quality because the cutting pressure keeps the work piece firmly pressed against the table.

Some other milling operations are:

Slab or plain milling, Face milling, Side milling, End milling, T- slot milling, Angular milling, Form milling and Gear cutting.

1. Slab or plain milling

Slab milling is the process by which the flat, horizontal surfaces parallel to the axis of cutter can be produced. The cutter used is called plain milling cutter. The plain milling operation is shown in Fig. 3.22

2. Face milling

Face milling is the process by which flat surface perpendicular to the axis of cutter is produced. The cutter used is called face milling cutter. The face milling operation is shown in Fig. 3.23

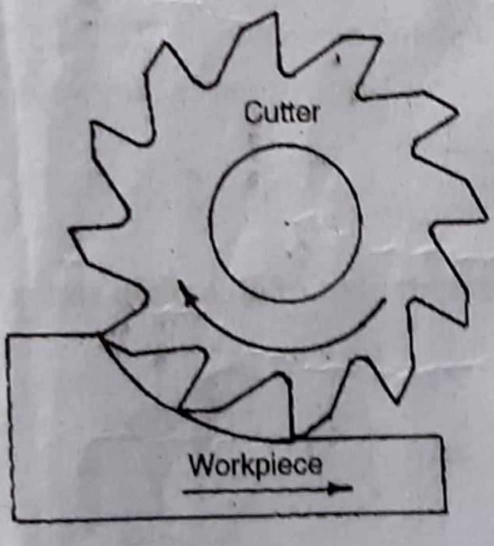


Fig. 3.22. Plain milling

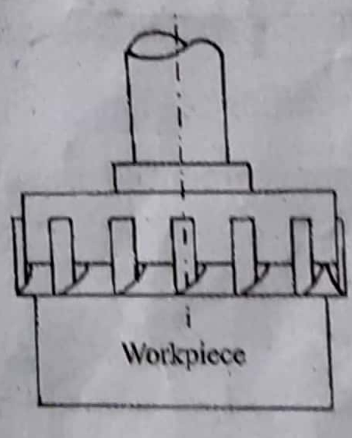


Fig. 3.23. Face milling

3. Side milling

Side milling is the process by which flat vertical face is produced at the side of a work pice. The cutter used is called side milling cutter. Side milling operation is shown in Fig. 3.24.

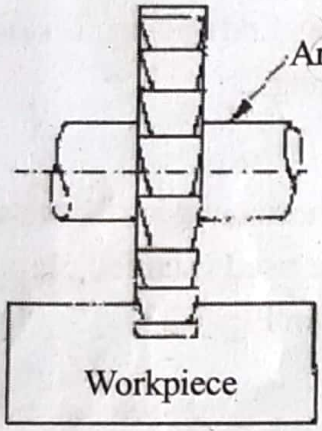


Fig. 3.24. Side milling

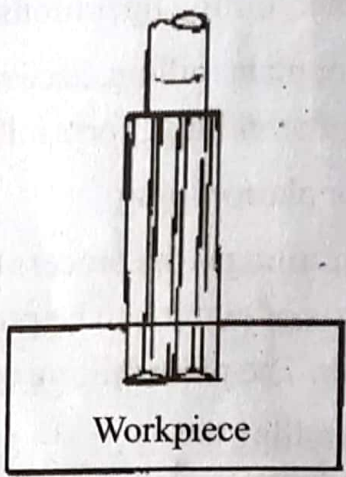


Fig. 3.25. End milling

4. End milling

End milling is the process by which a flat surface which may be vertical or horizontal is produced. The cutter used is called end milling cutter. It has cutting edges on the periphery of a shank as shown in Fig. 3.25. The end milling cutters are used for producing slots, grooves, keyways etc. End milling operation is shown in Fig. 3.25

5. T- slot milling

A T-slot is produced using a T-slot cutter. First of all a plain slot is cut

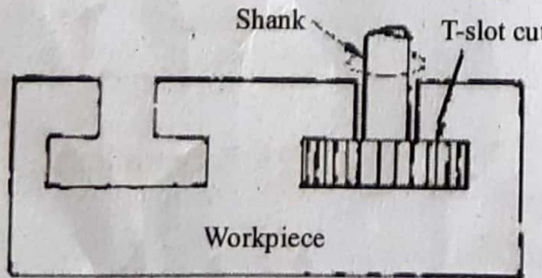


Fig. 3.26. Slot milling

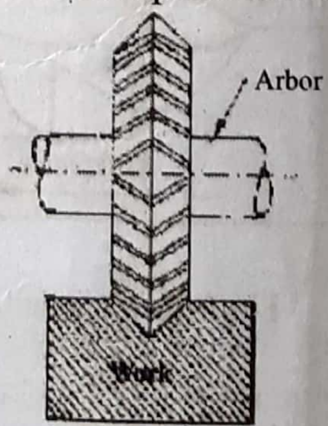


Fig. 3.27. Angular milling

on the work piece using an end milling cutter. Then the T-slot cutter is fed from one end of the work piece. The neck portion of the cutter passes through the already milled plain slot. T-slot milling operation is shown in Fig. 3.26.

6. Angular milling

Angular milling is the process in which angular surface are produced on a work piece. The cutter used is called angle milling cutter. Angular milling operation is shown in Fig. 3.27.

7. Form milling

Form milling is the process by which profiles on the work piece are produced. The cutter is called angle milling cutter. The shape of form milling cutter corresponds to the profile of the surface to be produced. Form milling operation is shown in Fig. 3.28.

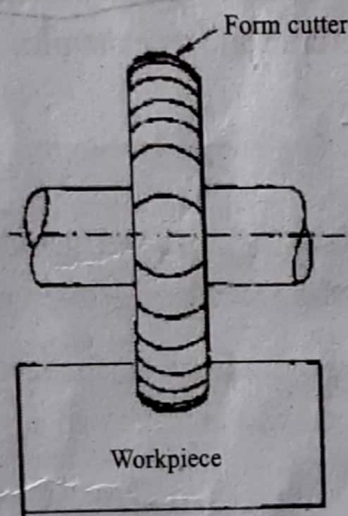


Fig. 3.28. Form milling

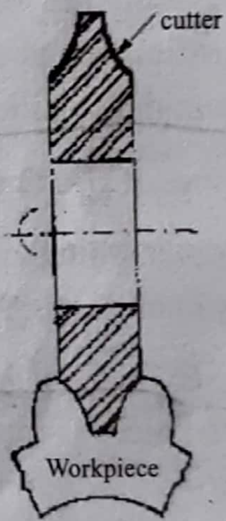


Fig. 3.29. Gear cutting

8. Gear cutting

Gear cutting is the process by which gears are produced using form cutters. The profile of the cutter corresponds to the tooth space of the gear. Gear cutting operation is shown in Fig. 3.29.

3.15. Grinding

Grinding is a process of metal removal in which the cutting tool used is an abrasive wheel. Grinding is mainly used for the following purposes.

(i) To remove small amount of metal from the workpiece to bring its di- mensions within very close tolerance of the size desired.

(ii) To obtain better finish on the surface.

(iii) To machine hard surfaces which are otherwise difficult to be ma- chined by other means.

(iv) To sharpen the cutting tools.

Grinding wheels

These are made of abrasive particles bonded together by some suitable bond. An abrasive is a hard material which can be used to cut or wear away other materials. There are two types of abrasive particles, natural and artificial. Natural abrasives include sandstone, emery, diamonds etc. Artificial abrasives are manufactured and its examples are silicon carbide, aluminium oxide and boron carbide.

Types of grinding

According to the type of surface to be ground, grinding is classified as cylindrical grinding, surface grinding and form grinding.

1 Cylindrical grinding produces cylindrical surface on a workpiece. The workpiece is rotated about its axis and is traversed across the face of a

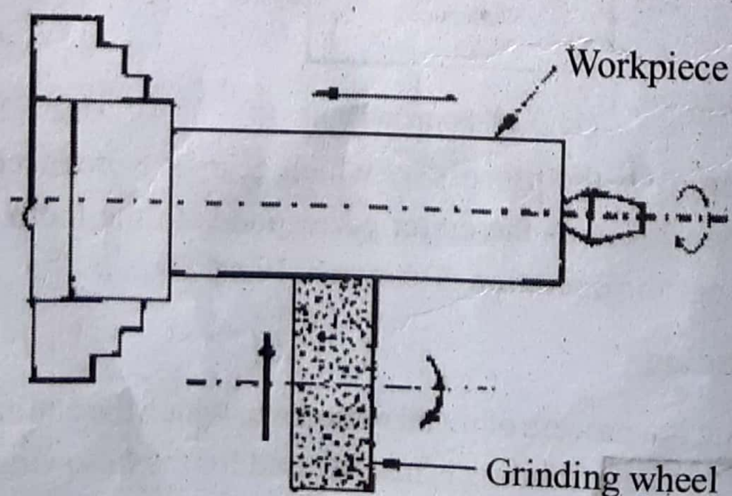


Fig. 3.30. Cylindrical Grinding

rotating abrasive wheel. After each traverse the wheel is moved towards the work a distance equal to the depth of metal to be removed. The working principle of external cylindrical grinding operation is shown in Fig. 3.30.

Surface grinding produces flat surfaces. The grinding wheel is rotated on a vertical axis as shown in Fig. 3.31. The work is traversed under the revolving grinding wheel.

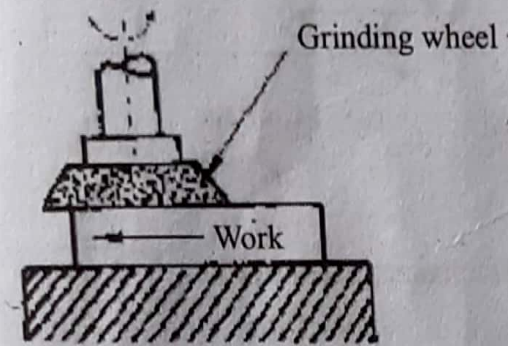


Fig. 3.31. Surface grinding

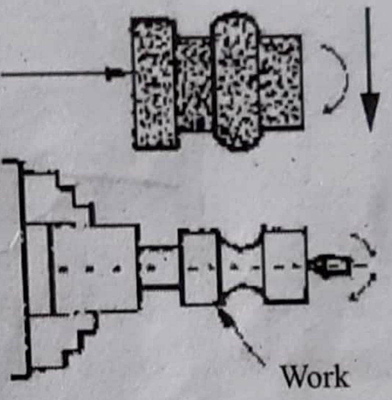


Fig. 3.32. Form grinding

Form grinding produces formed surfaces on a revolving cylindrical workpiece, the forms being determined by the shape of the grinding wheel or by the relative movement of the grinding wheel and the work. The principle of form grinding is shown in Fig. 3.32.

3.16. Lathe

Lathe is the most general purpose machine tool in which the workpiece is held and rotated against suitable cutting tool for the purpose of producing surface of revolution. Lathe has become so popular because of its versatality and it is usually found in almost all workshops.

The block diagram of a common lathe is shown in Fig. 3.33. The various important components are bed, head stock, tool post, lead screw and feed mechanism.

1. Bed

The lathe bed forms its body structure and is supported at convenient height. The headstock, tailstock, carriage etc. are mounted on the bed. The bed also provides the required strength and rigidity to the machine.

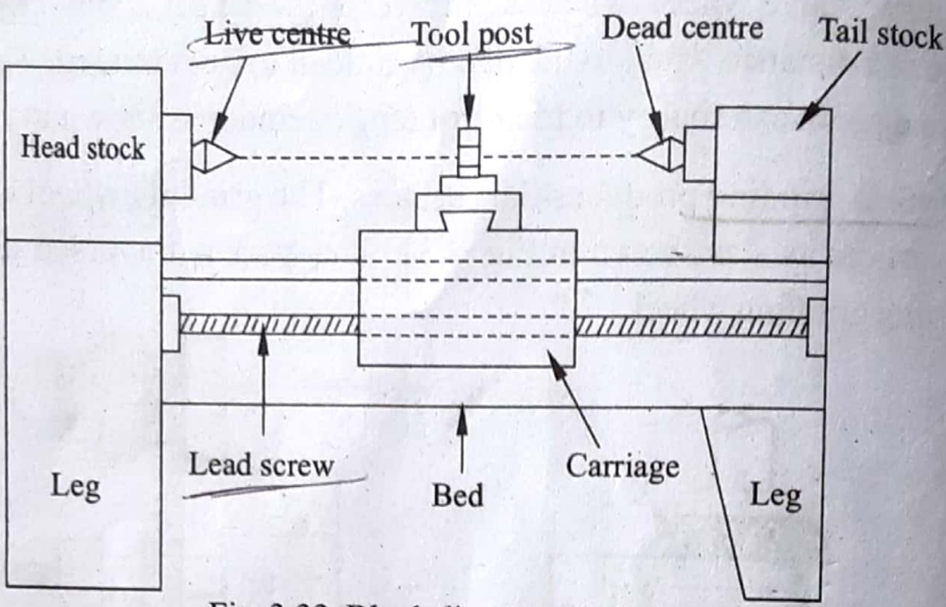


Fig. 3.33. Block diagram of a lathe

2. Headstock

The headstock is mounted on the bed at the left end and is permanently secured there. The head stock has a gear box for changing the speed of rotation of spindle and thereby the speed of rotation of workpiece.

3. Tailstock

The tailstock is mounted on the bed at the right end and can be clamped at any convenient position. It supports one end of the workpiece. It is also used for holding a tool for performing operations such as drilling, reaming etc.

4. Carriage

The carriage of a lathe consists of several parts that serves to support the cutting tool and to control the action of the cutting tool. It can be moved along the bed ways provided at the top of the bed.

5. Lathe centres

Lathe centres are tapered components fit into spindles provided in the headstock and tailstock. The centre connected to the head stock is called live centre since this centre rotates with the spindle. The centre connected to the tailstock is called dead centre since it does not rotate and its function is only to support the workpiece.

6. Toolpost

Toolpost is mounted on the carriage. It holds the cutting tool and enables the cutting tool to be adjust to a convenient working position.

7. Lead screw

The lead screw is a long threaded shaft which is brought into action only when threads have to be cut. The rotation of lead screw is used to move the tool along the work to produce screw thread.

8. Feed mechanism

The movement of tool relative to the workpiece is termed as feed. The lathe tool can be given three types of feed, longitudinal, cross and angular.

When the tool is moved parallel to the axis of rotation of workpiece, the movement is called longitudinal feed. 1

When the tool is moved perpendicular to the axis of rotation of workpiece, the movement is called cross feed. 2

When the tool is moved at an angle to the axis of rotation of workpiece, the feed is called angular feed. 3

Workpiece must be held properly for any machining operation. Several methods are available and the choice of method depends on the nature of the work itself and the operations to be performed on it. The most common devices used in lathe are, lathe centres and chucks. Lathe centres are used for holding the workpiece during turning operation. Central hole is made at each end of the workpiece and the workpiece is then supported in between the dead and live centres as shown in Fig. 3.15 (a). The chuck is also used for holding and rotating a workpiece. Refer Fig. 3.15 (b) . It is mounted concentric with the spindle and rotates with it. The jaws of the chuck can be moved radially by turning the screw head provided on the periphery of the chuck.

Several operations like turning, taper turning, thread cutting, drilling, boring, grinding, etc. can be performed on a lathe. A brief description of some of the important operations that can be performed on a lathe are given in section 3.12.

3.17. Drilling machine

Drilling is the operation of making holes in a workpiece by forcing a rotating tool called drill against it. The machine which primarily designed to make this operation is called drilling machine.

Principal parts of a drilling machine

The block diagram of a typical drilling machine is shown in Fig. 3.34. The principal parts are (i) Base, (ii) Column, (iii) Table and (iv) Drill head.

(i) Base

The base of the drilling machine is a rectangular casting on which the column is mounted.

(ii) Column

The column is the vertical member of the machine which supports a table. The head supporting the motor and spindle is mounted on the top of the column

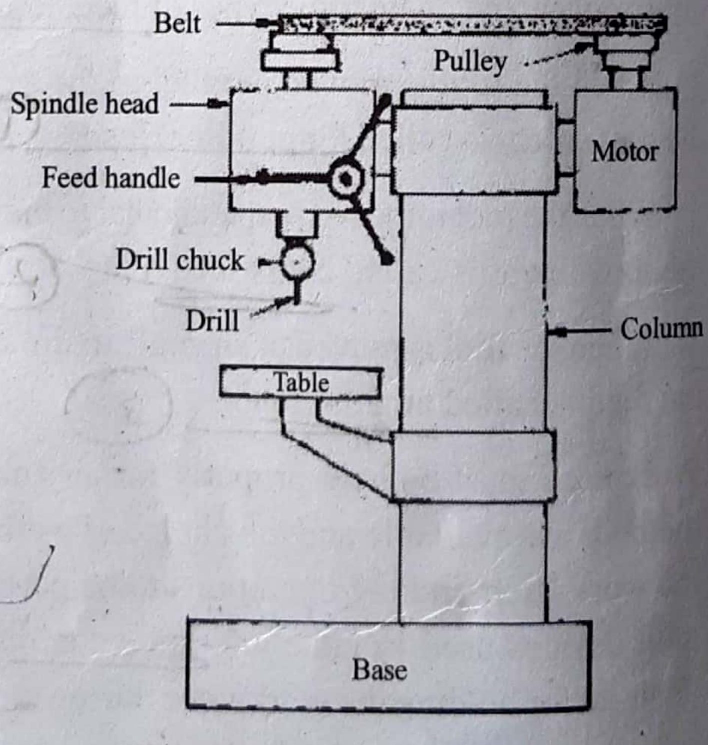


Fig. 3.34. Block diagram of drilling machine

(iii) Table

The table of the drilling machine supports the workpiece or other work holding device . It can be moved up and down on the column. Also it can be set in various positions in the horizontal plane.

(iv) Drill head

It is mounted on the top of the column and supports the spindle head and motor. The spindle head houses drill holding and rotating devices. A hand wheel is provided for upward and downward movement of the spindle. A drill chuck is mounted in the spindle for holding the drill. The spindle receives power from the motor through belt and pulley arranged as shown in Fig. 3.34. The speed of the spindle can be varied by shifting the belt on different steps of the cone pulley. Various operations that can be performed in a drilling machine are given in section 3.13.

3.18. Milling machine

Principal parts of a milling machine are the base, column knee, saddle, table, elevating screw, spindle, overarm and arbor as shown in Fig. 3.35.

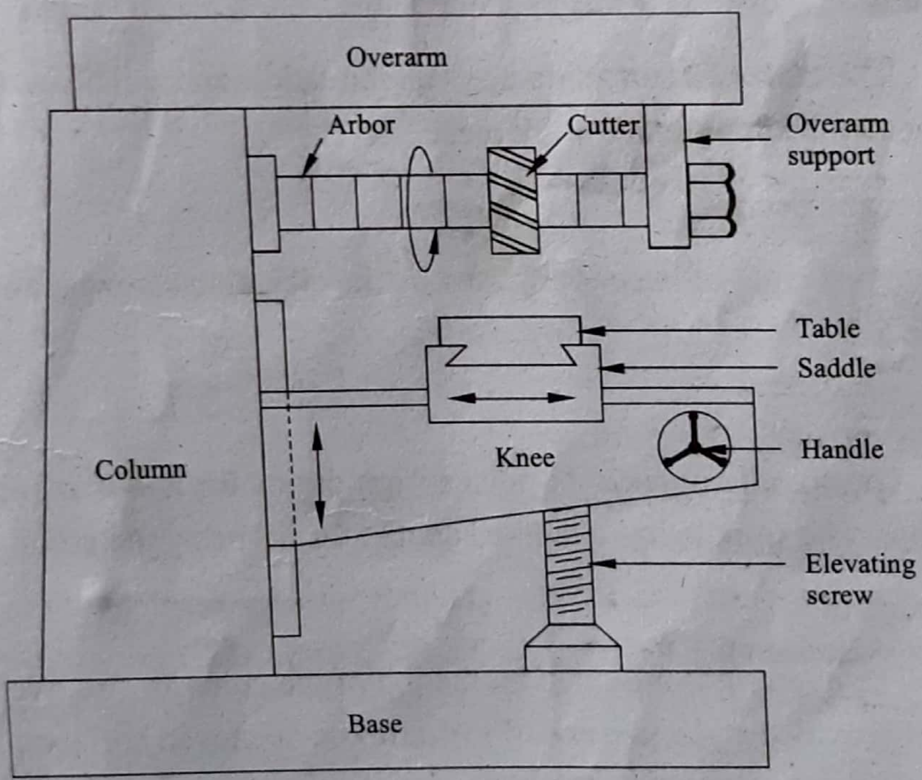


Fig. 3.35. Milling machine

Base

It is the foundation member for all other parts of the milling machine. It gives the machine the required rigidity and strength.

Column

It is the main supporting frame mounted vertically on the base. The front face of the column has vertical guide ways.

Knee

The knee is a rigid casting that slides up and down on the vertical guide ways of the column face. It has horizontal guide ways on top surface. It supports the saddle and table and is partially supported by the elevating screw which adjust the height of knee.

Saddle

The saddle supports and carries the table and is adjustable on guide ways on the top of the knee.

Table

The table rests on guide ways on the saddle and can be moved longitudinally. It supports the work piece.

Elevating screw

The height of knee is adjusted by the elevating screw. It also supports the knee.

Spindle

The spindle obtains its power from the motor and transmits it to an arbor. The spindle has a tapered socket for inserting the arbor.

Overarm

The overarm is mounted on the top of the column. The overarm support provided at the free end of overarm can be moved horizontally on the guide ways provided at the bottom surface of the overarm. The vertical movement of the knee horizontal movement of saddle and movement of table perpendicular to the motion of saddle etc. can be obtained either manually or by power from an electric motor.

Arbor

It is the rod on which the cutter is mounted. It is tapered at one end to fit into the spindle. The other end of the arbor is mounted in a bearing provided in the overarm support.

3.19. CNC machines

Production of complicated components in large quantities with high accuracy requires the transfer of instructions from man to the machine through automatic devices. The control systems used with such machines require the instructions to be encoded in a suitable language, in a particular pattern and on a convenient medium, so that the machine can read these instructions automatically to perform the job. Numerical control of machine tools refers to the operation of machine tools using numerical data. It is a technique for automatically controlling machine tools, equipment or processes. Numerical control can be defined as a form of programmable automation in which the process is controlled by numbers, letters and symbols. These numbers, letters and symbols gathered together and logically organized to direct a machine tool for a specific task is called NC program. Thus a numerically controlled machine tool is basically a conventional machine tool where the operator is replaced by NC program. The seromotors replace human operations in the positioning of work piece and positioning and operation of cutting tools.

It is possible to use computers instead of controller units in the numerical control machine tools thereby replacing much of the conventional NC hardware with software. Such a machine having a computer assigned to one particular task or a group of related tasks to perform some or all the basic numerical control actions is known as Computer Numerical Control [CNC] machine. Thus CNC is an NC system in which a dedicated computer is used to perform some or all the NC functions in accordance with control programs stored in the memory of the computer.

The advantages of CNC machines are the substantial reduction in the time required to set up the machine for doing a job, the drastic reduction of the time used to take trial cuts in order to obtain the required accuracy, consistency in the quality of product by eliminating human error, easy incorporation of changes in the design of the components. Since CNC machines produce ditto parts the inspection cost can be reduced. Flexibility is the main advantage of CNC machine. Flexibility means the possibility to incorporate changes by revising the software Newly developed options can be added after the installation. Equipment can be upgraded as new options are available. The requirement of special skill in programming and maintenance, high initial cost etc are the main demerits of CNC machines.

3.20. Principle of CAD/CAM

CAD/CAM is the abbrevation of computer aided design and computer aided manufacturing. It is the technology concerned with the use of digital computers to perform certain functions in design and manufacturing. CAD can be defined as the use of computer systems to help in the creation, modification, analysis or optimization of a design problem. Computer systems consists of hardware and software to perform a particular task. CAD hardware includes central processing unit (CPU), display terminal (monitor), keyboard etc. The CAD software consists of computer progrrams for implementing computer graphics on the system and application programs required for a particular job.

Some of the CAD softwares commonly used are Auto CAD LT, Solid works, MATLAB, CATIA.

CAM can be defined as the use of computer systems to plan, manage and control the operations of a manufacturing process.

CAM softwares are used for greater accuracy, higher speed of manufacturing, greater consistency and efficiency etc. Some of the CAM softwares in use are Siemens NX, Topsolid, PowerMILL, Solid CAM and work NC.

3.21. Rapid Manufacturing

Rapid manufacturing is the use of software automation and related manufacturing equipments to rapidly accelerate the manufacturing processes. It is a technique for manufacturing solid objects by the sequential delivery of material to specified points to produce that object. This form of manufacturing can be incredibly cost effective and the process is far more flexible than conventional manufacturing.

Advantages of rapid manufacturing process

1.These technologies don't require a product specific tool. Any part can be produced without an initial investment in a production tool.

2. The second major advantage of the technology is the virtual unlimited freedom of form that can be manufactured. The product design does not have to meet conventional production requirements.

3. The third advantage is that, although not available on all other technologies, it is possible to make multi-grade materials. By combining one or multiple of these advantages, new products can be defined.

Disadvantages:

Like any other immature technology, rapid manufacturing also has drawbacks and limitations. Some main disadvantages are as follows:

1. Material cost: High cost of most of the materials.

2. Material properties: The properties of the parts produced by the rapid manufacturing processes are not currently competitive with the parts produced by conventional manufacturing processes.

3. Support material removal: When production volumes are small, the removal of support material is not a big issue. When the volumes are much higher, it becomes an important consideration.

3.22. Additive manufacturing

Additive manufacturing is the industrial production name for 3D printing, a computer controlled process that creates three dimensional objects by depositing materials, usually in layers. It is a process that creates a physical object from a digital design.

Additive manufacturing is used to create a wide range of products across a growing number of industries, including:

(i) Aerospace

Additive manufacturing is particularly suited to aerospace applications due to its weight saving capability and ability to produce complex geometric parts.

(ii) Automotive

A variety of materials are widely additive manufactured for the automotive industry as they can be rapidly prototyped while offering weight and cost reductions.

(iii) Medical

The medical sector is finding an increasing number of applications for additively manufactured parts, especially for bespoke custom-fitted implants and devices.

Materials used for additive manufacturing:

There are a variety of materials used for additive manufacturing, these include:

(i) Biochemicals: Biochemicals used in additive manufacturing include silicon, calcium phosphate and zinc. These materials are generally used for health care applications.

(ii) Ceramics: A range of ceramics are used in additive manufacturing, including alumina tricalcium phosphate and zirconia as well as powdered glass which can be baked together with adhesive to create new types of glass products.

(iii) Metals: A variety of metals and metal alloys are used for additive manufacturing, including gold and silver, stainless steel and titanium.

(iv) Thermoplastics: Thermoplastics polymers are the most commonly used additive manufacturing materials and include a variety of types with their own advantages and applications.