UNIT – I

IT – I

METAL CASTING PROCESSES

Introduction:

Sand Casting : Sand Mould – Type of patterns - Pattern Materials – Pattern allowances – Moulding sand Properties and testing – Cores –Types and applications – Moulding machines– Types and applications; Melting furnaces : Blast and Cupola Furnaces; Principle of special casting processes : Shell - investment – Ceramic mould – Pressure die casting - Centrifugal Casting - CO2 process – Stir casting; Defects in Sand casting

In manufacturing engineering industries, most of the components are made by ferrous and non-ferrous material such as iron, steel, aluminium, copper and so on. The easiest way to manufacturing the complicated shaped components is casting while compare with any other manufacturing method.

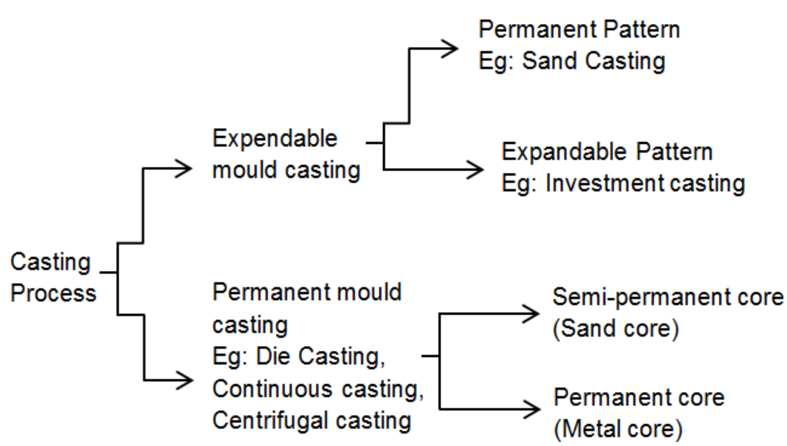
Casting:

The first traces of the Sand Moulding were found during 645 B.C. With technological advances, metal casting is playing a greater role in our everyday lives and is more essential than it has ever been.

Casting is a manufacturing process by which a liquid material is poured into a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting. The flow of molten metal into the mold cavity depends on several factors like minimum section thickness of the part, presence of corners, non-uniform cross-section of the cast, and so on.

The casting processes can be broadly classified into

1. Expendable mold casting
2. Permanent mold casting processes.



Expendable Mold Casting

Expendable mold casting is a generic classification that includes sand, plastic, shell, plaster, and investment (lost-wax technique) molds. All these methods use temporary, non-reusable molds. After the molten metal in the mold cavity solidifies, the mold is broken to take out the solidified cast. Expendable mold casting processes are suitable for very complex shaped parts and materials with high melting point temperature. However, the rate of production is often limited by the time to make mold rather than the casting itself. Following are a few examples of expendable mold casting processes.

Permanent Mold Casting processes

Permanent mold casting processes involve the use of metallic dies that are permanent in nature and can be used repeatedly. The metal molds are also called dies and provide superior surface finish and close tolerance than typical sand molds. The permanent mold casting processes broadly include pressure die casting, squeeze casting, centrifugal casting, and continuous casting.

Sand Casting

Sand casting is widely used for centuries because of the simplicity of the process. The sand casting process involves the following basic steps:

(a) Place a wooden or metallic pattern in sand to create a mold,
(b) Fit in the pattern and sand in a gating system,
(c) Remove the pattern,
(d) Fill the mold cavity with molten metal,
(e) Allow the metal to cool, and
(f) Break the sand mold and remove the casting.

The sand casting process is usually economical for small batch size production. The quality of the sand casting depends on the quality and uniformity of green sand material that is used for making the mold. Figure 1.1 schematically shows a two-part sand mold, also referred to as a cope-and-drag sand mold. The molten metal is poured through the pouring cup and it fills the mold cavity after passing through down sprue, runner and gate. The core refers to loose pieces which are placed inside the mold cavity to create internal holes or open section. The riser serves as a reservoir of excess molten metal that facilitates additional filling of mold cavity to compensate for volumetric shrinkage during solidification.

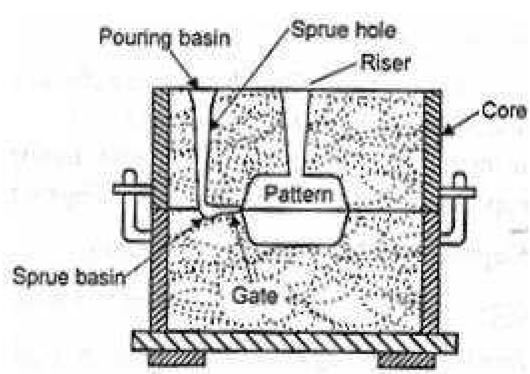


Fig.1.1 Method of sand casting

Advantages of sand castings process.

(a) It can be employed for all types of metal.
(b) The tooling cost is low and
(c) It can be used to cast very complex shapes.

Disadvantages of sand casting

(a) Rough surface.
(b) Poor dimensional accuracy.
(c) High machining tolerances.
(d) Coarse Grain structure.
(e) Limited wall thickness: not higher than 2.5-5 mm.

Pattern

The pattern is the primary tool during the casting process. It is the replica of the object to be made by the casting process, with some modifications. The main modifications are the addition of pattern allowances, and the provision of core prints. If the casting is to be hollow, additional patterns called cores are used to create these cavities in the finished product. The quality of the casting produced depends upon the material of the pattern, its design, and construction. The costs of the pattern and the related equipment are reflected in the cost of the casting.

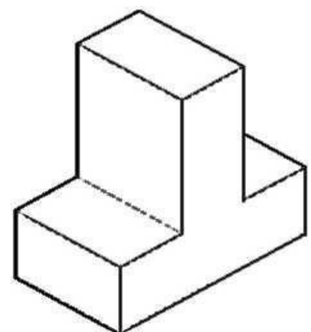


Fig.1.2 Single Piece Pattern or Solid Pattern

Functions of the Pattern

1. A pattern prepares a mold cavity for the purpose of making a casting.
2. A pattern may contain projections known as core prints if the casting requires a core and need to be made hollow.
3. Runner, gates, and risers used for feeding molten metal in the mold cavity may form a part of the pattern.
4. Patterns properly made and having finished and smooth surfaces reduce casting defects.
5. A properly constructed pattern minimizes the overall cost of the castings.

Types of pattern

1. Single piece pattern (or) solid pattern

This is the simplest type of pattern, exactly like the desired casting. For making a mould, the pattern is accommodated either in cope or drag. Used for producing a few large castings, for example, stuffing box of steam engine. Refer Figure 1.2

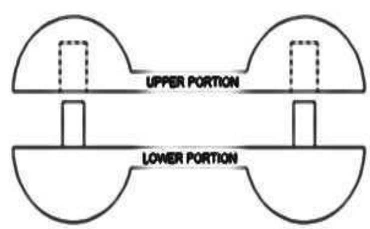


Fig.1.3 Split Pattern

2. Split pattern or Cope and drag pattern

These patterns are split along the parting plane (which may be flat or irregular surface) to facilitate the extraction of the pattern out of the mould before the pouring operation. The two part of the pattern are joined together with the help of dowel pins. For a more complex casting, the pattern may be split in more than two parts. Refer Figure 1.3

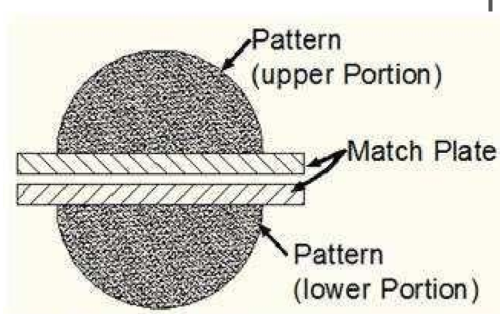


Fig.1.4 Match Plate Pattern

3. Match Plate pattern

A match plate pattern is a split pattern having the cope and drags portions mounted on opposite sides of a plate (usually metallic), called the "match plate" that conforms to the contour of the parting surface. The gates and runners are also mounted on the match plate, so that very little hand work is required. This results in higher productivity. This type of pattern is used for a large number of castings. Several patterns are mounted on one match plate if the size of the casting is small. Generally match plate pattern are used for moulding by moulding machine. Piston rings of I.C. engines are produced by this process. Refer Figure 1.4

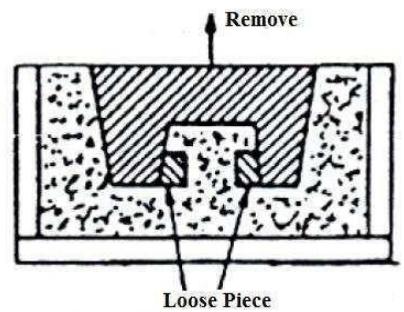


Fig. 1.5 Loose Piece Pattern

4. Loose piece pattern

When a one piece solid pattern has projections or back drafts which lie above or below the parting plane, it is impossible to with draw it from the mould. With such patterns, the projections are made with the help of loose pieces. A loose piece is attached to the main body of the pattern by a pin or with a dovetail slide. While moulding, the sand was rammed properly, then the loose piece was removed. One drawback of loose feces is that their shifting is possible during ramming. Refer Figure 1.5

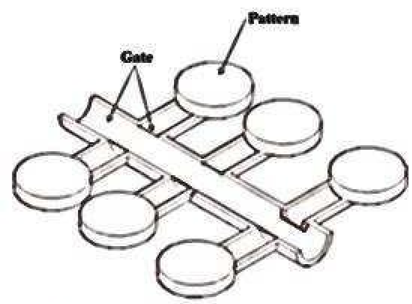


Fig. 1.6 Gated Pattern

5. Gated pattern

A gated pattern is simply one or more loose patterns having attached gates and runners. Because of their higher cost, these patterns are used for producing small castings in mass production systems and on molding machines. Refer Figure 1.6

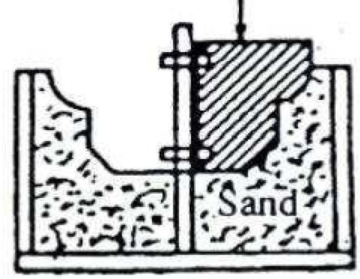


Fig.1.7 Sweep Pattern

6. Sweep pattern

A sweep is a section or board (wooden) of proper contour that is rotated about one edge to shape mould cavities having shapes of rotational symmetry. This type of pattern is used when a casting of large size is to be produced in a short time. Large kettles of C.I. are made by sweep patterns. Refer Figure 1.7

7. Skeleton pattern

For large castings having simple geometrical shapes, skeleton patterns are used. Just like sweep patterns, these are simple wooden frames that outline the shape of the part to be cast and are also used as guides by the molder in the hand shaping of the mould. This type of pattern is also used in pit or floor molding process. Refer Figure 1.8

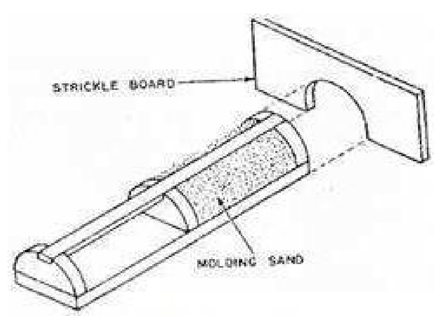


Fig. 1.8 Skeleton Pattern

8. Segmental pattern

Its function is similar to sweep pattern in the sense, that both employ a part of the pattern instead of a complete pattern, for getting the required shape of the mould. The segmental pattern is in the form of a segment, (refer figure 1.9) and is used for making moulding parts having circular shapes. To create the mould, it is rotated about the post in the same way as in sweep pattern, but it is not revolve continuously about the post to prepare the mould. Rather it prepares the mould by parts. When one portion of the mould is completed, the pattern is lifted up and moves to the next portion to make the next segment of the mould. This process is continued until the entire mould is completed. Example of product: Big gears and wheel rims (refer figure 1.9).

9. Shell pattern

It is a hollow pattern. The outer shape is used as mould, the core is placed inside the pattern, and hence it is also named as block pattern. This pattern is made of two half similar to split pattern but only for curved path, joined by dowel pin (refer figure 1.10. Example of product: curved drainage fitting.

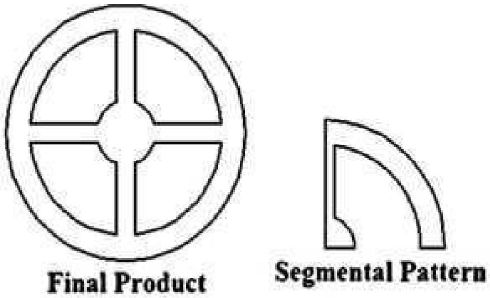


Fig.1.9 Segmental Pattern

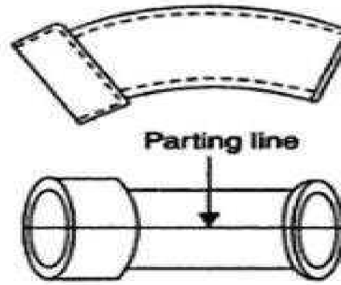


Fig.1.10 Shell Pattern

Pattern Material

Patterns may be constructed from the following materials. Each material has its own advantages, limitations, and field of application. Some materials used for making patterns are: wood, metals and alloys, plastic, plaster of Paris, plastic and rubbers, wax, and resins. To be suitable for use, the pattern material should be:

1. Easily worked, shaped and joined
2. Light in weight
3. Strong, hard and durable
4. Resistant to wear and abrasion
5. Resistant to corrosion, and to chemical reactions
6. Dimensionally stable and unaffected by variations in temperature and humidity
7. Available at low cost

The usual pattern materials are wood, metal, and plastics. The most commonly used pattern material is wood, since it is readily available and of low weight. Also, it can be easily shaped and is relatively cheap. The main disadvantage of wood is its absorption of moisture, which can cause distortion and dimensional changes. Hence, proper seasoning and upkeep of wood is almost a pre-requisite for large-scale use of wood as a pattern material.

Based on the above factor, we can choose the pattern material as follows:

Short run production or piece production : Wood

Large scale and mass production : Metal

Batch Production : Plastic, gypsum and cement

Wood:

Wood is a common material for the preparation for pattern and it should be dried and seasoned. It should not contain more than 10% moisture to avoid warping and distortion during subsequent drying. It should be straight grained and free from knots.

Merits:

1. Light in weight
2. Comparatively inexpensive
3. Good workability
4. Lends itself to gluing and joining
5. Holds well varnishes and paints
6. Can be repaired easily.

Demerits:

1. Non-uniform structure
2. Possess poor wear and abrasion resistance
3. Cannot withstand rough handling
4. Absorbs and gives off moisture

Types of wood

Commonly used material are :

White pine, Mahogany, Maple,

Birch, Cherry Others material

like : teak kail, shisham, deodar

Metal:

A metal pattern can be either cast from master wooden pattern or may be machined by using the usual methods of machining. Metal pattern are widely used for machine moulding. These types of pattern mostly used for large number of casting are to be manufactured.

Merits:

1. More accuracy and durability than wooden material
2. Having smooth surface
3. Mass production is possible
4. Possibility for rough handling
5. Resistance to wear, abrasion and

swelling Types of wood

Demerits:

1. It cannot be easily modified
2. Costlier and heavier than wood
3. Possibility for corrosion
4. Not suitable for piece production

Commonly used material are : cast iron, brass, aluminium, white metal

Gypsum:

Gypsum pattern are capable of producing casting with intricate details and to very close tolerance. There are two main types of gypsum (1) soft – plaster of paris and (2) hard – plaster

Benefits of gypsum material

1. Easily formed
2. Good plasticity
3. Easy to repair

Plastic:

It is also cast from the wooden pattern.

Benefits of plastic material

1. Light in weight compared with wood and metal
2. More economical in cost and labour
3. No moisture absorption
4. Strong and dimensionally stable

5. Highly resistance to corrosion

Types of plastics

Plastic pattern are composition with based on epoxy, phenol formaldehyde and polyester resin. Commonly used material are : poly acrylates, polyethylene, polyvinylchloride

Wax:

Wax pattern are generally used in investment casting. Common materials are paraffin wax, shellac wax and microcrystalline wax.

Benefits of wax material

1. Good surface finish
2. High dimensional accuracy
3. Easy to work
4. Prevent moisture absorption.
5. Low cost

Drawback:

Suitable to small work piece only

Pattern Allowances

Pattern allowance is a vital feature as it affects the dimensional characteristics of the casting. Thus, when the pattern is produced, certain allowances must be given on the sizes specified in the finished component drawing so that a casting with the particular specification can be made. The selection of correct allowances greatly helps to reduce machining costs and avoid rejections. The allowances usually considered on patterns and core boxes are as follows:

1. Shrinkage or contraction allowance
2. Draft or taper allowance
3. Machining or finish allowance
4. Distortion or camber allowance
5. Rapping allowance

Shrinkage or Contraction

All most all cast metals shrink or contract volumetrically on cooling. The metal shrinkage is of two types:

i. **Liquid Shrinkage**: it refers to the reduction in volume when the metal changes from liquid state to solid state at the solidus temperature. To account for this shrinkage; riser, which feed the liquid metal to the casting, are provided in the mold.
ii. **Solid Shrinkage:** it refers to the reduction in volume caused when metal loses temperature in solid state. To account for this, shrinkage allowance is provided on the patterns.

The rate of contraction with temperature is dependent on the material. For example steel contracts to a higher degree compared to aluminum. To compensate the solid shrinkage, a shrink rule must be used in laying out the measurements for the pattern. A shrink rule for cast iron is 1/8 inch longer per foot than a standard rule. If a gear blank of 4 inch in diameter was planned to produce out of cast iron, the shrink rule in measuring it 4 inch would actually measure 4 -1/24 inch, thus compensating for the shrinkage. The various rate of contraction of various materials are given below

C.I., Malleable iron	= 10 mm/m
Brass, Cu, Al	= 15 mm/m
Steel	= 20 mm/m
Zinc, Lead	= 25 mm/m

Machining Allowance

In case the casting designed to be machined, they are cast over-sized in those dimensions shown in the finished working drawings. Where machining is done, the machined part is made extra thick which is called machining allowance.

Machining allowance is given due to the following reasons:

1. Castings get oxidized inside mould and during heat treatment. Scale thus formed requires to be removed.
2. For removing surface roughness, slag, dirt and other imperfections from the casting.
3. For obtaining exact dimensions on the casting.
4. To achieve desired surface finish on the casting.

The dimension of the pattern to be increased because of the extra metal required (i.e. finish or machining allowance) depends upon the following factors:

1. Method of machining used (turning, grinding, boring, etc.). Grinding removes lesser metal than turning.
2. Characteristics of metal (ferrous or non-ferrous, hard and easily machinable or soft). Ferrous metals get oxidised, aluminium does not.
3. Method of casting used. Centrifugal casting requires more allowance on the inner side. Die castings need little machining, sand castings require more.
4. Size and shape of the casting. For long castings, warpage is more and greater allowance is required. Thicker sections solidify late and impurities tend to collect there. This necessitates more machining allowance.
5. Degree of finish required. A higher degree of finishing requires more machining allowance.

The standard machining allowances for different metals and alloys are shown below

Material Cast	Overall length of external surface, cm			
	0 – 30	30 – 60	60 – 105	105 – 150
Al alloys	1.6	3.2	3.0	4.8
Brass, Bronze	1.6	3.2	3.0	4.8
Cast Iron	2.4	3.2	4.8	6.4
C.S	3.2	4.8	6.0	9.6

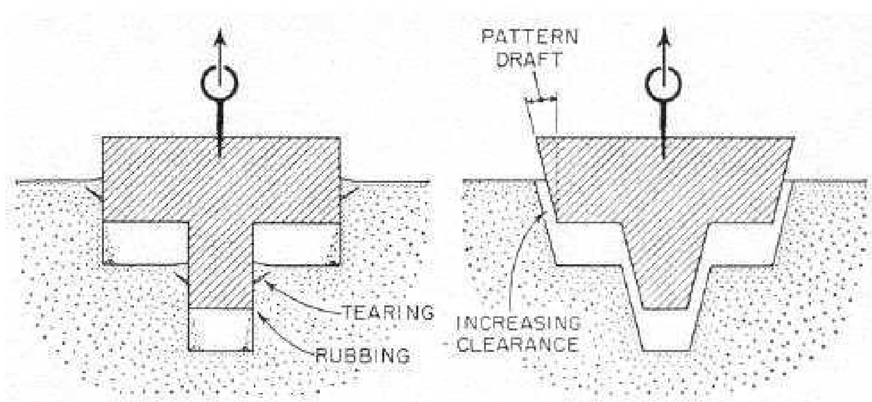
Draft Allowance or Taper Allowance

When a pattern is drawn from a mould, there is always a possibility of damaging the edges of the mould. Draft is taper made on the vertical faces of a pattern to make easier drawing of pattern out of the mould (Fig. 1.3). The draft is expressed in millimeters per metre on a side or in degrees.

The amount of draft needed depends upon (1) the shape of casting, (2) depth of casting, (3) moulding method, and (4) moulding material.

Generally, the size of draft is 5 to 30 mm per metre, or average 20 mm per metre. But draft made sufficiently large, if permissible, will make moulding easier. For precision castings, a draft of about 3 to 6 mm per metre is required.

Table shows different taper allowances used for different moulding methods.



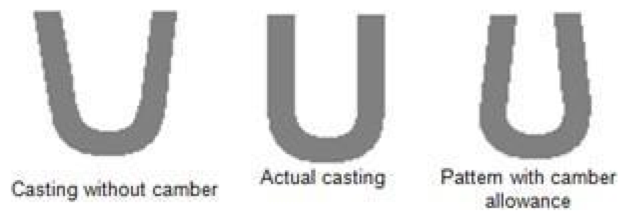
TAPER ALLOWANCES USED FOR DIFFERENT MOULDING METHODS.				
Height of Pattern mm	Shell Moulding	Sand Moulding		
		Metal	Wood	
		Machine drawn	Manual drawn	Machine drawn
Up to 20	0º 45‶	1º 30‶	3º	3º
20 to 50	0º 30‶	1º	1º 30‶	1º 30‶
100 to 200	0º 20‶	0º 30‶	0º 45‶	0º 45‶

Rapping or Shaking Allowance

When the pattern is shaken for easy withdrawal, the mould cavity, hence the casting is slightly increased in size. In order to compensate for this increase, the pattern should be initially made slightly smaller. For small and medium sized castings, this allowance can be ignored. But for large sized and precision castings, however, shaking allowance is to be considered. The amount of this allowance is given based on previous experience.

Distortion or Camber Allowance

Sometimes castings, because of their size, shape and type of metal, tend to warp or distort during the cooling period depending on the cooling speed. This is due to the uneven shrinkage of different parts of the casting. Expecting the amount of warpage, a pattern may be made with allowance of warpage. It is called camber. For example, a U-shaped casting will be distorted during cooling with the legs diverging, instead of parallel (Fig. 1.4). For compensating this warpage, the pattern is made with the legs converged but, as the casting cools, the legs straighten and remain parallel.



TYPICAL DISTORTION ALLOWANCE.							
Length in MM		3000			6000		
Wall Thickness in MM		12	25	50	12	25	50
Distorsion allowance for depth, in MM	450	12	8	3	27	20	50
	600	7.5	5	2	18	12.5	5

Moulding material

In foundry, various types of materials are playing a vital role in the manufacturing of casting product. These are grouped in to two categories: (1) Basic and (2) Auxiliary

Basic moulding materials includes silica sands, which forms the base and the various binders

Auxiliary groups include various additives which impart desired properties to the moulding and core sand.

The essential constitutions of a moulding sand are: Silica sand, Binder, Additives and water

Silica sand is widely used moulding material it has 80 to 90 % of silicon dioxide also gives refractoriness to the sand. A typical mixture by volume could be 89% sand, 4% water, 7% clay. Control of all aspects of the properties of sand is crucial.

It has the following advantage.

1. Cheap, plentiful and easily available
2. High softening temperature and thermal stability
3. Easily moulded, reusable and capable of giving good

Binder: In sand casting, the sand must contain some type of binder that acts to hold the sand particles together. Clay serves an essential purpose in the sand casting manufacturing process, as a binding agent to adhere the molding sand together. In manufacturing industry other agents may be used to bond the molding sand together in place of clay.

Additives: Additives impart to the moulding sand special properties (strength, thermal stability, permeability, refractoriness, thermal expansion etc….)

Sand: based on the amount of clayey content, they contain. The moulding sands are classified as follows:

1	Silica sand	Upto 2% clay
2	Lean or weak sand	2 to 10% clay
3	Moderately strong sand	10 to 20% clay
4	Strong sand	Upto 30% clay
5	Extra strong sand (loam sand)	Upto 50% clay

There are three types of sand

1. Natural sand
2. Synthetic sand
3. Chemically coated sand

Naturally Bonded- Naturally bonded sand is less expensive but it includes organic impurities that reduce the fusion temperature of the sand mixture for the casting, lower the binding strength, and require higher moisture content.

Synthetic Sand- Synthetic sand is mixed in a manufacturing lab starting with a pure (SiO2) sand base. In this case, the composition can be controlled more accurately, which imparts the casting sand mixture with higher green strength, more permeability, and greater refractory strength. For these reasons, synthetic sand is mostly preferred in sand casting manufacture.

Chemically coated sand: clean silica grains are sometimes coated with a non-thermosetting hydrocarbon resin, which act as a binder. An additional binder in the form of clay can also be used. The advantage of this sand is that the carbon in the resin which is an excellent refractory surrounds the sand grains and does not allow the molten metal to reach the sand grains. This produces casting with clean surface as the sand does not get fused in them. The moisture content in this sand is kept to above 3%

1. **Olivine Sand** : This sand is complex mix of ortho-silicates of Iron and Magnesium (Mg_2SiO_4: Fosterite, Fe_2SiO_4:Fayalite). This is prepared from the mineral Dunite. Olivine sand does not contain free-silica. And hence does not react with basic metals.

   It has a melting point of 1800°C.

2. **Chromite Sand** : It is a solid solution of complex metallic oxides having spinel structure. It has low silica content and exhibits very good thermal conductivity. In India availability of this sand is limited. In Odisha however, Chromite deposits are there. Chromite sand is produced by crushing Chromite ore.

   Typical composition is: Cr_2O_3: 44%, Fe_2O_3: 28%, SiO_2: 2.5%, CaO:

0.5%, Al_2O_3+MgO: 25%

3. **Zircon Sand:** : It is a combination of Zirconia (ZrO_2) 67% and Silica (SiO_2) 33%. The specific gravity is twice that of silica sand. It has a very high melting point of 2600 °C and a low coefficient of thermal expansion: 0.25% at 900 °C. Due to excellent quality and limited availability, it costs six times that of Silica sand. Supply is restricted by BARC due to the use of zirconia in nuclear applications. In India it is available in the Quilon beaches of Kerala and Gopalpur beaches of Odisha.

Typical composition of Quilon sand is: ZrO_2: 66.25%, SiO_2: 30.96%, Al_2O_3: 1.92%, Fe_2O_3: 0.74%

Zircon sand is used as wash and facing sand in casting. It is also used in precision castings.

4. **Chamotte Sand:** : These are obtained by calcining Al_2O_3-SiO_2 above 1100 °C. Chamotte sand has a melting point of 1750 °C and a coefficient of thermal expansion 0.5% at 900 °C. It has a very coarse grain size. Hence it is used in heavy castings (especially steel).

Moulding sand has maximum strength at maximum moisture content of 4% for lean sands and of 6 to 7 % for loam sands.

A typical green sand moulding sand for gray iron moulding are given as

below Silica sand = 68 to 86%

Clay = 10 to 20%

Water = 3 to 6%

Additives = 1 to 6%

Binder:

In sand casting, binders are used to hold the sand particles together. There are two types" namely (1) organic binder and (2) inorganic binder. Among these two organic binders are mainly used for core baking.

Clay binders are the most common inorganic binders. Clay are formed by the weathering and decomposition of rocks. The common types of clay used in moulding sand are: Fireclay, Kaolinite, Illite and Bentonite. Kaolinite and Bentonite clays are most popular, because they have high thermochemical stability.

Fire-clay : It is a refractory clay usually found in the coal measures

Kaolinite : It is one of the decomposition products of the slow weathering of the granite and basalt (a kind of black rock). It is the main constituent of china fire clay. Its melting point is 1750 to 1787ºC

Its general composition is Al_2O_3 $2SiO_2$ $2H_2O$

Illite : It is formed from the weathering of mica rocks. Its particle size is about the same as the kaolinite clay and has similar moulding properties

Its general composition is K_2O Al_2O_3 SiO_2 H_2O

Bentonite : It is formed from the weathering of volcanic or igneous rocks. It is creamy white powder. Its melting point is 1250 to 1300ºC

Its general composition is M_gO Al_2O_3 SiO_2 H_2O

The basic constituent which gives refractoriness to a clay is alumina, Al_2O_3 of all clays, bentonite is the most commonly used clay. It needs smaller amount of water to obtain a given degree of plasticity.

Other binders can be: Portland cement and sodium silicate.

The percentage of binder in the moulding sand is of great importance. The bond must be strong enough to with stand the pressure of and erosion by the melt; however the bond must not destroy the permeability of the sand so that the gases present in the melt can be escape.

Organic binder: these binders are mostly used for making core. Cereals binders are obtained from wheat corn or rye. Resin, drying oil for example linseed oil, fish oil, soyabean oil, and some mineral oils: pitch and molasses

Additives:

Additives are added to the moulding sand to improve the properties like refractoriness, permeability and strength of the moulding sand. These are helps to give good surface finish. Additives are not for binding purpose. There are various additives to meet the good surface finish. They are:

Sea coal: It is also named as coal dust. It tends to obtained smoother and cleaner surfaces of casting and also reduces the adherence of sand particles to the casting. It also increases the strength of the moulding sand. It is added upto 8% and also improves the permeability of the moulding sand.

Saw dust: It improves the permeability and deformability of the mould and cores. It must be dry. Instead of saw dust, Peat (fertilizer) having 70-73% of volatile (i.e. explosive) substances, not over 5 - 6% ash and 25 - 30% moisture can also be used.

Cereals: It is finely ground corn flour or corn starch. It increases the strength of the moulding sand by 0.25 - 2%. It is added about 1% with the moulding sand.

Wood flour: About 1% is added. It is ground wood particles or other cellulose materials such as grain hulls. They serve the same purpose as cereals except that they do not increase strength as like cereals

Silica flour: It is very fine powder. It is generally mixed with about twice as much conventional moulding sand to make facing sand. It is applied around the pattern. Because of its purity, it improves the strength and surface finish. It also resists metal penetration and minimizes sand expansion defects.

Special additives:

Fuel oil : It improves the mouldability of the

sand Iron oxide : It develops hot strength.

Dextrin : It increases the toughness and collapsibility and prevents sand from rapid drying.

Molasses : It is the by - product of sugar industry. It imparts high dry strength and collapsibility to mould and cores.

Moulding sand:

There are various types of moulding sand:

1. Green sand : It is composed of a mixture of silica sand (68 - 86%), clay (16 - 30%) and water (5 - 8%). The word "green" is associated with the condition of wetness or freshness. Hence in named as green sand
2. Dry sand : It is basically green sand. But mixed with 1 to 2% of cereals and 1 to 2 % of peat are added additives with the green sand also dried at 110 to 260ºC for several hours. It is used for making large casting. It has greater strength and rigidity.
3. Facing sand : This sand is directly cover the surface of the pattern and provides a smoother casting surface and should be of fine texture. It is made of silica sand and clay. The layer of the facing sand in the mould usually ranges from 25 to 50mm.
4. Backing sand : This is the sand which is used to back up the facing sand and to fill the whole volume of the flask. The old sand may be repeatedly used for this purpose.
5. System sand : In mechanized foundries, where machine moulding is employed a so called system sand is used to fill the whole flask. Because of this, the system sand must have the higher strength, permeability and refractoriness than the backing sand.
6. Parting sand : Parting sand is usually applied on the pattern surface, to avoid its sticking and permit its easy withdrawal from the mould, when the pattern is made of two half with cope and drag.

   Dry parting material : charcoal, limestone, groundnut shell, talc and calcium sulphate

   Wet parting material : wax based preparation, petroleum jelly mixed with oil, paraffin and stearic acid

7. Loam sand It consists of fine sand plus finely ground refractories, clay, graphite and fibrous reinforcements. In this sand percentage of clay is in the order of 50%. It is used in pit moulding process for making mould for very heavy and large parts (engine body, machine tool bed and so on ….).

Moulding sand properties:

The quality of the casting product is mainly depends on the quality of the moulding sand.

Moulding sand is must have the following requirements:

1. It should be able to retain and reproduce the details as imparted by the pattern.
2. It should be able to retain the bulk structure.
3. It should not be too much sticky either to the pattern or to the casting.

4. It should prevent reaction with the liquid metal.
5. It should let the casting cool at an optimum rate so as to develop desired microstructure.

To achieve the above requirement, the moulding sand must have the following properties

1. Permeability or porosity
2. Plasticity or flowability
3. Adhesiveness
4. Cohesiveness or strength
5. Refractoriness
6. Collapsibility

Permeability: During pouring and subsequent solidification of a casting, a large amount of gases and steam is generated. These gases are those that have been absorbed by the metal during melting, air absorbed from the atmosphere and the steam generated by the molding and core sand. If these gases are not allowed to escape from the mold, they would be entrapped inside the casting and cause casting defects. To overcome this problem the molding material must be porous. Proper venting of the mold also helps in escaping the gases that are generated inside the mold cavity.

Flowability: It is the measure of the moulding sand to flow around and over a pattern during ramming and to uniform fill the flask. This property may be enhanced by adding clay and water to the silica sand.

Adhesiveness: This is the property of the sand mixture to adhere to another body. The moulding sand should cling to the sides of the moulding boxes so that it does not fall out when the flasks are lifted and turned over. This property depends on the type and amount of binder used in the sand mix.

Cohesiveness:
Green Strength: The molding sand that contains moisture is termed as green sand. The green sand particles must have the ability to cling to each other to impart sufficient strength to the mold. The green sand must have enough strength so that the constructed mold retains its shape.

Dry Strength: When the molten metal is poured in the mold, the sand around the mold cavity is quickly converted into dry sand as the moisture in the sand evaporates due to the heat of the molten metal. At this stage the molding sand must possess the sufficient strength to retain the exact shape of the mold cavity and at the same time it must be able to withstand the metallostatic pressure of the liquid material.

Hot Strength: As soon as the moisture is eliminated, the sand would reach at a high temperature when the metal in the mold is still in liquid state. The strength of the sand that is required to hold the shape of the cavity is called hot strength.

Refractoriness: It is the ability of the molding material to resist the temperature of the liquid metal to be poured so that it does not get fused with the metal. The refractoriness of the silica sand is highest.

Collapsibility: The molding sand should also have collapsibility so that during the contraction of the solidified casting it does not provide any resistance, which may result in cracks in the castings. Besides these specific properties the molding material should be cheap, reusable and should have good thermal conductivity.

SAND TESTING

1. Molding sand and core sand depend upon shape, size composition and distribution of sand grains, amount of clay, moisture and additives.
2. The increase in demand for good surface finish and higher accuracy in castings necessitates certainty in the quality of mold and core sands.
3. Sand testing often allows the use of less expensive local sands. It also ensures reliable sand mixing and enables a utilization of the inherent properties of molding sand.

4. Sand testing on delivery will immediately detect any variation from the standard quality, and adjustment of the sand mixture to specific requirements so that the casting defects can be minimized.

Generally the following tests are performed to judge the molding and casting characteristics of foundry sands:

1. Moisture content Test
2. Clay content Test
3. Fineness test
4. Refractoriness of sand
5. Strength Test
6. Permeability Test
7. Flowability Test
8. Mould hardness Test.

Moisture Content Test

The moisture content of the molding sand mixture may determine by difference in weight of moist sand and dry sand.

1. Measurement by evaporation method:
   - Sample of moulding sand weighing about 20 to 50 grams are allowed to heat at a constant temperature up to 100°C in an oven for about one hour.
   - It is then cooled to a room temperature and then reweighing the molding sand.
   - The moisture content in molding sand is thus evaporated.
   - The loss in weight of molding sand due to loss of moisture, gives the amount of moisture which can be expressed as a percentage of the original sand sample.

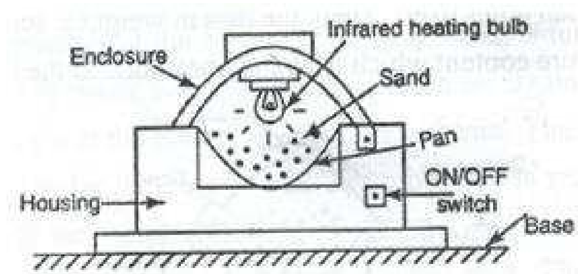


Fig.1.11 Evaporation method

2. Measurement by moisture teller method:
   - Sample of moulding sand placed in teller pan having 600 mesh screens at bottom. Hot air allows blowing over the moulding sand about 3 – 6 minute, now the moisture present in the moulding sand is removed. Once the moisture is removed, weighing the sample and find the deviation in weight of sample before and after placing in the teller pan. This method was quite faster than the evaporation method.

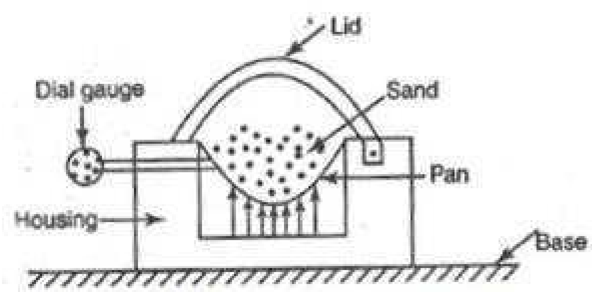


Fig.1.12 Moisture teller test

3. Measurement by moisture teller chemical reaction method:
   - This based worked on the principle that when water and calcium carbide react, they form acetylene gas which can be measured and this will be directly proportional to the moisture content.
   - Sample of moulding sand is placed in teller pan along with calcium carbide (CaC_2). This reaction will produce C_2H_2

$$CaC_2 + 2H_2O \longrightarrow C_2H_2 + Ca(OH)_2$$

   - The amount of C_2H_2 produced is directly proportional to the moisture content in the moulding sand.

- This instrument is provided with a pressure gauge calibrated to read directly the percentage of moisture present in the molding sand.

Clay Content Test

- The sample of molding sand weighing about 50 grams is mixed with water and 1% NaOH and allows stirring for 4-7 minute, and then waiting for 10-15 minute for sedimentation. Now the sand was settling down. The dirty water is present at the top portion of the pan
- The above process is repeated until to achieve clean water at the top portion of the pan. The water is drained off.
- The sand is dried and weighted. The loss of weight gives the clay content.

Refractoriness Test

- The refractoriness of the molding sand is judged by heating the A.F.S standard sand specimen to very high temperatures ranges depending upon the type of sand.
- The heated sand test pieces are cooled to room temperature and examined under a microscope for surface characteristics or by scratching it with a steel needle.
- If the silica sand grains remain sharply defined and easily give way to the needle. Sintering has not yet set in.
- In the actual experiment the sand specimen in a porcelain boat is placed into an electric furnace. It is usual practice to start the test from l000°C and raise the temperature in steps of 100°C to 1300°C and in steps of 50° above 1300°C till sintering of the silica sand grains takes place.
- At each temperature level, it is kept for at least three minutes and then taken out from the oven for examination under a microscope for evaluating surface characteristics or by scratching it with a steel needle.

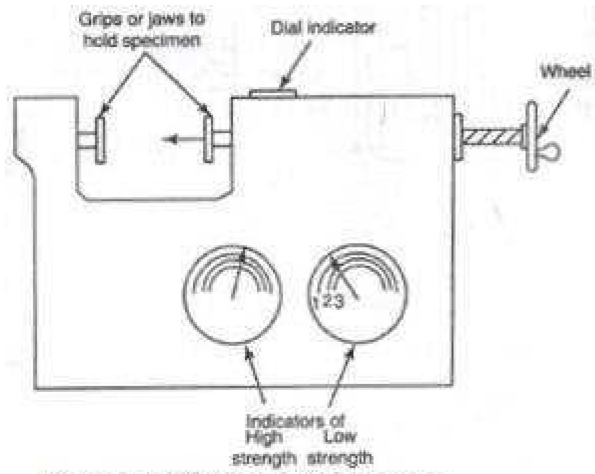


Fig.1.14 Strength Tester

Grain Fineness Test

- GFN is a measure of the average size of the particles (or grains) in a sand sample. The grain fineness of molding sand is measured using a test called sieve analysis.
- The test is carried out in power-driven shaker consisting of number of sieves fitted one over the other.
  i. A representative sample of the sand is dried and weighed, then passed through a series of progressively finer sieves (screens) while they are agitated and tapped for a 15-minute test cycle. The series are placed in order of fineness from top to bottom.
  ii. The sand retained on each sieve (grains that are too large to pass through) is then weighed and recorded.
  iii. The weight retained on each sieve is carried out through calculations to get the AFS-GFN.

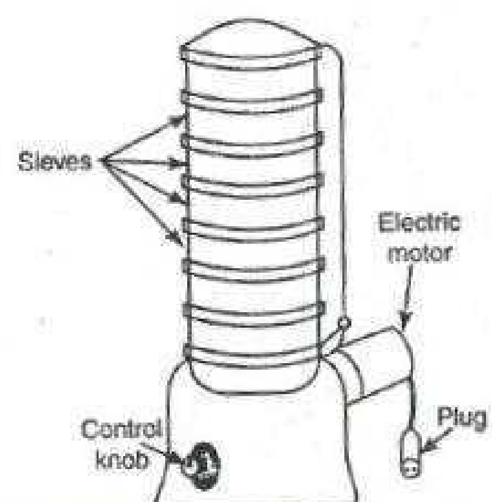


Fig. 1.13 Grain finess tester

*AFS = American Foundrymens's Society

Sieve Number	6	12	20	30	40	50	70	100	140	200	270	Pan
Weightage factor	3	5	10	20	30	40	50	70	100	140	200	300

Example: weight retained on each sieve is given as: 0.5, 1.0, 1.5, 2.0, 2.5, 4.5, 10, 15, 7.5, 3.5, 1.5, and 0.5

Sieve Number	Retained sample (g) Fi	Retained percentage (Pi)	Weightage factor (Wi)	WiFi	WiPi
6	0.5	1	3	1.5	3
12	1.0	2	5	5.0	10
20	1.5	3	10	15.0	30
30	2.0	4	20	40	80
40	2.5	5	30	75	150
50	4.5	9	40	180	360
70	10	20	50	500	1000
100	15	30	70	1050	2100
140	7.5	15	100	750	1500
200	3.5	7	140	490	980
270	1.5	3	200	300	600
Pan	0.5	1	300	150	300
	∑ = 50	**∑ = 100**		**∑ = 3556.5**	**∑ = 7113**

$$\therefore GFN = \frac{3556.5}{50} = 71.13 \quad (or) \quad \frac{7113}{100} = 71.13$$

Strength Test

- This is the strength of tempered sand expressed by its ability to hold a mold in shape. Sand molds are subjected to compressive, tensile, shearing, and bending stresses.
- The green compressive strength test and dry compressive strength is the most used test in the foundry.

Compression tests

a. A rammed specimen of tempered molding sand is produced that is 2 inches in diameter and 2 inches in height.
b. The rammed sample is then subjected to a load which is gradually increased until the sample breaks.
c. The point where the sample breaks is taken as the compression strength.

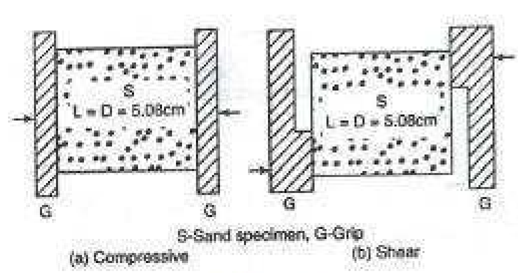


Fig.1.15

Shear tests

a. The compressive loading system is modified to provide offset loading of the specimen.
b. Under most conditions the results of shear tests have been shown to be closely related to those of compression tests, although the latter property increases proportionately more at high ramming densities.

Tensile test

a. A special waisted specimen is loaded in tension through a pair of grips.

Bending test

1. A plain rectangular specimen is supported on knife edges at the ends and centrally loaded to fracture.

Permeability Test

- Permeability of the moulding sand is determined by measuring the rate of flow of air through a compacted specimen under standard conditions. It is measured in terms of permeability number.
- A sample of moulding sand is placed in a tube. Time taken for 2000 CM^3 of air at a pressure of 10 g/cm^2 to pass through the specimen is noted
- Permeability meter consisting of the balanced tank, water tank, nozzle, adjusting lever, nose piece for fixing sand specimen and a manometer. The permeability is directly measured.
- Permeability number P is volume of air (in cm^3) passing through a sand specimen of 1 cm^2 cross-sectional area and 1 cm height, at a pressure difference of 1 gm/cm^2 in one minute.

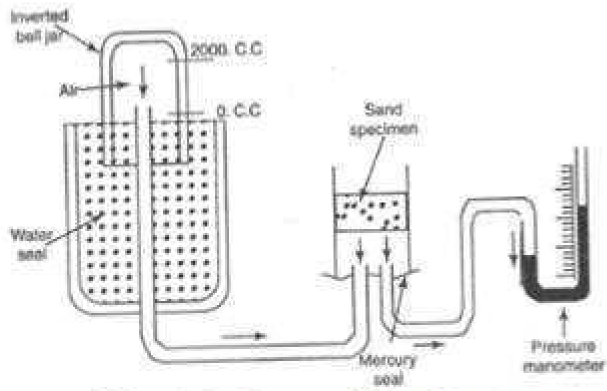


Fig. 1.16 Permeability Tester

$$P = \frac{Vh}{atp}$$

Where, P = permeability

v = volume of air passing through the specimen in c.c.
h = height of specimen in cm
p = pressure of air in gm/cm^2
a = cross-sectional area of the specimen in cm^2
t = time in minutes.

Mold Hardness Test

- This test is performed by a mold hardness tester.
- The working of the tester is based on the principle of Brinell hardness testing machine.
- In an A.F.S. standard hardness tester a half inch diameter steel hemi-spherical ball is loaded with a spring load of 980 gm.
- This ball is made to penetrate into the mold sand or core sand surface.
- The penetration of the ball point into the mold surface is indicated on a dial in thousands of an inch.
- The dial is calibrated to read the hardness directly i.e. a mold surface which offers no resistance to the steel ball would have zero hardness value and a mold which is more rigid and is capable of completely preventing the steel ball from penetrating would have a hardness value of 100.
- The dial gauge of the hardness tester may provide direct readings

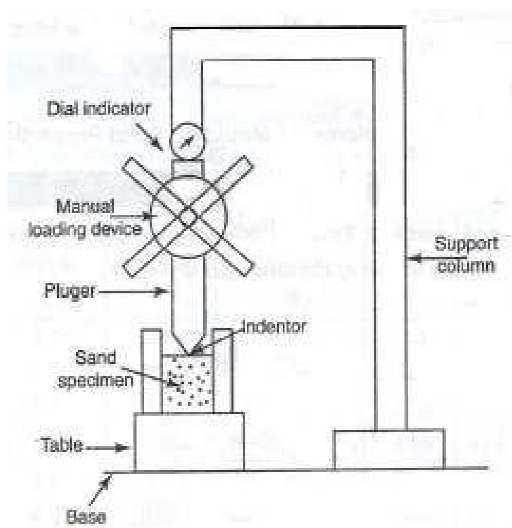


Fig. 1. 17 Mould Hardness Tester

Compatibility and flowability

- The compatibility test is widely accepted as both simple to perform and directly related to the behavior of sand in molding, particularly when involving squeeze compaction.
- A fixed volume of loose sand is compacted under standard conditions and the percentage reduction in volume represents the compatibility.

CORES

A core is a body made of refractory material, which is used for making cavity or a hole in casting. Its shape is similar to the required cavity in the casting. It is also used for making recess, projections, undercuts and internal cavities.

Core Print is a projection provided on the casting product. It forms a seat in the mould.

There are seven requirements for core:

1. Green Strength: In the green condition there must be adequate strength for handling.
2. In the hardened state it must be strong enough to handle the forces of casting; therefore the compression strength should be 100 to 300 psi.
3. Permeability must be very high to allow for the escape of gases.
4. Friability: As the casting or molding cools the core must be weak enough to break down as the material shrinks. Moreover, they must be easy to remove during shakeout.
5. Good refractoriness is required as the core is usually surrounded by hot metal during casting or molding.
6. A smooth surface finish.
7. Minimum generation of gases during metal pouring.

Purpose of cores:

1. It may form a part of green sand mould
2. Cores may be employed to improve the mould surface.
3. It helps to strengthen the mould.
4. Cores may be used to form the gating system of large size mould.
5. It acts as an internal cavity for hollow casting.

Core making material:

Core sand	:	It consists of refractory material such as silica sand, zircon, olivine, carbon and chamotte sand
Binder	:	Vegetable oil or mineral oil, core flour, resin water, fire clay bentonite, urea
Additives	:	Wood flour, coal powder, cow dung, straw and so on…

Core binder:

1. To bind the sand grains together
2. To give strength and hardness
3. To prevent breaking
4. To give collapsibility to core
5. To prevent moisture absorption.

Other binders:

Oil binders : 1. It is commonly used binder.
2. Linseed is the example of this oil binder.
3. 0.5 to 3% is added depends on the hardness and other properties

Water soluble binder : 1. Dextrin starch are example of water soluble binder
2. It gets hardened at 180 . Its mixing ratio is 1:8.
3. It gives green strength and edge hardness to the core

Resin binder : 1. Phenol formaldehyde and urea are example for resin binder.
2. It gives hardness at 200 .
3. It gives good strength and short time to bake and less gas will be formed.

Inorganic binder : 1. Fire clay, silica flour, kerosene etc…are the example;
2. They are used in the powder form.
3. It develops greater strength and gives smooth surface.

Types of core boxes

Half core box : It is used to form semicircular core (refer figure 1.18). After baking, if needed, the two core pieces will pasted together to form the complete core

Dump core box : This type is helpful for making complete core in polygon size like square, rectangle and so on.. (Refer figure 1.19)

Split core box : This is similar to half core box, but it has two half and it must connect by dowel pin on either side of box. After preparation, box are separated (Refer figure 1.20)

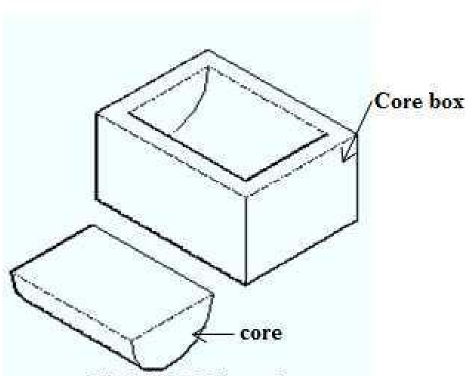


Fig.1.18 Half core box

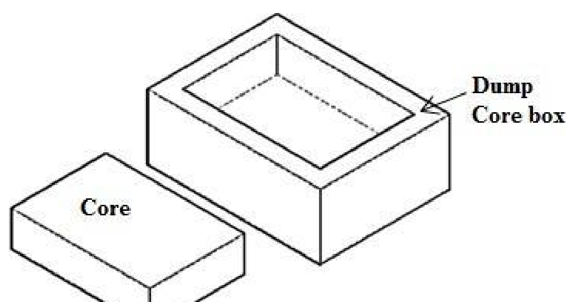


Fig.1.19 Dump Core box

Gang core box	**:**	During manufacturing, sometimes, we need an „n" number of cores. In that occasion, we can go for gang core box instead of any other single core box (Refer figure 1.21).
Left and right core box	**:**	For the preparation of curved core, the manufacturer can opt for left and right hand core box is best option for easiest preparation of core (Refer figure 1.22)
Strickle core box	**:**	To make an irregular shaped core, the strickle core box will fulfill the need of the manufacturer. Here, box will fill with required sand and rammed properly by using strickle board (Refer figure 1.23).

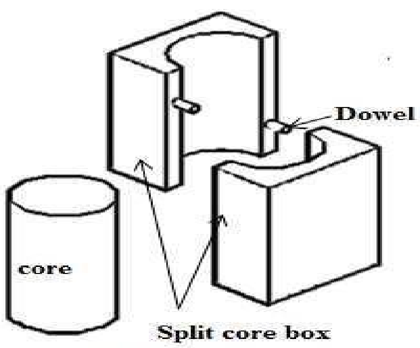


Fig. 1.20 Split core box

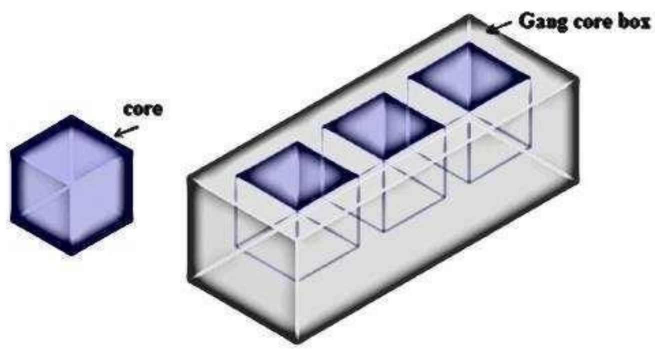


Fig. 1.21 Gang Core box

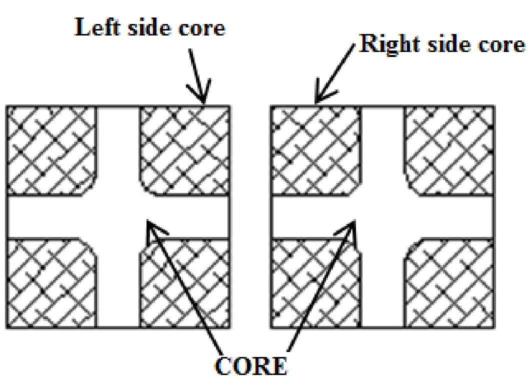


Fig.1.22 Left Hand and Right Hand core box

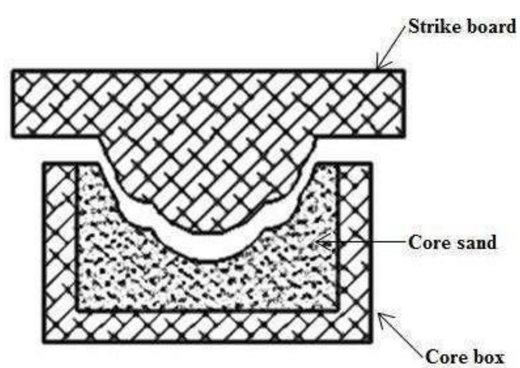
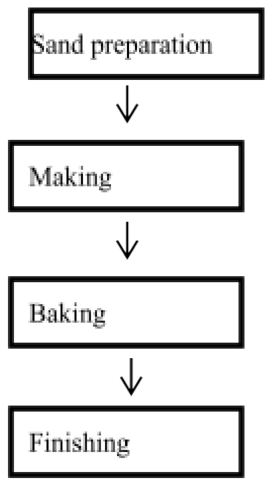


Fig. 1.23 Strike core box

Core making process:

The core may be manufactured either by manual or machine based on needed. The chart shown here are the important steps for making core.



Sand preparation:

Sands are mixed properly to meet the requirement with the help of any one of the following mechanical means.

1. Roller mills
2. Core sand mixer
   a. Vertical revolving arm type.
   b. Horizontal paddle type.

In the case of roller mills, the rolling action of the mullers along with the turning over action caused by the ploughs gives a uniform and homogeneous mixture.

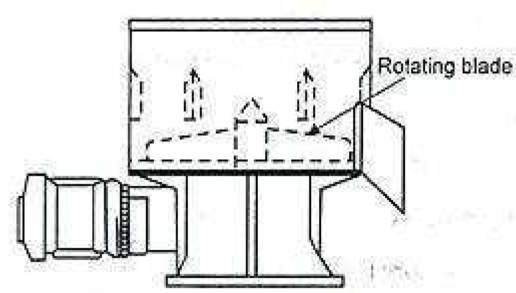


Fig.1.24 Core sand Mixer

Core making machine: It is broadly classified as follows.

- Core blowing machine
- Core ramming machine
- Core drawing machine
- Core extrusion machine

Core blowing machines:

The basic principle of core blowing consists of filling core sand into the core box by using the medium of compressed air. The velocity of the compressed air is kept high to obtain a *high* velocity of sand particles, thus ensuring their deposit in the remote comers of the core box. As the sand with high kinetic energy comes, the shaping and ramming is done simultaneously in the core box.

The core blowing machines can be classified into two basic groups.

Small bench blowers

Large floor blowers

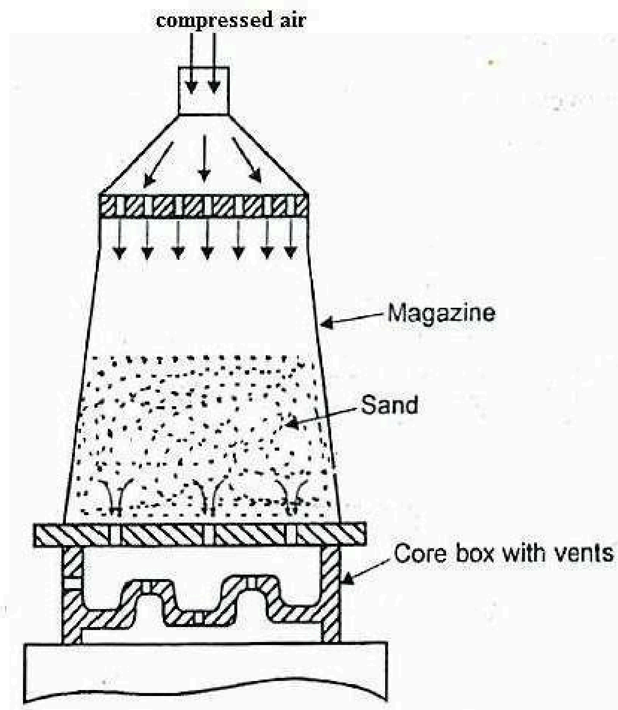


Fig.1.25 Core Blowing Machine

Core ramming machines:

Cores can also be prepared by ramming core sands in the core boxes by machines based on the following principles.

Jolting

Squeezing

Slinging

Out of these three, machines based on jolting and slinging are more commonly used for core making.

Core drawing machines:

The core drawing is preferred when the core boxes have deep draws. After ramming sand in it, the core box is placed on a core plate supported on the machine bed. A rapping action on the core box is produced by a vibrating vertical plate. This rapping action helps in drawing off the core box from the core. After rapping the box is raised leaving the core on the core plate.

Core extrusion machine:

Simple cores of regular shape uniform cross-section can be extruded easily on a core extrusion machine. Cores of square, round, hexagonal and over sections are produced made rapidly on a core extrusion machine. A core extrusion machine has a hopper through which the core sand is fed to a horizontal spiral conveyor (situated below the hopper). As the spiral conveyor is rotated. It forces core and through a die of specified shape (square, round, etc.). Long cores thus produced can be cut to the desired length.

Core baking

Cores are baked to remove the moisture and to develop the strength the strength of the binder in care ovens. The cores are dried in ovens equipped with drawers, shelves or other holding devices. They are dried in batches or continuously over moving shelves. The heat in oven is produced by burning oil or core or by electric resistance. The core drying time depends upon the quantity of moisture and binder used in the sand size of the core and temperature of the oven. According to the type of production, the core drying ovens or core baking ovens are classified as

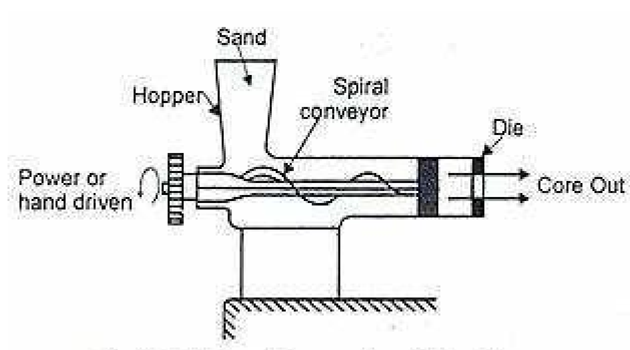


Fig.1.26 Core Extrusion Machine

Batch type

Continuous type

Dielectrically heated type

Batch type ovens

These make use of portable racks. The racks loaded with cores are transported by lift trucks or mono-rail conveyors to the oven. Large cores are moved directly into the oven by rail. The racks are admitted into the oven either through two doors which swing open on hinges or through a single sliding door of counter balanced type.

Continuous type ovens

In this type oven the core racks move slowly through the oven on a continuous rail or chain. The loading and unloading are continuous. The baking time is controlled by the rate of travel of the conveyor.

The temperatures of the various parts of the oven and the conveyor speed are coordinated in such a way that the core comes out from the oven not only baked but also cooled. In some of the designs, for saving the floor space, the cores move vertically upwards through the oven and get baked. They get cooled on their return trip downwards.

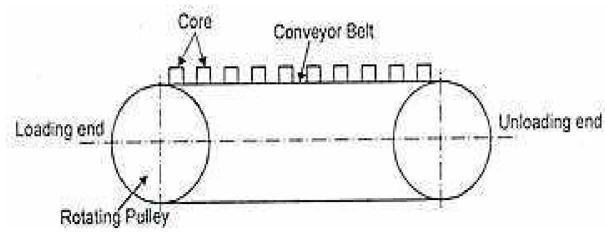


Fig.1.27 Continuous type oven

Dielectrically heated type

These are modem core ovens employed for high quality cores using plastic binders. The cores to be heated dielectrically are placed between the parallel plates or electrodes and a very high frequency current is passed. This high frequency current tends to deform the sand molecules. The sand molecules resist the deformation and required heating effect is produced. In core ovens proper temperature control is necessary for maintaining the most effective temperature.

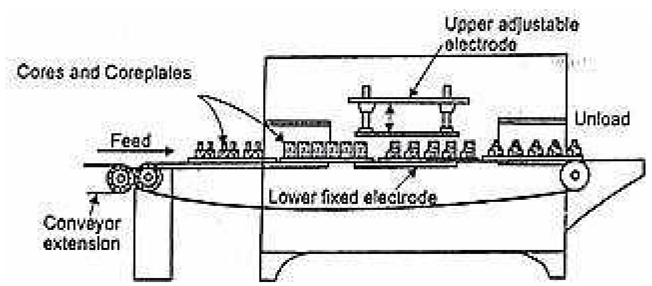


Fig.1.28 Di - electrically heated oven

Core finishing

After baking, the cores are given certain finishing operations 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. Cores are also coated with refractory or protective materials to improve their refractoriness and surface finish.

Types of cores

There are many types of cores available. The selection of the correct type of core depends on production quantity, production rate, required precision, required surface finish, and the type of metal being used.

For example, certain metals are sensitive to gases that are given off by certain types of core sands; other metals have too low of a melting point to properly break down the binder for removal during the shakeout.

The cores as classified as follows.

a. *According to the shape and position of the core*
- Horizontal core
- Vertical core
- Hanging or cover core
- Balanced core
- Drop core or Stop off core
- Ram up core
- Kiss core

b. *According to the State or condition of Core*
- Green sand core
- Dry sand core
- Sodium silicate cores

c. *According to the type of core-hardening process employed*
- C02-process
- The hot box process
- The cold set process
- Fluid (or) Castable sand process
- Nishiyama process.
- Furan No-Bake system
- Oil-No-Bake Process

The horizontal and vertical cores are used in foundry work frequently. A horizontal core is placed horizontally in the mould. The ends of the core rest in the seats provided by core prints on the pattern.

A vertical core is placed vertically in the mould. The upper end of the core is forced in the cope and the lower end in the drag.

A balanced core is used when the casting has opening only on one side and only one core print is available on the pattern. It extends horizontally in the mould cavity.

A cover core extends vertically downwards. It is suspended from the top of the mould

A hanging core hangs from the top and does not have any support at the bottom in the drag.

A ram-up core is set in the mould with the pattern before ramming. It is used when the cored detail is located in an inaccessible position.

When the pattern is not provided with core prints and no seat is available for the core to rest, the core is held in position between the cope and drag simply due to the pressure of the cope. Such a core is known as *'Kiss core '*.

Green sand cores

Green sand cores are formed by' the pattern itself. A green sand core is a part of the mould. It is made out of the same sand from which the rest of mould has been made.

Dry sand cores

Dry sand cores, unlike green sand cores are not produced as a part of the moulding. Dry sand cores are made separately and independent of the mould. A dry sand core is made up of core sand which differs very much from the sand out of which differs very much from the sand out of which the mould is constructed.

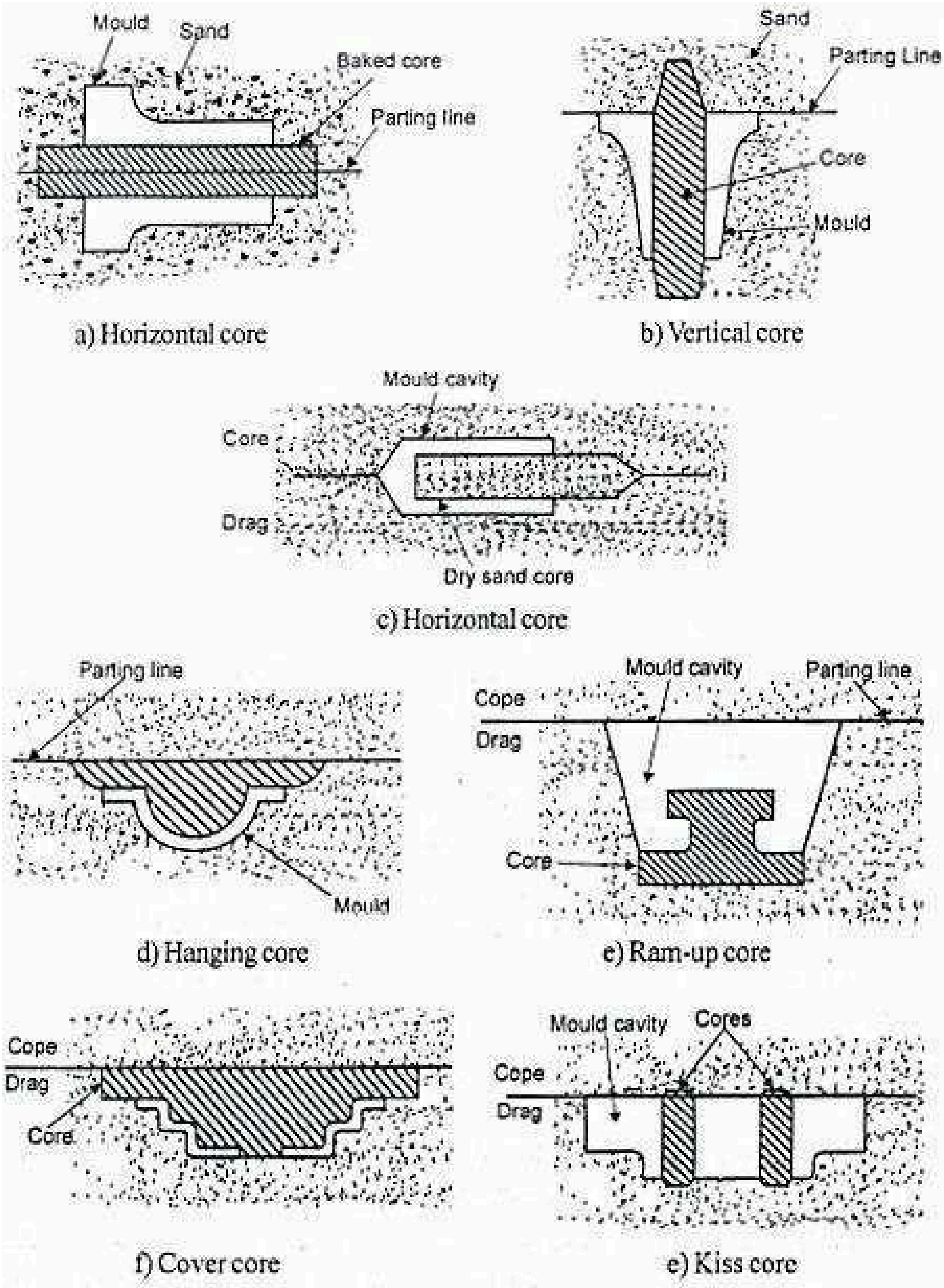


Fig.1.29 Various types of cores

Oil bonded cores

Conventional sand cores produced by mixing silica sand with a small percentage of linseed oil. Oil bonded cores base themselves on the principle of the oxidation and polymerization of a combination of oils containing chemical additives which, when activated by an oxygen bearing material, set in a pre-determined time.

Resin-bonded cores

It is the type of cores phenol resin bonded sand is rammed in a core box. The core is removed from the core box and baked in a core oven at 375 to 450°F to harden the core.

Sodium Silicate and CO_2 cores

These cores use a core material consisting of clean, dry sand mixed with a solution of sodium silicate. The sand mixture is rammed into the core box. The rammed core while it is in the core box is gassed for several seconds with Carbon-di-Oxide gas. As a result a silica gel forms which binds sand grains into a strong, solid form

$$Na_2SiO_3 + CO_2 \longrightarrow Na_2CO_3 + SiO_2 \text{ (Silica gel)}$$

The Hot box process

It uses heated core boxes for the production of cores. The core box is made up of cast iron, steel or aluminium and possesses vents and ejectors for removing core gases and stripping core form the core box respectively, Core box is heated from 350 to 500°F. Heated core boxes are employed for making shell cores dry resin bonded mixtures.

The cold set process

While mixing the core-sand, an accelerator is added to the binder. The sand mixture is very flowable and is easily rammed. Curing begins immediately with the addition of accelerator and continues until the core is strong to be removed from the core box. A little heating of the core hardens it completely. Cold set process is preferred for jobbing production. Cold set process is employed for making large cores.

Castable sand process

A setting or hardening agent such as Dicalcium silicate is added to sodium silicate at the time of core sand mixing. The sand mixture possesses high flowability and after being poured in the core box, it chemically hardens after a short interval of time.

Nishiyama process

Nishiyama process uses sodium silicate bonded sand, which is mixed with 2% finely powdered ferrosilicon, Hardening occurs because of exothermic reaction of silicon with NaOH produced bydrolysis in the solution of sodium silicate. Cores thus made possess short bench life.

Furan-no-bake system

The core sand mixture contains washed and dried sand with clay content less than 0.5% furan no-bake resin 2% and activator (phosphoric acid) 40%. The basic reaction between the furan resin and phosphoric acid results in an acid dehydration of the resin. The core sand mixture has high flowability and needs reduced rodding (to handle the core). Uniform core hardness, exact core dimensions, better fitting cores, lower machining and layout costs, and reduction of oven baking are some of the good characteristics of cores made by Furan-No-Bake system.

Oil-no-bake process

The process employs a synthetic oil-binder which when mixed with basic sands and activated chemically, produces cores that can be cured at room temperature.

Moulding process

The process of forming moulds is called moulding. It is an important operation involved in the casting. After preparing moulds at the moulding shop and making cores at the core room of the foundry, the next important operation is the assembly of moulds for pouring.

Moulding tools

Shovel

It is just like rectangular pan fitted with a handle. It is used for mixing the moulding sand and for moving it from one place to the other.

Riddle

It is used for removing foreign materials like nails, shot metal splinters of wood, etc., from the moulding sand.

Rammer

It is a wooden tool used for ramming or packing the sand in the mould. Rammers are made in different shapes.

Strike-off bar

It is a cast iron or wrought iron bar with a true straight edge. It is used to remove the surplus sand from the mould after the ramming has been completed.

Vent wire

It is a mild steel wire used for making vents or openings in the mould.

Lifter

It is a metal piece used for patching deep section of the mould and removing loose sand from pockets of the mould.

Slick

Different types of slicks are used for repairing and finishing moulds.

Trowel

It contains of a flat and thick metal sheet with upwards projected handle at one end. It is used for making joints and finishing flat surfaces of a mould.

Swab

It is made of flax or hemp. It is used for applying water to the mould around the edge of the pattern.

Draw spike

It is a metal rod with a pointed or screwed end. It is used for removing the pattern from the mould.

Rawhide mallet

It is a mallet to loosen the pattern in the mould by striking slightly, so that it can be withdrawn without damaging the mould.

Gate cutter

It is a metal piece to the gate- the opening that connects tee sprue with the mould cavity.

Rapping plate (or) Lifting plate

It is used to facilitate shaking and lifting large pattern from the mould.

Spirit level

It is used to check that the sand bed, moulding box or table of moulding machine is horizontal.

Clamps

Clamps are used to hold the cope and drag of the complete mould together so that the cope may not float or rise when the molten metal is poured into the mould.

Gaggers (or) Lifters

These are iron rods bent at one or both ends. These are used to reinforce the moulding sand in the top portion of the moulding box and for supporting hanging sand.

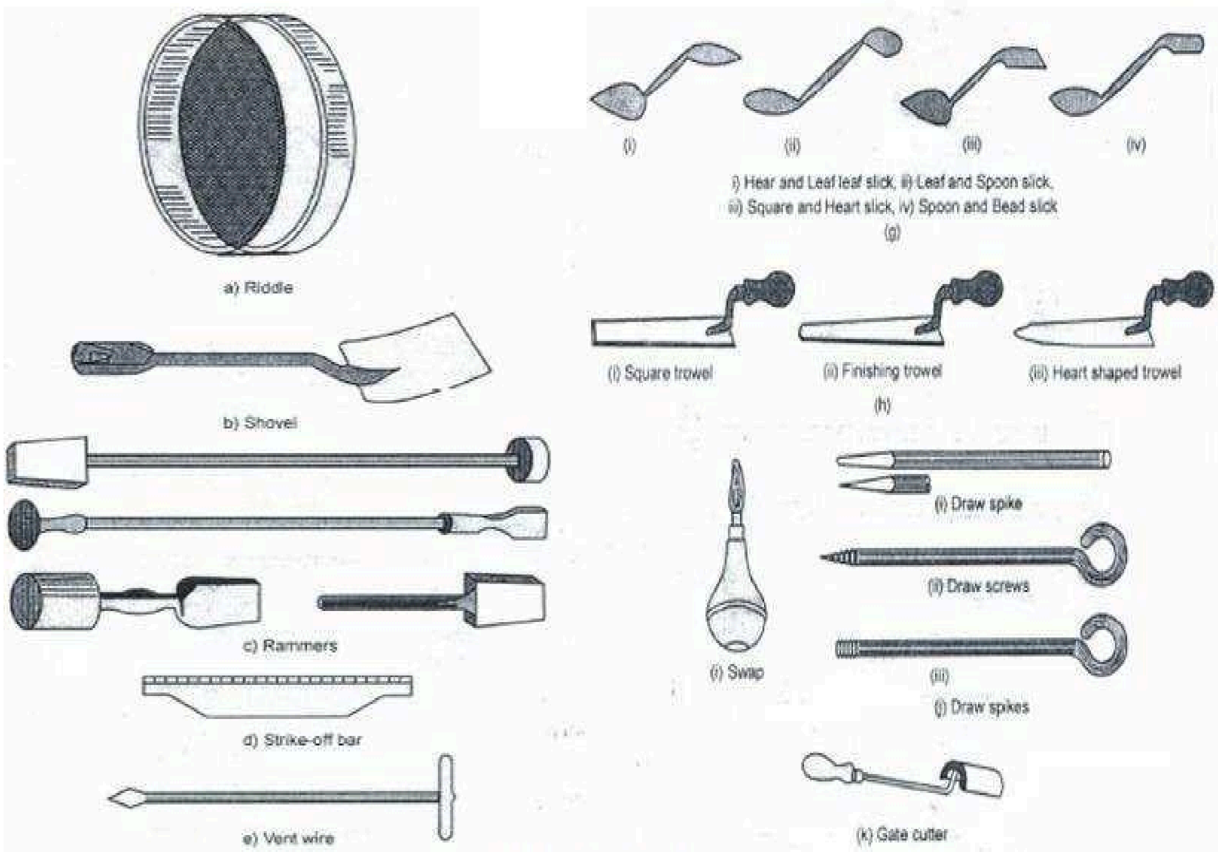
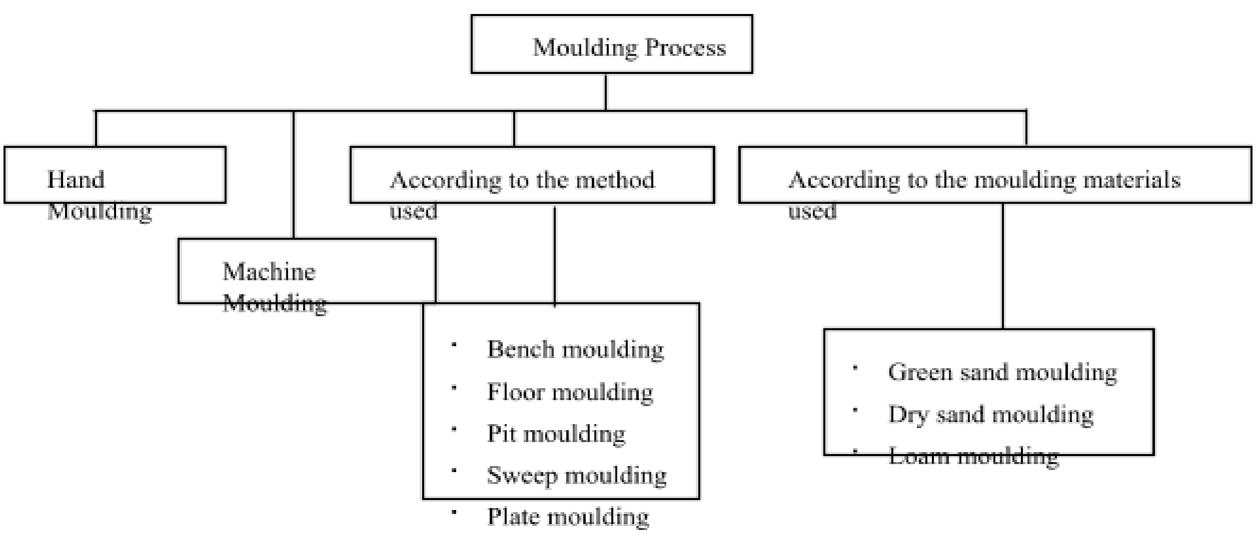


Fig. 1.30 Moulding Tools

Sand moulding process:



Sand mould can be made either by manual or on moulding machine. Manual moulding is done for piece and for small lot production, whereas machine moulding is employed in large lot and mass production.

Based on the nature of work place, the manual moulding can be classified as

Bench Moulding : This is done only for small work

Floor Moulding : This process is done on the foundry floor and is employed for medium sized large casting

Pit Moulding : This method is used for very large casting and is done on the foundry floor. However, a pit dug in the floor acts as the lower flask(drag) and the upper flask (cope) is placed over the pit to complete the assembly

Machine moulding: All the operations are done by machine, and then it is called as machine moulding. The operations includes – compacting the sands, rolling the mould over and drawing the pattern from the mould and so on…..

GREEN SAND MOULDING

A green sand mould is composed of a mixture of sand (silica sand SiO_2), clay (act as binder), and water. The word green is associated with the condition of wetness or freshness and because the mould is left in the damp condition, hence the name "green sand mould". This type of mould is the cheapest and has the advantage that used sand is readily reclaimed. But the mould being in the damp condition, is weak and cannot be stored for a longer period. Hence such moulds are used for small and medium sized casting.

Principal Methods of Green-sand Moulding are:

- Open-sand method
- Bedded-in-method
- Turn-over method

Open-sand Method

It is simplest form of green sand moulding, particularly suitable for solid patterns. For convenience in working and pouring, the entire mould is made in the foundry floor or in a bed of sand above floor level. Moulding box is not necessary and the upper surface of the mould is open to air. After proper levelling the pattern is pressed in the sand bed for making mould. Pouring basin is made at one end of the mould, and the overflow channel cut at the exact height from the bottom face of the mould for giving necessary thickness.

Bedded-in method

In this method, the pattern is hammered down or pressed to bed it into the sand of the foundry floor or in a drag filled partially with sand to form the mould cavity. The sand should be rammed close to the pattern sand; a cope is placed over the pattern. The cope is rammed up, runners and risers are cut and the cope box is lifted. Now the pattern is withdrawn, the surfaces of drag and cope replaced in its correct position for completing the mould.

iii) Turn-over method

One pattern-halfis placed with its flat side on a moulding board, a drag is rammed and rolled over. The other pattern half and a cope box are placed in position. After ramming the cope is lifted off and the two pattern halves shaken and withdrawn. Now the cope is replaced on the drag for assembling the mould.

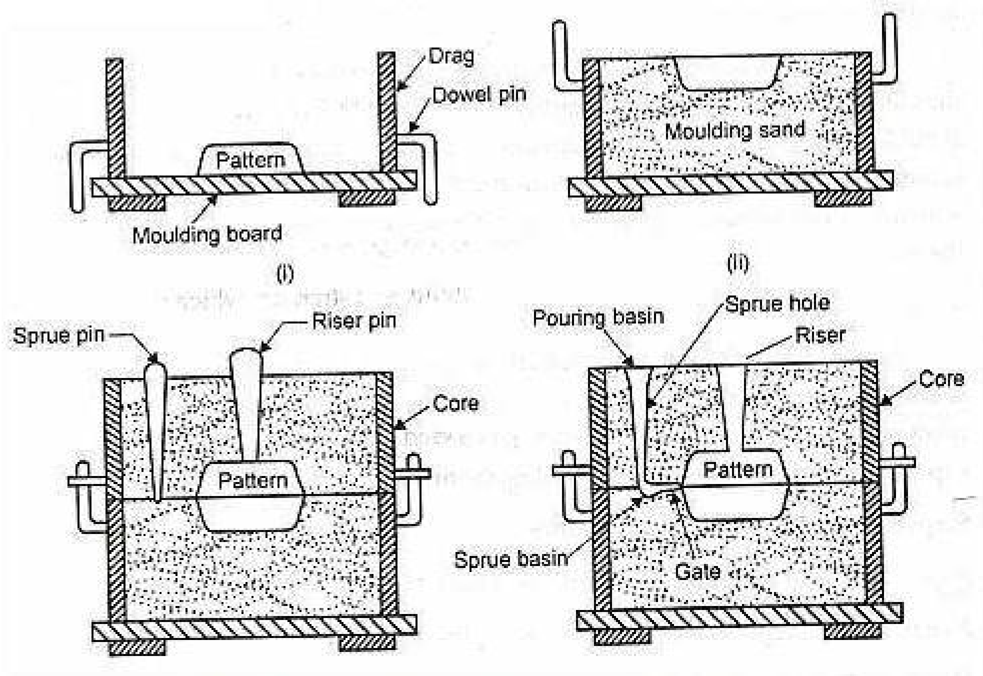


Fig. 1.31 Green sand Moulding Processes

Steps involved in Green sand moulding

First one half of the pattern is placed on the moulding board.

The drag is placed with the dowel pins down.

Moulding sand is filled in the moulding box to cover the pattern.

The drag is completely filled with sand up to the top and rammed by the peen end of the hand rammer.

Excess sand is levelled by a strike-off bar.

The drag is tilled upside down.

Parting sand is applied on the surface.

The other half of the pattern is how placed correctly on the already placed half

The cope is placed in position on the drag and aligned using dowel pins.

The sprue pin is placed vertically for the purpose of pouring the molten metal.

The risers are placed over the highest point of the pattern for the purpose of escaping the gases and identify the level of molten metal.

Again the moulding sand filled in the cope box, and rammed.

The riser and the sprue pin are removed.

The funnel shaped opening called a pouring basin is cut at the top of the sprue pinhole.

The cope is lifted, turned over and placed on the floor.

The pattern pieces are carefully removed.

The gate is cut that is connecting the sprue basin and the mould cluity.

The cope is placed carefully over the drag.

Pouring the molten metal.

Advantages

Green sand moulds are softer than dry sand moulds. This allows greater freedom in construction when the castings solidify and cool.

Green sand mou1ds are quite strong for small depths, as the gases escape from them.

Green sand moulds do not require any backing operations or equipment, but dry sand cores are to be used.

Disadvantages

The green sand moulds cannot be stored for long time.

The green sand moulds are not so strong as other moulds are liable to be damaged during handling or pouring.

The surface finish of the casting obtained from green sand mould is not very smooth.

The green sand mould lacks permeability and strength, which causes certain defects like blow holes etc.

DRY SAND MOULD

Dry sand moulds are basically green sand moulds with two essential differences: the sand used for dry sand moulds contains 1 to 2% cereal flour and 1to 2% of pitch, whereas the sand mixture for green sand moulds may not contain these additives. Also the prepared moulds are baked in an oven at 110º to 260ºC for several hours. The additives increase the hot strength due to evaporation of water as well as by the oxidation and polymerization of the pitch. So, dry sand moulds can be used for large casting. This give better surface finish and also reduce the incidence of the casting defects such as blow holes, porosity that may occur as a result of steam generation in the mould. However, due to the greater strength of these moulds, tearing may occur in hot strength materials.

LOAM SAND MOULD

Loam sand consists of fine sand plus finely grounded refractories, clay, graphite and fibrous reinforcement. It differ from ordinary moulding sand in that the percentage of clay in it is very high (of the order of 50%)

Loam is sand and clay milled with water to form a thin plastic mixture to the consistency of mould. This loam mortar is applied as plaster (6 to 12 mm layer) to the rough structure of the mould. The loam sand mould is constructed to porous brick cemented together with loam mortar. Cast iron plates and bars are used to reinforce the brickwork which retains the moulding material. Loam moulds require adequate ventilation so as to open out pores in the otherwise compact, closely knit

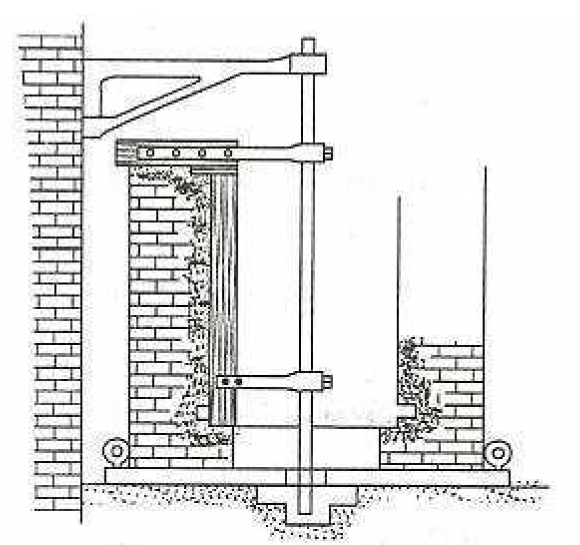


Fig.1.32 Loam Moulding with sweep pattern

mass by artificial means. For this, chopped
straw or horse manure is mixed up with the loam sand.

Moulding machine.

Moulding processes may be classified as hand moulding or machine moulding according to whether the mould is prepared by hand tools or with the aid of some moulding machine. Hand moulding is generally found to be ecoomical when the castings are required in a small number.

The main advantages of machine moulding are as follows.

When the number of castings is substantial, the additional cost of metallic patterns and other equipment is compensated by the high rate of production, and the overall cost per piece works out lower than in the case of hand moulding.

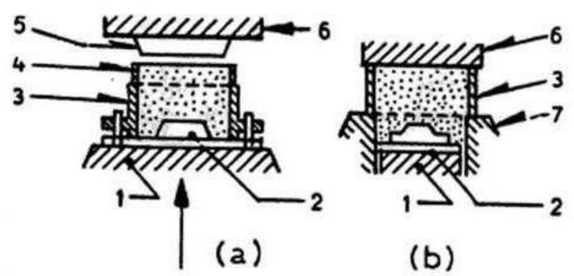
It affords great saving in time, especially when a large number of similar castings in small sizes are required.

A semi-skilled worker can do the machine job whereas hand moulding requires skilled craftsmanship.

The castings obtained are more uniform in size and shape and more accurate than those obtained by hand moulding due to steadier lift of the pattern.

Squeezing machine

A squeeze machine is very useful for shallow patterns. A squeezer (squeeze head), plate or presser board slides inside the flask to compress the sand above and around the pattern. For squeezing action the squeeze piston may by forced upward, pushing the flask up against the squeezer or presser board the presser board being forced into the flask



1) Table 2) Pattern 3) Flask 4) Sand Frame
5) Platen 6) Squeezer head 7) Frame

(a) Top Squeezer Machine (b) Bottom Squeezer machine

Fig.1.33 Squeeze moulding machine

The sand is rammed harder at the back of the mould and softer on the pattern face. In other words sand has greatest density at the surface where pressure is applied to sand and sand density decreases progressively towards the pattern.

Moulding force (M_f) = $P\left(\frac{\pi}{4} d^2\right) - W$

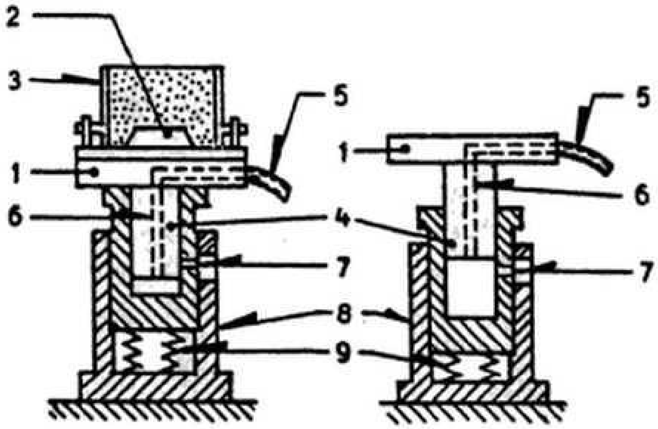
where

P - Pressure in squeeze

cylinder d - Piston diameter

W - Weight of flask pattern and sand

JOLT MACHINE



1) Table 2) Pattern 3) Moulding box
4) Plunger 5) Pipe 6) Channel
7) Through hole 8) Cylinder 9) Spring

Fig. 1.34 Jolt Moulding Machine

In jolt machine, the pattern and flask are mounted in the mould plate and the flask is filled with sand. The entire assembly is raised a small amount by means of an air cylinder and is then dropped against a fixed stop. The compacting of sand is achieved by the decelerating forces acting on it. The working of a jolt moulding machine is shown in figure. The table with moulding sand is lifted by plunger to a definite height, when compressed air is admitted through pipe and channel. Next the table drops since the air is released through pipe. In falling, the table strikes the stationary guiding cylinder and this impact packs the moulding sand in the flask. Springs by cushioning the table blows, reduced noise and prevent destruction of the mechanism and the foundation. About 20 to 50 drops are needed to compact the sand and the average machine operates at about 200 strokes per minute.

Drawback:

Density of the sand is not uniform

Noisy operation

Impact load on foundation.

SAND SLINGER

The sand slinger consists of a base, a sand bin, a bucket elevator, a swinging or movable arm, a belt conveyor and the sand impeller.

Prepared sand lying in the sand bin is picked up by the elevator buckets and is dropped on to the belt conveyor which takes the same to the impeller head. Inside the impeller head, rapidly rotating cup shaped blade picks up the sand and throws it downward into the moulding box as a continuous stream of sand with machine gun rapidity and great force. The sand is discharged into the moulding box at a rate of300 to 2000kg/minute.

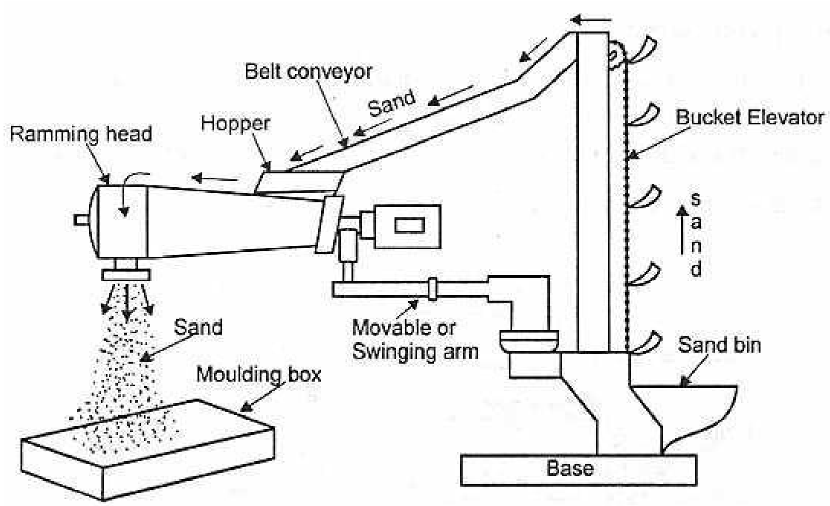


Fig. 1.35 Sand Slinger Machine

This force is great enough to ram the mould satisfactorily. In moulding boxes, sand is filled and rammed at the same time. The density of sand which is the result of sand's inertia is uniform throughout the mould.

MELTING FURNACE

Melting furnaces used in the foundry industry are of many diverse configurations. The selection of the melting unit is one of the most important decisions foundries must make with due consideration to several important factors including:

1. The temperature required to melt the alloy
2. The melting rate and quantity of molten metal required
3. The economy of installation and operation
4. Environmental and waste disposal requirements

Several types of furnaces are most commonly used in foundries:

For melting ferrous metal

- Cupola furnace
- Blast

furnace For melting

ferrous metal

- Direct fuel-fired furnaces
- Crucible furnaces
- Electric-arc furnaces
- Induction furnaces

Cupola Furnace

A cupola is a vertical cylindrical furnace equipped with a tapping spout neat its base. Cupolas are used only for melting cast irons, and although other furnaces are also used the largest tonnage of cast iron is melted in cupolas.

General construction and operating features of the cupola are shown in figure 1.36.

It consists of a large shell of steel plate lined with refractory. The charge, consisting or iron, coke, flux and possible alloying elements, is loaded through a charging door located less than halfway up the height of the cupola. The iron is usually a mixture of pig iron and scrap (including risers, runners, and sprues left over from previous

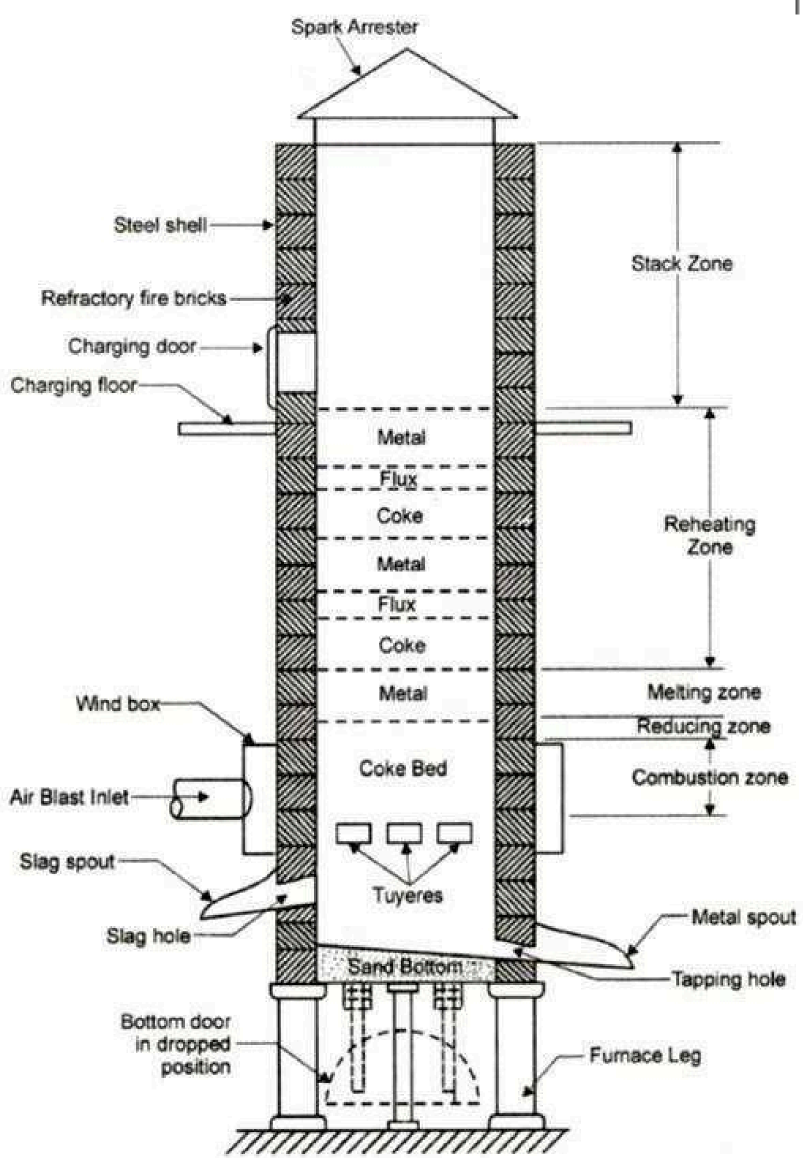


Fig.1.36 Cupola Furnace

castings). Coke is the fuel used to heat the furnace. Forced air is introduced through openings near the bottom of the shell for combustion of the coke. The flux is a basic compound such as limestone that reacts with coke ash and other impurities to form slag. The slag serves to cover the melt, protecting it from reaction with the environment inside the cupola and reducing heat loss. As the mixture is heated and melting of the iron occurs, the furnace is periodically tapped to provide liquid metal for the pour.

Cupola zones

Various zones of the cupola are illustrated in figure 1.36.

Combustion or Oxidizing zone

It is the zone where combustion takes place. It extends from the top of the tuyers to a surface boundary below which all the Oxygen of air is consumed by combustion.

Chemical reaction that takes place in the zone

is C(coke) + O_2 (from air) ~ CO_2 +

Heat

The temperature in this zone is about 1800°C.

Reducing zone

It extends from the top of the combustion zone to the top of the initial coke bed. The CO_2 produced in the combustion zone moves up and is reduced to CO. The temperature also drops to 1650°C.

$CO_2 + C_2 \sim CO$ - Heat

Melting zone

It includes the first layer of pig iron above the initial coke bed. In this zone, the pig iron is melted. The following reaction takes place.

$3\ Fe + 2\ CO \sim Fe_3C + CO_2$

Pre heating zone

It includes all the layers of cupola charges placed above the melting zone to the top of the last charge. The layers of charges are heated by the out-going gases. The temperature in the zone may be upto 1050°C.

Stack

It is the zone beyond the pre-heating zone, through which the hot gases go to the atmosphere.

Cupola construction:

- The cupola essentially consists of a cylindrical steel shell lined on the inside with refractory bricks.
- The entire structure is supported on legs and is open at top and bottom when not in use.
- At the bottom, doors are provided which can be closed and propped to prepare a hearth for burning coke.
- About 100 mm above the bottom of the shell is an opening called the tap hole with a projecting spout for taking out the molten metal.
- On the rear of the tap hole is a slag hole to drain out slag. It is about 50 to 150 mm above the level of the tap hole.
- This height decides the amount of metal that can be stored in the cupola between taps.

- This height may be less if the cupola is fitted with a receiver and the metal IS continuously drained form the cupola.
- About 50 to 150 mm above the slag hole are openings through the shell into the cupola shaft called tuyers.
- These openings permit a blast of air from a wind box surrounding the cupola shell around the tuyers.
- These tuyers are provided around the shell in one or more rows to provide a balanced supply of air.
- Air is supplied into the wind box from a blower through pipes.
- The cupola shaft extends further up from the wind box to a charging platform.
- The height of the cupola from the tap hole to the charging platform is called the effective height.
- It is about 4 to 6 times the internal diameter of the cupola for small and medium size cupolas and about 3 to 5 metre for larger ones.
- At the height of the charging platform is a charging opening through which the cupola can be charged in operation.
- The cupola shaft extends further up by another 3 to 5 metre to give a chimney effect for natural draft.
- The other dimensions of the cupola are empirically fixed based on melting area.
- The total tuyers area is 15 to 25 percent of the cupola melting area. The wind belt section is about 30 percent of cupola melting area and so on.
- Commercial cupola sizes vary from 450m m to over 2000mrri in inside diameter with melting capacities ranging from 1.5 to 35 tonnes per hour.

The cupola furnace has several unique characteristics which are responsible for its widespread use as a melting unit for cast iron. The cupolas is one of the only methods of melting which is continuous in its operation

High melt rates

Relatively low operating costs

Ease of operation

In more recent times, the use of the cupola has declined in favour of electric induction melting, which offers more precise control of melt chemistry and temperature, and much lower levels of emissions.

The construction of a conventional cupola consists of a vertical steel shell which is lined with a refractory brick. The charge is introduced into the furnace body by means of an opening approximately half way up the vertical shaft. The charge consists of alternate layers of the metal to be melted, coke fuel and limestone flux. The fuel is burnt in air which is introduced through tuyeres positioned above the hearth. The hot gases generated in the lower part of the shaft ascend and preheat the descending charge.

Most cupolas are of the drop bottom type with hinged doors under the hearth, which allows the bottom to drop away at the end of melting to aid cleaning and repaired. At the bottom front is a tap hole for the molten iron at the rear, positioned above the tap hole is a slag hole. The top of the stack is capped with a spark/fume arrester hood.

A typical operation cycle for a cupola would consist of closing and propping the bottom hinged doors and preparing a hearth bottom. The bottom is usually made from low strength moulding sand and slopes towards a tapping hole. A fire is started in the hearth using light weight timber; coke is charged on top of the fire and is burnt by increasing the air draught from the tuyers. Once the coke bed is ignited and of the required height, alternate layers of metal, flux and coke are added until the level reaches the charged doors. The metal charge would typically consist of pig iron, scrap steel and domestic returns.

An air blast is introduced through the wind box and tuyers located near the bottom of the cupola. The air reacts chemically with the carbonaceous fuel thus producing heat of combustion. Soon after the blast is turned on, molten metal collects on the hearth bottom where it is eventually tapped out into a waiting ladle or receiver. As the metal is melted and fuel consumed, additional charges are added to maintain a level at the charging door and provide a continuous supply of molten iron. At the end of the melting campaign, charging is stopped but the air blast is maintained until all of the metal is melted and tapped off. The air is then turned off and the bottom doors opened allowing the residual charge material to be dumped.

The Blast Furnace Process

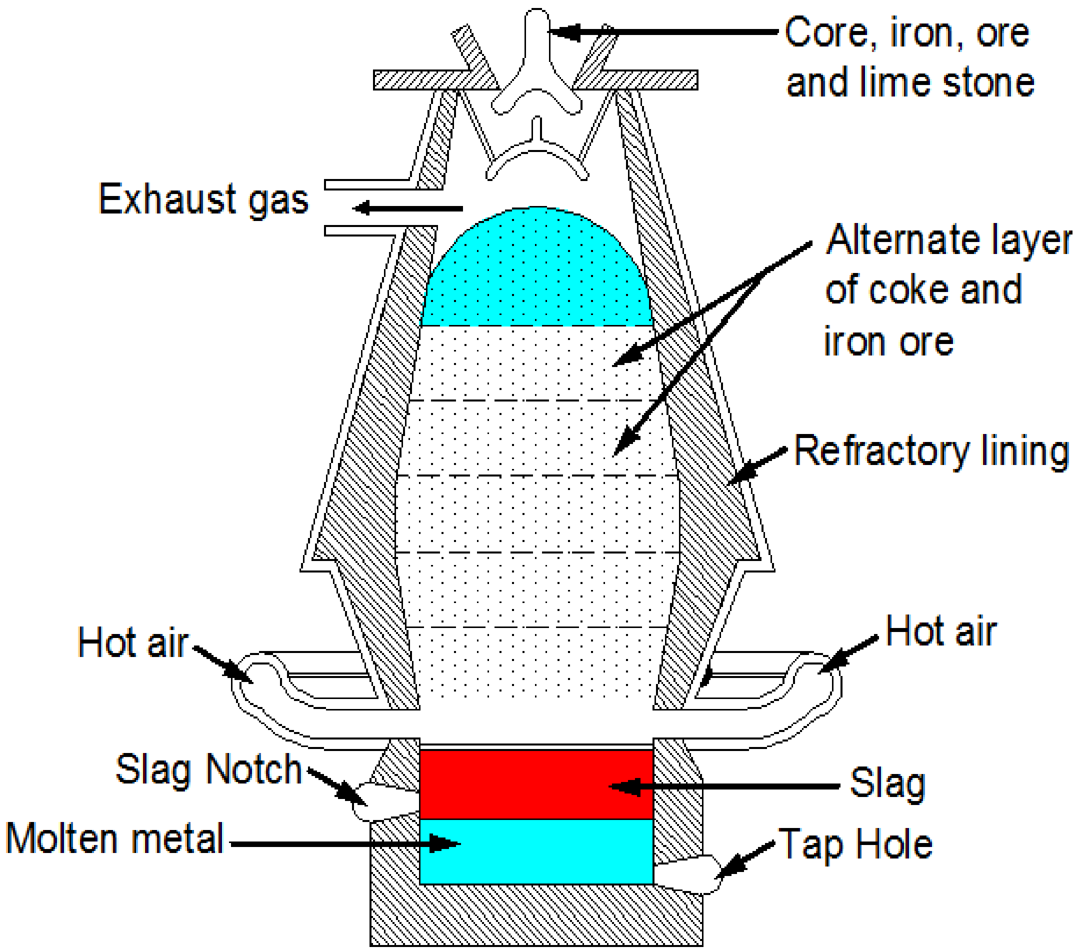


Fig. 1.37 : Blast Furnace

Working of Blast furnace

1. The Iron Ore, Coke and Limestone, (the Charge), is conveyed to the top of the Furnace.
2. The Charge is stored in Bells until the timing is right for the charge to be dropped into the Furnace.
3. Hot air is then blown through pipes called Tuyers, to fire the mixture.
4. The Coke burns to increase the temperature in the Furnace.
5. The Limestone attracts the impurities in the Iron Ore and forms Slag. This Slag is lighter than the molten Iron and so floats on top of it.
6. As the Furnace fills, the molten Iron is tapped off. The Slag is also tapped off at regular intervals. Most Iron is taken straight from the Blast Furnace to the Steel Mill, but some is poured into buckets called Pigs. This Iron is called Pig Iron and is used to make Cast Iron.

The Charge

The Charge consists of 3 parts:

- Iron Ore
- Coke
- Limestone

Iron Ore

The Iron Ore is first mined and then brought to the Blast Furnace. It contains impurities which have to be removed. Hematite and Magnetite are the most common ores. It takes about two tons of Iron Ore to produce one ton of iron, but this varies with different types of ores.

Coke

Coke is made by heating soft coal in the absence of air. As Coke is burned in the Blast Furnace it raises the temperature to about 2000°C which is enough to melt the Iron Ore. The Carbon in the Coke chemically reacts with the Oxygen in the Iron Ore to form Carbon di oxide (CO_2, and Carbon Monoxide (CO), which escapes through the Gas Outlet.

Limestone

The Limestone is mined then crushed before being brought to the Blast Furnace. It combines with the impurities in the Iron Ore to form Slag. A material which removes unwanted materials or cleans another material is called a Flux.

The Exhaust Gas Outlet

The Exhaust Gas Outlet collects any gaseous emissions from the chemical reactions that are taking place in the Furnace. As you know Carbon dioxide and Carbon monoxide are not exactly concussive towards healthy living and so they cannot be let to escape into the atmosphere as they are. Firstly because these gases are hot they are reused to save energy. They are piped to nearby Stoves in order to heat them. The gases are then 'cleaned' before being let into the atmosphere.

Charging Bells

You may notice that the Charging Bell system in the above diagram looks more complicated than those you see in books. The reason is that you are looking at a more accurate representation. You can understand that the manufacturers of Iron want to conserve as much energy as possible, not to do so would cost money and be mad! There are in fact two Bells in the system called, the Small Bell and the Large Bell. The Small Bell is filled directly from the Conveyor System, and when it is close to being full it is opened to allow the Charge drop into the Large Bell. The Large Bell is then opened when it is nearly full and the Charge can drop into the Furnace. Using this system greatly reduces the amount of heat that is lost to the atmosphere.

Gas Outlet

The Gas Outlet is simply an array of holes in the Furnace that allows the escaping gases to get to the Exhaust Gas Outlet.

Melting Iron Ore, Coke and Limestone

At the top of the Furnace the Iron Ore, Coke and Limestone is at a temperature of about 200°C. At this stage the materials are gone through the pre-heating stage. Close to the middle of the Furnace the temperature has increased to approximately 480°C, where the raw materials have started to melt. The temperature increases rapidly to about 2000°C at the bottom of the Furnace where the molten Iron is situated, waiting to be removed.

Tuyers

Strange word tuyers. (It's pronounced "2 ears"!). These are small pipes that permit hot air from the Bustle Pipe to enter the furnace. The hot air is necessary to keep the temperature in the furnace high. The tuyers are located all around the Furnace like spokes on the hub of a bicycle wheel. They also have valves so that nothing can escape from the Furnace. The diagram below shows the relationship between the tuyers, the Bustle Pipe and the Furnace. It is a view as if you were looking from the top of the Furnace.

Tap hole

The Tap hole is used to draw off the molten Iron at regular intervals of about 5 to 6 hours. You should notice that the Tap hole is located below the Slag hole. This is because the Slag is lighter than the molten Iron and so sits on top. The molten Iron leaves the Tap hole and is either poured into moulds called 'Pigs' or sent to other areas for further refining.

Slag Hole

The Slag hole, which is situated above the Tap hole, because Slag is lighter than molten Iron, is used to draw off the waste Slag. The Slag is scraped off every 3 or 4 hours and is then used for road beds, fertilizer or cement.

Bustle Pipe

The Bustle Pipe is a large diameter pipe that circles the base of the Furnace. It carries the hot air from the Stoves, where the air is heated, to the tuyers which allow the hot air to enter the Blast Furnace.

Refractory Lining

You might ask, that if the Blast Furnace is made from Steel and there is molten Iron inside the Furnace, how come the Furnace does not melt? That would be a good question, and the answer is quite simple. Inside the Steel shell of the Furnace there is a layer of Fire Brick called the Refractory Lining. This Refractory Lining reflects the heat back into the Furnace. You have seen a Refractory Lining before. If you look at the back of a fireplace, (preferably one that does not have a fire burning in it at the time), you will see a reddish cement. This is Fire Brick and causes the heat generated by the fire to be reflected back into the room, rather than be absorbed by the wall at the back of the fireplace.

Conveyor System

The Conveyor System takes the Charge from the area where it is maxed together to the top of the Blast Furnace. The Charge is carried in Skip Cars which run on a rail track.

Special Casting Processes:

Casting in sand moulds is economical and gives good results for many applications where dimensional accuracy and surface finish requirements are not too stringent and the casting wall thicknesses are not too small.

There are many applications in which it is desired to achieve better surface finish, finer details, thinner walls, better strength, and faster production rates or to eliminate further machining.

Special casting processes have been developed to meet these requirements.

Some of these special castings are discussed below.

- Shell moulding
- Investment casting
- Centrifugal casting
- Pressure die casting
- Ceramic moulding
- CO_2 process
- Stir casting

Shell moulding

Shell mould casting process also known as Croning or C-process makes use of moulds (and cores) made of relatively thin shells about 6 mm thick for casting.

- The shells are made from clay free silica sand 60-140 AFS fineness mixed with 3 to 10 percent by weight of phenolic thermosetting resins like phenol formaldehyde or urea formaldehyde.
- The resin may be used in the powder form in the mixture or may be mixed in liquid form and then dried on the sand grains.
- The mixture should be dry and free flowing.
- Sometimes about 112percent kerosene is added in dry mixtures and mulled to avoid dusting and loss of binder during operation.

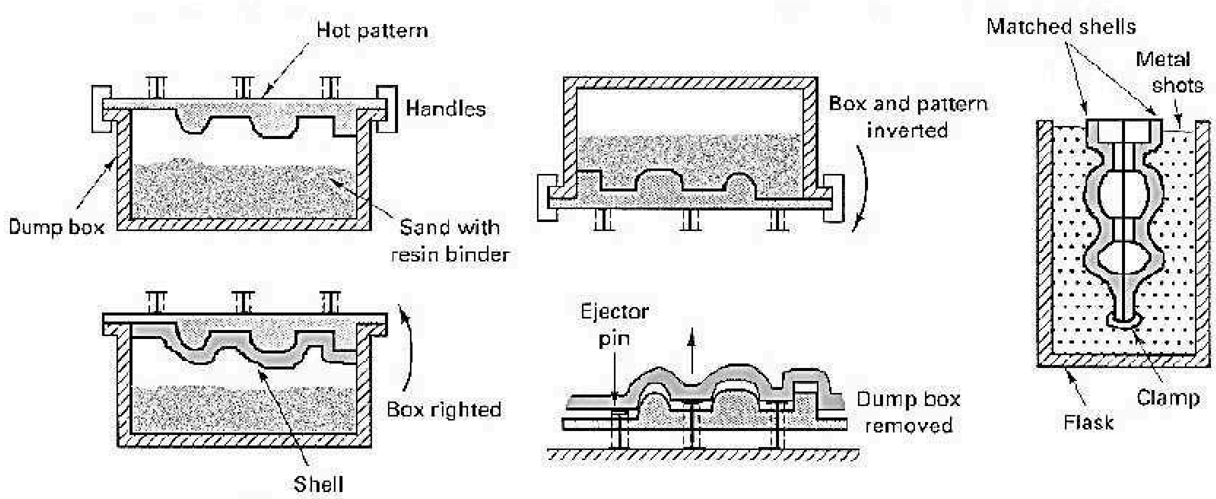


Fig.1.38 Step by step of shell moulding process

The main steps in the process are the following: (Fig. 1.38)

1. The sand resin mixture is invested on the pattern heated to a temperature of 200 to 400°C for a period of 15 to 45 seconds. During this period the sand mix around the pattern partially sets to a thickness of 6 to 15 mm depending on the dwell period and the type of mixture.
2. The unset sand is removed and the partially set shell sticking onto the pattern is cured at a temperature of 250° to 350°C for a period of 1 to 3 minutes depending on the pattern intricacy and shell thickness.
3. The cured shell is ejected from the pattern plate using ejector pins on the pattern. To aid in shell stripping a suitable releasing agent like silicon solution is applied on the heated pattern before investing the mould mixture.
4. The ejected mould parts are assembled with cores and clamped together for pouring. The assembled mould may be backed up by sand or shots if required.
5. The investment of the mould mixture is done either by blowing onto the pattern or by dumping the mixture on the pattern.
6. Blowing is more often used in the manufacture of shell cores and the dumping method in the manufacture of shell moulds.
7. In the dumping method, the heated pattern plate is placed inverted on a box" filled partially with the mould mixture.
8. The entire assembly of the pattern plate and the box is inverted to dump the mixture on the pattern plate.
9. After the dwell period, the box is brought back to the upright position to dump the unset mixture back into the box.
10. The pattern plate along with the sticking partially set shell is sent in for curing.
11. The steps in the dump method can be easily adapted to mechanization.
12. Modern shell moulding machines have been designed to complete a cycle of investment, dumping back of unset excess sand, curing and ejection automatically.

Advantages of shell moulding:

- Good surface finish of the order of 3 microns RMS and close dimensional tolerances of the order of ± 0.03 mm per mm.
- Dimensions across parting surfaces can be held to within 0.1 mm per mm.
- The moulds are highly permeable completely eliminating gas problems.
- The resin binder in the mould and core completely burns due to the heat of the poured metal leaving only loose sand with the casting which is easily cleaned. This simplifies shake out and cleaning operations.
- The process reduces the tendency for section variation in castings compared to green sand moulds.
- It also gives good surface finish and dimensional accuracy reducing machining allowance or eliminating machining in some cases.
- It is adaptable to mechanization and mass production.

Disadvantages of shell moulding

- High initial cost of the metal pattern plates,
- High cost of the binder
- Limitation of the size of the castings.

The process is used for manufacture of cams, pistons, piston rings, small pulleys, motor housings, fan blades etc.

Precision Investment Casting Methods:
Lost wax process:

- An age old process for the manufacture of precision castings with smooth surfaces makes use of disposable patterns of wax or polystyrene plastics.
- Patterns are made by injecting the pattern material in a die using a wax-injection machine.
- The injected patterns are joined together by wax welding or by suitable glue. Gates, runners and risers are added the same way.
- Several smaller patterns-may be assembled to a common gatting system so that a number of pattern can be placed in the same mould and poured simultaneously.
- The pattern assembly is sometimes given a primary investment coat of 300 mesh refractory grains made into a slurry in a suitable binder. The fineness of the grains in this coating determines the smoothness of the final casting.
- When the primary coat on the pattern is dried sufficiently the mould is invested around the pattern in a flask. Investment means the layer of refractory materials with which the pattern is covered to make the mould. Castings are produced by pouring the molten metal in these moulds.
- The injection pressure may vary from 4 to 35 bars depending upon the melting temperature of the injected material.
- The mould material is slurry of refractory silica with a suitable binder.
- For pouring temperatures upto 1000°C plaster binders may be used but for temperatures beyond 1000°C it is necessary to use a high temperature binder such as ethyl silicate.

Another method of investment used is to make a shell mould.

- In this method the pattern assembly is dipped in a series of slurries to build up a shell 3 to 6 mm thick of successively coarser grains.
- The invested moulds are allowed to set for a period of a few minutes to several hours depending upon the material.
- The flasks may also be vibrated to settle the investment material and drive out the air bubbles from the pattern surface.
- The moulds are then inverted and heat is applied to melt out the wax.
- Wax may also be removed by placing the mould in a solvent vapour bath such as a trichloroethylene bath.
- The vapour bath method removes wax more completely
- Vapour bath method is particularly suitable for shell type moulds.
- The completed moulds are preheated to temperatures ranging from 500 to 1000°C depending upon the metal to be cast.

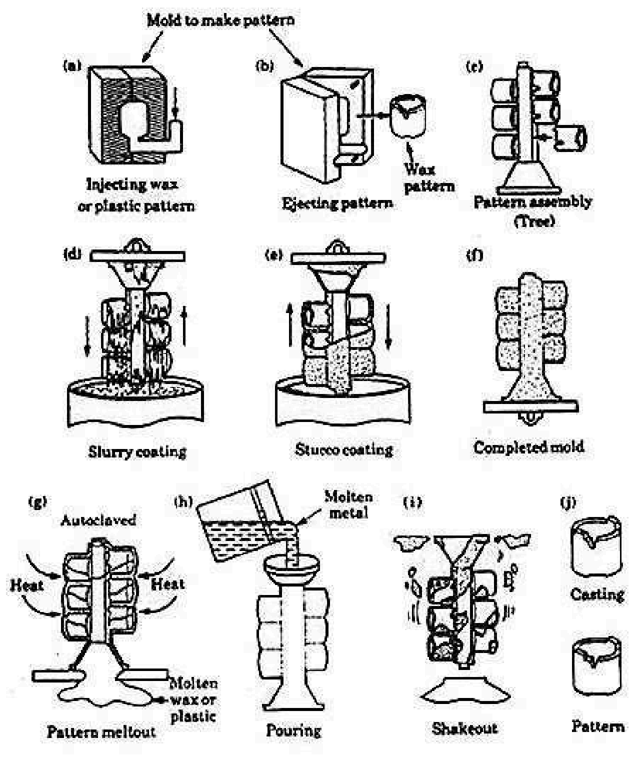


Fig. 1.39 Investment Casting Process

- This helps in removing any remaining wax and assures easy flow of the metal poured so that all cavities are filled properly. Moulds should be poured immediately after being preheated.
- Moulds with high permeability are poured under gravity but low permeability moulds may be poured under pressure or vacuum.

Mercast process:

In Mercast process or investment casting frozen mercury is used as a pattern material in place of wax.

- Mercury at room temperature is filled in the pattern dies which are then immersed in a bath maintained at - 60 to - 80°C.
- After the pattern has solidified the parts are joined by contact in a cold air atmosphere at - 60 to 75°C.
- The mercury patterns are then dipped in a series of ceramic baths maintained well below the freezing temperature of mercury.
- This produces a shell around the pattern.
- After the shell is built up and dried the mercury pattern is melted and flushed out at room temperature.
- The shell moulds are then fired at 1000°C for about 2 hours producing a porous mould resembling unglazed porcelain with a smooth finish in the cavity.
- The moulds are backed up in a flask with sand or shots and poured under gravity or pressure.

Advantages of investment casting:

- Since in investment-casting process patterns are melted out and not removed in the usual way, there is no parting line in the moulds and no draft is necessary on patterns. This results in better dimensional accuracies in castings produced by this method.
- Tolerances of the order of ± 0.05 mm per mm are readily obtained. Closer tolerances of upto ± 0.025 mm / mm can be possible.
- Surface finishes obtained range from 1 to 5 microns RMS.
- No machining operations are necessary in many cases.
- Intricate shapes in practically any ferrous or non-ferrous metal can be cast.
- Small diameter holes can be cast in thin sections.
- The process can also be made automatic.
- However, because of the number of steps involved investment casting usually cannot compete in cost with sand casting and other casting methods except where very small tolerances and fine finish are required.
- This process also becomes economical for casting of very high temperature melting alloys and in the production of complicated shapes that cannot be easily machined.
- The weight of castings made by investment process varies from a few gram to around 2.5 kg although 10 kg castings have been produced.

Disadvantages of investment casting:

- This process is expensive, is usually limited to small casting, and presents some difficulties where cores are involved.
- Holes cannot be smaller than 1/16 in. (1.6mm) and should be no deeper than about 1.5 times the diameter.
- Investment castings require very long production-cycle times versus other casting processes.
- This process is practically infeasible for high-volume manufacturing, due to its high cost and long cycle times.

Applications

Typical products include blades and, vanes, slides for cloth-cutting machines, camera and projector components, fuel parts for aviation carburetors etc.

Centrifugal Casting:

In centrifugal casting process, the molten metal poured at the center of a rotating mold or die. Because of the centrifugal force, the lighter impurities are crowded towards the center of the case. For producing a hollow part, the axis of rotation is placed at the center of the desired casting. The speed of rotation is maintained high so as to produce a centripetal acceleration of the order of 60g to 75g. The centrifuge action segregates the less dense nonmetallic inclusions near to the center of rotation that can be removed by machining a thin layer. No cores are therefore required in casting of hollow parts although solid parts can also be cast by this process.

The centrifugal casting is very suitable for axisymmetric parts. Very high strength of the casting can be obtained. Since the molten metal is fed by the centrifugal action, the need for complex metal feeding system is eliminated. Both horizontal and vertical centrifugal castings are widely used in the industry. Figure 1.40 schematically shows a set-up for horizontal centrifugal casting process.

Types of centrifugal casting:

Centrifugal casting can be divided into three categories namely

1. True centrifugal casting,
2. Semi centrifugal casting
3. Centrifuging.

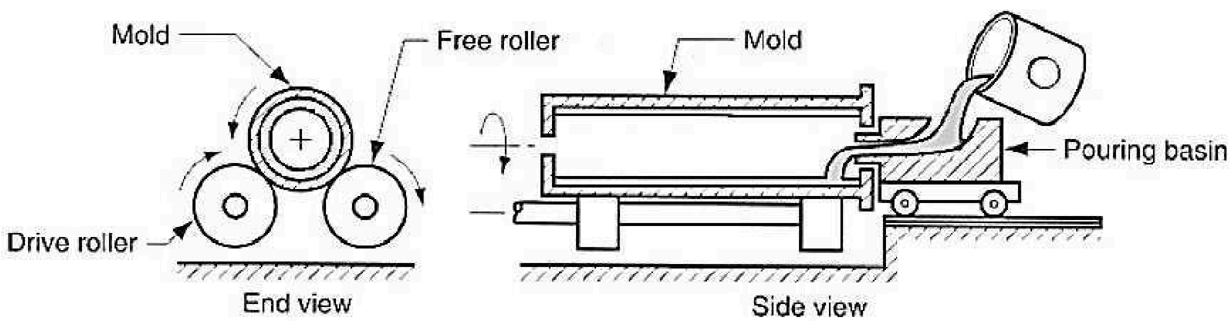


Fig. 1.40 Centrifugal casting

True centrifugal casting:

- The true centrifugal method of casting is used to produce hollow castings with a round hole.
- The characteristic feature of this process is that the hole is produced by the centrifugal force alone and no cores are used.
- The mould is rotated about the axis of the hole with the axis held horizontal, inclined or vertical.
- The outside surface of the job may be round, square, hexagonal etc. and should be symmetrical with the hole axis.
- The central hole should be round to be formed without cores.
- Long castings like cast iron soil pipes are cast with the moulds rotated about a horizontal axis.
- Castings with relatively short lengths are poured with moulds rotated about an inclined or vertical axis.
- Rotation about the vertical or inclined axis is convenient but the central hole produced will be slightly paraboloid with smaller diameter at the bottom because the metal has a tendency to settle down due to gravity.
- Fig. 1.40 gives a schematic diagram for a true centrifugal casting process.
- The speed of rotation for true centrifugal casting should be high enough to hold the metal on to the mould wall till it solidifies.
- A low speed of rotation would result in raining or slipping of the metal inside the mould.
- Too large a speed of rotation on the other hand may result in internal stresses and possible hot tears.
- A speed which would provide a centrifugal force of 60 to 75 times the force of gravity on horizontal moulds and 100 times force of gravity for vertical moulds is found to be suitable.
- The moulds used for the process may be metal moulds or refractory or sand lined moulds.

Applications:

Common products produced by true centrifugal casting include pipes, oil engine cylinders, piston ring stock, gear blank stock, bearing bushes and the like.

Semi centrifugal casting

- In semi-centrifugal casting process no attempt is made to produce a hole without a core.
- The centrifugal force resulting from rotation of the mould is used to properly feed the casting to produce a close grained clean casting.
- The process is suitable for large axis-symmetrical castings like gear blanks, fly wheels and track wheels.
- Any hole round or otherwise is made with the use of a core. The mould is clamped to a turn table with casting axis along the axis of rotation.
- The metal is poured along or near the axis to feed the points farthest from the axis of rotation under pressure.
- If made solid the central portion tends to be porous and with inclusion which are removed in subsequent machining.
- Fig. 1.42 shows a typical semi-centrifugal casting setup for the production of track wheels.

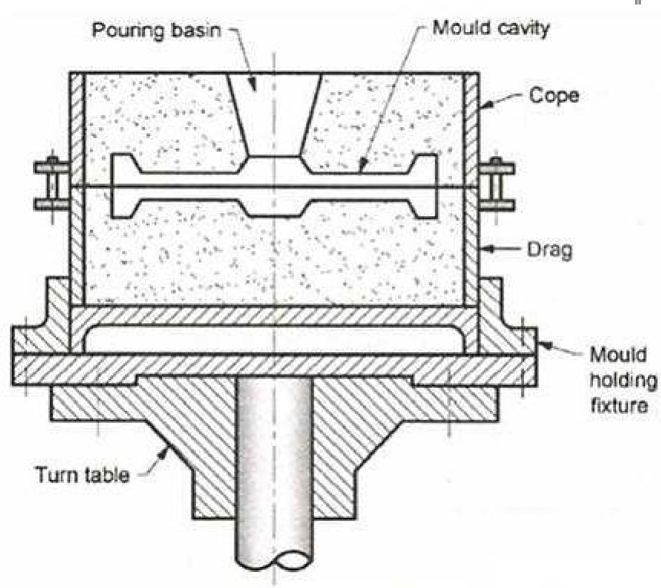


Fig. 1.41 Semi - centrifugal casting

Centrifuging:

- Centrifuging or centrifuge casting is employed to force metal under pressure into moulds of small castings or castings not symmetrical about any axis of rotation.
- The moulds are made around a central axis of rotation, to balance each other.
- The metal is poured along this axis of rotation through a central sprue and made to flow into mould cavities through radial ingates cut on the mould interface.
- Centrifuging helps in proper feeding of castings resulting in clean, close grained castings.
- Stack moulds can be used to advantage in centrifuging of castings required in very large numbers.
- A schematic diagram of a centrifuge casting set-up with stack moulds is given in Fig. 1.42.

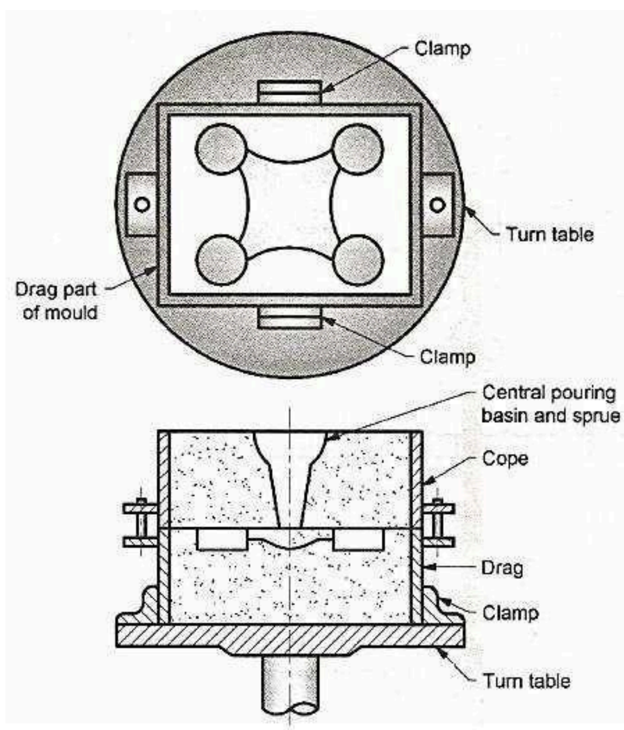


Fig.1.42 Centrifuge casting

Ceramic Mould Casting:

- Ceramic mould casting method uses a ceramic slurry prepared by mixing fine grained refractory powders of Zircon ($Zr SiO_4$), alumina ($Al_2 O_3$), fused silica ($Si O_2$) and a patented liquid chemical binder (alcohol based silicon ester) for making the mould.
- The patterns used are split gated metal patterns usually mounted on a match plate.
- Unlike the patterns in investment casting these patterns are reusable.
- The slurry is applied over the patterns surfaces to form a thin coating around it. The slurry fills up all cavities and recesses by it and no ramming or vibration of the mould is required.
- The pattern is withdrawn after it sets in about 3 to 5 minutes.
- The mould is removed from the flasks, treated with a hardener to promote chemical stabilization and transferred to an oven for heating to about 100°C.
- The mould is ready to take molten metal.

The advantages of the process include:

1. High precision and very good surface finish.
2. The process does not require any risering, venting or chilling because the rate of cooling is very slow.
3. Any patterns made of wood, metal or plastic can be used.
4. The process can be used for all types of metals including highly reactive titanium or uranium.

The method can be used for producing precision parts like dies for drawing, extrusion, casting, forging etc., pump impellers, components of nuclear reactors and air craft.

The main short comings of the process are its high cost and the difficulty in controlling dimensional tolerances across the parting line.

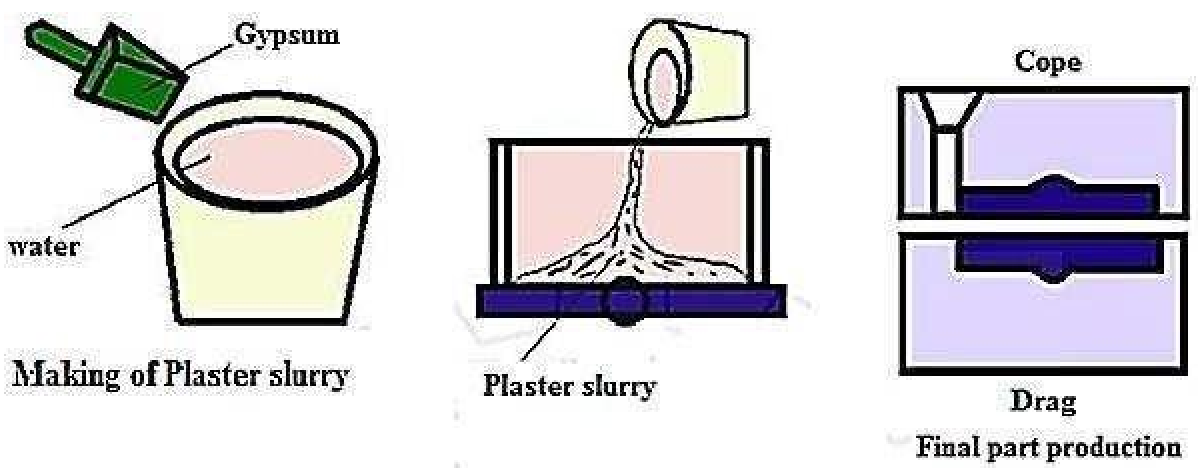


Fig.1.43 : Ceramic mould making

Pressure die casting

The pressure die casting process is the most common for Al, Zn and Mg castings (low melting point). The liquid metal is injected into the mold under high pressure and allowed to solidify at the high pressure. The solidified cast is then taken out of the mold or the die which is ready for the next cast. Pressure die casting is suitable for large batch size production.

Two types of pressure die casting are generally common in the industry –

- High pressure die casting (Hot chamber die casting)

- Low pressure die casting (Cold chamber die casting)

Very high production rates can be achieved in pressure die casting process with close dimensional control of the casting. However, the process is not suitable for casting of high melting temperature materials as the die material has to withstand the melting (or superheated) temperature of the casting. Pressure die castings also contain porosity due to the entrapped air. Furthermore, the dies in the pressure die casting process are usually very costly.

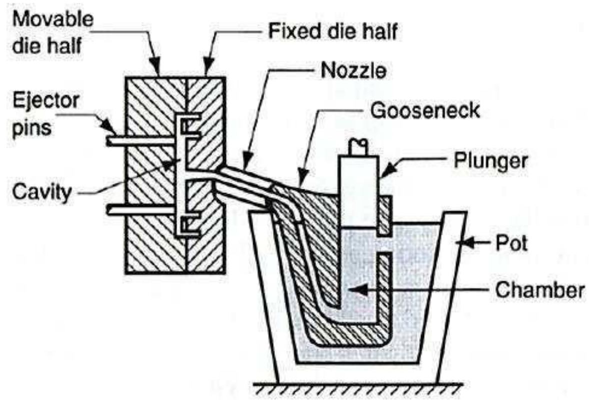


Fig. 1.44 : Hot chamber die casting

Figure 3.2.6 schematically presents the hot-chamber and the cold-chamber die casting processes. In the hot-chamber die casting process, the furnace to melt material is part of the die itself and hence, this process is suitable primarily for low-melting point temperature materials such as aluminum, magnesium etc.

Hot-chamber die-casting

In hot chamber die-casting, the metal is melted in a container attached to the machine, and a piston is used to inject the liquid metal under high pressure into the die.

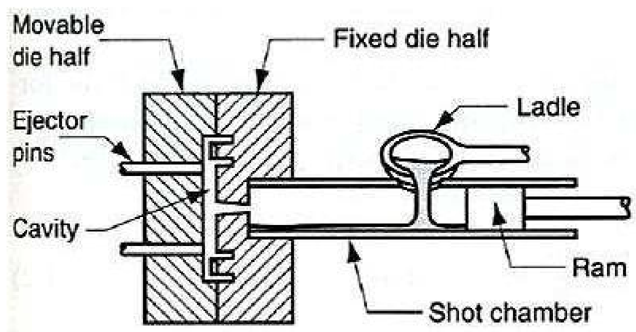


Fig. 1.45 : Cold chamber die casting

Advantages:

1. High productivity (up to 500 parts per hour)
2. Close tolerances
3. Good surface finish

Disadvantages:

1. The injection system is submerged in the molten metal
2. Only simple shapes

Area of application:

Mass production of non-ferrous alloys with very low melting point (zinc, tin, lead)

Cold-chamber die-casting

In cold-chamber die-casting, molten metal is poured into the chamber from an external melting container, and a piston is used to inject the metal under high pressure into the die cavity.

Advantages:

Same as in hot chamber die-casting, but less productivity.

Disadvantages:

Only simple shapes

Area of application:

Mass production of aluminium and magnesium alloys, and brass

Stir Casting:

Stir casting is a liquid state method of composite materials fabrication in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. Among the variety of manufacturing processes available for discontinuous metal matrix composites, stir casting is generally accepted and currently practiced commercially.

Process

In general, the metal matrix composites of stir casting involves production of molten metal of selected matrix material followed by the introduction of a reinforcing material in to the molten metal, obtaining a suitable dispersion through stirring.

Solidification containing suspended particles to obtain the desired distribution of the dispersed phase in the cast matrix. The schematic diagram of this process is shown in figure 1.46

Particle distribution changes significantly depending on process parameters during the melting and solidification stages of the process.

The addition of particles to the melt drastically changes the viscosity of the molten metal and this has implications for casting processes. It is important that solidification occurs before appreciable settling is allowed to take place.

Benefits:

Simplicity, flexibility and applicability to large scale production.

Able to sustain high productivity due to liquid metallurgy technique.

Cheaper 1/3 to ½ than the other method of special casting process.

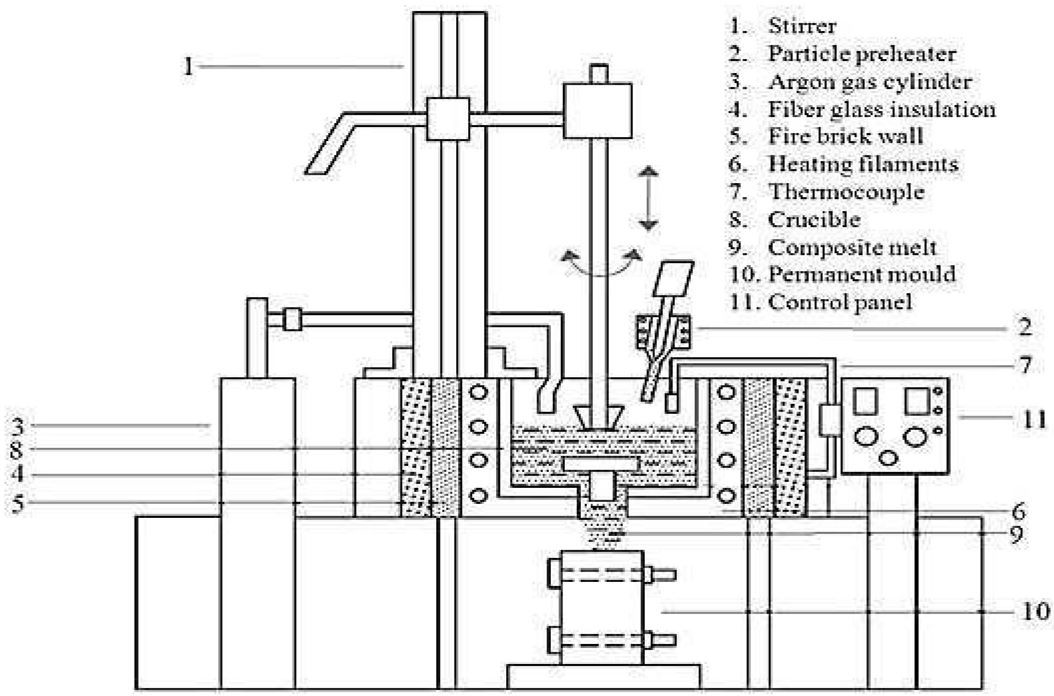


Fig. 1.46: Stir Casting

CO_2 Molding

Introduction: CO_2 Casting is a kind of sand casting process. In this process the sand molding mixture is hardened by blowing gas over the mold. This process is favoured by hobby metal casters because a lot of cost cutting can be done. In addition, one can be sure of getting dimensionally accurate castings with fine surface finish. But, this process is not economical than green sand casting process.

Process: The Mold for CO_2 Casting is made of a mixture of sand and liquid silicate binder which is hardened by passing CO_2 gas over the mold. The equipment of the molding process includes CO_2 cylinder, regulator, hoses and hand held applicator gun or nozzle. Carbon di oxide molding delivers great accuracy in production.

Any existing pattern can be used for the molding purpose which can be placed in the mold before the mold is hardened. This method helps in producing strong mold and cores that can be used for high end applications. If the process is carefully executed then casting can be as precise as produced by the shell casting method.

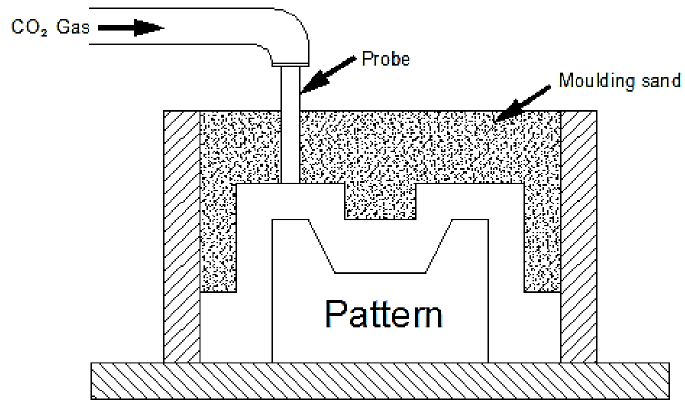


Fig. 1.47 Carbon - di - Oxide Processess

Carbon di oxide casting is favored both by the commercial foundry men and hobbyist for a number of reasons. In commercial operations, foundry men can assure customers of affordable castings which require less machining. The molding process which can be fully automated is generally used for casting process that require speed, high production runs and flexibility. In home foundries this is one of the simplest process that improves the casting quality.

Applications:

CO_2 casting process is ideal where speed and flexibility is the prime requirement. Molds and cores of a varied sizes and shapes can be molded by this process.

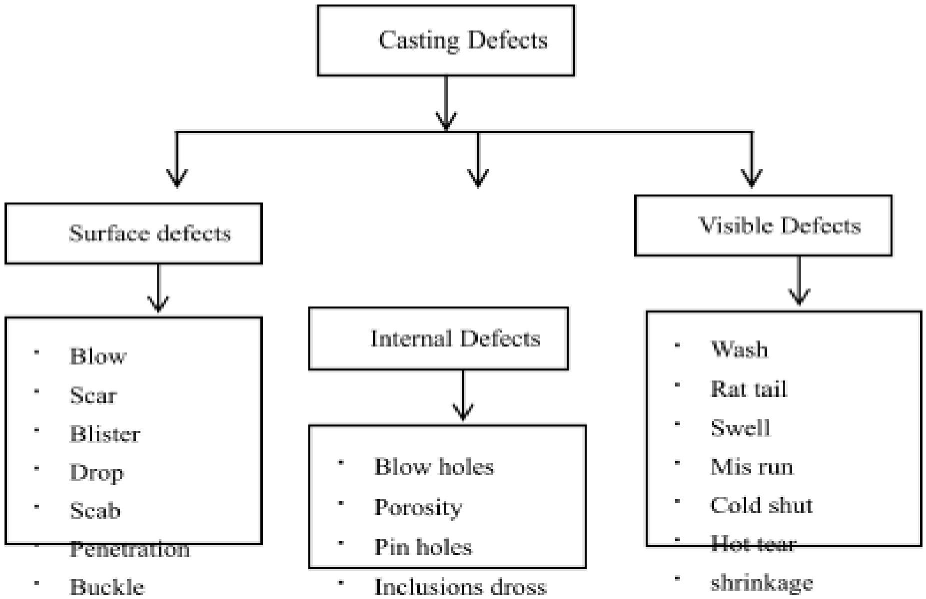
Advantages:

This process has many advantages in comparison to other forms of castings some of them are as follows:

a. Compared to other casting methods cores and molds are strong
b. Reduces fuel cost since gas is used instead of to other costly heating generating elements
c. Reduces large requirement for number of mold boxes and core dryers
d. Provides great dimensional tolerance and accuracy in production
e. Moisture is completely eliminated from the molding sand
f. This process can be fully automated.

Casting Defects

Casting defects are classified as below:



Scar Blow Blister

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

Blow is relatively large cavity produced by gases

which displace molten metal from convex surface.

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

Drop

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

Penetration

This defect appears as an uneven and rough external surface of the casting. It may be caused when the sand has too high permeability, large grain size, and low strength. Soft ramming may also cause metal penetration.

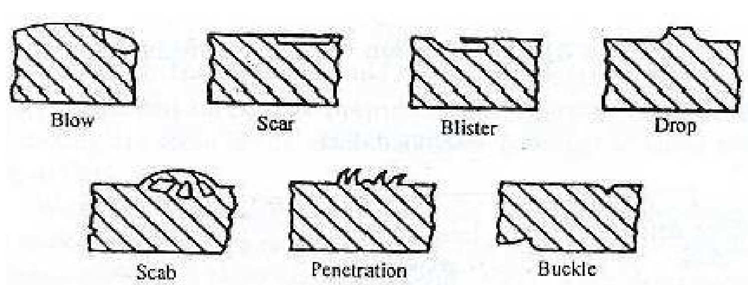


Fig. 1.48(a) Surface Defects

Buckle

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

Porosity

Porosity occurs in materials, especially castings, as they change state from liquid to solid during the manufacturing process. Casting porosity has the form of surface and core imperfections which either effects the surface finish or as a leak path for gases and liquids.

The poring temperature should be maintained properly to reduce porosity.

Adequate fluxing of metal and controlling the amount of gas-producing materials in the molding and core making sand mixes can help in minimizing this defect.

Blowhole

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

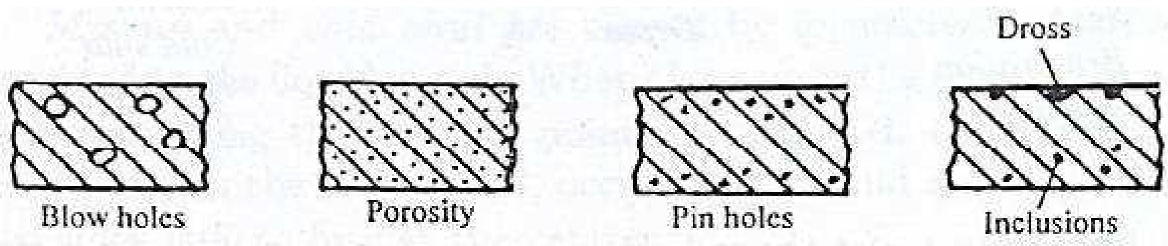


Fig. 1.48(b) Internal Defects

Dross

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

Pin holes

Pin holes are tiny blow holes appearing just below the casting surface.

Inclusions

Inclusions are the non-metallic particles in the metal matrix,

Shrinkage

Shrinkage of molten metal as it solidifies is an important issue in casting. It can reduce the 5-10% volume of the cast. Need to design part and mold to take this amount into consideration. Shrinkage defect can be reduced by decreasing the number of walls and increasing the draft angle.

Wash

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

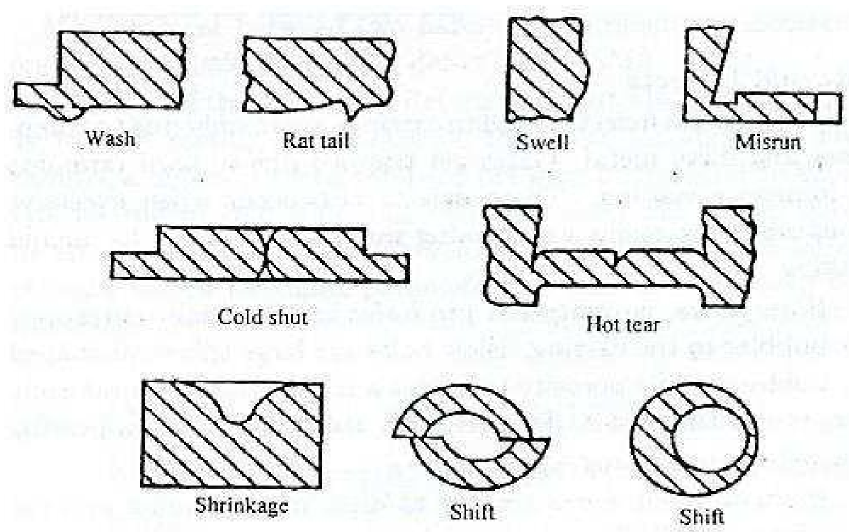


Fig.1.48 (c) Visible Defects

Rat tail

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

Swell

Swell is the deformation of vertical mould surface due to hydrostatic pressure caused by moisture in the sand.

Cold Shut and Mis-Run

A cold shut is a defect in which a discontinuity is formed due to the imperfect fusion of two streams of metal in the mold cavity. The reasons for cold shut or mis-run may be too thin sections and wall thickness, improper gating system, damaged patterns, slow and intermittent pouring , poor fluidity of metal caused by low pouring temperature, improper alloy composition, etc.

Hot tear

Hot tears are internal or external ragged discontinuities or crack on the casting surface, caused by rapid contraction occurring immediately after the metal solidified. Hot tear may be caused when the mold and core have poor collapsibility or when the mold is too hard causing the casting to undergo severe strain during cooling. Incorrect pouring temperature and improper placement of gates and risers can also create hot tears.

Shift

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