Unit 6: Casting Processes

2. Introduction

Manufacture of a machine part by heating a metal or alloy above its melting point temperature, thereby changing metal into liquid metal then pouring the liquid metal/alloy in a cavity approximately of same shape and size as the machine part, is called **casting or casting process**. After the liquid metal cools and solidifies, it acquires the shape and size of the cavity and resembles the finished part / product required.

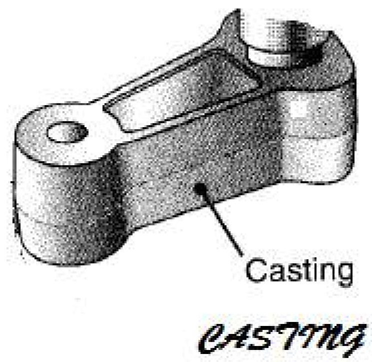
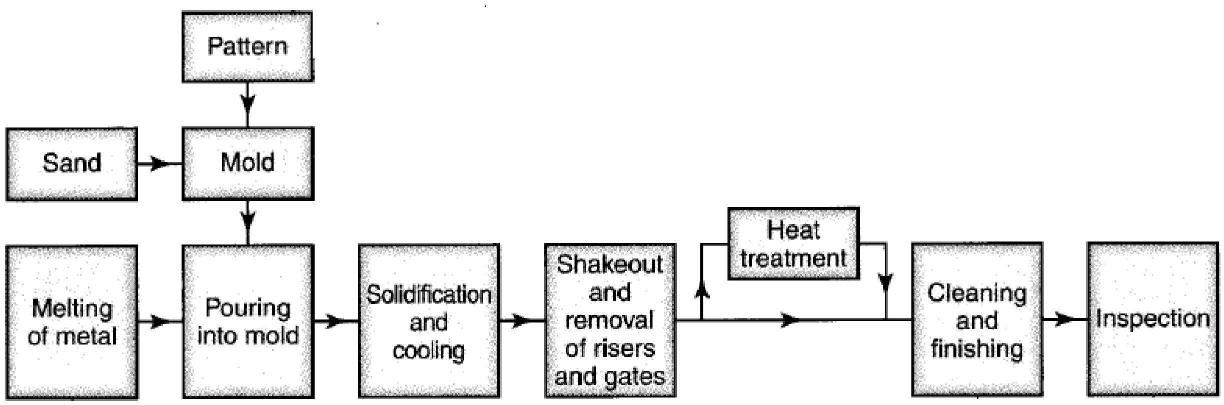


Fig 2(i) : CASTED MACHINE PART

Casting is an economical way of producing components of required shape either in small or large lots. However, castings are less strong as compared to wrought components produced by processes such as forging etc. The section of the workshop, where castings are made is called **foundry Shop**. In casting process, very little metal is wasted.

Castings are made of large number of metals and alloys, both ferrous and non-ferrous. Grey cast iron components are very common; steel castings are stronger and are used for components subject to higher stresses. Bronze and brass castings are used on ships and in marine environment, where ferrous items will be subjected to heavy corrosion. Aluminium and aluminium-magnesium castings are used in automobiles. Stainless steel castings are used for making cutlery items.

The steps involved in a casting process:



(*a*) Preparation of a pattern
(*b*) Preparation of a mould with the help of the pattern
(*c*) Heating metal or alloy above its melting point temperature in a suitable furnace, thereby changing metal into liquid metal.
(*d*) Pouring of molten metal into mould cavity and allow it to cool so that liquid metal solidify and acquires the shape and size of the cavity
(*e*) After solidification of the liquid metal, break the mould to retrieve the casting
(*f*) Cut off risers, runners etc., (this operation is called '**fettling**'), and Clean the casting.
(*g*) Inspect the casting for any visible defect.

Sand Casting.mp4

However castings offer the possibility of having slightly improved properties in certain part of the casting by techniques such as use of chill etc.

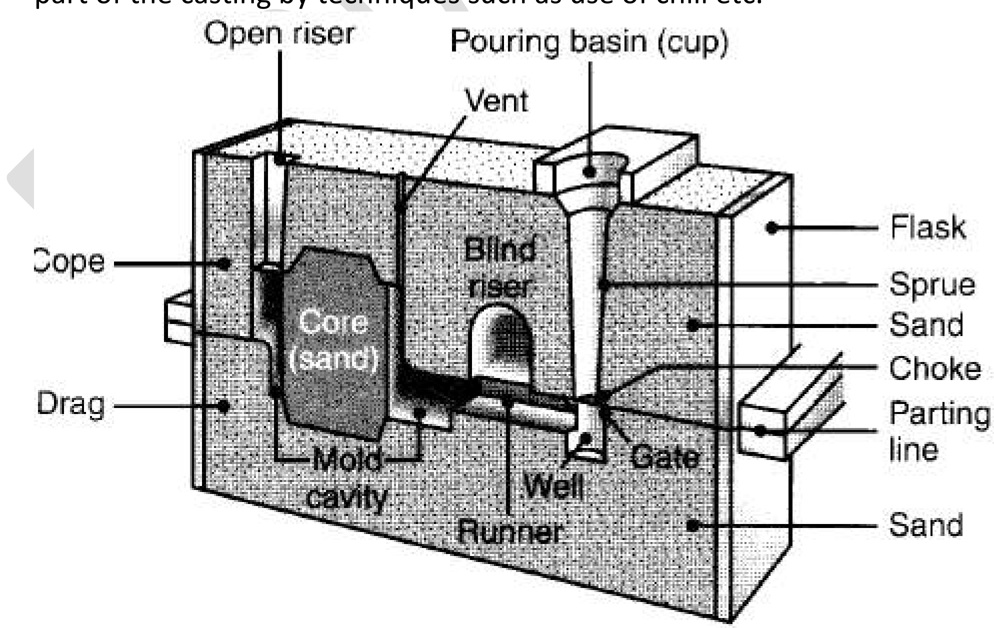


Fig. 2(ii) : Cut View of Gating System

2.1 PATTERNS

Patterns are replicas of the casting required. It is similar in shape and size to the final product, but not exactly. Usually, the mould is prepared in wet sand, to which some binder is added to hold sand particles together. The pattern is then withdrawn from inside the sand mould in such a manner that the impression/cavity made in the mould is not damaged or broken in anyway. Finally molten metal is poured into this cavity and allowed to solidify and cool down to room temperature.

2.2 Pattern Materials: There are many materials used for making patterns. Some of them are as follows:

a) **Wood**: It is the most common material for making a pattern. Normally the wood used for pattern making are Pine, Deodar, Teak, Shisham etc. Wood has following **Advantages**:
   i. It is also relatively cheap, abundant and easily available
   ii. It is economical
   iii. Acquires good smooth surface
   iv. Wood is easy to work, so easy to convert into required shape and size.
   v. Light weight
   vi. Properly seasoned wood retains its size
   vii. It can be preserved for long time

   Disadvantages:
   i. More tear and wear
   ii. It is effected by atmospheric moisture.
   Usually, they are made of aluminium-magnesium alloys.

b) **POP (Plaster of Paris)**: POP can be casted very easily to any shape. It has a very high compressive strength and can be used to make patterns of smaller sizes with closed dimensional control.

c) **Metals**: Metal patterns are used for mass production with more accuracy. Metals used for making the patterns are:
   i. **Cast iron** : It is more economical. It is easy to be casted into any shape and has better resistance to abrasion, gives good surface finish.
   ii. **Brass**: It is used for making pattern of small sizes. It has more strength and resistance to corrosion. It is suitable for good surface finish
   iii. **Aluminium**: It is used for making pattern of bigger sizes since the weight is less and is also economical. It not as strong as other metal
   iv. **Aluminium-magnesium alloys**: Patterns are also made of aluminium-magnesium alloys.

d) **Plastics**: Plastic is preferred for making patterns because of lighter weight, more strength with lesser wear, better surface finish, low shrinkage, melting is not costlier. Plastic used for pattern making are called thermosetting resins. Initially the moulds are made from Plaster of Paris then the resin is poured in the moulds at a particular temperature. After solidification of resin, we get plastic patterns.

e) **Wax**: In this the mould is made into two halves and the wax is poured in this. The cooling of die is done by circulation of water. After cooling, the die is separated and pattern is taken out.

2.3 TYPES OF PATTERNS

(i) **Solid or single piece pattern:** Such patterns are made in one piece and are suitable only for very simple castings. There is no provision for runners and risers etc. Moulding can be done either in the foundry floor (called pit moulding) or in a moulding box. There is no difficulty in withdrawing the pattern from the mould as the broadest portion of the pattern is at the top. As an example, if a cylindrical pin with a circular head has to be cast, a one piece pattern shown in Fig. 2.3(i) will be adequate.

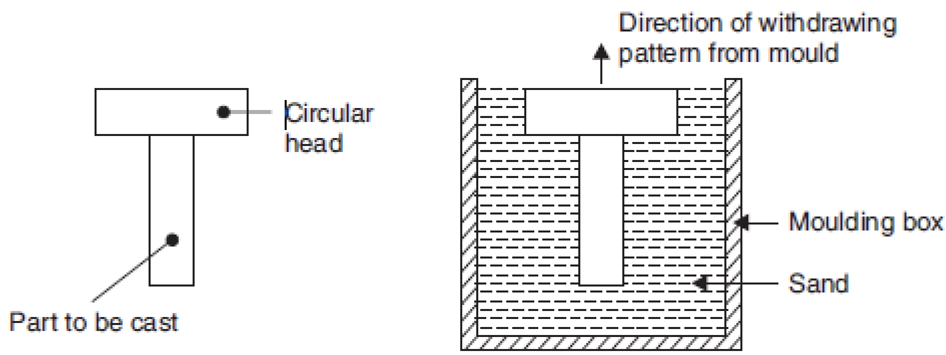


Fig. 2.3(i) : Solid Pattern

(ii) **Split pattern or Two Piece Pattern :** It is not practical to have one piece pattern for parts of complicated shapes, because it would not be possible to withdraw the pattern from the mould. For example, if a circular head was added to the bottom of the pin shown in Fig.1, it would make it necessary to go in for a split pattern as shown in Fig. 2.3(ii)

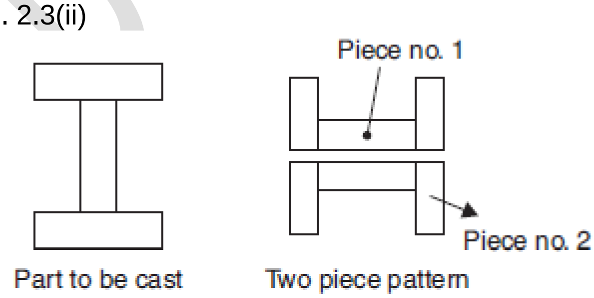


Fig. 2.3(ii) : Split pattern

One-half of the impression in the mould will be made by using piece no. 1 in one moulding box and the other half of the impression will be made by using piece no. 2 in a second moulding box. After withdrawing the pattern halves from the respective moulding boxes, the two boxes will be assembled and clamped together, so that the complete impression is available for pouring the metal. The two pattern halves are provided with locating dowels, so that one-half may sit on the other half in the exact position required with no mismatch. Also two tapped holes are provided on the flat mating surface of each part. These tapped holes are used to provide a grip to lift the pattern halves from the sand without damaging the mould-impression. The line along which the pattern is divided into halves is called “parting line” and it usually follows the broadest cross-section of the casting. Deciding where the parting line should be is a matter of considerable skill and experience. Some of the more complicated castings may require pattern to be split in three or even more pieces.

iii) **Multi piece Pattern:** Some time a casting is more complicated in design and need more parts in order to facilitate an easy moulding and withdrawal of pattern. In this case pattern may consist of 3 or more number of parts, depending upon the design.

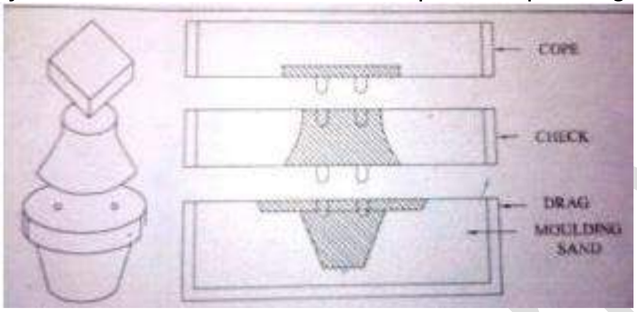


Fig.2.3 (iii) : Multi Piece Pattern

iv) **Loose piece pattern:** In some cases, the casting may have small projections over hanging portions. These projections make it difficult to withdraw the pattern from the mould. Therefore these projections are made as loose pieces. They are loosely attached to the main part of the pattern and the mould is made in the usual way. When the main pattern is withdrawn from the mould, the loose pieces slip off and remain behind in the mould. After removing the main body of the pattern, the loose pieces are taken out by first moving them laterally and then lifting them through the space vacated by the main pattern. The method is illustrated in Fig.2.3(iv).

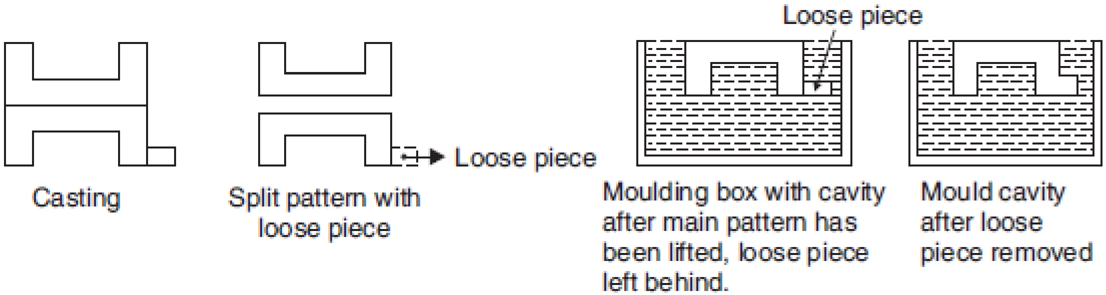


Fig.2.3(iv) : loose Pattern

V) **Match plate pattern:** Match plate is a metal plate, usually made of aluminium. The two halves of the split pattern are mounted on this match plate one on either side. While fixing them to the match plate, care is taken so that there is no mismatch. These patterns are used in conjunction with mechanically operated moulding machines.

Bottom side of match plate pattern is used for making the bottom half of the mould impression in one moulding box (known as the drag). The upper side of the match plate pattern is used for making the mould impression in another moulding box. Finally, the two moulding boxes are kept on top of each other, the bottom box is known as the drag, whereas the top one is called the cope.

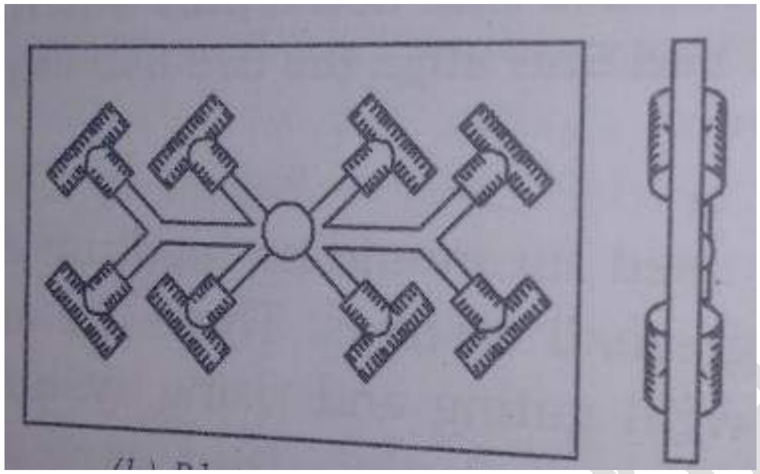


Fig. 2.3 (v): Match Plate Pattern

vi) **Gated patterns:** Sometimes along with the pattern for the casting, another portion is added so that when the impression is made in the moulding box, the cavity contains a shallow channel along with the main cavity for the object to be cast. This channel will be used for feeding molten metal into the main cavity and is known as the “gate”. Such patterns where provision for gating has been made are called gated patterns. It removes the necessity of making a gate separately. (*vi*) Other pattern types include skeleton pattern, sweep pattern and segmental pattern etc. In these patterns, the full pattern is not made and the mould is completed with an improvised pattern. This is done to reduce the cost of pattern making. This procedure is resorted to, if only one or two moulds are to be made.

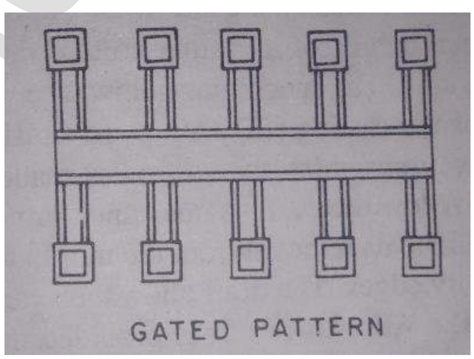


Fig. 2.3(vi) a: Gated patterns

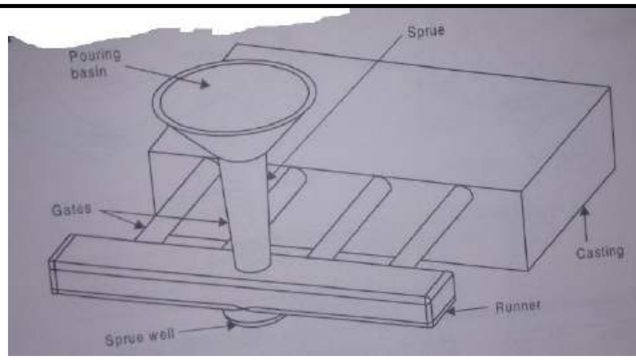


Fig. 2.3(vi) b: Gated patterns

vii) **Sweep Pattern:** Sweep pattern used for preparing moulds of large symmetrical casting, particularly of circular cross section. .This saves the time, labour and material. The full equipment consists of a base, suitably placed in the sand mass, a vertical spindle and a wooden template, called sweep. The outer end of the sweep carries the contour corresponding to the shape of the desired casting. The sweep is rotated about the spindle to form the cavity. Then the sweep and spindle are removed, leaving the base in the sand. The hole made by the removal of spindle is patched up filling the sand.

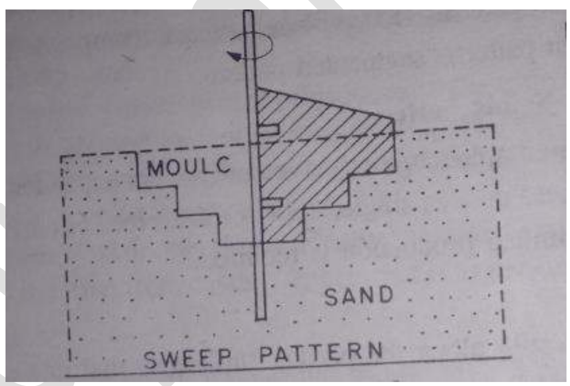
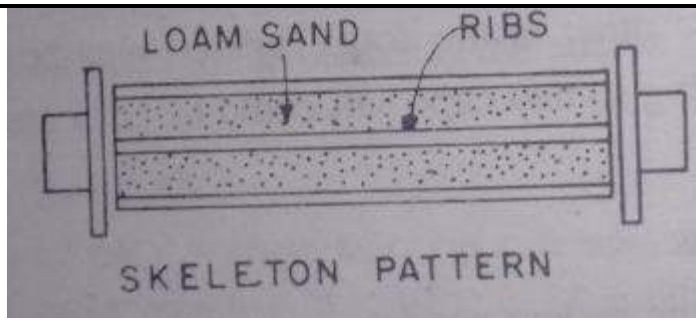


Fig. 2.3(vii): Sweep Pattern

viii) **Skeleton Pattern:** When the size of the casting is very large, but easy to shape and only a few numbers are to be made. It is not economical to make a large solid pattern of that size. In such cases, a pattern consisting of a wooden frame and strips is made, called **Skeleton Pattern**. It is filled with loam sand and rammed. The surplus sand is removed by means of a strickle. The core can be prepared separately and assembled in position in the mould.



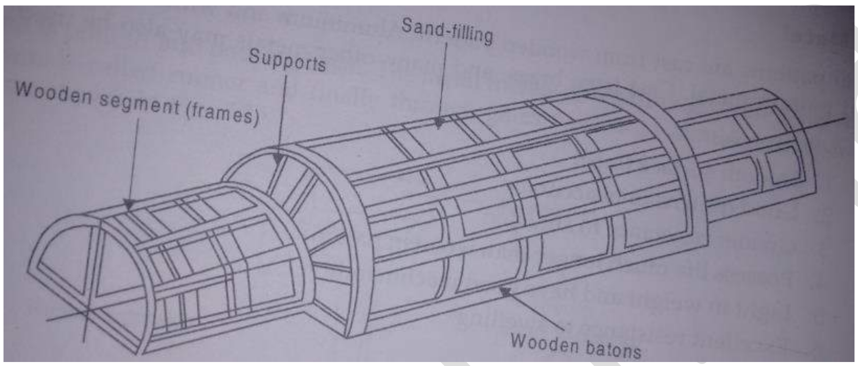


Fig. 2.3(viii): Skeleton Pattern

ix) **Cope and Drag Pattern:** When a very large casting are to be made. In this case the complete pattern becomes too heavy to be handled by single operator. In such situations a pattern is made in two parts which are separately moulded in different moulding boxes. After completion of the mould, the two boxes are essembled to form the complete cavity, in which one part is contained in cope and other part is contained in the drag. In other words it is split pattern or two piece pattern of which both the pieces are moulded separately instead of being moulded in the assembled position.

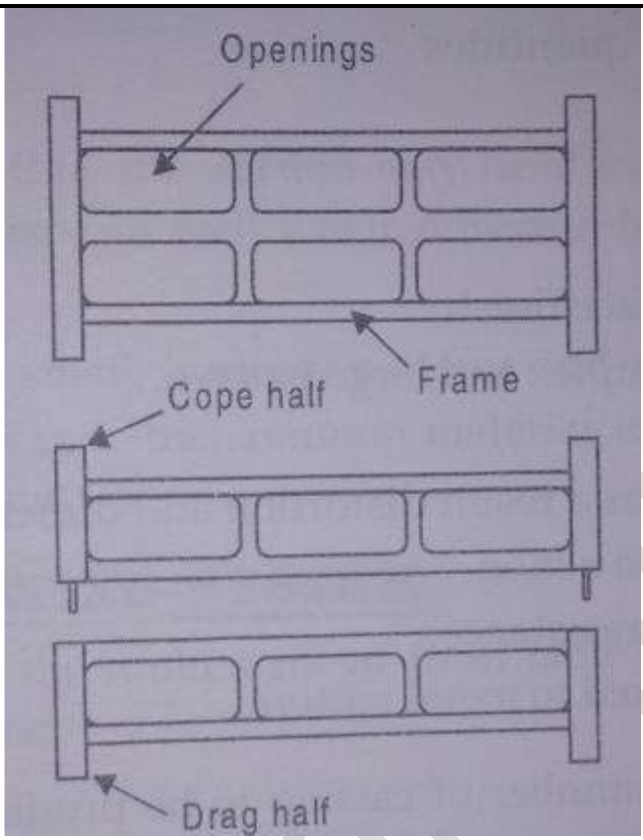


Fig. 2.3(ix): Cope and Drag Pattern

x) **Segmental Pattern**: These are used for preparing moulds of large circular castings, to avoid the use of a solid pattern of the exact size. A segmental pattern is a portion of the solid pattern itself and the mould is prepared in parts by it. It is mounted on a central pivot after preparing the part mould in one position, the segment is move to next position. This process is repeated till the complete mould is prepared.

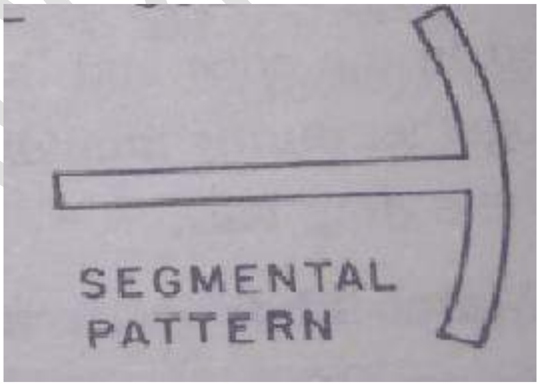


Fig. 2.3(x): Segmental Pattern

(xi) Master Pattern:

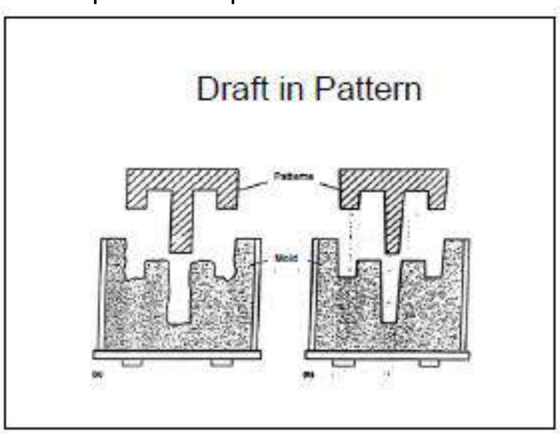
A master pattern, usually made of wood, is used an original for casting metal patterns. Several pattern may be cast from the master patterns and mounted on the pattern plate after they have been finished to their proper dimensions master patter may be the first step to obtain match plates. Most metal pattern are cast in sand mould from a wood master pattern provided with double shrinkage allowances.

2.4 PATTERN ALLOWANCES: There are following allowances provided in the patterns:

(a) Shrinkage Allowance: Most metals shrink in volume, when solidifying from liquid state and on cooling, it is obvious, that the pattern should be made slightly larger than the size of finished casting. This difference in size of the pattern is called **shrinkage allowance or contraction allowances**. For cast iron, this allowance is 1% and for aluminium, it is about 1.6%.

(b) Machining Allowance: On many occasions, castings produced in the foundry shop are machined subsequently to obtain good surface finish. The object of machining is to get exact sizes and better surface finish on the component. If such is the case, a layer of 1.6–12.5 mm thick material has to be provided all round the casting depending upon the type of casting metal, size and shape of casting, method of casting used, method of machining to be employed and the degree of finish required.. This is done by making the pattern suitably bigger than the casting. This increase in size of pattern is called “**machining allowance**” or **finishing allowances**.

(c) Draft or Taper Allowance: Draft allowance is an important allowance provided on vertical surfaces of the patterns. It facilitates withdrawal of pattern from the mould. The idea is to give an inclination of 2–3 degrees to vertical surfaces, so that while lifting the pattern from the sand cavity, the upper surface is wider. Withdrawing the pattern with draft provided will not damage the sand mould. On inner vertical surfaces, draft is provided in such a way that top surface is narrower and bottom portion of pattern is wider.



(d) **Shake or Rapping Allowance**: Before the pattern is withdrawn from the mould, the pattern first of all is shaken so that it is free from adjoining walls, due to this size of mould cavity increases so a negative allowance is given to the pattern. It means pattern is made little smaller than the required size of the part. This allowances is called shaking rapping allowance

(e) **Distortion or Camber Allowance**: There are certain castings in which the cooling of the metal is not uniform throughout the casting due to very complicated shape. Due to this there is distortion in the casting. To minimize its effect distortion in opposite direction is given in the pattern. This can be practically eliminated by providing an allowance and the pattern initially distored

(f) **Mould Wall Movement Allowance**:
Moment of mould wall in the sand mould takes place because of heat and the static pressure …… walls of the mould which comes in contact with the molten metal. Because of this, the size of the mould (cavity) increases. In order to compensate this, the pattern is made smaller so that the casting produced have an accurate size.

2.4 MOULDING SANDS

In foundries, sand is used for making moulds. Natural sand found on the bed and banks of rivers provides an abundant source, although high quality silica sand is also mined. Sand is chemically SiO_2, Silicon Dioxide in granular form. Ordinary river sand contains a certain percentage of clay, moisture, non-metallic impurities and traces of magnesium and calcium salts besides silica grains. This sand, after suitable treatment, is used for mould making. There are following common types of sands used in the Foundry shop:

1. **Natural Sand**: These sands are taken from river beds and are dug from pits and purely natural. They contains appreciable amount of clay and moisture. It also denotes well prepared foundry sand which contains just enough moisture to give it sufficient bond. Here moisture only acts as binder. Hence known as green sand. This does not require any baking before pouring the molten metal into them. Due to their low cost and easy availability, these are used for most of the ferrous and nonferrous castings. It is also known as **Tempered sand**.

2. **Synthetic Sand**: is an artificially obtained by mixing relatively clay free sand, binder and other materials required. It is better moulding sand as its properties can be easily controlled by varying the contents.

3. **Special Sand:** Contains the mixtures of inorganic compounds. Cost of these sands is more but they offer temperature stability, better cast surfaces etc. Special sands

used are zircon, olivine, chamotte, chromite etc.

4. **Green Sands:** These sands are taken from river beds and are dug from pits and purely natural. They contains appreciable amount of clay and moisture. Here moisture only acts as binder. The sand in its natural or moist state is called green sand. It is a mixture of silica sand with 18 to 30 percent clay having total amount of water 6 to 8 percent. The molten metal is poured in the green sand moulds without any prior baking (Heating). It is used for simple, small and medium size castings.

5. **Dry Sand**: The green sand mould when baked or dried before pouring the molten metal is called dry sand mould. The sand in this condition is called dry sand. The moisture contents of green sand have been evaporated from it by drying in a suitable oven to get the mould. Dry sand has more strength, rigidity and thermal stability as compared to green sand. These moulds are used for large and heavy castings.

6. **Loam Sand**: Contains much more clay as compared to ordinary moulding sand. The clay content is of the order of 50%.It is used for loam mould of large grey iron casting.

7. **Facing Sand**: This term is used for sand which forms the face of the mould or rammed around the pattern surface. This sand is used directly next to the surface of the pattern and comes in contact with the molten metal when the molten metal is poured It is the fresh prepared and well tempered foundry sand. Initial coating around the pattern surface is given by this sand and the remainder of the flask is filled with floor sand for economical reasons. It possess high strength and refractoriness. The layer of facing sand in mould usually ranges from 20 to 30 mm.

8. **Parting Sand**: This sand is clay free and consists of dry silica sand, sea sand or burnt sand. This sand is sprinkled on the parting and the parting surfaces of the mould so that the sand mass of one flask does not stick to that of the other or to the pattern. Burnt sand and dry silica sand are used for this purpose.

9. **Floor, Black or Baking Sand**: These terms are used to denote the used sand which is left on the floor after the castings have been removed from the mould. Before reusing, it is riddled to remove foreign materials and then used for filling the bulk of the moulding flask after the facing sand has been rammed around the pattern. It is the sand which backs up the facing sand. It is the floor sand which is repeatedly used. Backing sand has black colour due to the addition of caol dust and burning on coming in contact with molten metal.

10. **Core Sand**: This sand has high silica contents and is used for making core is known as core sand. This is also known as oil sand. It is silica sand mixed with linseed oil or any other oil as binder

11. **Molasses Sand**: The sand which is having molasses as binder, known as molasses sand. It is useful making moulds of small castings having intricate shapes and thin sections. Also used for core sand.

2.5 Main Constituent of Moulding Sands:

Generally fresh moulding sand prepared in the foundry has the following composition:

Silica	75% (approx.)
Clay	10–15%
Bentonite	2–5% (as required)
Coal dust	5–10%
Moisture	6–8%

Principal Constituent of Moulding Sand:

1. Silica Sand
2. Binder
3. Additives
4. Water

Properties like permeability, cohesiveness and green strength, dependent upon size and shape of sand grains, also upon the binding material and moisture content present in sand. Clay is a natural binder. Chemical binders like bentonite is sometimes added if clay content in natural sand is not enough. Core sand has oil as the main binding material. A core gets surrounded by molten metal which causes the oil to vaporize. This increases collapsibility of sand and makes it easy to remove sand from the holes in the casting.

a) Silica sand is the major portion of the moulding sand. Silica sand is found in nature on the bottoms and bank of rivers, lakes and large bodies of water. Sand grains imparts refractriness, chemical resistivity and permeability to the sand.

b) **Binders**: The purpose of adding a binder to the moulding sand is to impart strength and cohesiveness to enable it to retain its shape after the mould has been rammed and the pattern withdrawn.
Organic Binders: Molasses, Linseed oil, Cereal Binders etc
Inorganic Binders: Bentonite ($Al_2O_3.4SiO_2.H_2O.nH_2O$), fire clay ($Al_2O_3.2SiO_2.2H_2O$) Limonite etc. Of the above, Bentonite is widely used. It is found in Bihar and Rajasthan etc.

c) **Additives**: Additives are materials which are added to the moulding sand to improve upon some of the existing properties and also to impart certain desired properties to it. Common Additives are: Sea Coal, Pitch and Asphalt, Silica Flour, Graphite, Woof Flour, Corn Flour, Fuel Oil, Dextrin and Molasses etc.

d) **Water**: The clay content added to the foundry sand will not give the required strength and bond until a suitable quantity of water is added to it. Depending upon different requirements, water quantity varies from 2 to 10 percent. The water content present in the sand mass is partly in mixed form, called pore water and partly in free state, called free water. Part of the water filling into the pores of the clay form a micro film which is responsible for imparting the desired strength to the sand. When more water is present in the clay, it remains as fluid and is held between the clay particles separating them. This excess amount of free water acts as a lubricant, help in improving the mouldability and plasticity of the moulding sand. At the same time it reduces the strength of mould sand.

2.6 PROPERTIES OF MOULDING SAND

A good, well prepared moulding sand should have the following properties:

(*i*) **Refractoriness** : It is the ability of the moulding sand to withstand high temperature of the molten metal without fusion, cracking or buckling..

(*ii*) **Permeability** : ability of the sand to allow gases, water vapour and air to pass through it when come in contact with molten metal is called permeability.

(*iii*) **Cohesiveness** : *This is the* ability of sand grains to stick together. It may be defined as the strength of the moulding sand. Without cohesiveness, the moulds will lack strength. It is of three types:

- **(a) Green Strength**: Strength of the sand in its green or moist state is known as Green Strength. When a mould is made with moist sand, it should have sufficient strength, otherwise mould will break.
- **(b) Dry Strength**: The strength of the sand that has been dried or baked is called dry strength.
- **(c) Hot Strength**: After moistur has evaporated, the sand may be required to possess strength at some elevated temperature. So the strength of the sand at elevated temperature is called hot strength.

(*iv*) **Good flowability** : when it is packed around a pattern in a moulding box, it should be able to fill all nooks and corners, otherwise the impression of pattern in mould would not be sharp and clear.

(*v*) **Collapsibility** : it should collapse easily after the casting has cooled down and has been extracted after breaking the mould. It is particularly important in case of core making. If the mould or core does not collapse easily, it may restrict free contraction of solidifying metal and cause the same to tear or crack. Mouling sand has to addthe optimum amount of the binder in the moulding sand so that moulding sand have required strength as well as required collapsibility.

(*vi*) A**dhesiveness** :Property of sand due to which it adhere or clinch to other bodies. If the moulding sand does not stick to the walls of moulding box, the whole mould will slip through the box. It is due to this property that the sand mass can be successfully held in a mould box and does not fall out of the box when it is tilted.

(vii) **Durability**: The moulding sand should possess the capacity to withstand repeated cycles of heating and cooling during casting operations. This ability of sand is known as durability.

(viii) **Fineness**: Finer the sand Mould (small grain size) resists metal penetration and produce smooth casting surface. Fineness and permeability are inversely proportional. They must be balanced for good results.

(ix) Moulding sand should be chemically neutral.

(x) Moulding sand should be reusable, cheap and easily available.

2.7 MOULD MAKING TECHNIQUE

Mould making is a very skilled operation. Step by step, the procedure for making a mould for a split pattern is as follows:

Step 1: Place bottom half of the split pattern on a flat moulding board, with the parting surface face downwards. Sprinkle some parting sand on the pattern and the moulding board. Parting sand is silica sand without any clay or binding material. Then place a moulding box to enclose the pattern.

Step 2: Spread facing sand to cover all parts of the pattern up to a depth of 20 –25 mm. Facing sand is freshly prepared moulding sand. Fill up the remaining space left in the moulding box with backing sand. Backing sand is prepared by reconditioning the previously used foundry sand which is always available on the foundry floor. Use of backing sand reduces the requirement of facing sand, which is quite costly.

Step 3: Next, the sand in the moulding box is rammed with a special tool. Ramming means pressing the sand down by giving it gentle blows. Sand should be packed in the moulding box tightly but not too tightly. If as a result of ramming, the level of sand goes down in the box, more sand should be filled in and rammed. Then with a trowel, level the sand lying on the top of the mould box. Next take a venting tool (it is a long thick needle), make venting holes in the sand taking care that they are not so deep as to touch the pattern. This moulding box will form the lower box, and is called "**drag**".

Step 4: Now turn over the moulding box gently and let it rest on some loose sand after leveling the foundry floor. Place the top half of split pattern in correct relative position on the flat surface of the bottom half of the pattern. Place another empty moulding box on the top of first moulding box (*i.e.*, drag) and clamp them temporarily. Sprinkle some parting sand upon the exposed surface of the top half of pattern and the surrounding sand. Cover the pattern in 20 –25 mm deep facing sand. Place two taper pins at suitable places, where runner and riser are to be located. Full up the box with backing sand, pack in sand with ramming tool, level sand and make venting holes. Remove taper pins and make room on foundry floor, next to the drag box, for keeping the "cope" as the top box is called Unclamp the moulding boxes, lift '**cope**' and place it down on its back. Now the flat parting surface of both parts of the split pattern can be seen one in each box.

Step 5: In order to lift the patterns from cope and the drag, locate the tapped holes on the flat surface and screw in a lifting rod in these holes. This provides a handle with which the patterns can be easily lifted up vertically. However first the patterns are loosened a bit by rapping these handles gently before lifting them. This minimizes the damage to sand moulds.

Step 6: After removing wooden pattern halves, the mould cavities may be repaired in case any corners etc., have been damaged. This is a delicate operation. Also, if any sand has fallen into the mould cavity, it is carefully lifted or blown away by a stream of air.

Step 7: In case, any cores are used to make holes in the casting, this is time for placing the cores in the mould cavity. Of course, the cores are supported properly by means of core prints or other devices like chaplets etc. Lack of adequate support for cores may result in their displacement from correct position when the liquid metal is poured in.

Step 8: Before closing of the mould boxes, graphite powder is sprinkled on the mould surface in both boxes. In the drag box, a gate is cut below the location of the runner (in the cope box). The molten metal poured in the runner will flow through the gate into the mould cavity. In case, the moulds have been dried, instead of graphite powder, a mould wash containing suspension of graphite in water is lightly spread over the mould surface. After all these operations are complete, the cope box is again placed on the drag and clamped securely. Now the mould is ready for pouring molten metal. Molten metal is poured until it shows up in the riser. It ensures that mould cavities are full of metal and that it will not run short. A complete mould ready for pouring is shown in Fig. 2.6 Sand moulds are of three kinds:

(*a*) **Green sand mould:** In such moulds, pouring of molten metal is done, when the sand is still moist.

(*b*) **Skin dry moulds:** Such moulds are superficially dried by moving a flame over mould cavity so that mould dries only up to a depth of few mm.

(*c*) **Dry moulds:** After preparing such moulds, they are dried by keeping the mould for 24–36 hours in an oven whose temperature is maintained at 130–150°C. Dry sand moulds are stronger and cannot give rise to any moisture related defects in the casting. Mould wash improves the surface finish of castings.

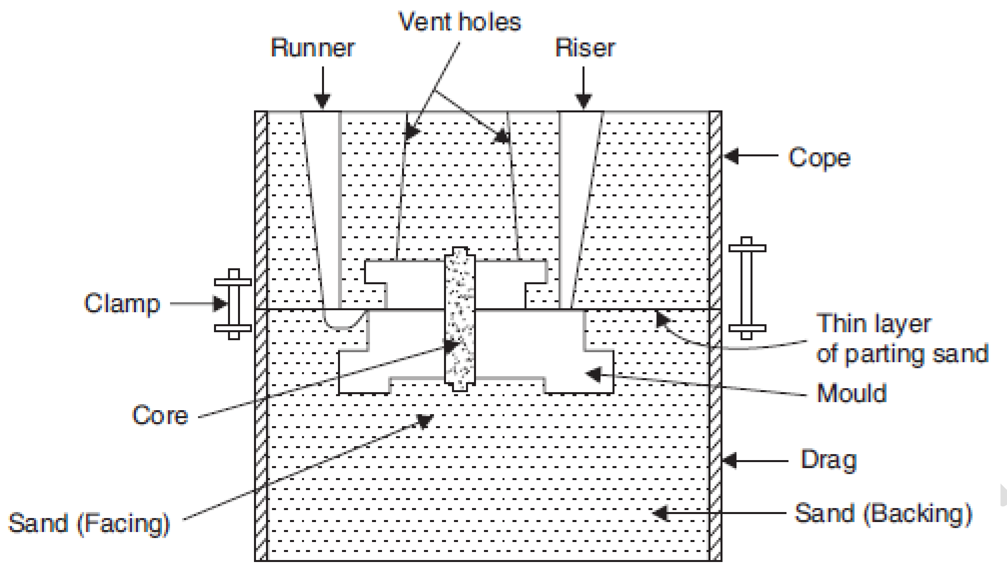


Fig.2..7 : A mould ready for pouring

2.8 CORES:

Whenever a hole, recess, undercut or internal cavity is required in a casting, a core, which is usually made up of a refractory material like sand is inserted at the required location in the mould cavity before finally closing the mould. A core, being surrounded on all sides by molten metal, should be able to withstand high temperature. It should also be adequately supported otherwise due to buoyancy of molten metal, it will get dislocate. When the molten metal around the core solidifies and shrinks, the core should give way, otherwise the casting may crack (hot tear). Cores, as explained previously, should be made of oil sand and dried in a oven before use. Cores are made with the help of core boxes. Core boxes are made of wood and have a cavity cut in them, which is the shape and size of the core. The sand in mixed and filled in the core boxes. It is then rammed. A core box is made in two halves, each half contains half impression of core. Sometimes a core may need reinforcements to hold it together. The reinforcements are in the shape of wire or nails, which can be extracted from the hole in the casting along with core sand.

Types of Cores: Various types of cores are described below:

a) **Horizontal cores**: It is the simple type of core and most used. It is assembled in the mould with its axis horizontal. It is supported in the mould at its both ends as shown in Fig. 2.8(a).

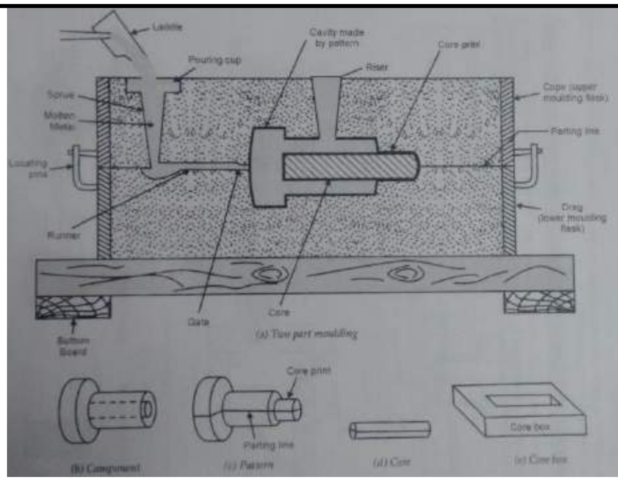


Fig. 2.8(a): Horizontal cores

b) **Vertical Core**: It is the similar to a horizontal core. It is assembled in the mould with its axis vertical. It is supported in the mould at its both ends as shown in Fig. 2.8(b).

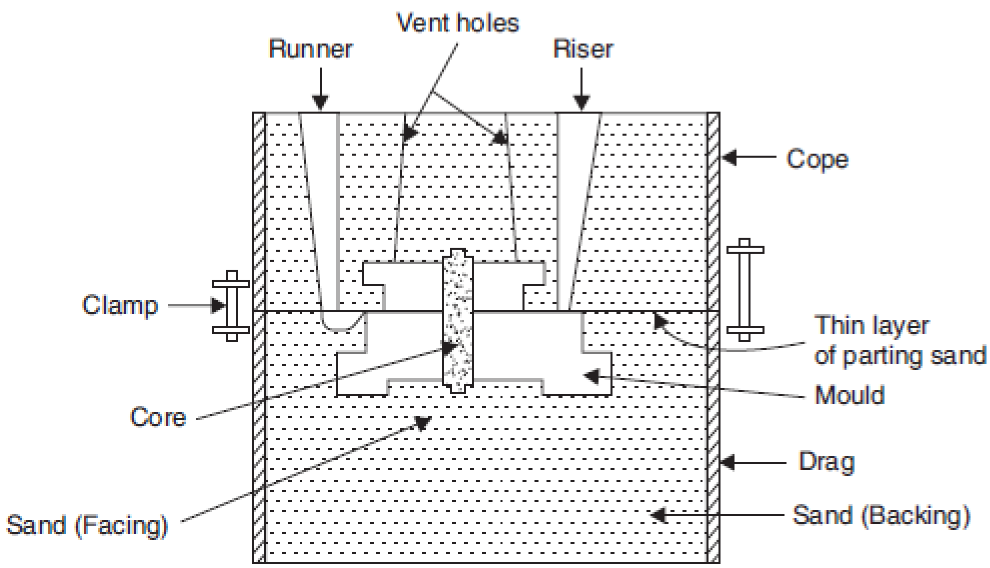


Fig. 2.8(b): Vertical Core

c) **Balanced Core**: It is used to produce a blind hole along a horizontal axis in the casting. It is just like horizontal core except that it is supported at one end and the other end remaining free in the mould cavity as shown in Fig. 2.8(c).

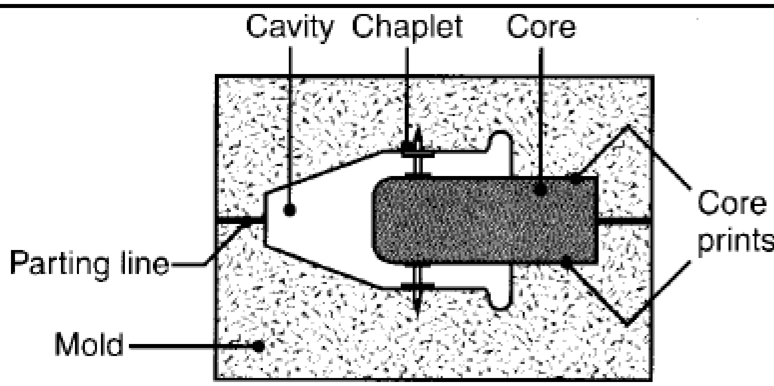


Fig. 2.8(c): Balanced Core

d) **Hanging or Cover Core**: This core hangs vertically in the mould and has no support at its bottom is known as hanging core. In this case entire mould cavity is contained in the drag only as shown in fig.2.8 (d).

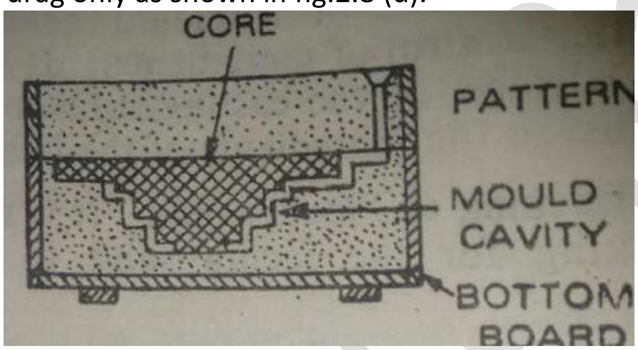


Fig.2.8(d): Hanging Core

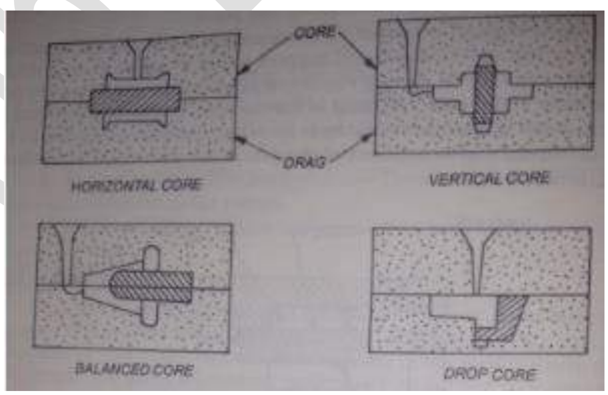


Figure 2.8 (e): Horizontal, Vertical, Balanced and Drop Core

2.9 CORE PRINTS

A core must be supported in the mould cavity. Wherever possible, this is done by providing core prints. Core prints are extensions of the core which rest in similar extensions of the mould cavity so that core remains supported in the mould cavity without the core falling to the bottom of the cavity. For example, if the pin with collars shown in Fig.5 had a central hole, the hole could be produced by inserting a core in mould cavity as shown in Fig.4.8.

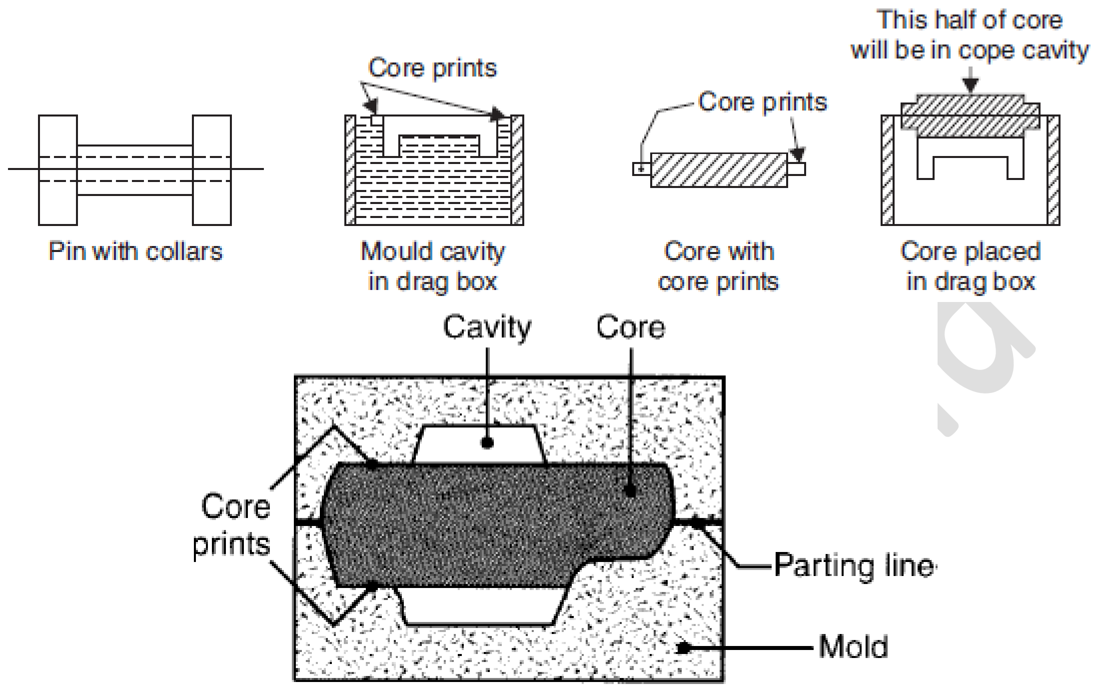


Fig. 2.9: Cores and Corse Prints

2.9 Chaplets:

Chaplets are metal shapes used for supporting large and odd shaped cores which cannot adequately supported their own core prints. Chaplets are clips made of thin sheets of the same metal as the casting. These clips are used to support the weight of cores. When the molten metal is poured, chaplets melt and merge into the molten metal.

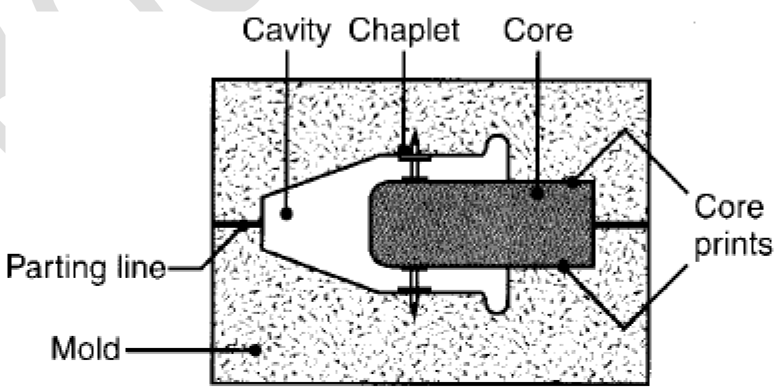


Fig . 4.9 : Chaplets

2.10 GATES, RUNNERS AND RISERS

The passage provided in the mould through which molten metal will flow into the mould cavity is known as the gating system. It is provided by scooping out sand in the drag box to cut necessary channels. The top of the runner hole in the cope is widened into a pouring basin. The molten metal then flows down through the runner into a well from where it enters the gating system and into the mould cavity. At a suitable location in the mould cavity the riser hole is connected. Without a gate, the metal would have fallen straight into the mould cavity damaging it. Besides, the gating system is so designed as to trap impurities from entering into mould cavity. The function of the riser is two fold. Firstly, it provides a visible indicator that the mould cavity is full. Secondly and more importantly, the molten metal in the riser provides a reservoir to feed the shrinkage caused as the casting progressively solidifies and cools. It is desirable that the metal in the riser remains molten as long as possible. This is done by providing a ''hot-top''. Sometimes, the riser does not open out to the top surface of the cope box, it is then called a blind riser. In that case, its sole function is to feed the shrinkage associated with solidification of molten metal. The various terms associated with gating system will be clear by studying the gating system shown in Fig. 2.10.

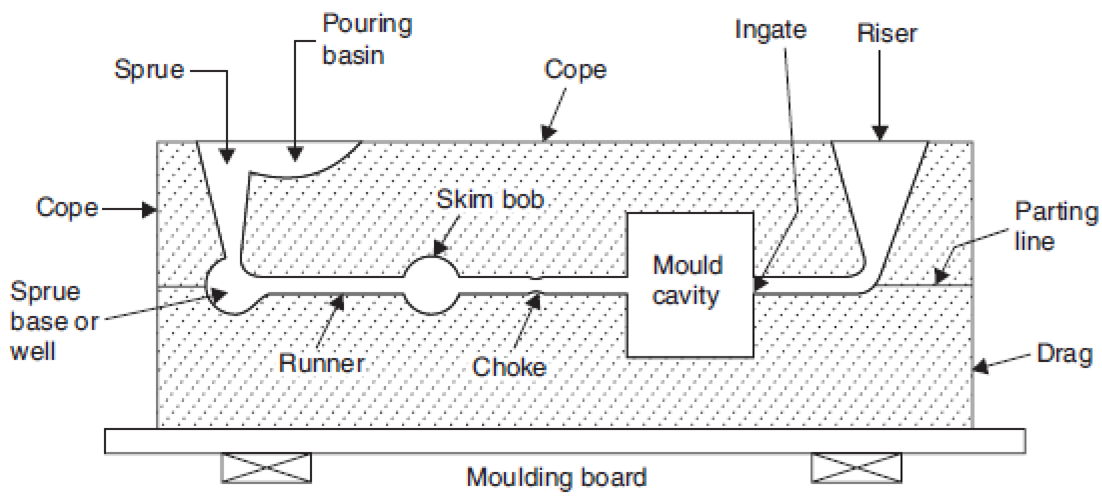


Fig. 2.10 : Gating system

2.11 CASTING DEFECTS

The factors, which are normally responsible for the production of these defects are:

- **Design of casing**
- **Design of pattern equipment**
- **Moulding and core making equipment**
- **Moulding and core material**
- **Gating and riser system**
- **Melting and pouring**
- **Melting and core making techniques**

- **Metal composition**

Some of the common defects in the castings are described below:

1. **Blow-holes:** They appear as small holes in the casting. They may be open to surface or they may be below the surface of the casting. They are caused due to entrapped bubbles of gases. They may be caused by excessively hard ramming, improper venting, excessive moisture or lack of permeability in the sand. Blow holes visible on the surface of a casting are called open blow holes. Where those occur below the surface of casting and not visible from outside are termed as blow holes. It can be avoided by controlled moisture contents, baking core properly, proper use of organic binders, core and mould should be properly vented and mould should not be rammed excessively hard.

2. **Shrinkage cavity:** Sometimes due to faulty design of casting consisting of very thick and thin sections, a shrinkage cavity may be caused at the junction of such sections. Shrinkage cavity is totally internal. It is illustrated in Fig.4.11: Shrinkage cavity. It is caused by faulty gating and riser system and improper chilling. It's remedy is to ensure proper directional solidification by modifying gating, riser and chilling.

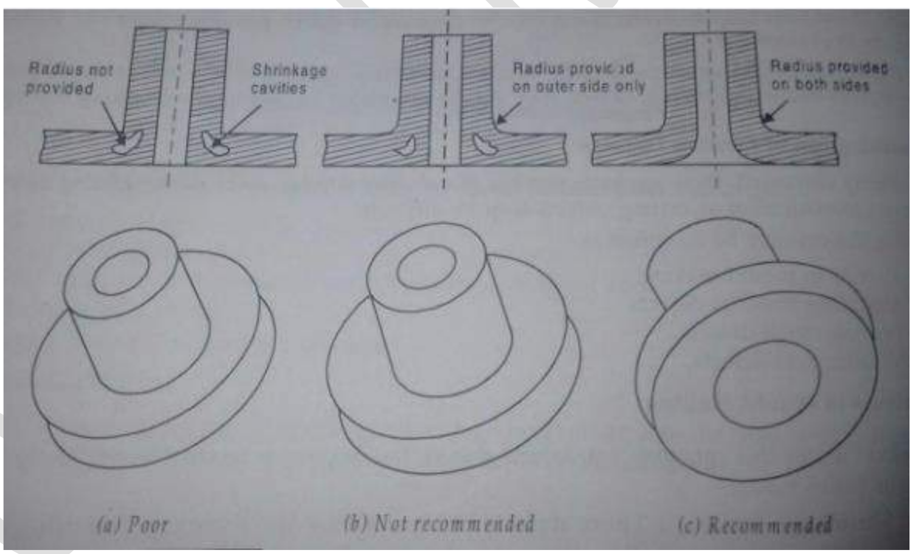


Fig. 4.11: Shrinkage cavity

3. **Misrun:** This denotes incomplete filling of mould cavity. It may be caused by bleeding of molten metal at the parting of cope and drag, inadequate metal supply or improper design of gating.

4. **Cold shut:** A cold shut is formed within a casting, when molten metal from two different streams meets without complete fusion. Low pouring temperature may be the primary cause of this defect.

5. **Mismatch:** This defect takes place when the mould impression in the cope and drag do not sit exactly on one another but are shifted a little bit. This happens

due to mismatch of the split pattern (dowel pin may have become loose) or due to defective clamping of cope and drag boxes.

6. **Drop:** This happens when a portion of the mould sand falls into the molten metal. Loose sand inadequately rammed or lack of binder may cause this defect.

7. **Scab:** This defect occurs when a portion of the face of a mould lifts or breaks down and the recess is filled up by molten metal.

8. **Hot tear:** These cracks are caused in thin long sections of the casting, if the part of the casting cannot shrink freely on cooling due to intervening sand being too tightly packed, offers resistance to such shrinking. The tear or crack usually takes place when the part is red hot and has not developed full strength, hence the defect is called "hot tear". Reason may be excessively tight ramming of sand.

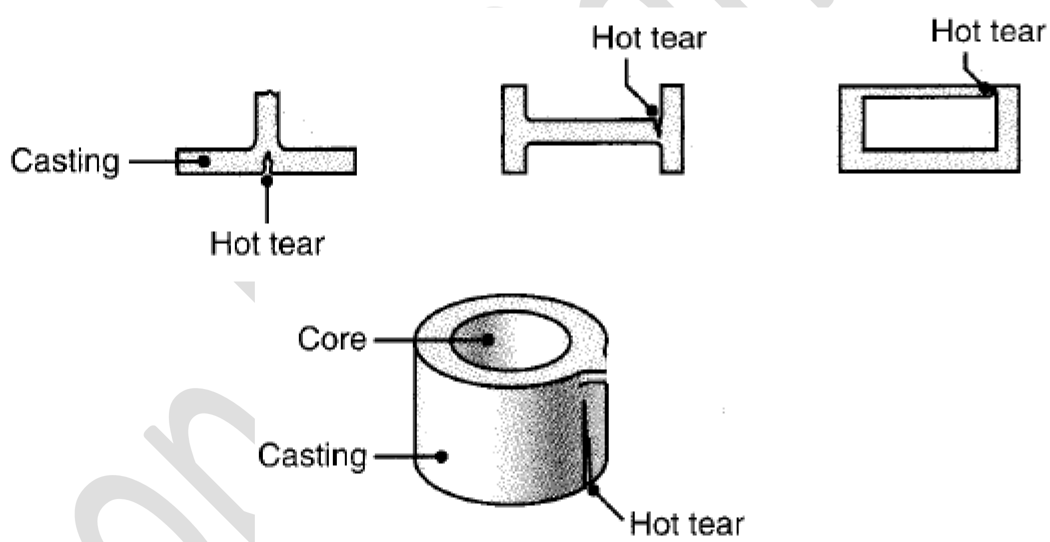


Fig. 4. ….. Hot Tears

9. Other defects include scars, blisters, sponginess (due to a mass of pin holes at one location) and slag inclusions etc.

INSPECTION OF CASTING:
After cleaning, the inspection of the casting is necessary to determine the presence of defect not readily visible. Following are the various inspection methods:

1. **Destructive Inspection**:
   In this method a few sample castings picked up and then cut into pieces at the points where defects are suspected and then examined their surfaces and mechanical properties are examined.
2. **Non Destructive Inspection Methods**:
   In Non Destructive Inspection Methods, inspection is done without destroying the casts. Various methods are:
   Visual Inspection: Castings are visually inspected to check cracks, dirt, blow hole, metal penetration, shifts, run outs etc.

Dimensional Inspection: It is necessary to check whether the certain details are within tolerances or not. Height and depth gauges, dividing heads, go and not go gauges, snap and ………… gauges are used for the inspection.

Pressure Testing: The pressure testing is used to locate leaks in a casting.

Radiography Inspection: The radiographic inspection (X – ray or gamma ray) is used for inspecting internal defects of a casting. The rays are passed through the test piece and the intensity of transmitted rays is recorded on a photographic film. The internal cracks and defects will appear on the film as darker areas.

3. **Magnetic Particle Inspection**:
   This Inspection Method is used on magnetic ferrous casting detecting invisible surface or slightly sub surface defects.
   In this method, the casting surface or areas to be inspected is magnetized and fine ferromagnetic particles are applied on it. When magnetizing force is passed through the metal, the surface and subsurface cracks and porosity will interrupt the magnetic field, which causes ferromagnetic particles to concentrate around the defect.
4. **Fluorescent Penetrant Method**:
   This method of inspection is used to find the pores and cracks on the surface of the casting that may be missed even under magnification. In this method, a fluorescent penetrating oil mix with whiting powder is applied to the surface by dipping, spraying or brushing. After the surface has been wiped dry, the oil will creep out of the cracks or other defects and become visible those places.

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 other hand, 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. Hence dies are made out of medium carbon low alloy steels. The dies are usually water or air blast cooled. Since most materials contract on cooling, extraction of castings from dies becomes important otherwise they will get entangled in the die as they cool. Therefore, in the design of dies, some arrangement for extraction of casting is incorporated.

Typical parts made by die casting are housings, business-machine and appliance components, hand-tool components, and toys. The weight of most castings ranges from less than 100g to about 25kg. Equipment costs, particularly the cost of dies, are somewhat high, but labor costs are generally low, because the process is semi- or fully automated. Die casting is economical for large production runs. The capabilities of die casting are given in In the die-casting process, molten metal is forced into the die cavity at pressures ranging from 0.7 to 700 MPa. There are two basic types of die-casting machines:

Hot-chamber Die Casting Process:
The hot-chamber process (Fig. 2.19) involves the use of a piston, which forces a certain volume of metal into the die cavity through a gooseneck and nozzle. Pressures range up to 35 MPa, with an average of about 15 MPa. The metal is held under pressure until it solidifies in the die. To improve die life and to aid in rapid metal cooling (thereby reducing cycle time) dies usually are cooled by circulating water or oil through various passageways in the die block. Low-melting-point alloys (such as zinc, magnesium, tin, and lead) commonly are cast using this process. Cycle times usually range from 200 to 300 shots (individual injections) per hour for zinc, although very small components, such as zipper teeth, can be cast at rates of 18,000 shots per hour.

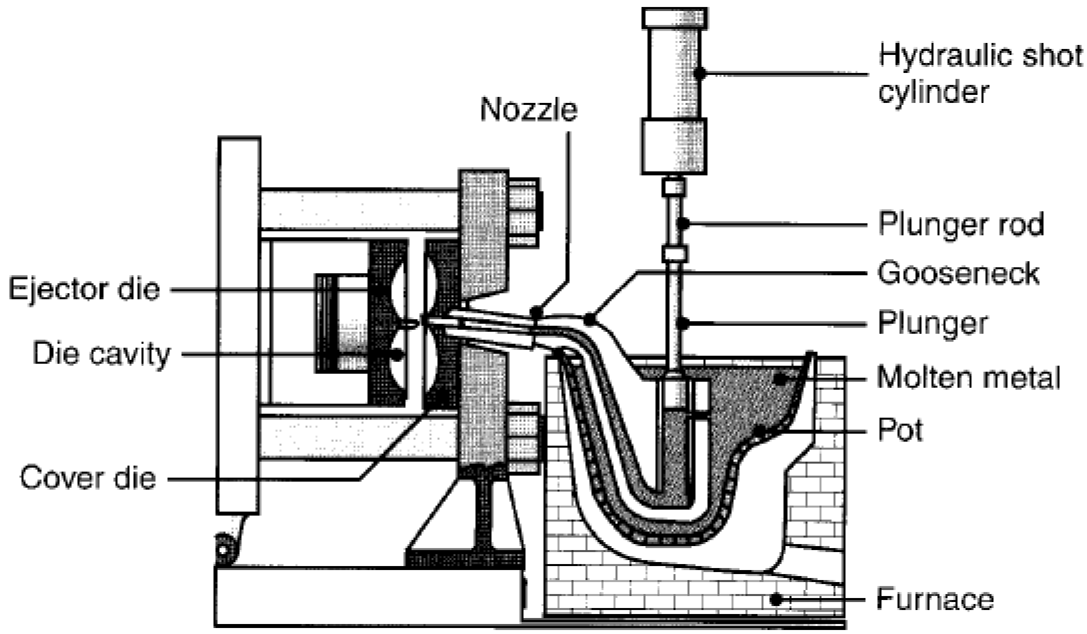
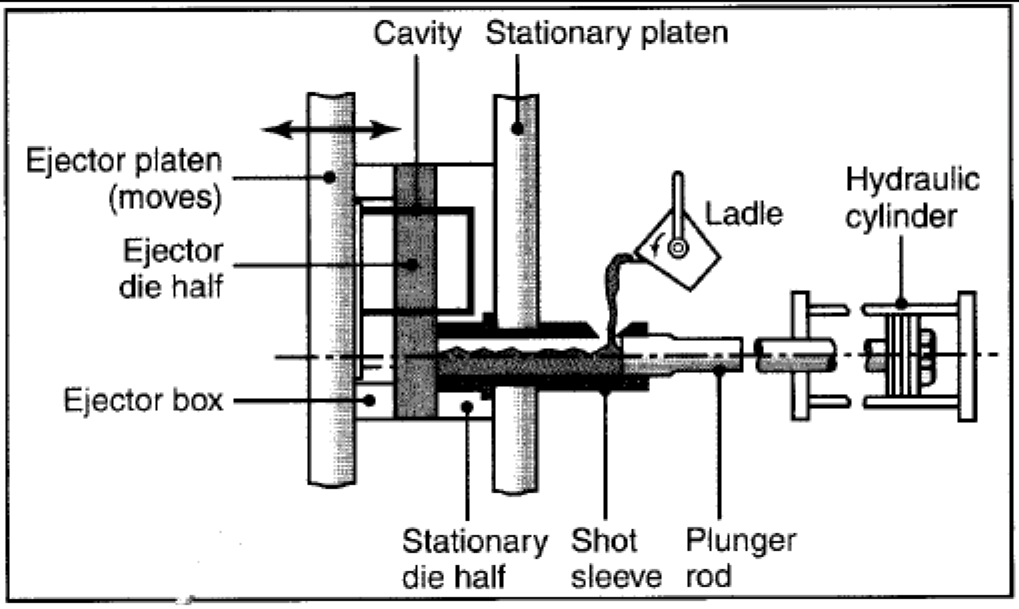


Fig. 2.19 :The hot-chamber Die Casting process

Cold-chamber Die Casting process:
In the cold-chamber process (Fig.2.20), molten metal is poured into the injection cylinder (shot chamber). The chamber is not heated-hence the term cold chamber. The metal is forced into the die cavity at pressures usually ranging from 20 to 70 MPa, although they may be as high as 150 MPa.



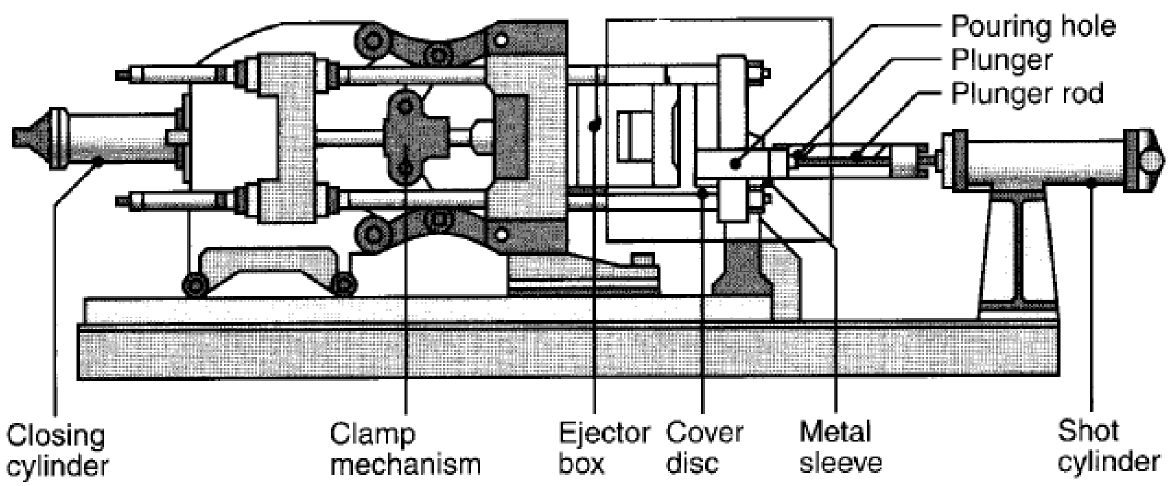


Fig.2.20: Cold-chamber Die Casting process

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.

Two pressure die casting methods are used:

1. **Hot chamber process:** This uses pressures up to 35 MPa and is used for zinc, tin, lead,

and their alloys. In this process the chamber, in which molten metal is stored before being pressure injected into the die, is kept heated.

2. **Cold chamber process:** In this process, pressures as high as 150 MPa are used. The storing chamber is not heated. This process is used mainly for metals and alloys having relatively higher melting point *e.g.,* aluminium, magnesium and their alloys.

Advantages and disadvantages of die casting:

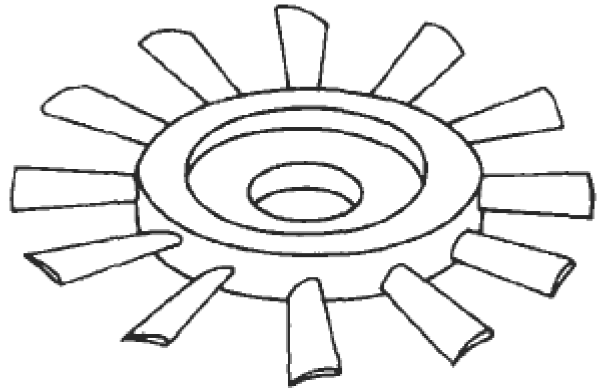
1. It is used for mass production of castings of small and medium size. *e.g.,* pistons of motorcycle and scooter engines, valve bodies, carburetor housings etc.
2. The initial cost of manufacturing a die is very high. It is a disadvantage.
3. This process produces high quality, defect free castings.
4. The castings produced by this process are of good surface finish and have good dimensional control and may not require much machining. All castings produced are identical.
5. Large size castings cannot be produced by this process. It is a disadvantage.
6. Castings with very complex shapes or with many cores are difficult to produce by die casting.
7. In case of mass production, castings can be produced cheaply.
8. The process does not require use of sand and requires much less space as compared to a conventional foundry using sand moulds.

3. Shell moulding

This is a form of sand casting done using a very fine sand mixed with synthetic resin. The pattern is made of machined and polished iron. The sand mixture is blown into a box containing the pattern which is heated **to** produce a hard, thin (6-10mm) mould which is split and removed from the pattern and then glued together. It is a high-speed process, producing highly accurate castings.

4. Investment castlng (lost wax casting)

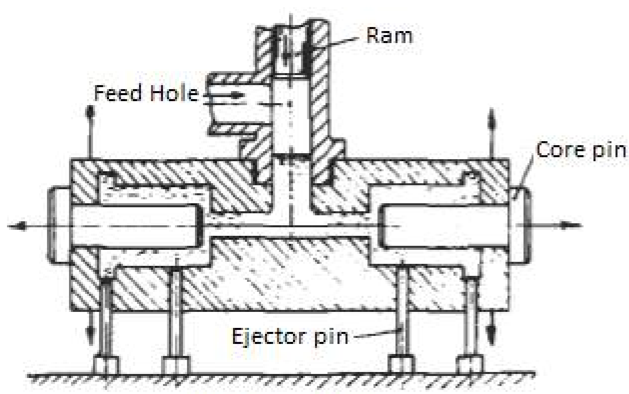
Wax patterns are made from a permanent metal mould. The wax patterns are coated with ceramic slurry which is hardened and baked so that the wax is melted out. The cavity is filled with molten metal to give a precision casting. Any metal can be cast using this process.



Fan impeller

5. ***Die casting***

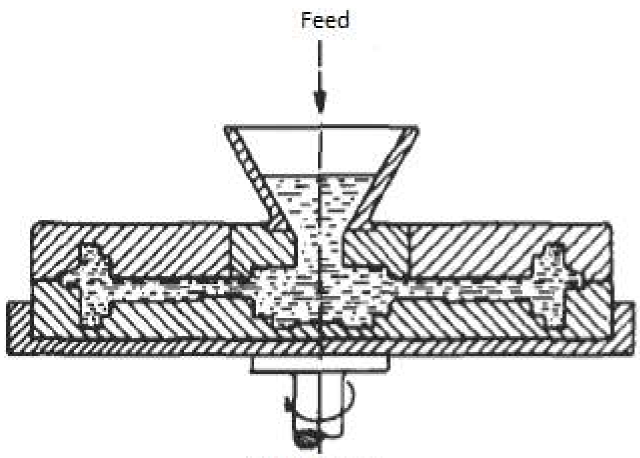
The mould is of steel in several parts dowelled together. Molten metal is fed by gravity or pressure and, when solid, is ejected by pins. Aluminium, copper, manganese and zinc alloy are suitable for casting by this method.



DIE CASTING

6. ***Centrifugal casting***

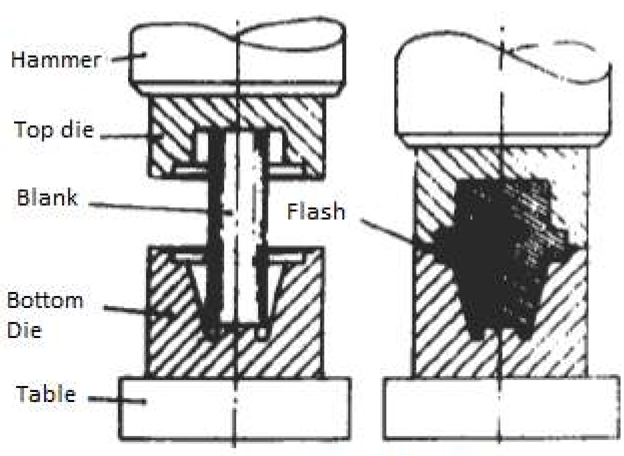
Cylindrical or circular components such as piston rings, cylinder liners, pipes, etc., may be cast in a rotating mould. Centrifugal pressure gives a fine grain casting. Any metal may be cast using this process.



CENTRIFUGAL CASTING

7. *Hand forging and drop forging*

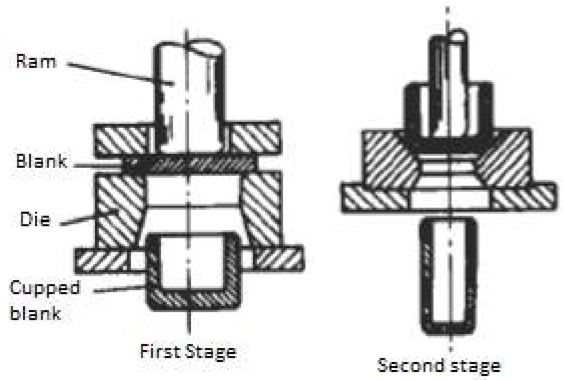
'Forging' is the forming of metal parts by hammering, pressing, or bending to the required shape, usually at red heat. 'Hand forging' involves the use of an anvil and special hammers, chisels and swages. A 'drop forging machine' uses pneumatic or hydraulic pressure to compress hot metal blanks between hard steel dies.



Drop Forging Machine

8. *Drawing process*

This is the forming of flat metal blanks into box and cup-like shapes by pressing them with a shaped punch into a die. The process is used for cartridge cases, boxes, electrical fittings, etc.



Deep Drawing

Assignment:

1. What are the advantages and limitations of casting process?
2. What are the basic steps followed while casting a component?
3. Sketch the cross section of a sand mould which is ready for pouring. Label the various important features of mould.
4. What is a casting pattern? Also differentiate between casting and Pattern.
5. What is core? Name different types of cores.
6. What are the pattern allowances? Why at all allowances are provided on a pattern?
7. Why draft allowances is important for patterns?
8. What is the benefit of a split pattern over a one piece or solid patter? How do the two halves of pattern maintain alignment?
9. What is meant by master pattern?
10. Name the various patterns which are normally used in foundry practice.
11. For what type of components segmental patterns are used?
12. What are materials used for making a pattern? What are their advantages and disadvantages over each other?
13. What are the characteristics desired for a moulding sand?
14. What are the main constituents of moulding sand?
15. What is the role of water and clay in deciding the characteristics of moulding sans?
16. Describe the method of sand preparation in a foundary.
17. Explain the advantages of synthetic sand over the natural sand.
18. Explain the function of the elements of gating system.
19. Explain clearly gates and runner with help of neat sketched.
20. What are the functions of the riser?
21. What is the difference between moulding sand and core sand?
22. Explain the dry sand core and green sand core.

23. How the core is supported in a mould cavity?
24. Write short note on casting defects.
25. Write and explain various casting defects along with their remadies.
26. Sketch and explain various types of ptterns used in foundary shope.
27. Write short note on Chaplts, Chillers and core print.
28. Explain the various types of cores used in casting process.
29. Explain the functions of the following:
    i) Core
    ii) Gates
    iii) Riser
    iv) Runner
30. Discuss following casting processes with the help of neat sketches:
    i) Centrifugal casting
    ii) Investment casting
31. What are the demerits of wooden pattern?
32. Discuss with meat sketch cold chamber and hot chamber die casting?
33. Describe the process of making a core.
34. What is meant by fettling of casting?
35. With the help of diagram discuss the centrifugal casting.
36. Write the advantages and disadvantages true centrifugal casting process.
37. Write the advantages and disadvantages semi centrifugal casting process.
38. What are the commonly materials for pattern making. Discuss their merits and demerits.
39. Discuss any three major casting defects along with their remedies.
40. What is a riser and what are its functions?