

## MODULE -2

# MELTING & METAL MOULD CASTING METHODS

**Melting furnaces:** Classification of furnaces, Gas fired pit furnace, Resistance furnace, Coreless induction furnace, electric arc furnace, constructional features & working principle of cupola furnace.

**Casting using metal moulds:** Gravity die casting, pressure die casting, centrifugal casting, squeeze casting, slush casting, thixocasting, and continuous casting processes. Casting defects, their causes and remedies.

## **MELTING FURNACES**

A pre-requisite to casting is the use of metal in molten state. The transformation of metal from solid to molten liquid is accomplished in a variety of ways through the use of various types of furnaces. The furnaces used for melting metal can be classified based on the following:

- The type of metal it can melt and
- The source of heat required for melting.

### **(a) Based on the type of metal it can melt**

#### **(i) Gray Cast Iron**

- Cupola furnace
- Electric Arc furnace
- Air furnace or Reverberatory furnace.

#### **(ii ) Steel**

- Open hearth furnace
- Electric Furnace
- Arc furnace
- High frequency Induction furnace.

#### **(iii) Non-Ferrous metals**

- Crucible furnace
- Pit type
- Electrical resistance type.
- Reverberatory furnace (fuel fired)
- Rotary furnace.
- Induction furnace
- Low frequency
- High frequency.
- Electrical Arc furnace

### **(b) Based on the source of heat**

#### **(i) Fuel fired furnace**

- Gas fired furnace
- Oil fired furnace

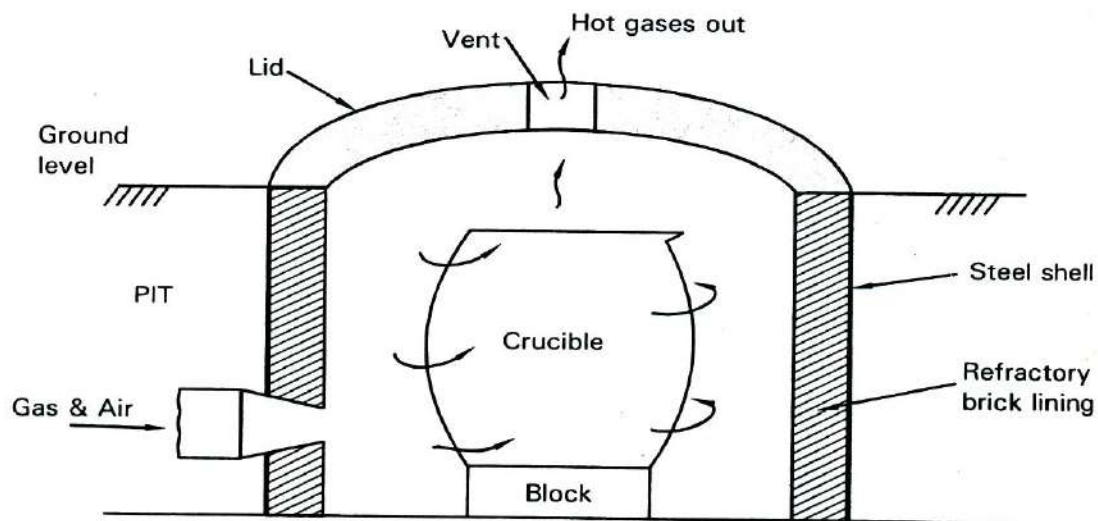
- Coke fired furnace
- Air furnace (Reverberatory furnace)

(ii) Electrical furnace

- Reverberatory furnace
- Induction Furnace
- Arc furnace
- Direct arc type
- Indirect arc type.

- **GAS FIRED PIT FURNACE:**

A gas fired pit furnace has a crucible placed in a pit, below the ground level as shown in figure. (Crucible - A vessel or pot, made of refractory substance or of a metal with a high melting point used for melting metals or other substances.)



**Construction:**

- The furnace consists of an outer steel shell lined with refractory bricks around. The refractory material resists heat shock, abrasion and erosion.
- At the bottom, a round base or pedestal block is placed upon which the crucible is supported. The diameter of the block is the same as that of the crucible in order to provide proper support. The crucible is usually made of clay, silicon carbide or graphite material.
- Towards the bottom of the steel shell, a small opening is made through which the **gas** (fuel) is passed. For complete combustion of fuel, **air** is forced into the furnace along with the fuel by means of a small blower.

- At the top of the furnace, a refractory lid with a small opening for the escape of hot gases is provided. The lid is generally hinged, so that it can be swung out of the way for easy removal of the crucible.

**Working:**

- In operation, the lid is opened and the charge (metal) is fed directly into the crucible.
- The fuel (Natural gas or liquid propane) and air mixture is introduced into the furnace at an angle which causes the flame to rise from the bottom of the furnace, swirl around the crucible and finally pass out of the furnace as shown in figure.
- The furnace atmosphere can be made neutral, oxidizing or reducing by regulating the flow of air from the blower.

(Air in suitable proportions must be supplied along with fuel for complete combustion of fuel to take place. The furnace atmosphere can be principally divided into neutral, oxidizing and reducing. Neutral atmosphere is created when the supplied air helps in complete combustion of fuel, while oxidizing implies excess of oxygen in the products of combustion, and reducing implies insufficient air to completely burn the fuel. Although neutral atmosphere which results from complete combustion of fuel is ideal atmosphere for foundry furnaces, it is difficult to maintain.

- After the metal melts and attains the desired temperature, the lid of the furnace is opened and the crucible is lifted with the help of tongs.
- The slag floating on the surface of the melt is removed, and the molten metal is poured into the mould cavity.

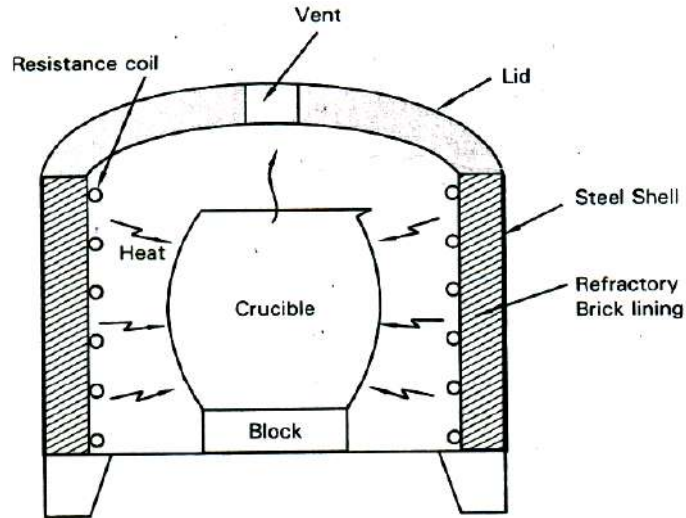
Gas fired pit furnace was used in olden days and is still preferred to melt non-ferrous metal for casting small jobs. In today's foundry practice, these furnaces operate at floor level instead of pits.

- **RESISTANCE OR ELECTRIC RESISTANCE FURNACE**

Figure shows the indirect type of resistance furnace used for melting non-ferrous metals.

**Construction:**

- The furnace consists of an outer steel shell lined with refractory bricks around. The refractory material resists heat shock, abrasion and erosion.
- At the bottom, a round base or pedestal block is placed upon which a crucible is supported. The diameter of the block is the same as that of the crucible in order to provide proper support. The crucible is usually made of Clay, silicon carbide or graphite.
- On the inside of the refractory lining, grooves are provided to accommodate resistors or heating coils. The resistors are connected to an electric power supply.
- At the top of the furnace, a refractory lid with a small opening for the escape of hot gases is provided.



**Working Principle:**

- The furnace works on the principle that, when electric current flows through a resistor or heating coil, heat is generated due to the resistance offered by the material of the coil to the flow of electric current. The heat generated in the coil is given by the equation:

$$H= I^2RT$$

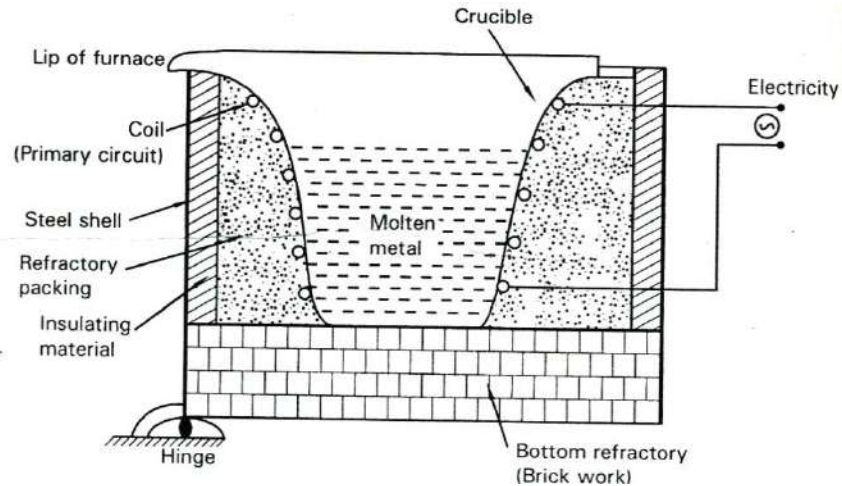
Where H = heat generated in Joules

I = flow of current in Amperes. R = resistance of the coil in Ohms and T = time of current flow in seconds.

- Heat transfer takes place through radiation and convection due to which the charge (metal) inside the crucible is melted.
- The lid at the top of the furnace is opened and the crucible is lifted out with the help of tongs.
- The slag floating on the surface of the melt is removed and the molten metal is poured into the mould cavity.

- **CORELESS INDUCTION FURNACE**

A coreless induction furnace shown in figure is used for melting ferrous metals.



### Construction:

- The furnace consists of an outer cylindrical steel shell hinged at the bottom to facilitate tilting of furnace during pouring.
- The inner surface of the shell is covered with an insulating material made of mica or asbestos, while the bottom surface is covered with refractory bricks.
- A refractory crucible which contains the charge rests on the brick work and surrounded by a helical coil made of copper tube. The copper tube being a heavy tube requires active cooling and this is achieved by passing a flow of water through it.
- The space between the crucible and the shell is packed by a dry refractory mass that provides the necessary insulation.

### Working Principle

- The furnace works on the principle of a transformer in which the **copper coil** acts as **primary**, and the **charge (steel scraps)** as **secondary**.
- When a high frequency electric current is passed through the primary coil, a much heavier secondary current is induced in the charge. Heat is generated due to the resistance of the metal causing it to melt.
- The liquid metal (melt) undergoes a **stirring action** due to the **eddy currents** induced by the EMF (Electromagnetic Force) that is concentrated in the center of the circular primary coil. This stirring action is beneficial in uniform distribution of temperature and alloy chemistry in the melt. But on the other hand, if stirring action is excessive, dross or surface impurities is drawn into the melt. When the molten metal has reached the desired temperature, the metal is deoxidized and tapped into ladles for pouring into moulds.

(Tapping - It is the operation of tilting the furnace to pour off molten metal.)

(The purpose of deoxidation is to lower the dissolved oxygen content of steel to improve its quality. This is accomplished by adding silicon and manganese shortly before the metal is tapped and adding aluminum to the ladle during pouring.)

- **ELECTRIC ARC FURNACE:**

An electric arc furnace utilizes the heat of the electric arc generated between two conducting materials to melt the charge. It is used for melting cast iron and steels. High thermal efficiency, rapid heating, close temperature control and strict atmospheric control are a few characteristics of the furnace that lead to the production of good quality metal.

**Arc furnace is of two types:**

**(a) Direct arc electric furnace**

In this furnace, the electrodes come in contact with the metal to create an arc.

**(b) Indirect arc electric furnace**

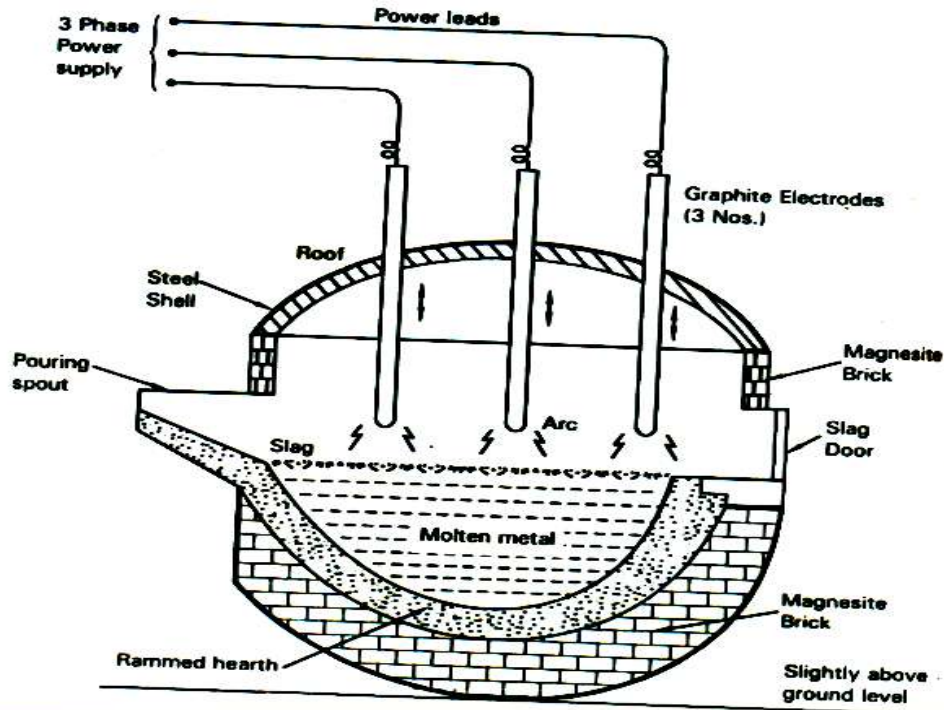
In this type of furnace, the electrodes never touches the metal to create an arc, instead, arc is struck between the electrodes.

**Direct Arc Electric Furnace:**

Figure shows the direct type of arc furnace used for melting steel and other non-ferrous metals.

**Construction**

The furnace consists of a heavy steel cylindrical shell with a spherical bottom, lined with refractory bricks. The furnace hearth and walls are lined with magnetite bricks. (**Hearth - is the bottom portion of the furnace that supports the charge and sometimes collects and holds the molten metal.**) The furnace is built on a tilting platform that facilitates tilting of the furnace forward for pouring molten metal into ladles. The furnace can also be tilted backwards for inspection, charging metal, flux, deoxidizers etc., and for removal of slag through the slag door. The roof of the furnace is made of steel shell lined inside with refractory bricks and can be clamped in position. Metal can also be charged from the furnace roof. The roof is provided with three circular holes through which non-consumable graphite electrodes are inserted. The electrodes can be raised and lowered by means of guides, and are usually water cooled to dissipate heat. They are connected to a 3-phase power supply as shown in the figure.



### Working Principle:

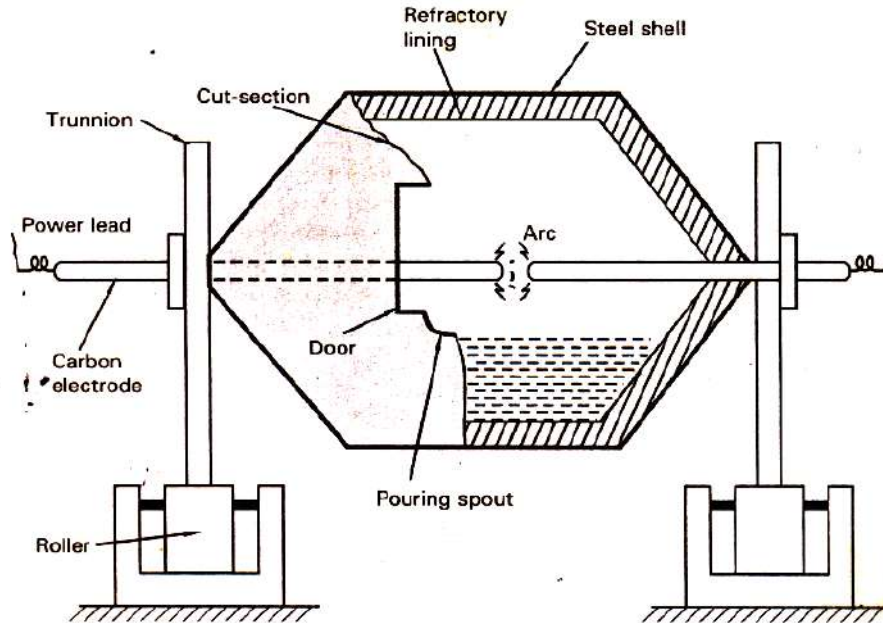
- Arc furnace works on the principle that, when an arc is struck between the electrode and charge material, heat is generated due to the resistance of the metal charge.
- In operation, the furnace is charged with ingots, steel scrap, alloy metals and fluxing agents through the charging door.
- The electrodes are lowered down. On supplying the necessary current and voltage, an arc is produced between the electrodes and the charge material.
- The gap between the electrodes and the charge is maintained by regulating the movement of electrodes, so that the arc remains between them and burns continuously melting the charge materials.
- The flux melts and forms a slag that floats on the surface of the liquid metal. The slag prevents oxidation, refines the metal and protects the furnace roof from excessive heat.
- After the liquid metal has achieved the desired temperature, the electrodes are raised to extinguish the arc, and the furnace is tilted backwards to remove the slag. The furnace is then tilted forward to pour the liquid metal into ladles. Insulating powders are thrown into ladles to prevent radiation loss of liquid metal. The metal from the ladle is then poured into the moulds.

### Indirect Arc Electric Furnace

Figure shows an indirect arc electric furnace used for melting small quantities of ferrous and non-ferrous metals.

### Construction:

- The furnace consists of a cylindrical or barrel shaped steel shell lined with a refractory material. The shell is mounted on rollers and can be tilted through 180°. This facilitates for easy pouring of liquid metal to the ladles. Also, the rollers provide rocking action to the furnace that speeds the melting rate and stirs the molten metal.
- Two non-consumable carbon electrodes are mounted along the horizontal axis and can be automatically adjusted for maintaining proper arc column.
- A charging door and pouring spout (partly shown in figure by a cut section) serve their usual purpose.



### Working:

- The ingot, steel scrap and alloy metals, and fluxing agents are charged into the furnace.
- On supplying the necessary current and voltage, an arc is struck between the two non consumable carbon electrodes. The electrodes are brought closer together and maintained, so that the arc remains between them.
- The charge melts by radiation from the heat produced by the arc, and also by conduction from the heat absorbed by the refractory lining.
- Once the metal melts, the furnace is rotated (set to rock to and fro). This helps the refractory lining to get heated up and also, the molten metal exposed to a larger area of the heated lining. Also, rocking stirs the molten metal homogeneously. When the liquid metal reaches the desired temperature, the furnace is tilted mechanically and the liquid metal is tapped in ladles and poured into the moulds.

### • CUPOLA FURNACE

A cupola is a vertical cylindrical furnace used for melting only **cast** iron. Although other furnaces are capable of melting cast iron, the largest tonnage of cast iron is melted in cupola furnace. Figure shows a cupola furnace.

### **Construction:**

The cupola consists of a cylindrical steel shell lined with a refractory material like firebrick and clay. The height of the furnace may range from 20 - 35 feet, while its diameter ranges from 10-50 inch. The furnace is open at both its top and bottom. At the bottom of the furnace, hinged insulated doors are provided, so that after melting is completed, the contents left inside the cupola can be dropped down by opening the hinged doors. The iron prop supports and helps in closing and opening of the hinged doors.

- A coarse refractory sand and clay are rammed slightly on the bottom doors. The sand is rammed in a tapered manner to allow the flow of molten metal easily through the tapping spout. Opposite to the tapping spout and little higher is a slag hole through which the slag is removed.
- Slightly above the slag hole is the wind box and tuyeres. The tuyeres are small openings (covered by wind box) through which air under pressure is forced into the furnace from the wind box, via a pipe from the blowing equipment.
- At the top end of the shell, a charging door is provided through which the charge is fed into the furnace.

### **Working:**

#### **a) Starting the cupola**

Initially, soft and dry wooden pieces are placed on the sand bottom after which coke is charged up to the tuyeres level. The wooden pieces are ignited through the tap hole and sufficient air is passed through the tuyeres for proper combustion of coke.

#### **b) Charging cupola**

The charge used in cupola consists of alternate layers of coke, flux and metal (iron). These three components are continuously built into the furnace as shown in figure. The most commonly used iron-to-coke ratio is 8:1. The flux may be limestone ( $\text{CaCO}_3$ ), fluorspar, sodium carbonate or calcium carbide. Limestone is the commonly employed flux. The total weight of the flux will be approximately  $1/5^{\text{th}}$  the weight of the coke charge.

#### **c) Melting**

Cupola works on the counter current principle. As the combustion takes place, the charge materials (coke, flux and metal) will be descending downwards, while the hot gases due to combustion will be ascending upwards. Heat exchange takes place between the rising hot gases and the descending charge thereby melting the metal. The liquid metal drops down, while the coke floats up on top of it.

The flux also melts and reacts with the impurities of the molten metal forming a slag. The slag floats on the surface of the molten metal thereby preventing oxidation of the metal. Supply of air at suitable intervals accelerates the combustion process.

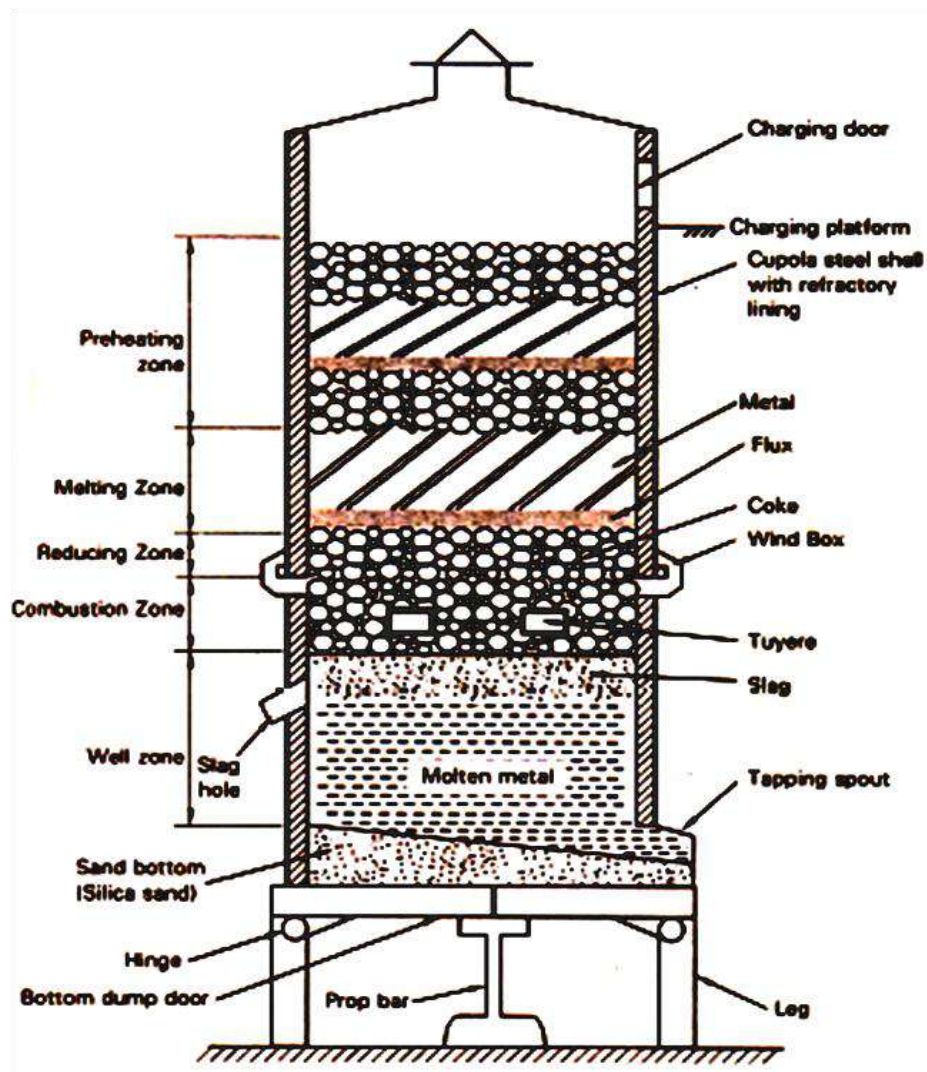
#### **d) Tapping slag and molten metal**

When sufficient liquid metal is collected in the reservoir, the slag door is opened and the slag floating on the surface of the molten metal is tapped and disposed off. Immediately the tapping spout which was closed with a bolt (a clay plug) is opened and the liquid metal is tapped into

ladles. When the ladle is filled with liquid metal, the tapping spout is again closed with the bott. The liquid metal from the ladle is poured into the moulds.

**e) Dropping down the bottom**

When melting is complete and no more liquid metal is required, the charging of cupola is stopped. The prop under the bottom door is knocked down and the bottom door is swung out of the way allowing the contents in the cupola to drop down. The un-melted charge is collected and used during the next melting. (The operation of dropping down the bottom is very dangerous and has to be done by trained person.)



**Zones of Cupola**

The various zones in a cupola are shown in figure and are as follows:

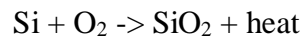
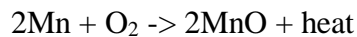
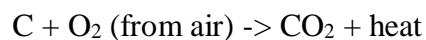
**(a) Well zone**

Well zone is the portion situated between the rammed sand bottom and just below the bottom edge of the tuyeres. The molten metal is occupied in this zone.

**(b) Combustion zone**

The combustion zone or oxidizing zone is situated normally 15 - 30 cm from the bottom edge of the tuyeres. It is in this zone where rapid combustion of coke takes place due to which a lot of heat is generated in the furnace. The combustion is rapid due to the supply of blast air through the tuyeres.

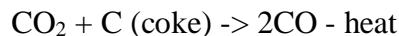
Oxidation of manganese and silicon evolve still more heat. The reactions that take place in this zone are:



The temperature in this zone varies from 1550° - 1850°C.

**(c) Reducing zone**

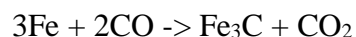
Reducing zone or protection zone is the portion located from the top of the combustion zone to the top of the coke bed. In this zone, some of the hot CO<sub>2</sub> gas moving upward through the hot coke gets reduced to CO. In other words, reduction of CO<sub>2</sub> to CO occurs in this zone. Due to the reducing atmosphere, the charge is protected from oxidation. The reaction taking place in this zone is given by:



Due to the reduction, the temperature reduces to around 1200°C in this zone.

**(d) Melting zone**

The portion located just above the coke bed to the top of the metal (iron) is called the melting zone. The metal starts melting in this zone and trickles down through the coke bed to the well zone. The molten iron while passing down through the reducing zone picks up carbon and the reaction is given by:



**(e) Preheating zone**

The portion occupied from the top surface of the melting zone to the charging door is called preheating zone. The hot gases rising upwards from the combustion and reducing zone gives its

heat to charge before passing out of the furnace. Thus, the charge is preheated before descending downwards.

## **CASTING USING METAL MOULDS**

### **• GRAVITY DIE CASTING**

Gravity die casting or permanent mould casting is a casting process in which the molten metal is poured into a metallic mould called die under the influence of gravity. Hence the name, gravity die casting. The mould or die is usually made from cast iron, tool steel, graphite, copper, or aluminum alloys, and the choice for a particular material depends on the type of metal being cast. Gating and risering systems are machined either in one or both the mould halves. Figure 3.7(a) shows a permanent mould made in two halves which resembles an open book. The mould halves are hinged and can be clamped together to close the mould.

#### **Steps involved in the process:**

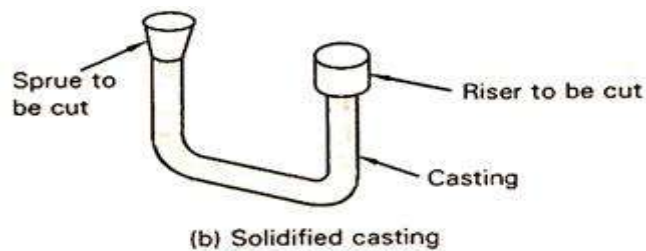
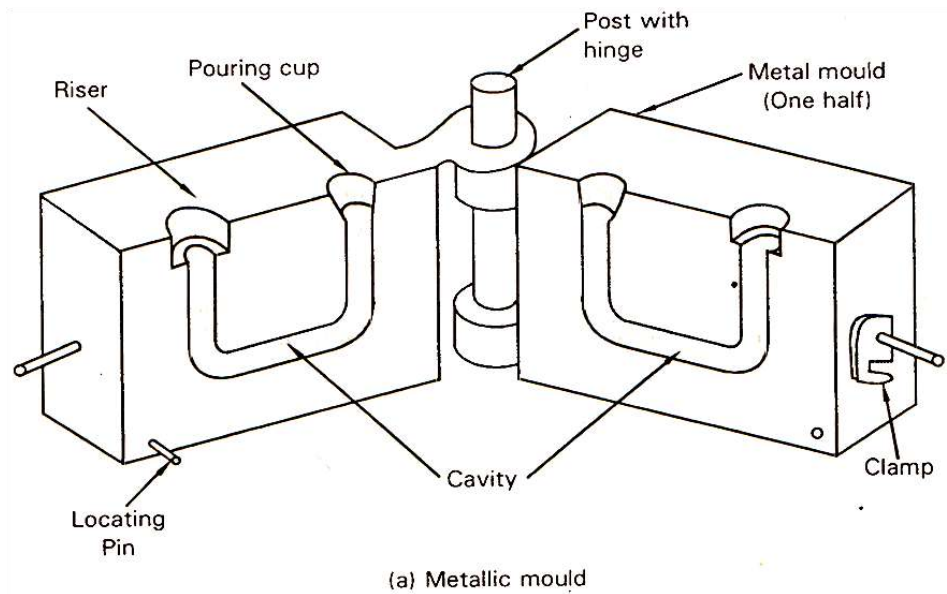
- a) The mould is cleaned using wire brush or compressed air to remove dust and other particles from it.
- b) It is preheated to a temperature of 200 - 280°C by gas or oil flame, and then the surface is sprayed with a lubricant. The lubricant helps to control the temperature of the die thereby increasing its life, and also assist in easy removal of the solidified casting.
- c) The mould is closed tightly and the liquid metal of the desired composition is poured into the mould under gravity.
- d) After the metal cools and solidifies, the mould is opened and the casting is removed. Refer figure Gating and risering systems are separated from the cast part.
- e) The mould is sprayed with lubricant and closed for the next casting. The mould need not be preheated, since the heat in the previous cast is sufficient to maintain the temperature.

#### **Advantages**

- Good surface finish and close dimensional tolerances can be achieved.
- Suitable for mass production.
- Occupies less floor space.
- Thin sections can be easily cast.
- Eliminates skilled operators.

### Disadvantages

- Initial cost for manufacturing moulds (dies) is high.
- Not suitable for steel and high melting point metals/alloys. .
- Un-economical for small productions.



Gravity die casting

### • PRESSURE DIE CASTING

Pressure die casting, often called Die casting is a casting process in which the molten metal is injected into a die under high pressure. The metal being cast must have a low melting point than the die material which is usually made from steel and other alloys. Hence, this process is best suitable for casting non-ferrous materials, although a few ferrous materials can also be cast. The two basic methods of die casting include:

- (a) Hot chamber die casting process
- (b) Cold chamber die casting process.

### Hot chamber die casting process

Figure shows a goose neck type of hot chamber die casting machine. In this process, the dies are made in two halves: one half called the fixed die or stationary die, while the other half called movable die. The dies are aligned in positions by means of ejector pins which also help to eject the solidified casting from the dies.

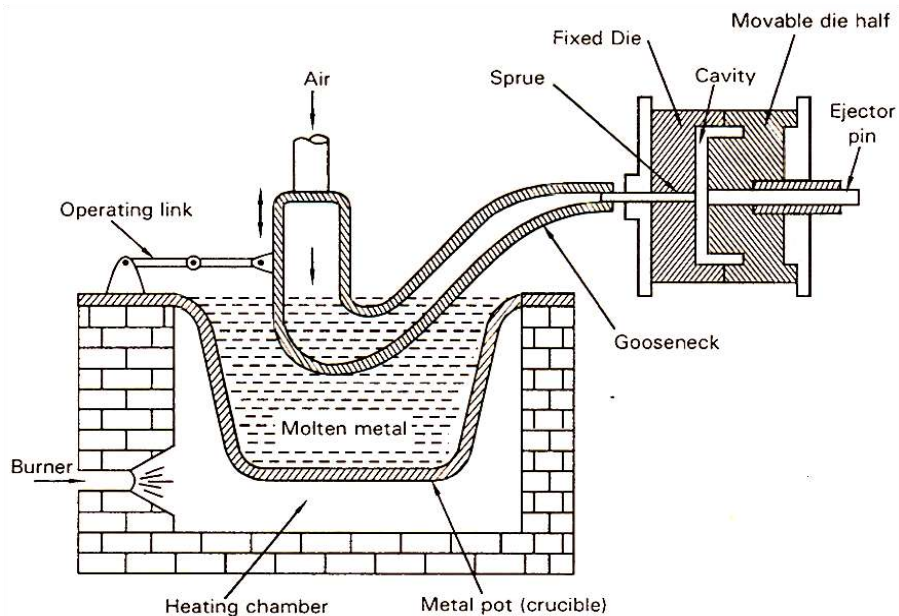


Figure 3.8 Hot chamber die casting (Goose neck type)

### Hot chamber die casting (Goose neck type)

#### Steps involved in the process:

- a) A pivoted cast iron goose neck is submerged in a reservoir of molten metal, where the metal enters and fills the goose neck by gravity.
- b) The goose neck is raised with the help of a link, and then the neck part (goose neck) is positioned in the sprue of the fixed part of the die.

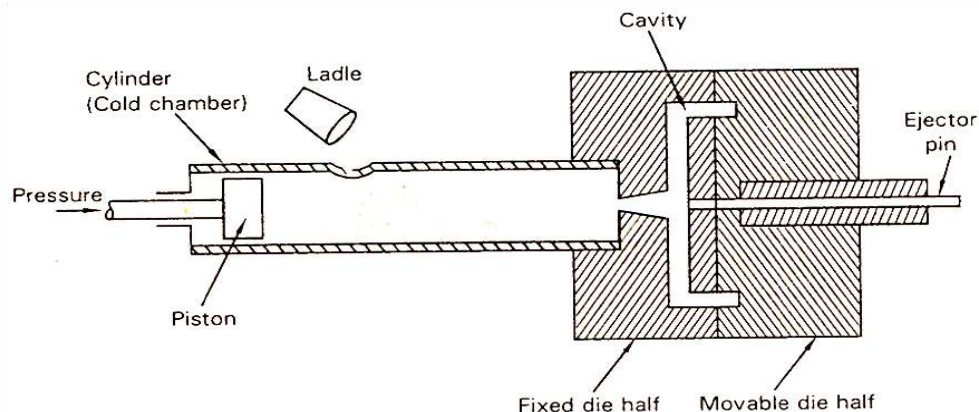
- c) Compressed air is then blown from the top, which forces the liquid metal into the die cavity.
- d) When the solidification is about to complete, the supply of compressed air is stopped and the goose neck is lowered back to receive the molten metal for the next cycle. In the meantime, the movable die half opens by means of ejector pins forcing the casting from the die cavity.
- e) The die halves close to receive the molten metal for the next casting.

Hot chamber process is used (or casting metals like zinc, tin, magnesium and lead based alloys).

### **Cold chamber Die Casting Process:**

In hot chamber process, the charging unit (goose neck) rests in the melting chamber, whereas in cold chamber process, the melting chamber is separate, and the molten metal is charged into the cold chamber by means of ladles.

Cold chamber process is employed for casting materials that are not possible by the hot chamber process. For example, aluminum alloys react with the steel structure of the hot chamber machine, and as a result there is a considerable iron pick-up by aluminum. This does not happen in cold chamber process, as the molten metal has a momentary contact with the structure of the machine. Figure 3.9 shows the cold chamber die casting machine



**Cold chamber die casting**

The machine consists of a die, made in two halves: one half called the fixed die or stationary die, while the other half called movable die. The dies are aligned in positions by means of ejector pins which also help to eject the solidified casting from the dies.

### **Steps involved in the process:**

- a) A cylindrical shaped chamber called cold chamber (so called because, it is not a part of melting or charging unit as is in the case of hot chamber process) is fitted with a freely moving piston and is operated by means of hydraulic pressure.
- b) A measured quantity of molten metal is poured into the cold chamber by means of ladles.
- c) The plunger of the piston is activated, and progresses rapidly forcing the molten metal into the die cavity. Pressure is maintained during the solidification process.

d) After the metal cools and solidifies, the plunger moves backward and the movable die half opens by means of ejector pins forcing the casting from the die cavity. Cold chamber process is slightly slower when compared to the hot chamber process.

**Advantages of Die casting process**

- Process is economical for large production quantities.
- Good dimensional accuracy and surface finish.
- Thin sections can be easily cast.
- Near net shape can be achieved.

**Disadvantages**

- High cost of dies and equipment.
- Not economical for small production quantities.
- Process not preferable for ferrous metals.
- Part geometry must allow easy removal from die cavity.

• **CENTRIFUGAL CASTING**

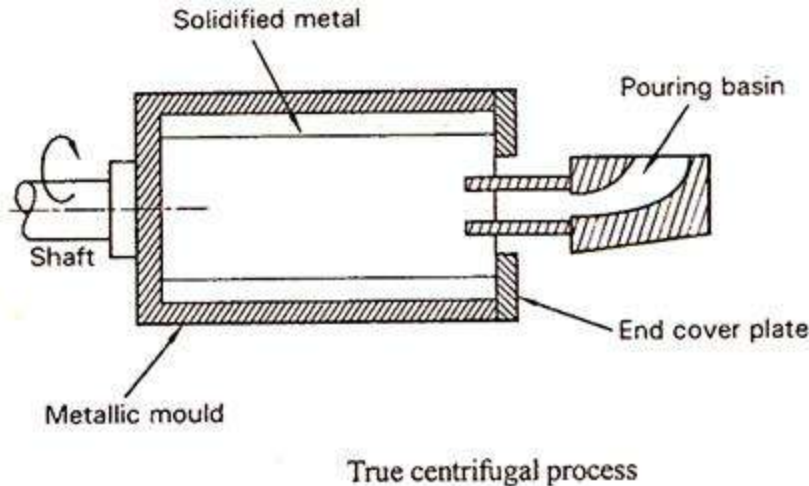
Centrifugal casting is a process in which the molten metal is poured and allowed to solidify in a revolving mould. The centrifugal force due to the revolving mould holds the molten metal against the mould wall until it solidifies.

The material used for preparing moulds may be cast iron, steel, sand, or graphite (for non-ferrous castings). The process is used for making castings of hollow cylindrical shapes. The various centrifugal casting techniques include:

- (a) **True centrifugal casting**
- (b) **Semi-centrifugal casting, and**
- (c) **Centrifuge casting.**

**True Centrifugal casting:**

True centrifugal casting is used to produce parts that are symmetrical about the axis, like that of pipes, tubes, bushings, liners and rings. The outside shape of the casting can be round, octagonal, hexagonal etc., but the inside shape is perfectly (theoretically) round due to radially symmetric forces. Hollow castings can be efficiently produced by this process without the need for cores. Figure shows the true centrifugal process.



### Steps involved in the process

- a) The mould of the desired shape is prepared with metal, and the walls are coated with a refractory ceramic coating.
- b) The mould is rotated about its axis at high speeds in the range of 300 - 3000 rpm. A measured quantity of molten metal is poured into the rotating mould.
- c) The centrifugal force of the rotating mould throws the liquid metal towards the mould wall and holds the molten metal until it solidifies.
- d) The casting cools and solidifies from its outer surface towards the axis of rotation of the mould thereby promoting directional solidification.
- e) The thickness of the casting obtained can be controlled by the amount of liquid metal being poured.

An inherent quality of true centrifugal castings is based on the fact that, the non-metallic impurities in castings being less dense than the metal, are forced towards the inner surface (towards the axis) of the casting due to the centrifugal forces. These impurities can be machined later by a suitable process (say boring operation).

### Advantages of true centrifugal casting

- Non-metallic impurities being less dense are forced towards the center of rotation due to centrifugal forces from where they can be easily machined to give a clean defect free casting.
- No need for cores to produce hollow castings.
- Gating system is not required, hence high casting yield.
- Suitable for mass production.

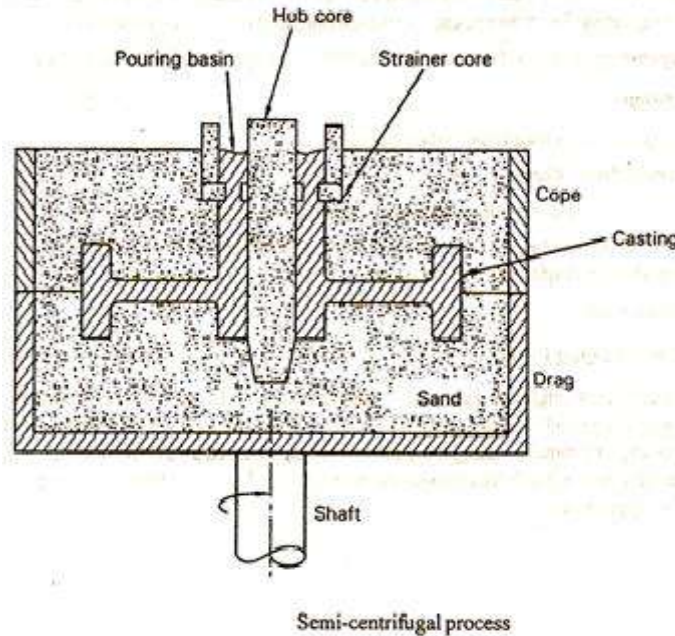
- Shrinkage is not a problem when manufacturing by true centrifugal casting, since material from the inner sections will constantly be forced to instantly fill any vacancies that may occur in outer sections during solidification.
- Quality castings with good dimensional accuracy can be produced with this process.

### **Disadvantages**

- Process is limited to hollow castings.
- Casting's wall thickness is controlled by the exact amount of material added during the pouring phase.
- Rotational rate of the mould during the manufacture of the casting need to be calculated carefully based on the mould dimensions and the metal being cast.
- Requires skilled workers.

### **Semi-centrifugal casting:**

Semi-centrifugal casting process is used to produce solid castings, and hence requires a core to produce hollow cavities. The process is used only for symmetrically shaped objects and the axis of rotation of the mould is always vertical. Gear blanks, sheaves, wheels and pulley are commonly produced by this process. Figure shows the process to produce a wheel shaped casting.



### Steps involved in the process

- The mould is prepared in the usual manner using cope and drag box.
- The mould cavity is prepared with its central axis being vertical and concentric with the axis of rotation.
- The core is placed in position, and the mould is rotated at suitable speeds, usually less than that used in true centrifugal casting process.
- The centrifugal force produced due to the rotation of the mould causes the molten metal to fill the cavity to produce the desired shape.

### Advantages of semi-centrifugal casting

- Non-metallic impurities being less dense are forced towards the center of rotation due to centrifugal forces from where they can be easily machined to give a clean defect free casting.
- The high forces in the outer section that push the molten material against the mould wall also ensure a great surface finish of cast parts manufactured by semi-centrifugal casting.
- Quality castings with good dimensional accuracy can be produced with this process.

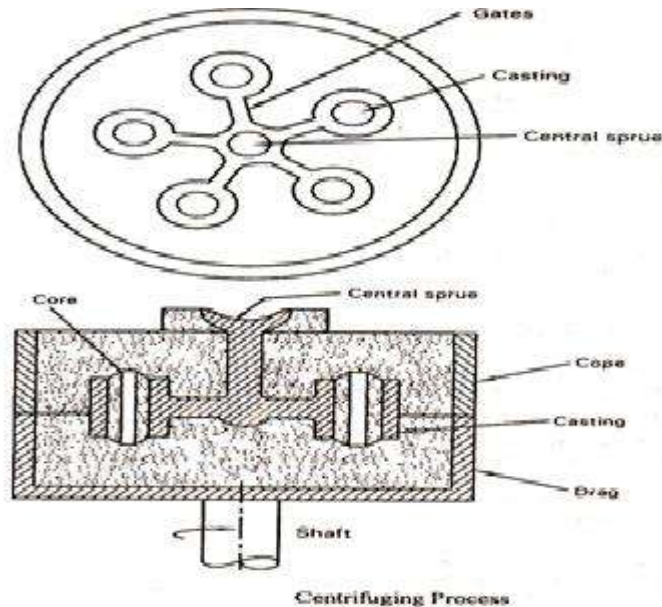
### Disadvantages

- Restricted to symmetrically shaped castings.
- Requires skilled workers.

- Density is greatest in the outer cast regions and decreases towards the center.
- Impurities such as inclusions and trapped air, tend to collect and solidify in the less dense material closer to the center of the axis of rotation.
- Consumes more time.

### Centrifuging Process

In true and semi-centrifugal casting process, the axis of the mould/cavity coincides with the axis of rotation; whereas in centrifuging process, the axis of the mould cavity does not coincide with the axis of rotation. The mould is designed with part cavities located away from the axis of rotation. Hence, this process is suitable for non-symmetrical castings. Figure 3.13 shows the principal views of centrifuging process.



### Steps involved in the process

- a) Several mould cavities are arranged in a circle and connected to a central down sprue through gates.
- b) The axis of the down sprue is common to the axis of rotation of the mould.
- c) As the mould is rotated, the liquid metal is poured down the sprue which feeds the metal into the mould cavity under centrifugal force.

d) The rotational speed depends on a number of factors such as, the moulding medium (sand, metal or ceramic), size of the casting, type of metal being poured, and the distance of the cavity from the central axis (sprue axis).

Centrifuging is done only about a vertical axis.

#### **Advantages of centrifuge casting**

- The process need not have rotational symmetry. Hence, desired shapes can be manufactured.
- Suitable for large quantity castings.

#### **Disadvantages**

- Centrifuging is done only about a vertical axis,
- Density is greatest in the outer cast regions and decreases towards the center.
- Impurities such as inclusions and trapped air, tend to collect and solidify in the less dense material closer to the center of the axis of rotation.
- Requires skilled workers.

#### **• SQUEEZE CASTING**

Squeeze casting or squeeze forming or liquid metal forging is a combination of casting and forging process. Figure shows the sequence of operations involved in the process.

#### Steps involved in the process

- a) The process makes use of two dies: bottom die and top die, cast and machined in such a way that upon mating leaves a cavity similar to the shape of the desired casting. Refer figure
- b) The bottom die is preheated to around 200 - 250°C with the help of a torch, and sprayed by a water based graphite lubricant to facilitate easy removal of the casting after solidification. Refer figure
- c) A measured quantity of molten metal is poured into the bottom die as shown in figure  
As the metal starts solidifying, pressure is applied to the top die, causing it to move rapidly towards the bottom die. This causes the molten metal to get squeezed and fill the mould cavity. Refer figure
- d) The squeezing pressure is applied until solidification is completed.
- e) The casting is ejected by operating the lift pin provided in the bottom die, and the die is then made ready for the next cycle. Refer figure

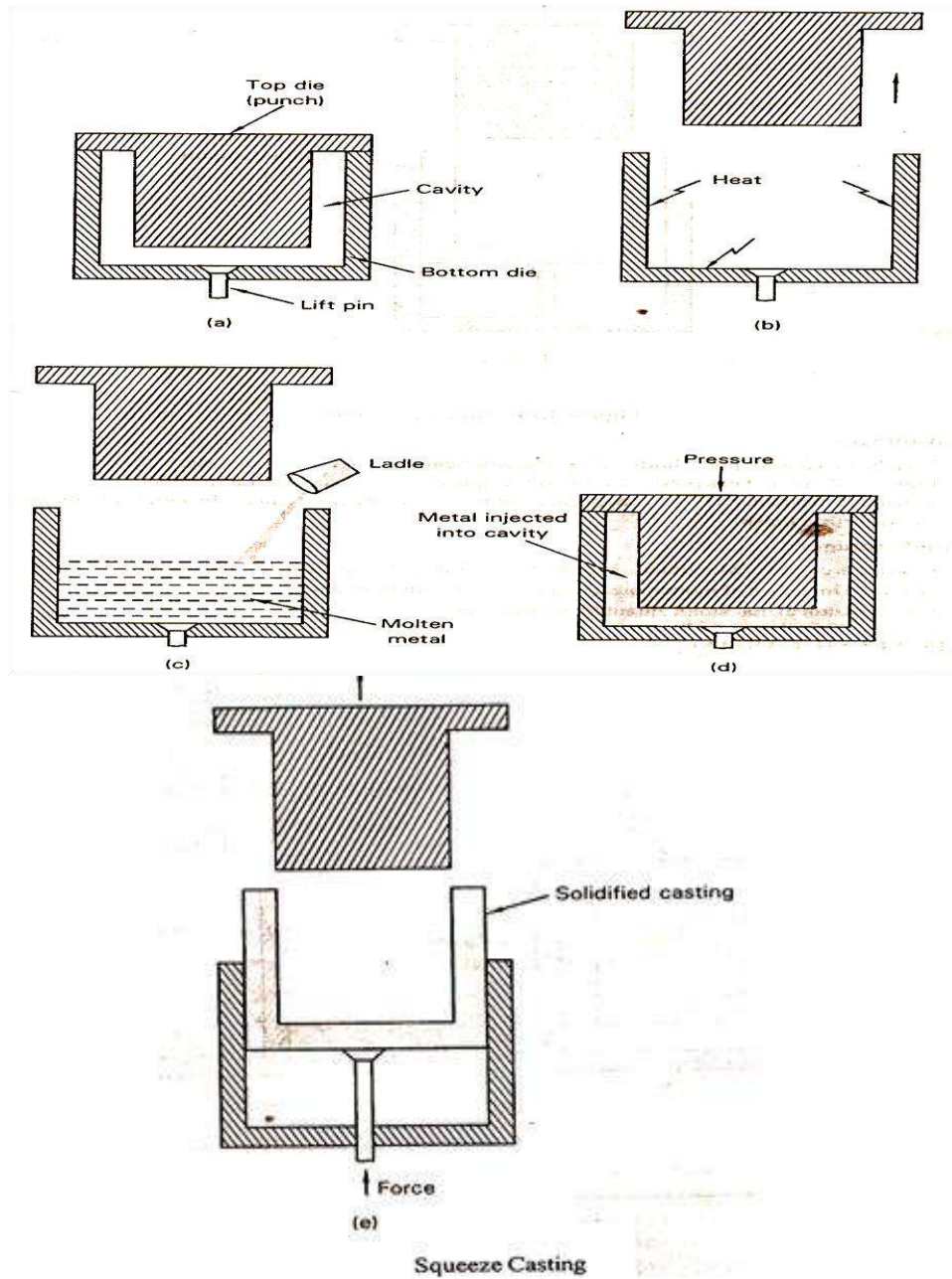
Squeeze casting is commonly used for casting aluminum and magnesium alloys. Cores can be used in this process to produce holes and recesses.

**Advantages**

- Metals which have poor fluidity characteristics can be cast by this process.
- Low shrinkage and gas porosity, due to the applied pressure during solidification.
- Enhanced mechanical properties because of fine grain structure caused by rapid solidification.
- Good surface finish.

**Disadvantages**

- Process is costlier. Manufacturing dies to accurate dimensions involves complex processes.
- Accurate metering of molten metal is a slight difficult problem.
- Un-economical for small quantity production.

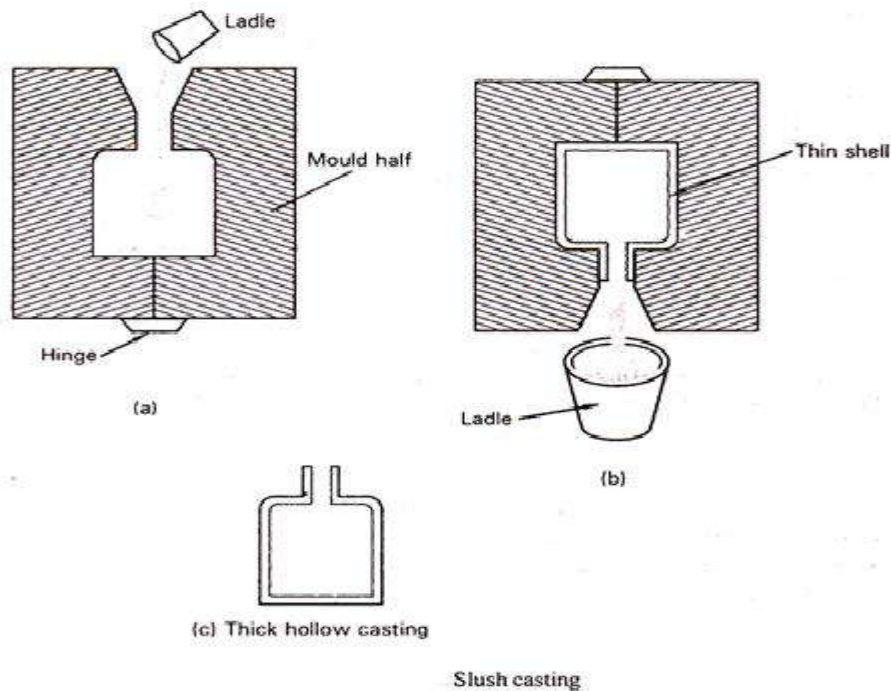


• **SLUSH CASTING**

Slush casting is a process in which hollow castings are produced without the use of cores. The process is not preferred to produce objects for engineering use. Instead, it is used to make objects like statues, toys, lamp base, candle sticks and others, where only the external features of the object are important. Refer figure

**Steps involved in the process**

- a) In this process, the molten metal is poured in a metallic mould and permitted to remain in the mould for a short interval of time. Refer figure
- b) Solidification begins at the mould walls, as they are relatively cool, and then progresses inward.
- c) When a shell of desired thickness is formed, the mould is inverted, and the metal which is still in the liquid state is drained off. Refer figure. The thickness of the shell obtained depends on the time for which the metal was allowed to remain in the mould, and also the thermal conductivity of the mould.
- d) When the mould halves are separated, a hollow casting with good features on its external surfaces, but variable wall thickness is obtained as shown in figure



**Advantages**

- a) Process is simple and inexpensive.
- b) Hollow castings can be made without using cores.

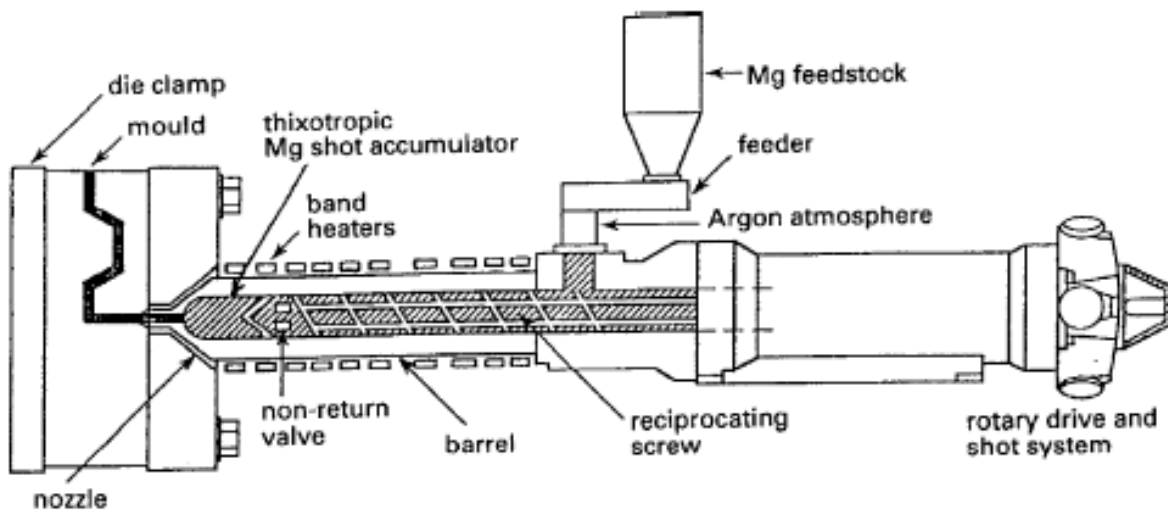
**Disadvantages**

- a) Process is used for art and decorative work only. Not suitable for engineering applications.
- b) Only low melting point alloys with narrow freezing ranges can be used.
- c) Castings with uniform wall thickness is difficult to achieve.

• **THIXOCASTING (THIXOFORMING) PROCESS**

Thixo casting, although similar to squeeze casting, is a more refined process in which the casting material, for example, aluminum alloy is subjected to a heating treatment to prepare a semi-molten material having solid and liquid phases co-existing therein.

The semi-molten material is injected into a cavity whose shape resembles to the shape of the desired product, and rapidly compressed at very high pressures. This is a high potential technology bringing together quality metallurgy, advanced mechanical properties and excellent dimensional precision. The yield strength of the part made by thixo casting is around 220 MPa compared to a maximum of 140 MPa, that obtained by a pressure die casting process. It is therefore used in the manufacture of light weight parts especially in automobiles that are subjected to severe stresses.



**Advantages**

- High quality with near net shape parts can be produced.
- Excellent mechanical properties of cast parts.

- Since the semi-solid metal injected into the cavity is just above the solidification temperature, there is a reduction in solidification and cycle times, resulting in increased production.
- Shrinkage porosity is reduced due to lower super-heat involved.

### **Disadvantages**

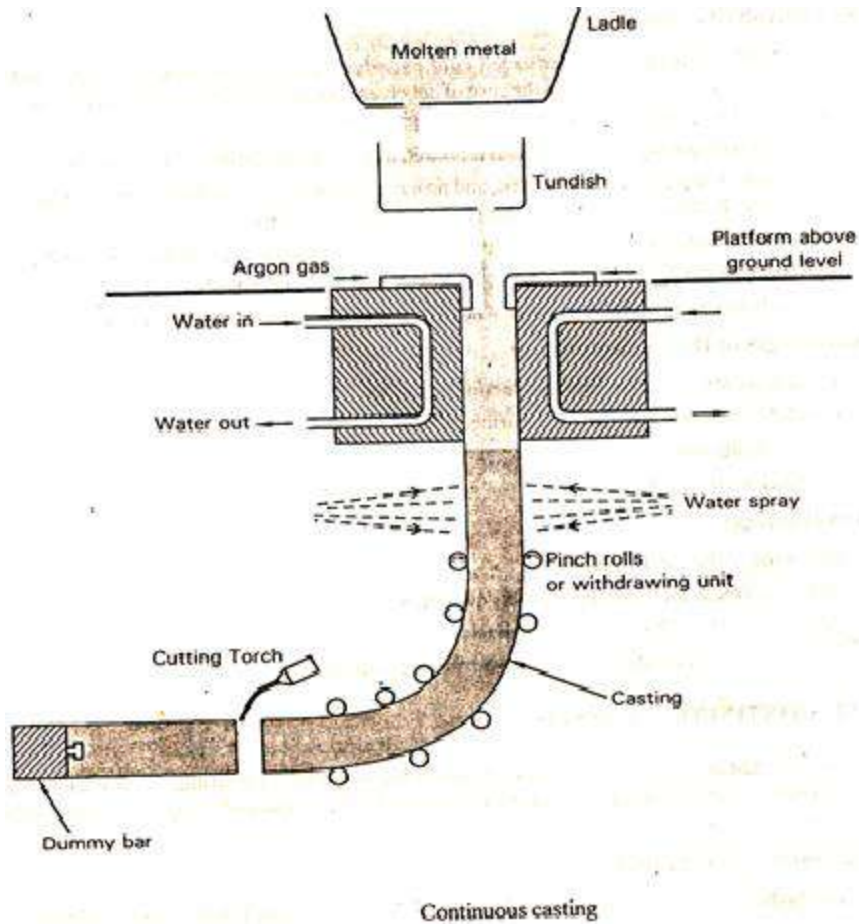
- Expensive due to the need for special billets for thixo casting.
- Process is restricted only to certain alloys.
- Scrap cannot be directly reduced.
- Not suitable for very thick parts.

### **• CONTINUOUS CASTING**

Continuous casting is a casting process in which the operation of pouring, solidification and withdrawal of casting from an open mould are carried out continuously. Figure 3.10 shows a schematic of the process.

#### **Steps involved in the process**

- a) The molten metal is continuously supplied from the ladle to the intermediate ladle called tundish from where it is continuously poured into the mould at a controllable rate, keeping the level at a constant position.
- b) The mould usually made of copper or graphite is open at the bottom and is water cooled so as to extract the heat of the metal causing its solidification. The shape of the mould corresponds to the shape of the desired casting.
- c) The process is started by placing a dummy bar at the bottom of the mould upon which the first liquid metal falls.
- d) The molten metal from the tundish enters the mould and takes the shape of the mould. The water cooled mould controls the cooling rate of the metal, so that it solidifies before it leaves the mould.
- e) The metal after coming out of the mould is further cooled by direct water spray (or water with air) for complete solidification to take place.
- f) The solidified metal is continuously extracted (along with the dummy bar) by pinch rolls, bent and fed horizontally, and finally cut to the desired length.



### Advantages

- Sprue, runner, riser etc., are not used. Hence, no waste metal. This leads to 100 % casting yield.
- Capable of producing in single operation, rods, sections and tubes with varying sizes and wall thickness.
- Process is automatic.
- Product has good consistent soundness.
- Mechanical properties are high and very reproducible.

### Disadvantages

- Not suitable for small quantity production.
- Continuous and efficient cooling of moulds is required; else, center-line shrinkage develops in the cast part.
- Requires large floor space.

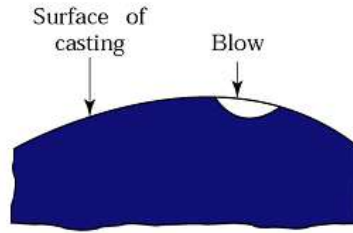
## TYPES OF CASTING DEFECTS

The proper designing and moulding can give a defect free cast but due to some control limitation and human interference, defects are generally occurring. By the proper assistance on work we can minimize the casting defects. Generally a proper casting product also has some defects so a research is going in foundry industry to minimize these defects. These casting defects can be found out by the non destructive testing methods which includes ultrasonic testing, radiography testing, magnetic particle testing, die penetration testing etc. Today I will point out some common casting defects, its causes and remedies of it. The basic conditions which spark the defects in casting or the favorable conditions of casting defects are

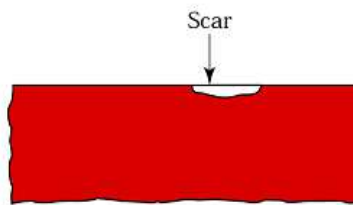
1. Defecting design of pattern
2. Improper melting of metal
3. Defects in mould
4. Due to moulding material
5. Improper cooling of mould
6. Defecting gating system
7. Improper venting in mould

These defects can be classified into three major categories.

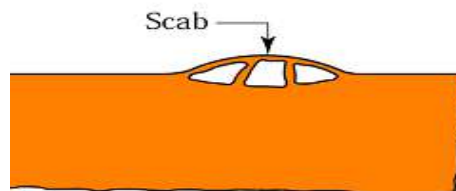
**1. Blow Hole:** It is a gas hole or gas cavity which is occurs at the surface or the internal part of casting. It is due to gas interrupted into the casting due to poor ventilation. Mostly it is occur at surface which makes a circular or oval shape gas hole. These defects can be seen after machining of surface. These defect cause due to improper venting system, excessive gas or moisture contain and due to low permeability of sand and high temperature of sand. It is also due to low pouring temperature of metal.



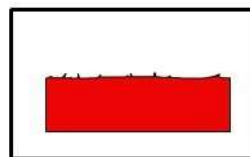
**2. Scar:** Scar is generally occurring at flat surface and it is due to improper venting or permeability of sand. The blow is covered by the thin layer of metal.



**3. Scab:** This is also known as slag inclusion or sand inclusion. This looks like slag inside the cast and is very difficult to remedy because generally it does not occur at a single point. This defect generally occurs due to a defective mould or core, low binding strength of moulding material or sand. It is also due to low permeability of sand.

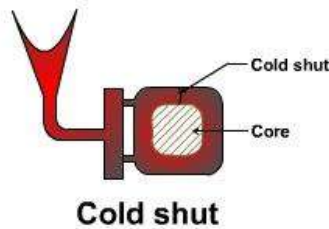


**4. Penetration:** This defect occurs when the fluidity of molten metal is high. When the mould is porous and does not have enough strength to resist molten metal, this defect occurs. The liquid metal penetrates the mould and mixes with sand. This gives an uneven casting surface.

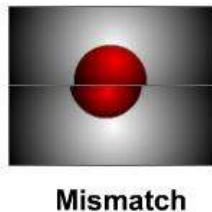


**Metal Penetration**

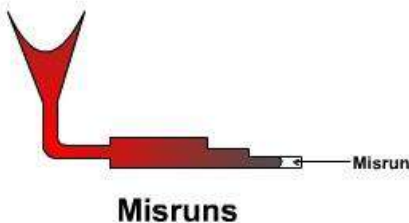
**5. Cold shut:** It is the basic defect which generally occurs. It occurs when the molten metal flows through two different paths. When the two streams of molten metal come in contact and solidify before they mix completely, some bubbles form between them. This phenomenon is known as cold shut. It is also known as cold lap.



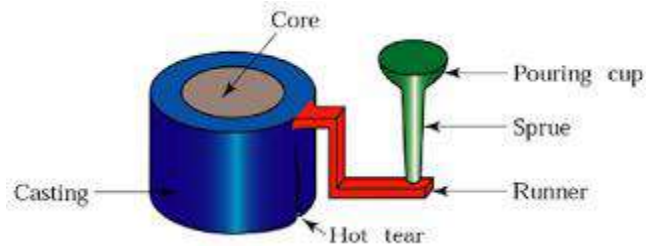
**6. Mismatch:** It is a defect due to mismatch of cope and drag. It is also known as shift. When the cope shifts relative to the drag, known as mould shift, and when the drag shifts, known as cope shift. It is due to the bounciness of the molten metal, loose box pins, etc.



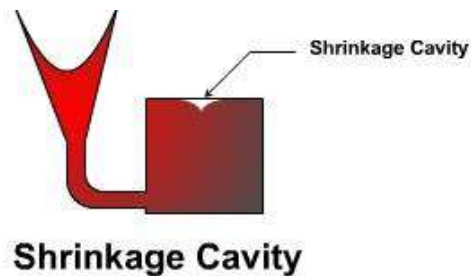
**7. Misruns:** Misrun is a phenomenon when the cast material solidifies before the proper filling of the mould. This results in the presence of incomplete cavity filling. It is due to too thin wall thickness, improper gating system, slow pouring, damaged pattern, and poor fluidity of molten metal.



**8. Hot tear:** A hot tear or crack is generally not visible because the casting has not separated into fragments. This is occurring due to uneven cooling and improper position of chills. This is generally occurring where there is an abrupt section change. This is occurring during solidification of casting when the solid portion has not sufficient strength to resist tensile force.



**9. Shrinkage:** This defect generally arises during volume contraction during solidification. It occurs when the liquid metal does not suffice to compensate the volume shrinkage. This is due to insufficient size of riser, improper direction solidification of casting, improper location of chills or in gates.



**10. Buckle:** The formation of uneven line on the cast surface is known as buckle. It generates due to failure of sand surface or expansion of sand surface due to heat of molten metal.

**11. Pin hole:** Pin holes are similar to blow holes but smaller in size. These are generally present at surface or sub surface and in large numbers. This is due to improper ventilation for gas and low permeability of moulding material.

**12. Warp page:** It is the defect or deformation in a casting that occurs during or after solidification due to different rates of solidification of different sections of casting, so stresses are set up in adjoining walls resulting in warpage in these areas.

**13. Swell:** This defect generated due to insufficient strength of mould when metal flow to the mould due to liquid metal pressure, the wall of the mould cavity damage. It is also due to rigidity of the pattern is insufficient then it cannot withstand with the ramming pressure and the wall of cavity damage.

**Advantages of casting process:**

1. Molten metal flows into small ant section in the molten cavity. Hence any complex shape can be easily produced.
2. Practically any material can be casted.
3. Ideal method is by producing small quantities
4. Due to small cooling rate from all directions, the properties of casting are same in all directions.
5. Any size of casting can be produced up to 200 tons.
6. Casting is the often cheapest and most direct way of producing a shape with certain desired mechanical properties.
7. Certain metals and alloys such as highly creep resistant metal-based alloys for gas turbines cannot be worked mechanically and can be cast only.
8. Heavy equipment like machine leads, ship's propeller, etc. can be thrown easily in the required size rather than fabricating them by joining several small pieces.

**Limitations of casting process:**

1. With normal sand casting process, the dimensional accuracies and surface finish is less.
2. Defects are unavoidable.
3. Sand casting is labour intensive.

**NONFERROUS FOUNDRY PRACTICE**

**ALUMINUM CASTINGS - ADVANTAGES, LIMITATIONS**

**ADVANTAGES**

- Many aluminium casting alloys display excellent fluidity for casting thin sections and fine detail.
- Aluminium casting alloys melt at relatively low temperatures.
- Aluminium casting processes can be highly automated.
- In many cases, multi component welded or joined assemblies can be replaced with a single cast part.
- Machining requirements are reduced.
- Aluminium castings display controlled variations in as-cast finish.

- Contrasts between as-cast and machined finishes can be highlighted to create pleasing cosmetic effects.
- Capital requirements are typically less than for wrought products.
- Tooling can range from simple patterns to complex tool steel dies depending on product requirements and production volume.
- Metallurgic ally or mechanically bonded bimetal parts can be routinely cast.
- Aluminium parts are routinely cast by every known process, offering a broad range of volume, productivity, quality, mechanization, and specialized capabilities.
- Most aluminium casting alloys display solidification characteristics compatible with foundry requirements for the production of quality parts.

### **LIMITATIONS**

- Very thin sections may not be cast able.
- There are practical limitations in size for specific casting processes. The solidification behaviour of some alloys precludes casting in difficult engineered configurations or in specific casting processes.
- The casting process is simpler and less capital intense than processes for producing forgings, extrusions, and rolled products. However, solidification in complex geometrical shapes, as with other fabrication options, can result in surface discontinuities and internal microstructure features with varying degrees of quality that affect properties and performance.

### **QUESTIONS**

1. Classify the types of furnaces. Explain briefly with sketch Gas pit furnace. **(June 2012)**
2. With a neat sketch explain the different zones present in CUPOLA furnace. **(Dec 2016)**

3. With a neat sketch explain the constructional features and working of electrical resistance furnace. List its advantages and disadvantages **(Dec 2016)**
4. With a neat sketch explain continuous casting process and mention its merits and demerits. **(Jun 2015)**
5. What is die casting? With a neat and labeled sketch, explain cold chamber die casting process? **(Jun 2015)**
6. With a neat sketch explain the constructional features and working of direct arc electrical furnace. **(Dec 2016)**
7. What is die casting? With a neat and labeled sketch, explain hot chamber die casting process? **(June 2013)**
8. Explain with neat sketch gravity die casting.**(May 2016)**
9. Explain with neat pressure die casting.**(Dec 2015)**
10. Explain with neat sketch Centrifugal casting, **(July 2014)**
11. Explain with neat sketch squeeze casting, **(June 2013)**
12. Explain with neat sketch thixo casting .**(May 2016)**
13. Explain with neat sketch slush casting .**(May 2016)**
14. With a neat sketch explain the working principle of coreless induction furnaces **(July 2014)**

\*\*\*\*\*