CLASSIFICATION OF CASTING PROCESS

Temporary moulds

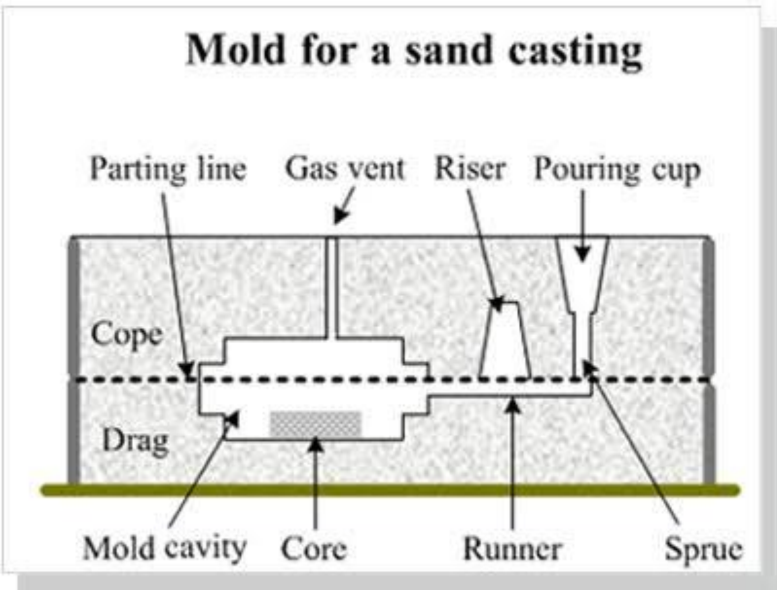
1. Sand mould casting
2. Shell mould casting
3. Investment casting
4. Carbon dioxide (Co2) mould casting

Permanent moulds

1. Die casting
2. Centrifugal casting
3. Continuous casting

SAND MOULD CASTING

Sand casting, the most widely used casting process, utilizes expendable sand molds to form complex metal parts that can be made of nearly any alloy. Because the sand mold must be destroyed in order to remove the part, called the casting, sand casting typically has a low production rate. The sand casting process involves the use of a furnace, metal, pattern, and sand mold. The metal is melted in the furnace and then ladled and poured into the cavity of the sand mold, which is formed by the pattern. The sand mold separates along a parting line and the solidified casting can be removed.



Sand casting is used to produce a wide variety of metal components with complex geometries. These parts can vary greatly in size and weight, ranging from a couple ounces to several tons. Some smaller sand cast parts include components as gears, pulleys, crankshafts, connecting rods, and propellers. Larger applications include housings for large equipment and heavy machine bases. Sand casting is also common in producing automobile components, such as engine blocks, engine manifolds, cylinder heads, and transmission cases.

SHELL CASTING

Shell moulding, also known as shell-mould casting is an expendable mold casting process that uses thermosetting resin covered sand to form the mold. As compared to sand casting, this process has better dimensional accuracy and higher productivity rate. It is used for small to medium parts that require high precision. Shell mold casting is a metal casting process similar to sand casting, in that molten metal is poured into an expendable mold. However, in shell mold casting, the mold is a thin-walled shell created from applying a sand-resin mixture around a pattern. The pattern, a metal piece in the shape of the desired part, is reused to form multiple shell molds. A reusable pattern allows for higher production rates.

The shell mold casting process consists of the following steps:

Pattern creation – A two-piece metal pattern is created in the shape of the desired part, typically from iron or steel.

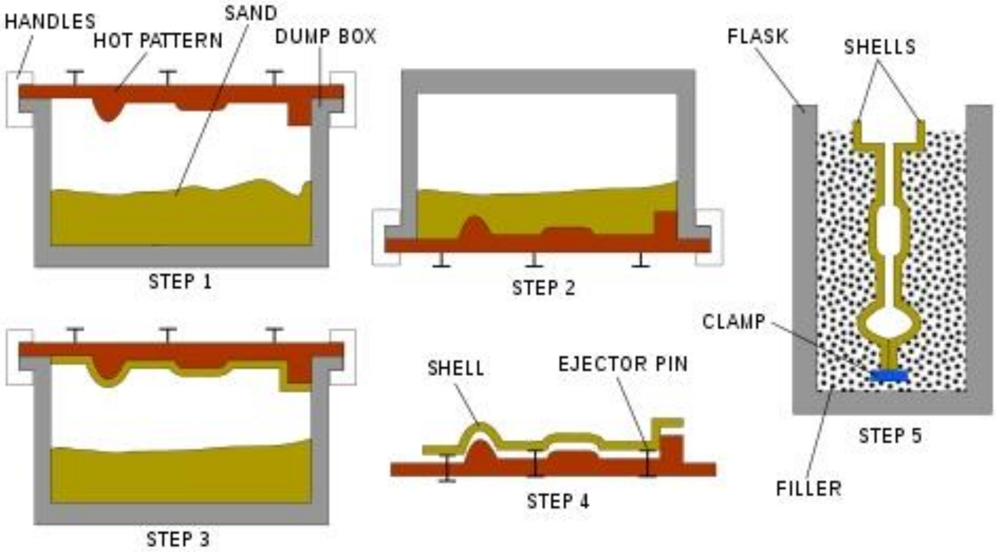
Mold creation – First, each pattern half is heated to 175-370 °C (350-700 °F) and coated with a lubricant to facilitate removal. Next, the heated pattern is clamped to a box, which contains a mixture of sand and a resin binder. The box is inverted, allowing this sand-resin mixture to coat the pattern. The heated pattern partially cures the mixture, which now forms a shell around the pattern and then the shell is ejected from the pattern.

Mold assembly – The two shell halves are joined together and securely clamped to form the complete shell mold. If any cores are required, they are inserted prior to closing the mold. The shell mold is then placed into a flask and supported by a backing material.

Pouring – The mold is securely clamped together while the molten metal is poured from a ladle into the gating system and fills the mold cavity.

Cooling – After the mold has been filled, the molten metal is allowed to cool and solidify into the shape of the final casting.

Casting removal – After the molten metal has cooled, the mold can be broken and the casting removed. Trimming and cleaning processes are required to remove any excess metal from the feed system and any sand from the mold.



Advantages:

1. Shell mould casting are generally more dimensionally accurate than sand castings.
2. A smoother surface can be obtained.
3. Very small amount of sand needs to be used.
4. Permeability of the shell is high and therefore no gas inclusions occur.

Limitations

1. The pattern are very expensive.
2. The size of the casting obtained by shell moulding is limited.
3. Highly complicated shapes can not be obtained.

Applications

Cylinder heads, connecting rods, Engine blocks and manifolds.

INVESTMENT CASTING

Investment casting is also referred to as lost-wax casting since the pattern is made of wax. In this process, ceramics formed around the wax patterns to create a casing for molten metal to be poured. Very high melting temperature material can be cast in investment casting process because of the refractory mold. Figure schematically shows an investment casting process. Very high dimensional accuracy and surface finish can be achieved in investment casting process. Investment casting process is primarily used for large size batch production or for specific requirements of complex shape or casting of very high melting temperature material.

Investment casting requires the use of a metal die, wax, ceramic slurry, furnace, molten metal, and any machines needed for cutting, or grinding. The process steps include the following:

Pattern Creation – The wax patterns are typically injection molded into a metal die and are formed as one piece. Cores may be used to form any internal features on the pattern. Several of these patterns are attached to a central wax gating system (sprue, runners, and risers), to form a tree-like assembly. The gating system forms the channels through which the molten metal will flow to the mold cavity.

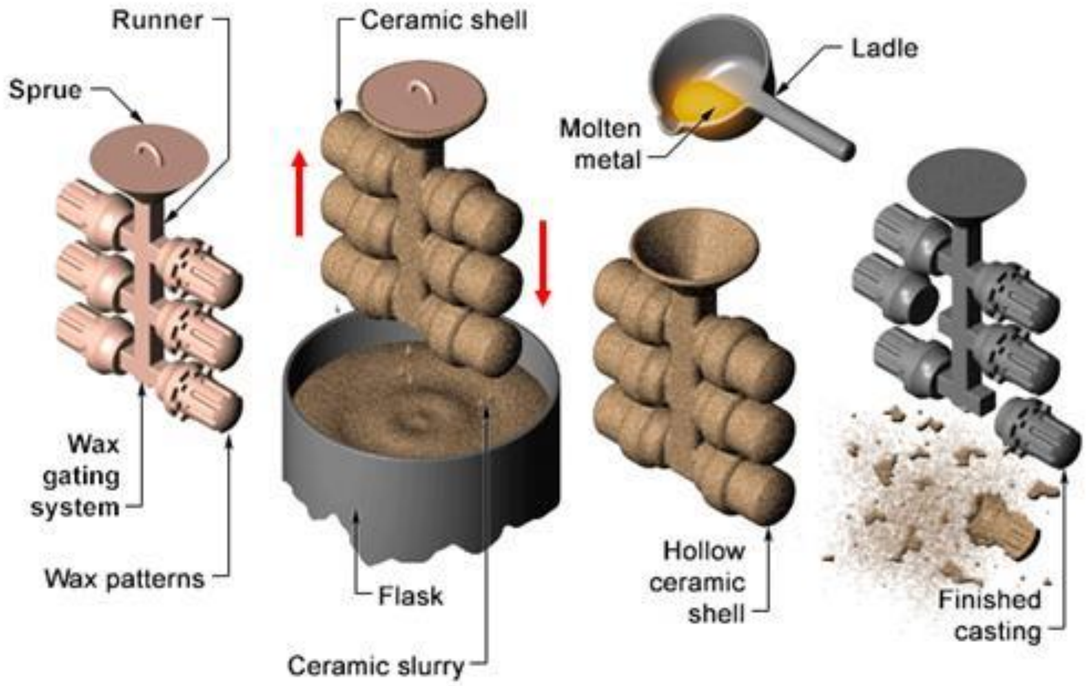
Mold Creation – This “pattern tree” is dipped into a slurry of fine ceramic particles, coated with more coarse particles, and then dried to form a ceramic shell around the patterns and gating system. This process is repeated until the shell is thick enough to withstand the molten metal it will encounter. The shell is then placed into an oven and the wax is melted out leaving a hollow ceramic shell that acts as a one-piece mold, hence the name “lost wax” casting.

Pouring – The mold is preheated in a furnace to approximately 1000°C (1832°F) and the molten metal is poured from a ladle into the gating system of the mold, filling the mold cavity. Pouring is typically achieved manually under the force of gravity, but other methods such as vacuum or pressure are sometimes used.

Cooling – After the mold has been filled, the molten metal is allowed to cool and solidify into the shape of the final casting. Cooling time depends on the thickness of the part, thickness of the mold, and the material used.

Casting Removal – After the molten metal has cooled, the mold can be broken and the casting removed. The ceramic mold is typically broken using water jets, but several other methods exist. Once removed, the parts are separated from the gating system by either sawing or cold breaking (using liquid nitrogen).

Finishing – Finishing operations such as grinding or sandblasting are used to smooth the part at the gates. Heat treatment is also sometimes used to harden the final part.



Investment casting process

Advantages

1. Complex shapes which are difficult to produce by any other method are possible since the pattern is withdrawn by melting it.
2. Very fine details and thin sections can be produced by this process.
3. Better surface finish can be produced.

Limitations

1. The process is normally limited by size and mass of the casting.
2. This is a more expensive process because of larger manual labour involved in the preparation of the pattern and the mould.

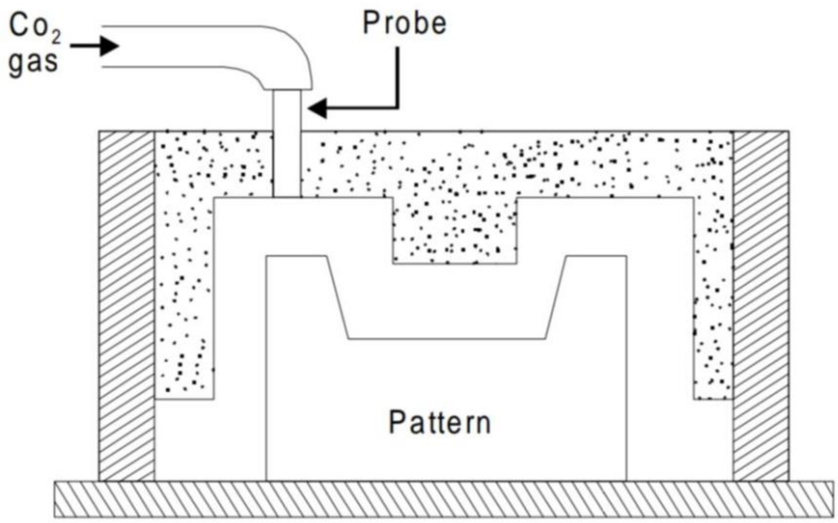
Applications

It is used for making jewellery, surgical equipment, blade for gas and turbine bolt.

CARBON DIOXIDE (CO2) MOULD CASTING

The principle of the working of CO2 process is based on the fact that if CO2 gas is passed at about 1.3-1.5 kg/cm2 pressure through a sand mix containing sodium silicate to about 20 to 30 seconds, the sand immediately became extremely strongly bonded as the sodium silicate presented in the mold reacts with CO2 and produce a very hard constituents or substance commonly called as silica gel. The sand used for the process must be dry and free from clay and patterns used in this process may be made of wood, metal or plastic.

$$Na_2SiO_3 + CO_2 \longrightarrow Na_2CO_3 + SiO_2.xH_2O \text{ (Silica Gel)}$$



(c) Using a Simple tube to provide entry to gas

Advantages

1. Compared to other casting methods, cores and moulds are strong.
2. Operation is speedy.
3. Good dimensional accuracy cab be obtained.

Limitations

1. Less suitable for non-ferrous casting.
2. Poor collapsibility due to inorganic nature of bond.

PERMANENT MOLD CASTING PROCESS

Permanent mold casting processes involve the use of metallic dies that are permanent in nature and can be used repeatedly. The metal molds are also called dies and provide superior surface finish than typical sand molds.

DIE CASTING

A sand mould is usable for production of only one casting. It cannot be used twice. Die is essentially a metal mould and can be used again and again. A die is usually made in two portions. One portion is fixed and the other is movable. Together, they contain the mould cavity in all its details. After clamping or locking the two halves of the dies together molten metal is introduced into the dies. If the molten metal is fed by gravity into the dies, the process is known as gravity die casting process.

On the otherhand, if the metal is forced into the dies under pressure (e.g., a piston in a cylinder pushes the material through cylinder nozzle), the process is called “pressure die casting”. The material of which the dies are made, should have a melting point much higher than the melting point of casting material. A great number of die castings are made of alloys of zinc, tin and lead, and of alloys of aluminium, magnesium and copper.

Steps In Die Casting

1. Close and lock the two halves of a die after coating the mould cavity surfaces with a mould wash, if specified
2. Inject the molten metal under pressure into the die.
3. Maintain the pressure until metal solidifies.
4. Open die halves.
5. Eject the casting along with runner, riser etc.
6. The above cycle is repeated.

The pressure die casting machine are two types:

1. Hot chamber die casting (pressure up to 35 MPa)
2. Cold chamber die casting (pressure as high as 150 MPa)

The main difference between these two types is that in the hot chamber casting, the holding furnace for the liquid metal is integral with the die casting machine, whereas in the cold chamber machine, the metal is melted in a separate furnace and then poured into the die casting machine with a ladle for each casting cycle which is also called shot. Figure 3.2.6 schematically presents the hot-chamber and the cold-chamber die casting processes

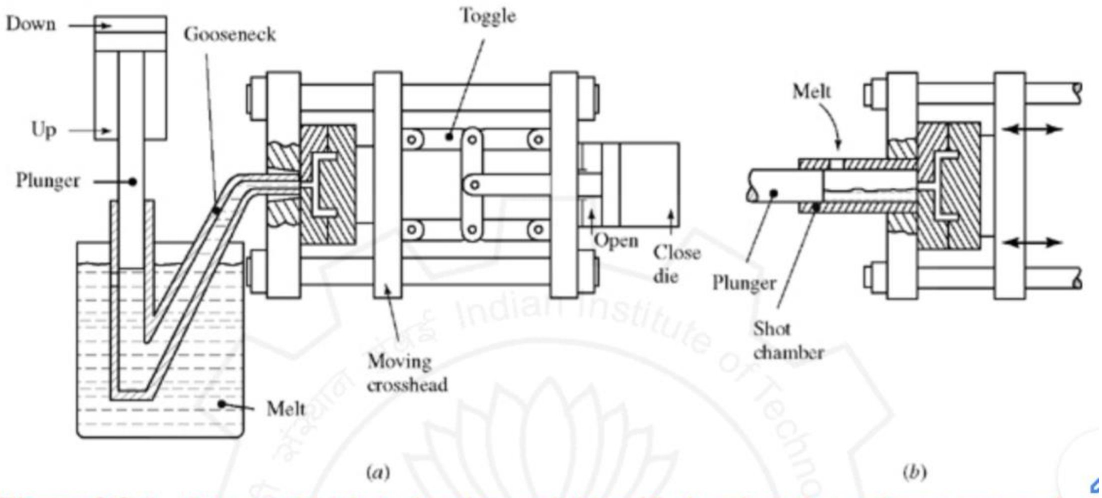


Figure 3.2.6 Set-up of (a) hot-chamber and (b) cold-chamber die casting processes [

Advantages

1. Very small thickness can be easily filled because the liquid metal is injected at high pressure.
2. Very high production rate can be achieved.
3. Because of metallic dies, very good surface finish is obtained.
4. It is very economical for large-scale production.

Limitations

1. The maximum size of the casting is limited.
2. This is not suitable for all materials because of the limitations on the die materials.
3. The air in the die cavity gets trapped inside the casting and is therefore a problem often with the die casting.

CENTRIFUGAL CASTING

In centrifugal casting process, the molten metal poured at the centre of a rotating mold or die. Because of the centrifugal force, the lighter impurities are crowded towards the centre of the case. For producing a hollow part, the axis of rotation is placed at the centre of the desired casting. The centrifuge action segregates the less dense non-metallic inclusions near to the centre of rotation that can be removed by machining a thin layer. Therefore no cores are required in casting of hollow parts although solid parts can also be cast by this process. The centrifugal casting is very suitable for axisymmetric parts. Very high strength of the casting can be obtained. Since the molten metal is fed by the centrifugal action, the need for complex metal feeding system is eliminated. Both horizontal and vertical centrifugal castings are widely used in the industry. Figure 3.2.8 schematically shows a set-up for horizontal centrifugal casting process. Figure 3.2.9 typically shows large pipes that are made using centrifugal casting process.

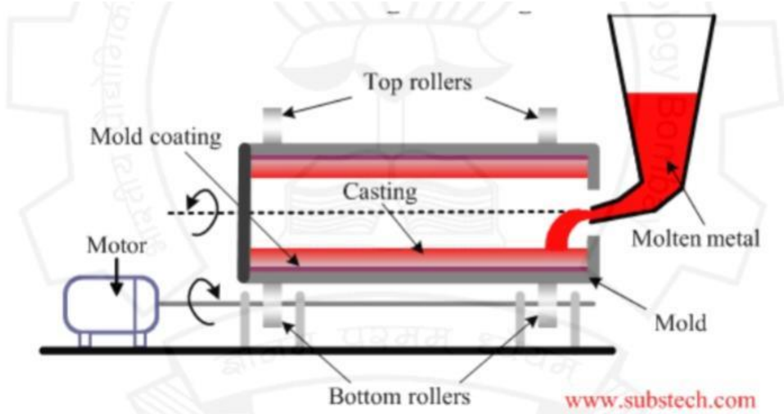


Figure 3.2.8 Schematic set-up of horizontal centrifugal casting process [7]

Figure 3.2.9 Metallic pipes made using centrifugal casting process [7]

Advantages

1. There is no need for gates and runners.
2. The axis of rotation can be either horizontal, vertical or any angle.
3. No cores are required for making concentric holes

Limitations

1. Skilled labors are to be employed.
2. An inaccurate diameter of the inner surface of the casting.
3. Only some shapes can be generated by this casting process.
4. Not all alloys can be cast in this way.

CONTINUOUS CASTING

Continuous casting process is widely used in the steel industry. In principle, continuous casting is different from the other casting processes in the fact that there is no enclosed mold cavity. Figure 3.2.10 schematically shows a set-up for continuous casting process. Molten steel coming out from the furnace is accumulated in a ladle. The ladle is transported to the top of the continuous casting set-up. From the ladle, the hot metal is transferred via a refractory shroud (pipe) to a holding bath called a tundish. The tundish allows a reservoir of metal to feed the casting machine. Metal is then allowed to pass through a open base copper mold. The mold is water-cooled to solidify the hot metal directly in contact with it and removed from the other side of the mold. The continuous casting process is used for casting metal directly into billets or other similar shapes that can be used for rolling. The process involves continuously pouring molten metal into a externally chilled copper mold or die walls and hence, can be easily automated for large size production. Since the molten metal solidifies from the die wall and in a soft state as it comes out of the die wall such that the same can be directly guided into the rolling mill or can be sheared into a selected size of billets.

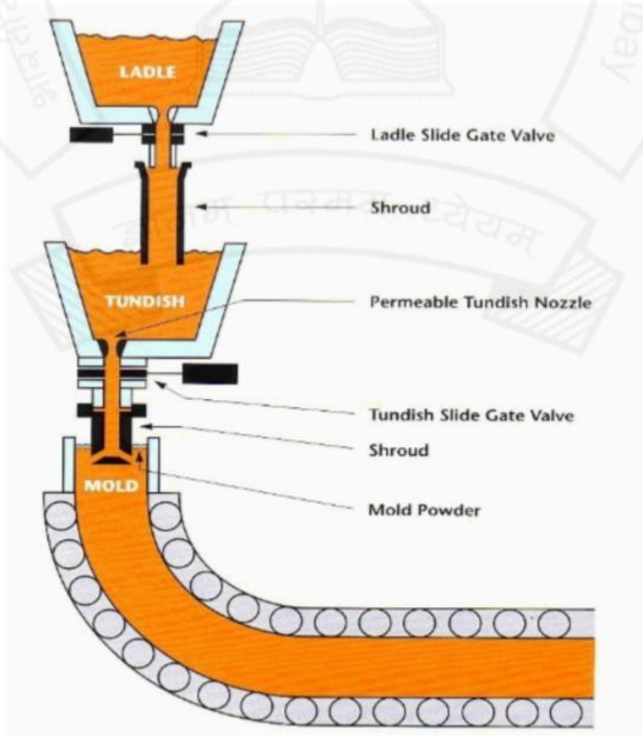


Figure 3.2.10 Schematic set-up of continuous casting process [8]

VACUUM CASTING

In this case, the material is sucked upwards into the mold by a Vacuum pump through a gating system from the bottom of the mold. The mold in an inverted position from the usual casting process, is lowered into the flask with the molten metal. The molted metal is drawn into the mold cavity. The pressure inside the mold is usually one-third of the atmospheric pressure. The vacuum casting process is very suitable for thin walled, complex shapes with uniform properties. Figure 3.2.4 schematically shows typical vacuum casting process.

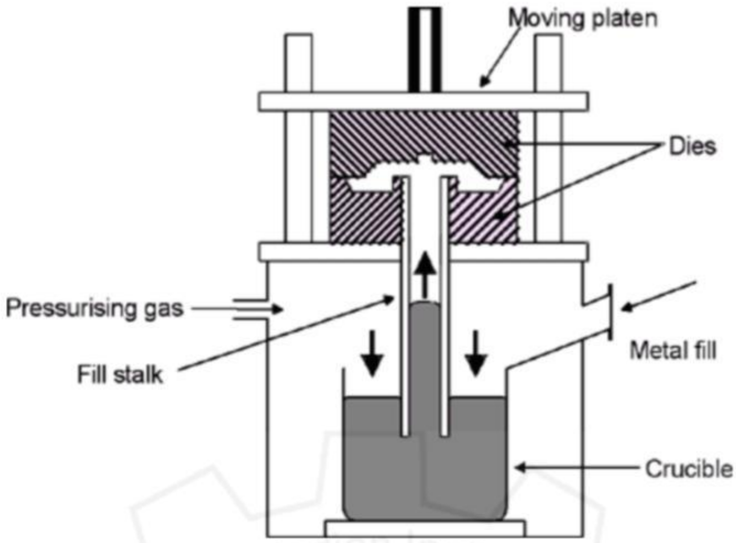


Figure 3.2.4 Schematic set-up of vacuum casting process [3]

DEFECTS IN CASTING PROCESSES

Figure 3.2.11 schematically shows various defects that are experienced during casting, in particular, sand casting processes. A brief explanation of some of the significant defects and their possible remedial measures are indicated in the text to follow.

Scar

It is usually found on the flat casting surface. It is a shallow blow.

Blowhole

Blowholes are smooth round holes that are clearly perceptible on the surface of the casting. To prevent blowholes, moisture content in sand must be well adjusted, sand of proper grain size should be used, ramming should not be too hard and venting should be adequate.

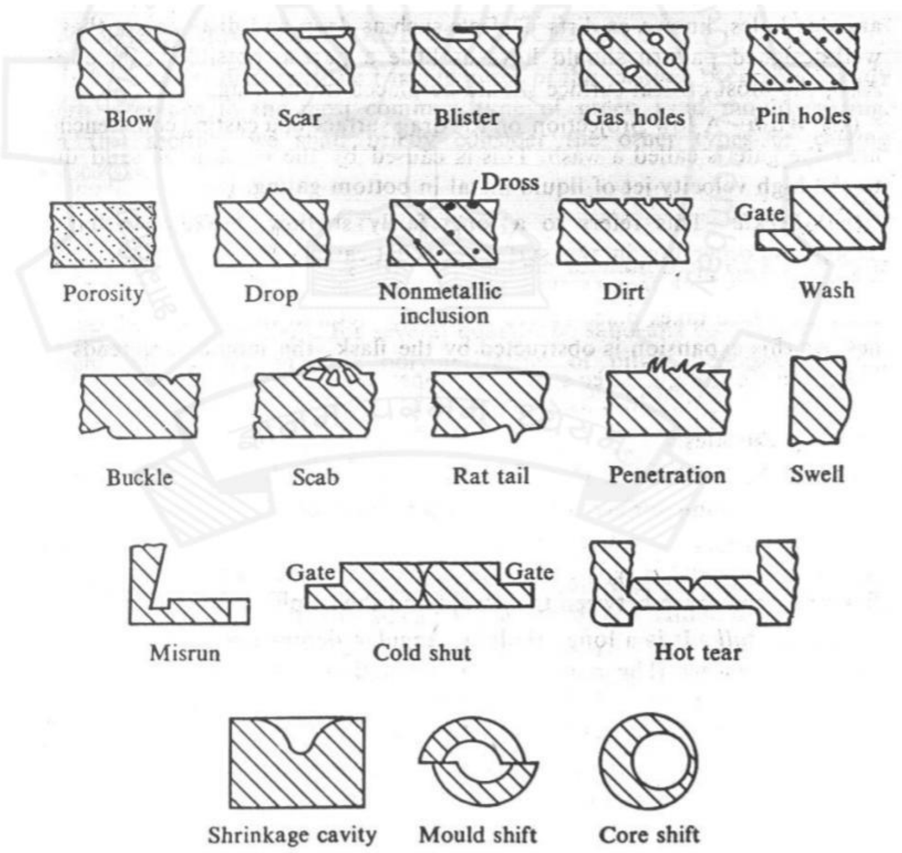


Figure 3.2.11 Schematic pictorial presentation of various casting defects [2]

Blister
This is a scar covered by the thin layers of the metal.

Dross
The lighter impurities are appearing on the top of the cast surface is called the dross. It can be taken care of at the pouring stage by using items such as a strainer and a skim bob.

Dirt
Sometimes sand particles dropping out of the cope get embedded on the top surface of a casting. When removed, these leave small angular holes is known as dirts.

Wash
It is a low projection on the drag surface of a casting commencing near the gate. It is caused by The erosion of sand due to high velocity liquid metal.

Buckle
It refers to a long fairly shallow broad depression at the surface of a casting of a high temperature Metal. Due to very high temperature of the molten metal, expansion of the thin layered of the Sand at the mold face takes place. As this expansion is obstructed by the flux, the mold tends to Bulge out forming a V shape.

Rat tail
It is a long shallow angular depression found in a thin casting. The cause is similar to buckle.

Shift
A shift results in a mismatch of the sections of a casting usually as a parting line. Misalignment is common cause of shift. This defect can be prevented by ensuring proper alignment of the Pattern for die parts, molding boxes, and checking of pattern flux locating pins before use.

Other defects include misrun, hot tear, shrinkage cavity, pin holes etc.

METAL FURNACE
For casting, metal has to be heated above its melting point. The heating is done in a furnace. Depending upon the fuel used, the furnaces may be classified as electric, oil fired or coal fired etc. Where metal free from any impurities is required, electric furnaces are used. Electric furnaces are costly and equally costly to operate. Usually, for non-ferrous metals and alloys, oil fired crucible furnaces are used. The metal is placed in large graphite crucibles and heated on the outside surface of crucibles, so that flames do not come in actual contact with metal.

CUPOLA FURNACE
For melting cast iron, a cupola furnace is used. It is one of the most economical and convenient ways of providing a supply of molten cast iron. Cupola uses coke as fuel. Coke is produced by heating ordinary steam coal in an inert atmosphere. It gives more intense heat than coal. Cupola consists of a long cylindrical steel shell with its interior lined with refractory fire-bricks. It is erected vertically up and rests on short pillars about 0.85 metres above the ground level. The bottom of the cupola is provided with steel doors which are also lined with fire resistant material and covered with a layer of good quality sand.