CASTING PROCESS

1.3 CLASSIFICATION OF MANUFACTURING PROCESS

The various processes available for manufacturing a product can be put into any one of the four categories mentioned below:

(i) Casting

(ii) Forming

(iii) Machining and

(iv) Joining.

The detailed classification is shown in figure 1.1 and their descriptions are discussed below.

(i) Casting

Casting is a manufacturing process which involves pouring molten metal (ferrous or non-ferrous) into a mould cavity whose shape resembles the shape of the desired product, and allowing the molten metal to solidify in it. The solidified part is then taken out of the mould to finish the final product.

Note The process is similar to that of making ice cubes in a refrigerator, wherein water is poured into a cavity (ice tray) and allowed to freeze. Whereas in casting process, the molten metal is allowed to solidify in the cavity.

Casting is further classified into two categories based on the type of mould:

(a) Expendable mould casting

In this type, the mould prepared from sand, plaster or similar materials is temporary, and is destroyed in order to remove the solidified part. In other words, a new mould has to be prepared for each new casting. ***Example*** Green sand moulds, dry sand moulds, shell moulds, plaster moulds, investment casting etc.

(b) Permanent mould casting

In this type, the mould fabricated out of a ductile material (*example* steel) is permanent and can be used repeatedly to produce many castings. ***Example*** Die casting, continuous casting, centrifugal casting process etc.

Classification

- Casting
  - Expendable mould
    - Sand casting (Green sand, dry sand etc.)
    - Shell casting
    - Lost Foam casting
    - Investment casting, etc.
  - Permanent mould
    - Gravity Die casting
    - Pressure die casting
    - Centrifugal casting
    - Continuous casting, etc.

1.4 INTRODUCTION TO CASTING PROCESS

Casting or Founding is one of the oldest manufacturing processes that has been practiced for over 5000 years. Pre-historic man found copper and shaped it to use as a weapon (arrowhead) for his defense. Later he found that weapons could be easily made by pouring copper in moulds (cast) than they could be beaten (forged) to size and shape. Progress in civilization made man to discover different metals and process for casting them.

Casting involves melting metal and pouring it into a mould cavity whose shape resembles the shape of the desired object and allowing the molten metal to solidify in it. The solidified part is taken out of the mould, cleaned and finished to make it suitable for use. Casting is not restricted to metals. Glass and plastics can also be cast using a variety of processes. Also, products ranging from a few millimeters to meters and a few grams to several tons can be cast efficiently and economically thereby making it a versatile method for shaping objects. Casting which was once practiced as an art has emerged to a science, and a major manufacturing process to shape objects.

1.5 STEPS INVOLVED IN MAKING A CASTING

The basic steps in making a casting are:

(a) Pattern making

(b) Mould preparation (including gating and risering)

(c) Core making

(d) Melting and Pouring

(e) Cleaning and Inspection

Note Readers can refer figure 1.2 for clear understanding of the casing process.

a) Pattern making

A pattern is a *replica* of an object to be cast. It is used to prepare a cavity into which the molten metal is poured. A skilled *pattern maker* prepares the pattern using wood, metal, plastic or other materials with the help of machines and special tools. Many factors viz., durability, allowance for shrinkage and machining etc., are considered while making a pattern.

b) Mould preparation

Mould preparation involves forming a cavity by packing sand around a pattern enclosed in a supporting metallic frame called 'flask' (mould box). When the pattern is removed from the mould, an exact shaped cavity remains into which the molten metal is poured. Gating and risering* are provided at suitable locations in the mould.

* *Gating – Passage through which molten metal flows and enter the mould cavity.*

Risering – A reservoir of molten metal connected to the mould cavity to supply additional metal so as to compensate for losses due to shrinkage, as the metal solidifies.

c) Core making

In some cases, a hole or cavity is required in the casting. This is obtained by placing a core in th mould cavity. The shape of the core corresponds to the shape of the hole required. The mould cleaned, finished and made ready for pouring molten metal.

d) Melting and Pouring

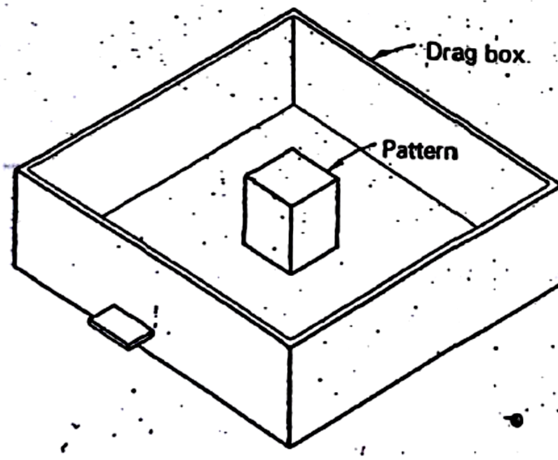
Metals or alloys of the required composition are melted in a furnace and then transfered (pourec into the mould cavity. Many factors viz., temperature of molten metal, pouring time, turbulenc etc., should be considered while melting and pouring.

e) Cleaning and Inspection

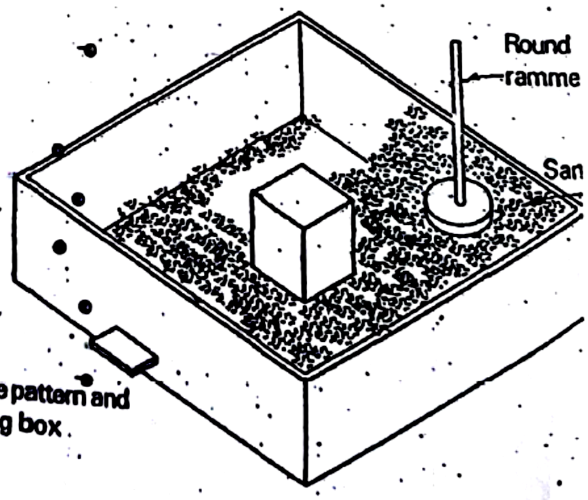
After the molten metal has solidified and cooled, the rough casting is removed from the moul cleaned and dressed (removing cores, adhered sand particles, gating and risering system fins, blisters etc., from the casting surface) and then sent for inspection to check for dimensior or any defects like blow holes, cracks etc.

1.5.1 Procedure for Making a Casting

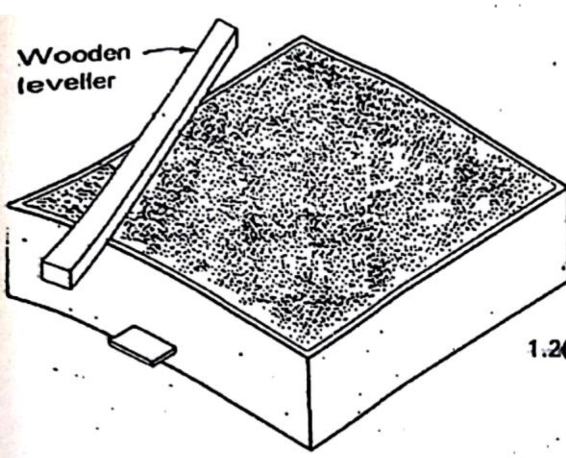
To understand and appreciate casting process, a detailed step-by-step procedure for the benefit readers is shown in figure 1.2



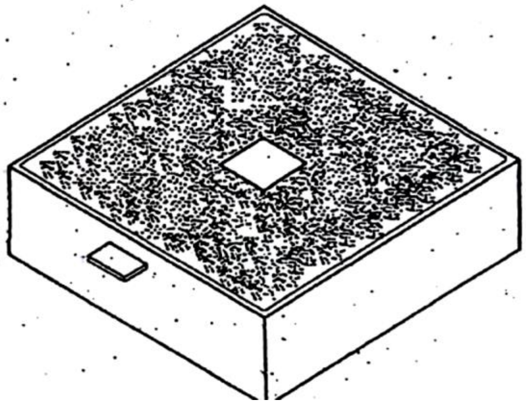
1.2(a) Place pattern in drag box



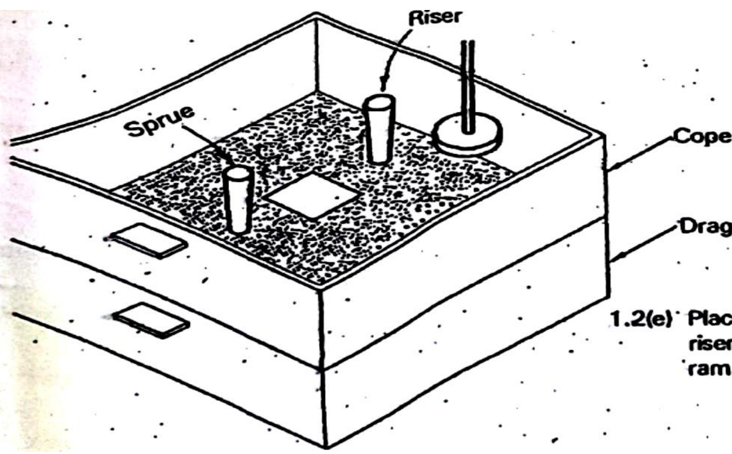
1.2(b) Ram moulding sand around the pattern and till the top surface of the drag box.



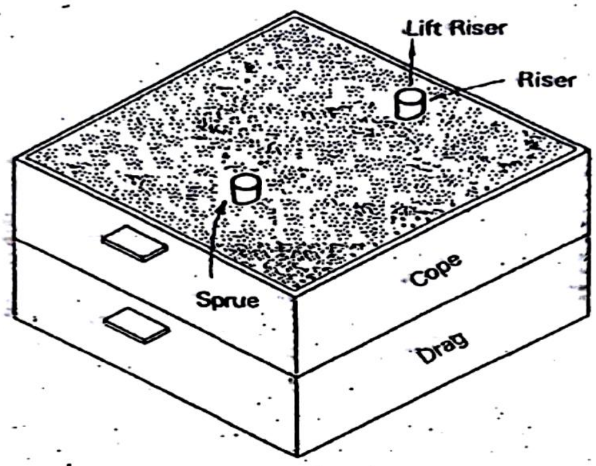
1.2(c) Level the sand in the drag box



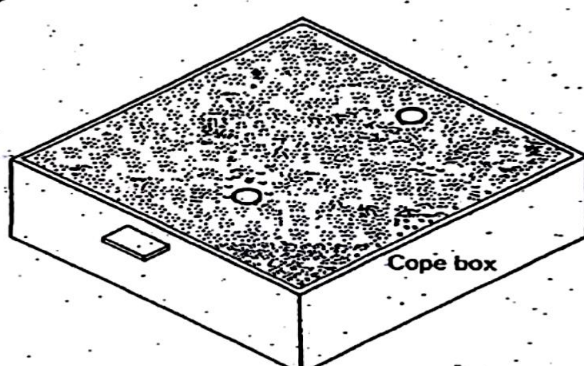
.2(d) Drag box is inverted, so that pattern is visible at the top surface



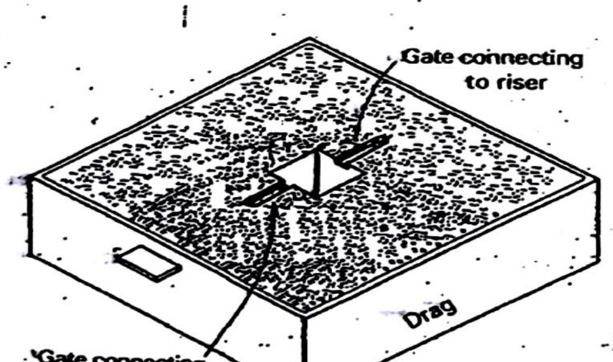
1.2(e) Place cope on top of drag box. Place riser and sprue at proper location and ram sand into the cope box



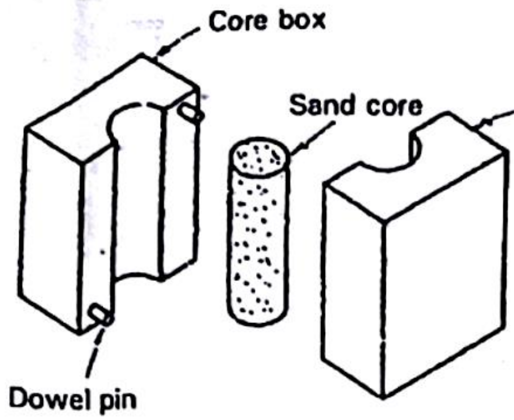
1.2(f) Cope box is rammed till its top surface. Riser & sprue are removed



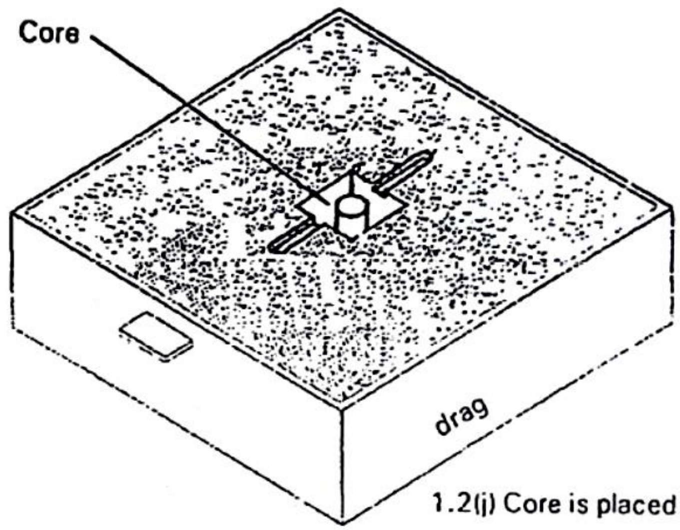
1.2(g) Cope box is lifted and placed aside



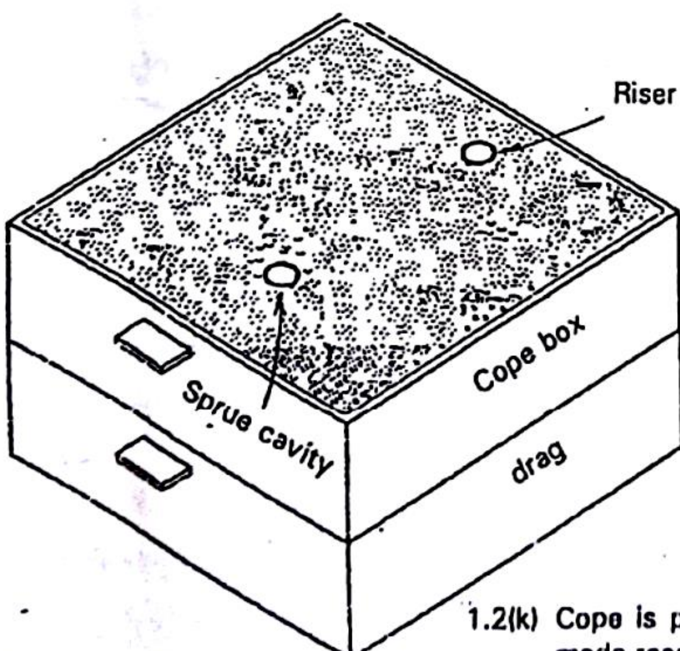
1.2 (h) Pattern is removed from the drag box. Gates are cut



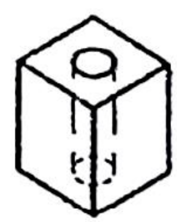
1.2(i) Sand core prepared in core box



1.2(j) Core is placed in drag box



1.2(k) Cope is placed on drag & mould made ready for pouring



1.2(l) Finished casting

Figure 1.2 Casting process

1.5.2 Terms Involved in Casting

Figure 1.3 shows the cross-section of the mould shown in figure 1.2(k) ready for pouring.

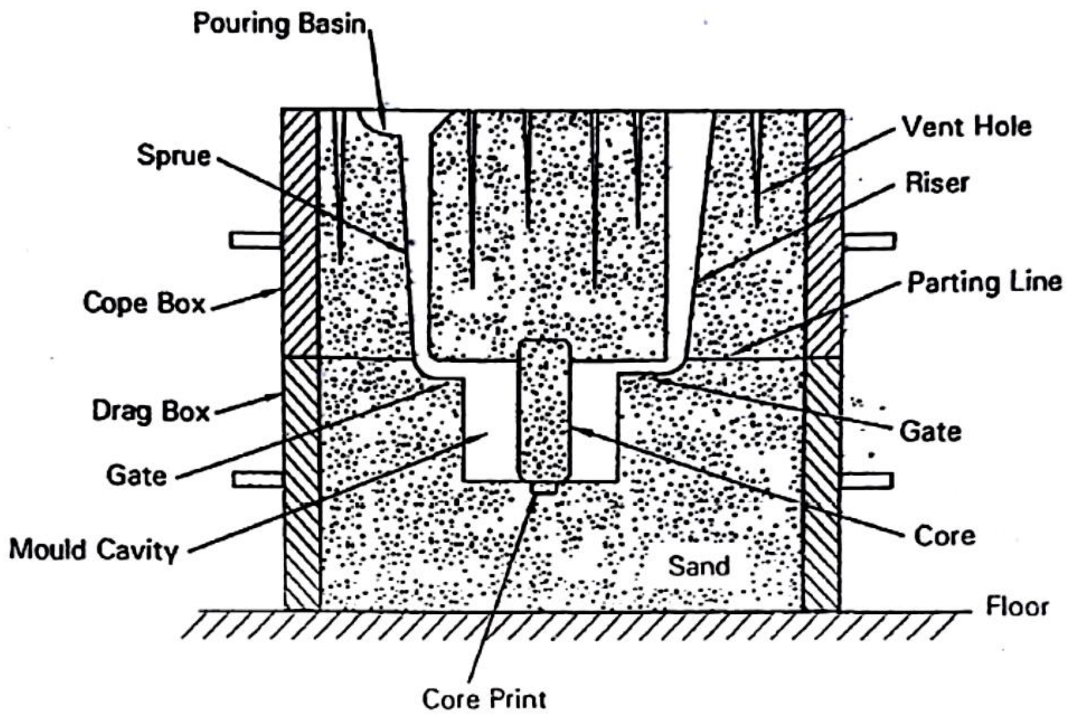


Figure 1.3 Cross-section of a mould

Following are a few important terms involved in casting process.

a) **Mould box (flask) :** It is usually a metallic frame used for making and holding a sand mould. The mould box has two parts: the upper part called 'cope', and the lower part called 'drag'.

b) **Parting line/parting surface:** It is the zone of separation between cope and drag portions of the mould in sand casting.

c) **Sprue:** It is a vertical passage through which the molten metal will enter the gate, and then into the mould cavity.

d) **Pouring basin:** The enlarged portion of the sprue at its top into which the molten metal is poured.

e) **Gate/ingate:** It is a short passageway which carries the molten metal from the runner/ sprue into the mould cavity.

h) **Riser:** A riser or feedhead is a vertical passage that stores the molten metal and supplies (feed) the same to the casting as it solidifies.

i) **Mould cavity:** The space in a mould that is filled with molten metal to form the casting upon solidification.

j) **Core:** A core is a pre-formed (shaped) mass of sand placed in the mould cavity to form hollow cavities in castings.

k) **Core print:** It is a projection attached to the pattern to help for support and correct location of core in the mould cavity.

1.7 ADVANTAGES AND LIMITATIONS OF CASTING PROCESS

Following are a few advantages and limitations of casting process.

Advantages

a) Large hollow and intricate shapes can be easily cast.

b) Quick process, and hence suitable for mass production.

c) No limit to size and shape. Parts ranging from few millimeters to meters and few grams to tons can be cast efficiently and economically.

d) Better dimensional tolerances and surface finish can be obtained by good casting practice.

e) Castings exhibit uniform properties in all the directions – longitudinal, lateral and diagonal.

Limitations

a) Presence of defects in cast parts is a major disadvantage.

b) Casting process is not economical for small number of parts.

c) Properties of cast materials are generally inferior when compared to those made by machining or forging process.

3.2 GREEN SAND MOULDING

Green sand moulding is the most widely used process for casting both ferrous and non-ferrous metals. Nearly 60% of the total castings are produced from green sand moulds.

Procedure involved in making green sand moulds

a) Suitable proportions of silica sand (85 – 92 %), bentonite binder (6 – 12 %), water (3 – 5 %) and additives are mixed together to prepare the green sand mixture.

b) The pattern is placed on a flat surface with the drag box enclosing it as shown in figure 3.1(a). Parting sand* is sprinkled on the pattern surface to avoid green sand mixture sticking to the pattern. Also, refer figure 1.2 for 3-D sketches.

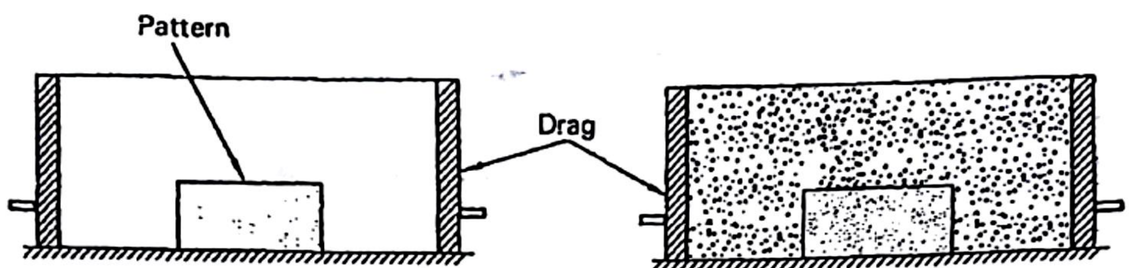
c) The drag box is filled with green sand mixture and rammed manually till its top surface. Refer figure 3.1(b). The drag box is now inverted so that the pattern faces the top as shown in figure 3.1 (c). Parting sand is sprinkled over the mould surface of the drag box.

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 figure 3.1(d).

e) The sprue and the riser are removed from the mould. The cope box is lifted and placed aside, and the pattern in 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. Refer figure 3.1(e) and 3.1(f).

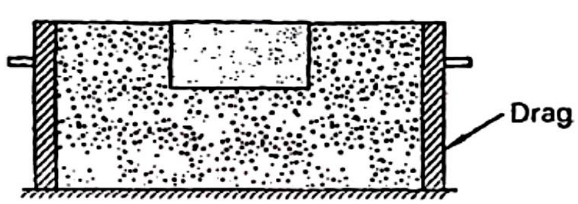
f) The mould cavity is cleaned and finished. Cores, if any, are placed in the mould to obtain a hollow cavity in the casting. Refer figure 3.1 (g).

g) 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. Refer figure 3.1 (h).

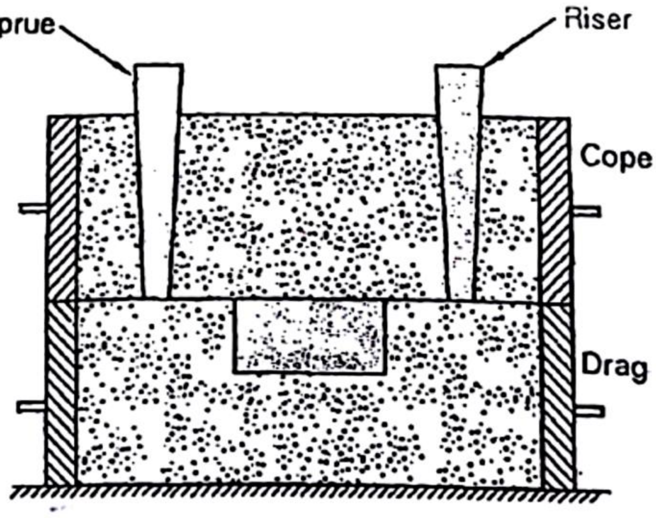


(a) Pattern placed in drag box

(b) Drag is filled with sand

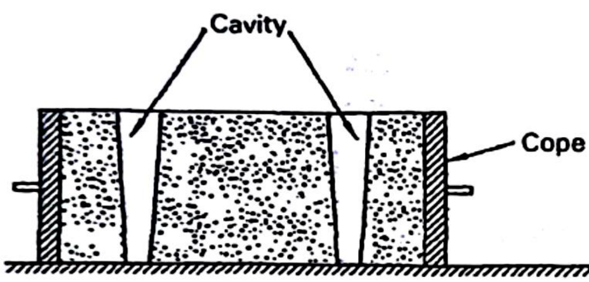


(c) Drag box inverted so that pattern faces the top

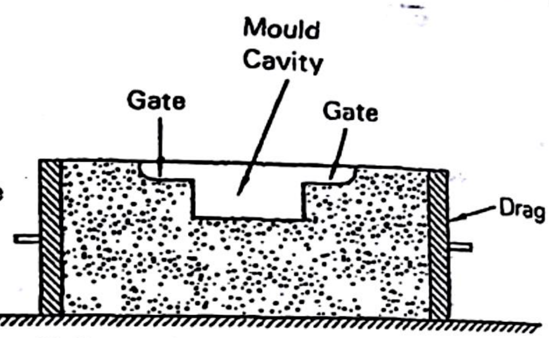


(d) Cope is placed on drag. Sprue & riser placed in position & sand rammed in cope box

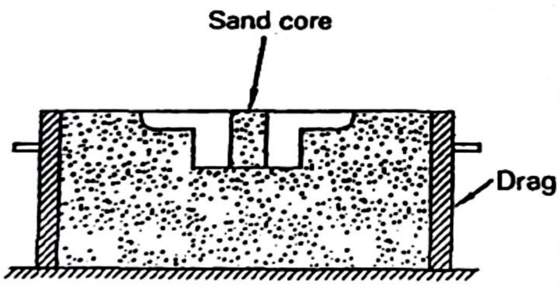
Figure cont....



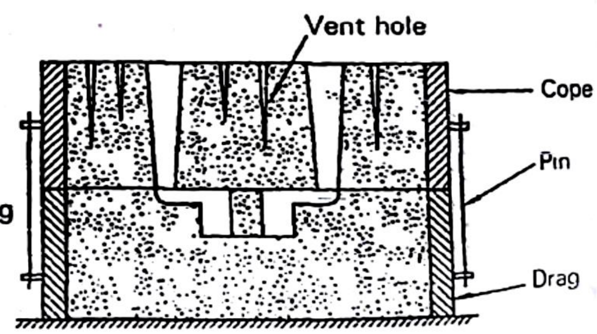
(e) Sprue & riser are removed. Cope box is placed aside of drag



(f) Pattern is removed to leave a cavity in the mould. Gates are cut.



(g) Core is placed in mould cavity



(h) Cope placed on drag & vent holes are made. Mould is ready for pouring

Figure 3.1 Green sand moulding

3.6 SHELL MOULDING

Shell moulding is an efficient and economical method for producing steel castings. The process was developed by *Herr Croning* in Germany during World war-II, and is sometimes referred to as the *Croning shell process*.

Procedure involved in making shell mould

a) A metallic pattern having the shape of the desired casting is made in one half from carbon steel material. Pouring element is provided in the pattern itself. Refer figure 3.3(a).

b) The metallic pattern is heated in an oven to a suitable temperature between 180 – 250°C. The pattern is taken out from the oven and sprayed with a solution of a lubricating agent viz., silicone oil or spirit to prevent the shell (formed in later stages) from sticking to the pattern.

c) The pattern is inverted and is placed over a box as shown in figure 3.3(b). The box contains a mixture of dry silica sand or zircon sand and a resin binder (5% based on sand weight).

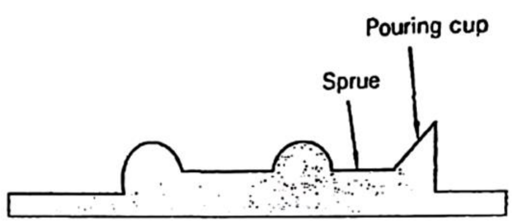
d) The box is now inverted so that the resin-sand mixture falls on the heated face of the metallic pattern. The resin-sand mixture gets heated up, softens and sticks to the surface of the pattern. Refer figure 3.3(c).

e) After a few seconds, the box is again inverted to its initial position so that the lose resin-sand mixture falls down leaving behind a thin layer of shell on the pattern face. Refer figure 3.3 (d).

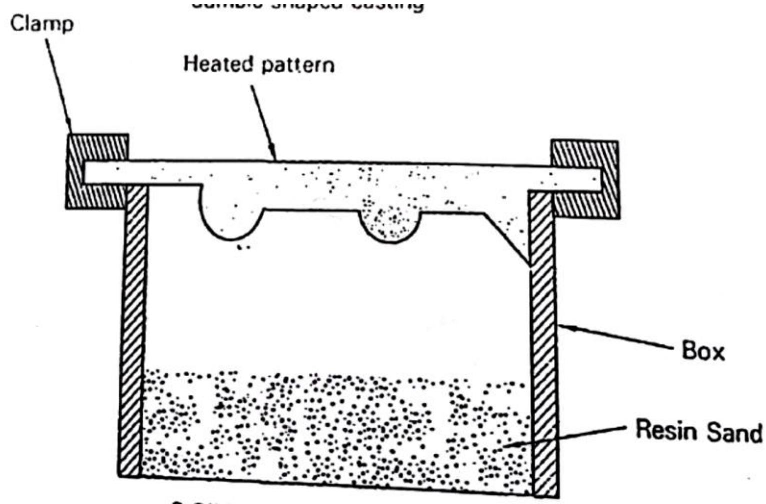
f) The pattern along with the shell is removed from the box and placed in an oven for a few minutes which further hardens the shell and makes it rigid. The shell is then stripped from the pattern with the help of ejector pins that are initially provided on the pattern. Refer figure 3.3(e).

g) Another shell half is prepared in a similar manner and both the shells are assembled together with the help of bolts, clips or glues to form a mould. The assembled part is then placed in a box with suitable backing sand* to receive the molten metal. Refer figure 3.3(f).

h) When the molten metal solidifies, it is removed from the mould, cleaned and finished to obtain the desired shape and size.

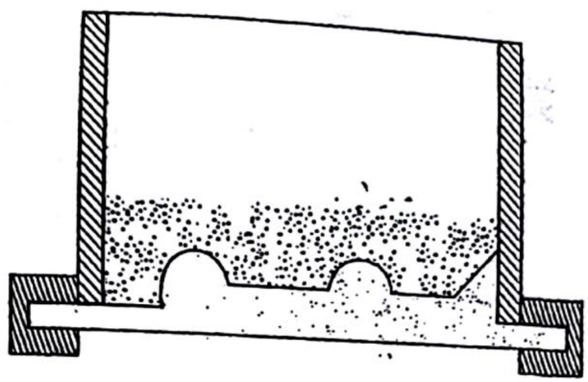


3.3(a) One half of a pattern to produce dumble shaped casting

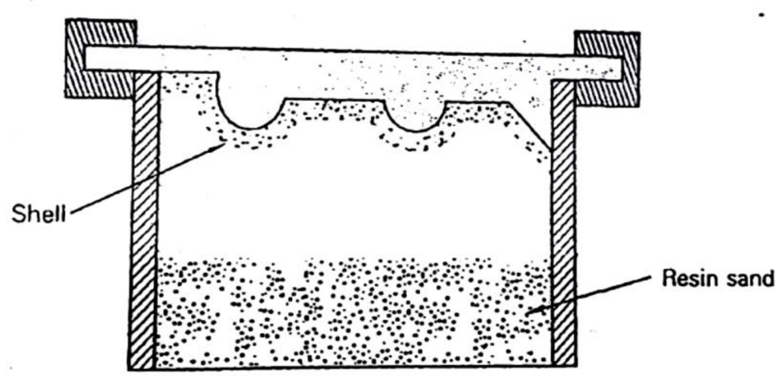


3.3(b) Pattern clamped to a box containing Resin Sand

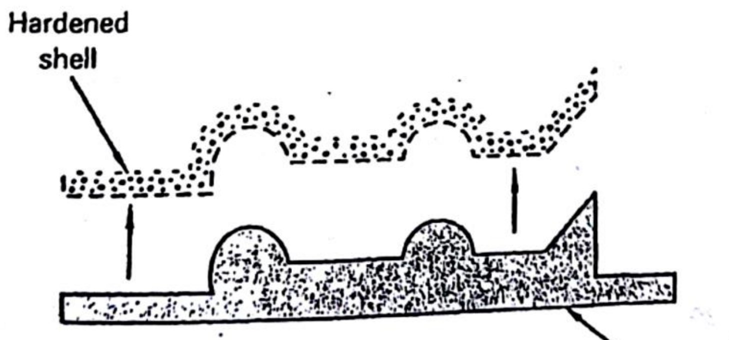
* *Backing sand – It is aged sand which cannot produce a strong bond and has changed its grain size and shape because of continuous use.*



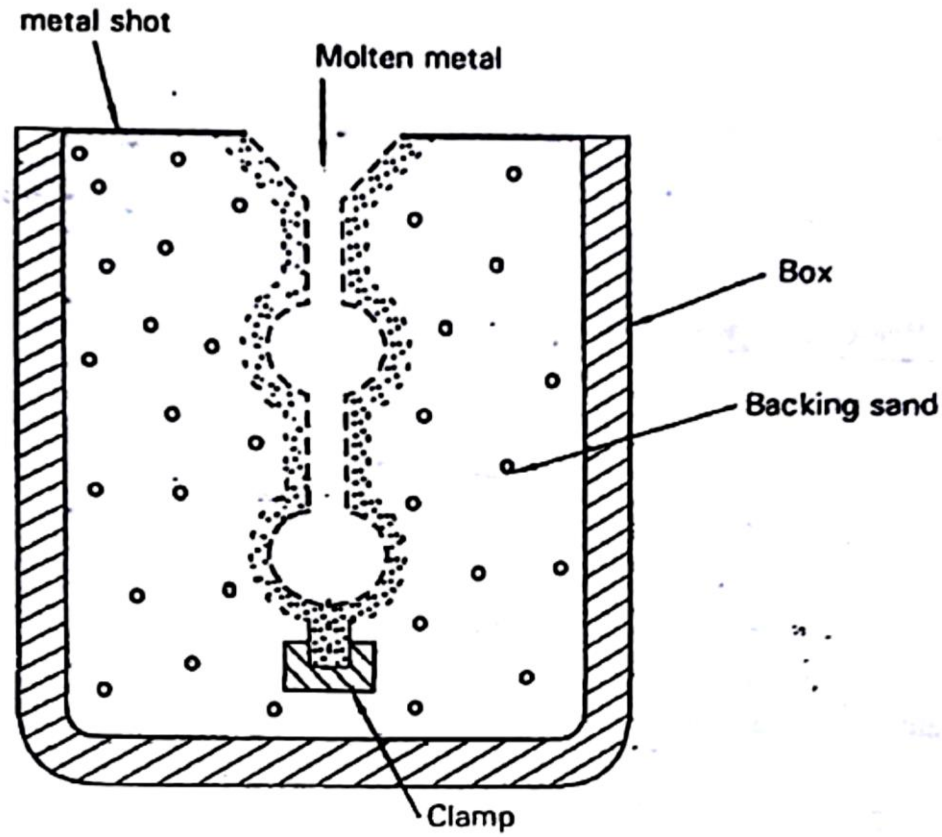
3.3(c) Box Inverted



3.3(d) Box re-inverted to original position



3.3(e) Shell stripped from pattern



3.3(f) Mould ready for pouring

Figure 3.3 Shell Moulding

3.7 INVESTMENT MOULD

Investment mould, also called as 'Precision casting' or 'Lost wax process' is an ancient method of casting complex shapes like impellers, turbine blades and other airplane parts that are difficult to produce by other manufacturing techniques. The various steps involved in this process are:

Step 1 Die* and Pattern making

A wax pattern is prepared by injecting liquid wax into a pre-fabricated die having approximately the same geometry of the cavity of the desired cast part. Refer figure 3.4(a). Several such patterns are produced in the similar manner and then attached to a wax gate and sprue by means of heated tools or melted wax to form a 'tree' as shown in figure 3.4(b).

Step 2 Pre-coating wax patterns

The tree is coated by dipping into refractory slurry which is a mixture of finely ground silica flour suspended in ethyl silicate solution (binder). The coated tree is sprinkled with silica sand and allowed to dry. Refer figure 3.4(c).

Step 3 Investment

The pre-coated tree is coated again (referred as 'investment') by dipping in a more viscous slurry made of refractory flour (fused silica, alumina etc.) and liquid binders (colloidal silica, sodium silicate etc.), and dusted with refractory sand. The process of dipping and dusting is repeated until a solid shell of desired thickness (about 6 – 10 mm) is achieved.

Note The first coating is composed of very fine particles that produce a good surface finish, whereas the second coating which is referred as '*Investment*' is coarser so as to build up the shell of desired thickness.

Step 4 De-waxing

The tree is placed in an inverted position and heated in a oven to about 300°F. The wax melts and drops down leaving a mould cavity that will be filled later by the molten metal. Refer figure 3.4(d).

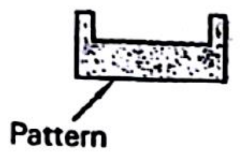
Step 5 Reheating the mould

The mould is heated to about 1000 - 2000°F (550-1100°C) to remove any residues of wax and at the same time to harden the binder.

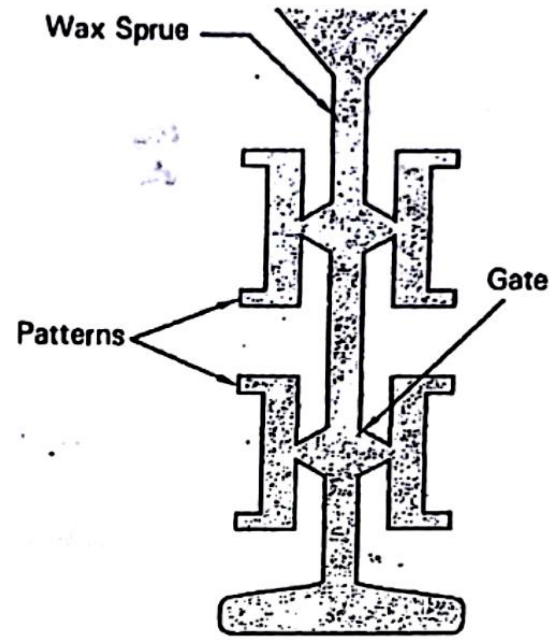
Step 6 Melting and Pouring

The mould is placed in a flask supported with a backing material, and the liquid metal of the desired composition is poured under gravity or by using air pressure depending on the requirement. Refer figure 3.4(e). After the metal cools and solidifies, the investment is broken by using chisels or hammer and then the casting is cut from the gating systems, cleaned and finished. Refer figure 3.4(f).

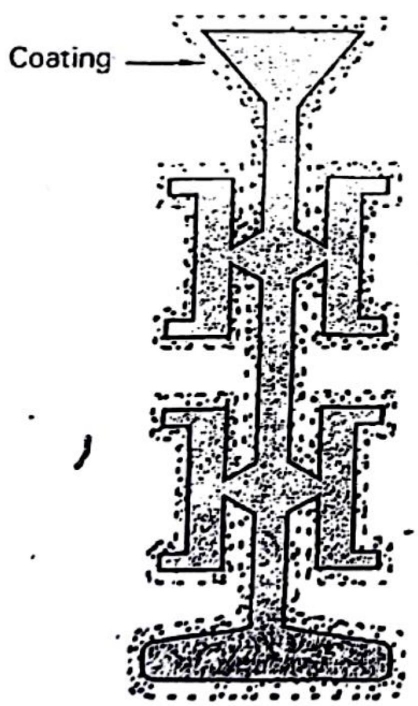
** Die – The cavity of a metallic mould into which molten metal is poured under gravity/ pressure is called 'die'. The die is initially cast by a master pattern made from wood or other materials.*



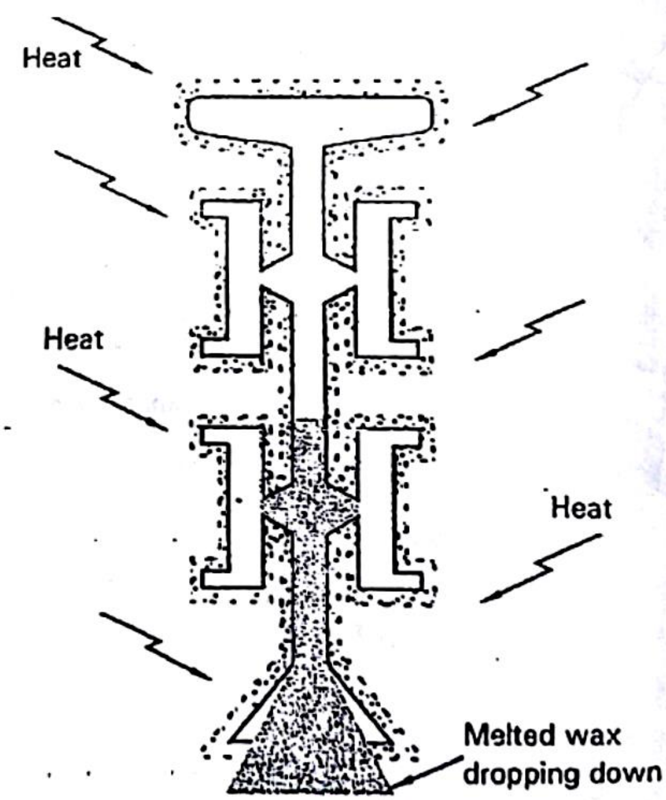
3.4(a) Wax pattern



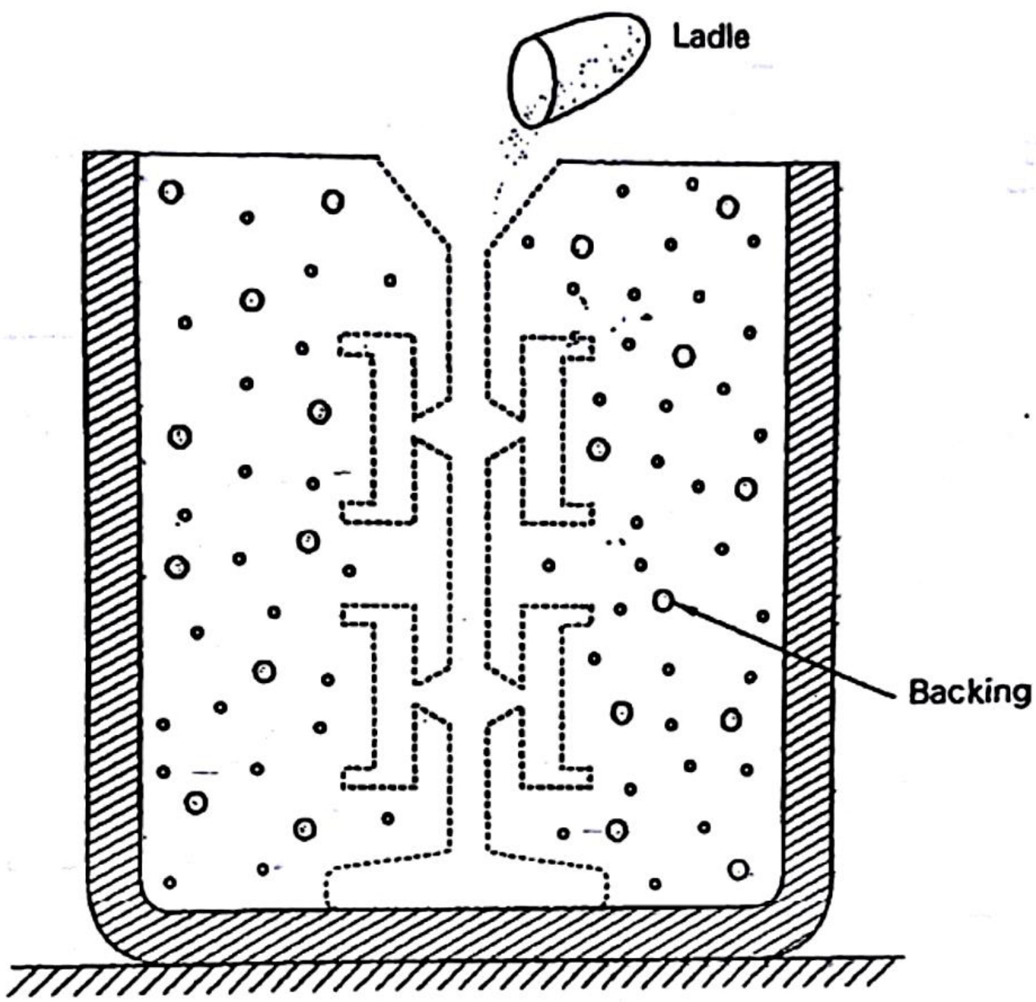
3.4(b) Pattern tree



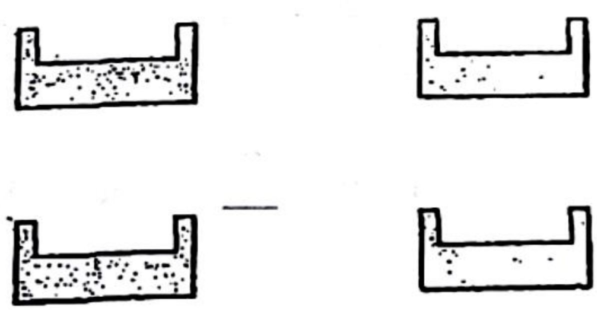
3.4(c) Pre-Coating and Investment



3.4(d) De-waxing



3.4(e) Pouring molten metal



3.4(f) Finished casting

Figure 3.4 Investment moulding

3.10 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 a book. The mould halves are hinged and can be clamped together to close the mould.

Steps involved in the process

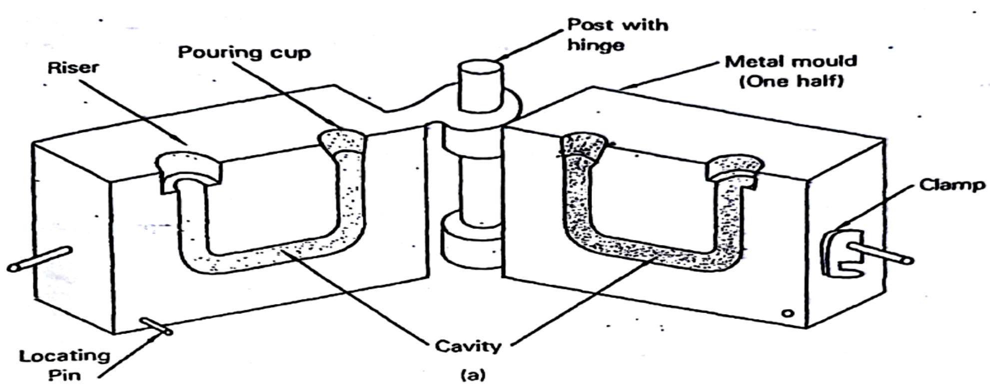
a) The mould is cleaned using wire brush or compressed air to remove dust and other particles from it.

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 3.7(b). 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.



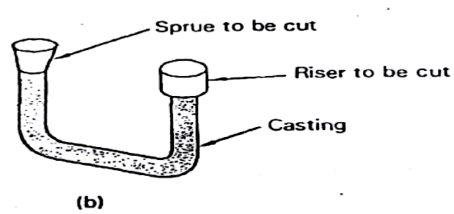


Figure 3.7 Gravity die casting

3.11 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 pressures*. 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 be cast. The two basic methods of die casting include:

(a) Hot chamber die casting process

(b) Cold chamber die casting process.

3.11.1 Hot chamber die casting process

Figure 3.8 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.

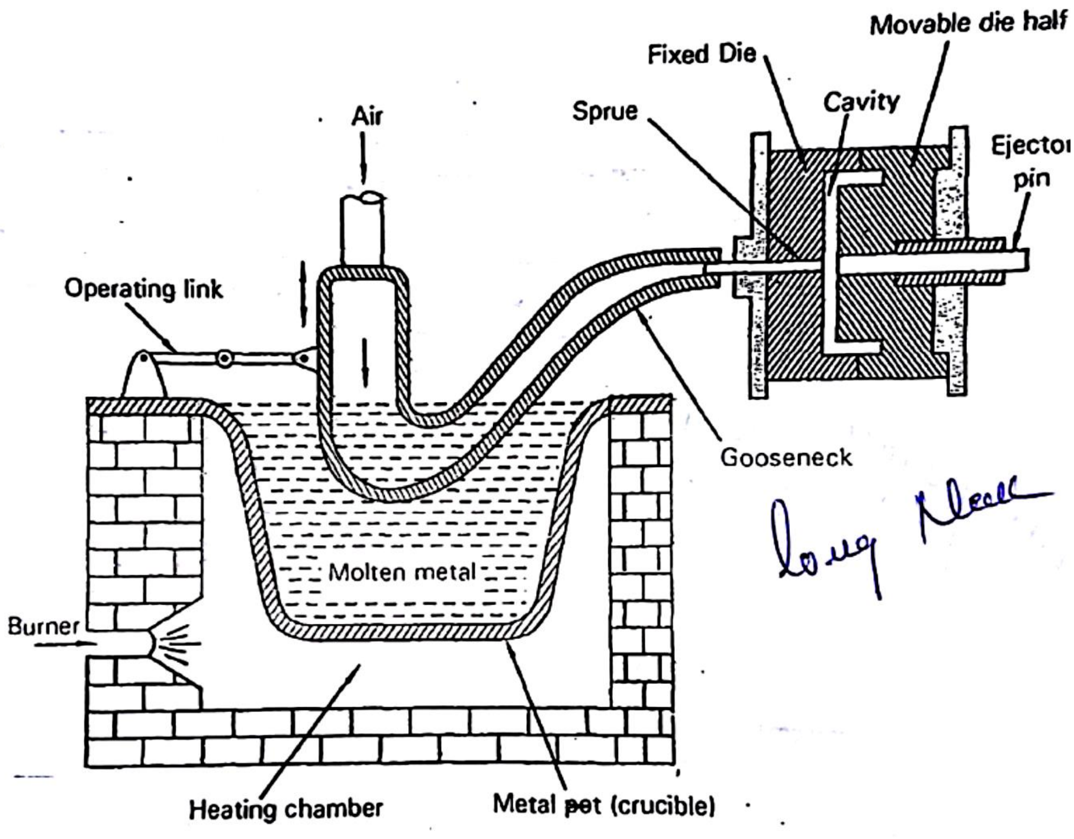


Figure 3.8 Hot chamber die casting (Goose neck type)

- **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 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 for casting metals like zinc, tin, magnesium and lead based alloys.

3.11.2 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

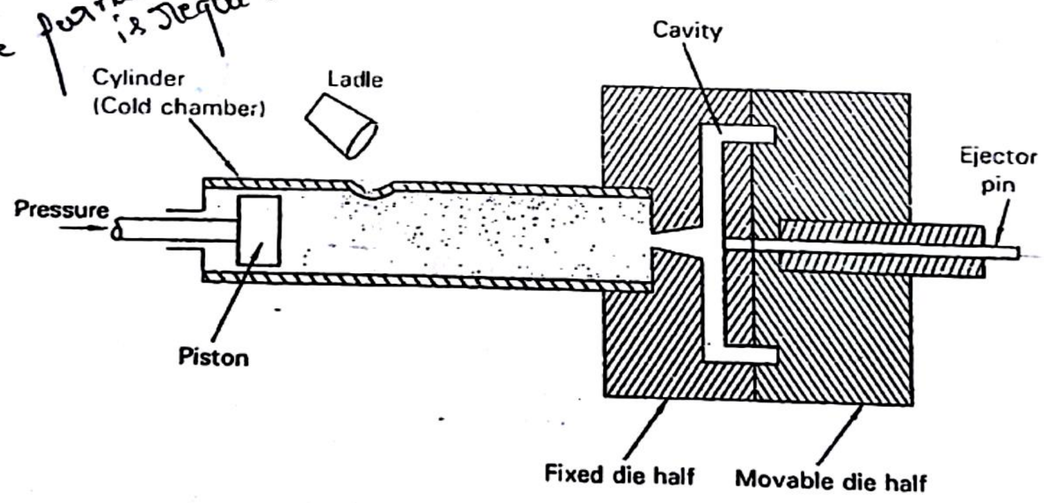


Figure 3.9 Cold chamber die casting

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 like in 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. The 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.

The cold chamber process is slightly slower when compared to the hot chamber process.

3.13 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.

3.13.1 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. This eliminates the need for cores for producing hollow castings. Figure 3.11 shows the true centrifugal process.

* *Yield – Comparison of casting weight to the total weight of the metal poured into the mould.*

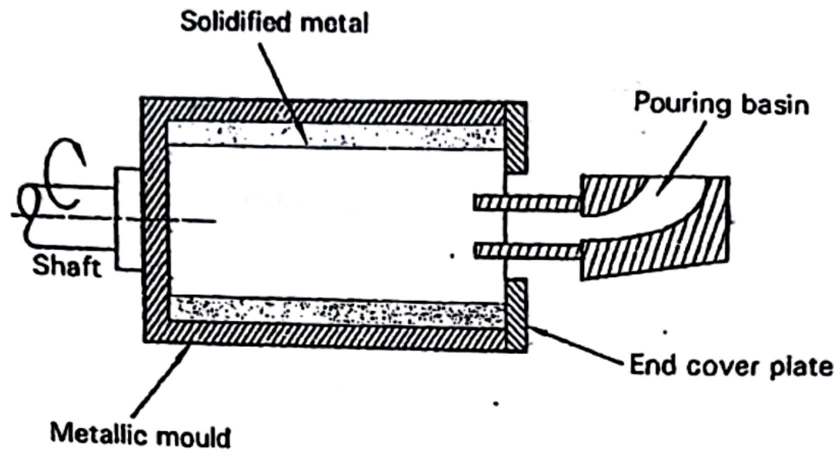


Figure 3.11 True centrifugal process

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).

Note

- The mould may be rotated horizontally or vertically. When the mould is rotated about a ***horizontal axis***, a true ***cylindrical inside surface*** is produced; if rotated on a ***vertical axis***, a ***parabolic inside surface*** is produced.
- Cores and gating/risering systems are not required for this process.