STUDY MATERIAL ON

PRODUCTION TECHNOLOGY

3RD SEMESTER

Prepared by

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PROGRAMME: MECHANICAL ENGINEERING

COURSE: PRODUCTION TECHNOLOGY (TH1), 3rd sem

COURSE OUTCOMES:

At the end of this subject Students will be able to:

CO1: Understand the industrial requirements of metal forming.

CO2: Describe various methods of welding.

CO3: Distinguish the various casting methods for product making with their merits and demerits

CO4: Identify the steps in powder metallurgy.

CO5: Discover the different components and processes involved in press tool operation.

CO6: Design the job setting and tool setting in mass production.

PSOs:

PSO – 1: Develop the knowledge and skill relevant to Automobile, Thermal and fluid power industries.

PSO – 2: Exhibit the ability to make a product related to Mechanical Engineering and allied engineering fields.

COs with POs and PSOs:

CO-PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PSO1	PSO2
CO1		2	1		2		2	2	3
CO2		2	1		2		2	2	3
CO3		2	2		2		2	2	3
CO4		2	2		1		2	2	2
CO5		2	1		1		2	2	3
CO6		2	2		1		2	2	3

SYLLABUS

1.0 Metal Forming Processes 1.1 Extrusion: Definition & Classification 1.2 Explain direct, indirect and impact extrusion process. 1.3 Define rolling. Classify it. 1.4 Differentiate between cold rolling and hot rolling process. 1.5 List the different types of rolling mills used in Rolling process. 2.0 Welding 2.1 Define welding and classify various welding processes. 2.2 Explain fluxes used in welding. 2.3 Explain Oxy-acetylene welding process. 2.4 Explain various types of flames used in Oxy-acetylene welding process. 2.5 Explain Arc welding process. 2.6 Specify arc welding electrodes. 2.7 Define resistance welding and classify it. 2.8 Describe various resistance welding processes such as butt welding, spot welding, flash welding, projection welding and seam welding. Explain TIG and MIG welding process 2.10 State different welding defects with causes and remedies. 3.0 Casting 3.1 Define Casting and Classify the various Casting processes. 3.2 Explain the procedure of Sand mould casting. 3.3 Explain different types of molding sands with their composition and properties. 3.4 Classify different pattern and state various pattern allowances. 3.5 Classify core. 3.6 Describe construction and working of cupola and crucible furnace. 3.7 Explain die casting method. 3.8 Explain centrifugal casting such as true centrifugal casting, centrifuging with advantages, limitation and area of application. 3.9 Explain various casting defects with their causes and remedies. 4.0 Powder Metallurgy 4.1 Define powder metallurgy process. 4.2 State advantages of powder metallurgy technology technique 4.3 Describe the methods of producing components by powder metallurgy technique. 4.4 Explain sintering. 4.5 Economics of powder metallurgy. 5.0 Press Work 7 5.1 Describe Press Works: blanking, piercing and trimming. 5.2 List various types of die and punch 5.3 Explain simple, Compound & Progressive dies 5.4 Describe the various advantages & disadvantages of above dies 6.0 Jigs and fixtures 6.1 Define jigs and fixtures 6.2 State advantages of using jigs and fixtures 6.3 State the principle of locations 6.4 Describe the methods of location with respect to 3-2-1 point location of rectangular jig 6.5 List various types of jig and fixtures

1. METAL FORMING PROCESSES

HOT WORKING AND COLD WORKING

The metal-working processes are traditionally divided into hot working and cold-working processes. The division is on the basis of the amount of heating applied to the metal before applying the mechanical force.

Those processes, working above the recrystallisation temperature, are termed as hot-working processes whereas those below are termed as cold-working processes.

Under the action of heat and the force, when the atoms reach a certain higher energy level, the new crystals Start forming which is termed as recrystallisation. Recrystallisation destroys the old grain structure deformed by the mechanical working, and entirely new strain free crystals are formed. The grains in fact start nucleating at the points of severest deformation. Recrystallisation temperature as defined by American Society of Metals is "the approximate minimum temperature at which complete recrystallisation of a cold-worked metal occurs within a specified time".

The recrystallisation temperature generally varies between one third to one half the melting point of most of the metals.

In hot working, the process may be carried above the recrystallisation temperature with or without actual heating. For example, for lead and tin the recrystallisation temperature is below the room temperature and hence working of these metals at room temperature is always hot working. Similarly for steels, the recrystallisation temperature is of the order 1000°C, and therefore working below that temperature is still cold working.

During the deformations the metal is said to Flow, called the Plastic Flow of the metal, and the shapes of the grains are changed. If the deformation is carried out at higher temperatures, new grains start growing at the locations of internal stresses caused in the metal by slip or twin formation. When the temperature is sufficiently high, the growth of new grains is accelerated and continuous till the metal] comprises fully of only the new grains. This process of formation of new rains is known as Recrystallisation and is said to be complete when the metal structure consists of entirely new grains. The temperature at which this process is completed is known as the Recrystallisation Temperature of the metal, and it is this point which differentiates cold working from hot working. Mechanical working of a metal below its recrystallisation temperature is called Cold Working and that accomplished above this temperature but below the melting or burning point is known as Hot Working.

HOT WORKING

As described above, Hot Working is accomplished at a temperature above the recrystallisation temperature of the metal. However, this temperature should not be too high to reach the solidus temperature; otherwise the metal will burn and become unsuitable for use. As a general rule it can be mentioned that for any Hot Working Process the metal should be heated to such a temperature, below its Solidus temperature, that after completion of the hot working its temperature will remain a little higher than and as close as possible to its recrystallisation temperature. Hot Working of metals is generally accompanied by the following advantages and disadvantages.

ADVANTAGES

1. Larger deformation can be accomplished, and more rapidly, by hot working since the metal is in plastic state.

2. Porosity of the metal is considerably minimized.

3. Concentrated impurities, if any, in the metal are disintegrated and distributed throughout the metal.

4. Grain structure of the metal is refined and physical properties improved.

5. No residual stresses are introduced in the metal due to hot working.

Disadvantages

1. Due to high temperature a rapid oxidation or scale formation takes place on the metal surface, leading to poor surface finish and loss of metal.

2. On account of the loss of carbon from the surface of the steel piece being worked the surface layer loses its strength, which ig a disadvantage when the part is put to service.

3. Close tolerances can not be maintained.

4. High cost of tooling.

COLD WORKING

Inspite of a number of operations being common to both Hot and Cold working of metals the latter has an altogether different effect on the structure and physical properties of the worked metal.

Unlike Hot working it distorts the grain structure and does not provide an appreciable reduction in size.

It requires much higher pressures than hot working.

Since recrystallisation does not take place in cold working, the grains are permanently distorted. As a result of the greater resistance offered by the metal to deformation, its strength and hardness are increased. This type of hardening of metal is called Strain Hardening.

The extent to which a metal can be cold worked depends upon its ductility. The higher the ductility of the metal, the more it can be cold worked. Residual Stresses are setup during cold working. As their presence is undesirable a suitable Heat Treatment is generally necessary to neutralize these stresses and restore the metal to its original structure.

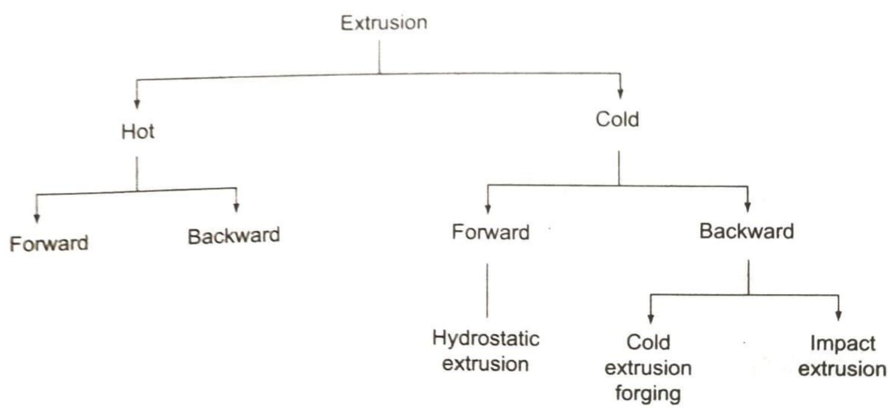
Advantages and Limitations

1. Better dimensional control than hot working is possible because the reduction in size is not much.
2. Surface finish of the component is better because no oxidation takes place during the process.
3. Strength and hardness of the metal are increased, but ductility is decreased.
4. It is an ideal method for increasing hardness of those metals which do not respond to the heat treatment. . .

5. Only ductile metals can be shaped through cold working.
6. Over-working of metal results in brittleness and it has to be annealed to remove the same.

7. Subsequent heat treatment is mostly needed to remove the residual stresses setup during cold working.

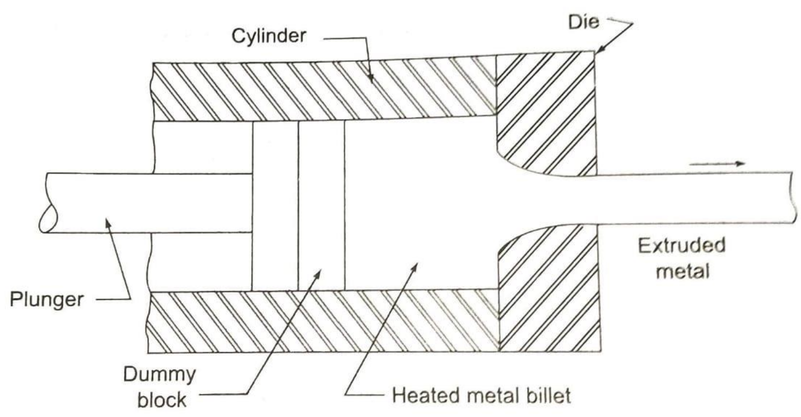
EXTRUSION



Extrusion is the process of confining the metal in a closed cavity and then allowing it to flow from only one opening so that the metal will take the shape of the opening. The operation is identical to the squeezing of toothpaste out of the tooth paste tube.

Extrusion Principle

A typical extrusion process is presented in Fig. The equipment consists of a cylinder or container into which the heated metal billet is loaded. On one end of the container, the die plate with the necessary opening is fixed. From the other end, a plunger or ram compresses the metal billet against the container walls and the die plate, thus forcing it to flow through the die opening, acquiring the shape of the opening. The extruded metal is then carried by the metal handling system as it comes out of the die. A dummy block which is a steel disc of about 40 mm (0.50 to 0.75 of diameter) thick with a diameter slightly less than the container is kept between the hot billet and the ram to protect it from the heat and pressure.

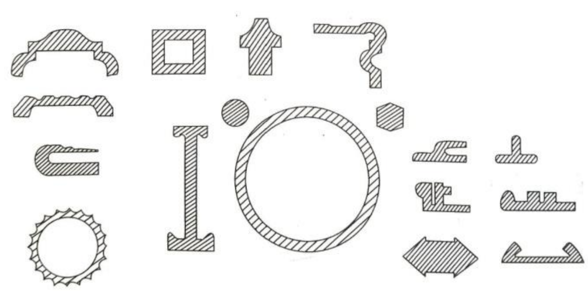


Typical extrusion set up

Fig 1

By the extrusion process, it is possible to make components which have a constant cross-section over any length as can be had by the rolling process. Some typical parts that are extruded are shown in Fig. The complexity of parts that can be obtained by extrusion is more than that of rolling, because the die required being very simple and easier to make. Also extrusion is a single-pass process unlike rolling. The amount of reduction that is possible in extrusion is large. Generally, brittle materials can also be very easily extruded. Large diameter, thin walled tubular products with excellent concentricity and tolerance characteristics can be produced.

The extrusion ratio is defined as the ratio of cross sectional area of the billet to that of the extruded section. The typical values of the extrusion ratio are 20 to 50.



Typical extrusion shapes

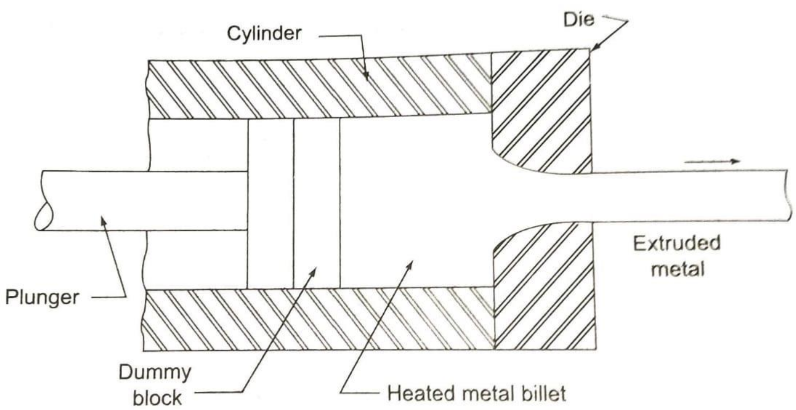
Fig 2

- For Hot extrusion temperature range: 500^0C to 1200^0C
- Pressure applied in the range of: 35 to 1000MPa.
- The work material extruded, the cylinder and ram may be severely affected by these temperature and pressure.
- The extrusion pressure for a given material depends on the extrusion temperature, the reduction in area and the extrusion speed.
- The extrusion speed depends on: the work material. Some light alloys may be extruded at a speed of 0.05m/s, whereas for the copper alloys it may be as high as 4.50m/s.
- Too high extrusion speed would cause excessive heat generation.

HOT EXTRUSION

1. FORWARD HOT EXTRUSION

The process represented in fig 1 is called the forward hot extrusion, signifying the flow of metal in the forward direction, i.e. the same as that of the ram.

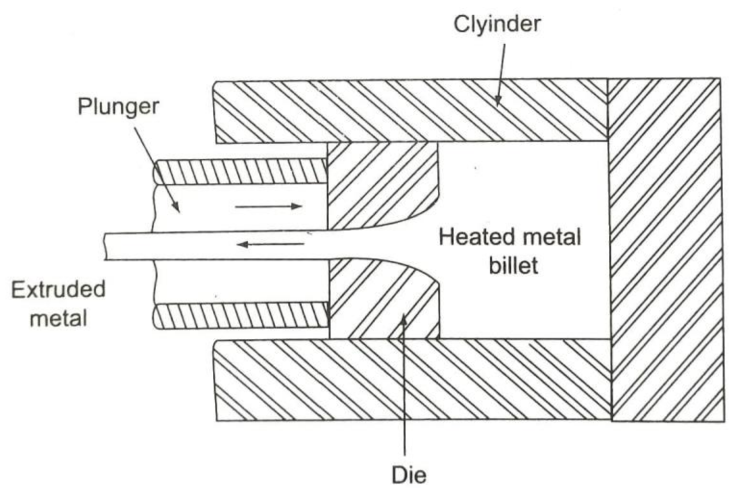


- In forward extrusion, the problem of friction is prevalent because of the relative motion between the heated metal billet and the cylinder walls. This is particularly severe in the case of steels because of their higher extrusion temperatures.
- To reduce this friction, lubricants are to be used. At lower temperatures, a mixture of oil and graphite is generally used. The problem of lubrication gets compounded at the higher operating temperatures.
- Molten glass is generally used for extruding steels. This stays in liquid form at the operating temperature and provides necessary heat insulation to the hot metal billet in addition to lubrication.

To reduce the damage to equipment, extrusion is finished quickly and the cylinder is cooled before further extrusion.

2. BACKWARD HOT EXTRUSION

- In order to completely overcome the friction, the backward hot extrusion, as shown in Fig.3 is used. In this, the metal is confined fully by the cylinder.
- The ram which houses the die, also compresses the metal against the container, forcing it to flow backwards through the die in the hollow plunger or ram. It is termed backward because of the opposite direction of the flow of metal to that of ram movement.
- Thus, the billet in the container remains stationary and hence no friction. Also, the extrusion pressure is not affected by the length of the billet in the extrusion press since friction is not involved.
- The surface quality achieved is generally good since there is no heat cracking due to the friction between the billet and the extrusion cylinder interface.
- The disadvantage of backward extrusion is that the surface defects of the billet would end up in the final product unlike direct or forward extrusion where these are discarded in the extrusion container.
- Though advantageous, this process is not extensively used because of the problem of handling extruding metal coming out through the moving ram.



Backward hot extrusion process

Fig 3

COLD EXTRUSION

1. FORWARD COLD EXTRUSION

The forward cold extrusion is similar to that of forward hot extrusion process except for the fact that the extrusion ratios possible are lower and extrusion pressures are higher than that of hot extrusion.

It is normally used for simple shapes requiring better surface finish and to improve mechanical properties.

Examples of the applications are cans, various aluminum brackets, shock absorber cylinders, rocket motors and heads, etc.

2. IMPACT EXTRUSION (BACKWARD COLD EXTRUSION)

The backward cold extrusion is much more common particularly with softer materials such as aluminium and its alloys.

In backward cold extrusion called the impact extrusion, the set up consists of a die and a punch as shown in Fig.4. The slug for making the component is kept on the die and the punch strikes the slug against the die. The metal is then extruded through the gap between the punch and die opposite to the punch movement.

Because of the impact force, the side walls go straight along the punch though they are not confined. The height of the side walls is controlled by the amount of metal in the slug. This process is more commonly used for making the collapsible tubes for housing pastes, liquids and similar articles.

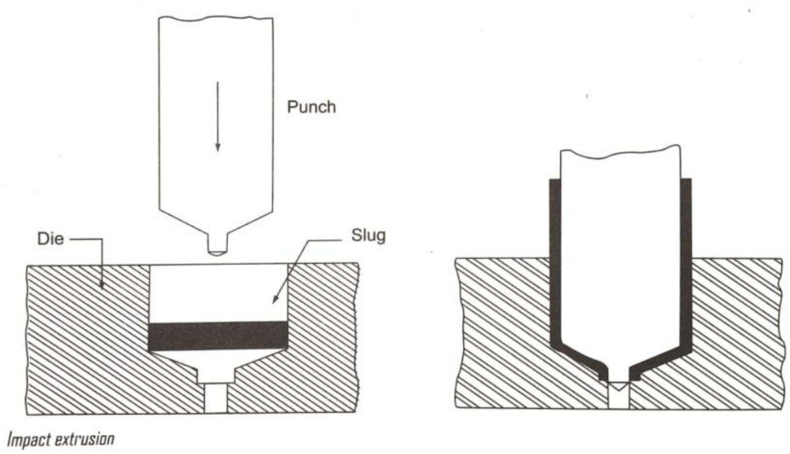


Fig 4

3. COLD-EXTRUSION FORGING

The cold extrusion forging is similar to impact extrusion but with the main difference that the side walls are much thicker and their height is smaller.

This also contains a die and punch set as shown in Fig.5. The punch slowly descends over the slug kept on the die, thus forging some metal between the punch and the die and the rest being extruded through the clearance between the punch and die side walls.

The side walls thus generated are short and thick with any profile in the end unlike the impact extrusion. Afterwards, the component is ejected by means of the ejector pin provided in the die.

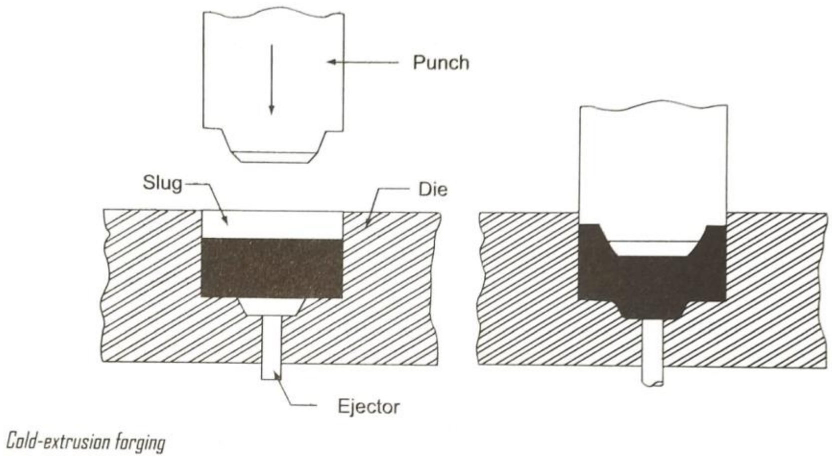


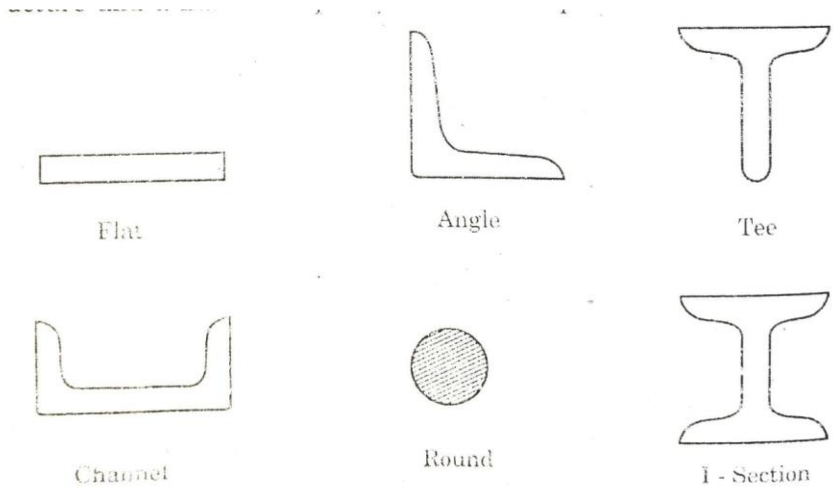
Fig 5

The backward cold extrusion processes are different from other extrusion processes in that, each stroke of the punch prepares a directly usable single component which may not necessarily have a uniform cross section over its entire length.

ROLLING PROCESS

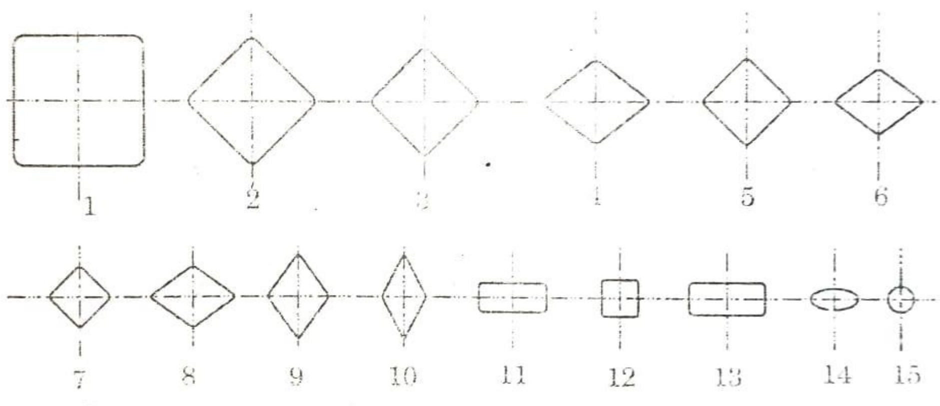
HOT ROLLING

- The purpose of Rolling is to convert larger sections, such as ingots, into smaller sections which can be used either directly in ‘as rolled’ state or as stock for working through other processes.
- As a result of rolling, the coarse structure of cast ingot is converted into a fine grained structure and a marked improvement is accomplished in its various physical properties such as strength, toughness, ductility and shock resistance.
- A large number of useful articles like structural sections, sheets, rails, plates and bars etc., are produced through rolling. Some commonly used Rolled Steel Sections are shown in figure.

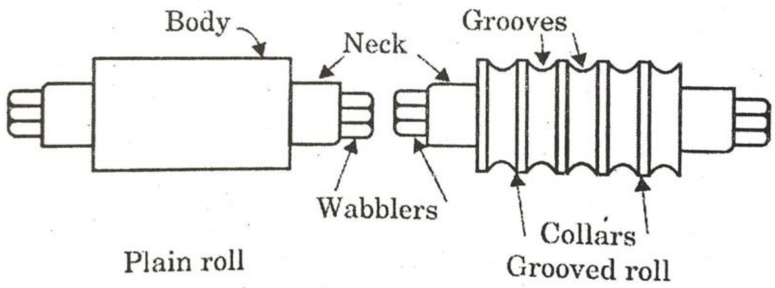


Commonly used rolled steel sections

- The desired reduction in the cross section of the billet and the desired shape of the rolled section is not achieved in a single pass. It has to be rolled again and again several times before the desired shape and cross section of the rolled product is obtained. This is clearly 'illustrated in Fig, which shows the Sequence of Rolling and the number of passes required to reduce the cross-section of a billet to a round steel bar



- In this process, the Ingots are first heated to the rolling temperature in Soaking Pits and then rolled in Blooming Mills to convert them into Blooms.
- Blooming mills carry mechanical manipulators to turn the hot ingot (billet) through 90° after every pass. This enables all the surfaces of the ingot to come in contact with the rolls.
- Grooved rolls, of the type shown in figure are used on blooming mulls for this process.

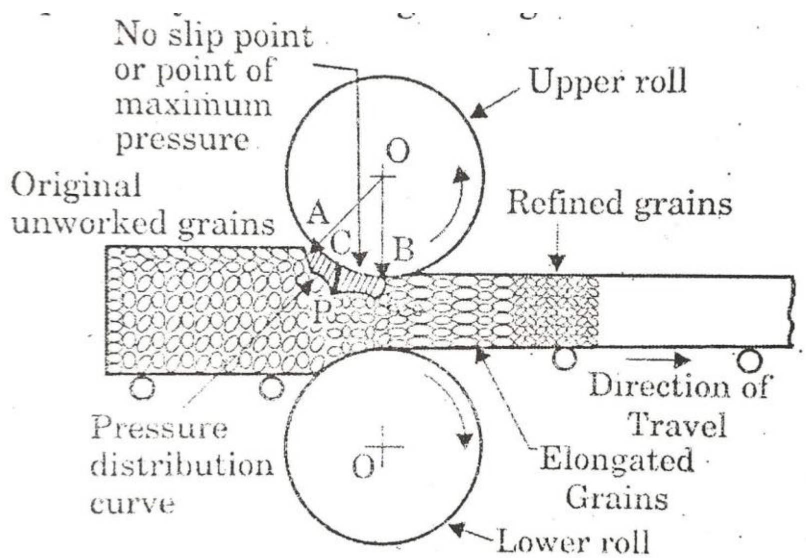


➢ Since the Blooming Mill is the first mill through which all the ingots are passed before being rolled on other mills it is called the Mother Mill.

PRINCIPLE OF ROLLING

The process of rolling basically consists of passing the hot ingot through two rolls rotating in opposite directions at a uniform peripheral speed.

The space between the rolls is adjusted to confirm to the desired thickness of the rolled section, and the same is always less than the thickness of the ingot being fed. The rolls, thus, squeeze the passing ingot to reduce its cross-section and increase its length.



The process is illustrated in Figure which shows the changes that take place in the grain structure of the metal as it passes through the rolls.

As a result of squeezing the grains are elongated in the direction of rolling and the velocity of material at exit is higher than that at the entry. After crossing the stress zone the grains start refining. But this is the case only in Hot Rolling. In Cold Rolling they tend to retain the shape acquired by them during rolling.

The Rolls are in contact with the passing-metal piece over a sufficient distance, represented by the arc AB in the diagram.

The angle AOB subtended at the centre of the roll by the arc AB is called the Angle of Contact or the Maximum Angle of Bite.

It is the friction between the surfaces of the metal piece and the rolls which provides the required grip of the rolls over the metal piece to draw the latter through them. The greater the coefficient of friction, the more the possible reduction.

The pressure exerted over the metal by the rolls is not uniform throughout, but varies as represented by the Pressure Distribution Curve in the diagram. It will be observed that it is minimum at both the extremities and maximum at a point somewhere within the curve.

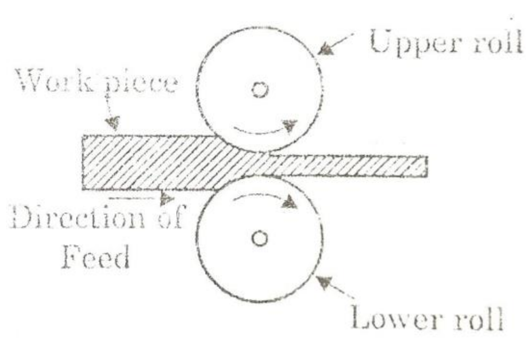
The line CP, representing the maximum pressure, is called the Neutral or No Slip Line, and the point C is known as No-Slip Point or the Point of Maximum Pressure. At this point the surfaces of the metal and the roll move at the same speed. Before reaching this point, i.e., from A to C the metal moves slower than the roll and the frictional force acts in the direction to draw the metal piece into the rolls.

After crossing the neutral point C, i.e., from C to B, the metal moves faster than the roll surface, as if it is being extruded, and the friction opposes the travel, tending to hold the metal back.

TYPES OF ROLLING MILLS

1. Two-high Mill.

- It consists of two heavy horizontal rolls, placed exactly one over the other.
- The rolls are supported on bearings housed in sturdy upright side frames, called Stands.

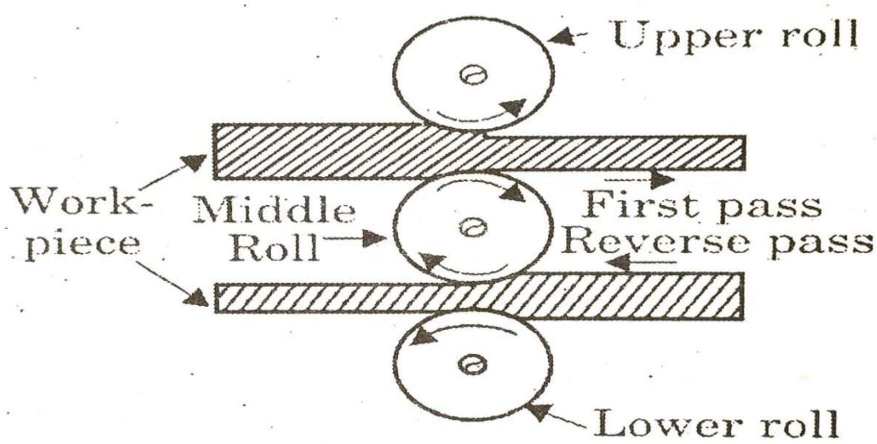


- The space between the rolls can be adjusted by raising or lowering the upper roll. The position of the lower roll is fixed.

- Both the rolls rotate in opposite directions to one another, as shown in Fig. Their direction of rotation is fixed and cannot be reversed. Thus, the work can be rolled by feeding from one direction only.
- There is another type of Two-high Mill which incorporates a drive mechanism that can reverse the direction of rotation of the rolls. This facilitates rolling of the workpiece continuously through back-and-forth Passes between the rolls. This type of rolling mill is known as a two high Reversing Mill. They are normally employed for the initial rolling of an ingot.

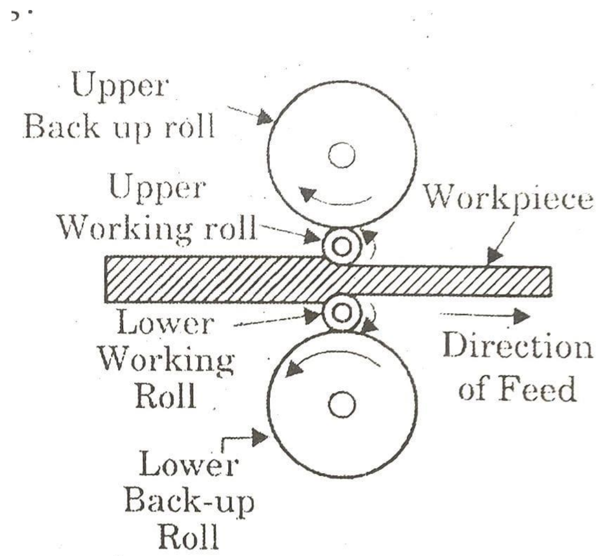
2. **Three-high Rolling Mills.**

- It consists of three horizontal rolls, positioned directly one over the other, as shown in Fig. The directions of rotation of the upper and lower rolls are the same, but the intermediate roll rotates in a direction opposite to both of these.



- All the three rolls continuously revolve in the same fixed directions and are never reversed. The work piece is fed in one direction between the upper and middle rolls and in the reverse direction between the middle and lower rolls.
- This results in a high rate of production than two high mill.
- This mill may be used for blooming, billet rolling or finish rolling.

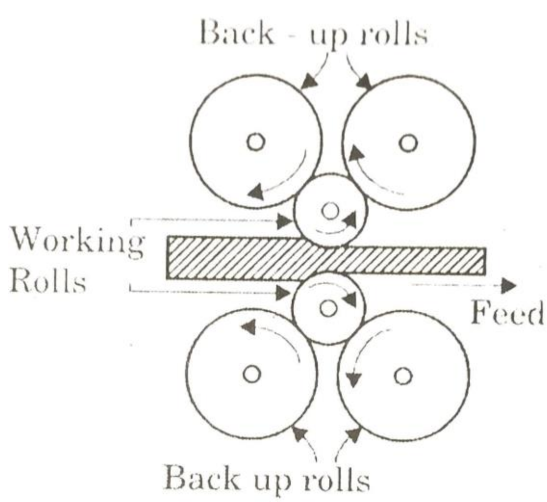
3. **Four-high rolling mill.**
   - It consists of four horizontal rolls, two of smaller diameter and two of larger diameter, arranged directly one over the other as shown in Fig.



- The larger diameter rolls are called Backup Rolls and their main function is to prevent the deflection of the smaller rolls, which otherwise would result in thickening of rolled plates or sheets at the centre.
- The smaller rolls are known as Working Rolls and they are the rolls which concentrate the total rolling pressure over the metal.
- These mills are generally used for subsequent rolling of slabs.
- The common products of these mills are hot or cold rolled sheets and plates.

4. **Cluster mill.**

It consists of two Working Rolls of smaller diameter and four or more Back-up Rolls of larger diameter. The arrangement of rolls for this mill is shown in Fig.



The number of back-up rolls may go up as high as 20 or more, depending upon the amount of support needed for the working rolls during the operation.

This type of mill is generally used for cold rolling.

5. **Continuous rolling mill.**
   It consists of a number of non-reversing Two-high Mills arranged one after the other, so that the material can be passed through all of them successively.
   The rolls of each successive mill stand rotate at a faster speed than that of the preceding rolls in order to accommodate the increasing length of the metal piece being rolled.
   This arrangement facilitates a very rapid production because the component passes continuously from one stand to the other until it reaches the final pass. But it is suitable for mass production only.
6. **Other types of rolling mills and their rolled products**

The above Rolling Mills are known with various different names according to the types of operations performed and the products obtained from them. A few important names are described below:

(i) **Blooming Mills.** A rolling mill used for reducing ingots to Blooms is called a Blooming Mill. A Bloom is a square or rectangular piece of metal of which the cross-section ranges between 150 mm x 150 mm to 250 mm x 300 mm.

Billets: They are similar to blooms but have smaller cross-' sections. Their sizes range from 50 mm x 50 mm to 150 mm x 150 mm. Generally other types of Rolling mills are used for producing billets than those used for blooming.

(ii) **Slabing mills.** The Rolling Mills used for producing slabs are known as Slabing Mills. Generally, Two-high Reversing type rolling mills are used for this purpose.

Slabs: Slabs are also metal pieces with rectangular cross-section having their thickness between 50 mm to 150 mm and width between 300 mm to 1500 mm.

(iii) **Primary and secondary mills.** Blooming and slabing mills are quite often known as Primary Mills, and those used for further rolling work as Secondary Mills. Primary and secondary rolling mills are also sometimes known as Roughing and Finishing mills respectively.

COLD ROLLING

- Cold Rolling is generally employed for providing a smooth and bright surface finish to the previously hot Rolled steel.
- It is also used to finish the hot rolled components to close tolerances and improve their toughness and hardness.

- The items generally subjected to cold rolling for this purpose are bars, rods, sheets, plates, strips and wires, etc. Before being put to cold rolling the hot rolled articles are cleaned through Pickling and other operations.
- The same types of Rolling Mills, described earlier in connection with hot rolling, are used in cold rolling. In order to obtain a smooth surface finish the roll surfaces are polished and scratches, if any removed.

HOT WORKING	COLD WORKING
1. It is carried out above recrystallisation temperature but below the melting point of metal. Hence deformation of metal and recovery takes place simultaneously.	1. It is carried out below recrystallisation temperature of metal. There is no appreciable recovery.
2. No internal or residual stresses are set up in the metal in hot working	2. internal or residual stresses are set up in the metal in cold working
3. Negligible strain hardening	3. Metal gets strain hardened.
4. Due to higher deformation temperatures used, the stress required to deform the metal is less	4. Stress required to deform metal is higher.
5. If cracks and blow holes are present in the metal, they are finished through hot working.	5. The existing crack propagates and new crack may develop.
6. It results in improving some mechanical properties like impact strength and elongation.	6. Impact strength and elongation are reduced.
7. Surface finish is relatively poorer due to oxidation and scaling.	7. Better surface finish.
8. Close dimensional tolerances can not be achieved.	8. Superior dimensional accuracy can be obtained.
9. It is mainly preferred where heavy deformation is required.	9. It is preferred where work hardening is required and it is desired to obtain a better surface finish with close dimensional tolerances.

2.WELDING

CLASSIFICATION OF WELDING PROCESSES

FUSION WELDING:

The basic purpose of Welding is to provide a means to join pieces by raising their temperature to the fusion point so that they form a sort of pool of molten metal at the ends to be joined, and if needed, supplement this pool with Filler Metal (wire or rod) which normally has nearly the same composition as that of the parent pieces and then allow the said pool to form a homogeneous mixture and solidify at the ends to form what is known as a Weld. This is known as Fusion Welding process.

PRESSURE WELDING

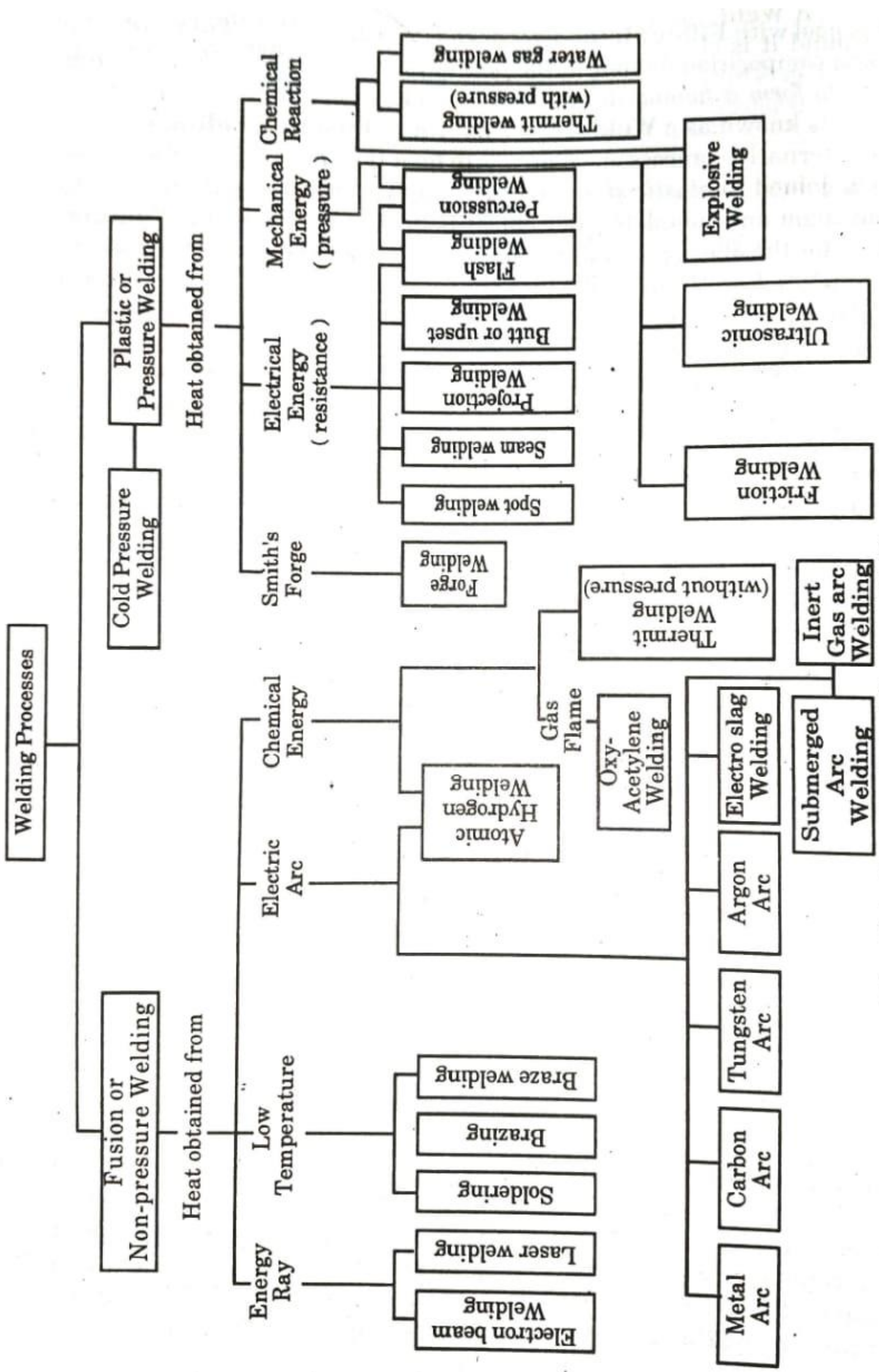
An alternative process of welding is to heat the ends of the metal pieces to be joined to plastic state and then apply some external pressure to join them and complete the weld. It is known as Pressure Welding.

(Heat for the above purpose can be obtained from many sources, such as a Smith's hearth for Forge Welding, electric current for Resistance Welding, gas flame for Gas Welding, chemical reaction for Thermit Welding and electric arc for Arc Welding etc.)

Besides the conventional fusion and pressure welding methods, welding can also be accomplished by sound and even by light through laser. Such wide diversity of welding methods has made the conventional definition of welding obsolete. A more appropriate way to define Welding will, therefore, be to say that welding is the art of joining metals and plastics by such methods which do not employ fasteners and adhesives. The classifications of different Welding Processes which are in general use are given in figure.

The common sources of heat generation for effecting the desired fusion of metal are:

- Fire of a Smith’s Forge (Forge welding)
- Electric arc (Metal arc, Carbon arc, Argon arc, etc.)
- Gas flame (Oxy-acetylene, Water-gas Welding, etc.)
- Gas plus Electric arc (Atomic Hydrogen Welding)
- Electrical resistance (Resistance and Electro-slag) Chemical reaction (Thermit Welding)
- Energy ray (Electron Beam and Laser Weldings)
- Mechanical Energy (Friction and Ultrasonic Welding).


Welding Processes
Fusion or Non-pressure Welding
Cold Pressure Welding
Plastic or Pressure Welding
Heat obtained from
Heat obtained from
Energy Ray
Low Temperature
Electric Arc
Chemical Energy
Smith's Forge
Electrical Energy (resistance)
Mechanical Energy (pressure)
Chemical Reaction
Electron beam Welding
Laser welding
Soldering
Brazing
Braze welding
Atomic Hydrogen Welding
Gas Flame
Oxy-Acetylene Welding
Thermit Welding (without pressure)
Metal Arc
Carbon Arc
Tungsten Arc
Argon Arc
Electro slag Welding
Submerged Arc Welding
Inert Gas arc Welding
Forge Welding
Spot welding
Seam welding
Projection Welding
Butt or upset Welding
Flash Welding
Percussion Welding
Thermit welding (with pressure)
Water gas welding
Friction Welding
Ultrasonic Welding
Explosive Welding

RESISTANCE WELDING

It is the process of joining metal pieces together by raising the temperature of the pieces to fusion point and applying a mechanical pressure to join them.

In this, the pieces to be joined are held together and a strong Electric Current (A.C.) of high amperage and low voltage is passed through them. This current comes across a certain resistance in passing from one piece to the other and it is this resistance offered to the flow of current which results in raising the temperature of the two pieces to fusion or melting point at their junction. The mechanical pressure applied at this moment completes the weld.

(In resistance welding, a low voltage (1 volt) and very high current (15000A) is passed through the joint for a very short period of time.)

The heat generated in resistance welding can be expressed as $H = k I^2 R t$

Where H =Total heat generated in the work,

I = Electric current, A

t = Time for which the electric current is passing through the joint, s

R= Resistance of the joint, ohms, and

k = Constant to account for the heat losses from the welded joint.

The resistance of the joint R is a complex factor to know because it is composed of

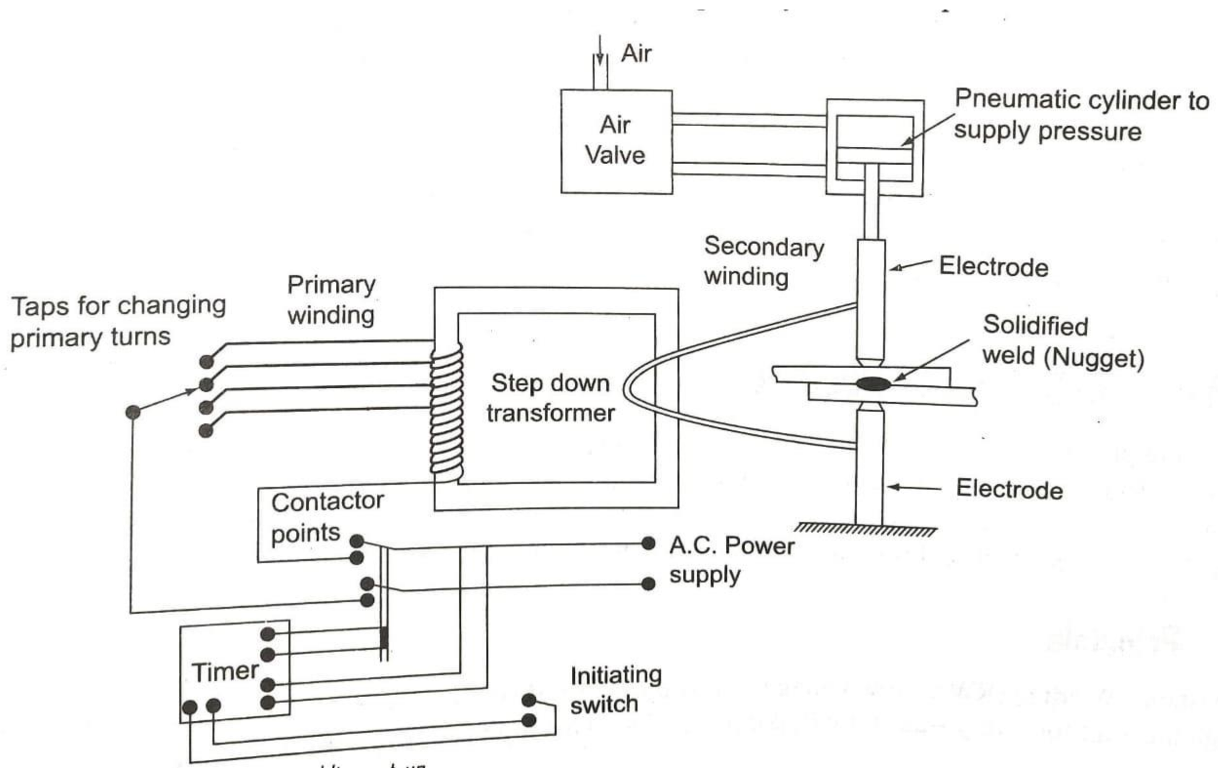
(a) the resistance of the electrodes,

(b) the contact resistance between the electrode and the workpiece,

(c) the contact resistance between the two workpiece plates, and

(d) the resistance of the workpiece plates.

- The amount of heat released is directly proportional to the resistance. It is likely to be released at all of the above-mentioned points, but the only place where large amount of heat is to be generated to have an effective fusion is at the interface between the two workpiece plates. Therefore, the rest of the component resistances should be made as small as possible, since the heat released at those places would not aid in the welding.



The schematic representation of the resistance welding process is shown in Fig. The main requirement of the process is the low voltage and high current power supply. This is obtained by means of a stepdown transformer with a provision to have different tappings on the primary side, as required for different materials. This method of welding is widely used in modern practice for making Welded Joints in sheet metal parts, bars and tubes, etc.

- Successful application of a Res
- istance Welding process depends upon correct application and proper control of the following factors:

1. Welding Current. Enough current is needed to bring the metal to its plastic (or sometimes molten) state for welding. It should be properly adjusted on the current control device on the machine.

2. Welding Pressure. In Resistance Welding, mechanical pressure is required, to be applied at two stages-first to hold the metal pieces tightly between the Electrodes, while the current flows through them, and secondly when the metal has been heated to its plastic state, to forge or squeeze the metal pieces together to form the weld. The former is known as Weld Pressure and the latter Forge Pressure.

3. Time of Application. It can also be described as Cycle Time and is the sum total of the following time periods allowed during different stages of welding:

(a) Hold Time. It is the time period during which the current flows through the metal pieces to raise their temperature.

(b) Squeeze Time or Forging Time. It is the time period during which the Mechanical Pressure is applied to the metal pieces to squeeze them together to form the weld.

(c) Hold Time. It is the time period during which the metal pieces are held together under forge pressure for a short while to enable the weld to solidify. It can, therefore be called Cooling Time also.

(d) Off-Time. After cooling of weld the electrode pressure is released and the metal pieces removed for the next Operation Cycle. The time period between this release of electrodes and the start of next welding cycle is called Off-Time.

4. Contact Area of Electrodes. The weld size depends on the Contact Area of the face of the Electrodes. It can be varied by selecting suitable sets of electrodes to provide the desired area of contact at their tips.

Some of the very important advantages of the resistance welding process are the following:

- Very little skill is required to operate the resistance welding machine. Mostly the machines are semiautomatic or automatic and hence properly set for a particular operation. Anyone with a little training would be able to operate the machine.
- These are very well suited for mass production, as they give a high production rate.
- There are no consumables used in this process except for the electrical power and a relatively smaller electrode wear. As a result, it is a very economical process.
- Heating of the workpiece is confined to a very small part, which results in less distortion.
- It is possible to weld dissimilar metals as well as metal plates of different thicknesses.

In spite of these advantages, there are certain limitations and disadvantages of the resistance welding process.

1. The resistance welding machine is highly complex with various elements such as a heavy transformer, electrodes and heavy conductors for carrying the high currents, the electrode-force applying mechanism such as a pneumatic cylinder and its supply, the heavy machine structure to support the large forces and an expensive timing arrangement. All these make the resistance welding machine highly expensive, unless it 1s used for large-scale production.

2. Certain resistance welding processes are limited only to lap joints. This limits its use to sheet metal whose thickness is less than 3 mm. The lap joints have an inherent crevice between the sheets, which is responsible for stress concentration and a loss of fatigue life. Also for materials that are prone to corrosion, the lap joint may be a source of trouble.

Resistance welding is further sub-divided into six main methods as given below:

1. Spot Welding

2. Butt Welding

3. Flash Welding

4. Seam Welding

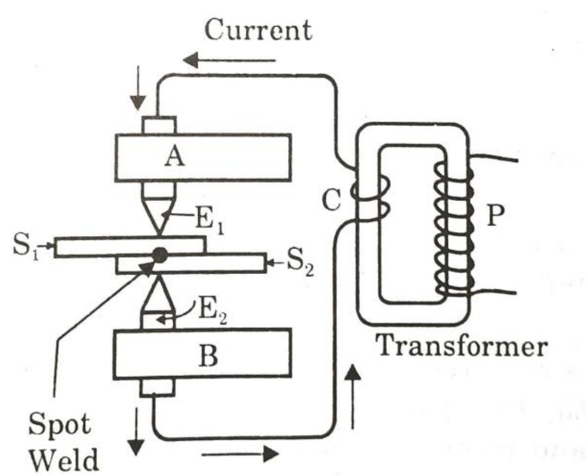
5. Projection welding

6. Percussion Welding.

1. RESISTANCE SPOT WELDING

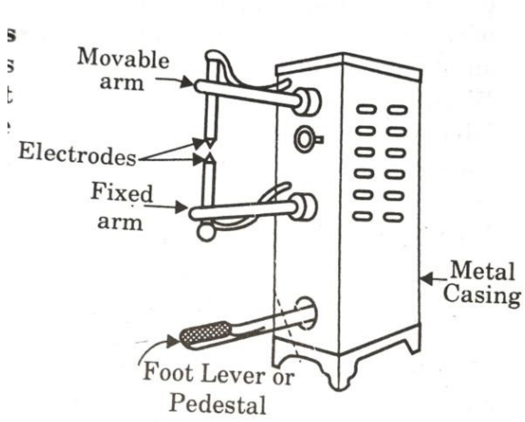
It is the simplest and probably the most commonly used method of making Lap Welds in thin sheets (upto a maximum thickness of 12.7 mm) using the principle of Resistance Welding. It owes its popularity to the fact that it can quite suitably replace riveting in sheet metal products without altering the design of the article.

The Principle of Spot Welding is illustrated in Fig.where a Transformer Core is shown having primary and secondary windings P and C respectively. One end of the secondary windings is connected to the upper Electrode E_1 carried in the movable copper or bronze arm A and the other end to the lower Electrode E_2 mounted on the fixed arm B.



In operation, 'the metal sheets S_1 and S_2 are held and pressed between the electrodes and a strong current at low voltage is switched on. Due to the resistance offered by the sheet metal to the flow of this current the temperature at the contact surfaces rises to fusion point and the weld is completed under the Contact pressure of the Electrodes.

Spot Welding Machines are manufactured in various shapes and varying designs but they all work basically on the same principle, as explained above. A simple but common type of these, known as Pedestal Type Spot Welder, is shown in Fig.



It consists of a metallic casing having the Transformer housed in it. The lower arm, called the Fixed Arm, is rigidly fixed to the machine body and the upper arm (or Movable Arm) is pivoted about a point inside the case. A Pedestal at the bottom operates the upper arm through a spring. When this pedestal is pressed downwards the inside end of the upper arm is raised up and the outside projecting end, carrying the upper electrode, is brought downwards to apply pressure on the sheets held between the electrodes. The Foot Lever (pedestal) in being pressed downwards also simultaneously switches on the current, thus enabling the production of the weld. The spring, described above, enables the application of a constant pressure so long as the current is flowing. After a Weld is complete the pressure on the foot lever is released and the work moved to the next position where it is to be welded.

Assignments:

Write short notes on

1. Gun welding
2. Shot welding

SPOT WELDING ELECTRODES AND ELECTRODE HOLDERS

All resistance Spot Welding Electrodes have to perform three major functions:

1. They conduct the electric current to the workpieces.

2. They hold the workpieces together and transmit the required amount of force to the work area to complete the weld.

3. They have to dissipate heat from the weld zone as quickly as possible.

Also, during the process of Welding these electrodes are subjected to high compressive stresses at elevated temperatures. For successful welding the electrodes should be capable of resisting these stresses without much deformation in order to confine the conducted current to a fixed area within the workpieces. A frequent inspection of Electrode Tips, their regular dressing and, as and when needed, their replacement should, therefore, be made regularly.

In order to perform the above functions successfully these electrodes should possess the following characteristics:

1. They should be good conductors of electricity.

2. They should be good conductors of heat.

3. They should possess high mechanical strength and hardness.

4 They should not have a tendency of alloying with the metal of the workpieces.

Electrode Materials:

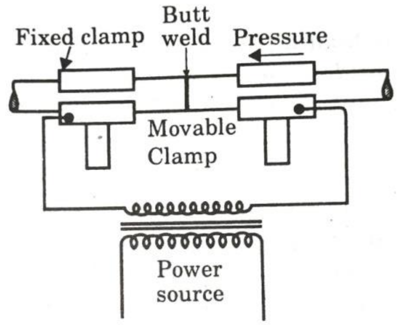
- Copper-base Alloys and Refractory Metal-Alloys are commonly used for manufacture of all Resistance Welding Electrodes.
- Cu-tungsten mixture, pure tungsten, pure molybdenum, etc

Electrode Holders:

- Spot Welding Electrode Tips are held in suitable Electrode Holders.
- Most of these holders are water cooled, and so are the electrode tips which are made hollow for this purpose.
- Holders carry hose connections for supply of water for cooling.
- Ejector mechanisms are usually provided in holders for easy removal of electrode tips, when needed. In most of the Spot Welding Machines these Electrode Holders can be adjusted for length and position.
- All the Electrode Holders are made of copper alloys carrying good electrical conductivity and rigidity.

2. RESISTANCE BUTT WELDING

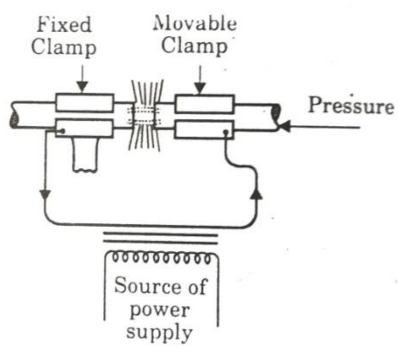
Also known as Upset Welding, it is used to join the metal pieces end to end. In this process, the metal pieces, usually bars and rods of the same cross-section, are held in suitable clamps or vices with their previously squared ends abutting against each other.



- The clamps holding the pieces either form the Electrodes themselves or are fitted with separate electrodes in them. One of these clamps is rigidly fixed to the frame of welding machine and the other is mounted on a Movable Slide operated by a Hand Lever in case of large machines and a Spring in case of small machines.
- After abutting the ends together the current is switched on and the contacting surfaces heated to the fusion point. At this moment additional mechanical pressure is applied by means of the hand lever or the spring attachment and this completes the Weld.
- This pressure should be maintained for a few seconds, actual time depending upon the cross-section of the pieces, to allow the metal pieces to join together.
- The Butt Welding method is very suitable for joining end to end the items like bars, rods, tubes and wires etc.

3. RESISTANCE FLASH WELDING

- Flash welding is also used for joining metal pieces end to end but it differs from the butt welding process in the method of heating and sequence of operation.



- Flash welding (FW) is similar to upset welding except that the heat required for melting is obtained by means of an arc rather than the simple resistance heating.
- The flash welding equipment consists of essentially two platens (clamps), to which the two pieces to be joined are clamped. One of the platens is fixed while the other is movable, the movement being controlled by means of a cam, as shown in Figure.
- The two pieces are brought together and the power supply is switched on. Momentarily, the two pieces are separated to create the arc to melt the ends of the two pieces. Then again the pieces are brought together and the power switched off while the two ends are fused under force.

It is generally a faster operation compared to that of upset welding and would be automatically controlled by a cam arrangement

Single phase A.C. machines are most commonly used for Flash Welding.

The main advantages and disadvantages of Flash Welding over simple buttwelding are as follows:

Advantages of the Process:

1. It is comparatively much quicker than butt-welding.

2. On account of only a small portion of the metal being heated the current consumption is less as compared to butt-welding.

3. A flash-welding joint is stronger than the butt-welding joint.

4. The end faces of the metal pieces need not be squared which is a primary requirement in butt-welding.

Disadvantages of the Process

1. During flashing, particles of molten metal are thrown out, which may enter into the slideways and insulation, etc. This needs periodic maintenance of machine and replacement of insulation.

2. Operator has to take enough care against possible fire hazard due to flashing.

3. Additional stock has to be provided to compensate the loss of metal during flashing and upsetting. This adds to the cos

t of product.

4. Cost of removal of flash and upset metal by trimming, chipping, grinding, ete. further adds to the product cost.

Metals which can be Flash Welded:

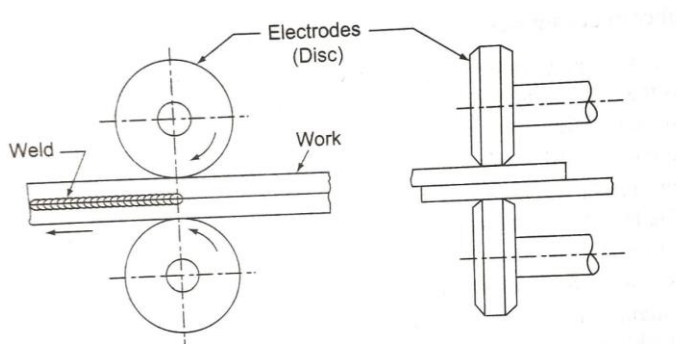
Metals commonly welded are low carbon steels, low-alloy steels, tool steels, stainless steel, copper alloys, aluminium alloys, nickel alloys, molybdenum alloys magnesium alloys and titanium alloys. This process is unsuitable for welding of lead, tin, antimony, zinc, bismuth and their alloys.

Some Applications:

This process is widely used in automobile industry, welding of tubular and solid structural assemblies, etc. in aircraft industry, welding of band saw blades, welding of tool steel, drills, reamers and taps etc., to mild steel or alloy steel shanks, welding of pipes and tubes to increase their lengths, in joining wire ends for producing coils of wires, and many other similar jobs.

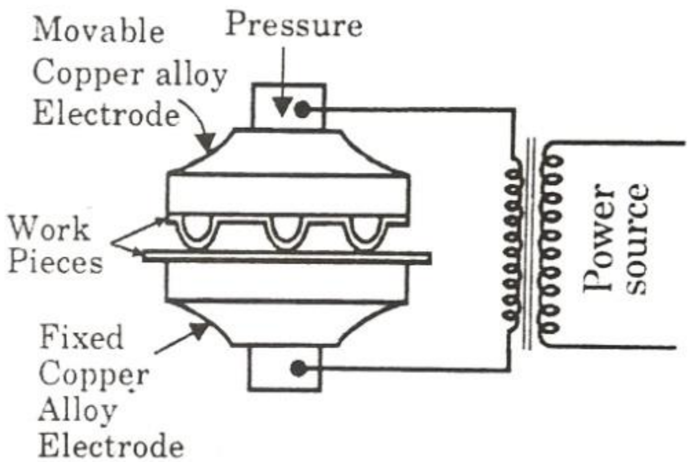
4. **RESISTANCE SEAM WELDING**

- In principle it is very similar to Spot Welding except that in this process the Spot Welding Tips are replaced by continuously rotating Wheel Type Electrodes. With the result, the weld produced is continuous instead of being intermittent.
- A Seam Weld can best be described as consisting of a continuous series of spot welds produced by passing the workpieces between the revolving electrodes.
- In operation, the current is switched on and the metal pieces pushed together to travel between the revolving electrodes. The metal between the electrodes gets heated to welding heat and welded continuously under the constant pressure of rotating electrodes as it passes between them.
- This is a quicker operation than spot welding and gives a stronger joint than that. The surfaces to be joined should be cleaned before being subjected to this process.



RESISTANCE PROJECTION WELDING

- This process is similar to Spot Welding, but differs from the latter in that the spots at which welding takes place are previously located by providing projections at the desired locations on the surface of one of the work-pieces, as shown in Fig.



- Thus, the surfaces of the workpieces are in contact with each other only at the projections. As current is switched on the projections are melted and the workpieces pressed together to complete the weld, by pressing the upper electrode downwards. The melted projections form the welds.
- This method enables production of several spot welds simultaneously. The Electrodes, if required, may be designed and shaped to work as holding fixtures for workpieces and assemble them in proper relative location through welding.
- However, this process is economical only for large-scale production.

GAS WELDING

- It is a Fusion or Non-pressure welding method in which a strong gas flame is used to raise the temperature of the ends of the pieces to be joined to a heat sufficient to melt them. The metal thus melted starts flowing along a definite path to form a strong weld.
- A filler metal may be added to the flowing molten metal to fill up the cavity made during the joint preparation. The filler rod or welding rod which provides the additional metal required is of the same or nearly same composition as that of the metal of which the pieces to be joined are made.
- So many different combinations of gases can be used to obtain a heating flame, but the most common of these are Oxygen and Acetylene, oxygen and hydrogen and oxygen with coal gas, of which the first one is very extensively used.
- Oxy-hydrogen mixture can be used for welding of only such metals of which the melting point is low such as aluminium, magnesium, lead, etc. It is for the reason that the temperature of the flame produced is too low to produce effective fusion of high melting point metals.
- For similar reasons the other gas mixtures, like oxygen-natural gas, oxygen-Propane, oxygen-coal gas, etc., cannot be used for welding of high melting point metals. If,

however, efforts are made to raise the flame temperature of these mixtures, by increasing the proportion of oxygen, the flame atmosphere becomes highly oxidizing, which is an obvious disadvantage.

- The oxygen used should be highly pure since even a small proportion of impurities have a considerable effect on the combustion value of oxygen. Its purity should be above 99.5%. The common impurities associated may be nitrogen, argon and water vapour.

OXY-ACETYLENE WELDING:

The process of Oxy-Acetylene Welding can be used for welding almost all metals and alloys used in engineering practice. The advantage of using Acetylene, instead of other fuels, with Oxygen is that it produces a comparatively higher temperature and also an **Inert gas Envelope**, consisting of carbon dioxide and water vapours, which prevents the molten metal from oxidation. The highest temperature that can be produced by a flame of oxygen and acetylene is nearly 3200°C. There are two systems of Oxygen-Acetylene Welding.

(i) High Pressure System. In this method both oxygen and acetylene are derived for use from High Pressure Cylinders.

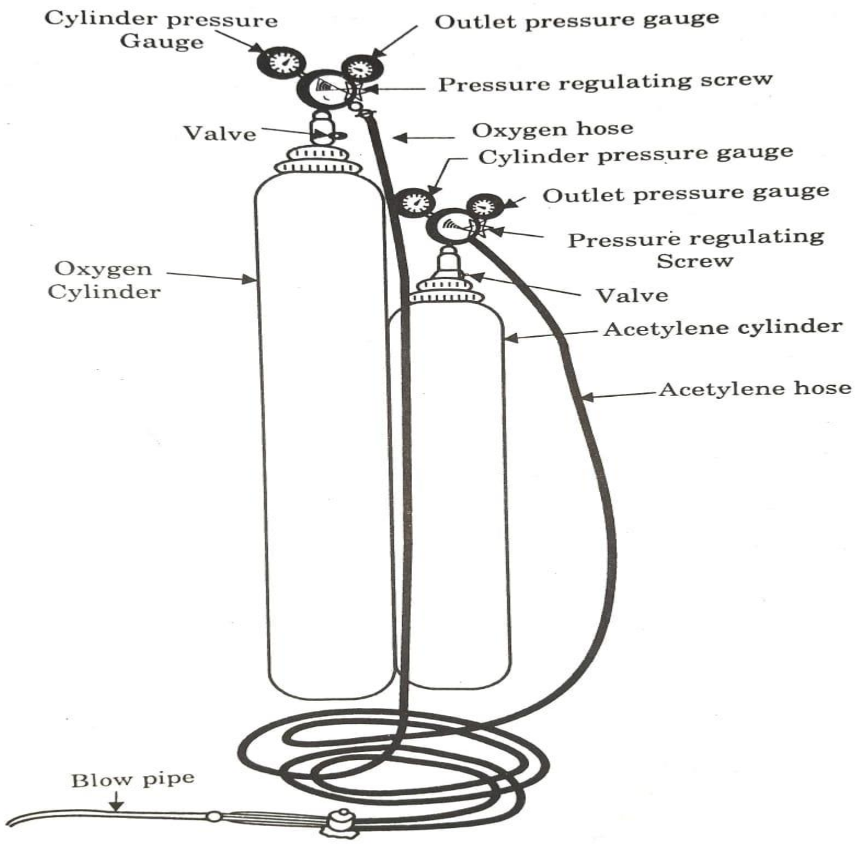
(ii) Low Pressure System. In this system oxygen is taken as usual from a high pressure cylinder but acetylene is generated by the action of water on carbide (usually calcium carbide), in a Low Pressure Acetylene Generator.

OXY-ACETYLENE WELDING EQUIPMENTS:

The High Pressure Oxy-acetylene Welding and Cutting Equipment consists of two large steel strong Cylinders; one containing oxygen at high pressure (13.8MPa to 18.2MPa) and the other Dissolved Acetylene, also at high pressure.

Both these cylinders are usually painted with distinct colours on the outside surfaces; **Oxygen Cylinder in Black and acetylene cylinder in Maroon**.

Free acetylene is highly explosive, if stored at a pressure more than 200 kPa, where it becomes very unstable and is likely to explode. Hence, acetylene needs to be carefully stored in a strong cylinder, filled with 80 to 85% porous material such as calcium silicate and then filled with acetone which can absorb upto 420 times its volume of acetylene at a pressure of 1.75 MPa. It is expected that the acetylene molecules fit in between the acetone molecules. This helps in storing acetylene at a much higher pressure than permitted when it is in free form.

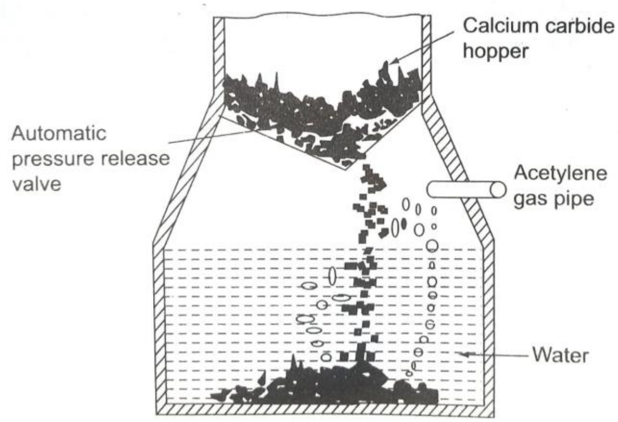


In the low pressure equipment we use oxygen as usual from a high cylinder but acetylene is drawn from a low pressure acetylene generator.

Acetylene is normally produced by a reaction between calcium carbide and water which is instantaneous as shown below:

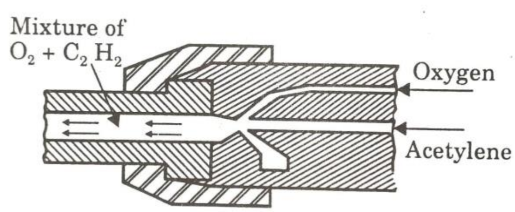
$$CaC_2 + 2H_2O = C_2H_2 + Ca(OH)_2$$

A schematic cutaway view of the acetylene generator is shown in Fig. It consists of a cylinder, which is partially filled by water. The calcium carbide is stored in a hopper near the top of the generator. A pressure regulated valve controls the flow of calcium carbide into water, depending on the pressure of the acetylene in the generator. The acetylene is taken out through a gas pipe.

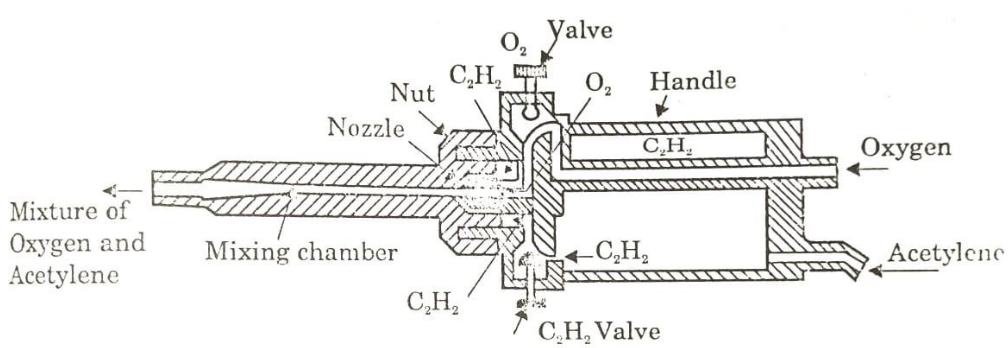


BLOWPIPES OR TORCHES:

Blow Pipes or Torches used both in welding and cutting are made in different designs and sizes to suit the work. The High Pressure Blow Pipe, shown in Fig. consists of different passages (connected to hoses) which mix in a chamber. One of these passages is for oxygen and the other for acetylene. Both these gases are mixed in the chamber and then driven out through the Orifice of the Blowpipe Nozzle with the desired velocity. These nozzles are usually known as tips and are made interchangeable so that the same blow pipe can be used for different sizes of the tips.



The Low Pressure Blow Pipe is constructed to work on the principle of an Injector. The reason for such a design is that the pressure of acetylene that can be obtained from the generator is too low calling for oxygen to be drawn at a considerably high pressure. In this blowpipe, oxygen at high pressure is made to pass through the Injector type Nozzle which, in doing so, draws the acetylene along with it to the mixing chamber and then to the outlet of the tip.



The different Sizes of Tips enable the operator to select a suitable one to obtain the desired size of the flame that will suit the particular thickness of the metal to be welded. These tips are replaceable and the sizes of their orifices control the flow of gas mixture. Tips with smaller orifices produce Smaller Flames and those with larger size orifices Larger Flames. The former should be chosen for fine work and welding of thin sections whereas the latter for heavier work.

Assignment – 2

Q. Write short note on Pressure regulators used in gas welding.

WELDING RODS

- Sufficient care should be taken in selecting a suitable Welding Rod or Filler Rod for welding a particular material. Always the best available quality of the rods should be selected as the cheaper qualities are likely to contain more impurities and they will result in the production of an unsound Joint.
- However, it is reckoned that a welding rod will possess the same or nearly same composition of its constituents as that of the metal which is to be welded.

FLUXES

- Except for the common grades of mild-steel, a Flux is always necessary for successfully welding of different metals and alloys.
- Enough restraint should be exercised so that the quantity of flux used should not be above requirement. It should, however, be sufficient enough to dissolve the scale (oxide) present on the surface of the metal due to its long exposure to the atmosphere and that formed during heating.
- Also, the flux should be lighter in comparison to the molten metal so that it may float on the top of this metal during the operation and may deposit on the upper surface of the solidified metal after cooling, so as to be chipped off after this.
- It should be stored in a dry place and should not be allowed to mix with other types of fluxes.
- Borax and Sodium Carbonate are good fluxes for ferrous metals.
- The fluxes should not be allowed to remain on the finished weld as their presence will lead to a quick corrosion of the joint, which may ultimately result in its failure. A weld should, therefore, be cleaned well soon after it is finished.

OTHER EQUIPMENTS

The other equipment needed in oxy-acetylene working includes

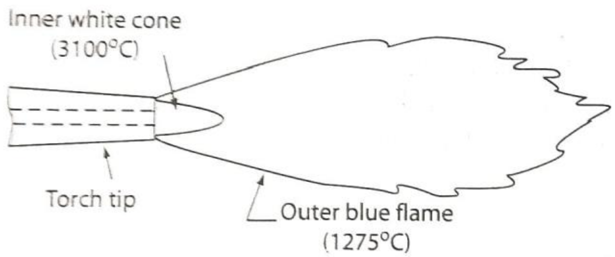
- keys for cylinder valves,
- hoses for oxygen and acetylene with connections and spanners,
- safety equipment like goggles, screens, leather hand gloves and leather apron,

- chipping hammer, wire brush and spark lighter, etc.

In addition a Trolley is needed to carry the oxygen and acetylene cylinders from one work place to the other.

TYPES OF FLAMES:

In all the oxy-fuel gas welding processes, the combustion takes place in two stages. The first reaction takes place when the fuel gas such as acetylene and oxygen mixture burn releasing intense heat. This is present as a small white cone as shown in Fig.



Neutral flame

For the oxy-acetylene welding, the following reaction takes place in this zone.

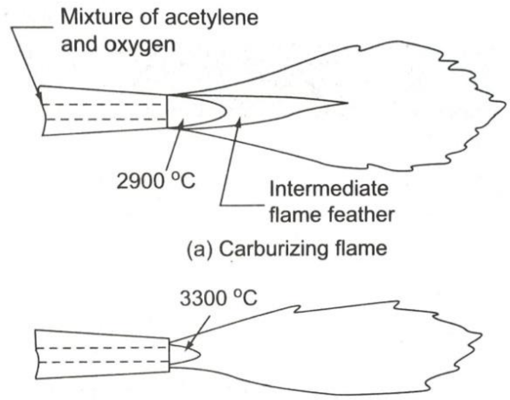
$$C_2 H_2 + O_2 = 2CO + H_2 + 448 \text{ kJ/mol}$$

The carbon monoxide (CO) and hydrogen produced in the first stage further combine with the atmospheric oxygen and give rise to the outer bluish flame, with the following reaction.

$$4CO + 2H_2 + 30_2 = 4CO_2 + 2H_2 O + 812 \text{ kJ/mol}$$

Though higher amount of heat is produced in the second stage, since it is distributed over a larger area, the temperature achieved is small (of the order of 1200 to 2000°C) in the flame, which may be used for preheating the steels. The inner white cone temperature is of the order of 3100°C, which is used for directly melting the steel joint.

When the oxygen supply varies, the flame appearance obtained would also vary. Above Figure shows the ideal condition, i.e. the complete combustion, called neutral flame. In neutral flame, all the acetylene present is completely burned and thus all the available heat in the acetylene is released. Thus, this is the most desirable flame to be used in oxy-acetylene welding.



(a) Carburizing flame

(b) Oxidizing flame

However, it is also possible to provide more or less oxygen than that theoretically required for complete combustion. When less oxygen is provided, part of the combustible matter is left as it is and it results in a reducing or carburising flame as shown in Fig. This flame is similar to the neutral flame, only with the addition of a third phase in between the outer blue flame and the inner white cone as shown in Fig. It is called 'intermediate flame feather' which is reddish in colour. The length of the flame feather is an indication of the excess acetylene present. This excess carbon causes the steel to become extremely hard and brittle.

The carburising flame is not suggested for general use. However, since this flame provides a strong reducing atmosphere in the welding zone, it is useful for those materials, which are readily oxidised, for example, oxygen-free copper alloys. It is also used for high-carbon steels, cast irons and hard surfacing with high-speed steel and cemented carbides.

When oxygen is in excess, it is called the oxidising flame whose appearance is shown in Fig. The flame is similar to the neutral flame with the exception that the inner white cone is somewhat small, giving rise to higher tip temperatures (3300°C). There is an excess amount of oxygen present in the flame, which badly oxidises the weld metal. This flame would be useful for welding some nonferrous alloys such as copper-base alloys and zinc-base alloys. Some alloys of iron such as cast iron and manganese steel are also better welded by an oxidising flame. The presence of excess oxygen in the oxidising flame causes an oxide film to form quickly which provides a protective cover over the base metal pool.

ELECTRIC ARC WELDING

In welding, generation of heat by an electric arc is one of the most efficient methods. Approximately, 50% of the energy is liberated in the form of heat. The electric-arc welding process makes use of the heat produced by the electric arc to fusion weld-metallic pieces. This is one of the most widely used welding process, mainly because of the ease of use and high production rates that can be achieved economically.

Principle of Arc:

An arc is generated between two conductors of electricity, cathode and anode (considering direct current, dc), when they are touched to establish the flow of current and then separated by a small distance.

An arc is a sustained electric discharge through the ionised gas column called plasma between the two electrodes.

It is generally believed that electrons liberated from the cathode move towards the anode and are accelerated in their movement. When they strike the anode at high velocity, a large amount of heat is generated. Also, when the electrons are moving through the air gap between the electrodes, also called the arc column, they collide with the ions in the ionised gas column between the electrodes. The positively charged ions, moving from the anode and would be impinging on the cathode, thus 'liberating heat. About 65 to 75% of the total heat is liberated at the anode by the striking electrons. A temperature of the order of 6000°C is generated at the anode.

In order to produce the arc, the potential difference between the two electrodes (voltage) should be sufficient to allow them to move across the air gap. The larger air gap requires higher potential differences. If the air gap becomes too large for the voltage, the arc may be extinguished. In the case of the arc, the extra energy spent crossing the air gap is liberated as heat. .

For convenience of explanation, we have chosen a direct-current arc for the above description. But even with an arc of the alternating current (ac), would be similar, with the main difference that the cathode and anode would change continuously. As a result, the temperature across the arc would be more uniform, compared to a dc arc.

ELECTRIC ARC WELDING

It is a Fusion Welding Process in which no mechanical pressure is applied for joining the metals. In this, the metal pieces to be joined are heated locally to the melting temperature, by creating an Electric Arc, and then allowed to solidify to form the Welded Joint.

In some cases only the metal of the pieces to be joined is made to form the joint while in the others additional metal is provided by melting a wire into the weld metal. The weld metal obtained from the work pieces is known as Parent Metal while the additional metal provided by melting the wire, as described above, is known as Filler Metal.

This additional material is provided by the Core Wire of the Electrode in cases of Metal Arc Welding and by a filler rod in case of Carbon Arc Welding.

The Electric Arc Welding processes are divided into the following two main kinds:

1. Metallic arc welding   2. Carbon arc welding

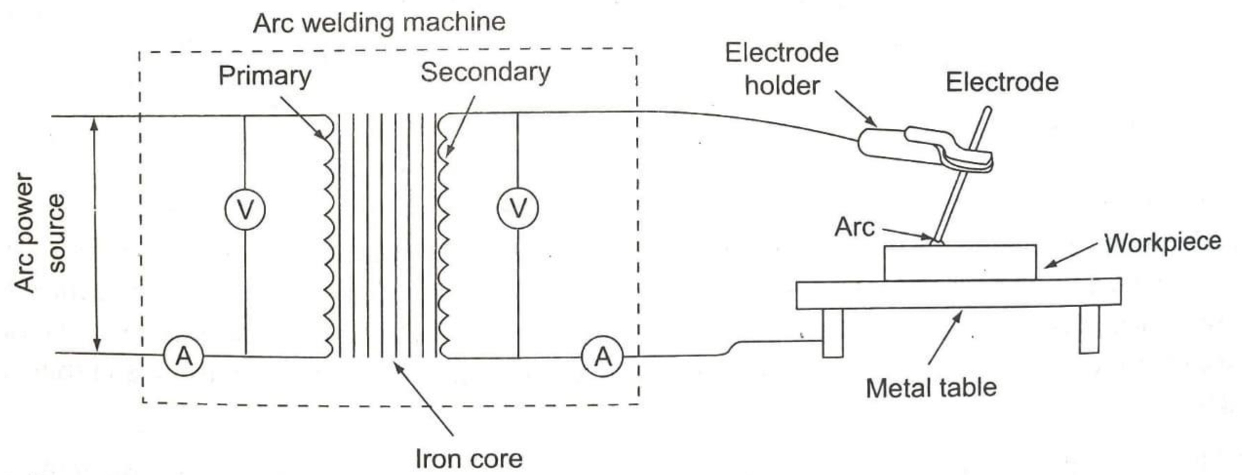
1. METAL ARC WELDING

- In this process a Metal Electrode is used and the Arc is maintained between this electrode and the workpiece, which respectively form the two terminals.
- The electrode used can be either bare or coated type.
- Bare electrodes have the same or nearly the same composition as that of the parent metal. They have the disadvantage that their surfaces may be subjected to oxidation.
- Coated electrodes may either have a light coating of some material, which prevents their surface from being oxidised, or may carry a strong coating of Flux.
- For welding of-ferrous metals the core of the electrodes is usually made of mild steel and the coating around it is made such that it acts a as a flux as well as provides the necessary constituents to the weld metal.

SHIELDED METAL ARC WELDING/MANUAL METAL ARC WELDING

- The Principle of Shielded Metal Arc Welding consists of establishing an Electric Arc between a metal electrode and the workpiece to be welded.
- The metal of the workpiece to be joined is called Base Metal or Parent Metal.
- The manual metal arc welding also called the Shielded Metal Arc Welding (SMAW) is the most extensively used manual welding process, which is done with stick (coated) electrodes. Though in USA, its use is decreasing in comparison to the other arc-welding processes, in India, it still, is the most used arc-welding process.
- This process is highly versatile and can be used extensively, for both simple as well as sophisticated jobs. Further, the equipment is least expensive than most of the arc-welding processes. Welds by this process can be made in any position.
- Job of any thickness can be welded by shielded metal arc welding. But very small thicknesses, below 3 mm, may give rise to difficulty in welding because of their lack of rigidity. Similarly, very large thicknesses, above 20 mm, may take a long time for filling up the joint groove.
- The shielded metal arc welding can be done with either ac or dc power source. The typical range of the current usage may vary from 50 to 500 A with voltages from 20 to 40 V.
- The main disadvantage of the shielded metal arc-welding process is the slow speed. The typical weld-metal deposition rates may be in the range of 1 to 8 kg/hr in the flat position. This reduces substantially for the vertical and overhead positions.
- Further, a lot of electrode material is wasted in the form of unused end, slag and gas. There are more chances of slag inclusions in the bead. Also special precautions are needed to reduce moisture pick up so that it would not interfere with the welding.

The typical shielded metal arc welding set-up with ac power source is shown in Fig.



The electrodes for the welding operation should be selected properly, depending on the requirements of the welding. The main points to be considered are

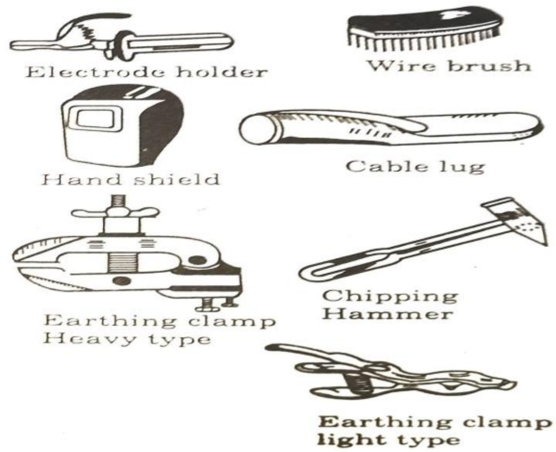
1. The composition of the base metal, which determines the electrode composition

2. The tensile strength of the required joint

3. The thickness of the base metal. For thinner metals the current setting should be lower.

ARC WELDING EQUIPMENTS:

- Both Alternating Current (A.C) and Direct Current (D.C.) are used for Arc Welding.
- When D.C. arc welding is to be employed the current is generated by a D.C. Generator. This generator can be driven by means of an electric motor or by means of a petrol or diesel engine.
- Whether it is a motor generator set or an engine generator set, both can be either of Portable type or Stationary type. With the result, the D.C. Arc Welding Processes can be employed irrespective of the fact whether the main A.C. supply is available or not. In absence of the same an engine driven D.C. Generator set can easily be used.
- For A.C. Arc Welding a step down Transformer is used which receives current from the supply mains at 400-440 Volts and transforms it to the required voltage for welding, i.e., 80-100 Volts.
- Apart from the above main equipment a number of other equipments, particularly for safety and clamping the work, holding the electrodes etc. are required as illustrated in Fig. A brief list of this equipment is given below:



List of Equipments:

1. Well insulated electrode Holders.
2. Wire cables and cable connectors.
3. Welding Helmet and Hand Screen or Shield.
4. Safety goggles.
5. Welder's Chipping Hammer.
6. Earthing Clamps.
7. Hand Gloves.
8. Aprons and Sleeves, etc.
9. Wire Brush

USE OF AC. AND D.C. FOR WELDING

- As already described in the foregoing articles, we receive A.C. supply from power mains at 400-440 volts whereas we require a much less voltage for welding. We, therefore, use a Step Down Transformer which lowers the voltage to about 80-100 volts.
- This voltage is actually required only for striking the arc and for maintaining the same we require a still lower voltage, say about 30 to 40 volts. This is accomplished by means of the Current Regulator, through which we can adjust the flow of current and also the resistance and hence can obtain the desired voltage.
- There is no fixed polarity at the terminals when using A.C. and they interchange in every cycle. Also the Alternating Current acquires zero value twice in each cycle. With the result, at these particular moments, the Potential Difference between the terminals is also zero and hence a higher voltage is required to maintain the arc at this moment.
- Unlike A.C., in D.C. welding the electrode acts as one terminal and the job the other terminal (either +ve or -ve). The potential difference can be so adjusted that the heat developed at the positive terminal is higher, (nearly 2/3 rd) and that on the negative terminal lower, (nearly 1/3 rd) of the total heat evolved. Here again the temperature of the

arc is 3700°C to 4000°C. The voltage required in case of D.C. welding is 60 to 80 Volts for striking the arc and 15 to 25 Volts for maintaining the arc.

Polarity is a very significant factor in all D.C. welding works. This polarity can be of two types:

1. **Straight Polarity (DCEN).** In this, the electrode forms the negative terminal and the workpiece positive.
2. **Reverse Polarity (DCEP).** In this, the electrode forms the positive terminal and the workpiece negative.

These two polarities are known as Electrode Negative and Electrode Positive respectively. Selection of correct polarity plays a significant role in obtaining a successful weld. It is only due to this factor that almost all the metals can be welded by using D.C. as many metals require more heat to acquire the fusion state than the electrode used e.g. copper, and it is possible only through different polarities to have more heat on the job and less on the electrode.

Assignment 3:

Q1. Differentiate between A.C arc welding and D.C arc welding.

Q2. Describe forward welding and backhand welding processes in detail.

CARBON ARC WELDING

- Only D.C. is used in Carbon Arc Welding. The Negative Terminal of the supply is connected to the carbon electrode and the Positive Terminal to the workpiece.
- The use of A.C. is not advisable for the reason that no fixed polarity can be maintained.
- The reason of connecting the carbon electrode to the negative terminal is that the heat generated at the electrode tip is less than that at the job so that the carbon content of the electrode is not carried over to the job. If this happens the resultant weld will be very brittle and unsound.
- This method is suitably used for joining steel sheets and repairing steel castings.
- Electrode Holders used for holding carbon electrodes are usually provided with a magnetic coil inside, which directs the arc properly and keeps it concentrated at the desired place.
- This process is carried out both by hands as well as machines.
- A flux is usually employed to prevent the weld metal from picking up carbon from the fused electrode.

ELECTRODES:

The electrodes used for providing heat input in arc welding are of two types, the consumable and the non-consumable electrodes.

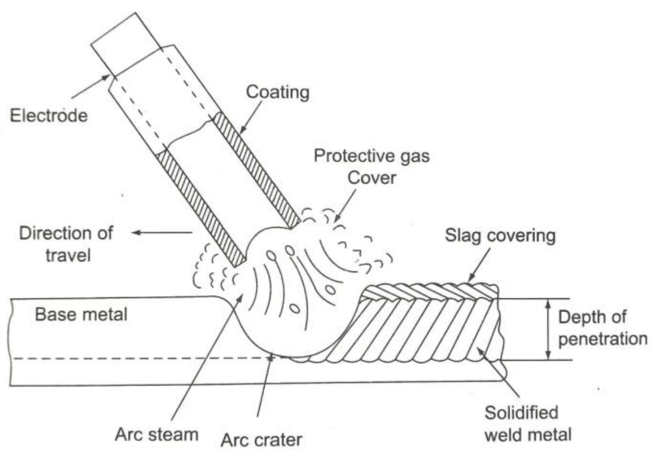
1. Consumable electrodes

- When the arc is obtained with a consumable electrode, the weld metal under the arc melts as also the tip of the electrode. The molten metal from the electrode and that obtained from the base metal gets intimately mixed under the arc and provides the necessary joint after solidification.
- So in this process, once the arc is initiated, the electrode is continuously consumed and hence, the electrode should be moved continuously towards the workpiece to maintain the constant arc length.
- Since the electrode continuously melts, it also acts as the filler rod to provide the filler metal into the joint. Thus, the functions of providing a filler metal and heat are both built into a single electrode.
- Consumable electrodes are made of various materials depending on the purpose and chemical composition of the metals to be welded. Thus, they may be made of steel, cast iron, copper, brass, bronze or aluminium.

2. Non consumable electrodes

- It is also possible to use non-consumable electrodes made of carbon, graphite or tungsten.
- The carbon and graphite electrodes are used only in dc welding, whereas tungsten electrodes are used for both ac and dc welding.
- The filler metal required has to be deposited through a separate filler rod.
- Thus, in this welding method it is possible to properly control the heat input as well as the amount of filler metal deposited, since both are separately controlled.

A consumable electrode, used in welding, can be either bare or coated. The coated electrode also called stick electrode, is used for the manual-arc-welding process.



The coatings on the electrodes serve a number of purposes which are detailed as follows:

1. The coatings give off inert gases such as carbon dioxide under the arc heat, which shields the molten metal pool and protects it from the atmospheric oxygen, hydrogen, and nitrogen pick-up, thus reducing contamination of the weld metal.

2. The coatings provide flux to the molten metal pool, which mixed with the oxides and other impurities present in the puddle, forms a slag. The slag being lighter, floats on the top of the puddle and protects it against the surrounding air during the weld bead solidification. The slag covering also helps the metal to cool slowly, preventing the formation of a brittle weld. When the weld is sufficiently cooled, the slag can be removed exposing the shiny weld underneath.
3. Some elements that are required for stabilisation of the arc are also added in these coatings. The coatings are different for ac welding and dc welding.
4. Special alloying elements can be introduced through these coatings to improve the strength and physical properties of the weld metal.
5. The coatings are normally insulators of electricity and thus, permit the electrode to be used in narrow grooves and other difficult locations without causing any short circuits.

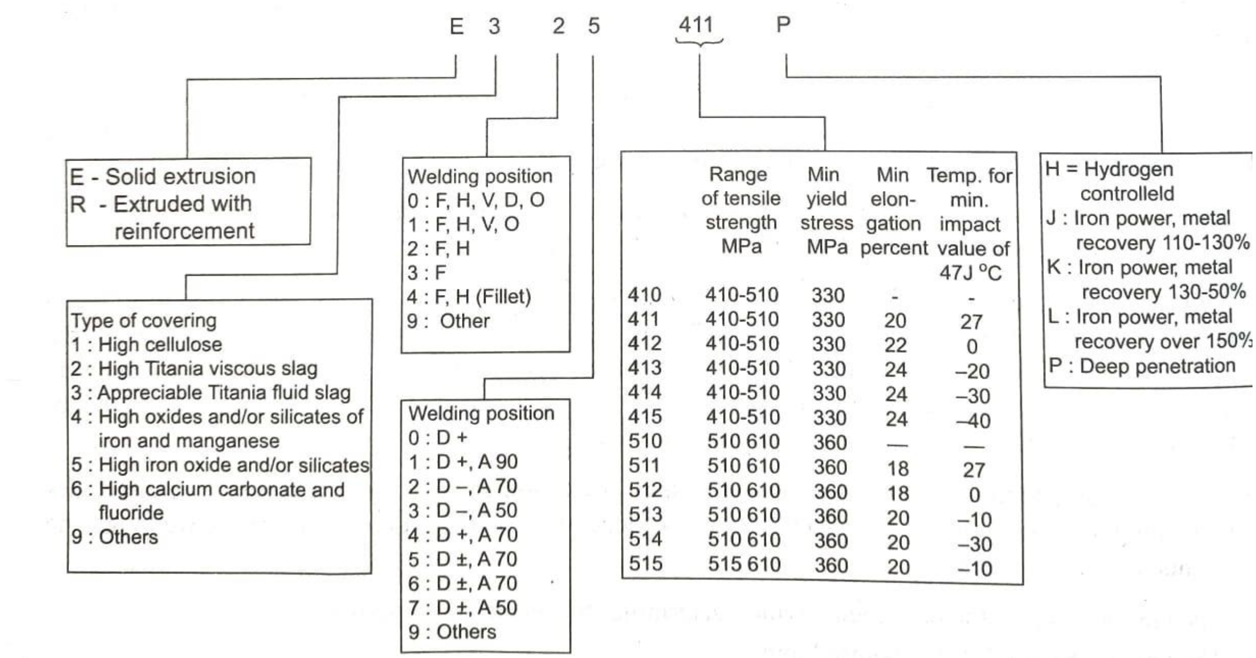
Coating materials:

- The common ingredients of a flux which help in slag formation and metal refining are asbestos, mica, silica, fluorspar, stealite, titanium dioxide, iron oxide, magnesium carbonate, calcium carbonate and different aluminas.
- Ingredients used for producing the reducing atmosphere include cellulose, calcium carbonate, dolomite, wood floor, starch, dextrin, etc. iron powder provides a higher deposition rate. Ferromanganese and manganese oxide provide alloying elements. The latter also helps in slag formation.
- Potassium silicate and potassium titanate are the principal Arc Stabilizers. Arc stability is also helped by titanium dioxide, feltspar and mica.

The stick electrodes are normally available in diameters 3.2, 4, 5, 6, 8 and 9mm and the length is 350mm or 450mm.

Specification of a welding electrode:

The electrodes are marked with a 6-digit numeral associated by a prefix and a suffix. The meaning of these and the various values it can take is shown schematically in Fig.



D+ :- DCEP

A90: - Open circuit voltage not less than 90V. (For electrode size of 4 or 5mm)

INERT GAS TUNGSTEN ARC WELDING (TIG)

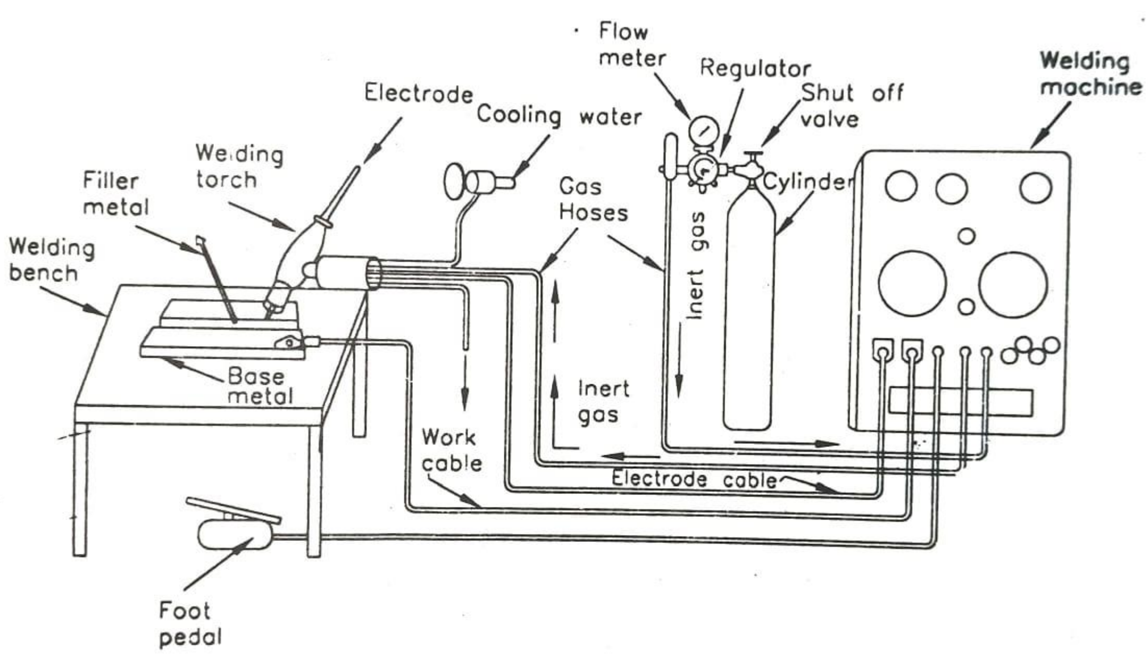
- It is basically an Arc welding process in which the arc is struck between a non-consumable tungsten electrode and the base metal.
- The electrode is held in a special type of Electrode-holder which is so designed that apart from holding the electrode, it also carries a passage around the electrode for flow of Inert gas to provide the protective shield around the arc. This gaseous shield protects the electrode, molten metal, the arc and adjacent heated areas of base metal from atmospheric contamination.
- The Electrode Holder also carries a provision for water cooling or air cooling. This process can be adopted for both manual and automatic operations.
- This process is capable of producing continuous, intermittent or spot welds.
- Due to non-consumable nature of electrode no filler metal is provided by it. However, if needed, additional filler metal can be provided from outside by fusing a filler rod under the arc in the same way as in Gas welding.
- This process is suitable for welding in all positions. Thin Metal Foils upto a minimum thickness of 0.125 mm can be easily welded with this process.
- It is suitable for welding of most metals and alloys except lead and zinc, which have very low melting points.

- Its specific applications include welding of Al-alloys, Mg-alloys, Nickel alloys, Zirconium alloys, Titanium alloys, Beryllium alloys, Refractory metals, Carbon steels, alloy steels and Stainless steels.
- It is advisable to use manual welding for complex and irregular shapes and difficult to reach sections since manipulation of manual torch is easier in such cases. For regular shapes automatic welding can be easily adopted.

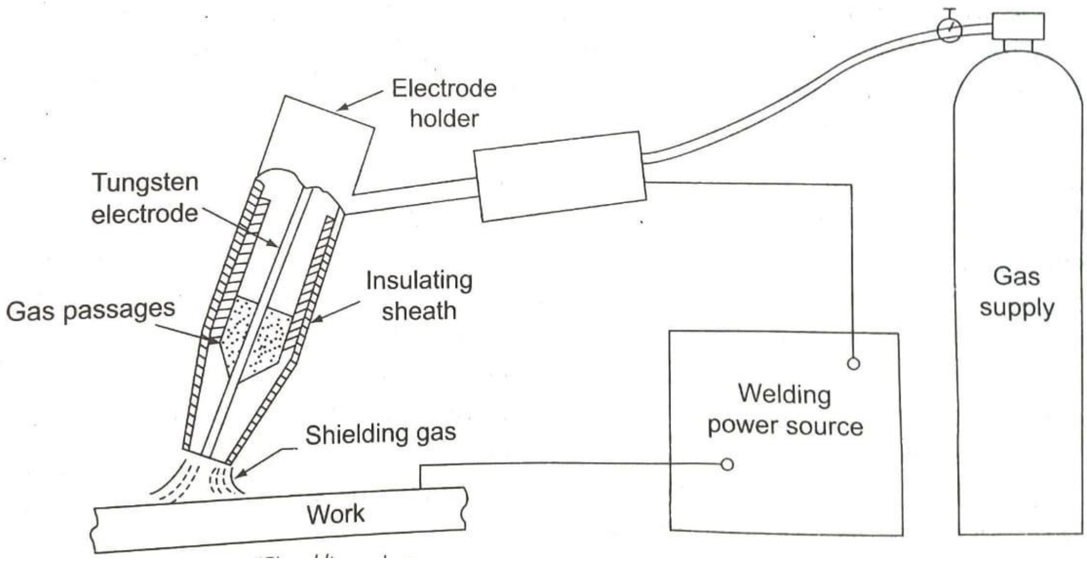
TIG Welding Equipment:

The following equipment is required in TIG Welding

1. An inert gas cylinder.
2. An inert gas regulator and flowmeter.
3. Inert gas hoses and hose connections.
4. an inert gas shut-off valve
5. An arc welding machine
6. Welding cables for electrode and ground connections.
7. A welding bench.
8. Electrode holder (water cooled or air cooled).
9. Water supply with inlet and outlet hoses (if water cooled holder is used).
10. Non-consumable Tungsten Electrode.



In most of the cases the inert gas hose, welding cable for electrode and the water hose are all enclosed in a common jacket to form what looks like a single cable. Apart from the above equipment the welder should use proper eye-shield to protect his eyes since the Arc in TIG Welding is fully exposed.



Welding Current:

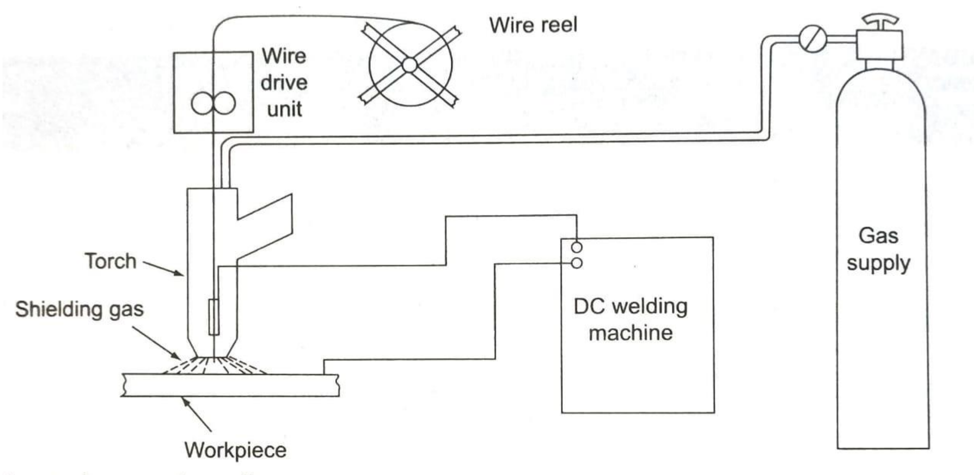
- Both A.C. and D.C. are used in TIG Welding.
- A.C. enables good penetration and less surface oxidation. It is preferred for welding of aluminium, magnesium and beryllium copper.
- D.C. with straight polarity is the least used because it provides less penetration.

Welding Procedure:

- Before stating welding, the Joint should be prepared well and thoroughly cleaned to remove dirt, grease, oil, oxides, etc. from the work surface. The workpieces should be firmly held, preferably in suitable fixtures.
- Select a suitable Electrode Size, hold it firmly in the holder, set the current and proper polarity, if using D.C., turn on the cooling water or air, turn on the gas and adjust the flowmeter and then switch on the power supply.
- After striking the arc, make a small puddle of molten metal, at the place where welding is to commence, using a very small circular motion of the electrode.
- The electrode should be held at an angle of 60° to 80° with the workpiece and the filler metal (if used) at 15° to 20° with the workpiece.
- Then the welding may proceed almost in the same way as in Oxy-acetylene welding. After the desired length has been welded the electrode holder should be lifted quickly to break the arc and the current flow switched off. However, the inert gas flow should be continued till the electrode cools down.

INERT GAS METAL-ARC WELDING (MIG WELDING)

- This process, popularly known as Metal Inert Gas (MIG) Welding, involves welding of metals using a consumable metal electrode in an Inert gas atmosphere.
- The arc is struck between the metal electrode and the workpiece.
- The electrode is in the form of a continuous wire which is fed into the arc, by an Adjustable Speed Electric Motor, at the same speed at which it is melted and deposited in the weld.
- A specially designed Electrode Holder is used which, in addition to a passage for wire electrode, also incorporates passages for supply of Inert Gas for shielding the electrode, molten weld metal, arc and the adjacent hot area of base metal from atmospheric contamination and for supply of cooling water.
- A schematic diagram of MIG Welding Torch is shown in Fig.



- This method can be employed for welding carbon steels, low alloy steels, stainless steels, aluminium and al-alloys, heat resisting alloys, magnesium alloys, copper and Cu-alloys.
- With Special Techniques, like preheating of base metal, a more close control of inert gas, in some cases post-heating of parent metal etc., it is possible to weld cast iron, titanium and its alloys, refractory metals, manganese bronze also.
- It is not suitable for welding of low melting point metals like lead, tin and zinc and also those metals which carry coatings of these low melting point metals.
- Economically welded metal thicknesses with this method range from 0.5 mm to 12.5 mm.
- This process can be used for welding in all welding positions. However, best results are obtained in flat and horizontal positions.

The main equipment needed in this process is as follows :

- An Inert gas cylinder.
- Gas regulator and Flowmeter.
- Gas hoses and connections.

- A power source and welding leads.
- MIG welding gun.
- A spool of electrode wire.
- Electrode wire feeder.
- Water supply with water hoses.

- Usually, D.C. with Reverse Polarity is used in MIG Welding. A.C. is not used in this method. Even D.C. with Straight Polarity is not often used. It is used only sometimes when a very small penetration is required. Use of D.C. Reverse Polarity enables a deeper penetration and a clean weld surface.
- In MIG Welding, inert gases like argon, helium, carbon-dioxide or a mixture of these gases are used for providing the inert gas shield. Formerly only argon and helium were used, but now CO, is more widely used, both as a single gas and also in mixture with other inert gases.

Before starting welding, a similar joint preparation and cleaning is necessary in MIG Welding as is done in TIG welding. Two principal MIG welding methods are the following:

1. Spray Arc Method. This method uses a heavy flow of D.C. Reverse Polarity causing the electrode to melt in the form of a steady stream or spray of very minute droplets, which are transferred across the arc to the joint without interfering the stability of arc. It is used for good fit-up joints and faster welding.
2. Short Circuiting Method. It is also known as Dip Transfer Method. In this method, the melted filler metal from the electrode separates in the form of large drops which touch the base metal before separating from the electrode. As a result, the arc is short circuited temporarily for an instant, and as soon as the drop is separated and proper gap between the electrode tip and workpiece restored the arc is reestablished. This process is used for poor fit-up joints and thin sections.

Advantages of MIG Welding:

1. It is faster than shielded metal-arc welding due to continuous feeding of filler metal.
2. There is no slag formation.
3. It provides higher deposition rate.
4. Deeper penetration is possible.
5. More suitable for welding of thick sheets.
6. Welds produced are of better quality.

Disadvantages:

1. Equipment used is costlier and less portable.

2. It is less adaptable for welding in difficult to reach portions.

3. It is less suitable for outdoor work because strong wind may blow away the gas shield.

Welding defects:

Common causes:

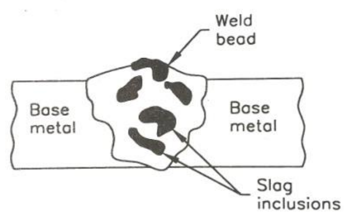
1. Lack of welding skills
2. Use of poor quality welding consumables
3. Faulty welding techniques and procedures
4. Low welding temperature
5. Humid atmosphere around the weldment
6. Faulty voltage and current set ups

Common defects:

1. Inclusions
2. Distortion
3. Inadequate fusion
4. Porosity
5. Spatter
6. Cracks
7. Poor Penetration
8. Undercut
9. Overlapping
10. Faulty Profile and Weld Size.

Inclusions

Normally the Slag, being lighter, is expected to float over the surface of the Molten Metal Pool. But, several times, specially in case of multi-pass welds, it is not fully squeezed out and a portion of it remains entrapped in the weld metal and is known as Slag Inclusion. Such inclusions may also be added due to many foreign materials like dirt, mill scale, rust, etc. present on the surface of the base metal.



The Slag Inclusions appear as large patches and other foreign material inclusions are dispersed finely in the weld. Such inclusions render the welded joint weak.

Cracks

A Crack is the discontinuity of metal. This discontinuity may occur in the Base metal or Weld metal or at Fusion face between the weld metal and base metal.

If the Crack is large enough to be visible by naked eye, it is called a Macro crack. If it is too small to be detected by the naked eye, it can be revealed through a Microscopic Examination only, and then it is known as a Micro-Crack.

A Crack may also appear in the Crater, in the root of the bead or on the surface of the weld. Presence of cracks in a welded joint renders it unsound and weak and may ultimately lead to the failure of the welded joint during service. For details of cracks refer to Fig.

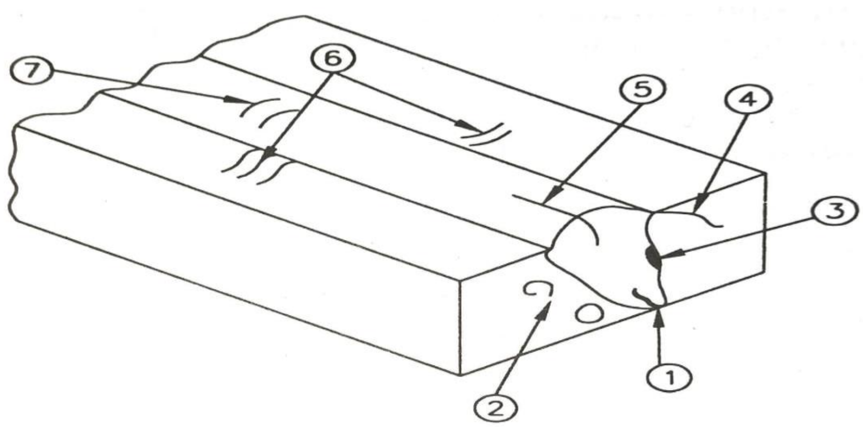


Fig. 24.29. Different types of cracks in welds.

1. Root Crack
2. Fusion face Crack
3. Under bead Crack
4. Toe Crack
5. Weld-metal Crack (Longitudinal)
6. Heat effected zone (base metal) Transverse Cracks
7. Weld metal Transverse Cracks.

5. Inadequate Fusion. Sometimes the deposited weld metal by the electrode does not *fuse* fully with the *base metal* or with the previously deposited *layer* of the *weld metal* because the latter two are relatively cooler. This leads to the existence of a sort of *cushion* of an unfused metal between the above two.

The main *reasons* of this defect are presence of oxide, dirt, scale, slag and other foreign material between the two fusing surfaces. It can be prevented by thoroughly cleaning these surfaces through deslagging, chipping, wire brushing, etc., to remove these materials from the surfaces. Fig. 24.32 shows the results of **Inadequate fusion** at different locations in a weld.

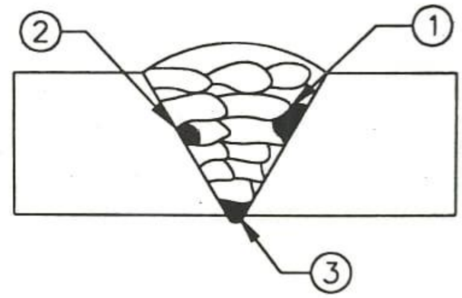
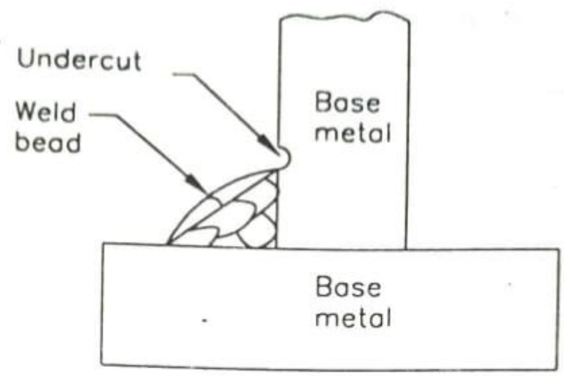


Fig. 24.32. Result of inadequate fusion at different locations in a weld.

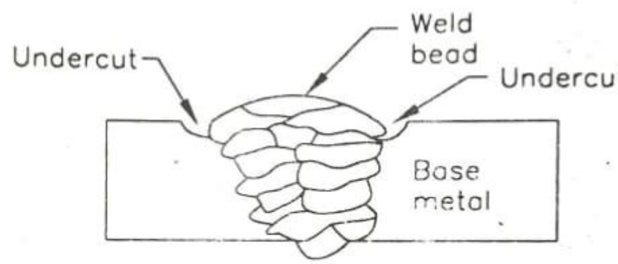
Inadequate fusion between :

1. Two passes of welding.
2. Parent metal and weld metal on the side of 'V'.
3. Weld metal and parent metal at the root of the joint.

6. Undercut. An **Undercut** is a **Groove** formed in the *parent metal* at the *toe* of a *weld pass*, *i.e.* along the side of a *Weld Bead*. The main *reasons* for its formation are too high current, wrong inclination of electrode, long arc, excessive side manipulation of arc, too fast welding speed, etc. In effect, it *weakens* the joint. A proper control of the above parameters enables to minimise this defect. Fig. 24.33 illustrates the two cases of **Undercutting**.



(*a*) In a Fillet weld.



(*b*) In a Butt weld.

Fig. 24.33. The undercutting.

7. Porosity. This term is used to indicate the presence of small *pores* or *voids* in the weld. These *voids* are created by the entrapment of *gases* in the weld metal. During *solidification* of molten *weld metal* the gases try to evolve, creating the voids, which are actually their passages for exit. When these *pores* are quite small, their group is called **Porosity.** If a larger amount of gas is accumulated at a *single place*, a bigger void is created, which is known as a **Blow Hole.** In some cases these voids are formed in *tabular* shape, then they are called **Piping**.

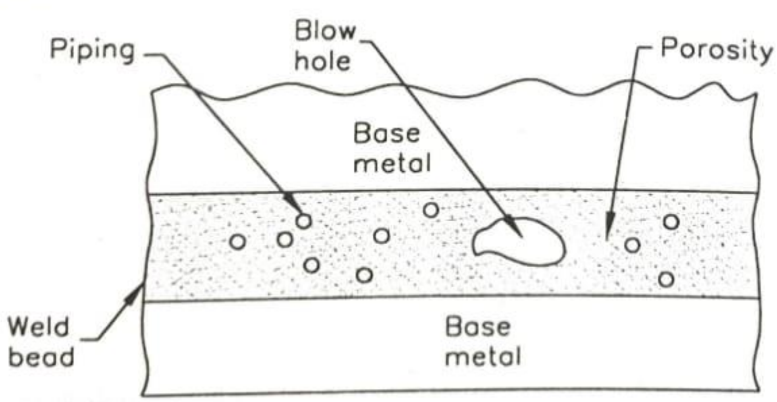


Fig. 24.34. Porosity, blowhole and piping.

The main *Factors* which *promote* these defects are the presence of oil, grease, scale and moisture on the joint surface; use of chemically faulty electrodes, presence of *moisture* in *electrode coating* and *flux*, *longer arc, improper gas shielding, faulty composition* of base metal, *wrong welding techniques, low welding current*, etc. (See Fig. 24.34).

8. Overlapping. Sometimes the molten *Weld metal* flows over to the surface of the base metal without *fusing* with the latter. It is known as *overlap* (Fig. 24.35). In appearance it looks like an unintended extension of the *Weld Bead* without fusing to the base metal. It may be *Continuous* or *Discontinuous* along the bead or only at a single location.

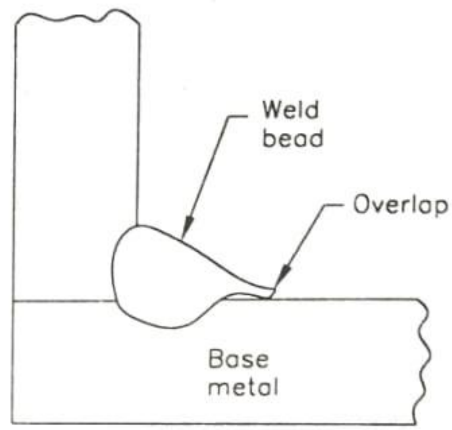


Fig. 24.35. The undercutting.

The main reasons for the occurrence of this *defect* are the use of oversize electrode, very low welding speed, incorrect manipulation of electrode, too high current, too long arc, etc. The defect can be controlled to a large extent by controlling the above parameters.

9. Spatter. During welding, tiny *Electrode metal particles* are blown out of the *arc* which get deposited over the adjoining base metal surface and also on the surface of the *Bead*. These particles strongly adhere to these surfaces and are known as **Spatter**. They give *poor appearance* to the surfaces concerned and their removal adds to the cost of welding, although they don't have any appreciable effect on the *weld strength*.

The main reasons of this defect are use of damp electrodes, too high welding current, wrong composition of flux coating, discontinuous arc, **Are Blow** (in case of D.C. welding), etc. Adequate control of these parameters will prevent this defect.

10. Faulty Profile and Weld Size. A Weld is known to have a *Faulty Profile* and *Size* when it differs from the specified shape and size. The main reasons for the occurrence of this defect are lack of skill in the welder, inconsistent arc length, wrong end preparation, discontinuous and non-uniform electrode coating, wrong electrode manipulation, wrong electrode size, wrong welding speed, etc.

3.CASTING

Foundry or casting is a process of forming metallic products by melting the metal, pouring it into a cavity known as the mould, and allowing it to solidify. When it is removed from the mould it will be of the same shape as the mould. Almost any article may be cast with proper technique and design, and there is practically no limit as to the size and shape of the castings that may be made.

Steps:

- Making mould cavity
- Material is first liquefied by properly heating it in a suitable furnace.
- Liquid is poured into a prepared mould cavity
- Allowed to solidify
- Product is taken out of the mould cavity, trimmed and made to shape

ADVANTAGES

- Molten material can flow into very small sections so that intricate shapes can be made by this process. As a result, many other operations, such as machining, forging, and welding, can be minimized.
- Possible to cast practically any material: ferrous or non-ferrous.
- The necessary tools required for casting moulds are very simple and inexpensive. As a result, for production of a small lot, it is the ideal process.
- There are certain parts (like turbine blades) made from metals and alloys that can only be processed this way.
- Size and weight of the product is not a limitation for the casting process.

LIMITATIONS

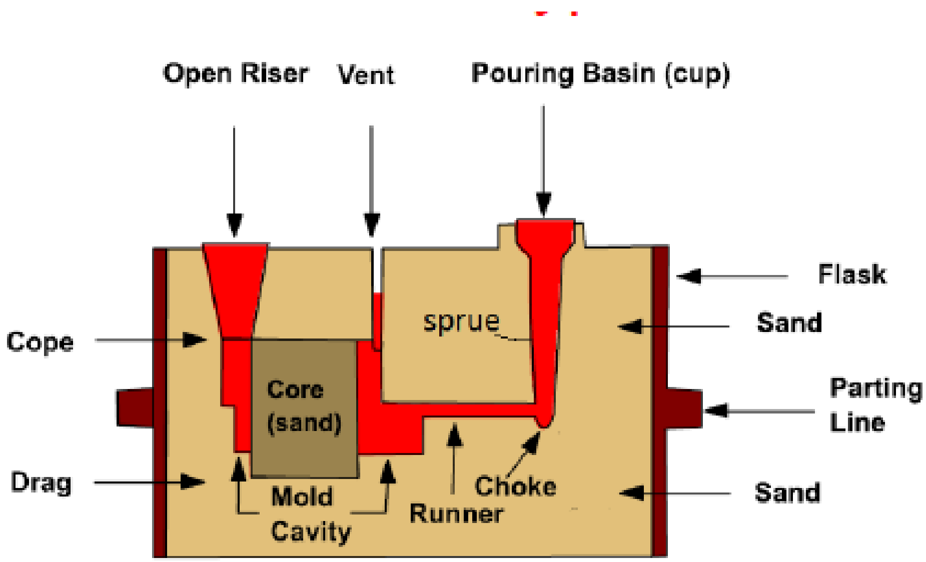
- Metal casting is a labour intensive process
- For some materials, it is often difficult to remove defects arising out of the moisture present in sand casting.
- Dimensional accuracy and surface finish of the castings made by sand casting process would not be adequate in many applications.

APPLICATIONS

Cylinder blocks, machine tool beds, pistons, piston rings, mill rolls, wheels, water supply pipes, etc.

SAND CASTING

Casting terms:



Flask. A moulding flask is one which holds the sand mould intact. It is a metal or wood frame, without fixed top or bottom, in which the mould is formed. Depending upon the position of the flask in the moulding structure, it is referred to by various names such as drag – lower moulding flask, cope – upper moulding flask, cheek – intermediate moulding flask used in three piece moulding.

Pattern: It is a replica of the final object to be made with some modifications. The mould cavity is made with the help of pattern.

Parting line: This is the dividing line between the two moulding flasks that makes up the mould.

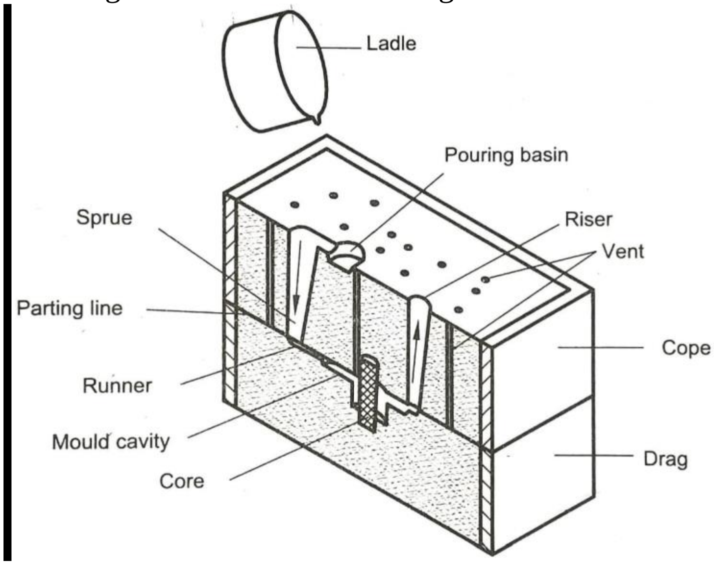
Bottom Board: This is a board normally made of wood, which is used at the start of the mould making. The pattern is first kept on the bottom board, sand is sprinkled on it, and then the ramming is done in the drag.

Facing Sand: The small amount of carbonaceous material sprinkled on the inner surface of the moulding cavity to give better surface finish to the castings.

Moulding Sand: It is the freshly prepared refractory material used for making the mould cavity. It is a mixture of silica, clay and moisture in appropriate proportions to get the desired results and it surrounds the pattern while making the mould.

Backing Sand: It is what constitutes most of the refractory material found in the mould. This is made up of used and burnt sand.

Core: It is used for making hollow cavities in castings.



Pouring Basin: A small funnel shaped cavity at the top of the mould into which the molten metal is poured.

Sprue: The passage through which the molten metal from the pouring basin reaches the mould cavity. In many cases, it controls the flow of metal into the mould.

Runner: The passageways in the parting plane through which molten metal flow is regulated before they reach the mould cavity.

Gate: The actual entry point through which molten metal enters the mould cavity.

Chaplet: Chaplets are used to support cores inside the mould cavity.

Chill: Chills are metallic objects, which are placed in the mould to increase the cooling rate of castings, to provide uniform or desired cooling rate.

Riser: It is a reservoir of molten metal provided in the casting, so that hot metal can flow back into the mould cavity, when there is a reduction in volume of metal due to solidification.

Pattern

- Pattern is the Replica of the part to be cast and pattern is used to prepare the mould cavity.
- It is the physical model of the casting and is used to make the mould cavity. The mould cavity is made by packing some readily formed aggregate material, such as moulding sand, surrounding the pattern.
- When the pattern is withdrawn, its imprint gives rise to the mould cavity. This cavity is then filled with liquid molten metal.

Moulding- Moulding is nothing but the mould preparation activities for receiving the molten metal.

Moulding usually involves:

(i) preparing the sand mould around a pattern held within a supporting metal frame (flask),

(ii) Removing the pattern.

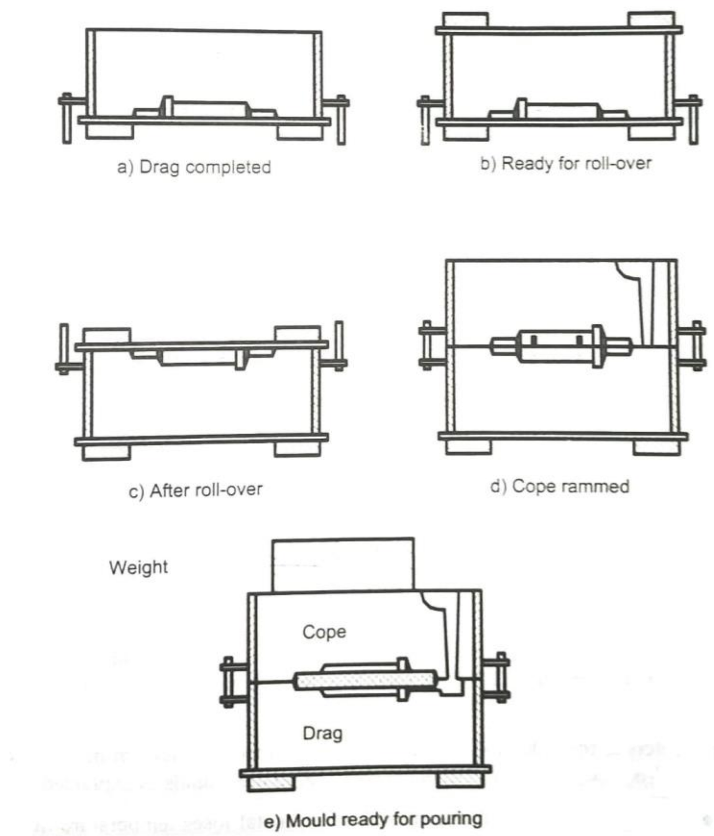
The mould cavity receives the liquid metal.

SAND MOULD MAKING PROCEDURE

The procedure for making a typical sand mould is described in the following steps.

1. First, a bottom board is placed on the floor. The drag-moulding flask is kept upside down on the bottom board along with the drag part of the pattern at the centre of the flask on the board.
2. Dry-facing sand is sprinkled over the board and pattern to provide a nonsticky layer.
3. Freshly prepared moulding sand of requisite quality is now poured into the drag and on the pattern to a thickness of 30 to 50 mm.
4. Rest of the drag flask is completely filled with the backup sand and uniformly rammed to compact the sand.
5. The ramming of the sand should be done properly, so as not to compact it too hard, which makes the escape of gases difficult, nor too loose, so that mould would not have enough strength.
6. Now, with a vent wire, vent holes are made in the drag to the full depth of the flask as well as to the pattern to facilitate the removal of gases during casting solidification. This completes the preparation of the drag.
7. The finished drag flask is now rolled over, to the bottom board exposing the pattern as shown in Fig(c).
8. Now cope-half of the pattern is placed over the drag pattern and aligned with it by dowel pins.
9. The dry-parting sand is sprinkled all over the drag and on the pattern.
10. A sprue pin for making the sprue passage is located at a small distance of about 50 mm from the pattern, Also, a riser pin, if required, is kept at an appropriate place.

11. Then freshly prepared moulding sand along with the backing sand is sprinkled. The sand is thoroughly rammed, excess sand scraped and vent holes are made all over in the cope as in the drag.
12. The sprue pin and the riser pin are carefully withdrawn from the flask.
13. The pouring basin is cut near the top of the sprue.
14. The cope flask is separated from the drag flask.
15. Now the cope and the drag-pattern halves are withdrawn.
16. The runners and the gates are cut in the mould carefully without spoiling the mould. Now the facing sand in the form of a paste is applied all over the mould cavity and the runners, which would give the finished casting a good surface finish.
17. The cope is then replaced on the drag taking care of the alignment of the two by means of the pins.
18. A suitable weight is kept on the cope to take care of the upward metallostatic force during the pouring of molten metal. The mould now, as shown in Fig. (e), is ready for pouring.



PATTERN MATERIALS

Pattern material should be

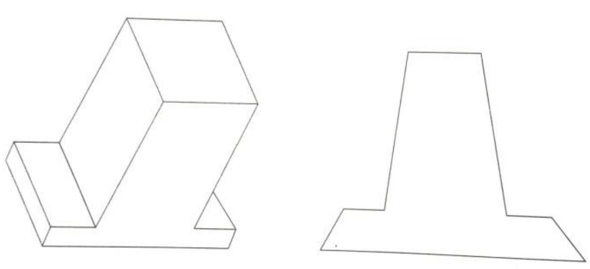
- Easily worked, shaped and joined;
- Light in weight;
- Strong, hard and durable So that it may be resistant to Wear and abrasion, to corrosion and to chemical action ;
- dimensionally stable in all Situation;
- easily available at low cost ;
- repairable and reused ;
- Able to take good surface finish.

Pattern Materials

: **wood, metal (cast iron, brass, aluminium), plastics, rubber, plasters, waxes**

TYPES OF PATTERN

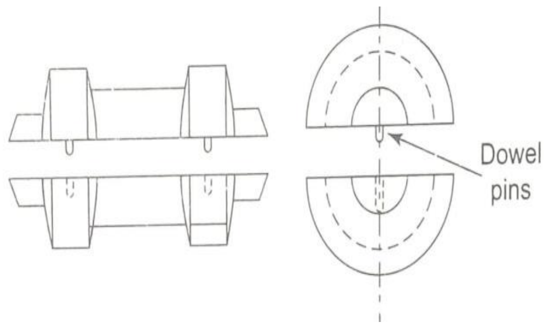
1. **Single-piece or solid pattern:**
    - A pattern that is made without joints, partings, or any loose pieces in its construction is called a single-piece of solid pattern.
    - A single-piece pattern is not attached to a frame or plate and is, therefore, sometimes known as a loose pattern.
    - These patterns are cheaper.
    - Mould cavity will be either entirely in the drag or entirely in the cope.
    - When using such patterns, the moulder has to cut his own runners and feeding gates and risers.
    - This operation takes more time, and they are not recommended except for limited production. Single-piece patterns are usually used for large castings of simple shapes.



(a) Casting (b) Pattern

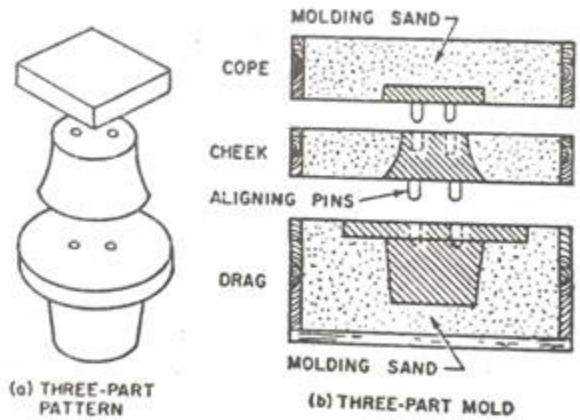
2. split pattern/ two piece pattern

- Many patterns cannot be made in a single piece because of the difficulties encountered in making them. To eliminate this difficulty and for castings of intricate design or unusual shape, split patterns are employed to form the mould.
- These patterns are usually made in two parts, so that one part will produce the lower half of the mould cavity; and the other, the upper half.
- The two pattern parts, which may or may not be of the same size and shape, are held in their proper relative positions by means of dowel-pins.
- The surface formed at the line of separation of the two parts, usually at the centreline of the pattern, is called the parting surface or parting line.



Multi-piece pattern

It is sometimes necessary to construct a pattern for a complicating casting that requires three or more parts instead of two to make the completed pattern. This type of pattern is known as multi-piece pattern. A three-part pattern may necessitate the use of a flask having three parts.

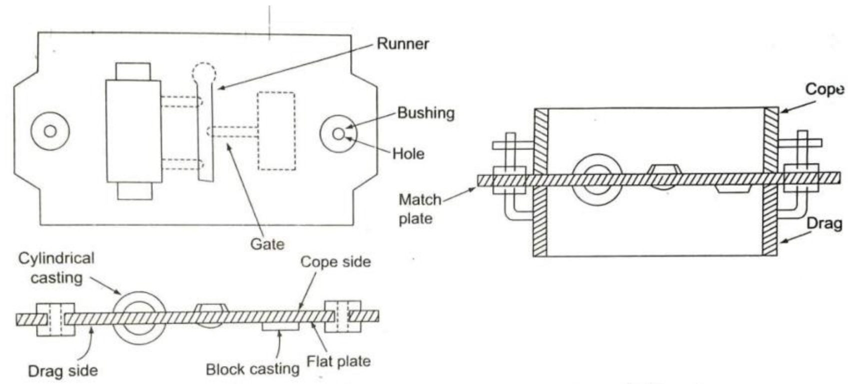


Three-piece split pattern

Spindles, cylinders, steam valve bodies, water stop cocks and taps, bearings, small pulleys and wheels are few examples of castings that require the use of split patterns.

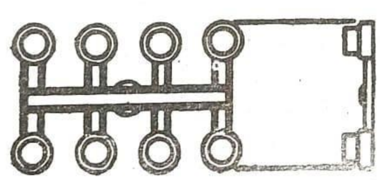
3. **Match plate pattern**

- When split patterns are mounted with one half on one side of a plate and the other half directly opposite on the other side of the plate, the pattern is called a match plate pattern.
- Patterns for gates and runners are fastened to the drag side of the plate in their correct positions to form the complete match plate.
- When the match plate is lifted off the mould, all patterns are drawn, and the cope or upper half of the mould matches perfectly with the drag or lower half of the mould. The gates and runners are also completed in one operation.
- These patterns are used for producing small casting in large quantities rapidly with accuracy. They are expensive to construct.

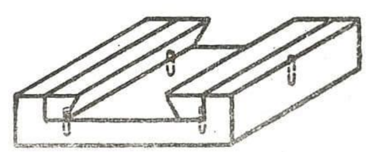


4. **Gated Pattern**

This is an improvement over the simple pattern where the gating and runner system are integral with the pattern. This would eliminate hand cutting of the runners and gates and help in improving the productivity of a moulder.



Gated pattern



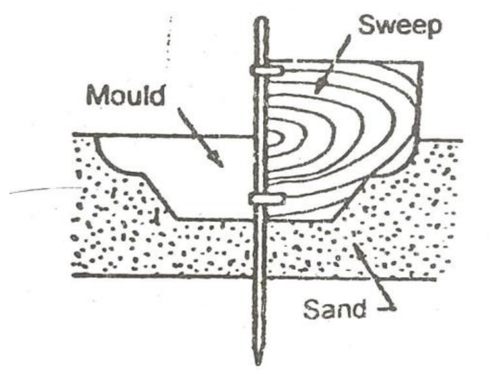
Loose-piece pattern

5. **Loose-piece pattern.** Some patterns are produced as assemblies of loose component pieces. The loose-piece patterns are needed when the part is such that the pattern cannot be removed as one piece. In this case, the main pattern is usually removed first, then the separate pieces are removed.

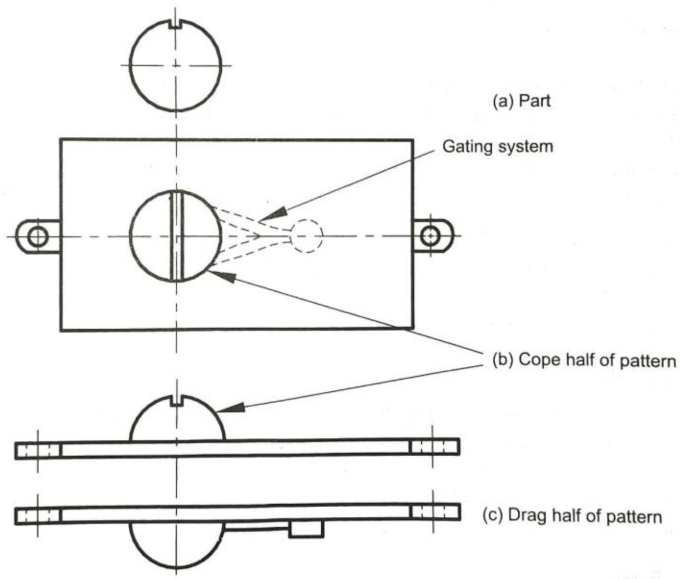
6. **Sweep pattern.**

- Symmetrical moulds and cores, particularly in large sizes, are sometimes shaped by means of sweep patterns.

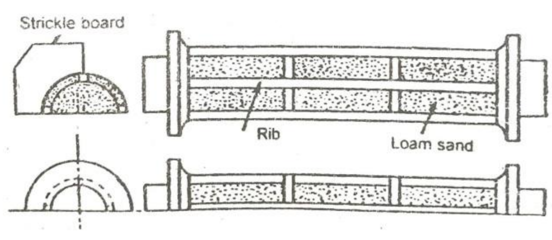
- The sweep pattern consists of a board having a shape corresponding to the shape of the desired casting and arranged to rotate about a central axis as illustrated in the Fig.
- The sand is rammed in place and the sweep board is moved around its axis of rotation to give the moulding sand the desired shape.
- Sweep patterns are employed for moulding part having circular sections.



7. **Cope and drag pattern.**
    - In the production of large castings, the complete moulds are too heavy to be handled by a Single operator.
    - Therefore, cope and drag Patterns are used to ease this problem to efficient operation. The patterns are made in halves, split on a convenient joint line, and Separate cope and drag patterns are built and mounted on individual plates or boards.
    - This arrangement permits one operator or group of operators to prepare the cope half of the mould while another operator or group worked on the drag half. This planned distribution of labour increases production appreciably.



8. **Skeleton pattern**.
    - Patterns for very large castings would require a tremendous amount of timber for a full pattern. In such cases a skeleton pattern as in Fig. may be employed to give the general contour and size of the desired casting.
    - This is a ribbed construction with a large number of square or rectangular openings between the ribs which form a skeleton outline of the pattern to be made.
    - It is usually built in two parts: one for the cope and the other for the drag. Soil and water pipes, pipe bends, valve bodies, and boxes are few examples of castings which are made by making skeleton patterns.



PATTERN ALLOWANCES

1. **Shrinkage allowance.**
   - As metal solidifies and cools, it shrinks and contracts in size. To compensate for this, a pattern is made larger than the finished casting by means of a shrinkage or contraction allowance.
   - Most of the metals used in casting work contract during cooling from pouring temperature to room temperature. This contraction takes place in three forms, viz., Liquid Contraction, Solidifying Contraction and Solid Contraction; the first two are compensated by Gates and Riser and the last one by providing adequate allowances in the pattern. The amount of contraction varies with different metals and, therefore, their corresponding allowances also differ.
   - Some average values of contraction allowances for different materials which can be safely adopted for all general practical purposes are given below.

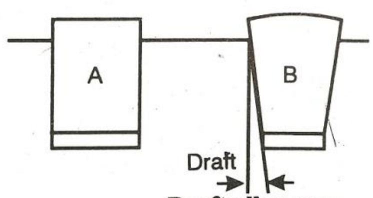
Contraction allowances for different metals

Metal	*Allowance mm/metre*	*Metal*	*Allowance mm/metre*
Cast iron (Grey)	10.5	Aluminium	16.0
Cast iron (white)	21.5	Zinc	24.0
Malleable iron	10.5	Lead	24.0
Steel	21.0	Tin	7.0
Brass	16.0	Copper, Nickel and Magnesium	16.0
Bronze	10.5 – 21.0	Silver	10.0

Remember that the contraction of metals is always volumetric, but the contraction allowances are always expressed as linear measures.

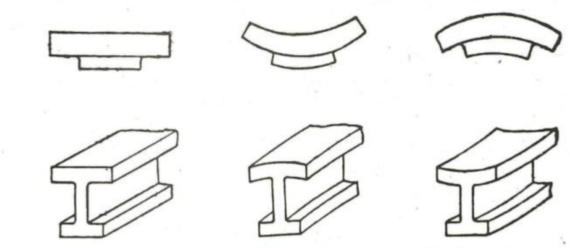
2. **Draft allowance.**
   - When a pattern is drawn from a mould, there is always some possibility of injuring the edges of the mould.
   - This danger is greatly decreased if the vertical surfaces of a pattern are tapered inward slightly. This slight taper inward on the vertical surfaces of a pattern is known as the draft.

- Draft may be expressed in millimeter per metre on a side, or in degrees, and the amount needed in each case depends upon (1) length of the vertical side, (2) intricacy of the pattern, and (3) the method of moulding.
- Under normal conditions the draft is about 10 to 20 mm per Metre on exterior surfaces and 40 to 60 mm per metre on interior surfaces. Figure shows how a draft is provided in a pattern.



Draft allowance

3. **Finish or Machining Allowance**
   - The finish and accuracy achieved in sand casting are generally poor and, therefore, when the casting is functionally required to be of good surface finish or dimensionally accurate, it is generally achieved by subsequent machining.
   - Also, ferrous materials would have scales on the skin, which are to be removed by cleaning. Hence, extra material is to be provided which is to be subsequently removed by the machining or cleaning process.
   - This extra amount of metal provided on the surfaces to be machined is called machine finish allowance and the edges of these surfaces are indicated by a finish mark V or F.
   - The amount that is to be added to the pattern depends upon dimensions of casting, the type of casting material and the finish required. This may range from 2 to 20 mm.
4. **Distortion or camber allowance.**
   - Some castings, because of their size, shape and type of metal, tend to warp or distort during the cooling period.
   - This is a result of uneven shrinkage and is due to uneven metal thickness or to one surface being more exposed than another, causing it to cool more rapidly.
   - The shape of the pattern is thus bent in the opposite direction to overcome this distortion. This feature is called distortion or camber allowance.
   - As an example, a casting shaped like the letter U will be distorted with the legs diverging, instead of parallel. To compensate for this condition, the pattern is made in such a manner that the legs converge but as the casting cools after its removal from the mould, the legs straighten and remain parallel.
   - Although no distortion data in published form is available, the distortion allowance ranges from the Standard finish allowance upto 20 mm when large castings are considered.



Distortion in casting

5. **Rapping or Shake allowance.**
   When a pattern is to be withdrawn from the mould, it is first rapped or shaken, by striking over it from side to side, so that its surface may be free of the adjoining sand wall of the mould. As a result of this the size of the mould cavity increases a little and a *negative allowance* is to be provided in the pattern to compensate the same. However, it may be considered negligible for all practical purposes in small and medium sized castings.

THE MAIN CONSTITUENTS OF MOULDING SAND

1. Silica sand grains
2. Binder (usually clay)
3. Water
4. Additives

Silica sand grains:

- Silica in the form of granular quartz, itself a sand, is the chief constituent of moulding sand.
- Silica sand contains from 80 to 90 per cent Silicon dioxide and is characterized by a high softening temperature and thermal stability.
- It is a product of the breaking up of quartz rocks or the decomposition of granite, which is composed of quartz and feldspar. The feldspar, also when decomposed, becomes clay.
- However, silica sand grains impart refractoriness, chemical resistivity, and permeability to the sand. They are specified according to their average size and shape.

Binder:

The purpose of adding a binder to the moulding sand is to impart it sufficient strength and cohesiveness so as to enable it to retain its shape after the mould has been rammed and the pattern withdrawn. However, it produces an adverse effect on the permeability of the sand mould.

The common binders used in foundry can be grouped as:

1. Organic binders. 2. Inorganic binders

Organic Binders find their specific use in core making. Common binders coming in this category are Molasses, Dextrin, Linseed oil, Cereal binder, Pitch-up to 2% max., Resins like phenol and urea formaldehyde.

In the Inorganic group the common binders are clay, sodium silicate and Portland cement. Out of all these, the clay binders are commonly used. The following types of clays are commonly used:- Bentonite, Kaolonite, Limonite, Ball clay, Fire clay, Fuller's earth. Out of the above six varieties Bentonite is most widely used. In our country its deposits are found in Bihar, Rajasthan and Jammu Kashmir.

Water: water in requisite amount, furnishes the bonding action of clay. When water is added to clay, it penetrates the mixture and forms a microfilm which coats the surface of flake-shaped clay particles. The bonding quality of clay depends on the maximum thickness of water film it can maintain. The bonding action is considered best if the water added is the exact quantity required to form the film. On the other hand, the bonding action is reduced and the mould gets weakened if the water is in excess. The water should be between 2 and 8 per cent.

Additives: Additives are those materials which are added to the moulding sand to improve upon some of its existing properties or to impart certain new properties to it. The commonly used additives are:

1. Coal Dust. Its main purpose is to react chemically with the oxygen present in the sand pores and, thus, produce a reducing atmosphere at mould-metal interface and prevent oxidation of the metal.

2. Sea Coal. It is a finely ground soft coal. It restricts the mould wall movement and improves surface finish. It reduces permeability and hot strength of the mould and requires a higher percentage of water in the sand. Its proportion varies from 2 to 8 percent.

3. Cereals or Cornflour. Improves strength, toughness and collapsibility of the sand and decreases permeability and flowability. Its proportion in the sand varies from 0.25 to 2.0 percent.

4. Silica Floor. It increases hot strength, decreases metal penetration into the mould, reduces expansion defects and improves surface finish.

5. Wood Flour. It promotes mould wall movement, reduces expansion defects, increases collapsibility, improves surface finish and thermal stability of mould.

6. Pitch. It improves hot strength and surface finish on ferrous castings

Moulding sands may be classified generally into three different types:

- Natural

- moulding sands
- Synthetic or high silica sand
- Special sands

Natural moulding sands, called green sands, are taken from river beds or are dug from pits. They possess sufficient amount of clay which acts as a bond between the sand grains and are used as received with water added. Due to their ease of availability, low cost, and high flexibility of operation natural moulding sands are used for most of the ferrous and nonferrous light castings.

Synthetic sands (sharp sands) are basically high silica sands containing little (less than 2 per cent) or no binder (clay) in natural form. The desired strength and bonding properties of these sands are developed by separate additions such as bentonite, water and other materials. Synthetic sands are more expensive than natural sands.

Special sands are ideal in getting special characteristics, which are not ordinarily obtained in other sands. Zircon, olivine, chamotte, chromite, and chrome-magnesite are often used as special sands. Zircon sands are suitable for cores of brass and bronze castings. Some foundries use olivine sand for nonferrous castings of an intricate nature. Chamotte is valuable for heavy steel castings.

Moulding sands may again be classified, according to their use, into a number of varieties. These are described below.

1. **Green sand.** It is a mixture of silica sand with 18 to 30% clay, having a total water of from 6 to 8%. The clay and water furnish the bond for green sand. It is fine, soft, light, and porous. Being damp, when squeezed in the hand, it retains the shape and the impression given to it under pressure. Moulds prepared in this sand are known as green sand moulds.
2. **Dry sand.** Green sand that has been dried or baked (in oven or furnace) after the mould is made is called dry sand. They are suitable for larger castings. Moulds prepared in this sand are known as dry sand moulds.
3. **Loam sand**. Loam sand is high in clay, as much as 50% or so, and dries hard. This is particularly employed for loam moulding usually for large castings. .
4. **Facing sand.** Facing sand forms the face of the mould. It is used directly next to the surface of the pattern and it comes into contact with the molten metal when the mould is poured. Consequently, it is subjected to the severest conditions and must possess, therefore, high strength and refractoriness. It is made of silica sand and clay, without the addition of used sand.

The layer of facing sand in a mould usually ranges from 20 to 30 mm. From 10 to 15 per cent of the whole amount of moulding sand used in the foundry is facing sand.

5. **Backing sand.** Backing sand or floor sand is used to back up the facing sand and to-fill the whole volume of the flask. Old, repeatedly used moulding sand is mainly employed for this purpose.

The backing sand is sometimes called black sand because of the fact that old, repeatedly used moulding sand is black in colour due to the addition of coal dust and burning on coming in contact with molten metal.

6. **System sand.** In mechanical foundries where machine moulding is employed a so-called system sand is used to fill the whole flask. In mechanical sand preparation and handling units, no facing sand is used. The used-sand is cleaned and reactivated by the addition of water binders and special additives. This is known as system sand.
7. **Parting sand.** Parting sand is used to keep the green sand from sticking to the pattern and also to allow the sand on the parting surface of the cope and drag to separate without clinging.
8. **Core sand.** Sand used for making cores is ‘called core sand, sometimes called oil sand, This is silica sand mixed with core oil which is composed of linseed oil, resin, light mineral oil and other binding Materials.

CHARACTERISTICS OF FOUNDRY SANDS

1. **Refractoriness.**
    - It is that property of the moulding sand which enables it to withstand high temperature of the molten metal without fusing, thus facilitating a clean casting.
    - The extent to which this property is needed depends upon the metal which is to be cast. For example, steel is poured at a higher temperature than cast iron. Similarly, cast iron is poured at a higher temperature than brass. Therefore, the mould for steel casting should have higher degree of refractoriness than that used for iron castings and the latter should have more refractoriness than the one used for brass casting.
    - If sand lacks in this property it will fuse on coming in contact with the molten metal, form slag on the surface of the casting and will, thus, spoil the casting.
2. **Permeability.**
    - It is also termed as **Porosity**. It is that property of the sand which allows the gases and steam to escape through the Sand mould.
    - When the hot molten metal is poured in the mould a very large volume of gases and steam is formed due to heating of moisture, coal dust, oil and similar other materials present in the sand. If these gases are not allowed to go out they will either make the casting unsound or blast the mould.
    - Therefore, this is a very important property required in the moulding sand. It largely depends upon the sand grain size and shape and the proportion of moisture and clay present in the sand.

- Rounded grains of uniform size lead to a higher permeability.
- This property is also affected by ramming of sand. A soft ramming will increase the permeability and hard ramming will reduce it. In practice, it is further increased by applying vent wires in the prepared mould.

3. **Flowability or Plasticity.**
   - It is that property of the sand due to which it flows during ramming to all portions of the moulding flask, packs properly around the pattern to acquire the desired shape and distributes the ramming pressure evenly to all parts of the mould.
   - It increases with the addition of clay and water content and reduction of grain size.

4. **Adhesiveness.**
   - It is that property of the sand due to which it is capable of adhering to the surfaces of other materials.
   - It is entirely due to this property that the heavy sand mass is successfully held in a moulding flask without any danger of its falling down.
5. **Cohesiveness.**
   - It is that property of the sand due to which its rammed particles bind together firmly so that the pattern is withdrawn from the mould without damaging the mould surfaces and edges.
   - Also, due to this property the mould faces get sufficient strength to withstand the pressure of the flowing molten metal and do not get washed under this pressure. This property of the sand in green state is known as Green Bond or **Green Strength**.
   - When the molten metal is poured into the mould or the mould is baked in an oven, it gets dried due to the evaporation of the moisture: The cohesiveness in sand grains is still required to give sufficient strength to the mould faces to retain their shapes and resist the flow of molten metal into the sand mass. This property in dry state of the sand mould is known as Dry Bond or **Dry Strength**.
6. **Collapsibility.**
   It is the property due to which the sand mould automatically collapses after solidification of the casting to allow a free contraction of the metal.
7. **Other Requirements.** In addition to the above main characteristics, the moulding sand should also possess the following properties :

a) It should be cheap and easily available.
b) Its coefficient of expansion should be sufficiently low.
c) It should be reusable to effect economy.
d) It should not react chemically with the molten metal. It should not stick to the surface of the casting.

CORES

- A Core can be defined as a body of sand, generally prepared separately in a core box, which is used to form a cavity of desired shape and size in a casting.
- However, there are some exceptions to this definition. For example, a pattern can be used to form a core as a part of the mould, this being known as a **Green Sand Core**. Similarly, in permanent moulds or dies the cores are formed by the metallic moulds themselves as an integral part of theirs.
- Cores which are prepared separately in core boxes are called **Dry Sand Cores** and are held and located in the moulds by the **Core prints** provided on the patterns.

The main characteristics required in a good core are the following:

1. It must be sufficiently permeable to allow an easy escape of the gases formed.
2. It should be highly refractory to withstand the intense heat of molten metal.
3. It should be hard and strong enough to bear its own weight and the force of molten metal.
4. It should have high collapsibility i.e., it should be able to disintegrate quickly after the solidification of the metal is complete.
5. It should not carry such constituents which will give rise to excessive gases on coming in contact with the molten metal.

TYPES OF CORES

The cores used in foundries are typed according to their shape and their position in the mould. The common types of cores are described below.

Horizontal cores: The most common type is the horizontal core. The core is usually cylindrical in form and is laid horizontally at the parting line of the mould. The ends of the core rest in the seats provided by the core prints on the pattern.

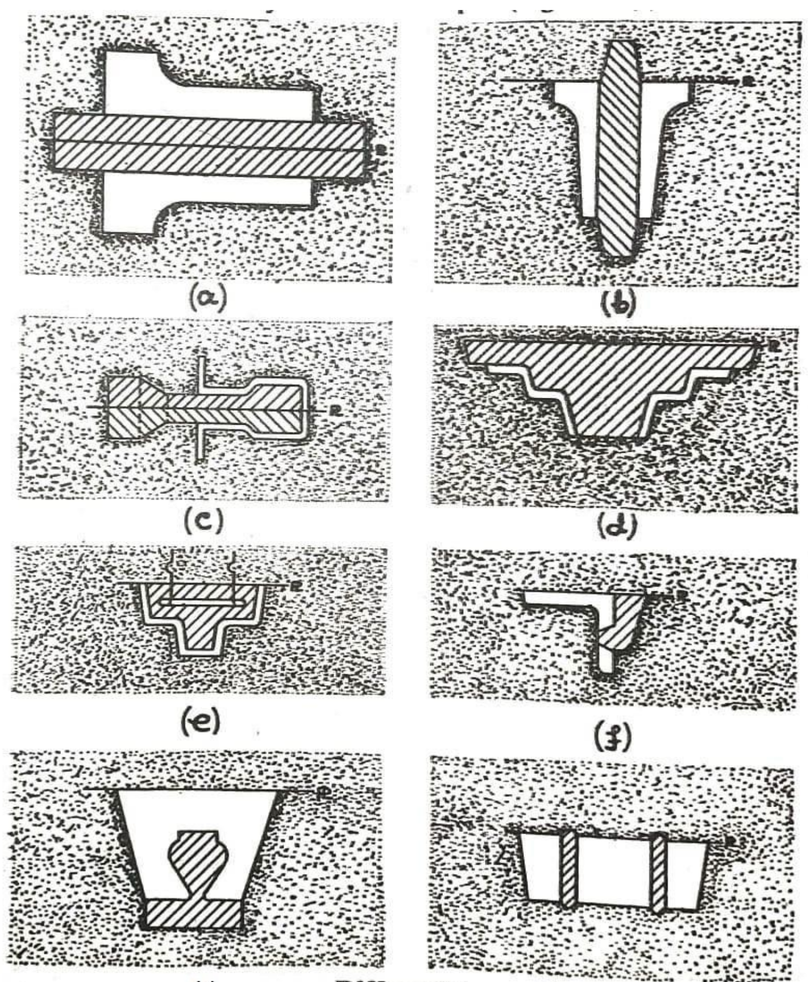
Vertical core: This is placed in a vertical position both in cope and drag halves of the mould. Usually top and bottom of the core are provided with a taper, but the amount of taper on the top is greater than that at the bottom.

Balanced core: When the casting is to have an opening only one side and only one core print is available on the pattern a balanced core is suitable. The core print in such cases should be large enough to give proper bearing to the core. In case the core is sufficiently long, it may be supported at the free end by means of a chaplet.

Hanging and cover core: If the core hangs from the cope and does not have any support at the bottom of the drag, it is referred to as a hanging core. In this case, it may be necessary to fasten the core with a wire or rod that may extend through the cope. On the other hand, if it has its support on the drag it is called cover core.

Wing core: A wing core is used when a hole or recess is to be obtained in the casting either above or below the parting line. This core is sometimes designated by other names such as drop core, tail core, chair core, and saddle core, according to its shape and position in the mould.

Kiss core: When the pattern is not provided with a core print and consequently no seat is available for the core, the core is held in position between the cope and drag simply by the pressure of the cope. This core is referred to as a kiss core. Kiss cores can be simultaneously positioned in order to obtain a number of holes in casting.



(g) **Different types of cores** (h)

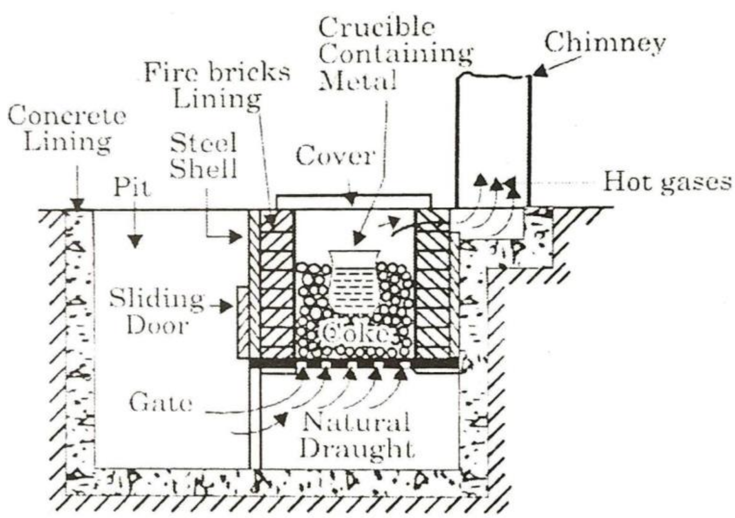
a. Horizontal core, b. Vertical core, c. Balanced core, d. Cover core, e. Hanging core, f. Wing core, g. Ram-up core, h. Kiss core

TYPES OF FURNACES

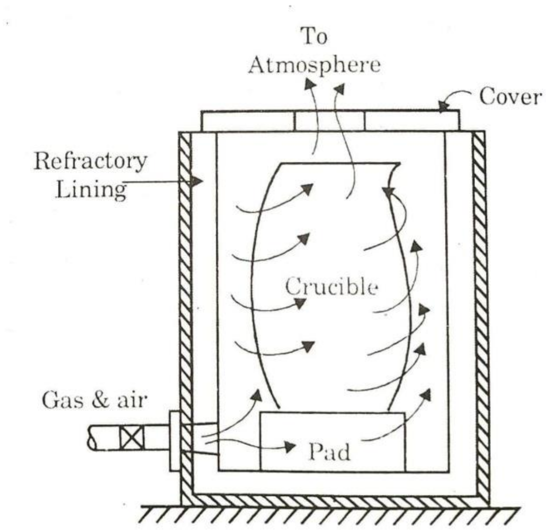
The main Types of Furnaces used in foundries for melting of various varieties of ferrous and non-ferrous metals and alloys are described below:

1. **CRUCIBLE FURNACES.** These are the simplest of all the furnaces used in foundries. They are sparingly used in most of the small foundries where melting is not continuous and a large variety of metals is to be melted in small quantities. In these furnaces the entire melting of metal takes place inside a melting pot, called Crucible, which is made of clay and graphite. The sizes of these crucibles vary from No. 1 to No. 400, each number representing a definite quantity of metal that can be held conveniently by the crucible. This type of furnace is normally used for non ferrous materials. These furnaces can be classified into two groups as follows:

   (a) Coke-fired Furnaces. These furnaces are generally installed in a formed Pit and are used for melting small quantities of ferrous metals (pig iron) for producing iron castings and also for non-ferrous metals and alloys. They are provided with Refractory Lining inside and Chimney at the top. Coke is used as fuel. Both natural as well as artificial draughts can be used. Broken pieces of metal are placed in the crucible. Bed coke is fired in the furnace and the crucible placed into it. Afterwards more coke is placed all round the crucible. A usual design of a Pit Type Crucible Furnace is shown in Fig.



   (b) Oil and Gas Fired Furnaces. These furnaces utilize oil or gas as a fuel. In fact a mixture of gas and air or oil is fed into the furnace which burns inside to produce the desired temperature. The mixture usually enters tangentially and encircles the crucible while burning. The furnaces essentially consist of a cylindrical steel shell, provided with refractory lining inside and proper passage for entry of the fuel mixture. The crucible is seated on a pad formed at the bottom. A Cover is produced at the top to prevent heat losses. These furnaces may be of Stationary Type or Tilting Type. The latter type is more preferred. A good design of a Stationary type Gas fired furnace is shown in Fig.



2. CUPOLA FURNACE (for ferrous metals)

The primary objective in cupola is to produce iron of desired composition, temperature and properties at the required rate in the most economical manner. Besides, this furnace has many distinct advantages over the other types, e.g., simplicity of operation, continuity of production, and increased output coupled with a high degree of efficiency.

Parts of Cupola Furnace:-

Cylindrical Shell:
It is the outermost part of the Cupola Furnace. It is made up of steel sheet and other parts of this furnace are present inside this shell.

1. Legs:
At the bottom of the Cupola Furnace legs are provided to support this furnace.

2. Cast Iron Door:
This cast iron is present at the bottom of the furnace above the legs which is closed by the support of the legs.

3. Sand Bed:
Above the cast iron door sand bed is present. It is in tapered form so that the melted iron can flow out easily from its top.

4. Slag Hole:
It is present at the opposite side of the hole from which melted iron comes out. It is present near the elevated part of sand bed. This slag hole is used to remove slag formed on melted iron due to impurities.

5. Air Pipes and Tuyers:
The air pipe is provided to allow the air to reach inside the furnace. Inside the furnace wind belt is present. The air entering from the air pipes reaches each part of the wind belt and in the wind belt there are holes which are called tuyers. Air reaches the furnace through this tuyers and will

help in combustion.

6. Spark Arrester Or Cap Of Furnace:
It is present at the top of the furnace. When gases are released out of the furnace, some burning particles are present in it which can harm the environment. So this cap or spark arrester is used to capture the burning particles and only allow the gas to pass to the environment.

7. Charging Door:
It is present near the top of the furnace. It is used to supply charge to the furnace. The charges in this furnace are Pig Iron, Coke and Lime Stone. Coke is used for combustion, pig iron is the material that is to be melt and lime stone is used as a flux. This flux mix with impurities to form slag and this slag comes out of the slag hole.

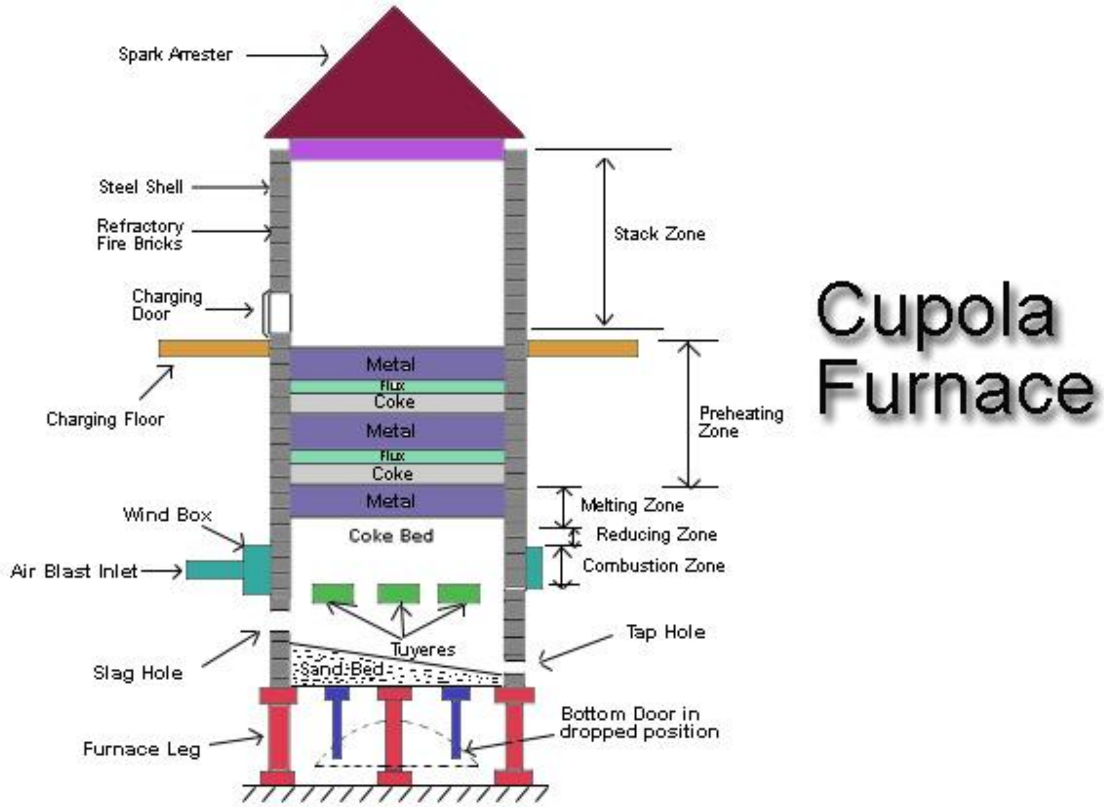
8. Well:
The part of the furnace from the send bed to lower part of tuyers is known as Well. It is named as well as in this part molten iron is stored and then the molten iron comes out of the tapping hole.

9. Tuyers Zone:
The part of the furnace in which the wind belt and tuyers are present is known as Tuyers Zone.

10. Combustion Zone:
In this zone combustion takes place. The air coming from the tuyers contains oxygen and this oxygen reacts with carbon to form carbon dioxide. It is also known as oxidixing zone as carbon oxidizes in this zone to form carbon dioxide and liberate heat. Apart from carbon other impurities like manganese,silicon also oxidizes in this zone to form their oxides and liberate heat.

11. Reducing Zone:
It is present above the combustion or oixdizing zone. It this zone carbon reacts with carbon dioxide to form carbon monoxide. In this zone temperature is reduced by a small amount, so this zone is known as reducing zone.

12. Melting Zone:
In this zone iron melts and this molten iron comes out of the tap hole. The temperature of this zone is very high nearly 1600 degree Celcius.



Zones in a cupola: On the basis of combustion reactions, the entire shaft of the cupola may be divided as under:

1. **Crucible zone** is between top of the sand bed and bottom of the tuyeres. The molten iron is accumulated here. This is also called the well or hearth.

2. **Combustion or oxidizing** zone is situated normally 150 to 300 mm above the top of the tuyeres. All the oxygen in the air blast is consumed here owing to the actual combustion taking place in this zone. Thus a lot of heat is liberated and this is supplied from here to other zones. Heat is also evolved due to the oxidation of silicon and manganese. Due to this high heat, the temperature being 1550° to 1850°C, molten drops of cast iron pour into the hearth (crucible zone). The chemical reactions which occur in this zone are :

$$C + O_2 \rightarrow CO_2 + \text{Heat}$$
$$Si + O_2 \rightarrow SiO_2 + \text{Heat}$$
$$2\,Mn + O_2 \rightarrow 2\,MnO_2 + \text{Heat}$$

3. **Reducing zone** extends from the top of the combustion zone to the top of the coke bed. In this zone, the reduction of CO_2 to CO occurs and the temperature drops to about 1200°C at the coke bed. Due to the reducing atmosphere, the charge is protected from any oxidizing influence. The reaction taking place in this zone is :

$$CO_2 + C(coke) = 2CO - Heat$$

4. **Melting zone** starts from the first layer of metal charge above the coke bed and extend up to a height of 900 mm. Highest temperature is developed in this zone for complete combustion of the coke and iron is thus melted here. The temperature in this zone is around 1600°C. A considerable carbon pick-up by the molten metal also occurs in this zone according to the following reaction:

$$3Fe + 2CO = Fe_3C + CO_2$$

5. **Preheating zone** or charging zone starts from above the melting zone and extends up to the bottom of the charging door. Preheating zone contains cupola charge as alternate layers of coke, flux and metal and they are preheated there at a temperature of about 1100°C before coming to the melting zone.
6. **Stack zone** extends from above the preheating zone to the top of the cupola. It carries the gases generated within the furnace to the atmosphere.

CUPOLA EFFICIENCY

The thermal efficiency of the cupola is given by the ratio of heat actually utilised in melting and superheating the metal to the heat evolved in it through various means. This ratio can be expressed mathematically as follows:

$$\eta_{\text{percent cupola}} = \frac{\text{Heat utilised in melting and superheating the metal} \times 100}{\text{Cal. value of coke + Heat evolved due to oxidation of iron, Si and Mn}}$$

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In case of a **Hot Blast Cupola** the above expression will change as follows :

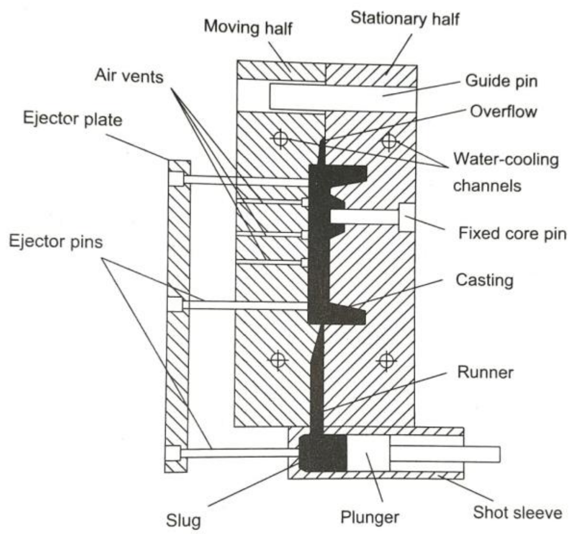
$$\eta_{\text{percent cupola}} = \frac{\text{Heat utilised in melting and superheating the metal} \times 100}{\text{Cal. value of coke + Heat evolved due to oxidation of iron, Si and Mn + Heat supplied by the air blast}}$$

Experiments reveal that the thermal efficiencies of different cupolas normally range between 30 to 50 per cent.

DIE CASTING

Die casting involves the preparation of components by injecting molten metal at high pressure into a metallic die. Die casting is closely related to permanent mould casting, in that both the processes use reusable metallic dies. In die casting, as the metal is forced in under pressure compared to permanent moulding, it is also called pressure die casting. Because of the high pressure involved in die casting, any narrow sections, complex shapes and fine surface details can easily be produced.

In die casting, the die consists of two parts. One is the stationary half or cover die which is fixed to the die-casting machine. The second part is the moving half or ejector die which is moved out for the extraction of the casting. The casting cycle starts when the two parts of the die are apart. The lubricant is sprayed the die cavity manually or by the auto lubrication system so that the casting will not stick to the die. The two die halves are closed and clamped. The required amount of metal is injected into the die. After the casting is solidified under pressure, the die is opened and the casting is ejected. The die-casting die needs to have the provision of ejectors to push the casting after it gets solidified as shown in Fig. It will also have cooling channels to extract the heat of the molten metal to maintain proper die temperature.



Cross section of a die-casting die used for cold-chamber die casting

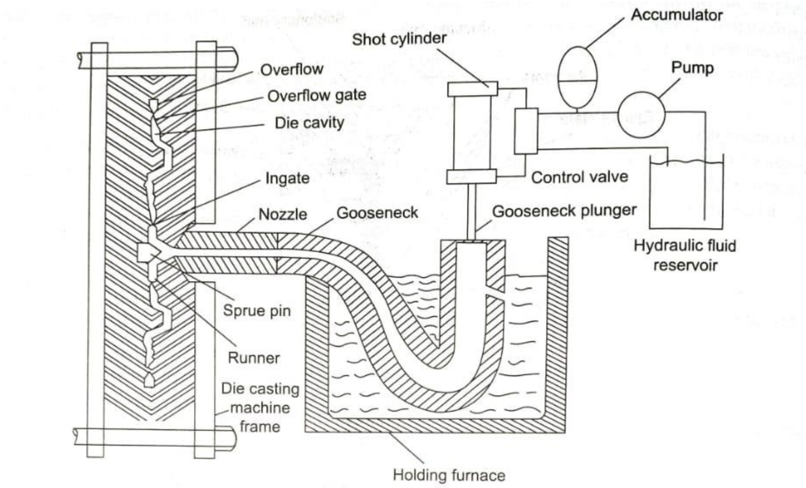
The die casting machines are of two types:

A. **Hot-chamber die casting, and** B. **Cold-chamber die casting**.

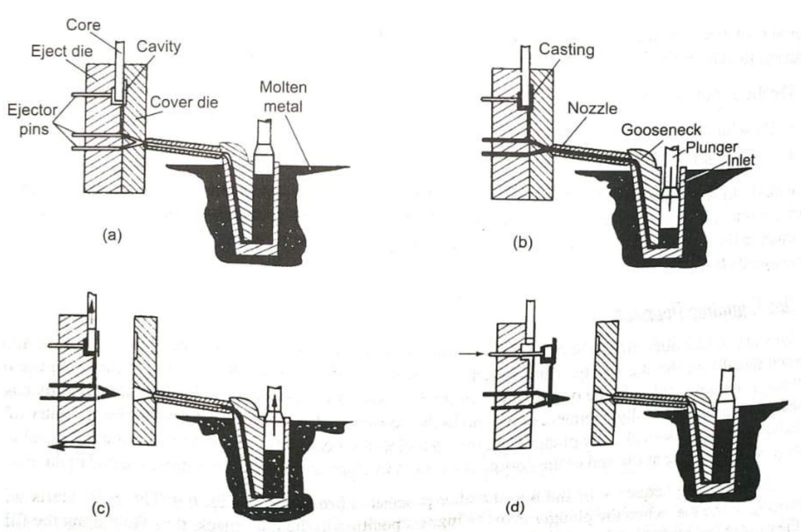
The main difference between these two types is that in the hot chamber die casting, the holding furnace for the liquid metal is integral with the die-casting machine, whereas in the cold-chamber die casting, the metal is melted in a separate furnace and then poured into the die-casting machine with a ladle for each casting cycle which is also called shot.

A. Hot-Chamber Process

A typical hot-chamber die-casting machine is shown in Fig. In this, a gooseneck is used for pumping the liquid metal into the die cavity. The gooseneck is submerged in the holding furnace containing the molten metal. The gooseneck is made of grey alloy or ductile iron, or of cast steel. A plunger made of alloy cast iron, and which is hydraulically operated, moves up in the gooseneck to uncover the entry port for the entry of liquid metal into the gooseneck. The plunger can then develop the necessary pressure for forcing the metal into the die cavity. A nozzle at the end of the gooseneck is kept in close contact with the sprue located in the cover die.



.8 *Schematic of a hot chamber die-casting machine*

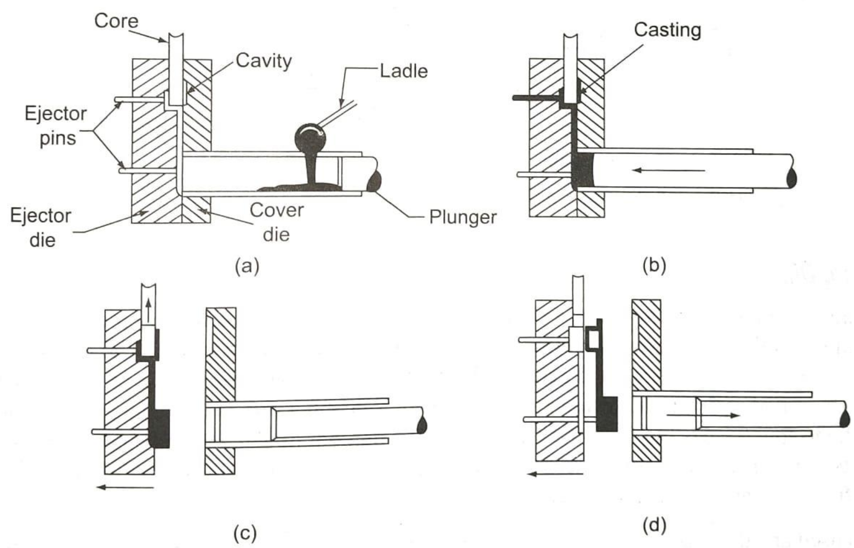


9 *Operation sequence of hot-chamber process*

The operating sequence of the hot-chamber process is presented in Fig. The cycle starts with the Closing of the die, when the plunger is in the highest position in the gooseneck, thus facilitating the filling of the gooseneck by the liquid metal. The plunger then starts moving down to force the metal in the gooseneck to be injected into the die cavity. The metal is then held at the same pressure till it is solidified. The die is opened, and any cores, if present, are also retracted. The plunger then moves back returning the unused liquid metal to the gooseneck. The casting which is in the ejector die is now ejected and at the same time the plunger uncovers the filling hole, letting the liquid metal from the furnace to enter the gooseneck.

B. Cold-Chamber Process

The hot-chamber process is used for most of the low-melting-temperature alloys such as zinc, lead and tin. For materials such as aluminium and brass, their high melting temperatures make it difficult to cast them by the hot-chamber process, because the gooseneck of the hot-chamber machine is continuously in contact with the molten metal. Also, liquid aluminium would attack the gooseneck material and thus hot-chamber process is not used with aluminium alloys. In the cold-chamber process, the molten metal is poured with a ladle into the shot chamber for every shot. This process reduces the contact time between the liquid metal and the shot chamber.



Operation sequence of cold-chamber process

The operation sequence shown in Fig is similar to hot-chamber process. The operation starts with the spraying of die lubricants throughout the die cavity and closing of the die when molten metal is ladled into the shot chamber of the machine either manually by a hand ladle or by means of an autoladle. Then the plunger forces the metal into the die cavity and maintains the pressure till it solidifies. In the next step, the die opens. The casting is ejected. At the same time, the plunger returns to its original position completing the operation.

The main disadvantage of cold chamber die casting is longer cycle time. Also since the metal is ladled into the machine from the furnace, it may lose the superheat and sometimes may cause defects.

Advantages

1. Very small thicknesses can be easily filled because the liquid metal is injected at high pressure.
2. Very high production rates can be achieved. Typical rate could be 200 pieces per hour since the process is completely automated.
3. Because of the metallic dies, very good surface finish can be obtained. The surfaces generated by die casting can be directly electroplated without any further processing.
4. Closer dimensional tolerances for small dimensions can be obtained compared to the sand castings.
5. The die has a long life, which is of the order of 300 000 pieces for zinc alloys and 150 000 for aluminium alloys.
6. Die casting gives better mechanical properties compared to sandcasting, because of the fine-grained skin formed during solidification.
7. Inserts can be readily cast in place.
8. It is very economical for large-scale production

Limitations

1. The maximum size of the casting is limited. The normal sizes are less than 4 kg with a maximum of the order of 15 kg because of the limitation on the machine capacity.
2. This is not suitable for all materials because of the limitations on the die materials. Normally, zinc, aluminium, magnesium and copper alloys are die cast.
3. The air in the die cavity gets trapped inside the casting and is, therefore, a problem often with the die Castings.
4. The dies and the machines are very expensive and therefore, economy in production is possible only when large quantities are produced.

Applications

The typical products made by die casting are carburetors, crank cases, magnetos, handle-bar housings, and other parts of scooters, motor cycles and mopeds, zip fasteners, head-lamp bezels and other decorative items on automobiles.

CENTRIFUGAL CASTINGS

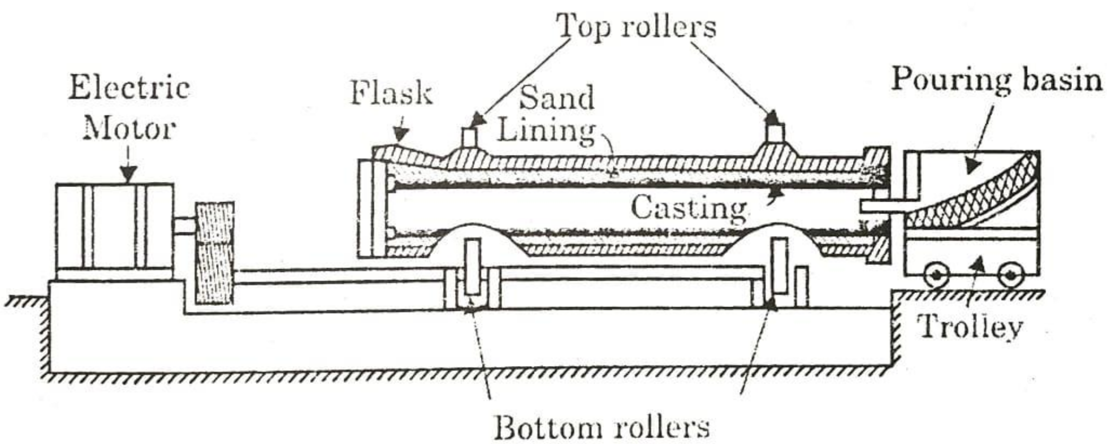
The process of Centrifugal Casting is also known as Liquid Forging. It consists of rotating the mould at a high speed as the molten metal is poured into it. Due to the Centrifugal Force the molten metal is directed outwards from the centre, towards the inside surface of the mould, with considerable pressure. As a result of this, a uniform thickness of metal is deposited all along the inside surface of the mould, where it solidifies, and the impurities being lighter remain nearer to the axis of rotation.

Although many different shapes can be cast through this process, those with symmetrical shapes are best suited for it. The Centrifugal Casting Methods can be classified as follows:

1. **True centrifugal casting 2. Semi-centrifugal casting 3. Centrifuging.**

TRUE CENTRIFUGAL CASTING

The main features of a True Centrifugal Casting are that the axis of rotation of the mould and that of the casting are the same. Also, the central hole through the casting is produced by the Centrifugal force without the use of a central core. The axis of rotation of the mould may be horizontal, vertical or inclined at any suitable angle between 70° and 90°. End Cores are usually employed at the two ends of the mould to prevent the molten metal from being thrown out at the ends. A few examples involving the application of this method are the hollow cast iron pipes, gun barrels, bushings, etc.

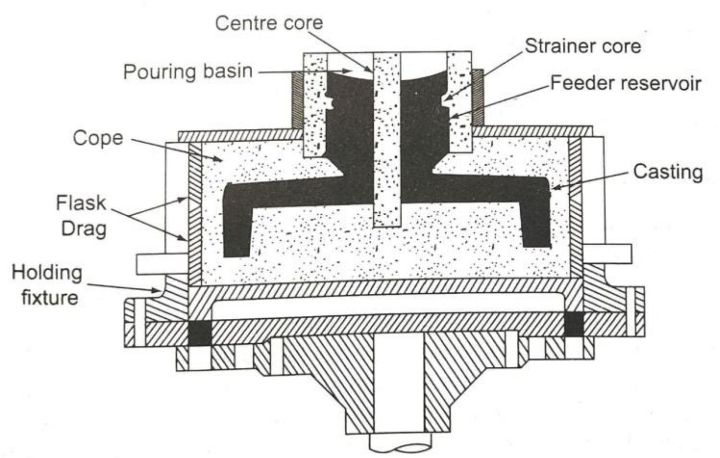


A typical horizontal True Centrifugal Casting Machine is illustrated in Fig. It is shown having a large cylindrical mould for casting cast iron pipes. Similar equipment can be used for casting other cylindrical items. The mould consists of an outer metallic flask provided with rammed sand lining inside. The mould is rotated between two sets of rollers as shown. The bottom rollers are mounted on a shaft driven by a Variable speed Motor mounted at one end. Pouring in the mould is done through a Pouring Basin formed on the body of a Trolley. Initially, during pouring, the mould is rotated at a slow speed. After the pouring is over, the mould is rotated at a very fast speed to effect even distribution of the metal all along the inside surface of the mould and proper directional solidification. After solidification, the flask is replaced by a new one and the process repeated. Wall thickness of the casting is controlled by the volume of molten metal poured into the mould. Pouring temperatures range between 1482° to 1649°C.

Vertical and inclined axes of rotation for moulds are adopted for short length castings.

SEMICENTRIFUGAL CASTING

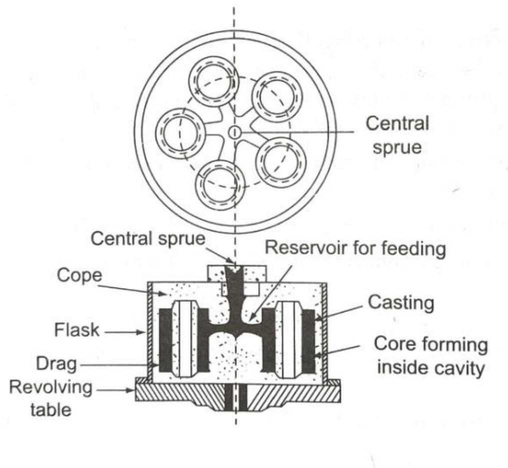
This process is widely used for relatively large castings which are symmetrical in shape, such as discs, pulleys, wheels, gears, etc. In this method the mould is rotated about a vertical axis and the metal poured through a central sprue. It is not necessary to cast only one mould at a time. Several moulds can be stacked together, one over the other, and fed simultaneously through a common central sprue, as shown in Fig. This provision increases the rate of production considerably. The centrifugal force is used to feed the metal outwards to fill the mould cavities completely. The centre of the castings is usually solid, but, if required, a dry sand central core may be used to produce the central hole.



The speed of rotation of these moulds is much lower than that in True Centrifugal Casting. With the result, the pressure developed is too low and the impurities are not directed towards the centre as effectively as in True Centrifugal Casting. The moulds used may be of green sand, dry sand, metal or any other suitable material.

CENTRIFUGING

The axis of rotation casting and that of the moulds do not coincide with each other, as the moulds are situated at a certain distance from the central vertical axis of rotation all around the same. Shapes of castings do not carry any limitations in this method and a variety of shapes can be cast. A number of small mould cavities are made around a common central sprue and connected to the same through radial gates. For a higher rate of production the stacked moulds can be used with advantage. As in Semi Centrifugal Method, in this method also the mould assembly is rotated about a vertical axis and centrifugal force used to force the molten metal from the central spruce into the mould cavities through the radial gates.



Advantages

1. The mechanical properties of centrifugally cast jobs are better compared to other processes, because the inclusions such as slag and oxides get segregated towards the centre and can be easily removed by machining. Also, the pressure acting on the metal throughout the solidification causes the porosity to be eliminated giving rise to dense metal.

2. Up to a certain thickness of objects, proper directional solidification can be obtained starting from the mould surface to the centre.

3. No cores are required for making concentric holes in the case of true centrifugal casting.
4. There is no need for gates and runners, which increases the casting yield, reaching almost 100%.

Limitations

I. Only certain shapes which are axi-symmetric and having concentric holes are suitable for true centrifugal casting.

2. The equipment is expensive and thus is suitable only for large quantity production.

DEFECTS IN CASTINGS

Sand casting, particularly, are subject to certain defects which in a well designed casting, are controllable by proper foundry technique, but are not wholly preventable. However, the common types of defects found in castings, their causes and remedies are explained hereunder.

1. Shifts. This is an external defect in a casting caused due to core misplacement or mismatching of top and bottom parts of the casting usually at a parting line. Mis-

alignment of flasks is another likely cause of shift. The defect can be prevented by ensuring proper alignment of the pattern or die part, moulding boxes, correct mounting of patterns on pattern plates, and checking of flasks, locating pins, etc. before use.

2. Warpage. Warpage is unintentional and undesirable deformation in a casting that occurs during or after solidification. Due to different rates of solidification different sections of a casting, stresses are set up in adjoining walls resulting in warpage in these areas. Large and flat sections or intersecting sections such as ribs are particularly prone to warpage.

The remedy is to produce large areas with wavy, corrugated construction, or add sufficient ribs or rib-like shapes, to provide equal cooling rates in all areas. A proper casting design can go a long way in reducing the warpage of the casting.

3. Fin. A thin projection of metal, not intended as a part of the casting, is called the fin. Fins usually occur at the parting of the mould or core sections. Moulds and cores incorrectly assembled will cause fins. Insufficient weighting of the moulds, or improper clamping of flasks may again produce the fin.

   The remedy lies on the use of sufficient weight on top part of the mould so that the two parts fit tightly together, and correct assembly of the moulds and cores used for the casting.
4. Swell. A swell is an enlargement of the mould cavity by metal pressure, resulting in localised or overall enlargement of the casting. This is caused by improper or defective ramming of the mould. To avoid swells, the sand should be rammed properly and evenly.
5. Blowholes. Blow holes are smooth, round holes appearing in the form of a cluster of a large number of small holes below the surface of a casting. These are entrapped bubbles of gases with smooth walls. Blow holes are caused by excessive moisture in the sand, or when permeability of sand is low, sand grains are too fine, sand is rammed too hard, or when venting is insufficient.

   To prevent blowholes, the moisture content in sand must be well adjusted, sand of proper grain size should be used, ramming should not be too hard, and venting should be adequate.
6. Drop. A drop occurs when the upper surface of the mould cracks, and pieces of sand fall into the molten metal. This is caused by low Strength and soft ramming of the sand, insufficient fluxing of molten metal and insufficient reinforcement of sand projections in the cope. The above factors are eliminated to avoid drop.
7. Dirt. In some cases, particles of dirt and sand are embedded in the casting surface. This is caused by crushing of the mould due to improper handling, sand wash and presence of slag particles in the molten metal. Dirt may be prevented from entering the mould cavity by proper fluxing and the use of dirt traps.
8. Honeycombing or sponginess. This is an external defect consisting of a number of small cavities in close proximity. Honey-combing is caused by dirt or “scurf” held

mechanically in suspension in the molten metal, and is due to imperfect skimming in the ladle. The remedy is to prevent the sand wash and to remove the slag particles present in the molten metal by the proper skimming in the ladle.

9. Metal penetration and rough surface. This defect appears as an uneven and rough external surface of the casting. The metal penetration between the sand grains occurs due to low strength, large grain size, high permeability and soft ramming of sand. Remedies involve removing the causes mentioned above.
10. Sand holes. Sand holes are found on external surface or inside the casting. They are caused by loose sand washing into the mould cavity and fusing into the interior of the casting or rapid pouring of the molten metal. Sand holes are prevented by proper cleaning of the mould and careful pouring of the molten metal.
11. Pin holes. Pinholes are numerous small holes, usually less than 2 mm, visible on the surface of the casting cleaned by shot blasting. They are caused by sand with high moisture content, absorption of hydrogen or carbon monoxide gas or when steel is poured from wet ladles or is not sufficiently gasified. The defect can be minimised by using good melting and fluxing practices, by reducing the moisture content of moulding sand and increasing its permeability, and by promoting .a rapid rate of solidification.
12. Scabs. Scabs are a sort of projection on the casting that occur when a portion of the face of the mould or core lifts and metal flows underneath in a thin layer. In other words, liquid metal penetrates behind the surface layer of sand. Scabs can be identified as rough, irregular projections on the surface containing embedded sand. They are caused by using too fine sand, sand having low permeability and moisture content, and by uneven mould ramming or intermittent or Slow running of molten metal over the sand surface thereby producing intense local heating. Mixing additives such as wood flour, ‘sea coal, or dextrine, into the Sand is one step which will eliminate the defect.
13. Shrinkage cavity. Shrinkage cavity is a void or depression in the casting caused mainly by uncontrolled and haphazard solidification of | the metal. This may also be produced the pouring temperature is too high. The defect can be eliminated by applying the principle of directional solidification in mould design and by judicious use of chills, padding, etc.
14. Hot tears (Pulls). They are internal or external cracks having ragged edges occurring immediately after the metal has solidified. Hot tears may be produced if the casting is poorly designed and abrupt sectional changes take place, no proper fillets and comer radii are provided, and chills are wrongly placed, Incorrect pouring temperatures and improper placement or gates and risers and hard ramming can also create hot tears. Improved design, proper directional solidification, even rate of cooling, correct pouring temperatures, and control of mould hardness eliminate hot tears.
15. Cold shut and misrun. A cold shut is an external defect formed due to imperfect fusion of two steams of metal in the mould cavity or unequal sections of pattern assembled together. The defect may appear like a crack or seam with rounded edges. A misrun

casting is one which lacks completeness due to the failure of the metal to fill the mould cavity. The reasons for cold shut or misrun may be due to thin sections and wall thickness, improper gating system, damaged patterns, slow and intermittent pouring, poor fluidity of metal caused by low pouring temperature, improper alloy composition, etc. Use of hotter metal, frequent inspection and replacement of patterns and core boxes and proper design of the casting keeping in mind the fundamental principles of gating and risering are some of the steps that may be used to eliminate cold shut and misrun.

16. Poured short. When the metal cavity is not completely filled at one pouring, the defect is called poured short. Sufficient metal in the ladle at correct temperature will eliminate this defect.
17. Internal air pocket. This appears as small holes inside the casting and is caused by pouring boiling metal or by rapid pouring of the molten metal in the mould. Faulty and poor quality of metal and excessively moist sand may also create air pockets. Correct pouring temperature of the molten metal, right quality of metal and dry sand minims this defect to a great extent.

4.POWDER METALLURGY

Why Powder Metallurgy is Important?

- Typically used when large amounts of small, intricate parts with high precision are required.
- Little material waste and unusual mixtures can be utilized.
- PM parts can be mass produced to net shape or near net shape, eliminating or reducing the need for subsequent machining.
- PM process wastes very little material -~ 97% of starting powders are converted to product
- PM parts can be made with a specified level of porosity, to produce porous metal parts Filters, oil impregnated bearings and gears
- Certain metals that are difficult to fabricate by other methods can be shaped by powder metallurgy. Tungsten filaments for incandescent lamp bulbs are made by PM.
- Certain alloy combinations and cermets made by PM cannot be produced in other ways.
- PM compares favorably to most casting processes in dimensional control.

DEFINITION:

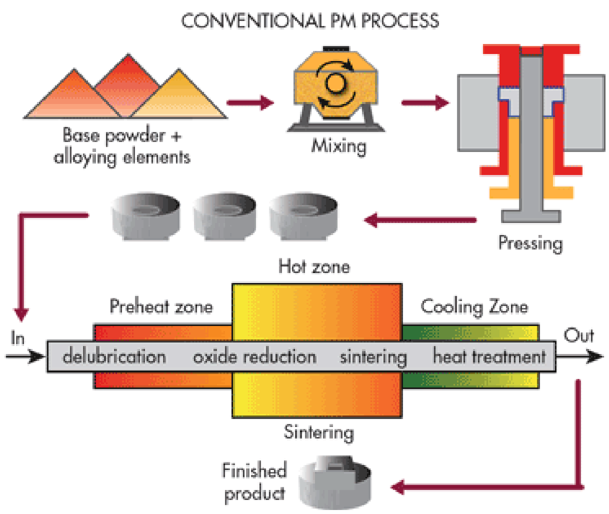
Powder metallurgy can be described as an art of manufacturing commercial articles from powder metals by placing these powders in moulds and applying pressure. These compressed parts are then heated to bind the particles together and improve their strength and other properties. This is known as sintering and the temp. during sintering is kept below the m.p of the powder.

- Powder metallurgy is the name given to the process by which fine powdered materials are blended, pressed into a desired shape, and then heated to bond surfaces.
- The products made through this process are very costly as the metals in powder form are costly and the dies used in PM are costly. So PM is economically feasible for mass production. (over 10000 units)
- Examples of PM products:- tungsten carbide cutting tools, self lubricating bearings, turbine blades.
- Components can be made from a single metal powder or alloyed metal powders. According to the need, non metallic powders may or may not be required to be added.

The Basic Processes:

1. Production of metal powders

2. Mixing or blending of metal powders in required proportions
3. Pressing and compacting the powders into desired shapes and sizes
4. Sintering the compacted parts in a controlled furnace atmosphere
5. Subjecting the sintered parts to secondary processing, if required.



1. **PRODUCTION OF METAL POWDERS**

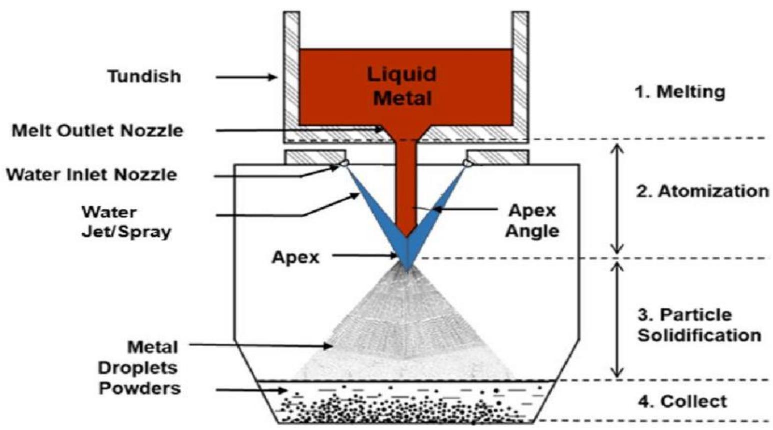
- The powders most commonly used are copper base and iron base materials.
- Also powders of these materials are used :- S.S, W, Ni, Ag, Ti, Be, Cr, B, Al-alloys and other refractory materials.

The following processes are generally used to produce these powders:-

a) Atomization(water atomization, air atomization, gas atomization, rotating electrode process, centrifugal atomization)
b) Reduction process
c) Electrolysis or electrolytic process
d) Milling and grinding or mechanical pulverization
e) Shotting
f) Machining

Atomization

- It consists of forcing the molten metal through a nozzle into a stream of air or water. As it comes in contact with the stream, the metal solidifies into small particles of various irregular shapes and sizes.
- These things control the size of these particles:- size of nozzle, rate of flow of metal, temp. and pressure of air or water stream.
- Maximum amount of metal powders is produced through water atomization process.
- In water atomization process there is a hopper like container, called TUNDISH, at the top. This tundish is fitted on the top of a larger container, which carries provision for water jets inside.
- Molten metal is poured into the tundish from a ladle at the top of it. As this metal flows down in the form of a stream through the nozzle , water streams from both side impinges on it.
- This results in instantaneous cooling of the flowing metal in the form of small metal particles, which fall down and collected at the bottom.
- Particle size is governed by – pressure of water stream. (higher press = smaller particle)



In air atomization , an air stream replaces the water jets.

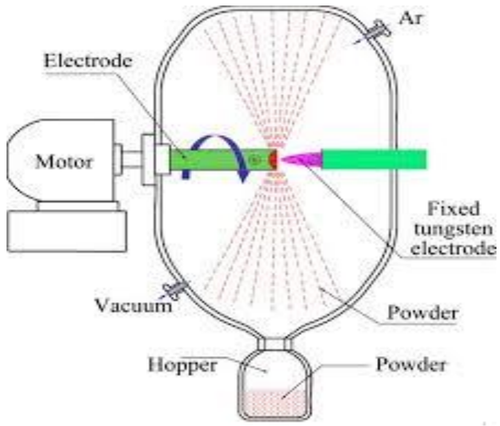
- If inert gas stream is used (to avoid oxidation of powder particles) – Gas atomization

Rotating electrode process:-

This process consists of two electrodes.

- ✓ Tungsten electrode (non consumable and non rotating)
- ✓ Formed by the metal of which the atomization has to be done(consumable, rotates at 15000 r.p.m)

An arc is struck between these two electrodes. The whole set up is enclosed in a chamber of inert gas. Due to this arc, the metal melts from the rotating electrode, which is then cooled and changed into small particles and collected at the bottom of the chamber.



Centrifugal atomization:-

Streams of molten metal strikes against the flat surface of a rotating chilled disc. This disc rotates about its vertical axis and the melt stream falls over it from the nozzle of the tundish centrally.

All the above melt atomisation processes involves an extremely high solidification rate and also known as RST(rapid solidification technology)

) Reduction process (chemical process followed by mechanical process)

- By reducing refined ores or oxides by contact with a gas at a temp. below the m.p temperature.

Ex:- hydrogen provides an appropriate gaseous atmosphere for this purpose. This hydrogen combines with oxygen of the metal oxide and the metal becomes free of oxides. Then by mechanical means , like crushing and grinding these oxide free metals may be converted to powder form.

- Iron, W, Ni, Co, and Mo powders are produced by this method.

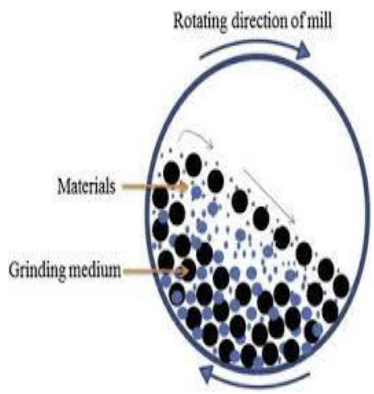
c) Electrolytic process (Electrolysis)

- The powder produced through this process are the purest, but cost is high.
- Widely used for Fe, Cu, Ta and other metals.

Milling and grinding (mechanical pulverisation)

- Breaking down the metal into small particles by crushing and impact through ball mills, stampers, crushers etc.

- Ball milling is a grinding method that grinds nanotubes into extremely fine powders. During the ball milling process, the collision between the tiny rigid balls in a concealed container will generate localized high pressure. Usually, ceramic, flint pebbles and stainless steel are used.
- The process involves pulverising the metal mechanically so that it will disintegrate into small particles.
- Brittle materials suits best for this method. Also used for ductile materials.
- Very fine powder particles can be produced



CHARACTERISTICS OF METAL POWDERS

1. Particle shape :- it may be flat, angular, spherical or any irregular shape depending upon the method used for its production. It affects compactness, porosity and strength of the part.
2. Particle size:- use of particles of similar size increases porosity of the final product. Use of all coarse grains reduces density. Use of all fine particles increases density, but needs high compacting pressure. Thus a balanced proportion of different particle sizes has to be found out.
3. Flow rate or flowability:- it is this property which enables a powder to flow readily and fill the mould cavity. It decides the time required to fill a mould and affects the rate of production.
4. Compressibility:- it is the ratio of the initial volume of the powder to the final volume after compression. It governs the green strength of the powder(strength of compressed part before sintering).
5. Purity:- presence of impurity adversely affects the compacting and sintering processes. Impurity reduces the life of dies.

6. Apparent density:- it is the specific gravity of powder. Any reduction in it will call for the use of more powder and hence it should be maintained constant. By controlling it properly one part of a component can be made harder and denser than the remaining part

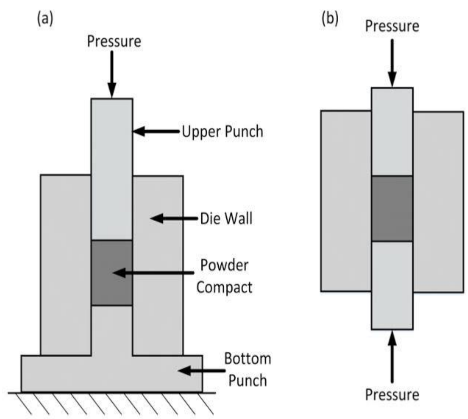
2. BLENDING OR MIXING

- If one metal powder of correct particle size distribution is being used, no blending is required. But blending becomes essential when different metal powders are used.
- The process consists of a thorough mixing of the constituents either wet or dry. Wet mixing reduces dust and minimizes the danger of explosion.
- Lubricants are added during blending to reduce friction during pressing and enable easy ejection of pressed parts. (Lubricants :- graphite, wax, polymers, stearic acid, etc)
- Blending regulates uniform distribution of particle size.
- Blending a coarse particle with a finer particle ensures that the spaces between large particles will be filled out.
- Powders of different metals and other materials may be mixed in order to impact special physical and mechanical properties of the final product.

3. COMPACTING OR BRIQUETTING

- It is the process of converting loose powder into a green compact of accurate shape and size.

- It is done with steel dies and punches. Due to inter particle friction, the pressure applied from one side is not uniformly distributed throughout the mass. Two punches are therefore used, one from the bottom and other from the top of the powder as shown in figure.
- The lower punch also works as an ejector for the compressed part. Due to low flowability of metal powders, the density variation is kept at a minimum by both side pressing.



- The dies and punches used should be highly polished.
- Clearance between punch and die should be kept minimum in order to maintain proper alignment. However the clearance should be sufficient enough to allow a free movement.
- The punch should have high toughness.
- High carbon steels, high cr-v steel and tungsten carbide are the principal die materials.
- During the process the powder is compressed to nearly one third of its original volume.
- The presses (machines) used for compacting are either mechanical or hydraulic or combination of both. Hydraulic presses are best suited where higher pressures are employed. They also produce products of uniform density, which is not possible by mechanical presses.
- The metal powders can also be compacted into a form of a sheet by passing continuous stream of powder through a pair of rolls rotating in opposite direction. It is known as roll pressing.

Pre sintering :-

- Pre sintering means heating the green compact to a temperature below the sintering temperature.

- It is done to increase strength of green compact and remove the lubricants and binders added during blending.
- Some metals like tungsten carbide are machined in pre sintered state only as they become too hard after sintering. So if machining is not required , this operation can be avoided for them.

4. SINTERING

- Sintering of compacted parts is done in large continuous furnaces having controlled atmosphere for protection against oxidation and other chemical reaction.
- The parts are kept at the correct temp. for a certain period of time, during which the particles are strongly bonded together by atomic forces.
- Strength of the parts is increased to the required extent and required hardness is imparted to them.
- The important factors governing sintering are :- temperature, time, atmosphere.

Objectives of sintering:-

a. Achieving high strength

b. Achieving good bonding of powder particles

c. Producing a dense and compact structure

d. Producing parts free of oxides

e. Causing atomic diffusion and facilitates alloying of constituent materials

f. Achieving good dimensional accuracy and improved mechanical properties in final product.

The process of sintering is carried out at substantially high temperature but below the melting point of material being sintered. The actual values of sintering temperatures for most materials range between 70-80% of their melting point temp. (for ceramics it's 90%)

In case the compacted part is being made from two or more materials, the sintering temp. may be more than the m.p of some of the constituent materials.

Sintering generally carried out in 3 stages. For this most of the furnaces used for sintering have 3 distinct areas:- burn off chamber, high temperature zone and cooling zone.

1. In the 1st chamber (burn off chamber) volatile substances, air, lubricants and binders are burnt off from the compacted part and its temp. is slowly raised.

2. In the 2nd stage (high temp zone), the temp. of the compact is raised to sintering temp. the part is held there for sufficient time to enable solid state diffusion and bonding between particles.

3. In 3rd stage (cooling zone), the sintered part is gradually cooled down in the controlled atmosphere of furnace.

- The preferred atmosphere for furnace is either neutral or reducing. A mixture of nitrogen, methane, ammonia and burnt hydrocarbons provide an ideal reducing atmosphere for this purpose.

  [As a result of atomic diffusion metallurgical bond develops amongst the powder particles, leading to an increased strength and increased electrical and thermal conductivity of the compacted material. Density also increases and porosity reduces. If the powders are of different chemical composition, alloy formation may also takes place]

5. SECONDARY PROCESS

Many of the products can be used in the as sintered state, but where close tolerances and better surface finish are desired, further processing is necessary. The operations performed for this purpose are:-

b) **Sizing** :- placing the sintered part in a die, made to correct dimension, and re pressing that sintered part to bring it to the required size.

c) **Coining** :- the purpose of re pressing the sintered part is to close the voids and provide the desired density. Re sintering often follows coining to relieve stresses.

d) **Machining** :- in most of the cases the parts produced through p.m are finished to required dimensions and tolerances and no further machining is required on them. However , some times in order to hold very close tolerances or for producing small holes, threads, undercuts, etc. which can't be produced through P.M process, machining may have to be done. (P.M products are finished to required dimensions and tolerances and no further machining is required on them)

e) **Infiltration:-** The process consists of placing a shaped piece of copper or brass on the top of pre sintered part and heating it again. The infiltration piece melts and enters the pores of the part by capillary action. This increases the strength, density and hardness of the part.

f) **Impregnation:-** The process is performed to provide self lubricating properties to sintered parts. For this , the parts are placed in a tank, carrying the lubricant, and heated to about 93 degree Celsius for about 20 mins. The lubricant enters the pores of the part through capillary action and is retained there.

g) **Heat treatment:-** All the sintered metal parts can be heat treated through the usual methods.

APPLICATIONS OF POWDER METALLURGY

1. Porous metal bearings, made from brass, iron, aluminum, bronze, etc., which are later impregnated with lubricants.
2. Machine parts are produced from powders of iron, brass and bronze.
3. Filament wire for electric bulbs is made from tungsten powder.
4. Highly heat and wear resistance cutting tools and dies are made from tungsten carbide powders and cobalt
5. Titanium carbide, boron carbide and tantalum carbide powders are used for similar cutting tools and die manufacturing materials.
6. Cu and graphite powders are used for manufacturing automobile parts
7. Iron and graphite powders are used to make pump rotor and gears
8. Electric contact points, grinding wheels, clutch facings, welding rod, laminated metals and brake linings are some of the products by p.m process.

❖ The combination of metal (strength and toughness) and ceramics(refractoriness), which are bonded by similar process as metal powder are called cermets.

ADVANTAGES OF POWDER METALLURGY

- It facilitates production of many such parts which can not be produced through other methods, such as sintered carbides and self lubricating bearings
- It also facilitates mixing of both metallic and non metallic powders to give products of special properties
- The products carry very high dimensional accuracy.
- Layers of different metal powders can be molded together to obtain multi metallic products
- The products are highly pure
- Savings in material as no material loss occurs during fabrication
- It is possible to ensure uniformity of composition, since exact proportion of constituent metal powders can be used.

- The rate of production is quite high
- The p.m process does not need highly skilled workmen
- The process enables an effective control over purity, density, porosity, particle size, etc.
- Mutually insoluble constituents in liquid state (such as copper and lead) can be mixed in powder form and can be easily processed and shaped through this process
- Hard to process materials like diamond and ceramics, can be converted into usable components and tools through this process

DISADVANTAGES OF POWDER METALLURGY:-

- The metal powders and the equipments are very costly
- There is a limitation to the size of the product as it depends on the size and capacity of the press used.
- Storing of powders is not an easy task (fire and explosion hazards)
- Design restriction, due to low flowability of metal powders, restrict the production of intricate shapes
- Sintering of low m.p metal powders(lead, zinc and tin) offers serious difficulties
- Not economical for small scale production
- Its not easy to convert brass, bronze and a number of steels into powder form.

QUESTIONS

1. **What is meant by powder metallurgy ?**
2. **What are main stages of powder metallurgy ?**
3. **What are different methods of producing metal powders ? Describe the atomization process in detail.**
4. **Explain the main characteristics of metal powders.**
5. **Explain the following process:-**

- ✓ **Blending**
- ✓ **Compacting**
- ✓ **Presintering**

6. **Describe the sintering process in detail**
7. **Explain the utility and applications of secondary processes in powder metallurgy.**
8. **Write down the various applications of powder metallurgy**
9. **Write down advantages and disadvantages of powder metallurgy process.**

5.PRESS WORK

- Presses are generally employed in mass production of identical components. Basically ,the process of press working consists of shearing out and then plastically working the metal to the desired finished shape and size through a few quick strokes under heavy loads.

- It is a metal working process, where each new dissimilar component required a new shape of tools. (differs from metal cutting)
- Tools used are costlier. So press working is suitable for mass production.
- Usually avoided where the production of items are small in numbers and particularly when they are dissimilar.
- Much faster production than metal cutting .
- Widely used in telephone industries, aircraft industries, radio industries, electrical goods manufacturing industries, etc.

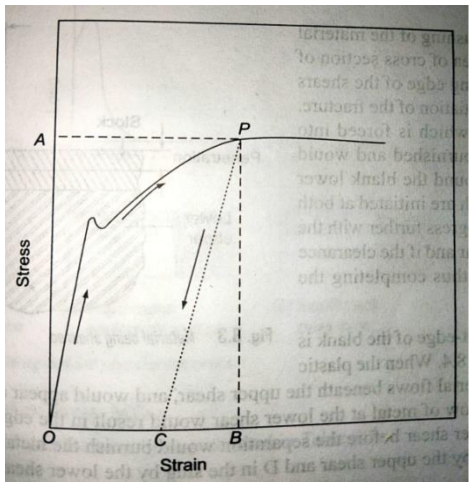
Press tools and operations

operations	Stresses induced
Shearing, blanking, piercing, trimming, shaving, notching, nibbling	**shearing**
Stretch forming	**Tension**
Coining, sizing, ironing, hobbing	**Compression**
Drawing, spinning, bending, forming, embossing	**Tension and compression**

- Many of the consumer goods enjoyed today by modern humans owe their low cost to press tools, But for the cheap way of making these sheet-metal components, we possibly could not have even thought of having automobiles, type writers, mechanical toys, etc. at such a low cost. The press-tool operation is by far one of the cheapest and fastest way of the complete manufacture of a component.
- One of the principal concerns in sheet-metal operations is the spring back of the metal. When the metal is deformed, it is first elastically deformed and then plastically. When the

applied load is removed, the plastic component of the deformation remains permanent while the elastic part springs back to its original shape.

- This can be schematically observed from Fig. where the stress-strain diagram is shown. In the stress-strain diagram, a stress OA is applied on the material so that it reaches the point P and has a strain of OB under the load. When the load is removed, the material springs back to the position C, finally with a permanent deformation of OC only. The amount CB is the amount of spring back.

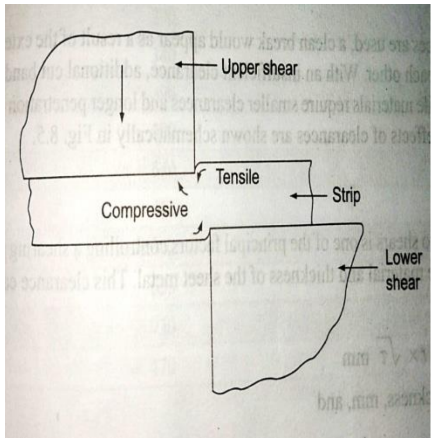


SHEARING ACTION:-

- The metal is brought to the plastic stage by pressing the sheet between two shearing blades so that fracture is initiated at the cutting points. The fractures on either side of the sheet further progressing downwards with the movement of the upper shear finally result in the separation of the slug from the parent strip.

- The metal under the upper shear is subjected to both compressive and tensile stresses as shown in Fig. In an ideal shearing operation, the upper shear pushes the metal to a depth equal to about one third of its thickness.

- Because of pushing of the material into the lower shear, the area of cross section of the metal between the cutting edge of the shears decreases and causes the initiation of the fracture.

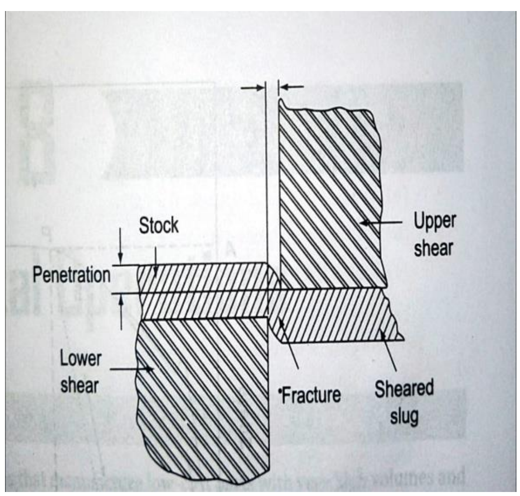


- The fractures which are initiated at both the cutting points would progress further with the movement of the upper shear and if the clearance is sufficient, would meet, thus completing the shearing action

- When correct clearances are used, a clean break would appear as a result of the extension of the upper and lower fractures towards each other. With an insufficient clearance, additional cut bands would appear before the final separation.

- Ductile materials require smaller clearances and longer penetration of the punch compared to harder materials.

- The clearance between two shears is one of the major factors controlling a shearing process. This clearance depends on the material and thickness of sheet metal.



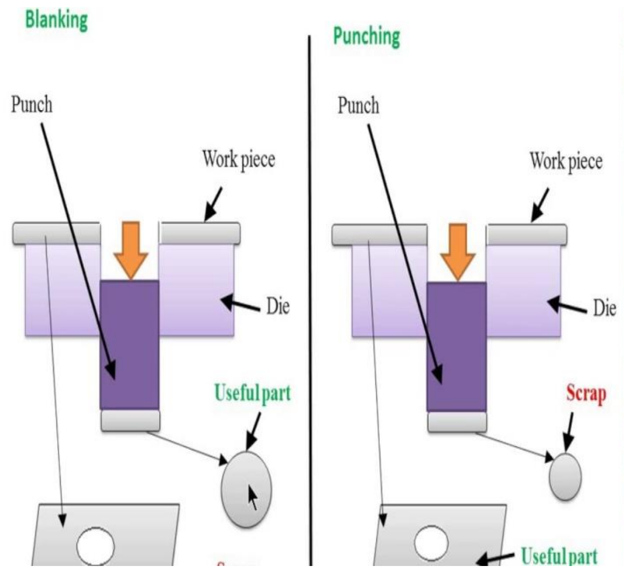
SHEARING OPERATIONS

- Straight-line shears, as described earlier, are used for general purpose shearing work. for example, in cutting the small pieces from a large sheet. But the more useful are the die-shearing operations where the shears take the form of the component to be made.

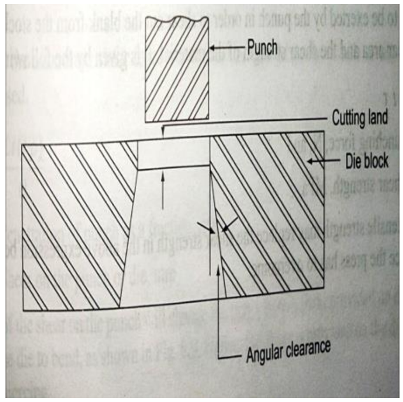
- The upper shear is called the punch and the lower shear is called the die. The two widely used processes are blanking and punching.

Blanking :- It is a process in which the punch removes a portion of material from the stock, which is a strip of sheet metal of the necessary thickness and width. The removed portion is called a blank and is usually further processed to be of some use, e.g. blanking of a padlock key.

Punching :- Also sometimes called piercing, the punching is making holes in a sheet. It is identical to blanking except of the fact that the punched-out portion coming out through the die in piercing is scrap. Normally, a blanking operation will generally follow a piercing operation.



- Angular Clearance:- After the final breaking, the slug will spring back due to the release of stored elastic energy. This will make the blank to cling to the die face, unless the die opening is enlarged. This enlargement is normally referred to as angular clearance or draft as shown in Fig. The draft provided depends on the material, thickness, and shape of the stock used. For thicker and softer materials, generally higher angular Clearances are provided. The normal value is from 0.25 to 0.75 degree per side but occasionally a value as high as 2 degrees may be used.



- Punching Force :- The force required to be exerted by the punch in order to shear out the blank from the stock can be estimated from the actual shear area and the shear strength of the material. It is given by the following formula.

$$P = L\,t\,\zeta$$

where P= Punching force(N) , ζ = Shear strength(MPa) and t= thickness of sheet

- Shear:- To reduce the required shearing force on the punch, for example to accommodate a large component on a smaller capacity punch press, shear is ground on the face of the die or punch. providing the shear only reduces the maximum force to be applied but lot the total work done in shearing the component.

PRESS TOOLS:-

- The commonly used tools on presses are punches and dies. A punch is usually that part of the unit which is fastened to the ram and is forced into the die. The die, which can be termed as the female part of the assembly, is normally rigidly held on the bed of the press. It carries an opening in perfect alignment with the punch, through which the latter enters into It. Both these parts work together as a unit and they known as a die set.

Die details and accessories:- The complete die set consists of a punch, die and a number of other components, called accessories. These components or accessories are provided in the set for ensuring proper alignment of punch and die to guide the moving part, correct location of stock and easy ejection of the finished parts, etc.

1. Punch holder. It is directly fastened to the ram of the punch press and holds the punch below it. It is also sometimes known as upper shoe of the die set.

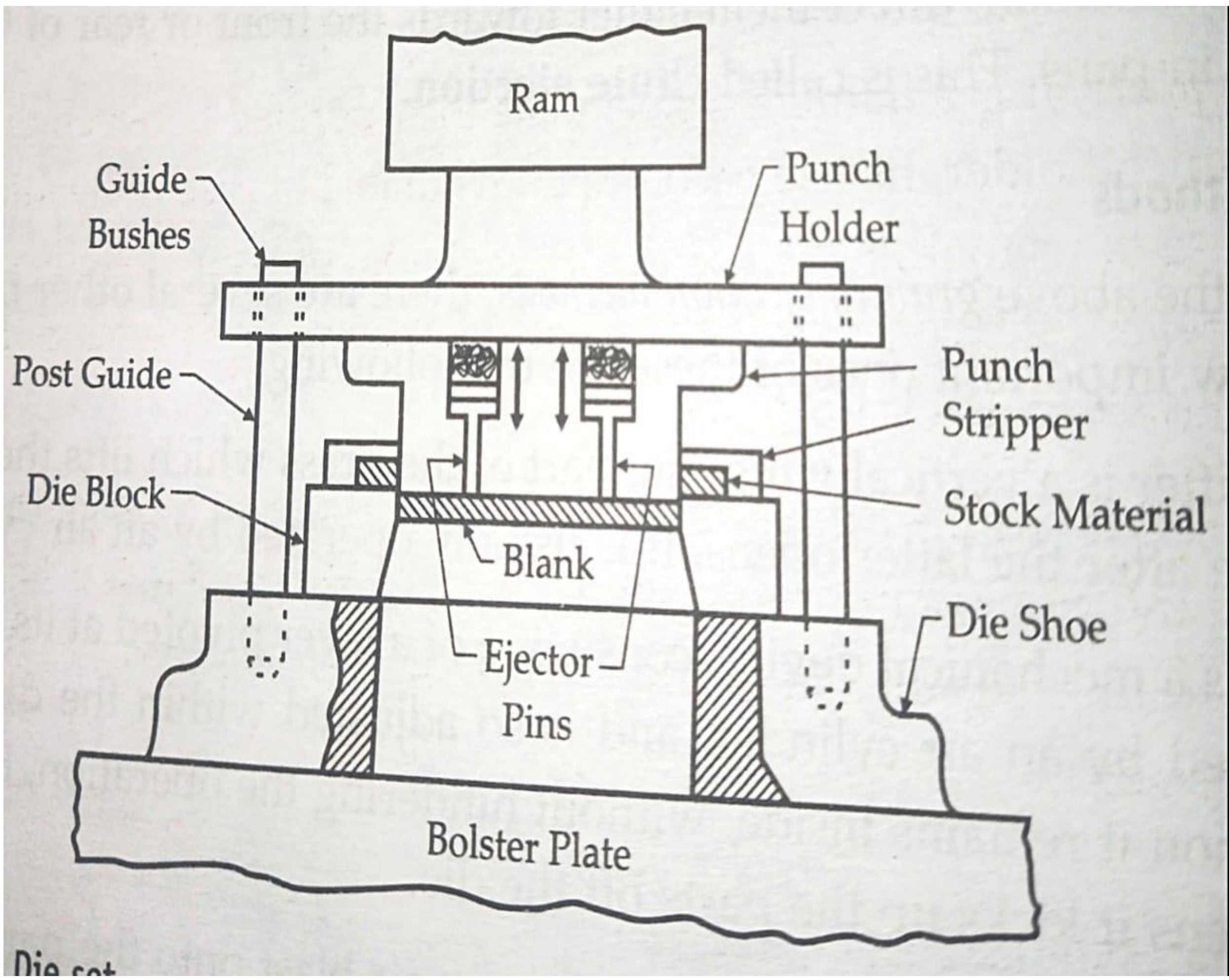
2. Punch. The male member of the die assembly is called punch. It is made sufficiently strong and rigid from a hard and wear resistant material and accurately finished to provide just the required clearance between it and the die. It is secured to the ram or slide of the press.

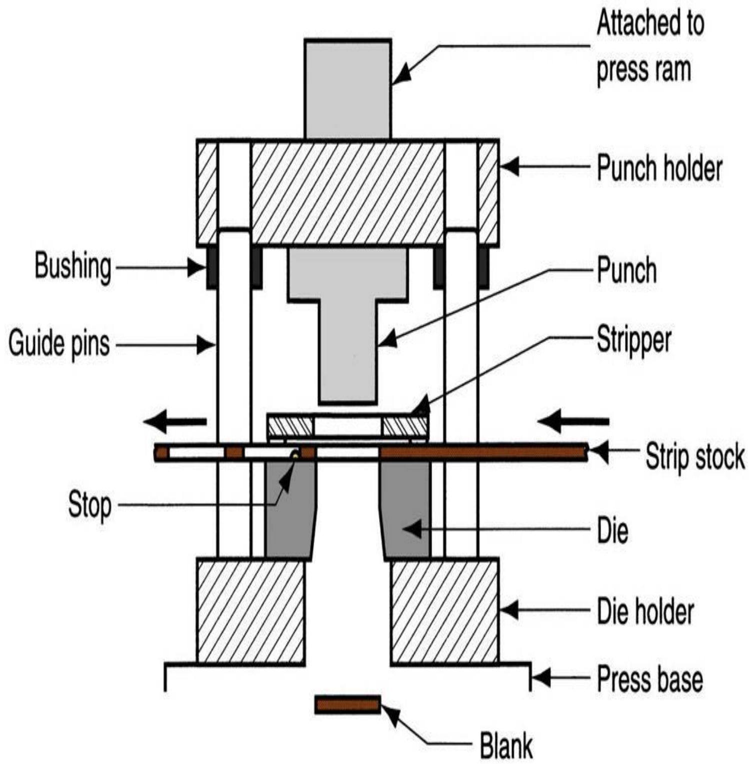
3. Die shoe. It acts as a support for the die block and is fastened to the bolster plate of the press. It is also known as the lower shoe of the die set.

4. Stops. They are used for restricting the feed of the stock material to a pre-determined length each time, so that correct spacing may always occur and there may not be any waste of material and time. The commonly used stops are the button stop and lever stop.

5. Guide posts. They help in obtaining correct alignment of the punch holder with the die shoe.

6. Stripper. It helps in freeing the punch from the scrap in the return stroke, as the latter tries to cling to the former.



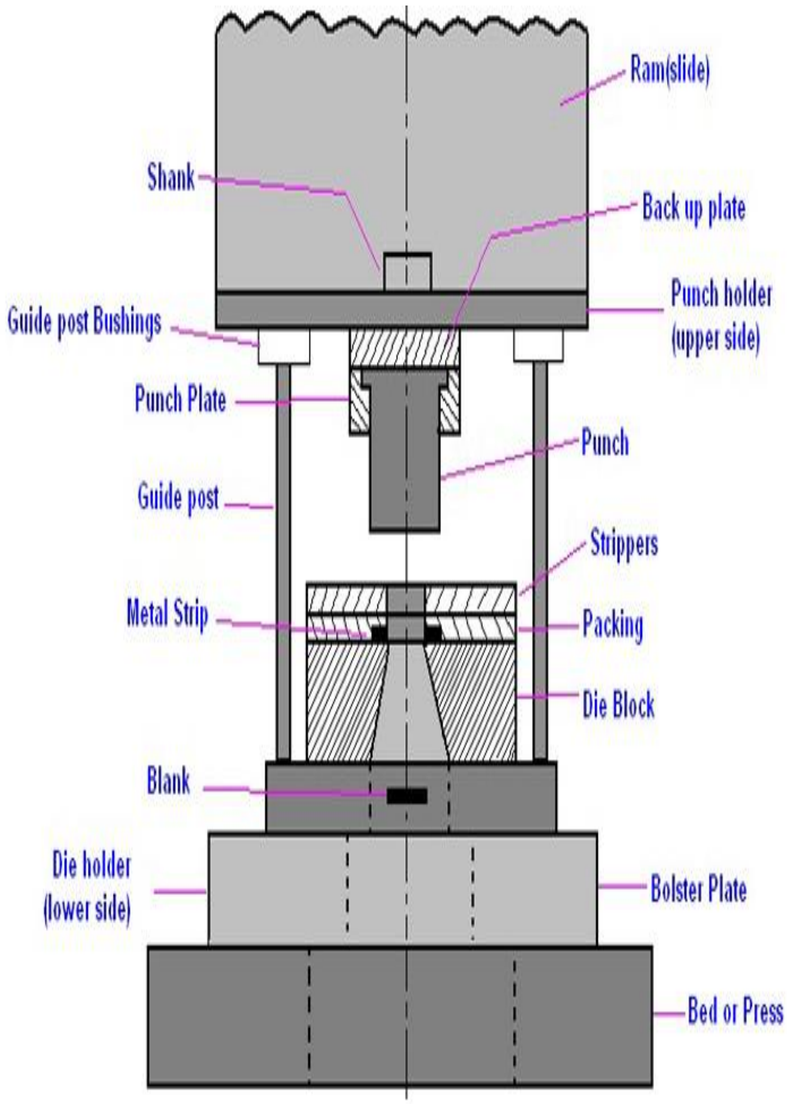


8. Knock out pins. They help in knocking away the sheared blank from the face of the punch to make free the latter from the former.

9. Punch plate. It holds the punch in proper alignment with the die and is secured to the punch holder. It is also known as punch retainer.

10. Backing plate. It is a hardened steel plate incorporated between the punch top and the punch holder. Its use becomes unavoidable in case of headless punches. The purpose of using this plate is to distribute the pressure evenly over a wider area and prevent the concentration of the pressure on the punch holder. This plate is also known as Back-up plate.

11. Die retainer. It has the same function for a die as the punch retainer for a punch, i.e., to hold the die block in proper alignment with the punch. It is held in the die shoe, but in some cases the die is directly held in the die shoes, i.e.; the latter itself acts as die retainer.



Component of die and punch Assembly

CLASSIFICATION OF DIES:-

The dies used in presswork can be broadly classified into the following two groups :

- Single operation dies, i.e., those designed to perform only a single operation in each stroke of the ram or rams (in case of double action presses).
- Multi-operation dies, i.e., those designed to perform more than one operation in each stroke of the ram or rams.

The single operation dies are further classified as :

(i) Cutting dies. These dies are basically designed to cut the sheet metal into blanks, through shearing action. These blanks are used as stock material in several further operations.

(ii) Forming dies. They are not metal cutting dies, but they alter the configuration of the blank to form desired shapes without stock removal.

Similarly, the multi-operation dies can be further classified broadly into :

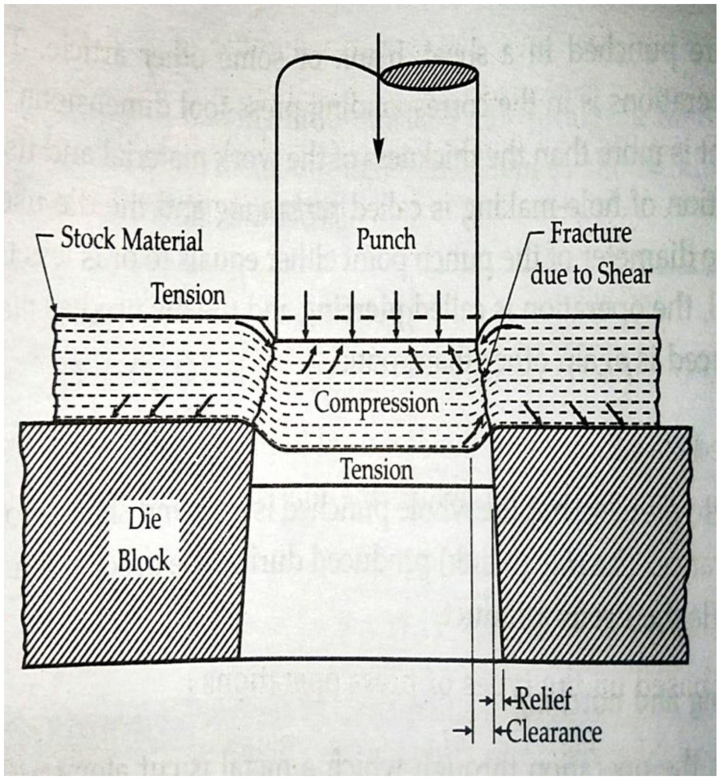
a) Compound dies. In which two or more cutting operations can be performed in a single stroke of the ram or at a single station.

b) Combination dies. In these dies a combination of cutting and some other operation can be performed at a single station.

Progressive dies. This die carries a number of stations in a row. A separate Operation is performed on each station and the work piece shifts from one Station to the next one in each stroke of the ram(s).

CUTTING OF A METAL IN A PUNCH AND DIE SETUP:-

- The basic cutting action, due to which blanks are produced in press work, is to shearing, as shown in Figure.
- When the punch is forced into the die, the metal between the two cutting edges is stressed in shear to the fracture point, resulting in the separation of the blank from the parent metal.
- Both tensile and compressive stresses act on the metal, stretching it to beyond its elastic limit. This results in plastic deformation and reduction of area and ultimately fracture of metal along the planes in the reduced area.
- The maximum concentration of the stresses is at the edges of the punch and the die. If the clearance between the punch and the die is correct, the cracks emanating from the edges of the two will meet and a clean edge will be produced, otherwise a ragged edge will result on the blank.
- Optimum clearance. It is that value of the clearance which is just sufficient to enable production of a blank with a clean edge.

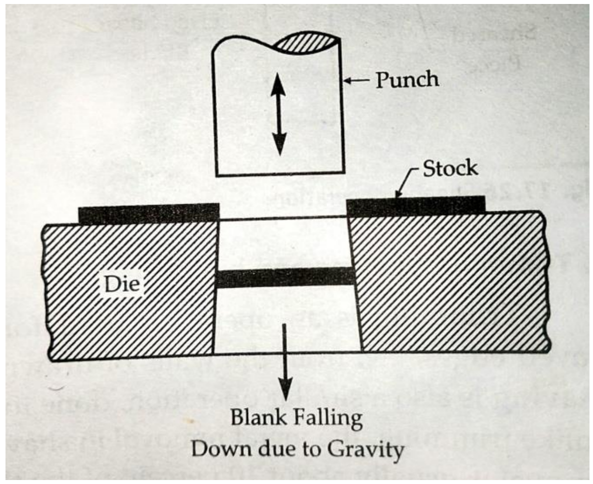


COMMON SHEARING OPERATIONS

1. Blanking: It is normally the first operation to be performed, through which flat shapes, called blanks, are cut out of the metal sheet. The die used is known as blanking die, and the same is provided with some shear angle to enable production of flat blanks. The punch used is flat as shown in figure.

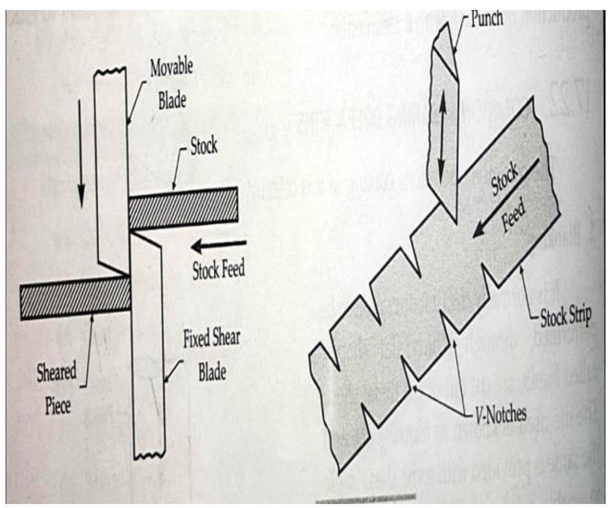
2. Perforating and piercing: They both are similar operations in that they are used for producing holes. The metal punched out in this manner is the scrap. Perforating gives the idea of an operation through which a large number of identical holes are punched in a sheet, blank or some other article.

The main difference between these operations is in the corresponding press-tool dimensions. When the diameter of the punch point is more than the thickness of the work material and its shape is other than round, the operation of hole-making is called perforating and the die used as perforating die. Against this, if the diameter of the punch point either equals to or is less than the thickness of the work material, the operation is called piercing and the die used as piercing die.



3. **Punching:** It is similar to piercing but the whole punched is of round shape. For this, the die carries the required clearance. The slug (blank) produced during the process is a waste and the metal carrying the hole is the useful product.

4. Shearing, parting and notching: Shearing is the operation through which a metal is cut along a single line, usually a straight line. Parting is the name given to the operation through which the metal is cut simultaneously along two parallel lines. Notching is a sort of blanking operation, but in this the full surface of the punch point does not participate in the cutting of metal since it is usually performed on the edges of the sheet metal.



SHEET METAL DIE DESIGN

- The dies, discussed previously, are involved in carrying out only a single operation. In practice, components are produced essentially by combinations of blanking, piercing, bending or drawing operations in a certain order. Most practical dies have to do more than one operation for making a finished component, and the details of the design of such dies are discussed here.

➢ Types of Dies

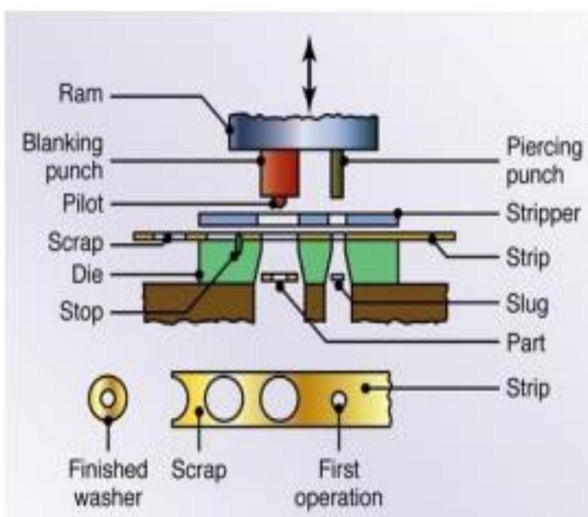
The sheet metal dies can be broadly categorized into three types:

- Progressive dies
- Compound dies and
- Combination dies.

PROGRESSIVE DIES

➢ The progressive dies perform two or more operations simultaneously in a single stroke of a punch press, so that a complete component is obtained for each stroke. The places where each of the operations are carried out are called stations. The stock strip moves from station to station undergoing the particular operation. When the strip finally leaves the last station, a finished component is ready.

➢ At the start of the operation, the sheet is fed into the first station. After undergoing the operations at this station, the ram of the press moves to the top and the stock is advanced from the first station to the second station, while a fresh portion of the stock comes under the first station. The distance moved by the strip from station one to two, so that it is properly registered under the stations, is called advance distance.

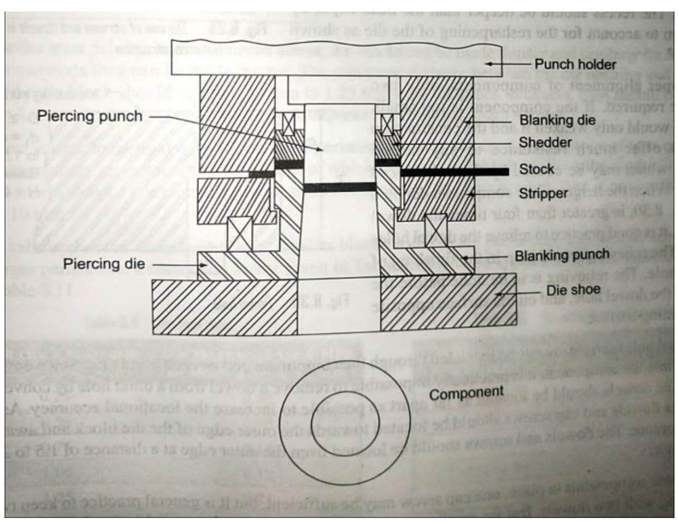


➢ This advance distance should be the same between any two stations in sequence. Another variable called the feed distance, is the amount of stock fed under the punch, when the ram comes for the next stroke. The feed distance may or may not be the same as the advance distance.

- Progressive dies contain a large number of stations. It is generally preferred to have piercing operation first in the sequence and a blanking or cut-off operation in the end to get the final component.
- The choice of progressive dies is made only when, the production is of large numbers so that the handling costs are saved

COMPOUND DIES

- In a compound die, as distinct from the progressive die, all the necessary operations are carried out at a single station, in a single stroke of the ram.
- To do more than one set of operations, a compound die consists of the necessary sets of punches and dies. During the part of the stroke, piercing of holes is done in the stock and upon further travel, the blanking operation is done. For the blanking operation, the punch used for piercing becomes a die as shown in Fig. In other words, blanking is done in a direction opposite to that of piercing.
- Compound dies are somewhat slower than the corresponding progressive dies in operation
- Higher tolerances can be achieved than progressive dies. This is mainly because the part located in one position undergoes all the operations.
- Also in compound dies, small strips can be advantageously used, whereas in progressive dies very long strips are required to cover all the stations.



COMBINATION DIE

- A combination die is same as that of a compound die with the main difference that here noncutting operations such as bending and forming are also included as part of the operation. Often the nomenclature compound and combination are interchangeably used for the same type of die.

QUESTION BANK

PRODUCTION TECHNOLOGY, 3RD SEMESTER

MODULE 1

METAL FORMING PROCESSES

SHORT ANSWER TYPE QUESTIONS (2 MARKS AND 5 MARKS)

1. Define extrusion.
2. List various types of metal forming processes.
3. Classify extrusion process.
4. How are collapsible tubes of aluminum (tooth paste tubes) manufactured? Explain.
5. What is impact extrusion?
6. What are the differences between impact extrusion and cold extrusion forging?
7. How is lubrication done in hot extrusion?
8. What are the lubricating methods employed for extrusion of steel?
9. What are the advantages of hot working over cold working?
10. What are the specific merits of cold working over hot working?
11. What is the significance of recrystallisation temperature in metal working?
12. Define rolling.
13. Classify rolling processes.
14. Differentiate between cold rolling and hot rolling processes.
15. List the different types of rolling mills used in Rolling process.

LONG ANSWER TYPE QUESTIONS (10 MARKS)

1. Explain with sketches the differences between direct and indirect extrusion.
2. Show by schematic sketches the process of forward and backward extrusion. Discuss their relative merits and demerits. Give two examples of components produced by extrusion.
3. How many types of rolling mills are there in commercial use? Describe their arrangement of rolls, specific uses and other details.
4. Sketch and describe the different types of rolls used in rolling mills.

MODULE 2

WELDING

SHORT ANSWER TYPE QUESTIONS (2 MARKS AND 5 MARKS)

1. Define welding.
2. Classify welding processes.
3. What are the functions of flux used in welding?
4. What are the required properties of a flux?
5. What is Welding and why is it done?
6. What is Resistance Welding? Give its classification.
7. Describe with the help of a neat sketch the principle of Spot Welding.
8. Briefly explain Butt welding and Seam welding.
9. Explain with the help of a neat diagram the principle of Flash welding.
10. What is seam welding?
11. What do you understand by Gas welding?
12. Describe in brief the equipment required for Oxy-acetylene Welding and Cutting.
13. What is the main difference between the Blow-pipes used for High pressure and Low pressure gas welding? Explain with the help of suitable sketches.
14. Briefly describe various types of flames in gas welding.
15. Describe with the help of suitable sketches the various types of joints made in welding.
16. What procedure you will follow and what care will you take in operating: (i) A low pressure plant (ii) A high pressure plant.
17. (a) What is an Electric Arc method of Welding?

    (b) How many methods of Arc welding do you know?
18. Give a list of equipments required in general for Electric Arc Welding.
19. Compare the merits and demerits of using A.C. and D.C. for arc welding.
20. What is Forge or smithy welding?
21. What are the electrodes used in Arc Welding made of?
22. What are Electrode Coverings and why are they provided?
23. How is an Electrode specified? Explain with example.
24. What factors govern the selection of an Electrode?

25. Differentiate between TIG and MIG.
26. What are ‘Acceptable’ and ‘Unacceptable’ welding defects? What factors govern them?
27. (a) What are common sources of Welding Defects? (b) List the common Welding Defects.
28. What is Porosity? Why and in how many forms does it occur?

LONG ANSWER TYPE QUESTIONS (10 MARKS)

1. What different methods of welding you know? Describe them in brief.
2. Write short notes on:
   (i)Welding rods (ii) Fluxes (iii) Gas flames.
3. Explain oxy acetylene welding process in detail.
4. Explain the principles of Arc-welding in detail.
5. (a) What do you understand by the term ‘Polarity’?
   (b) What is the advantage of having different polarities?
6. Describe briefly the methods of Carbon arc and Metallic arc welding.
7. Explain the processes of Soldering and Brazing. Write short notes on: (a) Leftward welding (b) Rightward welding (c) Vertical welding
8. Describe the following welding methods and their specific applications: (a) TiG welding (b) MIG welding (c) CO, MIG welding.
9. Write short notes on any two of the following Welding Defects and their remedies: (a) Inclusions (b) Cracks (c) Overlapping (d) Incomplete Penetration (e) Inadequate fusion.
10. Describe the following welding defects and their remedies: (a) Spelter (6) Distortion (c) Faulty profile and weld size (d) Poor Penetration

MODULE 3

CASTING

SHORT ANSWER TYPE QUESTIONS (2 MARKS AND 5 MARKS)

1. Define casting.
2. Classify casting process.
3. What is a pattern?
4. How patterns are classified?

5. What are the common materials used for pattern-making? Discuss their relative merits and demerits.
6. What are the factors which govern the selection of a proper material for pattern-making?
7. What are Master Patterns? How does their size differ from other patterns?
8. Explain the use of a solid pattern?
9. What are Split and Multi-piece patterns? What are the advantages of making them in two or more pieces? Give examples.
10. What is the specific advantage of Match plate patterns? Describe how they are used for making the moulds.
11. Sketch and describe the use and advantages of a Gated pattern.
12. How are Skeleton Patterns made? What is the advantage of using such patterns?
13. Describe, with the help of a neat sketch, the working of a Sweep pattern stating its advantages.
14. How are the different mould materials classified? What are the factors which influence their selection for a particular use?
15. How do natural moulding sands differ from synthetic sands? Enumerate a few sources of obtaining moulding sands in India.
16. What is meant by ‘Green strength’ and ‘Dry strength’ as applied to a moulding sand?
17. Explain, how the grain size and shape affect the performance of foundry sand.
18. What is the function of additives in moulding sands? Explain the effects of various additives used in moulding sands.
19. On what factors depends the selection of suitable core sand? What main characteristics a good core sand should possess?
20. Which are the main core binders?
21. What are ‘mould and core facings’? Why are they used?
22. State the effects of clay and moisture on permeability of moulding sand.
23. Why are the following materials added to moulding sand?
    (a) Dextrin (b) Silica flour (c) Sea coal (coal dust) (d) Wood flour.
24. What do you understand by the term ‘mould’ and ‘core’?
25. What is a riser?
26. What is the function of a riser?

27. What is a core? What is its use?
28. Classify cores.
29. What are the characteristics of a good core.
30. What are chaplets?
31. What are crucible furnaces? Where are they preferred and why?
32. How is the thermal efficiency of a cupola determined?
33. Why care is necessary in operating the cupola?
34. What is the difference between gravity die casting and pressure die casting?
35. What is a vacuum die casting? What are its main advantages?
36. Write a short note on die casting dies.
37. What are the main advantages and disadvantages of die-casting ?
38. What do you understand from ‘centrifugal casting’ ? How are the centrifugal casting methods classified ?
39. What are the material commonly used for making the moulds for centrifugal casting ?
40. What are the main factors which are responsible for producing defects in the castings ?
41. List the defects you would expect from the following stating the precautions necessary to prevent them: (i) Improper pouring technique (ii) Poor or defective cores. (iii) Use of defective gating system. (iv) High moisture content in sand.

<u>LONG ANSWER TYPE QUESTIONS (10 MARKS)</u>

1. What are the common allowances provided on patterns? Explain each allowance in detail.
2. How are the patterns classified? Explain each pattern type in detail with sketches.
3. Write short notes on the following, giving suitable sketches wherever necessary: (i) cope and Drag patterns (ii) Follow Board patterns (iii) Segmental patterns. (iv)Core boxes.
4. What are the main characteristics which good moulding sand should possess? How do these characteristics influence the performance of moulding sand during moulding and casting?

5. What are the main constituents of a moulding sand? How are binders classified? Name a few binders of each type.
6. Explain the procedures of Sand mould casting.
7. Explain different types of molding sands with their composition.
8. How many types of cores are there? Explain them with the help of sketches.
9. Explain with the help of neat sketches, the construction and working of the following types of crucible furnaces (a) coal fired pit furnace (b) gas fired crucible furnace (c) oil fired tilting furnace.
10. Make a neat cross sectional sketch of a cupola, indicating its various zones and describe the following (i) its construction (ii) advantages (iii) methods of charging (iv) different zones and their functions (iv) its operation
11. Sketch and explain the construction and operation of a hot chamber die casting machine.
12. How does a cold chamber die casting machine differ from a hot chamber die casting machine? Explain the working of a cold chamber machine with the help of a diagram.
13. Discuss the advantages, disadvantages and application of hot chamber and cold chamber die casting.
14. With the help of a neat diagram describe the process of true centrifugal casting. How can this method be used for production of pipes ? What are the advantages and disadvantages of true centrifugal casting ?
15. Illustrate and describe the process of semi-centrifugal casting.
16. What is centrifuging ? Describe the process, stating its differences with other centrifugal casting methods.
17. Name the various defects which occur in sand castings and state their probable causes and remedies.
18. Discuss briefly the causes and remedies of the following casting defects: (i) Blow holes (ii) Hot tears (iii) Shrinkage cavities (iv) Gas porosity (v) Scabs.
19. Write short notes on the following casting defects : (1) Misrun and cold shuts (ii)Cuts and washes. (iii) Sand inclusions (iv) Metal penetration (v) Drops (vi) Warpage.

20. Explain the causes and remedies of the following casting defects : (i) Fusion (ii) Shot metal (iii) Shifts (iv) Rat tails or buckles {iv} Swells (v) Hard spots (vi) Run out. (viii) Crushes.

MODULE 4

Powder Metallurgy

SHORT ANSWER TYPE QUESTIONS (2 MARKS AND 5 MARKS)

1. What is meant by 'Powder metallurgy' ?
2. What are the main stages of powder metallurgy process ?
3. Enumerate the main characteristics of metal powders.
4. What are the primary and secondary proceses, used for processing of metal powders ?
5. Describe the 'Sintering' process in detail.
6. Explain the utility and applications of secondary processes in powder metallurgy.
7. What are 'cermets'? Give a few examples of useful applications of powder metallurgy.
8. What are cemented carbides ? How are they processed ?
9. What are the advantages of powder metallurgy processes ?
10. What are the disadvantages and limitations of powder metallurgy ?

LONG ANSWER TYPE QUESTIONS (10 MARKS)

1. What are the different methods of producing metal powders ? Describe the 'Atomisation' process in detail.
2. Explain the following powder metallurgy processes :
   (a) Blending or mixing (b) Briquetting or compacting (c) Pre sintering.
3. Describe the methods of producing components by powder

MODULE 5
PRESS WORK

SHORT ANSWER TYPE QUESTIONS (2 MARKS AND 5 MARKS)

1. What is blanking operation in press work?

2. What is piercing operation?
3. What is trimming operation?
4. List various types of dies used in press work. State their applications.
5. List various types of punch used in press work. State their applications.

LONG ANSWER TYPE QUESTIONS (10 MARKS)

1. With the help of schematic diagrams explain working of simple dies and compound dies. State their advantages and disadvantages.
2. With a neat sketch explain the working of progressive die. Write its advantages and disadvantages.

MODULE 6

JIGS AND FIXTURES

SHORT ANSWER TYPE QUESTIONS (2 MARKS AND 5 MARKS)

1. What is jig?
2. What are jigs and fixtures ? Why are they used ?
3. What essential factors will you consider while designing a jig or a fixture ?
4. Explain the aspect 'Degrees of freedom of movement of a free body' with special reference to jigs
5. What different types of 'locating pins' you know ? Illustrate and explain their uses.

LONG ANSWER TYPE QUESTIONS (10 MARKS)

1. What is the difference between a jig and a fixture ? What are the main advantages of using jigs and fixtures in mass production ?
2. What are the main elements of jigs and fixtures ? What is the principle of 'Six-point location' ? Explain.
3. What important considerations should be made in location of workpieces ? What are 'locating devices' or 'locators' ? Which factors govern the selection of a locator ?
4. State the principle of locations. Describe the methods of location with respect to 3-2-1 point location of rectangular jig.

5. How are jigs classified? Give a broad classification of jigs you know.
6. How are fixtures classified? Give a broad classification of fixtures you know.

Watch videos:

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https://youtu.be/bAEdNrb5xWA

https://youtu.be/CdgBwlz1Al4

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