MODULE-2

MELTING & METAL MOLD CASTING METHODS

STUDY OF IMPORTANT MOULDING PROCESSES

Moulds can be prepared with ***sand*** or ***metal***. There are various ***sand moulds*** and ***metallic moulds*** in which castings are made. The following moulds are discussed below:

(a) Sand Moulds

- Green sand mould
- Dry sand mould
- Core sand mould
- Carbon dioxide mould (CO_2 mould)
- Shell mould
- Investment mould
- Sweep mould
- Full mould

(b) Metal moulds

- Gravity die casting or Permanent mould casting
- Pressure die casting
- Continuous casting
- Centrifugal casting
- Squeeze casting
- Slush casting
- Thixocasting process

a. SAND MOULDS

Green sand mould:
Green sand moulding is the most widely used process for casting both ferrous and non-ferrous metals.

Procedure involved in making green sand mould:

a) It is made from silica sand (85-92%), clay (bentonite binder) - (6-12%), water (3-5%) and additives are mixed to prepare green sand mixture.

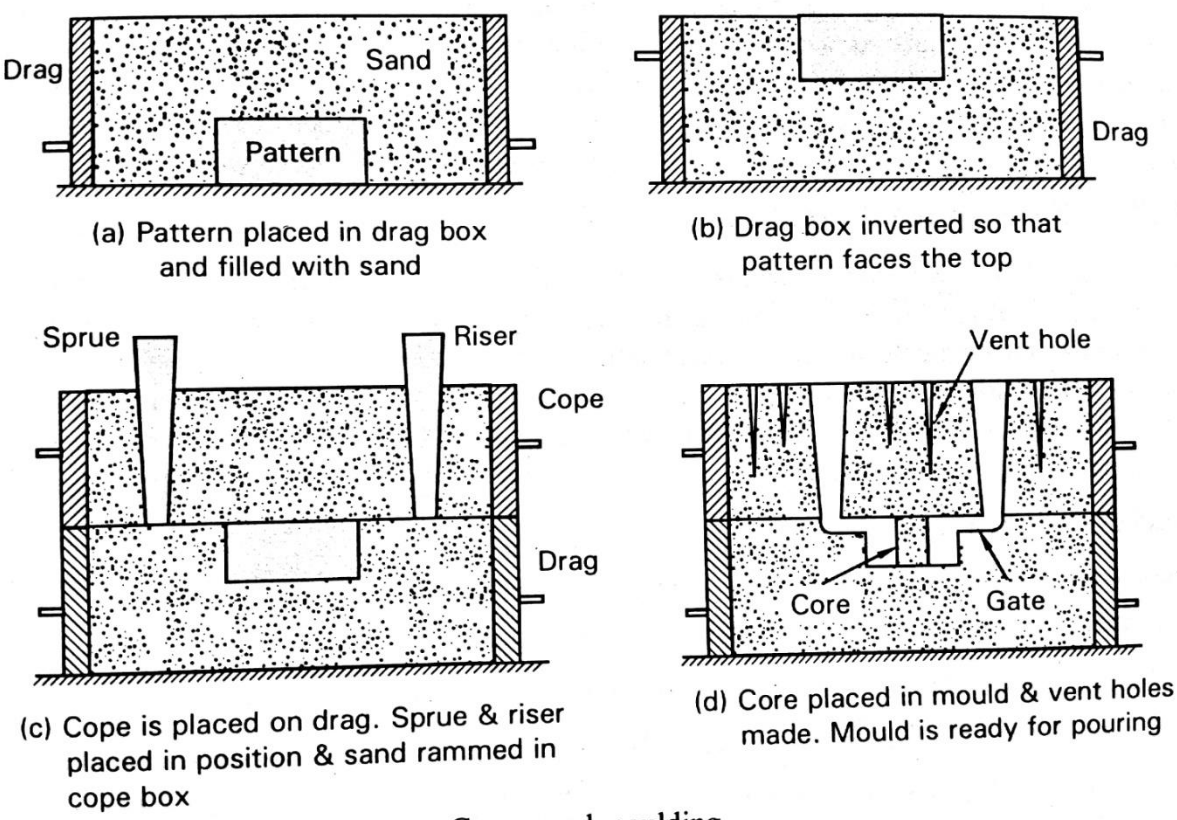
b) The pattern is placed on a flat surface with the drag box enclosing it as shown in fig 1(a). Parting sand *(it is dried silica sand)* is sprinkled on the pattern surface to avoid green sand mixture sticking to the pattern.

c) The drag box is filled with green sand and rammed manually till its top surface as shown in fig.. The drag box is now inverted so that the pattern faces the top as shown in Fig. Parting sand is sprinkled over the mould surface of the drag box.

d) The cope box is placed on top of the drag box and the sprue and riser pin are placed in suitable locations. The green sand mixture is rammed to the level of cope box as shown in fig.

e) The sprue and the riser are removed from the mould. The cope box is lifted and placed aside, and the pattern is the drag box is withdrawn by rapping it carefully so as to avoid damage to the mould. Gates are cut using hand tools to provide passage for the flow of molten metal. Fig. The mould cavity is cleaned and finished. Cores, if any, are placed in the mould to obtain a hollow cavity in the casting fig.

f) The cope is now placed on the drag box and both are aligned with the help of pins. Vent holes are made to allow the free escape of gases from the mould during pouring. The mould is made ready for pouring fig.



Green sand moulding

Advantages of green sand moulding:

- Least expensive method.
- Sand can be reused many times after reconditioning with clay and moisture.
- Preferred for simple, small and medium size castings.
- Suitable for mass production.

Disadvantages:

- Moulds prepared by this process lack permeability, strength and stability.
- The give rise to many defects like porosity, blow holes, etc., because of low

permeability and lot of steam formation due to moisture presence.
- Moulds cannot be stored for quite long time.
- Not suitable for very large castings.
- Surface finish and dimensional accuracy of castings are not satisfactory.

Dry Sand Moulding

Dry sand moulding is prepared in the same manner as that of green sand moulding, except that the mould is baked in a oven to remove the moisture present in the sand and also to harden the moulds.

Advantages:

- Strength and stability of dry sand moulds is high when compared to green sand moulds.
- Baking removes moisture and hence defects related to moisture are eliminated.
- Dry sand moulds give better surface finish and dimensional tolerance of castings.

Disadvantages:

- Consumes more time, labour and cost due to baking process, hence not suitable for mass production.
- Not suitable for large and heavy size castings, as they are difficult to bake.
- High capital cost of baking moulds in oven.
- Under baked or over baked moulds is another disadvantage.

Core sand moulding

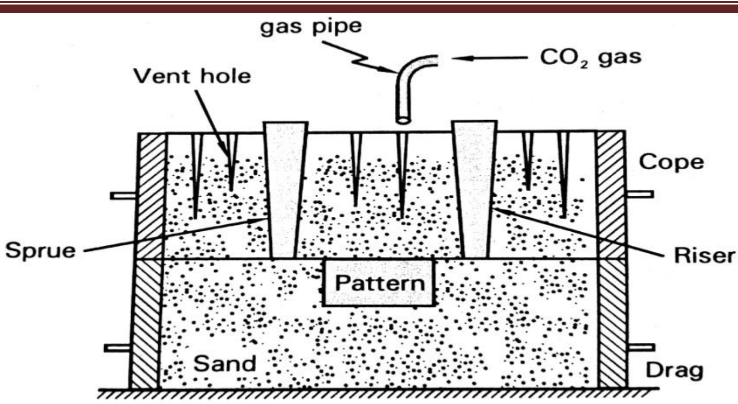
In this process, sometimes complete mould can be obtained by assembling a large number of intricate cores to obtain the desired mould cavity and the cores are baked to develop greater strength. Such a mould is called core sand mould. This is a useful moulding process when the intricacy of the casting is such that green sand moulding becomes impracticable. The motor block is a good example. Good surface finish can be obtained.

Carbon dioxide (CO_2) moulding

Carbon dioxide moulding also known as sodium silicate process is one of the widely used process for preparing moulds and cores. In this process, sodium silicate is used as the binder. But sodium silicate activates or tend to bind the sand particles only in the presence of carbon dioxide gas to form silica gel & sodium carbonate. For this reason, the process is commonly known as CO_2 process, as shown in fig.

$Na_2\,SiO_3 + CO_2$ $\quad$ $Na_2\,CO_3 + SiO_2$ $\Longrightarrow$
(Sodium silicate) (Silica gel)

Silica gel acts as a strong binder between silica sand grains and this process takes place without the application of heat.



CO_2 moulding

Advantages:

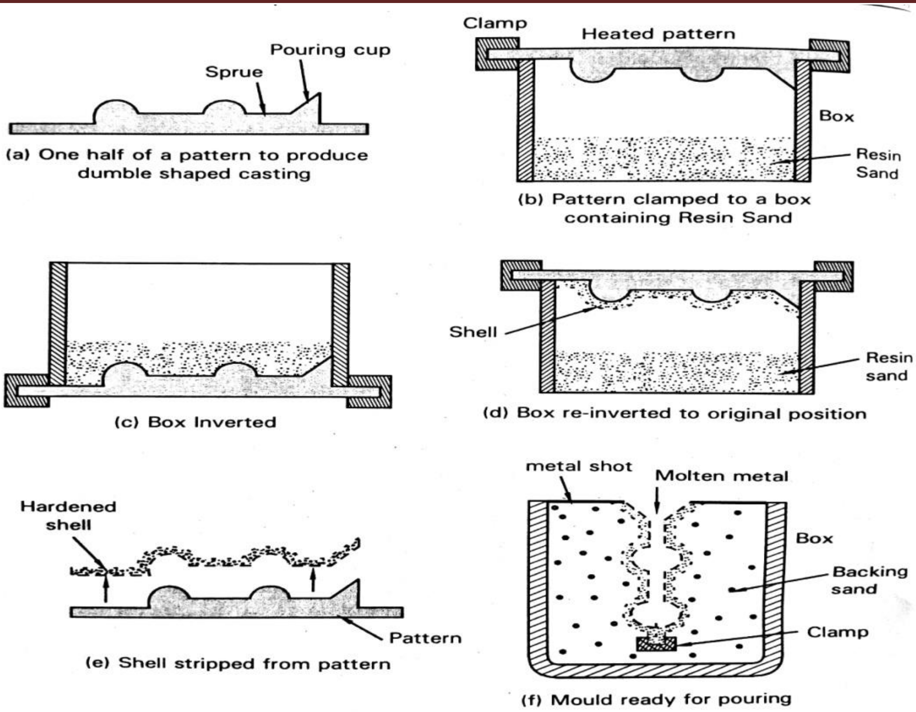
- Operation is faster, moulds and cores can be used immediately after processing
- Eliminates baking ovens
- Semi skilled labourers can be used.

Disadvantages:

- Moulds are more expensive compared to other process.
- Difficulty is reclaiming the used sand.

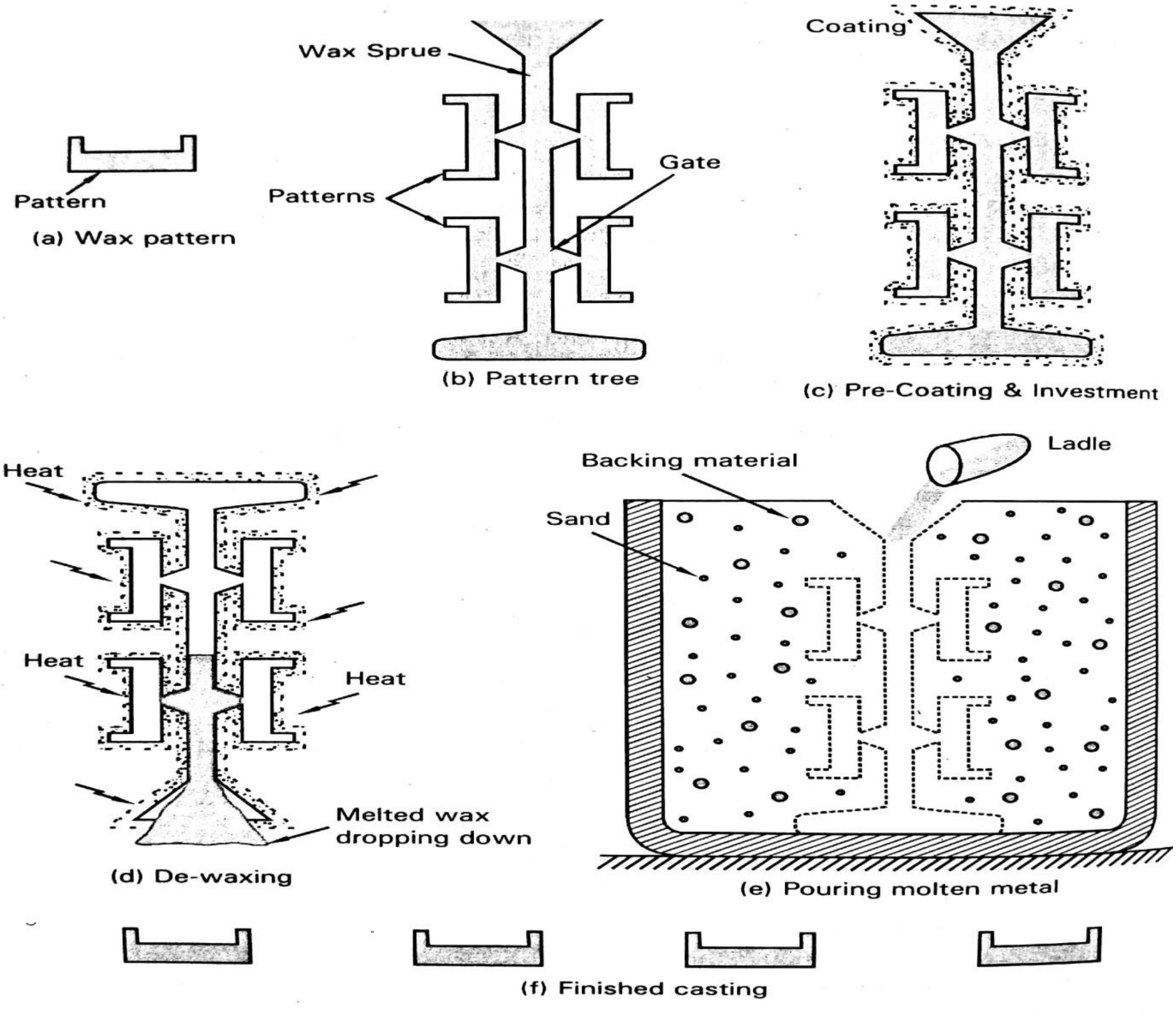
Shell Moulding

- It is a special form of sand moulding.
- It is used for producing small castings (up to 50 Kg steel castings)
- Very intricate, accurate, very good surface finish castings can be produced.
- Machining can be eliminated almost.
- Sand mix consists of washed and dried fine sand (+60 – 150 sieve), 3-4% thermosetting binder (urea/phenol formaldehyde) resin.
- Sand mix is prepared dry in a mixer and taken in a box.
- A metal pattern (aluminium) is heated 200-250^{o}C and coated with the releasing agent. (silicon grease) (only one half of the pattern is used).
- The sand mix is dumped on the heated metal pattern.
- A thin layer/shell of sand is formed on the pattern in about 30 sec.
- Now the shell along with the pattern is cured in a oven at about 300 ^{o}C for 2 to 3 min. to make the shell strong.
- The shell is ejected out of the pattern.
- Similarly another half of the shell is prepared.
- Two halves are joined together with the gum.
- The completed shell is kept in an empty mould box and packed with sand, metal shots or gravel as support.
- Molten metal is poured through the sprue and castings are made.
- The pattern along with gates and riser are fixed on to a metal plate to facilitate preparing the shell, i.e., heating, coating with the resin sand and ejecting the shell easily. Fig. 3.



Shell Moulding

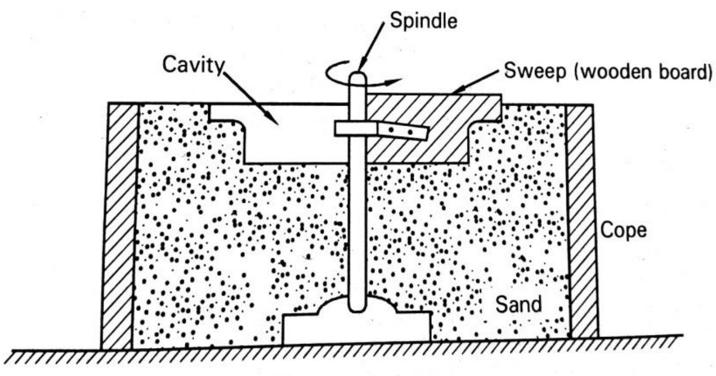
Investment shell moulding (Investment moulding)



Investment moulding

- Is a process to produce intricate, complex shape and highly smooth surface casting.
- Absolutely no machining is required on the casting.
- Any metal or alloy can be cast in the shell.
- A disposable pattern material such as wax is used. Wax is the most popular pattern material used.
- Sand mix is a refractory slurry consisting of -200 mesh sand, a binder (ethyl silicate or colloidal silica etc.) accelerator (HCl), water.
- First the required shape of the pattern is got by injecting molten wax into a metallic die. After freezing, the pattern is taken out of the die.
- A number of patterns may be attached onto a common sprue with necessary gates, to form a cluster.
- The cluster pattern is dipped in the refractory slurry and taken out. A thin layer of coating is formed on the pattern.
- This process is continued several times (7-8) so that 8-10mm shell thickness is formed.
- Now the shell is heated suddenly at 110-1200oC to remove wax as well as sintering the shell (to harden the shell).
- The sintered shell with the cavity is ready to receive molten metal.
- After casting the metal, the shell is broken and the required castings are separated/cut off from the sprue and gate.
- Wax is collected and reused.
- The castings are then collected for dispatch.
- All types of metals and alloys can be easily cast.
- Mainly Ni alloys, alloy steel, high temperature alloys are cast.
- Surgical instruments, turbine blades, aerospace parts, etc., are produced by this method.
- Process is costly.

Sweep Moulding



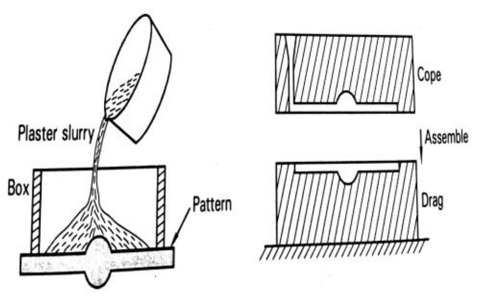
Sweep moulding

In sweep moulding, the cavity is formed as the pattern sweeps the sand all around the circumference.

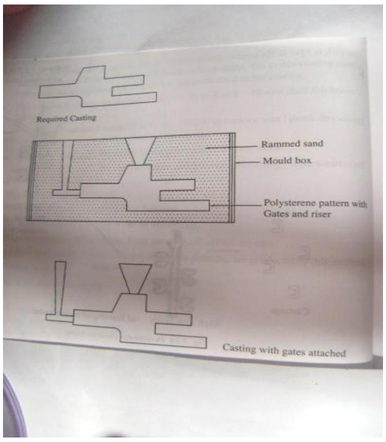
A thin wooden piece is attached to the spindle at one edge while the other edge has a contour depending on the desired shape of the casting. (Refer Fig. 5). The spindly is placed at the center of the mould and rotated so that the wooden piece sweeps in the mould box generating the shape of the required casting. Green sand, loam sand or sodium silicate sand can be used to prepare moulds. The process is used for producing large castings of circular sections and symmetrical shapes.

Full Moulding

- The mould contains pattern along with the sand.
- No cavity is seen in the mould.
- When molten metal is poured into the sprue, mould cavity is created instantaneously.
- The pattern burns off and makes away for the molten to occupy the space left.
- Hence the name full moulding.
- Here polysterene pattern is used.
- Polysterene has very low ash content and burns of easily at molten metal temperature.
- Extremely complex shaped castings can be made by this method.
- Any metal or alloy can be cast.
- Pouring rate of metal is very important in the process.
- Regular moulding sand can be used for moulding.
- Pattern is placed in the mould box and sand is rammed alround.
- The pattern with gates and riser is left in the mould itself.
- Molten metal is poured through the sprue at a rapid rate.
- Pattern burns off, cavity is created in its place and molten metal fills up this, instantaneously.
- Thus mold cavity is created and is filled up with liquid metal at the same time.
- After cooling, the casting is taken out (solidified metal).
- Each time a new pattern must be used, to produce a casting.



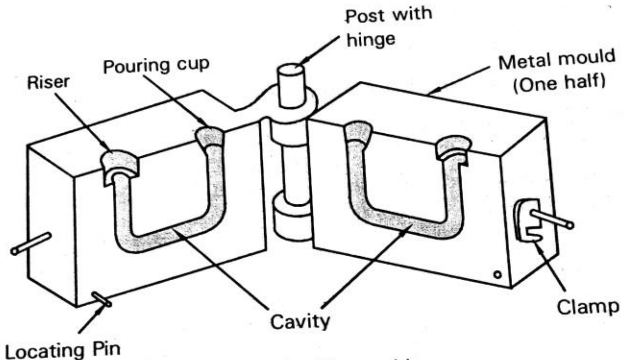
Plaster moulding



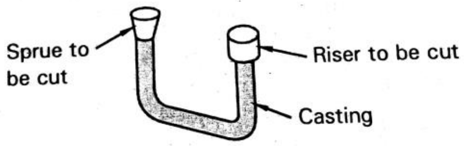
- Good accurate, consistent quality castings can be produced in the mould.
- Very much useful in mass production.
- The molten metal is subjected to gravitational force.
- Suitable for small & medium size castings.
- Section thickness of <6mm can be cast.
- The metal moulds incorporate gating & risering.
- Process is costlier than sand mould.

Gravity die casting or Permanent mould casting

- It is referred to as ***Gravity Die Casting*** or ***Permanent Mould Casting***. The
- process makes use of a metallic mould to produce the casting.
- Two halves of the dies are used to produce the casting.
- The die halves are cleaned well first.
- Then the dies are preheated.
- The dies are coated with a refractory mould coating.
- The die halves are closed and clamped.
- Molten metal is then poured into the cavity via sprue/pouring cup and allowed to solidify under gravity or atmospheric pressure.
- Metal is then allowed to cool.
- After solidification, casting is removed by opening the mould/die halves.
- The molten metal cools faster in metal moulds than in sand moulds.
- Section >6mm thickness can only be cast.



(a) Metallic mould



(b) Solidified casting

Gravity die casting

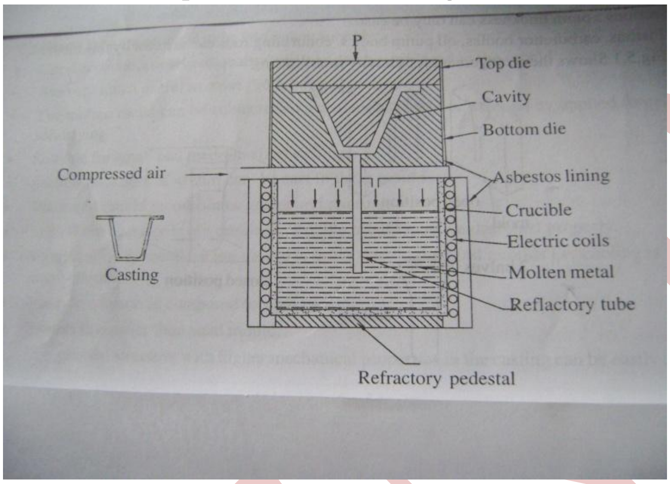
- Ex. Piston, carburetor bodies, oil pump bodies, connecting rods, etc.

Pressure die casting

- Here also a permanent mould in two halves is used to produce castings, repeatedly.
- But external pressure is used to force the molten metal into the mould cavity.
- Hence much thinner castings can be produced as compared to gravity castings.
- It can be further classified as *Low Pressure Die Casting* (LPDC) and *High Pressure Die Casting* (HPDC).

Low Pressure Die Casting (LPDC) process:

- Here a pressure of approximately 1N/mm^2 is applied on the molten metal during solidification.
- Die halves are closed and molten metal is poured into the mould cavity and pressure is applied immediately.
- After few minutes, the die is opened and the casting is removed.



Construction:

- *Consists of a crucible positioned inside a resistance type electric furnace.*
- *Metal ingots are placed inside the crucible and current is passed through the coils.*
- *Temperature of the molten metal is maintained constant.*
- *The entire crucible and furnace is housed inside a metal chamber.*
- *The lid of the crucible is closed with asbestos lined hollow plate with an opening for passing air through the plat. The plate has holes extended to the inside of the crucible.*
- *A refractory tube enters the molten bath and connects the die cavity.*
- *Whenever compressed air is passed through the opening the molten metal is pushed upwards through the pipe into the die.*
- *After the metal cools casting is removed from the die.*
- *Thin castings can be made.*

High Pressure Die Casting (HPDC) process

- A pressure of 7-500 N/mm^2 is applied on the molten metal during solidification.
- Very thin and intricate castings can be made.
- Very high mechanical properties, good surface finish castings can be produced.
- Section thickness, 6mm can easily be produced.
- Any metal or alloy can be cast.
- Very large number of castings can be produced in a single die.

  High pressure die castings can be classified into:

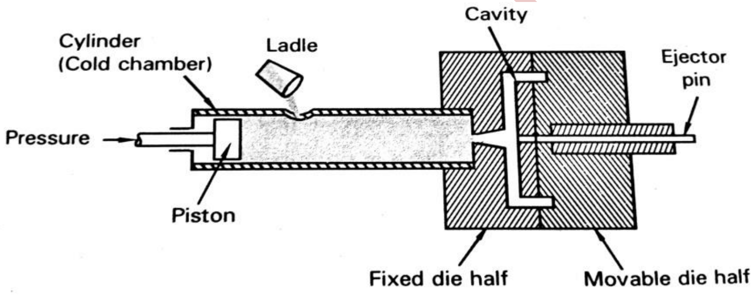
  1. Cold chamber die-casting process (CCDP)

2. Hot chamber die-casting process (HCDP)

- In CCDP, molten metal is poured outside the die chamber and then forced into the die.
- There will be a drop in the metal temperature by the time it reaches the die cavity.
- A separate melting unit is used to prepare the molten metal.
- In HCDP, molten metal is carried through a unit which a submerged in the molten metal itself. And the molten metal is forced into the die cavity. Hence, the metal does not loose any temperature at all.

Cold Chamber die casting process (CCDP)

It consists of a cylinder and a plunger arrangement. One end of the cylinder is connected to the movable die. A fixed die engages the moveable die. The moveable die and cylinder move together. The cylinder has an opening on the periphery. Through this opening the molten metal is poured inside the cylinder. As and when the plunger moves towards the die, the molten metal is forced into the die with high pressure. The dies are separated after few seconds. By the help of an ejector solidified casting is removed. Process is repeated.



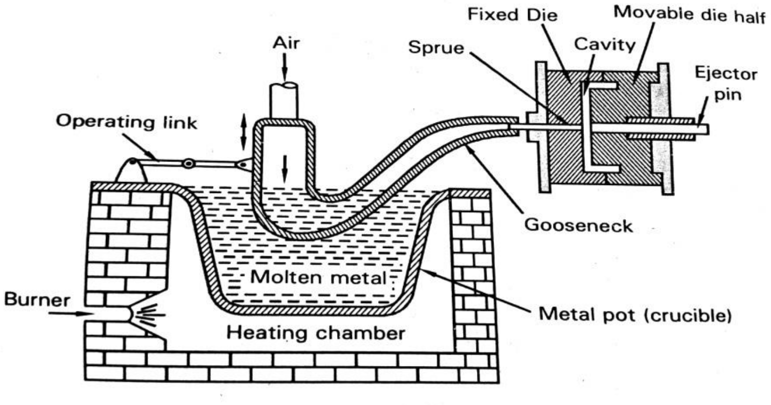
Cold chamber die casting

- Dies in closed position. Molten metal poured into the cylinder
- Plunger pushes the metal into the die out.
- Moveable die and plunger moves out.
- Ejector pushes the casting out of the die.
- Dies close and ready for the next casting
  Very high pressure 20-200 N/mm^2 is applied through the plunger.

Hot Chamber die casting process (HCDP)

i) Using compressed air

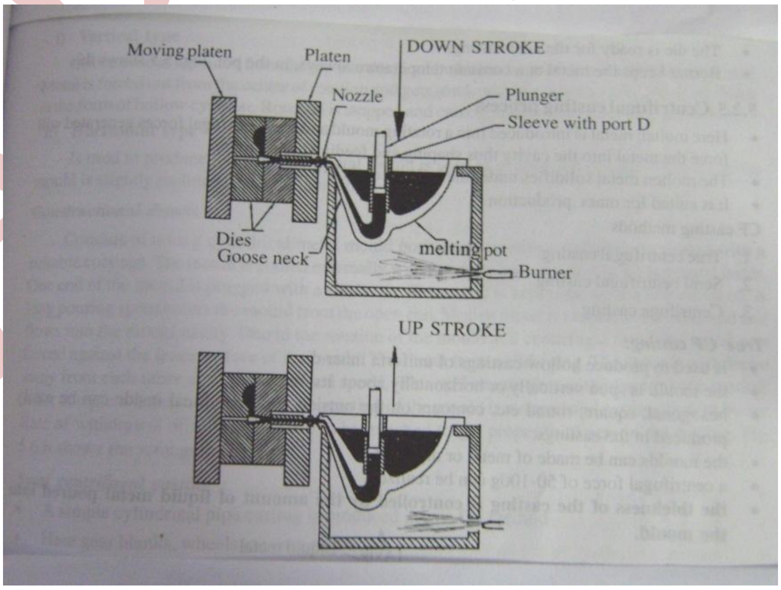
- It consists of a goose neck chamber housed in a melting pot.
- Melting pot holds liquid metal and is heated by a furnace.
- The goose neck has a nozzle end which connects the die opening.
- The die is closed and the goose neck chamber draws molten metal from the melting pot.
- Now compressed air is allowed into the goose neck chamber.
- This forces molten metal into the die cavity.
- The molten metal solidifies after few seconds.
- The die is opened and the solidified casting is ejected out.
- The die is ready for the next cycle.



Hot chamber die casting (Goose neck type)

ii. Using a plunger:

- It consists of a melting pot with a goose neck secured on to brick lining.
- The pot is heated from outside.
- A burner is located which supplies flame for heating the pot.
- Molten metal enters the goose neck chamber through the inlet.
- The goose neck portion of the chamber ends as nozzle and connects the opening of the dies (fixed end).
- The die is closed to start with.
- The goose neck chamber draws molten metal from the pot. Goose neck connects the die.
- Now the plunger moves down forcing molten metal into the die cavity. Plunger is withdrawn after few seconds.
- After few seconds the metal solidifies. The die is opened and casting is taken out.
- The die is ready for the next casting.
- Burner keeps the metal at a constant temperature always, in the pot. Refer Fig. 10.

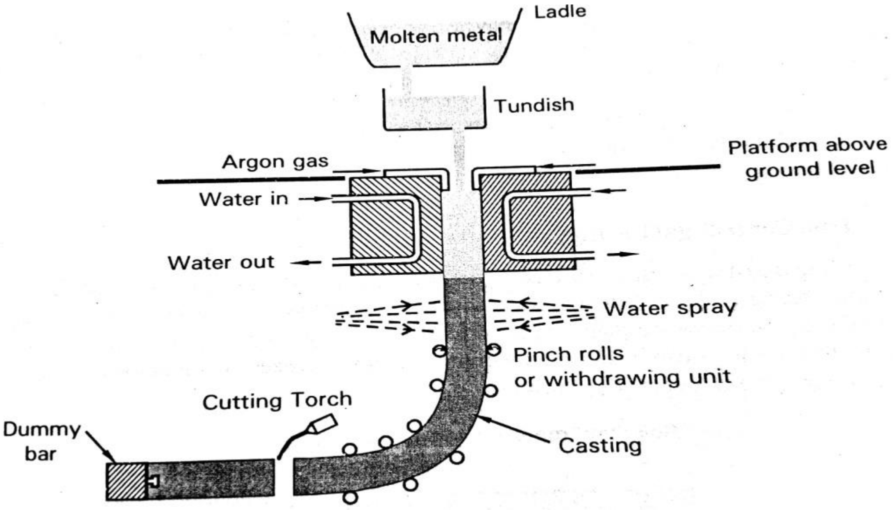


Hot chamber die-casting machine (using plunger)

Continuous casting

Here liquid metal is directly converted into solid form in one stretch to produce billets, bars, structural sections, etc.

It is a continuous casting process in which the operation of pouring, solidification and withdrawal of casting from an open mould are carried out continuously.



Continuous casting

- The molten metal is continuously supplied from the ladle to the intermediate ladle called tundish, through the opening in the tundish; the molten metal is fed into the mould with minimum turbulence and keeping the level at a constant position.
- The mould is usually made of copper or graphite is open at the bottom and is water cooled to extract the heat of the metal causing its solidification. The shape of the mould corresponds to the shape of the desired casting.
- The process is started by placing a dummy bar at the bottom of the mould upon which the first liquid metal falls.
- 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.
- The metal after coming out of the mould is further cooled by direct water spray (or water with air) to complete solidification.
- 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.

  Note: The dummy bar is initially placed at the bottom of the mould to receive the first liquid metal. It is latter disconnected from the casting.

Advantages:

1. No wastage of metal, no riser / no runner / no ingate are required.
2. The casting yield is very high almost 100%.
3. Continuous production of castings can be carried out which is not possible in other processes.
4. Since directional solidification is present, the casting will have superior properties.

5. Grain size can be controlled very easily by controlling the cooling rates.
6. Human skill is almost eliminated.
7. Surface of the casting will be extremely good.
8. The output of the continuous casting can be easily converted to sheet, bar billet et.
9. Complete automation is possible.

Disadvantages:

1. Initial cost of equipment is very high.
2. Close maintenance of the plant is very much desirable.
3. Cost of the product is on the higher side.

Centrifugal casting

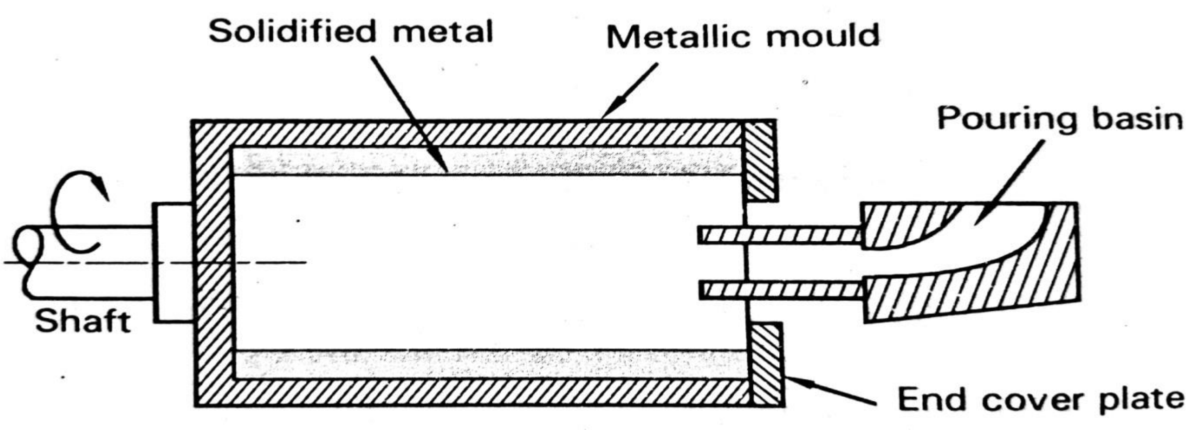
Centrifugal casting is a process in which the molten metal is poured and allowed to solidify in revolving mould. The centrifugal force due to the revolving mould holds the molten metal against the mould wall until it solidifies.

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.

a. 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 perfectly (theoretically) round due to radially symmetric forces. This eliminates the need for cores for producing hollow castings.



True centrifugal process

Process:

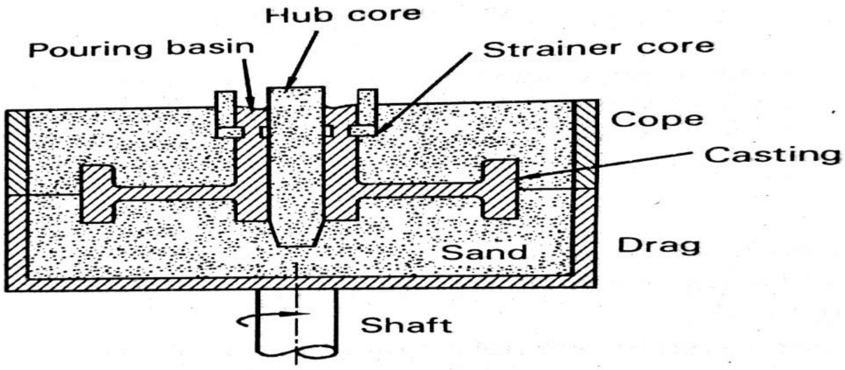
1. The mould of the desired shape is prepared with metal and the walls are coated with a refractory ceramic coating.
2. The mould is rotated about its axis at high speed in the range of 300-3000 rpm. Measured quantity of molten metal is poured into the rotating mould.
3. The centrifugal force of the rotating mould throws the liquid metal towards the mould wall and holds the molten until it solidifies.
4. The casting cools and solidifies from its inner surface towards the axis of rotation of the mould thereby promoting directional solidification.
5. The thickness of casting obtained can be controlled by the amount of liquid metal being poured.

Note: The mould can be rotated horizontally or vertically. When the mould is rotated about a *horizontal axis*, a true cylindrical inside surface is achieved, if rotated on a *vertical axis*; a parabolic inside surface is achieved.

Cores and gating / risering systems are not required for this process.

b. Semi Centrifugal Casting

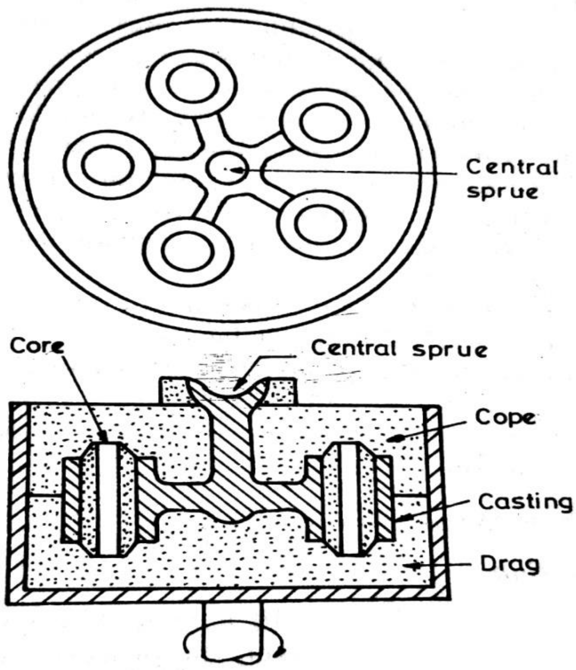
- It is a process to produce solid castings and hence requires a core to produce hollow cavities.
- A simple cylindrical pipe casting is produced in true CF method.
- Gear blanks, wheels, pulleys are produced.
- CF force is used to force the molten metal to get the shape in the casting.
- A speed of 300-500 rpm is employed.
- Cope and drag moulds are made in sand and fixed on to the casting machine.
- Core is also assembled.
- The riser extended to the top surface acts as pouring basin.
- The mould is kept rotating and molten metal is poured
- Molten metal gets thrown outward forcing it against the mould wall.
- Molten metal solidifies and casting shape is formed.
- After cooling, casting is taken out.
- A fresh mould box is kept and the process is repeated.



Semi-centrifugal process

Centrifugal Casting

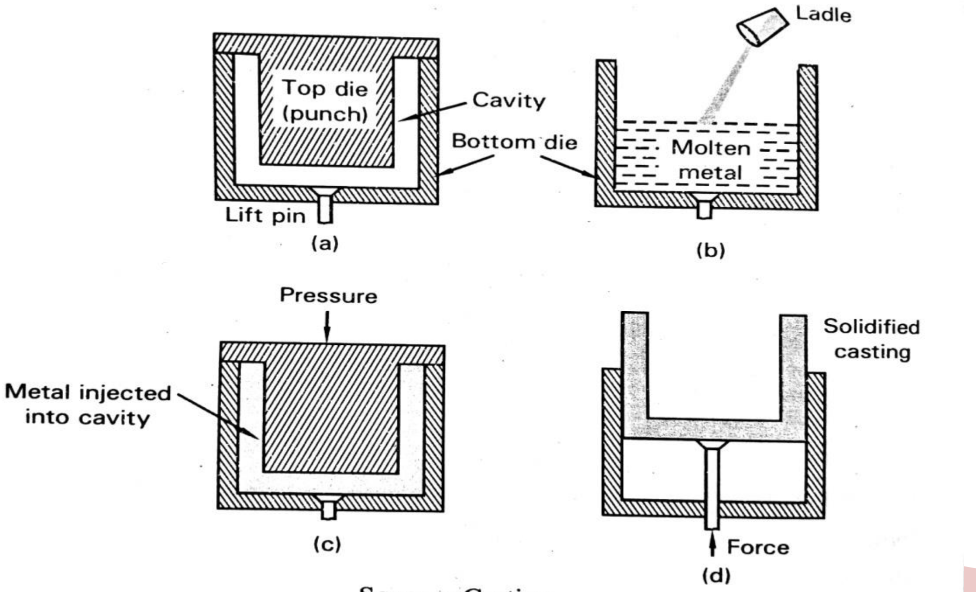
- A number of castings whose axis is away from the axis of rotation can be made each time.
- Any casting shape that can be created in the sand mould can be formed in this process.
- A number of mould impressions are grouped around a central sprue and subjected to CF force due to rotation.
- Small castings are done by this method.



Centrifuge casting

Squeeze casting

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



Squeeze Casting

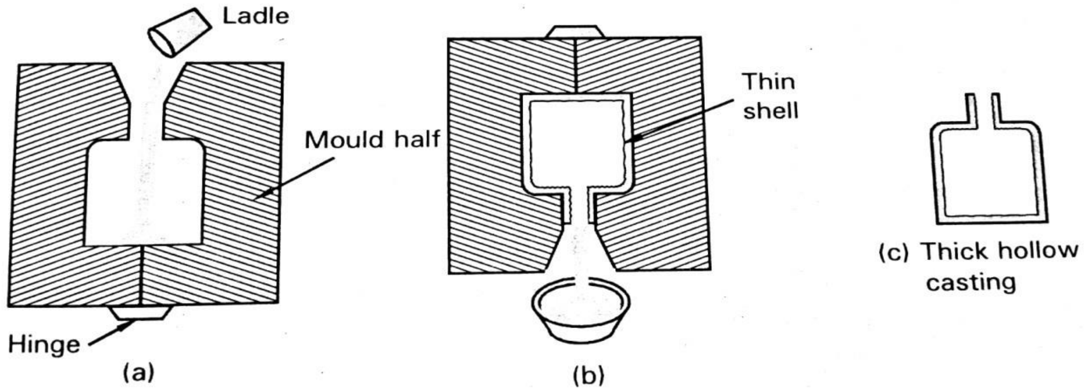
Process:

1. 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.
2. The bottom die is preheated to around 200-25$0^{o}$C with the help of torch and sprayed by a water based graphite lubricant to facilitate easy removal of casting after solidification.
3. Measured quantity of molten metal is poured into the bottom die as shown. 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.
4. The squeezing pressure is applied until solidification is completed.
5. The casting is ejected by operating the lift pin provided in the bottom die, and the die is made ready for the next cycle.

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

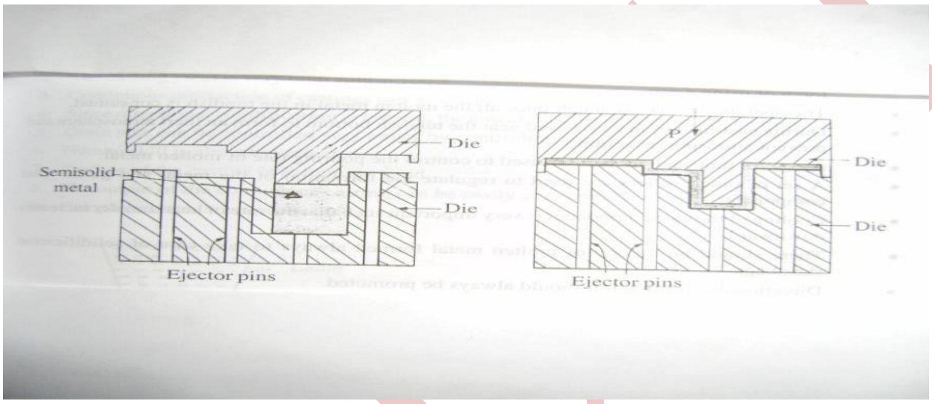
Slush casting

- Castings with external features having aesthetic value are made by this technique.
- Castings will be hollow inside and wall thickness may be non-uniform.
- Core is not required for the purpose.
- Ex. Lamp posts, statues, toys, etc are produced by this method.
- Molten metal is poured into the metal mould.
- After few seconds the mould is inverted and the molten metal is drained out into a container.
- A thin layer of solidified metal is formed in the mould.
- The mould is opened.
- The thin layered hollow casting is taken out.



Slush casting

Thixocasting process



In this process, semi solid metal is subjected to compressive force inside a die and the metal, is shaped as required.

Principle:

A known quantity of metal is heated in a furnace to its softening point then subjected to external force when kept inside a die cavity. Since the metal is subjected to squeezing action, when it is in plastic state or semi-solid state, it is referred as ***"Thixocasting".***
Process:

- The metal pieces are kept in a furnace and maintained at a known temperature.
- When the metal reaches to a pasty zone as indicated by an indicator, semi-solid metal is transferred into the cavity and forced between two dies.
- The dies used for the purpose are capable of withstanding wear & tear and high temperature.
- The semi-solid metals cool very fast and gets solidified. The component is withdrawn, the
- casting is ejected out. Fig shows the details.

Metals and alloys are converted to liquid state using an equipment (a refractory lined metallic shell wherein this conversion takes place) called ***"furnace".***

The source of heat provided to the furnace for the conversion of solid to liquid is called as ***"melting furnace".***

Furnaces are selected based on the type of metal to be melted, quantity, fuel used and quality of metal required, etc.

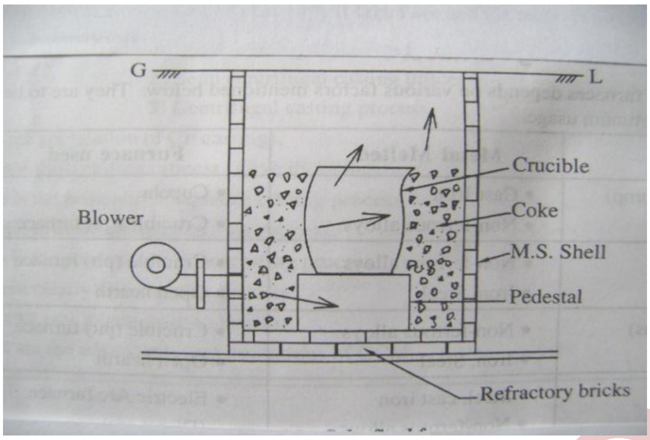
CLASSIFICATION OF FURNACES

The melting furnaces used for melting various ferrous and non-ferrous metals and alloys can be classified based on:

Fuel	**Metal melted**	**Furnace used**
Coke (solid lump)	• Cast iron • Non-ferrous alloys	➢ Cupola ➢ Crucible/Pit furnace
Oil (liquid)	❖ Non-ferrous alloys ❖ Iron, steel	▪ Crucible (pit) furnace ▪ Open hearth
Gas (gaseous)	▪ Non-ferrous alloys ▪ Iron, steel	❖ Crucible (pit) furnace ❖ Open hearth
Electricity	○ Steel, cast iron ○ Non-ferrous alloys ○ Iron, steel	• Electric Arc furnace (Direct arc) • Resistance furnace • Induction furnace

COKE FIRED FURNACE

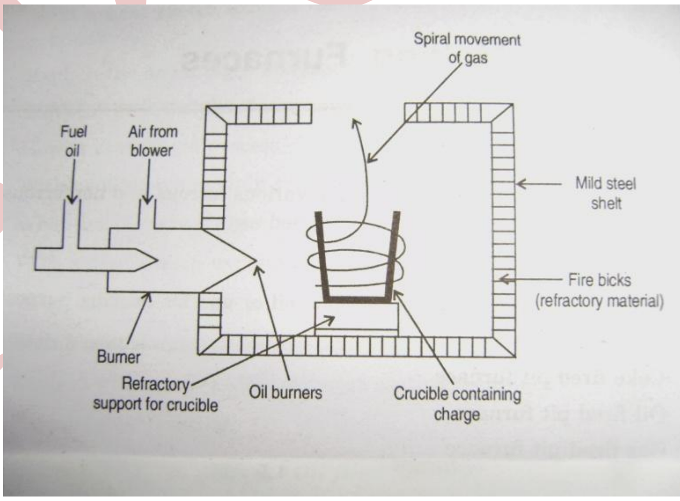
In this type of furnace, the crucible kept on the pedestal (refractory support) charged with the ingot, coke lumps are packed around the crucible and ignited. Once it starts burning, blower is switched on, and then the coke is charged slowly, till the coke reaches the level of crucible. A lid is placed on the crucible and the blower is kept full blast. Metal starts melting and once it reaches the desired temperature blower is switched off. Crucible is taken out, and the molten metal is treated and poured.



Coke fired furnace

OIL FIRED FURNACE

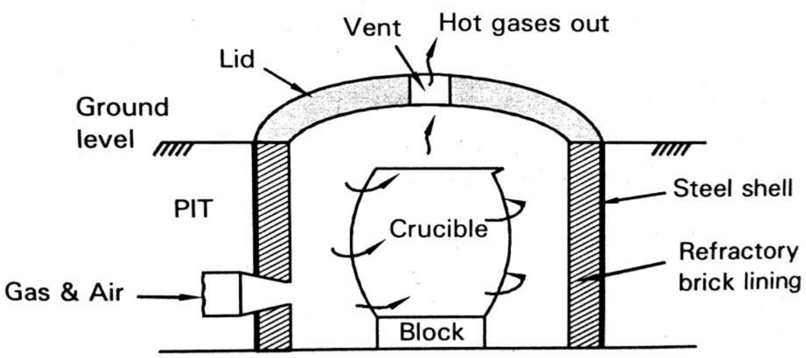
In this type of furnace, the crucible kept on the pedestal (refractory support) charged with the ingot. A burner is situated at the bottom on one side. Valves are provided to control the amount of air and oil supplied to the burner, so that the flames can be controlled. The oil from the burner is ignited and the desired flame is controlled by valves. After the metal melts and attains the desired super heat, the crucible is taken out and the molten metal is treated and poured.



Oil fired furnace

GAS FIRED FURNACE

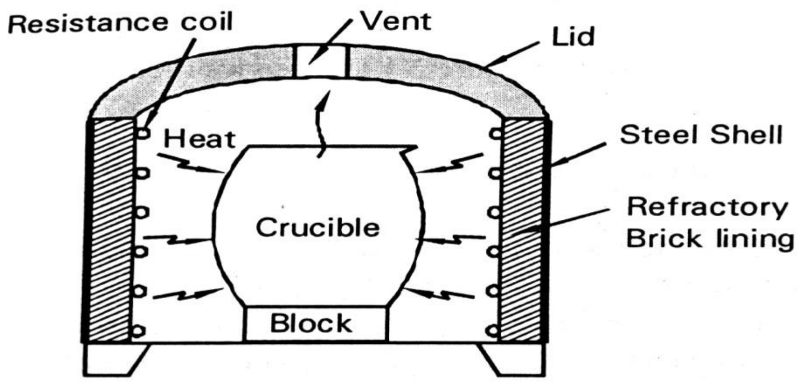
Fire is created at the bottom using waste/coke/wood, etc. Gas is blown through the burner. This will create a flame and heats the inside of the lining. The burner is switched off and the crucible with ingots is placed. The burner is switched on. Flame will sweep round the crucible and the flame is used to melting. Once the metal reaches the desired temperature, the burner is switched off and the crucible is taken out and the molten metal is treated and poured.



Gas fired pit furnace

RESISTANCE FURNACE

Fig. shows the indirect type of resistance furnace. It consists of current carrying coils inside the refractory bricks. The crucible with ingots charged is kept in the furnace on the pedestal and the lid is closed. Current is switched on. The temperature of the furnace is controlled by a temperature controller. The melting starts slowly. After completion of melting, the lid is opened; crucible is taken out for pouring. Heating takes place due to the resistance offered by the coil material on the principle of I^2Rt. This type of furnace is normally used for melting non-ferrous alloys.



Resistance furnace

Principle of working:

Due to the flow of current in the coil, the metal of the coil offers resistance and heat is generated according to the formula:

$Q = I^2 R t$ joules

where, Q = heat generated in joules

I = flow of current in amps

R = resistance of the coil in ohms

t = time of current flow in seconds

The heat generated from the coil is utilized to heat the metal in the crucible to melt. Very cleaned molten metal is easily obtained. Controlling is very easy.

INDUCTION FURNACE (IF)

It is the most popular furnace for carrying out melting operation with simplicity. Good quality of melt can be obtained. It works on the principle of induced ***emf*** as in the case of transformer. Molten metal acts as the secondary and the current carrying conductor acts as the primary.

Principle of working

- Induction furnace works on the transformer principle
- Water cooled copper coil carrying current acts as the primary
- The metallic charge in the crucible acts as secondary
- Current induced in the charge is by electromagnetic induction
- The charge offers resistance to the flow of induced secondary current
- Due to this, heat is developed and the charge starts melting
- Induction furnace is capable of melting all types of metals and alloys from small quantities to large quantities (25 kg to 10T) very easily, conveniently and quickly.
- Due to the induced emf caused, stirring of molten metal in the melting process is the special feature, thereby gives excellent homogeneity in the composition
- The furnace houses a crucible inside copper coils.
- The crucible is formed by ramming refractory grains and sintering it
- A sheet of mica or asbestos separates the coil and the refractory
- The outer shell of the furnace is made of mild steel

Types of Induction Furnace

The types of induction furnace are:

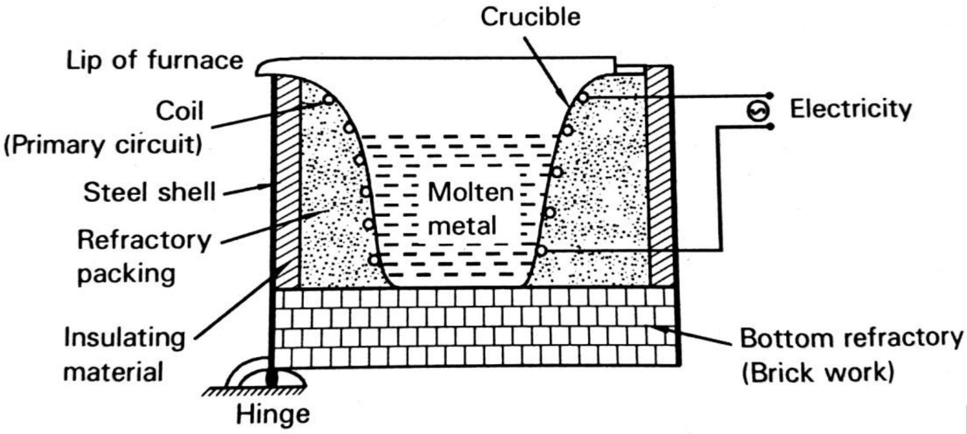
- Core type I.F.
- Core less type I.F.

In the first type the coils are surrounded by the molten metal.

In the second type the coils surround the molten metal.

Coreless type I.F.

The constructional features of coreless type I.F.



Coreless Induction furnace

- The furnace consists of an outer cylinder steel shell and is hinged at the bottom front side to facilitate tilting for pouring.
- The inner surface of the shell is covered with mica or asbestos and the bottom surface is covered with refractory bricks.
- Next to the insulation layer hollow copper tube coils are present for the entire height of the shell.
- These tubes carry current and are water cooled.
- A layer of insulation is provided to the coils.
- Compacted ramming refractory packing is provided above the bricks to form the base.
- A thin steel (shell) former is provided on the top of the base.
- The annular space between the shell and the coil is rammed with the ramming mass.
- The steel former holds the ramming mass surrounding it.
- The top of the furnace front ends in the form of lip or spout to facilitate the metal to flow.
- The inside portion of the former determines the furnace capacity.

Working principle

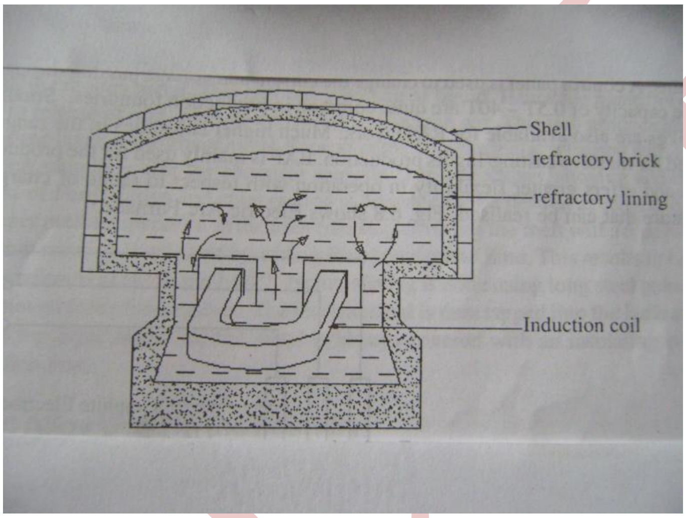
- The furnace works on the principle of a transformer in which the copper coils acts as primary and the charge (scrap) as secondary.
- Sintering consists of passing low amperage current through the coil for several hours.
- Due to this, emf is induced in the former and gets heated up.
- The former becomes red hot and this starts heating the ramming mass and sinters.
- Slowly layer by layer of refractory mass gets sintered.
- The current is slowly increased and heating is continued for several hours.
- Loose thin scrap is slowly charged into the crucible.
- The scrap slowly starts melting and liquid metal pool is formed.
- After some time molten metal starts stirring and the stirring action is due to the eddy

current induced in the metal which will be flowing opposite to the direction of main current.

- The stirring action or churning ensures homogeneous molten metal.
- Necessary alloying elements can be easily be added.
- The charge needs to be properly selected, since slag removal is difficult due to stirring action.

Core type of induction furnace

Here the oil is surrounded by the metal. The principal of working is the same as above. The furnace is not very popularly used in practice.



Core type induction furnace

ELECTRIC ARC FURNACE

It is a versatile furnace used to melt mainly steel. It makes use of electric current to generate the arc in the metal. The arc heats and melts the charge. Melting using electricity as a source of energy is more common. This is because electric furnace provides more flexibility and cleanliness in operation.

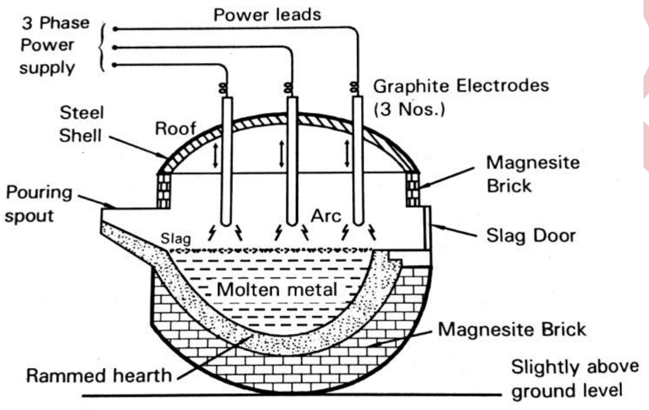
These are suitable for the production of high quality of steels. There are two types of electric arc furnaces:

1. Direct Arc Furnace
2. Indirect Arc Furnace

Direct Arc Furnace

It consists of a steel shell, cylindrical in shape with a spherical or flat base, which is mounted on rollers to enable tilting the furnace to tap out the molten metal. The shell is lined with fire bricks. The roof is made of silica bricks. The hearth is lined with basic material such as magnesite bricks. The charging may be done either from the top or from the side. In top charging type the roof can be swung along with electrodes, while in side charging type, a side door is provided. A tapping hole with spout is provided to tap out the molten metal.

Generally, three electrodes are arranged in a triangular pattern. These electrodes can be raised or lowered by mechanical or other automatic means. This helps in setting the arc and to maintain the desired temperature. The electric current (three phase) is led into the furnace through the three carbon or graphite electrodes. The arc is struck between the electrodes and the charge. The arc gives out high temperature (about 2000 to 5000^{o}C) which melts the charge below the electrodes. Gradually, a pool of molten metal forms below the electrodes, which in turn melts the remaining metal in the furnace.



Direct arc electric furnace

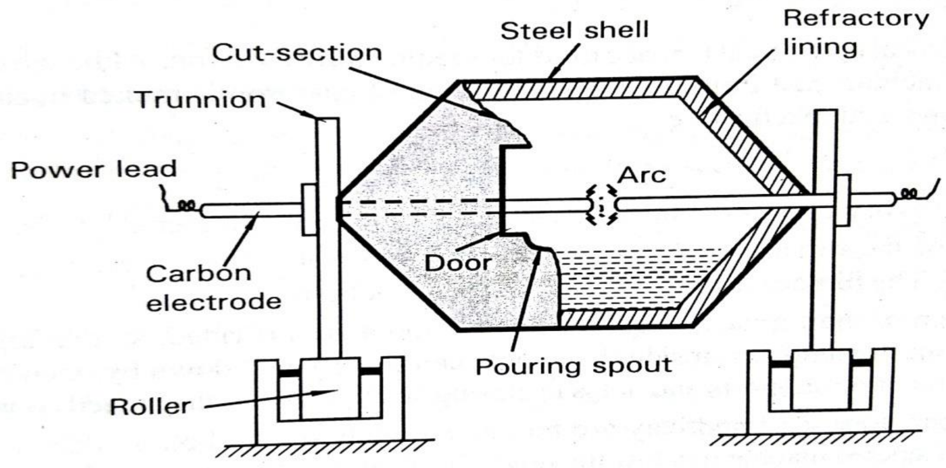
The electrodes should have high electrical and low thermal conductivity, good refractoriness and resistance to oxidation or chemical reaction also should have good strength at high temperature. Usually graphite or amorphous carbon is used as electrode material.

Then excess slag is removed from the slag door. The molten metal is then tapped into the ladle and taken for teeming.

Indirect Arc Furnace

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

The furnace consists of a cylindrical or barrel shaped shell lined with a refractory material. The shell is mounted on rollers and can be titled through 180^{o}. This facilitates for easy pouring. Also, the rollers provide rocking action to the furnace that speeds the melting rate.



Indirect arc electric furnace

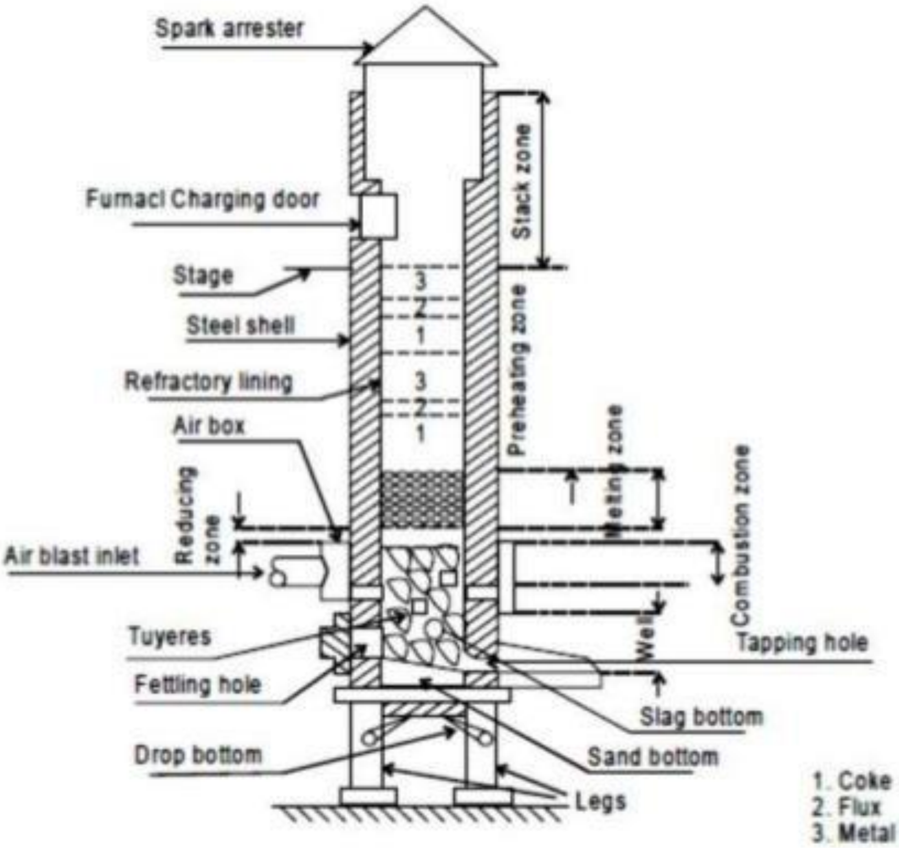
Two carbon electrodes are mounted along the horizontal axis and can be automatically adjusted for maintaining proper arc column. A charging door and pouring spout serve their purpose.

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. Rocking stirs the molten metal homogenously.
- When the liquid metal reaches the desired temperature, the furnace is tilted mechanically and the metal is tapped in ladles and poured into the moulds.

CUPOLA FURNACE
- Cupola is a vertical cylindrical shape type furnace.
- It works on counter current principle.
- Charge materials will be descending downwards. Flue gases will be ascending upwards.
- Thereby exchange of heat between the rising gases and the descending charge takes place efficiently.
- Coke lumps are used as the fuel.
- Lime stone is used as flux material.
- Coke, lime stone and metal charge are charged into the cupola in the same sequence with a definite ratio.

CUPOLA FURNACE



Construction

- It consists of a cylindrical steel shell of large **H/D** (height to diameter) ratio supported on legs at the bottom.
- It has two semi-circular steel doors hinged at the bottom and it can opened or closed as required.
- The inside shell is lined with fire clay refractory bricks.
- The entire structure is placed vertical on a rigid concrete base.
- When the doors are closed and clamped the furnace bottom is prepared by ramming sand mixed with fire clay on top of the door.
- Immediately above this, an opening is provided on the circumference of the shell and is called **metal hole.**
- A small channel is provided corresponding to this using steel plate and refractory material is called **metal spout**.
- Through this spout, molten metal is drawn from the furnace.
- Opposite to the metal spout, another hole is provided in the shell to tap the slag.
- Slightly above this a wind box is provided around the shell. Numbers of holes are provided in the steel shell (covered by the wind box).
- These are called **tuyers**.

- The wind box is connected to a **blower** through which the air is made to enter.
- This blast of air enters the inside portion of the lined shell radially inwards.
- This air provides necessary oxygen for combustion process.
- Far above the wind box a charging platform is provided to facilitate storing of charges and movement of operators.
- Close to the platform, a charging door is provided with a hood or spark arrestor.
- This ensures arresting of the sparks emanating from the furnace.
- To facilitate easy operation and reduce the projection of furnace above the ground, a pit of 3-4 feet is dug below the ground to house the furnace.
- The height of the coke inside the cupola from bottom and up to the wind box is referred as **coke bed height**.

Working

a. Starting the Cupola

- Before starting the cupola, the bottom doors are closed and locked.
- On this door, sand bed is prepared and the metal spout is closed with a clay slug.
- Burning wood splinters are dropped from the door of the furnace. Slowly wood pieces starts burning and some more wooden pieces are dropped.
- When this also catches fire, coke pieces are dropped from top.
- The coke pieces slowly catches fire, ignite and become red hot.

b. Charging cupola

- Now coke lumps are dropped continuously into the furnace up to the **wind box** level.
- The wind blast is slowly turned on supplying air for combustion.
- This results in the burning of coke pieces continuously.
- Now alternate layers of **coke, flux (lime stone) and metal (iron)** charges are dumped inside the furnace till the inside portion of the furnace is filled up to the charging door.
- The blast of air is increased and kept at maximum.
- The air enters the furnace through **tuyers**.
- Coke not only acts as fuel but also act as burden until melting occurs.
- Lime stone act as flux and protects the metal against excessive oxidation.

c. Melting

- As the temperature inside the furnace reach very high value the coke burns off, lime stone fuses and metal charge melts and trickles of 1liquid metal starts dropping down to bottom of the furnace.
- Molten metal collects at the bottom and accumulates.
- The external charging of the furnace is continued.
- Just above the tuyers in the wind box, maximum temperature is attained and this zone is referred to as ***superheating zone***.
- Here the molten is heated to above its melting point, hence referred to as ***super heat***.
- Above this zone, the actual melting of metal takes place.

- This zone is called ***melting zone***. This zone is approximately 2 times that of super heat zone.
- Above this zone and upto the charging door is the ***preheating zone***. Here the metal charge, lime and coke will be preheated.
- Above the door and upto the hood region is the ***stack zone***. Only flue gases escapes through this zone.
- As the cold charges are moving downwards the hot flue gases will be ascending.
- This results in very good heat exchange between the two. Charges gain heat and the flue gases lose heat.
- This phenomenon is referred to as ***Counter Current Principle***.
- The charging of cupola is continued and the molten metal gets accumulated and the slag formed also accumulates above the molten metal due to density difference.

d. Tapping slag and molten metal

- The slag door is kept open always and when the slag level inside the furnace reaches the slag spout, slag starts coming out continuously.
- This is an indication that the molten metal is ready for tapping.
- This should happen at around 15 minutes after full blast of air to the furnace.
- The bottle green color of slag also suggest that the molten metal quality is good.
- Now the metal spout is opened and molten metal is tapped into the ladle and collected.
- The furnace operation is continued and the molten metal is continuously tapped.
- The furnace is stopped by stopping charging.

e. Dropping down the bottom

- After tapping the molten metal completely from the furnace, the bottom doors are dropped down.
- The slag drops out of the furnace.
- After cooling, the necessary patchwork of lining is done before the next melting operation.
- The ratio of **coke : metal** is referred to as ***coke to metal ratio***, for a good coke it should be anywhere between **1:8 to 1:10** by weight.
- The percentage of **lime stone** is around 5-7% of the metal charge.
- Inside Lined diameter of cupola determines the ***melting capacity*** of the cupola.
- It may vary from approximately 68 to 275 cm.
- Cupola is specified by the **quantity of molten metal** that can be melted per hour. *Example:* 10 tons / hour, means 10 tons of cast iron is melted in 1 hour.

- Cupola is used to produce ***cast iron***.
- Cupola is the most popular and widely used furnace in a ***foundry.***

ZONES IN CUPOLA

The various zones in a cupola are shown in fig.

The height of the furnace can be divided into various zones for study purpose and observe how the melting process is taking place.

a. Well Zone

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

b. Combustion Zone

The combustion zone or oxidizing zone is situated from the bottom edge of the tuyers. In this zone where rapid combustion takes place due to which a lot of heat is generated in the furnace. The temperature in this zone varies from 1550^{o}C – 1850^{o}C.

c. Reduction Zone

Reduction zone or protection zone is the portion located from the top of the combustion zone to the top of coke bed. In this zone, some of hot CO_2 gas moving upward through the hot coke gets reduced to CO. In other words, reduction of CO_2 to CO occurs in this zone. Due to reduction, the temperature reduces to around 1200^{o}C in this zone.

d. 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 the charge before passing out of the furnace. Thus the charge is preheated before descending downwards.