MEC 402
Casting, Forming and Welding

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Casting (20 hrs)

Foundry: foundry materials- moulding and core sand- binders – additives; sand preparation- sand control tests	2
pattern and pattern making	3
mould and core making, expendable and non-expendable moulds,	3
mould assembly; solidification of pure metals and alloys, grain growth.	1
Casting processes- sand casting, shell moulding, investment casting, slush casting, gravity and pressure die casting, centrifugal casting; continuous casting	5
casting design, gateway system design, riser design	3
casting defects- inspection, testing- destructive and non-destructive.	3

Course Outcomes

- CO1. Learn different types of casting process.
- CO2. Select suitable manufacturing process for typical components.
- CO3. Learn the various welding process.
- CO4. Explain the concept of forging, rolling process and drawing.

Introduction

Casting is a manufacturing process by which a molten material such as metal or plastic is introduced into a mold, allowed to solidify within the mold, and then ejected or broken out to make a fabricated part.
Casting is used for making parts of complex shape that would be difficult or uneconomical to make by other methods, such as cutting from solid material.

Metal casting processes

- Casting is one of the oldest manufacturing process. It is the first step in making most of the products.

- Steps:
 - Making mould cavity
 - Material is first liquefied by properly heating it in a suitable furnace.
 - Liquid is poured into a prepared mould cavity
 - allowed to solidify
 - product is taken out of the mould cavity, trimmed and made to shape

We should concentrate on the following for successful casting operation:
(i)Preparation of moulds of patterns
(ii)Melting and pouring of the liquefied metal
(iii)Solidification and further cooling to room temperature
(iv)Defects and inspection

Advantages

- Molten material can flow into very small sections so that intricate shapes can be made by this process. As a result, many other operations, such as machining, forging, and welding, can be minimized.
- Possible to cast practically any material: ferrous or non-ferrous.
- The necessary tools required for casting moulds are very simple and inexpensive. As a result, for production of a small lot, it is the ideal process.
- There are certain parts (like turbine blades) made from metals and alloys that can only be processed this way. Turbine blades: Fully casting + last machining.
- Size and weight of the product is not a limitation for the casting process.

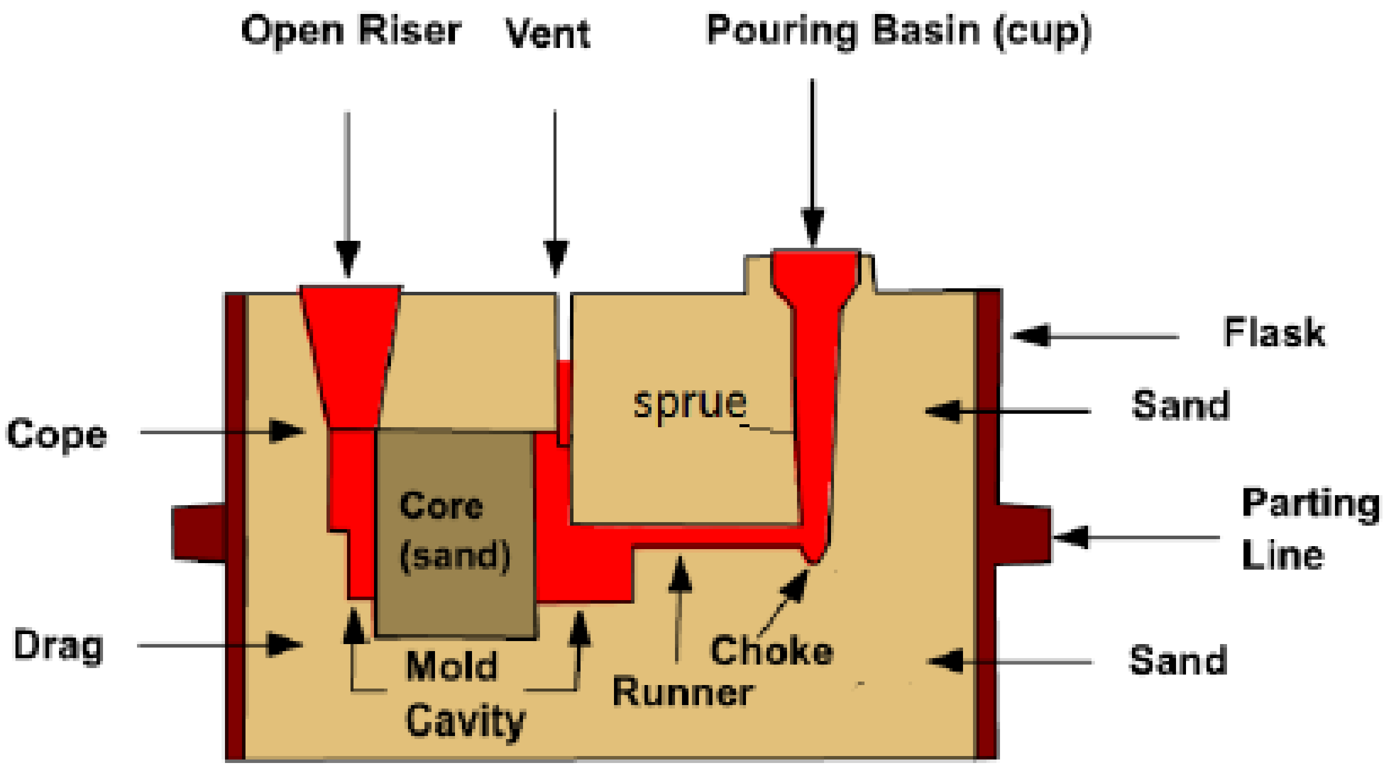
Limitations

- Dimensional accuracy and surface finish of the castings made by sand casting processes are a limitation to this technique.

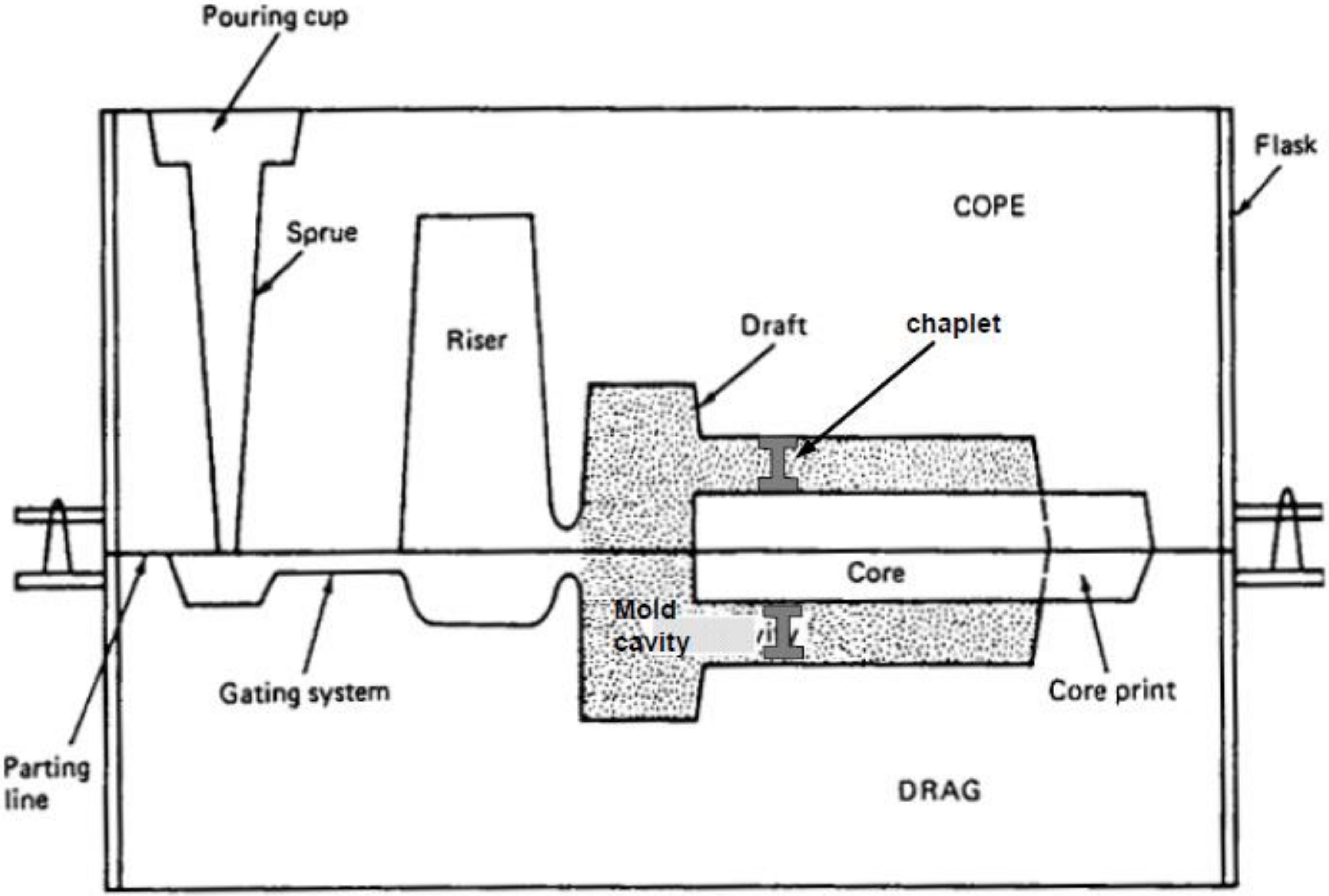
- Many new casting processes have been developed which can take into consideration the aspects of dimensional accuracy and surface finish. Some of these processes are die casting process, investment casting process, vacuum-sealed moulding process, and shell moulding process.

- Metal casting is a labour intensive process

- Automation: a question



Mould Section and casting nomenclature



Pouring cup
Flask
COPE
Sprue
Riser
Draft
chaplet
Core
Mold
cavity
Gating system
Core print
Parting
line
DRAG

Flask: A metal or wood frame, without fixed top or bottom, in which the mould is formed. Depending upon the position of the flask in the moulding structure, it is referred to by various names such as drag – lower moulding flask, cope – upper moulding flask, cheek – intermediate moulding flask used in three piece moulding.

Pattern: It is the replica of the final object to be made. The mould cavity is made with the help of pattern.

Parting line: This is the dividing line between the two moulding flasks that makes up the mould.

Moulding sand: Sand, which binds strongly without losing its permeability to air or gases. It is a mixture of silica sand, clay, and moisture in appropriate proportions.

Facing sand: The small amount of carbonaceous material sprinkled on the inner surface of the mould cavity to give a better surface finish to the castings.

Core: A separate part of the mould, made of sand and generally baked, which is used to create openings and various shaped cavities in the castings.

Pouring basin: A small funnel shaped cavity at the top of the mould into which the molten metal is poured.

Sprue: The passage through which the molten metal, from the pouring basin, reaches the mould cavity. In many cases it controls the flow of metal into the mould.

Runner: The channel through which the molten metal is carried from the sprue to the gate.

Gate: A channel through which the molten metal enters the mould cavity.

Chaplets: Chaplets are used to support the cores inside the mould cavity to take care of its own weight and overcome the metallostatic force.

Riser: A column of molten metal placed in the mould to feed the castings as it shrinks and solidifies. Also known as “feed head”.

Vent: Small opening in the mould to facilitate escape of air and gases.

Steps in making sand castings

The six basic steps in making sand castings are,
(i) Pattern making, (ii) Core making, (iii) Moulding, (iv) Melting and pouring, (v) Cleaning

Pattern making

- Pattern: Replica of the part to be cast and is used to prepare the mould cavity. It is the physical model of the casting used to make the mould. Made of either wood or metal.

-The mould is made by packing some readily formed aggregate material, such as moulding sand, surrounding the pattern. When the pattern is withdrawn, its imprint provides the mould cavity. This cavity is filled with metal to become the casting.

- If the casting is to be hollow, additional patterns called 'cores', are used to form these cavities.

Core making

Cores are placed into a mould cavity to form the interior surfaces of castings. Thus the void space is filled with molten metal and eventually becomes the casting.

Moulding

Moulding is nothing but the mould preparation activities for receiving molten metal.

Moulding usually involves: (i) preparing the consolidated sand mould around a pattern held within a supporting metal frame, (ii) removing the pattern to leave the mould cavity with cores.

Mould cavity is the primary cavity.

The mould cavity contains the liquid metal and it acts as a negative of the desired product.

The mould also contains secondary cavities for pouring and channeling the liquid material in to the primary cavity and will act a reservoir, if required.

Melting and Pouring

The preparation of molten metal for casting is referred to simply as melting. The molten metal is transferred to the pouring area where the moulds are filled.

Cleaning

Cleaning involves removal of sand, scale, and excess metal from the casting. Burned-on sand and scale are removed to improved the surface appearance of the casting. Excess metal, in the form of fins, wires, parting line fins, and gates, is removed. Inspection of the casting for defects and general quality is performed.

Types of Pattern Allowances

The common allowances provided on patterns are:

1. Shrinkage allowance
2. Draft allowance
3. Finish allowance
4. Distortion allowance
5. Rapping allowance

1. **Shrinkage Allowance**

All the metals used for castings contract and shrink in size after solidification and cooling. To compensate for this, a pattern is made larger than the finished casting by means of a shrinkgae on contraction allowance.

In laying measurements for the pattern, the pattern-maker allows for this by using shrink or contraction rule. This rule is slightly longer than the ordinary rule of the same length. Different metals have different shrinkages. Therefore there is a shrink rule for each type of metal used in casting.

Pattern

The pattern and the part to be made are not same. They differ in the following aspects.

1.A pattern is always made larger than the final part to be made. The excess dimension is known as Pattern allowance.

Pattern allowance => shrinkage allowance, machining allowance

2.Shrinkage allowance: will take care of contractions of a casting which occurs as the metal cools to room temperature.

Liquid Shrinkage: Reduction in volume when the metal changes from liquid state to solid state. Riser which feed the liquid metal to the casting is provided in the mould to compensate for this.

Solid Shrinkage: Reduction in volume caused when metal looses temperature in solid state. Shrinkage allowance is provided on the patterns to account for this.

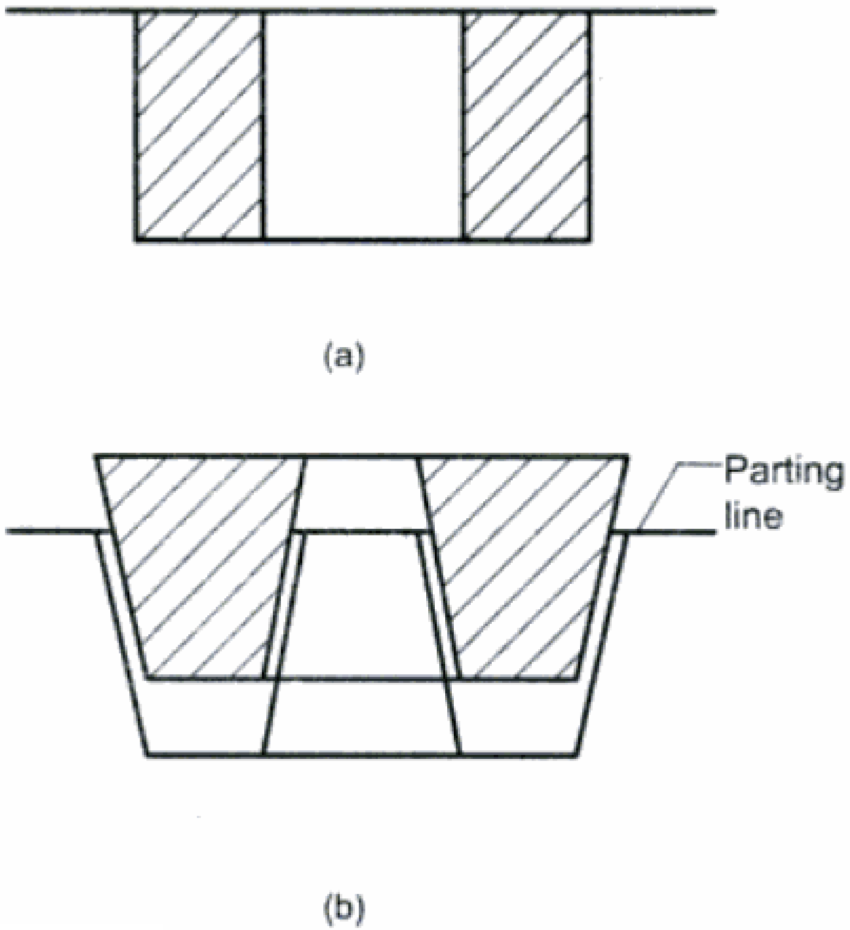
Shrink rule is used to compensate solid shrinkage depending on the material contraction rate.

Shrinkage allowances for various metals

Material	Pattern dimension, mm	Section thickness, mm	Shrinkage allowance, mm/m
Grey cast iron	up to 600	—	10.5
	600 to 1200	—	8.5
	over 1200	—	7.0
White cast iron	—	—	16.0 to 23.0
Ductile iron	—	—	8.3 to 10.4
Malleable iron	—	6	11.8
		9	10.5
		12	9.2
		15	7.9
		18	6.6
		22	4.0
		25	2.6
Plain carbon steel	up to 600	—	21.0
	600 to 1800	—	16.0

2. Draft Allowance or Taper Allowance

When the pattern is drawn from a mould, there is a possibility of damaging the edges of the mould. This possibility is decreased if the vertical surfaces of a pattern are tapered slightly inward. This slight taper inside on the vertical surfaces of a pattern is known as the draft.



Effect of draft on pattern withdrawing

Suggested draft values for patterns

Pattern material	Height of the given surface, mm	Draft Angle of surfaces, degrees	
		External surface	Internal surface
Wood	20	3.00	3.00
	21 to 50	1.50	2.50
	51 to 100	1.00	1.50
	101 to 200	0.75	1.00
	201 to 300	0.50	1.00
	301 to 800	0.50	0.75
	801 to 2000	0.35	0.50
	over 2000	—	0.25
Metal and plastic	20	1.50	3.00
	21 to 50	1.00	2.00
	51 to 100	0.75	1.00
	101 to 200	0.50	0.75
	201 to 300	0.50	0.75
	301 to 800	0.35	0.50

3. Finish or Machining Allowance

Rough surfaces of castings, that have to be machined, are made to dimensions somewhat over those indicated on the finished working drawings. The extra amount of metal to be machined is called finish or machine allowance. This allowance varies from 1.5 to 16 mm but 3 mm allowance is common for small and medium-size castings. The edges of these surfaces are shown by a finish mark V or f.

Machining allowances on patterns for sand castings

Dimension, mm	Allowance, mm		
	Bore	Surface	Cope side
Cast iron			
upto 300	3.0	3.0	5.5
301 to 500	5.0	4.0	6.0
501 to 900	6.0	5.0	6.0
Cast steel			
upto 150	3.0	3.0	6.0
151 to 500	6.0	5.5	7.0
501 to 900	7.0	6.0	9.0
Non ferrous			
upto 200	2.0	1.5	2.0
201 to 300	2.5	1.5	3.0
301 to 900	3.0	2.5	3.0

4. Distortion Allowance

Distortion is seen only in such castings which have an irregular shape and contraction is not uniform throughout. Such casting will distort or wrap during cooling due to setting up of thermal stresses in them. Such an effect is easily seen in some dome shaped or “U” shaped castings.

To eliminate this defect an opposite direction is provided in the pattern, so that the effect is neutralized and correct casting is obtained.

5. Rapping or Shake Allowance

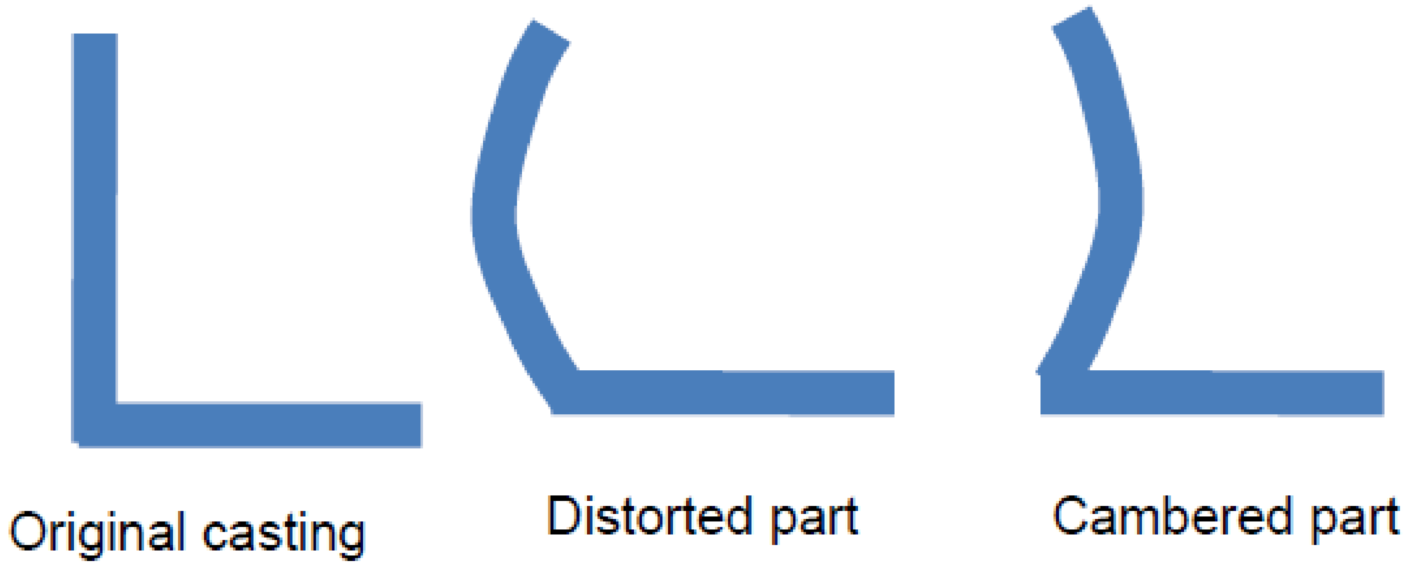
When a pattern is to be withdrawn from the mould, it is first rapped or shaken. As a result of this, the size of the mould cavity increases a little and a negative allowance is to be provided in the pattern to compensate for the same. This allowance may be considered negligible for small and medium-sized castings.

Distortion allowance (camber)

- Vertical edges will be curved or distorted
- This is prevented by shaped pattern converge slightly (inward) so that the casting after distortion will have its sides vertical
- The distortion in casting may occur due to internal stresses. These internal stresses are caused on account of unequal cooling of different sections of the casting and hindered contraction.

Prevention:

- providing sufficient machining allowance to cover the distortion affect
- Providing suitable allowance on the pattern, called camber or distortion allowance (inverse reflection)



Materials Used For Making Patterns

The common materials used for pattern making are:

1. Wood
2. Cast iron
3. Brass
4. Aluminium
5. White metal
6. Plastic
7. Plaster
8. Wax

Pattern materials

- Patterns for sand castings are subjected to considerable wear and tear due to ramming action that is required and the abrasive action of the sand
- Should be impervious to moisture because of changing surroundings
- Made of: wood, metal, plastics, plaster and synthetic materials
- Woods => white pine, sugar pine; The wood should be straight grain, light, easy to work, little tendency to develop crack and warp.
- More durable: Mahogany
- For large castings: metal such as cast iron or aluminium
- When metal pattern are cast from the wooden master pattern, double shrinkage must be provided on the wooden master pattern

1. Wood

Merits	Demerits
It is easy to work and readily available. Wood can be harvested and made into many forms by gluing, bending, and curving.	It is readily affected by moisture.
It is easily sanded to a smooth surface and may be preserved with shellac.	result of sand abrasion. If it is not stored properly, it may warp badly.
	Wood wears out instantly as a Its strength is low and it may break on rough usage.

2. Cast Iron

Merits	Demerits
It is strong and gives a good smooth mould surface with sharp edges.	Cast iron patterns are heavy and break easily.
cast iron is resistant to the abrasive action of the sand.	The iron pattern causes too much rust and requires a dry storage area.

3. Brass

Merits	Demerits
When metal patterns are small, brass is used. It is strong, does not rust, and takes a better finish than cast iron. It is able to withstand the wear of the moulding sand.	Brass patterns are heavier than cast iron.

4. Aluminum

Merits	Demerits
It is soft and easy to work.	Since aluminum is soft, its patterns may be damaged by rough usage.
It is light in weight and resistant to corrosion.	

5. White Metal

Merit	Demerit
The white metal has a low melting point. Can be easily into intricate shapes. It has no appreciable shrinkage.	It is soft and easily worn away by the moulding sand.

6. Plastic

Merit	Demerit
It is light in weight. It has high strength. High resistance to wear and corrosion. It gives a fine surface finish. it has low solid shrinkage.	Plastic patterns are fragile and hence light section requires metallic reinforcing. They do not work well when subjected to serve shocks.

7. Plaster

- Plaster can be easily cast into intricate shapes and can be easily worked also.
- Its extension can be easily regulated and it has a very high compressive strength.

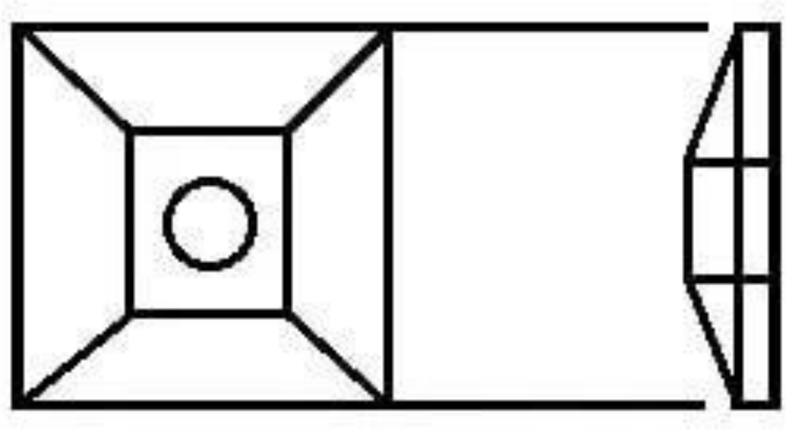
8. Wax

- Wax patterns are excellent for investment casting.
- Low ash content.
- High tensile strength and hardness.

- **Types of Pattern**
- Following are the different types of pattern used in casting:
- Single piece or solid pattern
- Split pattern
- Match plate pattern
- Cope and drag pattern
- Gated pattern
- Loose-piece pattern
- Sweep pattern
- Skeleton pattern
- Segmented pattern
- Shell pattern

1. Single-piece or Solid Pattern

This pattern made without joints, partings, or any loose pieces in its construction is called a **single-piece or solid pattern**. These patterns are cheaper. The moulder has to cut his own runner to feed the gate and riser. The moulding operation takes more time. Hence these patterns are in limited production.



Single Piece or Solid Pattern

Solid pattern is generally used for large castings of simple shape. The simplest type of pattern is the flat-back as shown in fig. It may have few or no irregularities and it may not have a core-point.

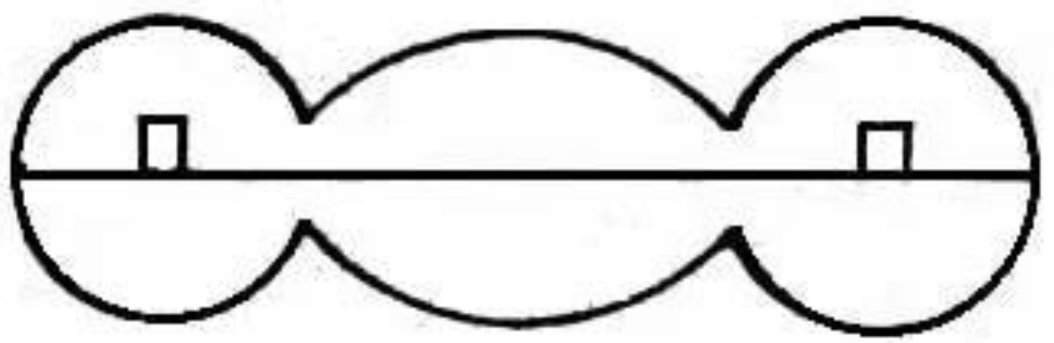
When completed, the mould cavity will be entirely in the drag or entirely in the cope. A few examples of castings that are made by making solid patters are soil tamper, stuffing-box, and glad of the steam engine.

2. Split Pattern

For casting unusual shape **split patterns** are used to form a mould. These **types of pattern** is usually made in two parts. One part will produce the lower half of the mould and the other upper half. The two parts may or may not be of the same size and shape.

These are held in their proper relative positions by means of dowel-pins. Dowl-pins are faster in one-piece and fitting at the holes bored in the other piece. The surface which the parting line or parting surface.

The patterns are made in two or three pieces. Because many times the design of casting offers difficulty in mould making and withdrawal of patterns if a solid pattern is used.

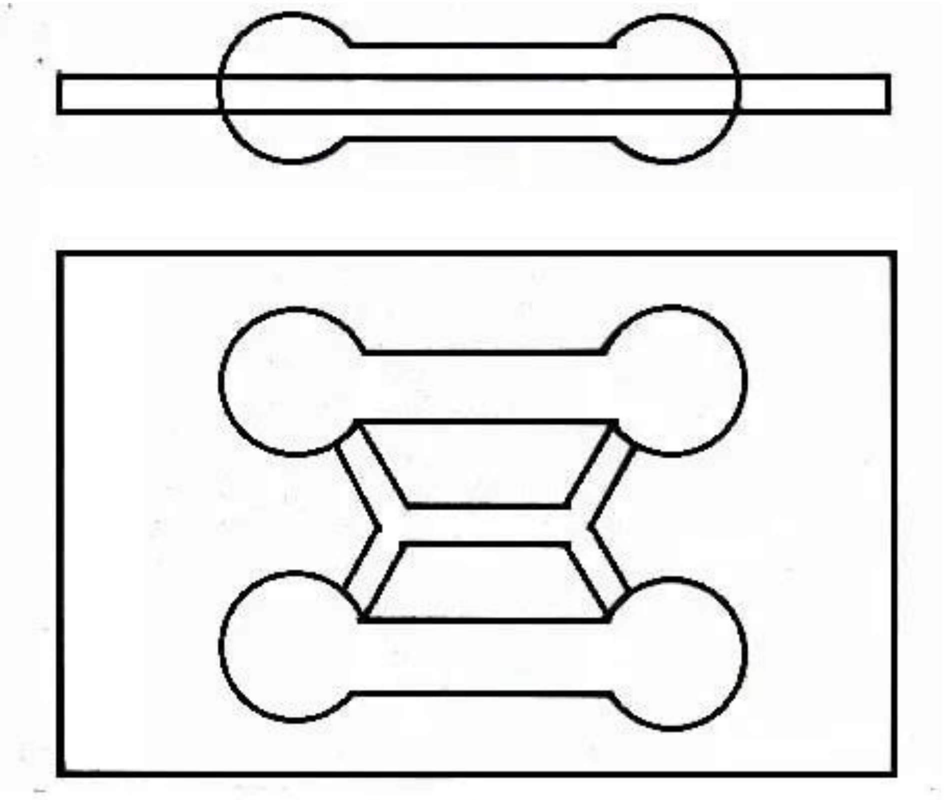


Split Pattern

3. Match Plate Pattern

These **types of pattern** is made in two pieces. One-piece mounted on one side of the plate and the other piece on the other side of the plate called the **match plate pattern**. The plate can only carry a pattern or a group of patterns on its two sides in the same way.

The plate is usually made of aluminum. The gate and runner are also connected to the plate with the pattern. These patterns are used where the rapid production of small and precise castings occurs on a large scale. These patterns are very favorable in machine moulding. Their manufacturing cost is quite high.

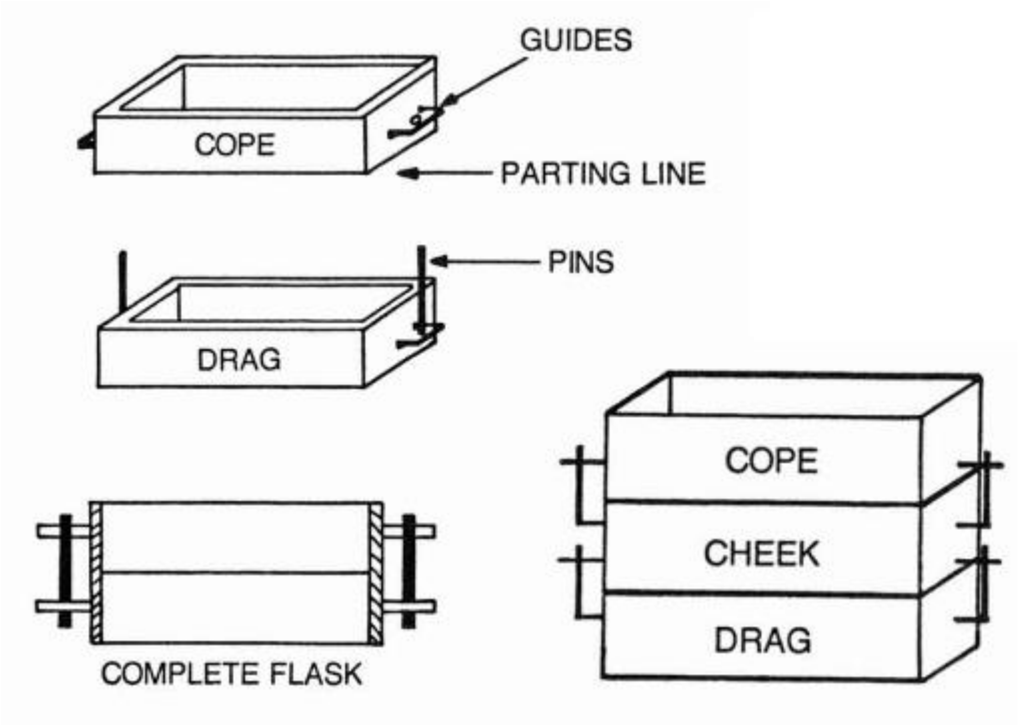


Match Plate Pattern

4. Cope or Drag Pattern

When quite large castings are to be made, the entire pattern becomes too heavy to be handled by anyone operator. Such **types of pattern** is made in two parts which are individually moulded into separate moulding boxes.

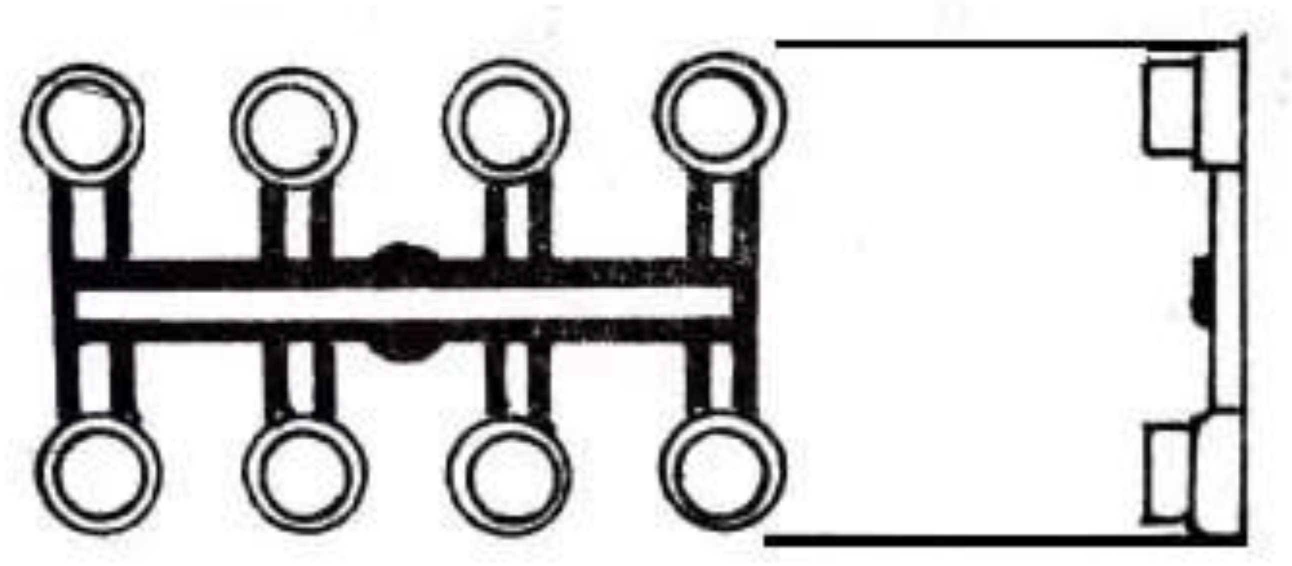
One group of operators prepare the cope half of the mould sand and another group prepares the drag half. After completion of the moulds, the two boxes are assembled to form the complete cavity.



5. Gated Pattern

Gated patterns are used in the mass production of small castings. For such castings, multi-cavity moulds are prepared i.e. a single sand mould carries a number of cavities as shown in the diagram. The patterns for these castings are interconnected by gate formers.

These gate formers provide suitable channels or gates in the sand for feeding the molten metal to these cavities. A single runner can be done to feed all cavities. This saves moulding time also there is uniform feeding of molten metal.

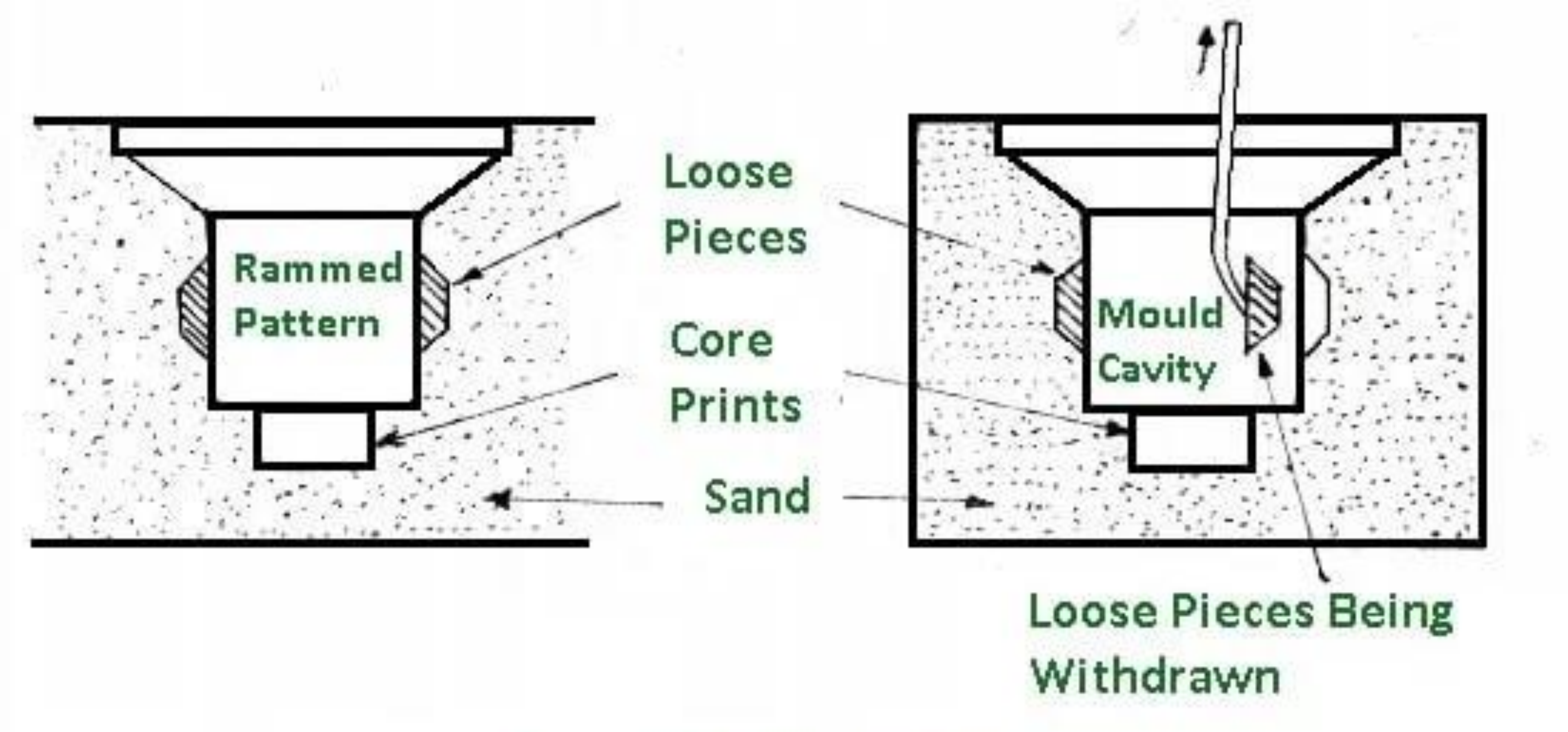


Gated Pattern

6. Loose Piece Pattern

In these **types of pattern**, some single piece patterns are made to have loose pieces in order to enable their easy withdrawal from the mould. These pieces make an integral part of the pattern while moulding.

After the mould is finished, the pattern is withdrawn, leaving the pieces in the sand. These pieces are later withdrawn separately through the cavity formed by the pattern as shown in the diagram.

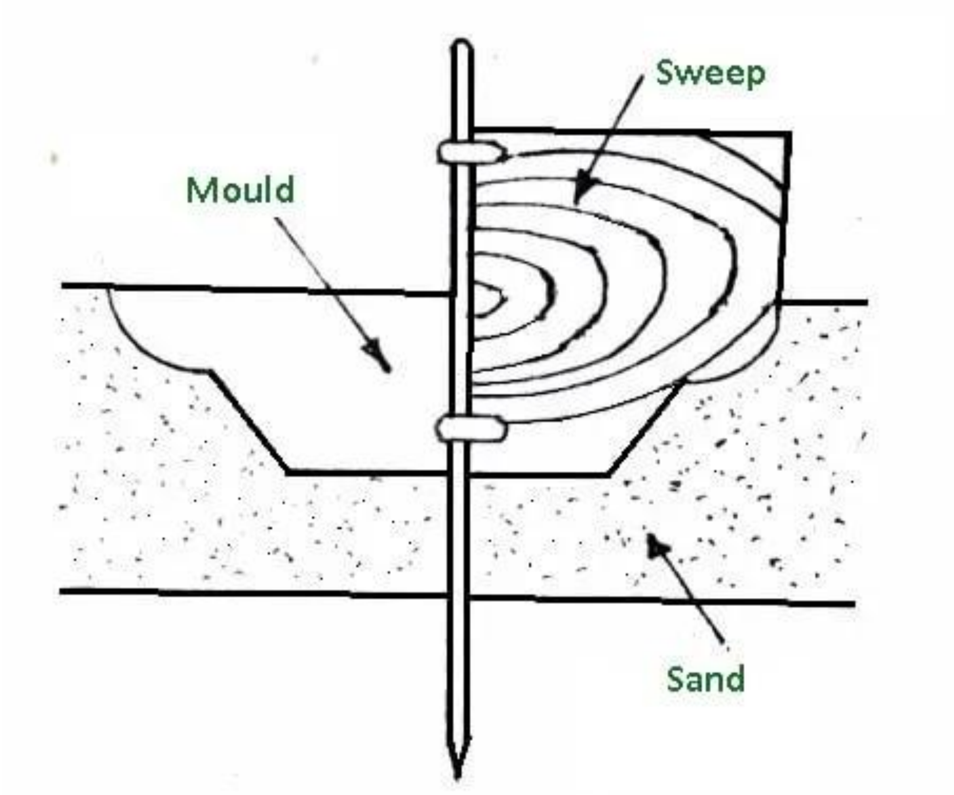


Loose Piece Pattern

7. Sweep Pattern

Sweep patterns are used for preparing moulds of large symmetrical castings, particularly of circular cross-section. Hence there is a large saving in time, labor, and material. The sweep pattern consists of a board that conforms to the shape of the desired casting.

This board is arranged to rotate about a central axis as shown in the diagram. The sand is rammed in place and the sweep board is moved around its axis rotation to give the moulding sand the desired shape. The principle advantage of this pattern is that it expensive pattern construction.



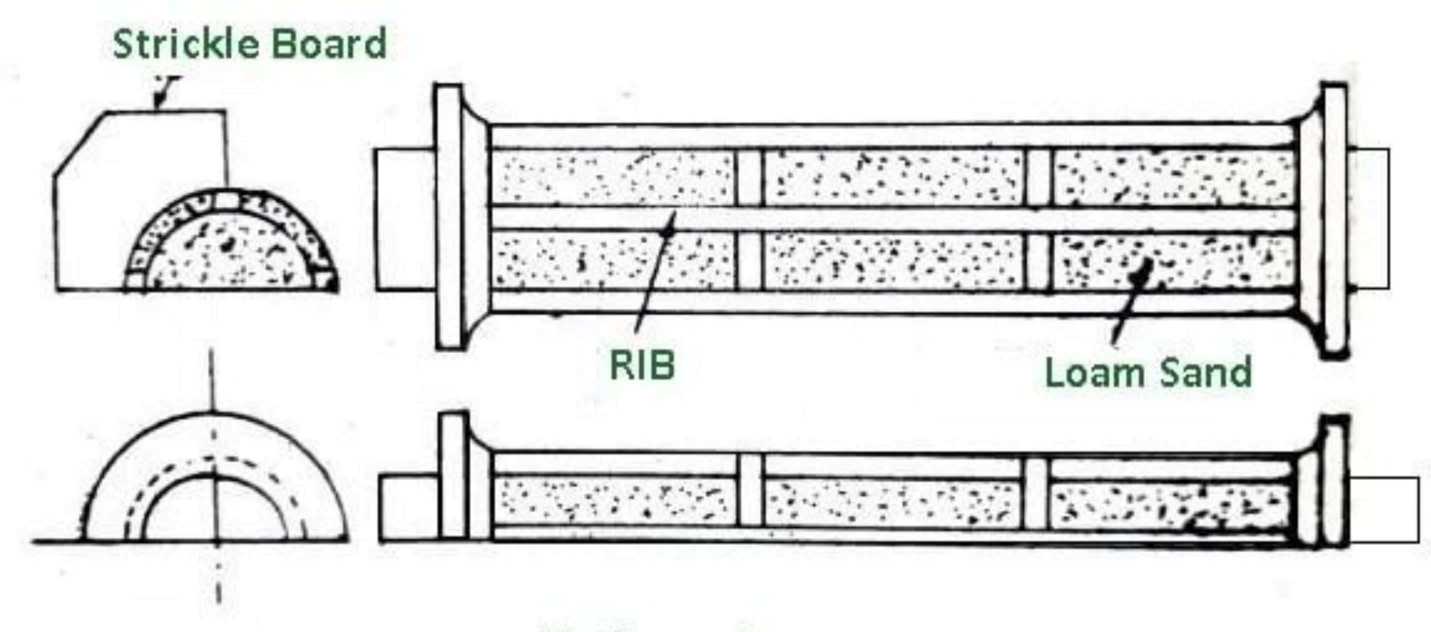
Sweep Pattern

8. Skeleton Pattern

When the size of the casting is very large and only a few numbers are to be made, it is uneconomical to make a solid pattern of that size. In such cases, a pattern consisting of a wooden frame and strips is made, called a **skeleton pattern**.

It is filled with loam sand and rammed. The excess sand is removed by means of a strickle. A half-skeleton pattern for a hollow pipe is shown in the diagram.

Since the pipe is symmetrical about the parting line, the same pattern will serve the purpose of moulding both the halves in two different flasks. These two flasks are joined later to form the complete cavity.

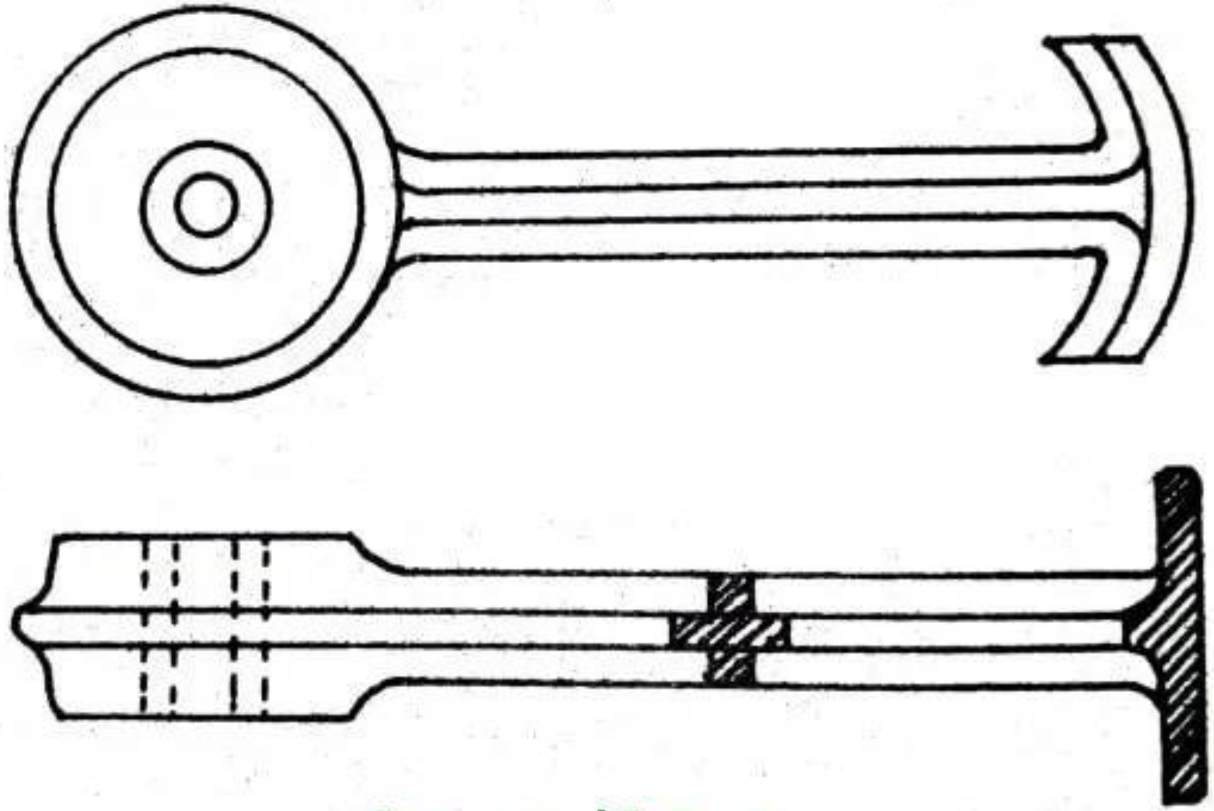


Skeleton Pattern

9. Segmented Pattern

These **types of pattern** is used to prepare moulds of large spherical castings. Hence the use of a solid pattern of the exact size is avoided. In principle, they work like a **sweep pattern**. But the difference is that a **segmented pattern** is a portion of the solid pattern itself and the mould is prepared in parts by it.

It is mounted on a central axis and after preparing the mould in one part, the section is moved to the next position. The operation is repeated until the complete mould is ready. A typical example is shown in the diagram.

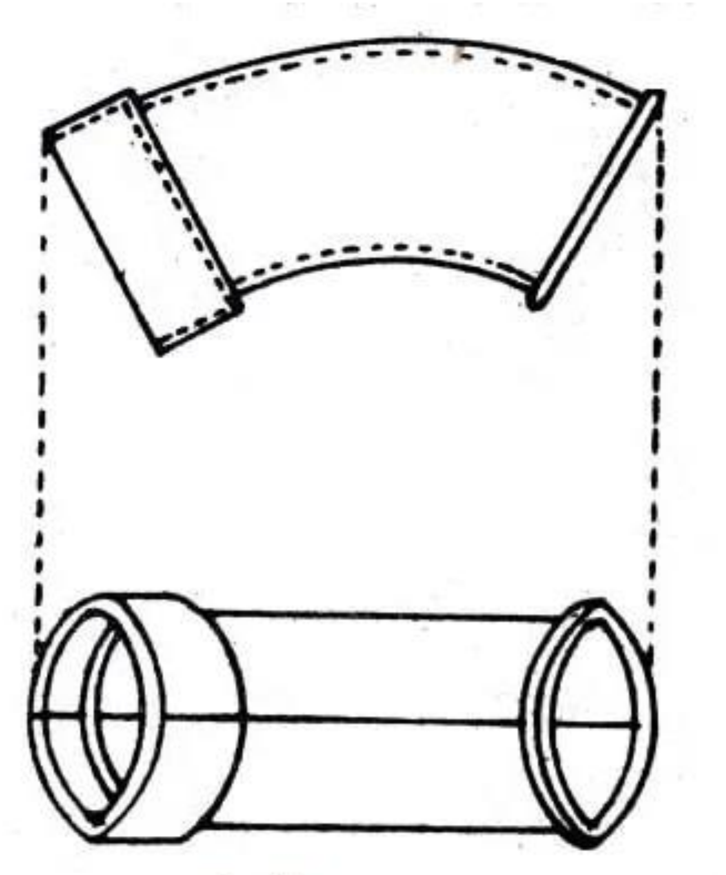


Segmented Pattern

10. Shell Pattern

These **types of pattern** are largely used for drainage fittings and pipework. A typical example is shown in the diagram. The shell pattern is usually made of metal. It is mounted on a plate and parted along the centerline.

The **shell pattern** is a hollow structure like a shell. The outside shape is used as a pattern to make the mould while the inside is used as a core-box for making core.



Shell Pattern

Permanent Mold Casting

In *permanent-mold casting* (also called *hard-mold casting*), two halves of a mold are made from materials with high resistance to erosion and thermal fatigue, such as cast iron, steel, bronze, graphite, or refractory metal alloys. Typical parts made are automobile pistons, cylinder heads, connecting rods, gear blanks for appliances, and kitchenware. Parts that can be made economically generally weigh less than 25 kg, although special castings weighing a few hundred kilograms have been made using this process.

The mold cavity and gating system are machined into the mold and thus become an integral part of it. To produce castings with internal cavities, cores made of metal or sand aggregate are placed in the mold prior to casting. Typical core materials are oil-bonded or resin-bonded sand, plaster, graphite, gray iron, low-carbon steel, and hot-work die steel. Gray iron is used most commonly, particularly for large molds for aluminum and magnesium casting. Inserts also are used for various parts of the mold.

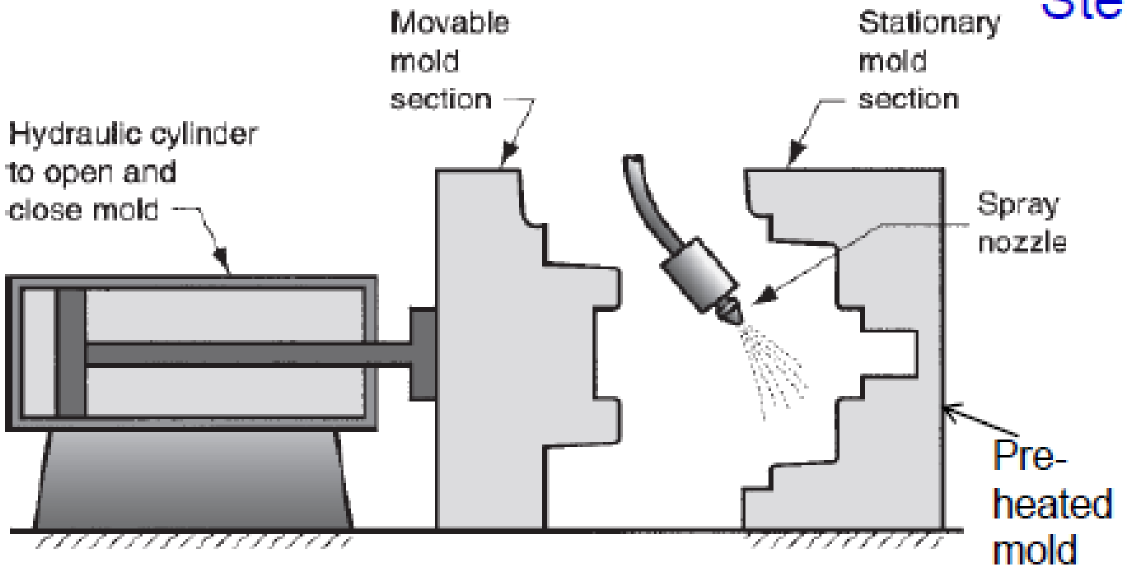
The molds are clamped together by mechanical means and heated to about 150° to 200°C to facilitate metal flow and reduce thermal damage to the dies due to high-temperature gradients. Molten metal is then poured through the gating system. After solidification, the molds are opened and the casting is removed. The mold often incorporates special cooling features, such as a means of pumping cooling water through the channels located in the mold and the use of cooling fins. Although the permanent-mold casting operation can be performed manually, it is often automated for large production runs. The process is used mostly for aluminum, magnesium, and copper alloys, as well as for gray iron, because of their generally lower melting points, although steels also can be cast using graphite or heat-resistant metal molds. Permanent-mold casting produces castings with a good surface finish, close dimensional tolerances, uniform and good mechanical properties, and at high production rates.

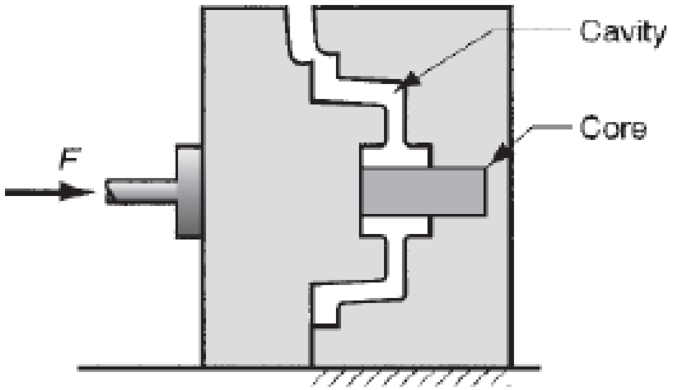
Although equipment costs can be high because of high die costs, labor costs are kept low through automation. The process is not economical for small production runs and is not suitable for intricate shapes, because of the difficulty in removing the casting from the mold.

Permanent mold processes:

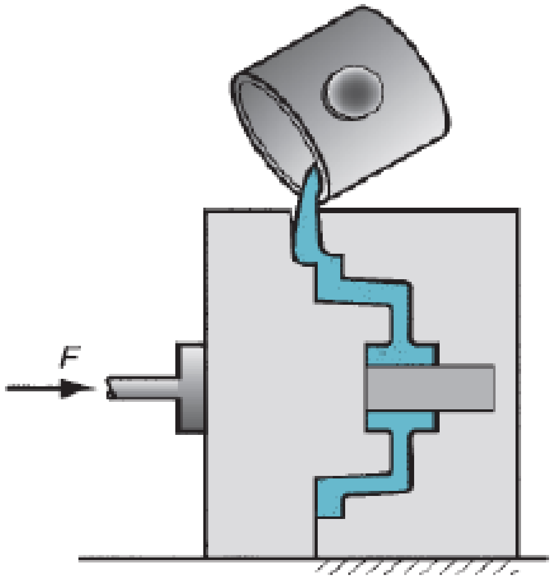
- using only metal mold for casting
- Molds are generally made of steel, CI
- materials that can be cast: Al, Mg, Cu based alloys, CI (affect the mold life, hence not used)
- cores are also made of metal, but if sand is used then called semi permanent-mold casting
- Advantages: good surface finish, dimension tolerance, rapid solidification causes fine grains to form giving stronger products
- limitations: restricted to simple part geometries, low melting point metals, mold cost is high. Best suitable for small, large number of parts

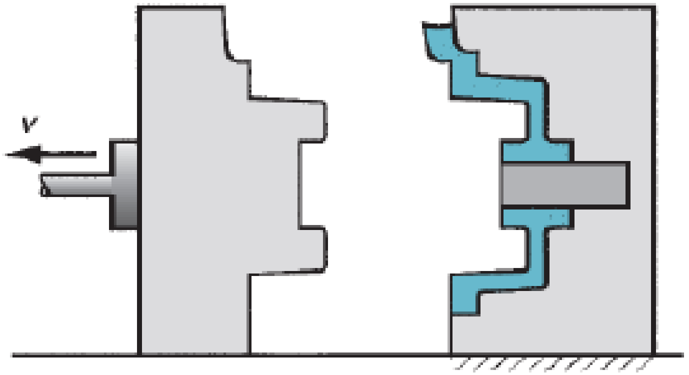
Steps in permanent mold process

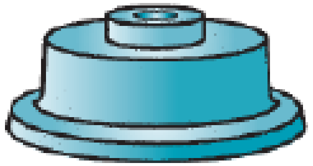




Preheating facilitates metal flow through the gating system and into the cavity.
The coatings aid heat dissipation and lubricate the mold surfaces for easier separation of the cast product







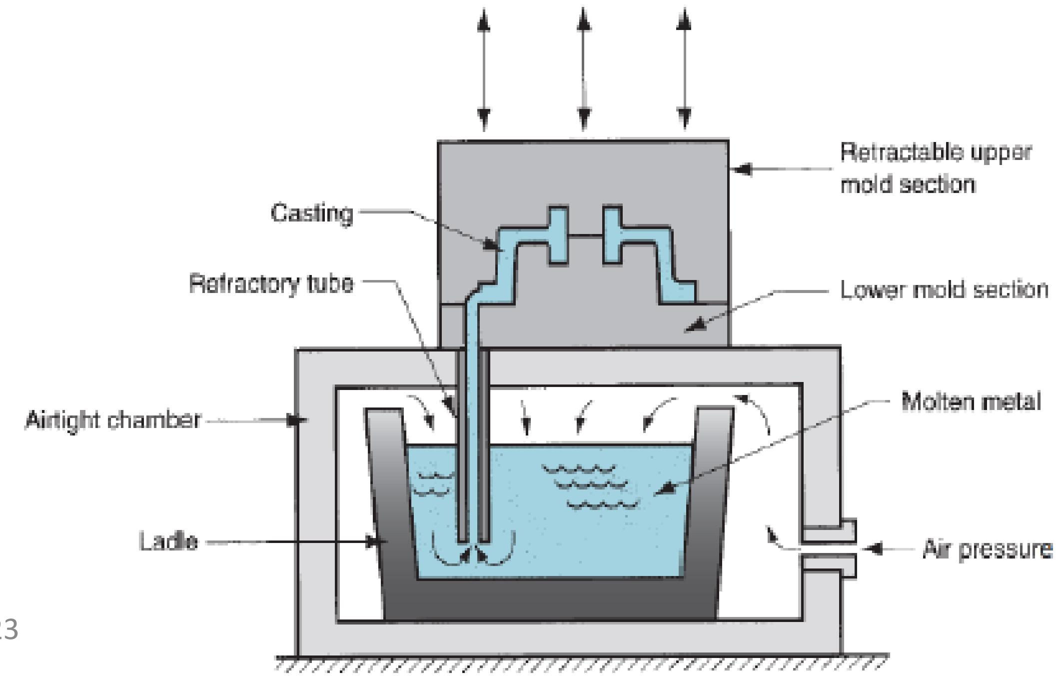
Variations of permanent mold casting

Low pressure casting:

• In the earlier casting process, metal flow in mold cavity is by gravity pull, but in low pressure casting, liquid metal is forced into the cavity under low pressure, app. 0.1 MPa, from beneath the surface so that metal flow is upward.

• advantage: molten metal is not exposed to air; gas porosity and oxidation defects are minimized

Vacuum permanent mold casting: variation of low pressure casting, but in this vacuum is used to draw the molten metal into the mold cavity.



Low pressure casting

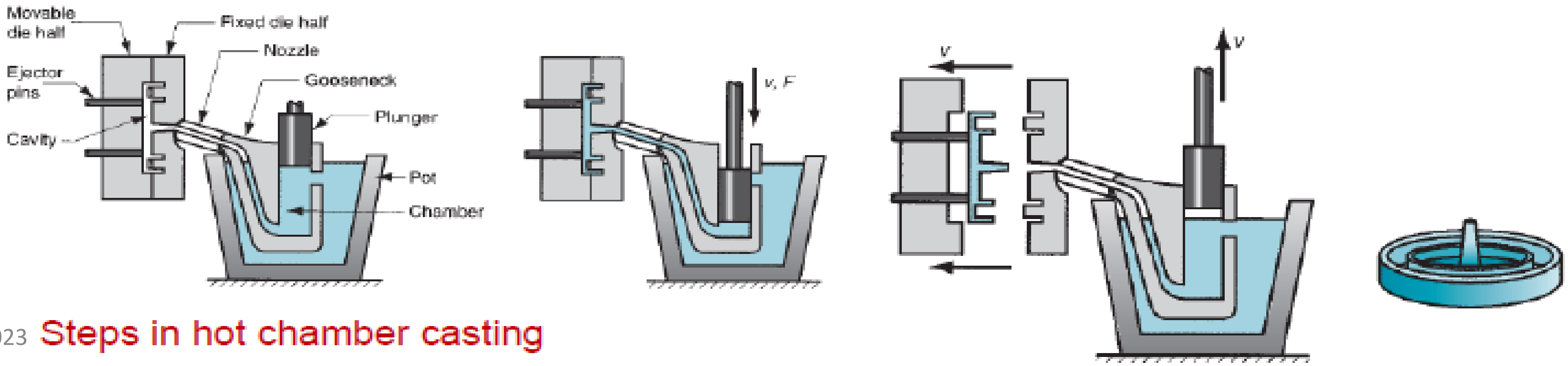
Die casting

In this process, high pressure of app. 7 to 350 MPa is used to pressurize the molten metal into die cavity. The pressure is maintained during solidification.

Category: hot chamber machines, cold chamber machines

hot chamber machines:

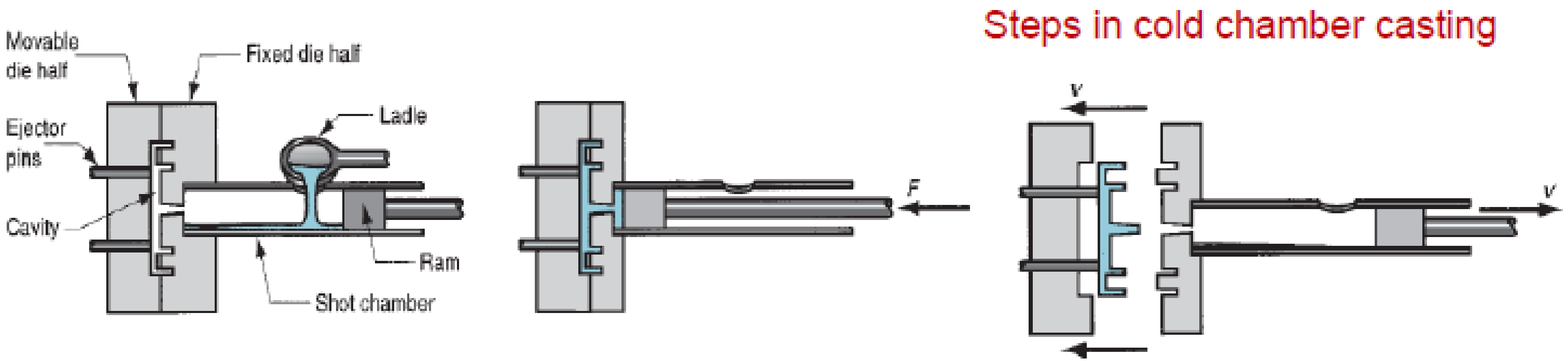
- Molten metal is melted in a container attached to the machine, and a piston is used to pressurize metal under high pressure into the die. Typical injection pressures are between 7 and 35 MPa.
- Production rate of 500 parts/hour are common.
- Injection system is submerged into the molten metal and hence pose problem of chemical attack on the machine components. Suitable for zinc, tin, lead, Mg.



Steps in hot chamber casting

cold chamber machines:

- Molten metal is poured from an external unheated container into the mold cavity and piston is used to inject the molten metal into the die cavity.
- Injection pressure: 14 to 140 MPa.
- Though it is a high production operation, it is not as fast as hot chamber machines.



Die casting molds are made of tool steel, mold steel, maraging steels. Tungsten and molybdenum with good refractory qualities are also used for die cast steel, CI.

Advantages of die casting:

- high production rates and economical
- Close tolerances possible of the order of ±0.076 mm
- thin section with 0.5 mm can be made
- small grain size and good strength casting can be made because of rapid cooling

Investment Casting

The *investment-casting* process, also called the **lost-wax process,** was first used during the period from 4000 to 3000 B.C. Typical parts made are components for office equipment, as well as mechanical components such as gears, cams, valves, and ratchets. Parts up to 1.5 m in diameter and weighing as much as 1140 kg have been cast successfully by this process.

The sequence involved in investment casting is shown in Fig. . The pattern is made of wax, or of a plastic such as polystyrene, by molding or rapid-prototyping techniques. The pattern is then dipped into a slurry of refractory material such as very fine silica and binders, including water, ethyl silicate, and acids. After this initial coating has dried, the pattern is coated repeatedly to increase its thickness for better strength. Note that the initial coating can use smaller particles to develop a better surface finish in the casting; subsequent layers use larger particles and are intended to build coating thickness quickly.

The term *investment* derives from the fact that the pattern is invested (surrounded) with the refractory material. Wax patterns require careful handling because they are not strong enough to withstand the forces encountered during mold making; however, unlike plastic patterns, wax can be recovered and reused.

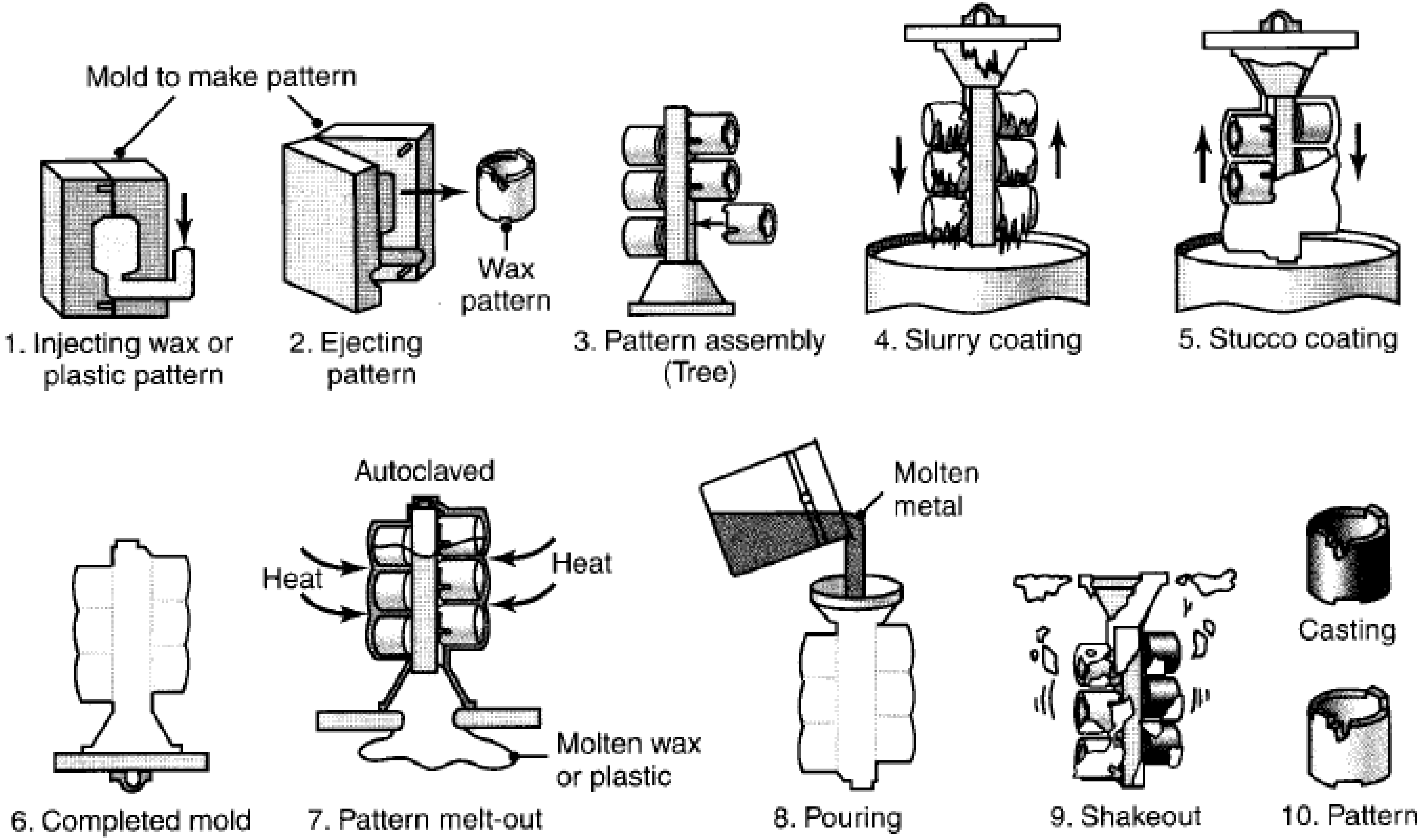
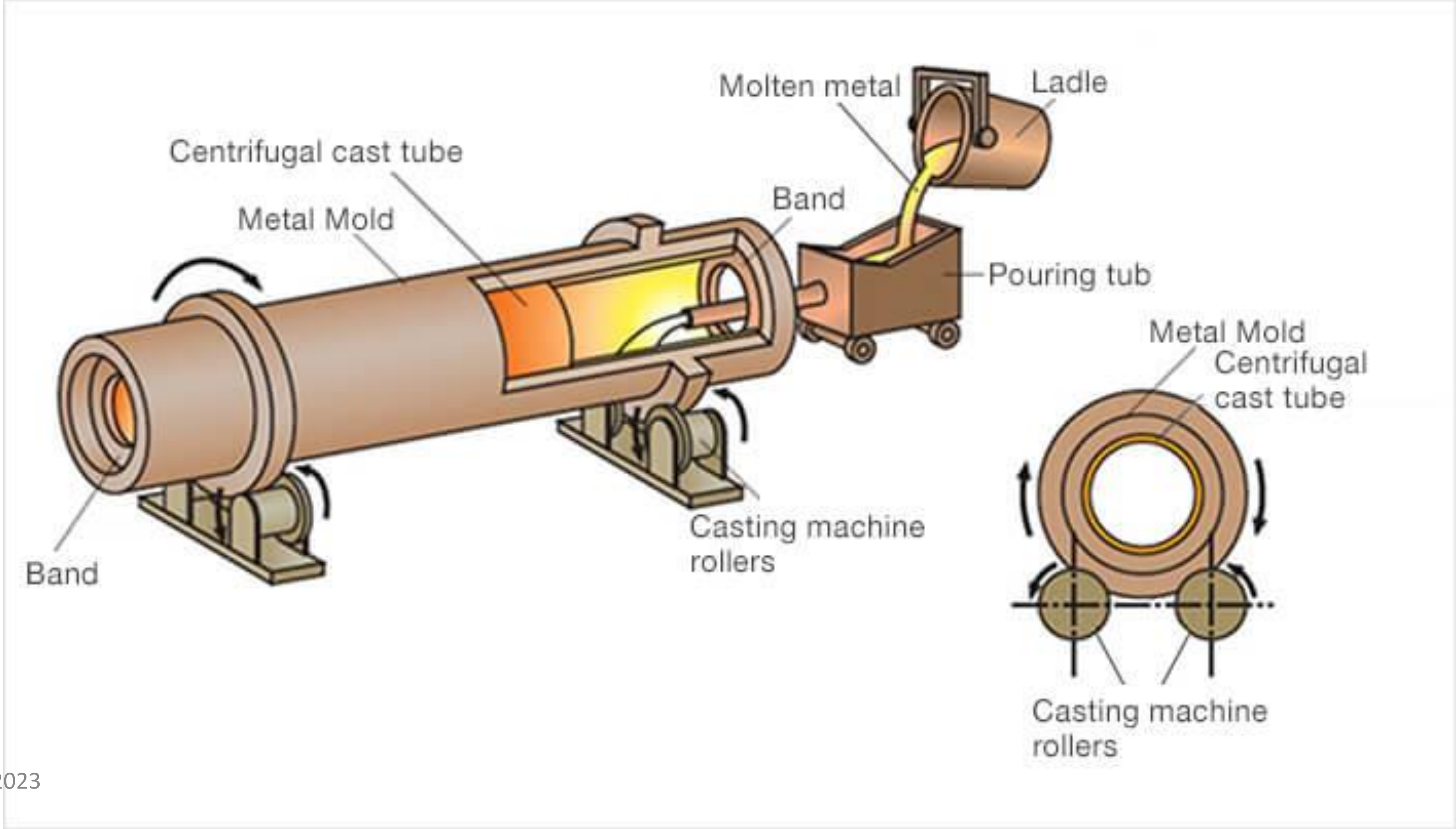


FIGURE Schematic illustration of the investment-casting (lost-wax) process. Castings produced by this method can be made with very fine detail and from a variety of metals.

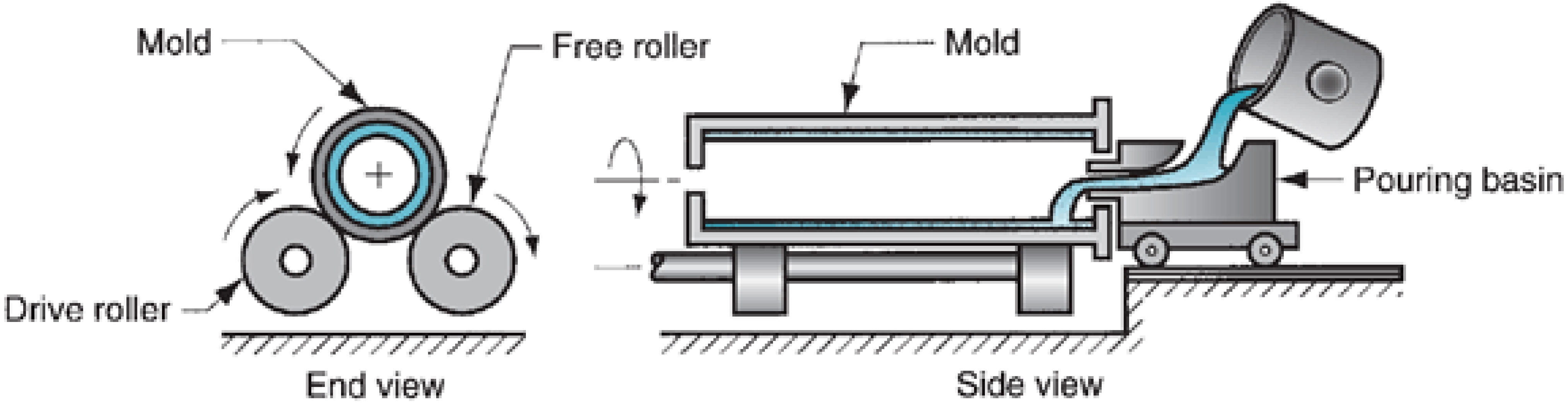
Centrifugal Casting

As its name implies, the *centrifugal-casting* process utilizes inertial forces (caused by rotation) to distribute the molten metal into the mold cavities—a method that was first suggested in the early 1800s. There are three types of centrifugal casting: true centrifugal casting, semicentrifugal casting, and centrifuging.



True Centrifugal casting

Molten metal is poured into a rotating horizontal mould to produce tubular parts such as pipes, tubes, rings, and bushes in this casting process. Mould rotation can take place on a horizontal or vertical axis, with the former being more common. The revolving speed of the horizontal true centrifugal casting is critical to the effectiveness of the casting process and part quality.

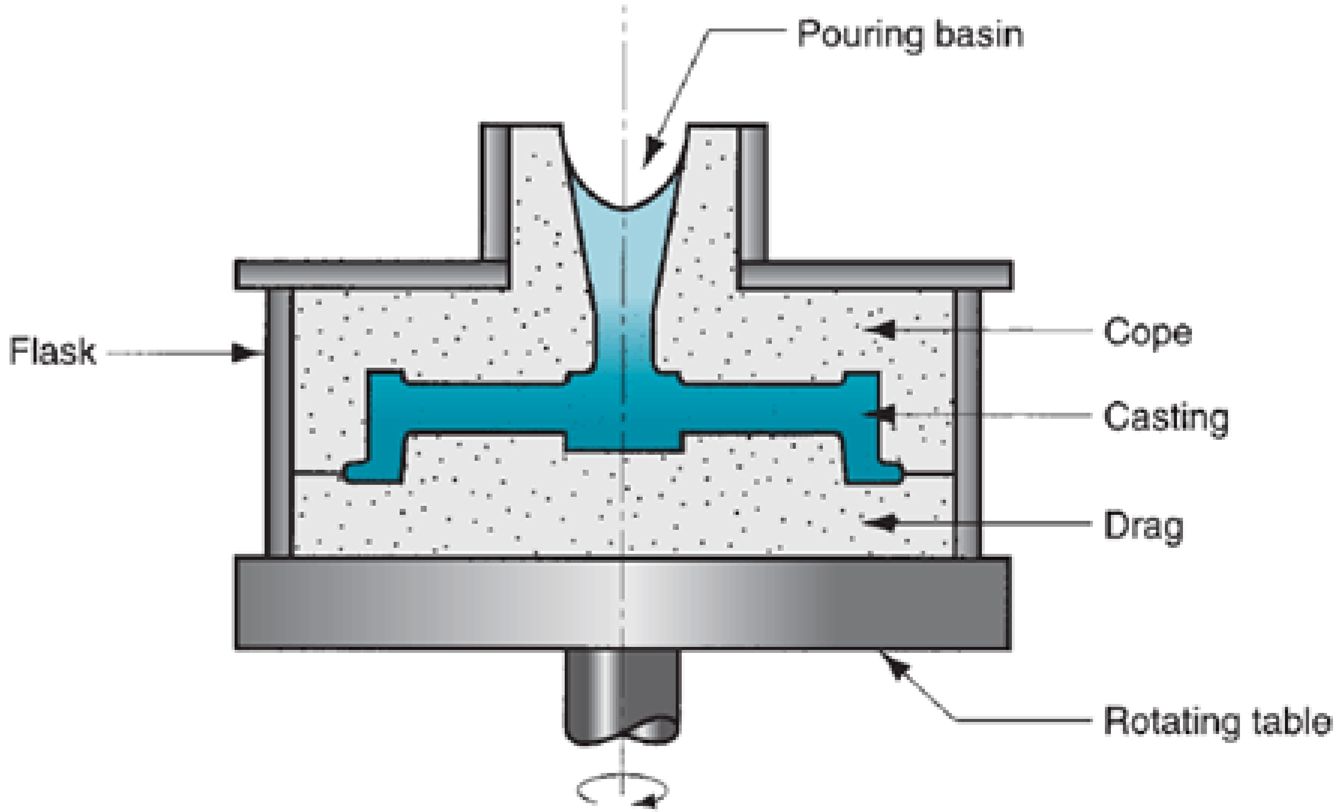


Moulds are made of steel, iron, or graphite, and they can be coated with a refractory lining to extend their life. The surfaces of the moulds are designed to allow for pipe casting with a range of outside styles. The inner surface of the casting remains cylindrical due to centrifugal forces that evenly distribute the molten metal.

Castings produced by true centrifugal casting have a high density, particularly in the outer portions of the component where centrifugal force is highest. Because centrifugal force constantly reallocates molten metal toward the mould wall during freezing, solidification shrinkage at the cast tube's outside is not an issue. Any imperfections in the casting tend to be on the inner wall and, if necessary, can be eliminated by machining.

Semicentrifugal Casting

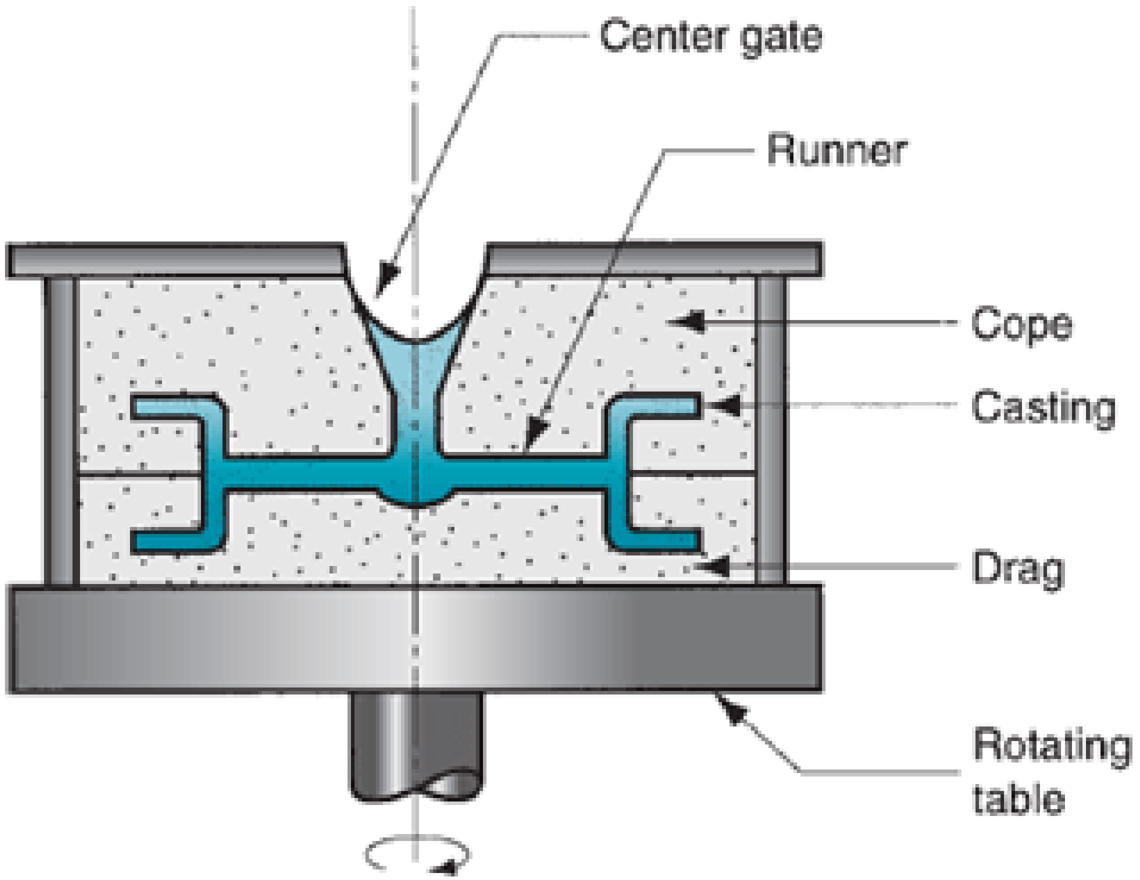
Semicentrifugal casting uses centrifugal force to produce solid casting rather than tubular casts. The image below shows an example of semi centrifugal casting where the moulds have their riser at the axis of rotation to feed the molten metal. Expendable moulds are more common and used to make parts such as spoked wheels, pulleys, gear blanks, brass bush and nozzles.



The exterior regions of items formed by semi centrifugal casting have a higher density than the centre of the rotating axis. This casting procedure is used to make things like spoked wheels that have rotational symmetry and can have the casting centre removed. Removing the centre section of the cast also removes the cast's lowest density component.

Centrifuging

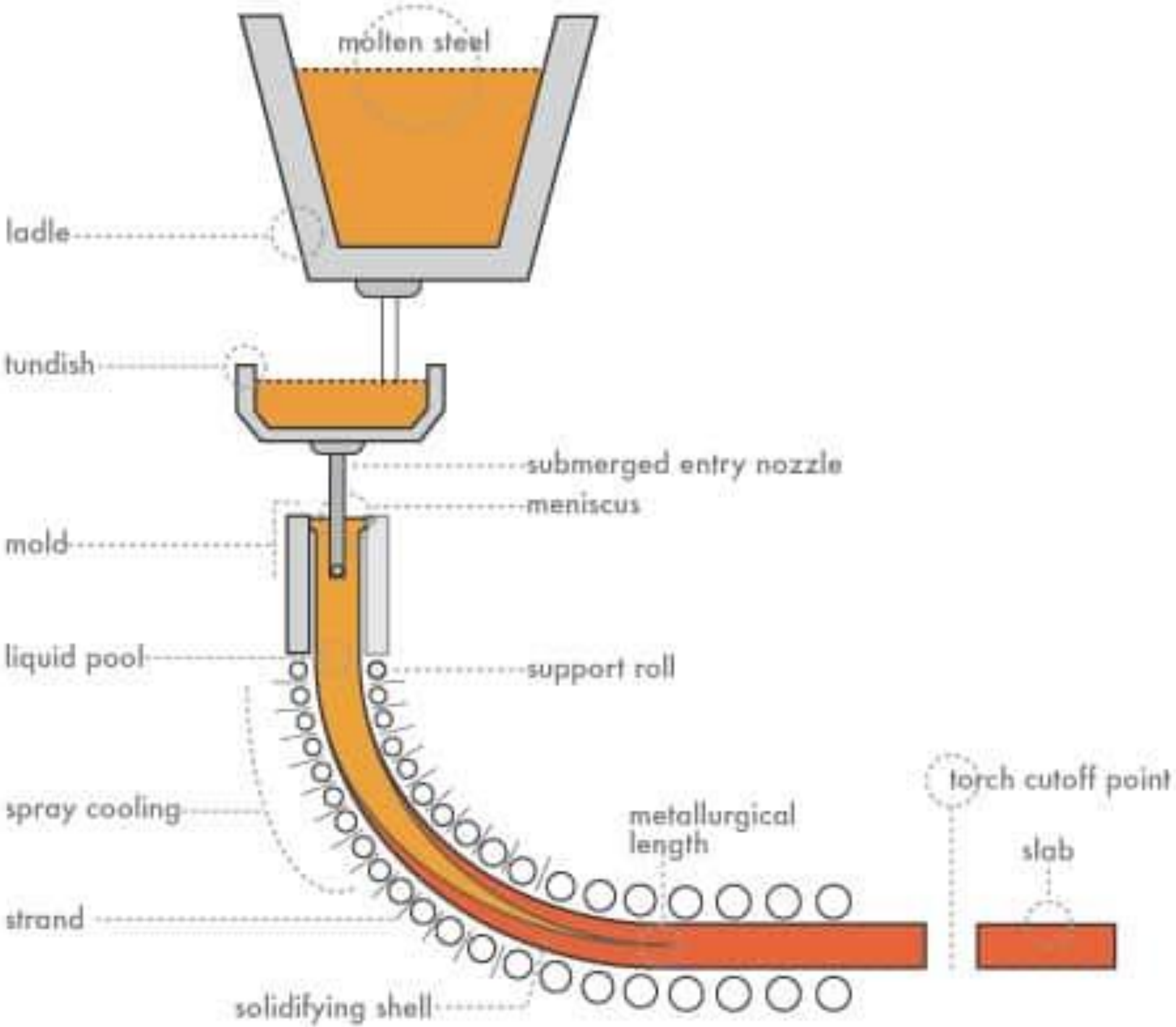
Centrifuging, also known as centrifuge casting, involves the placement of mould cavities of any shape at a certain distance from the axis of spin. The molten metal is poured from the centre, and centrifugal forces push it into the mould cavity through the sprue and the runner. Like true centrifugal casting, the characteristics of the castings might change with distance from the spin axis. This method is used for small parts such as jewellery, small bushes and sleaves.



Continuous Casting

Continuous casting, also known as strand casting, is the process where a metal is heated until it liquefies. The molten metal is then allowed to solidify until it becomes a semi-finished slab that is later rolled in the finishing mill. It is used to cast metals of uninterrupted lengths. In this process, the molten metal is continuously supplied to the mold. The mold has an indeterminate length. When the molten metal is cast through a mold, it keeps travelling downward increasing in its length as the time passes by. The molten metal is continuously passed through the mold, at the same rate to match the solidifying casting. This results in casting of long strands of metal. The whole process of continuous casting is a precisely deliberated process that can produce astounding results.

Continuous casting has several advantages but it is also a process that needs distinct resources. This is the reason why this process is employed only in industries that require high yield of steel cast. The metal is first liquefied and poured into a tundish, which is a container that leads to the mold that will cast the steel. The tundish is placed about 80-90 feet above the ground level and the whole process of casting sues gravity to operate. The tundish is constantly supplied with molten steel to keep the process going. The whole process is controlled to ensure there is smooth flow of molten steel through tundish. Further, the impurities and slag are filtered in tundish before they move into the mold. The entrance of the mold is filled with inert gases to prevent reaction of molten steel with the gases in the environment like oxygen. The molten metal moves swiftly through the mold and it does not completely solidify in it.The entire mold is cooled with water that flows along the outer surface. Typically, steel casting solidifies along the walls of the casting and then gradually moves to the interior of the steel casting. The metal casting moves outside the mold with the help of different sets of rollers. While one set of rollers bend the metal cast, another set will straighten it. This helps to change the direction of flow of the steel slab from vertical to horizontal.


molten steel
ladle
tundish
submerged entry nozzle
meniscus
mold
liquid pool
support roll
spray cooling
torch cutoff point
metallurgical
length
slab
strand
solidifying shell

Mold Material

- The mold material is the one out of which the mold is made.
- The mold material should be such that casting should be able to retain its shape till the molten metal has solidified.

Types of molds:

- **Permanent molds:** They are made up of **ferrous metals** and alloys (Steel, Grey CI, etc.).
- **Temporary refractory molds:** They are made of refractory sands and resins
- Molds made of **wax, plastic, Plaster of Paris , carbon, ceramics** are also employed.

MOLDING SAND

The general sources of receiving molding sands are the beds of sea, rivers, lakes, granulular elements of rocks, and deserts. The common sources of molding sands available in India are as follows:

1 Batala sand (Punjab)
2 Ganges sand (Uttar Pradesh)
3 Oyaria sand (Bihar)
4 Damodar and Barakar sands (Bengal- Bihar Border)
5 Londha sand (Bombay)
6 Gigatamannu sand (Andhra Pradesh) and
7 Avadi and Veeriyambakam sand (Madras)

Molding sands may be of two types namely natural or synthetic. Natural molding sands contain sufficient binder. Whereas synthetic molding sands are prepared artificially using basic sand molding constituents (silica sand in 88-92%, binder 6-12%, water or moisture content 3-6%) and other additives in proper proportion by weight with perfect mixing and mulling in suitable equipments.

CONSTITUENTS OF MOLDING SAND

The main constituents of molding sand involve silica sand, binder, moisture content and additives.

Silica sand

Silica sand in form of granular quarts is the main constituent of molding sand having enough refractoriness which can impart strength, stability and permeability to molding and core sand. But along with silica small amounts of iron oxide, alumina, lime stone, magnesia, soda and potash are present as impurities. The chemical composition of silica sand gives an idea of the impurities like lime, magnesia, alkalis etc. present. The presence of excessive amounts of iron oxide, alkali oxides and lime can lower the fusion point to a considerable extent which is undesirable. The silica sand can be specified according to the size (small, medium and large silica sand grain) and the shape (angular, sub-angular and rounded).

Binder

In general, the binders can be either inorganic or organic substance. The inorganic group includes clay sodium silicate and port land cement etc. In foundry shop, the clay acts as binder which may be Kaolonite, Ball Clay, Fire Clay, Limonite, Fuller's earth and Bentonite. Binders included in the organic group are dextrin, molasses, cereal binders, linseed oil and resins like phenol formaldehyde, urea formaldehyde etc. Organic binders are mostly used for core making. Among all the above binders, the bentonite variety of clay is the most common. However, this clay alone can not develop bonds among sand grins without the presence of moisture in molding sand and core sand.

Moisture

The amount of moisture content in the molding sand varies generally between 2 to 8 percent. This amount is added to the mixture of clay and silica sand for developing bonds. This is the amount of water required to fill the pores between the particles of clay without separating them. This amount of water is held rigidly by the clay and is mainly responsible for developing the strength in the sand. The effect of clay and water decreases permeability with increasing clay and moisture content. The green compressive strength first increases with the increase in clay content, but after a certain value, it starts decreasing.

Additives

Additives are the materials generally added to the molding and core sand mixture to develop some special property in the sand. Some common used additives for enhancing the properties of molding and core sands are discussed as under.

Coal dust

Coal dust is added mainly for producing a reducing atmosphere during casting. This reducing atmosphere results in any oxygen in the poles becoming chemically bound so that it cannot oxidize the metal. It is usually added in the molding sands for making molds for production of grey iron and malleable cast iron castings.

Corn flour

It belongs to the starch family of carbohydrates and is used to increase the collapsibility of the molding and core sand. It is completely volatilized by heat in the mould, thereby leaving space between the sand grains. This allows free movement of sand grains, which finally gives rise to mould wall movement and decreases the mold expansion and hence defects in castings. Corn sand if added to molding sand and core sand improves significantly strength of the mold and core.

Dextrin

Dextrin belongs to starch family of carbohydrates that behaves also in a manner similar to that of the corn flour. It increases dry strength of the molds.

Sea coal

Sea coal is the fine powdered bituminous coal which positions its place among the pores of the silica sand grains in molding sand and core sand. When heated, it changes to coke which fills the pores and is unaffected by water: Because to this, the sand grains become restricted and cannot move into a dense packing pattern. Thus, sea coal reduces the mould wall movement and the permeability in mold and core sand and hence makes the mold and core surface clean and smooth.

Pitch

It is distilled form of soft coal. It can be added from 0.02 % to 2% in mold and core sand. It enhances hot strengths, surface finish on mold surfaces and behaves exactly in a manner similar to that of sea coal.

Wood flour

This is a fibrous material mixed with a granular material like sand; its relatively long thin fibers prevent the sand grains from making contact with one another. It can be added from 0.05 % to 2% in mold and core sand. It volatilizes when heated, thus allowing the sand grains room to expand. It will increase mould wall movement and decrease expansion defects. It also increases collapsibility of both of mold and core.

Silica flour

It is called as pulverized silica and it can be easily added up to 3% which increases the hot strength and finish on the surfaces of the molds and cores. It also reduces metal penetration in the walls of the molds and cores.

Types of Moulding Sand:

- *Green Sand*
- *Dry Sand*
- *Loam Sand*
- *Parting Sand*
- *Facing Sand*
- *System Sand*
- *Floor Sand*
- *Core Sand*
- *Molasses Sand*

Green Sand:

The green sand is tempered sand and contains enough amount of moisture.

Greensand contains a mixture of 15% to 20% of clay, 6% to 8% of water and silica. Strength depends on the mixture of water and clay. The mixture acts as the bonding material in the sand.

Greensand mold is that mold which is basically made from Green Sand. Greensand is soft, porous, fine and light in nature. It is used in rough and simple casting and both for non-ferrous and ferrous metals. This sand feels damp when it is pressed in it.

The availability of green sand is good and it also costs low. So, green sand is commonly used by manufacturers most of the time.

Dry Sand:

Dry sand is the type of green sand, from which moisture is being removed.

Dry sand is made by baking or drying the mold made from the green sand in a decent oven. The dry sand contains a mixture of 15% to 20% of clay and silica.

This sand has more rigidity, thermal stability, and strength.

The casting of the dry sand is heavy and large. A dry sand mold is that mold that is made from Dry Sand.

Loam Sand:

Loam sand is like a thin paste of plastic in nature.

Loam sand is made up of the mixture of 30%-35% of clay, 18% of water and the rest of the thing is sand. With the help of Sweeping, shape is given to the loam sand.

In this sand, an appropriate amount of water is a must needed thing.

Loam sand mold is made from the loam sand. These molds from loam sand are heavy and large to be used in the hoppers and the parts of turbines.

Parting Sand:

Parting sand is the dry sand without a binder to induce a non-stickiness pattern. Parting sand is made of pure silica.

Parting sand is used to make the parting mold.

In general cases, the patter is removed from the mold. Then the mold used to stick. So, parting sand is used as the mold does not stick.

Before attaching the mold with the pattern, such parting sand is used to sprinkle on the mold as after removing the pattern the mold does not stick.

Facing Sand:

Facing sand is that kind of sand that forms the face of the mold.

This sand is mainly used by manufacturers to form the face, the molten metal which is then poured thus, it is termed as the Facing Sand. Facing sand is consists of 5% of sea-coal and 25% of iron.

It is placed as the next surface of the patter to come in contact with the hot molten metal.

Facing sand has high refractoriness and very high strength. Facing sand is very fine in nature.

System Sand:

System sand is that sand that is used to fill the flask of machine molding.

As this sand is used in machine molding, it is termed as the System sand.
This sand has very high strength, refractoriness, and permeability. Along which that System sand has mechanical heavy casting.
In the machine molding, facing sand is not used as facing sand as it cannot be cleaned easily and apart from that system and it has some other special additives.

Floor Sand:

The floor sand is black in color. The facing sand is mainly backed up by the floor sand, for this reason, Floor sand is also known as Backing Sand.
The floor sand is used to fill the whole molding flask by backing up the face sand.
Floor sand is used by engineers, from very old times.

Core Sand:

Core sand is the sand that is generally used to make the core, for that reason, this sand is termed as Core Sand. Core sand consists of the mixture of core oils like resin, linseed oil, mineral oil, rich silica and the other binding materials like corn flour, dextrin, sodium silicate.
As the sand consists of oil, it is also named as Oil sand. It has remarkable strength which has great importance in the whole process.
At the time of use, water can be used in that sand to make the work easier.

Properties of Moulding Sand:

Molding sand has many important properties. They are as follows:

- *Cohesiveness*
- *Adhesiveness*
- *Porosity*
- *Green Strength*
- *Plasticity*
- *Refractoriness*

Cohesiveness:

The property of Cohesiveness plays a very crucial role.

Cohesiveness is the property that can be termed as strength of sand.
Cohesiveness holds the other particles together, of the sand. It provides them with the strength to bear the molding process of the sand. Bentonite and clay help the sand to hold this cohesiveness property.
Insufficient strength might be the cause of the collapse.

Adhesiveness:

Adhesiveness is the property that helps to lift properly of the cope along with sand.
For this property of Adhesiveness, at the sides of the molding box, especially in the inner wall the sand particles used to stick.

Porosity:

Porosity is the property that helps to pass the gasses and the steam of the molding sand. This property of Porosity is also known as Permeability.

The steam and the gasses got generated when the molten metal is poured into the cavity of the sand. These gasses and steam are used to hindrance the particles to give proper shape and size.
According to the binding material, moisture, amount of clay, this property depends. Along with that, the shape, particle size is also important to maintain this property.

Green Strength:

The green strength is the property that comes out after mixing the water into the green sand. The water permits the mold to have enough toughness and strength at the time of handling or making the mold.

To make this property in action, there are some criteria also present. They are as follows:

- The grains of the sand must have the cohesiveness property as they can stick.
- Breaking of mold surface is not be taken.
- At the time of the flow of the molten metal, the wall of the mold erosion is should not be taken.
- Apart from that, the size and shape of the grain, moisture and amount of clay are also dependable.

Plasticity:

Plasticity is a property that makes the sand compact in nature and flowed all around the corners of the mold like a fluid when the mold is rammed.

As this property flows like fluid all over the mold, so that, this property is also known as Flowability.

It used to flow uniformly when the mold is rammed. This property depends on the other property named as Green strength.

Plasticity and Green strength and those are inversely proportional to each other when the subject is about increasing the plasticity, then the green strength is decreased and vice versa.

Plasticity depends on the clay and the moisture in the sand.

Refractoriness

Refractoriness is the property that is very important for molding sand.

By refractoriness, the mold does not break in very high temperatures as the molding process can be done with the help of high temperatures.

If this property of the sand becomes poor then the surface of the molding sand will not be so smooth after burning that.

This property depends on quartz content, SiO2 and the size and shape of the grain.

The sinter point of the sand is taken to measure the Refractoriness property rather than the melting point of the sand.

Permeability

It is also termed as porosity of the molding sand in order to allow the escape of any air, gases or moisture present or generated in the mould when the molten metal is poured into it. All these gaseous generated during pouring and solidification process must escape otherwise the casting becomes defective. Permeability is a function of grain size, grain shape, and moisture and clay contents in the molding sand. The extent of ramming of the sand directly affects the permeability of the mould. Permeability of mold can be further increased by venting using vent rods

Dry strength

As soon as the molten metal is poured into the mould, the moisture in the sand layer adjacent to the hot metal gets evaporated and this dry sand layer must have sufficient strength to its shape in order to avoid erosion of mould wall during the flow of molten metal. The dry strength also prevents the enlargement of mould cavity cause by the metallostatic pressure of the liquid metal.

Flowability or plasticity

It is the ability of the sand to get compacted and behave like a fluid. It will flow uniformly to all portions of pattern when rammed and distribute the ramming pressure evenly all around in all directions. Generally sand particles resist moving around corners or projections. In general, flowability increases with decrease in green strength, an, decrease in grain size. The flowability also varies with moisture and clay content.

Collapsibility

After the molten metal in the mould gets solidified, the sand mould must be collapsible so that free contraction of the metal occurs and this would naturally avoid the tearing or cracking of the contracting metal. In absence of this property the contraction of the metal is hindered by the mold and thus results in tears and cracks in the casting. This property is highly desired in cores

CORE

Cores are compact mass of core sand (special kind of molding sand) prepared separately that when placed in mould cavity at required location with proper alignment does not allow the molten metal to occupy space for solidification in that portion and hence help to produce hollowness in the casting. The environment in which the core is placed is much different from that of the mold. In fact the core has to withstand the severe action of hot metal which completely surrounds it. They may be of the type of green sand core and dry sand core. Therefore the core must meet the following functions or objectives which are given as under.

1 Core produces hollowness in castings in form of internal cavities.
2 It must be sufficiently permeable to allow the easy escape of gases during pouring and solidification.
3 It may form a part of green sand mold
4 It may be deployed to improve mold surface.
5 It may provide external under cut features in casting.
6 It may be inserted to achieve deep recesses in the casting.
7 It may be used to strengthen the mold.
8 It may be used to form gating system of large size mold.

CORE SAND

It is special kind of molding sand. Keeping the above mentioned objectives in view, the special considerations should be given while selecting core sand. Those considerations involves (*i*) The cores are subjected to a very high temperature and hence the core sand should be highly refractory in nature (*ii*) The permeability of the core sand must be sufficiently high as compared to that of the molding sands so as to allow the core gases to escape through the limited area of the core recesses generated by core prints (*iii*) The core sand should not possess such materials which may produce gases while they come in contact with molten metal and (*iv*) The core sand should be collapsible in nature, i.e. it should disintegrate after the metal solidifies, because this property will ease the cleaning of the casting.

The main constituents of the core sand are pure silica sand and a binder. Silica sand is preferred because of its high refractoriness. For higher values of permeability sands with coarse grain size distribution are used. The main purpose of the core binder is to hold the grains together, impart strength and sufficient degree collapsibility. Beside these properties needed in the core sand, the binder should be such that it produces minimum amount of gases when the molt metal is poured in the mould. Although, in general the binder are inorganic as well as organic ones, but for core making, organic binders are generally preferred because they are combustible and can be destroyed by heat at higher temperatures thereby giving sufficient collapsibility to the core sand.

CORE MAKING

Core making basically is carried out in four stages namely core sand preparation, core making, core baking and core finishing. Each stage is explained as under.

Core Sand Preparation

Preparation of satisfactory and homogenous mixture of core sand is not possible by manual means. Therefore for getting better and uniform core sand properties using proper sand constituents and additives, the core sands are generally mixed with the help of any of the following mechanical means namely roller mills and core sand mixer using vertical revolving arm type and horizontal paddle type mechanisms. In the case of roller mills, the rolling action of the mulling machine along with the turning over action caused by the ploughs gives a uniform and homogeneous mixing. Roller mills are suitable for core sands containing cereal binders, whereas the core sand mixer is suitable for all types of core binders. These machines perform the mixing of core sand constituents most thoroughly.

Core Making Process Using Core Making Machines

The process of core making is basically mechanized using core blowing, core ramming and core drawing machines which are broadly discussed as under.

Core blowing machines

The basic principle of core blowing machine comprises of filling the core sand into the core box by using compressed air. The velocity of the compressed air is kept high to obtain a high velocity of core sand particles, thus ensuring their deposit in the remote corners the core box. On entering the core sand with high kinetic energy, the shaping and ramming of core is carried out simultaneously in the core box.

Core baking

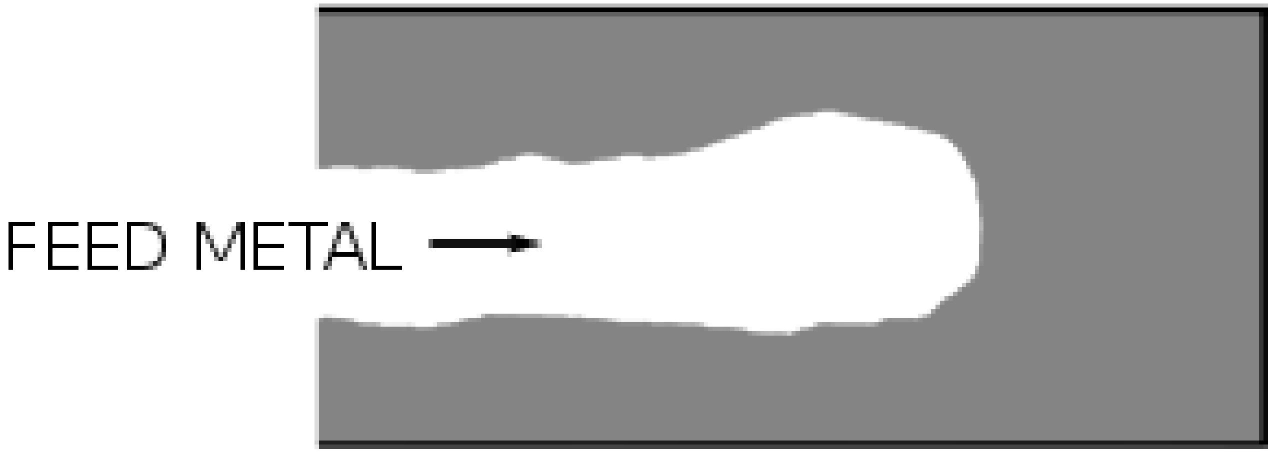
Once the cores are prepared, they will be baked in a baking ovens or furnaces. The main purpose of baking is to drive away the moisture and hard en the binder, thereby giving strength to the core. The core drying equipments are usually of two kinds namely core ovens and dielectric bakers. The core ovens are may be further of two type's namely continuous type oven and batch type oven.

CORE FINISHING

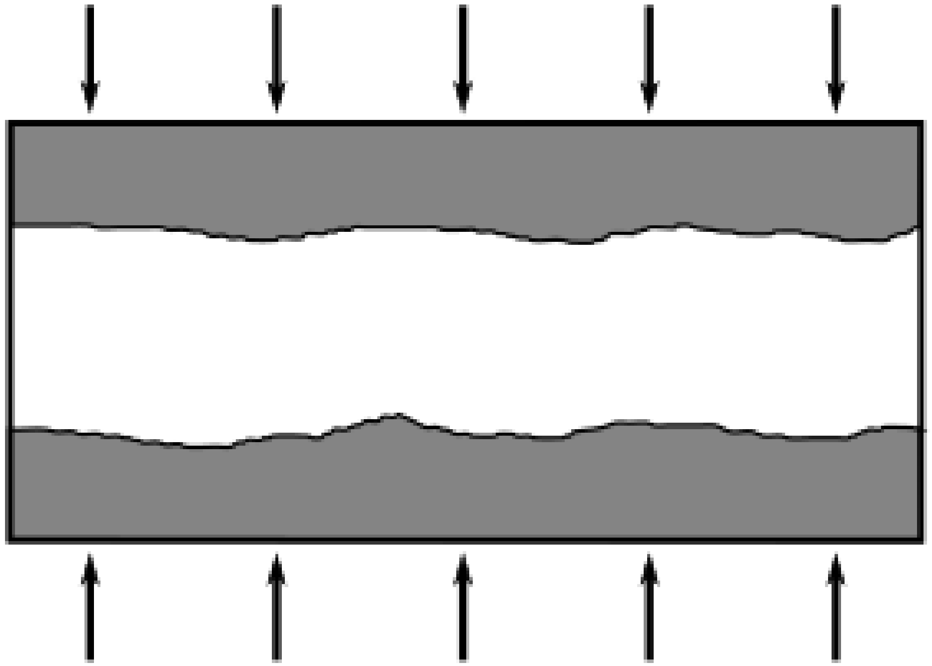
The cores are finally finished after baking and before they are finally set in the mould. The fins, bumps or other sand projections are removed from the surface of the cores by rubbing or filing. The dimensional inspection of the cores is very necessary to achieve sound casting. Cores are also coated with refractory or protective materials using brushing dipping and spraying means to improve their refractoriness and surface finish. The coating on core prevents the molten metal from entering in to the core.

Bars, wires and arbors are generally used to reinforce core from inside as per size of core using core sand. For handling bulky cores, lifting rings are also provided.

Directional solidification (DS) and **progressive solidification** are types of solidification within castings. Directional solidification is solidification that occurs from farthest end of the casting and works its way towards the sprue. Progressive solidification, also known as **parallel solidification**, is solidification that starts at the walls of the casting and progresses perpendicularly from that surface.



Directional solidification



Progressive solidification

S.N.	Pressurized gating systems	Unpressurized gating systems
1.	Gating ratio may be of the order of 3: 2: 1	Gating ratio may be of the order of 1: 3: 2
2.	Air aspiration effect is minimum	Air aspiration effect is more
3.	Volume flow of liquid from every ingate is almost equal.	Volume flow of liquid from every ingate is different.
4.	They are smaller in volume for a given flow rate of metal. Therefore the casting yield is higher.	They are larger in volume because they involve large runners and gates as compared to pressurized system and thus the cast yield is reduced.
5.	Velocity is high, severe turbulence may occur at corners.	Velocity is low and turbulence is reduced.

Solidification and Pouring Time:

- **Solidification time is a function of the size and shape:**

$$TST \propto \frac{1}{(surface\ area)^n}$$

$$TST = C_m \left(\frac{volume\ of\ casting}{surface\ area\ of\ casting}\right)^n$$

n: constant usually equal to 2.

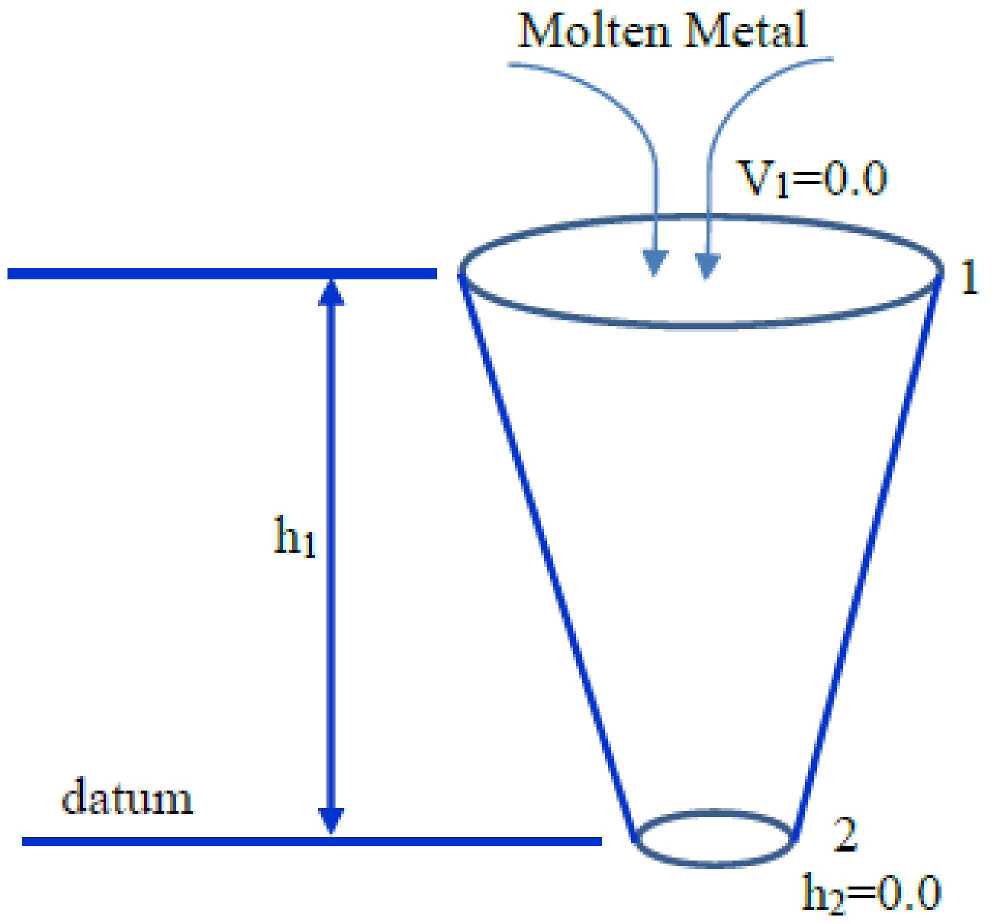
TST: total solidification time, sec, min.

C_m: (mold constant) experimentally determined value that depends on mold material, thermal properties of casting metal, and pouring temperature relative to melting point. For example: C_m=0.2 min/mm^2.

- **Pouring Time:**

  From Bernoulli's theorem at any two points in a flowing fluid:

$$h_1 + \frac{p_1}{\rho g} + \frac{v_1^2}{2g} = h_2 + \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_f$$



Where;

h: head,

p: static pressure,

ρ: density,

v: flow velocity,

g: gravity,

h_f: friction losses

assume h_f=0.0 and same static pressure p_1=p_2 then:

$$v_2 = \sqrt{2gh_1}$$

From continuity law:

$$Q = v_1 A_1 = v_2 A_2$$

$$\text{Mold Filling Time (MFT)} = V/Q$$

A: cross-sectional area of molten metal.

V: volume of casting (mold cavity volume)

Q: volume flow rate of metal

3 pieces of castings have the same volume but with different shapes. One is a sphere, one is a cube and the other is a cylinder with height equal to diameter. Which piece will solidify the fastest and which one the slowest?

We assume $V=1.0$ unit^3, calculate the areas

1. Sphere

$V_{sphere}= (4/3)\,\pi\, r^3$, $A_{sphere}=4\,\pi\, r^2$ (surface area)

$\therefore\ A_{sphere}=4.84$ unit^2

2. Cube

$V_{cube}=a^3 \Longrightarrow a=1$

$A_{cube}=6a^2=6$ unit^2 (surface area)

3. Cylinder

$V_{cylinder}=\pi\, r^2\, h= \pi\, r^2\,(2r)$

$A_{cylinder}=2\,\pi\, r^2 + 2\,\pi\, r\, h =2\,\pi\, r^2 + 2\,\pi\, r\,(2r)= 6\,\pi\, r^2 = 5.54$ unit^2 (surface area)

$\therefore\ TST_{sphere}= C_m\,(1/4.84)^2 = 0.043\ C_m$

$\therefore\ TST_{cube}= C_m\,(1/6)^2 = 0.028\ C_m$

$\therefore\ TST_{cylinder}= C_m\,(1/5.54)^2 = 0.033\ C_m$

Hence:

Cube casting will solidify the fastest

Sphere casting will solidify the slowest

A mold sprue is 20 cm long, and the cross-sectional area at its base is 2.5 cm2. The sprue feeds a horizontal runner leading into a mold cavity whose volume is 1560 cm3. Determine: (a) velocity of the molten metal at the base of the sprue, (b) volume rate of flow, and (c) time to fill the mold.

(a) The velocity of molten metal at the sprue base is given by

$$v_2 = \sqrt{2gh_1}$$

$$v_2 = \sqrt{2(981)(20)} = 198 \cdot 1\ cm/s$$

(b) The volume flow rate is given by

$$Q = v_1 A_1 = v_2 A_2 = (2 \cdot 5)(198 \cdot 1) = 495 \cdot 3\ cm^3/s$$

(c) Time required to fill the mold cavity is given by

Mold Filling Time (MFT) = V/Q = 1560/495.3 = 3.2 s

Melting Practice and Furnaces

The melting practice is an important aspect of casting operations, because it has a direct bearing on the quality of castings. Furnaces are charged with melting stock, consisting of metal, alloying elements, and various other materials (such as **flux** and slag-forming constituents). Fluxes are inorganic compounds that refine the molten metal by removing dissolved gases and various impurities. They may be added manually or can be injected automatically into the molten metal.

Melting Furnaces. The melting furnaces commonly used in foundries are electric-arc furnaces, induction furnaces, crucible furnaces, and cupolas.

- **Electric-arc furnaces,** are used extensively in foundries and have such advantages as a high rate of melting (and thus high-production rate), much less pollution than other types of furnaces, and the ability to hold the molten metal (keep it at a constant temperature for a period of time) for alloying purposes.
- **Induction** furnaces are especially useful in smaller foundries and produce smaller composition-controlled melts. There are two basic types. The *coreless induction furnace* consists of a crucible completely surrounded with a water-cooled copper coil through which a high-frequency current passes. Because there is a strong electromagnetic stirring action during induction heating, this type of furnace has excellent mixing characteristics for alloying and adding a new charge of metal.

The other type of induction furnace, called a *core* or *channel furnace*, uses a low-frequency current (as low as 60 Hz) and has a coil that surrounds only a small portion of the unit. These furnaces commonly are used in nonferrous foundries and are particularly suitable for (a) superheating (that is, heating above normal casting temperature to improve fluidity), (b) holding (which makes it suitable for die-casting applications), and (c) duplexing (using two furnaces—for instance, melt the metal in one furnace and transfer it to another).

- **Crucible** furnaces , which have been used extensively throughout history, are heated with various fuels, such as commercial gases, fuel oil, and fossil fuel, as well as electricity. Crucible furnaces may be stationary, tilting, or movable.
- **Cupolas** are basically vertical, refractory-lined steel vessels charged with alternating layers of metal, coke, and flux . Although they require major investments and increasingly are being replaced by induction furnaces, cupolas operate continuously, have high melting rates, and produce large amounts of molten metal.

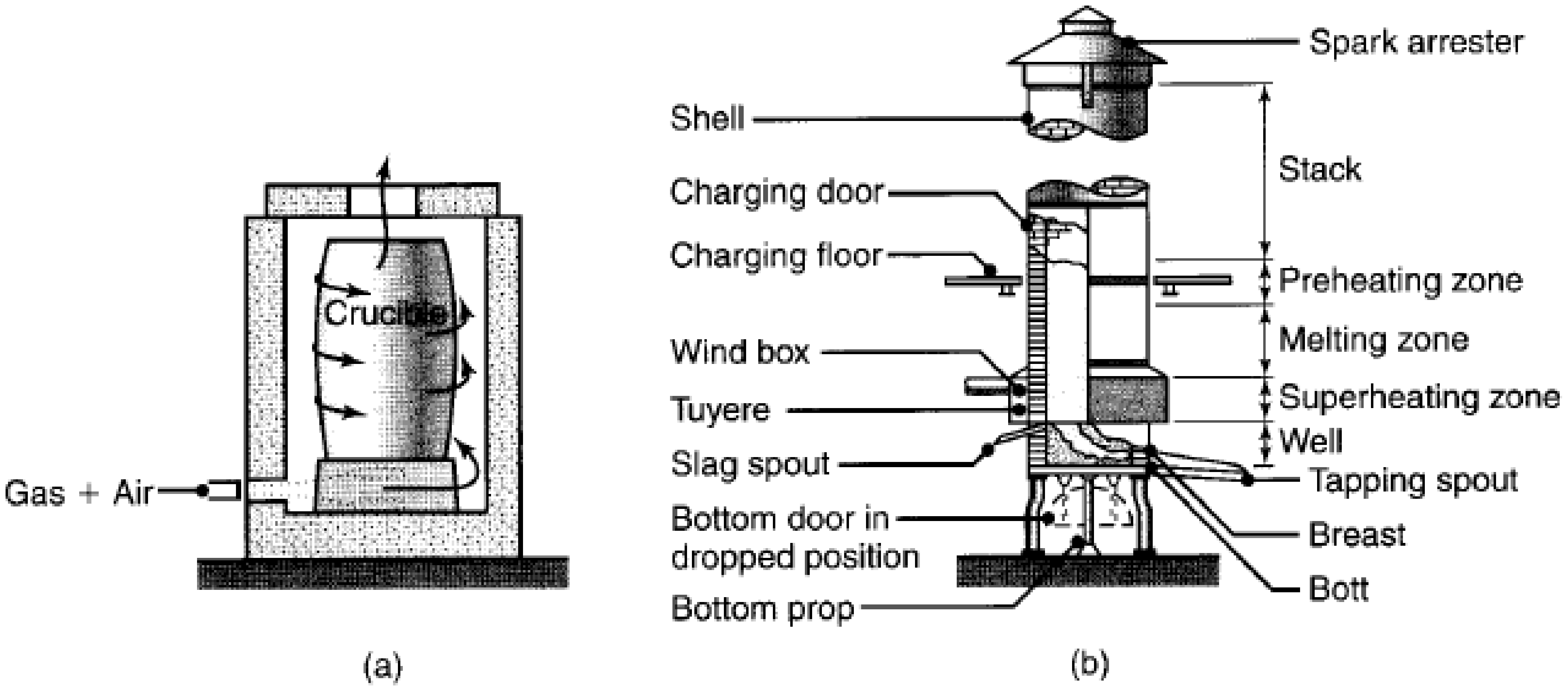


FIGURE Two types of melting furnaces used in foundries: (a) crucible and (b) cupola.

Cleaning and finishing of casting

Commonly, cleaning of casting refers to every process related to removal of adhere sand, risers and gates other metal not a part of casting. Cleaning operations may too consist of a certain amount of metal finishing or machining for obtain required casting dimensions.

The different cleaning operations generally perform on casting are enumerate and discuss under:

1. Rough Cleaning
2. Surface Cleaning
3. Trimming
4. Finishing

1. Rough cleaning

Rough cleaning contain removal of gates of risers. The follow points are worth-noting.

- In case of a pliable material casting, rough cleaning might be done by mechanical cut-off machines (using band saws abrasive cut-off wheels, and metal shears).
- Gating system of a brittle material casting might be busted off by crash as castings are dumped and vibrated in shake-out or knockout devices.
- Lest of steel castings, extremely large risers and sprues might be removed with cutting torches.
- In case of risers being large and cast of oxidation-resisting alloys, powder cutting (in which a stream of iron powder in introduce into oxygen torch flame) is working.

2. Surface cleaning

Surface cleaning includes cleaning of inner and outside surfaces while sand, scale and other adhering materials are mixed up. This kind of cleaning occupy the subsequent procedures:

a. Tumbling

This process is carried out by a barrel similar to machine call tumbling mill, which removes sand, scale and various fins and wires.

b. Blasting

Sand blasting is perform through using coarse sand as abrasive and air as carrying medium. Grit or sand blasting is carried out by throw metallic particle through centrifugal force as of a quickly rotating wheel.

c. Other Surface Cleaning Methods

The follow methods support in surface cleaning:

Various polishing procedures

Wire brushing

Pickling

Buffing

3. Trimming

Trimming involve removal of fins, gate and chaplets, riser pads, wires and other like unwanted appendage to casting which are not a part of its final dimensions.
It involves the follow procedures:

i. Chipping

Chipping is use to eliminate pins, gates and riser pads, wires etc. It can be carried out by hammer and chisel or with pneumatic chipping hammers.

ii. Grinding

Grinding is working to remove excess metal and is carried out, through moveable grinders, stand grinders and swing frame grinders.

4. Finishing

It is afterward stage of cleaning. In definite cases cleaning is whole after trimming process, but others might required extra surface finishing, eg., buffing, machining, polishing etc.

Definition of Casting Defects : It is an unwanted irregularities that appear in the casting during metal casting process. There is various reason or sources which is responsible for the defects in the cast metal. Here in this blog we will discuss all the major types of casting defects. Some of the defects produced may be neglected or tolerated and some are not acceptable, it must be eliminated for better functioning of the parts.

Types

1. **Gas Porosity:** Blowholes, open holes, pinholes
2. **Shrinkage defects:** shrinkage cavity
3. **Mold material defects:** Cut and washes, swell, drops, metal penetration, rat tail
4. **Pouring metal defects:** Cold shut, misrun, slag inclusion
5. **Metallurgical defects:** Hot tears, hot spot.

1. **Shift or Mismatch :** The defect caused due to misalignment of upper and lower part of the casting and misplacement of the core at parting line.

Cause :
(1) Improper alignment of upper and lower part during mold preparation.
(2) Misalignment of flask (a flask is type of tool which is used to contain a mold in metal casting. it may be square, round, rectangular or of any convenient shape.)
Remedies
(i) Proper alignment of the pattern or die part, molding boxes.
(ii) Correct mountings of pattern on pattern plates.
(iii) Check the alignment of flask.

2. Swell :

It is the enlargement of the mold cavity because of the molten metal pressure, which results in localized or overall enlargement of the casting.
Causes
(i) Defective or improper ramming of the mold.
Remedies
(i) The sand should be rammed properly and evenly.

3. Blowholes:

When gases entrapped on the surface of the casting due to solidifying metal, a rounded or oval cavity is formed called as blowholes. These defects are always present in the cope part of the mold.

Causes :

(i) Excessive moisture in the sand.
(ii) Low Permeability of the sand.
(iii) Sand grains are too fine.
(iv) Too hard rammed sand.
(v) Insufficient venting is provided.

Remedies :

(i) The moisture content in the sand must be controlled and kept at desired level.
(ii) High permeability sand should be used.
(iii) Sand of appropriate grain size should be used.
(iv) Sufficient ramming should be done.
(v) Adequate venting facility should be provided.

4. Drop:

Drop defect occurs when there is cracking on the upper surface of the sand and sand pieces fall into the molten metal.

Causes :
(i) Soft ramming and low strength of sand.
(ii) Insufficient fluxing of molten metal. Fluxing means addition of a substance in molten metal to remove impurities. After fluxing the impurities from the molten metal can be easily removed.
(iii) Insufficient reinforcement of sand projections in the cope.

Remedies :
(i) Sand of high strength should be used with proper ramming (neither too hard nor soft).
(ii) There should be proper fluxing of molten metal, so the impurities present in molten metal is removed easily before pouring it into the mold.
(iii) Sufficient reinforcement of the sand projections in the cope.

5. Metal Penetration

These casting defects appear as an uneven and rough surface of the casting. When the size of sand grains is larges, the molten fuses into the sand and solidifies giving us metal penetration defect.

Causes :

(i) It is caused due to low strength, large grain size, high permeability and soft ramming of sand. Because of this the molten metal penetrates in the molding sand and we get rough or uneven casting surface.

Remedies :

(ii) This defect can be eliminated by using high strength, small grain size, low permeability and soft ramming of sand.

6. Pinholes:

They are very small holes of about 2 mm in size which appears on the surface of the casting. This defect happens because of the dissolution of the hydrogen gases in the molten metal. When the molten metal is poured in the mold cavity and as it starts to solidify, the solubility of the hydrogen gas decreases and it starts escaping out the molten metal leaves behind small number of holes called as pinholes.

Causes :

(i) Use of high moisture content sand.
(ii) Absorption of hydrogen or carbon monoxide gas by molten metal.
(iii) Pouring of steel from wet ladles or not sufficiently gasified.

Remedies :

(i) By reducing the moisture content of the molding sand.
(ii) Good fluxing and melting practices should be used.
(iii) Increasing permeability of the sand.
(iv) By doing rapid rate of solidification.

7. Shrinkage Cavity

The formation of cavity in the casting due to volumetric contraction is called as shrinkage cavity.

Causes :

(i) Uneven or uncontrolled solidification of molten metal.

(ii) Pouring temperature is too high.

Remedies :

(i) This defect can be removed by applying principle of directional solidification in mold design.

(ii) Wise use of chills (a chill is an object which is used to promote solidification in a specific portion of a metal casting) and padding.

8. Cold Shut

It is a type of surface defects and a line on the surface can be seen. When the molten metal enters into the mold from two gates and when these two streams of molten metal meet at a junction with low temperatures than they do not fuse with each other and solidifies creating a cold shut (appear as line on the casting). It looks like a crack with round edge.

Causes:

(i) Poor gating system

(ii) Low melting temperature

(iii) Lack of fluidity

Remedies:

(i) Improved gating system.

(ii) Proper pouring temperature.

9. Misrun

When the molten metal solidifies before completely filling the mold cavity and leaves a space in the mold called as misrun.

Causes:

(i) Low fluidity of the molten metal.

(ii) Low temperature of the molten metal which decreases its fluidity.

(iii) Too thin section and improper gating system.

Remedies

(i) Increasing the pouring temperature of the molten metal increases the fluidity.

(ii) Proper gating system

(iii) Too thin section is avoided.

10. Slag Inclusion

This defect is caused when the molten metal containing slag particles is poured in the mold cavity and it gets solidifies.

Causes :

(i) The presence of slag in the molten metal

Remedies :

(i) Remove slag particles form the molten metal before pouring it into the mold cavity.

11. Hot Tears or Hot Cracks

when the metal is hot it is weak and the residual stress (tensile) in the material cause the casting fails as the molten metal cools down. The failure of casting in this case is looks like cracks and called as hot tears or hot cracking.

Causes :

(i) Improper mold design.

Remedies:

(i) Proper mold design can easily eliminate these types of casting defects.

(ii) Elimination of residual stress from the material of the casting.

12. Hot Spot or Hard Spot:

Hot spot defects occur when an area on the casting cools more rapidly than the surrounding materials. Hot spot are areas on the casting which is harder than the surrounding area. It is also called as hard spot.

Causes :

(i) The rapid cooling an area of the casting than the surrounding materials causes this defect.

Remedies :

(i) This defect can be avoided by using proper cooling practice.

(ii) By changing the chemical composition of the metal.