FOUNDRY ENGINEERING

6^{TH} SEMESTER, METALLURGICAL ENGG

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CHAPTER 01: INTRODUCTION TO FOUNDRY AS A MANUFACTURING PROCESS

- ***MANUFACTURING*** is the process of shaping, machining & joining the metal together to produce different component.

CASTING is the process of producing metal or alloy component parts of desired shapes by Pouring the molten metal into a prepared mold & then allowing the metal to cool & Solidified.

STEPS INVOLVED IN MAKING CASTING:

1. Making a pattern out of wood/metal/plastic.
2. Making a mold cavity.
3. Metal to be casted is liquefied by properly heating it in a suitable furnace.
4. Liquid is poured into a prepared mould cavity
5. Allowed to solidify
6. Product is taken out of the mould cavity, trimmed and made to shape

ADVANTAGES:

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

DISADVANTAGES:

1. Dimensional accuracy and surface finish of the castings made by sand casting processes are limitations to this technique.
2. Many new casting processes have been developed which can take into consideration the aspects of dimensional accuracy and surface finish. Some of these processes are die casting process, investment casting process, vacuum-sealed moldings process, and shell molding process.
3. Metal casting is a labor intensive process

CHAPTER 02: PATTERN & PATTERN MAKING:

PATTERN:

- It is the replica of the final object to be made, used to prepare the cavity into which molten material will be poured during the casting process.
- Patterns used in sand casting may be made of wood, metal, plastics or other materials.

DIFFERENCE BETWEEN PATTERN & CASTING

- The main difference between a pattern & the casting is their dimension.
- A pattern is slightly larger in size as compared to the casting because a pattern
    - o carries shrinkage allowances(1-2mm/100mm)
    - o Carries machining allowances.
    - o Carries a draft allowances.
    - o Carries a core print.
- A pattern may not have all holes & slots which a casting will have.
- A pattern may be in 2 or 3 pieces where as a casting is in 1 piece.

SELECTION OF PATTERN MATERIAL:

The following factors assist in selecting proper pattern material

□ Number of casting to be produced
□ Metal to be cast
□ Desired dimensional accuracy & surface finished.
□ Shape, complexity &size of casting.
□ Casting design parameters.
□ Type of molding materials.
□ The chances of repeat orders.
□ Nature of molding process.
□ Position of core print.

PATTERN MATERIALS:

The common materials of which the patterns are made are the following:

1) WOOD:

It is the most common material used for pattern making because of the following

ADVANTAGES:

- It is cheap and available in abundance.
- It can be easily shaped into different forms and intricate designs.
- Its manipulation is easy because of lightness in weight.
- Good surface finish can be easily obtained by only planning and sanding.
- It can be preserved for a fairly long time by applying proper preservatives like shellac varnish.

DISADVANTAGES:

- It wears out quickly due to its low resistance to sand abrasion. As such, a wooden pattern cannot stand a long constant use.
- It is very susceptible to moisture, which may lead to its warping or splitting. This needs its careful storing in a dry place and the application of preservatives. Its life, owing to the above reasons, is short as compared to other pattern materials.
- This confines its use to such cases only when a small number of castings are required.

2) METALS:

- Metals are used with advantage, as pattern material, only when the number of a casting to be made is very high and a closer dimensional accuracy is desired. They have a much longer life than wooden patterns and eliminate the inherent disadvantages of wood to a great extent.

DISADVANTAGES:

- They are costlier than wood and, therefore, cannot be used with advantage, where a smaller number of castings is to be made.
- For giving different shapes and fine surface finish they need machining. This again adds to their cost.
- Most of them are very heavy and in case of large castings the weight of the pattern always poses a problem in its manipulation.
- A large number of them have a tendency to get rusted.

3) PLASTER:

- Plaster of Paris or gypsum cement is advantageously used as a pattern material since it can be easily casted into intricate shapes and can be easily worked also.
- Its expansion can be easily controlled and it carries very high compression strength.
- Its specific use is in making small patterns and core boxes involving intricate shapes and closer dimensional control.
- A marked feature of this cement is that contrary to the action of metals, it expands on being solidified. Thus, if a cement of proper coefficient of expansion is selected, the effect of shrinkage of casting can be automatically neutralized.

4) PLASTICS:

- Plastics are gradually gaining favor as pattern materials due to their following specific characteristics:

o Lightness in weight
o High strength.
o High resistance to wear.
o High resistance to corrosion due to moisture.
o Fine surface finish.
o Low solid shrinkage.
o Very reasonable cost.

- The plastics used as pattern materials are thermosetting resins. Phenolic resin plastic and foam plastic suit best for this purpose.
- For making the pattern, first the moulds are made, usually from plaster of Paris. The resin is then poured into these moulds and the two heated. At a specific temperature, the resin solidifies to give the plastic pattern.

5) WAX:

- Wax patterns are exclusively used in investment casting. For this a die or metal mould is made in two halves into which the heated wax is poured. The die is kept cool by circulating water around it. As the wax sets on cooling, the die parts are separated and the wax pattern taken out.

DIFFERENT TYPES OF PATTERN:

The following factors affect the choice of a pattern.

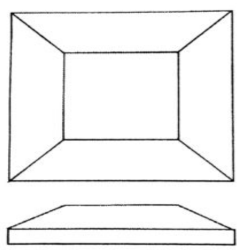
- Number of Castings to be produced.
- Size and complexity of the shape and size of casting
- Type of molding and castings method to be used.
- Machining operation
- Characteristics of castings

THE COMMON TYPES OF PATTERNS:

1. Solid or single piece pattern
2. Split pattern or two piece pattern
3. Multi-piece pattern
4. Cope and drag pattern
5. Match plate pattern
6. Gated pattern

7. Skeleton pattern
8. sweep pattern sand casting
9. Loose piece pattern
10. Segmental pattern
11. Follow board pattern
12. Shell Pattern

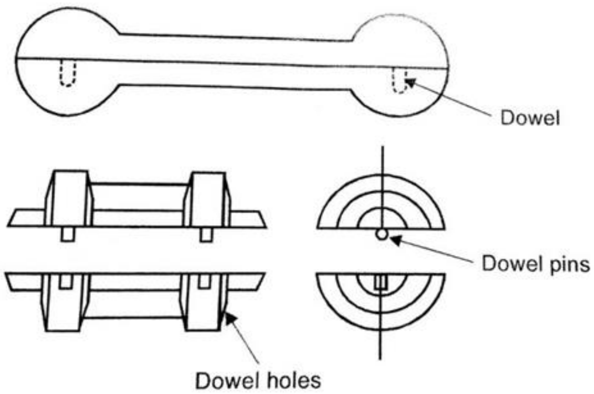
SOLID PATTERN:



(Solid pattern)

- The solid pattern types is a most and simple method for simple shape casting.
- It can make without any sub-part or joint in the mold part.
- In this type of pattern only produce simple shape and withdrawn for very easily from the mold.
- The solid pattern placed in the drag position. That is used for make a flat surface like as gear blanks, square blocks and more.
- Solid pattern made depend on design patterns material, shape and more.

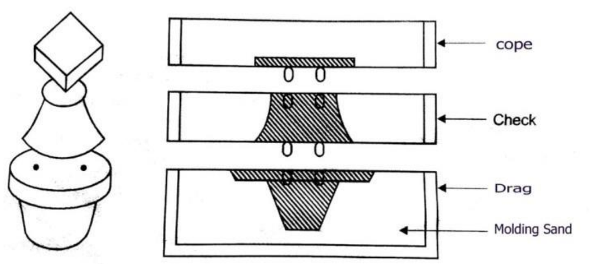
SPLIT PATTERN (OR) TWO PIECE PATTERN



(Split Pattern Diagram)

- When contour of casting manufacture the sand casting pattern making withdraw from the mold is difficult or when the part depth too high in the casting.
- The pattern is split into two half part. For one half is contained in the drag and another one in cope. For intricate shape part manufactured using the two or more pattern pieces.
- The dowel pins used to piece are aligning together. This pattern types is known as split pattern.
- The split pattern is common method for intricate casting part to produce.
- The two halves of pattern to align properly by using dowel pin. It placed on the top half of pattern.

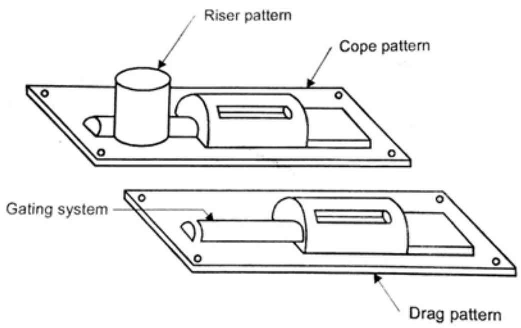
MULTI PIECE PATTERN:



(Multi piece pattern Diagram)

- It is one type of pattern types, when complicated part molded together, to require a sand casting pattern making in more than two parts in order to casting process with easily withdrawal and mold.
- This pattern contain may be three, or more number of pattern based on the design.
- It is having three piece patterns. The top part is cope, bottom is drag and middle part of molding box is called check.
- The three patterns will be connected by using dowel pins and molding box clamped by using clamp.

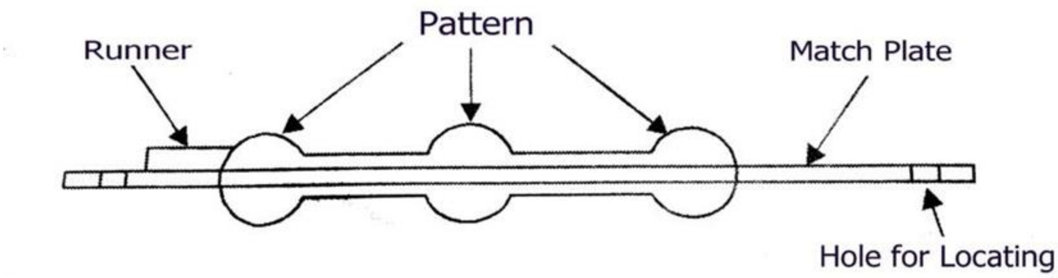
COPE AND DRAG TYPE OF PATTERN:



(Cope and Drag Pattern Types Diagram)

- This pattern types used to provide complicate product.
- The more complicated part to be made, the complete sand casting pattern making become too heavy to be handled by a single operator.
- In this cope and drag type of pattern made in two parts, which separately molded in different molding box.
- After molding process completed to form of complete mold cavity. When the one part is drag and another one is cope. It is called cope and drag.
- It is different from the split pattern because of drag and cope pattern both are molded separately in the assembled position. The cope and drag type of pattern as above diagram.

MATCH PLATE TYPE PATTERN:

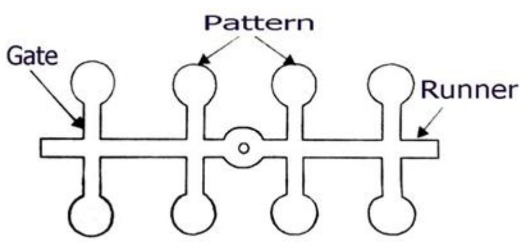


(Match Plate Pattern Diagram)

- The match plate pattern type is having two parts, one for one side and another one for another side of pattern. It is called match plate pattern.
- The sand casting pattern making in two pieces. It also having gates and runner attached with pattern.

- The molding process completed after that match plate removed together, the gating is obtained for joining the cope and drag.
- Pattern is mainly used for casting of metal, usually aluminum are machined in this method with light weight and machinability.
- It should be possible for mass production of small casting with high dimensional accuracy. They are also used for machine molding.
- The cost will be high of molding but it is easily compensated by high rate of production and more accuracy.

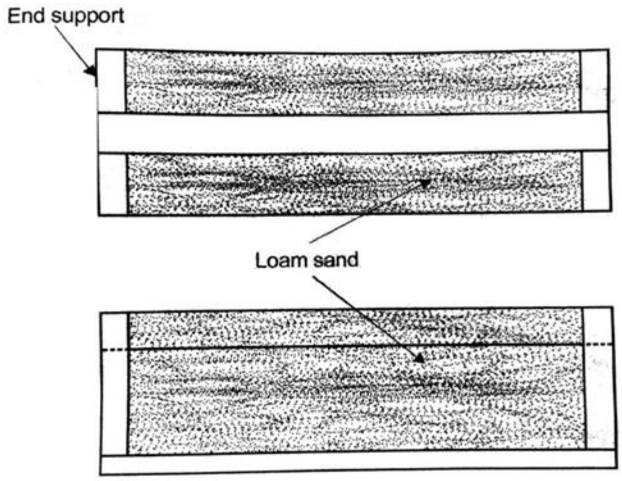
GATED PATTERN:



(Gated pattern Diagram)

- To make multiple parts with in single mold and single pattern for all the part cavity of mold.
- The multi cavity mold is prepared a single sand mold carries a multiple number of cavities. The gates are used to connect the pattern each other.
- The suitable gates or channels are provided for feeding the molten metal into cavity.
- All the cavity are feed by using single runner.
- It mainly consider for low molding time and uniformly feeding of molten metal. It used for mass production of small casting.

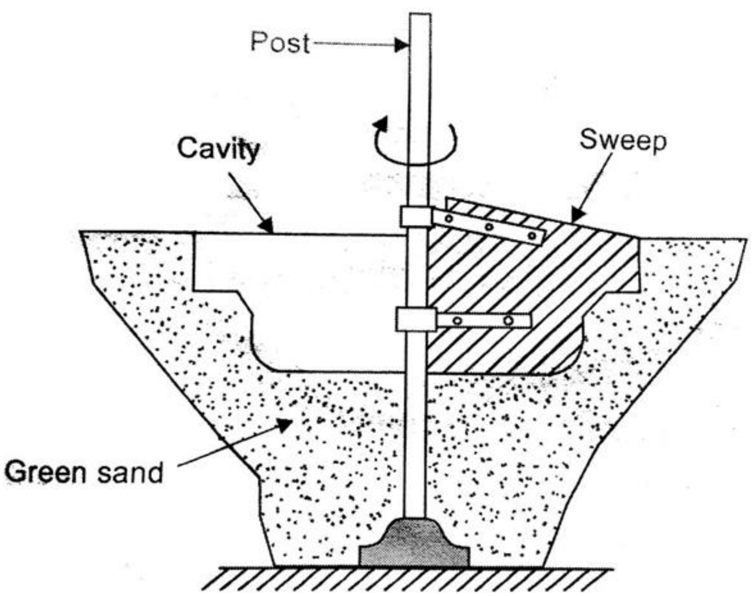
SKELETON PATTERN:



(Skeleton pattern Diagram)

- The casting size is very large but easy to shape and only possible for little number of parts to be made, also not economical with low quantity of large solid pattern of size
- In this stage a pattern consists of wooden frame and strips is made. It is called skeleton pattern.
- The mold is filled properly. The surplus sand is removed together by means of stickler.

SWEEP PATTERN SAND CASTING METHOD:

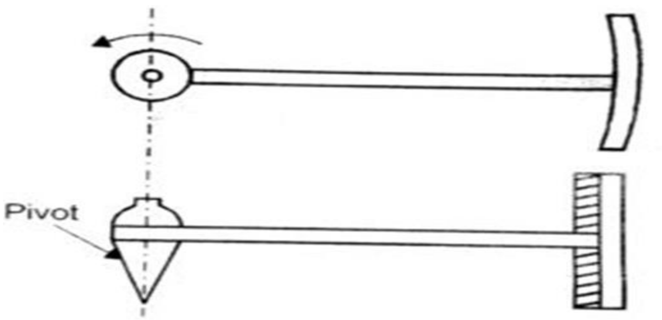


- The plane is rotated about an axis with 360^0 called symmetry or sweep. In this sweep pattern sand castings prepare the sand mold by using this method. It is called sweep pattern.
- It could be economical to save money and make with full pattern because of symmetry.

In this pattern used for prepare the mold of large symmetrical casting by mean of circular cross section.

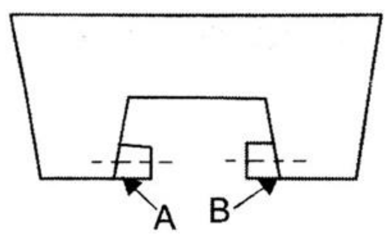
- The sweep pattern sand casting consists of base is placed on the sand mass, vertical spindle and wooden template is called sweep.
- The outer ends of the sweep having corresponding to the shape of require casting.
- The cavity formed together, from sweep is rotated about the axis.
- The sweep and spindle is removed from the cavity for leaving the base in the sand.
- The removal of spindle, in this cause to provide hole and it is patched up by filling the sand.
- Sweep pattern sand casting Method mainly for Circular solid Part make.

SEGMENTAL PATTERN:



- The segmental pattern is used to prepare the mold of larger circular casting to avoid the use of solid pattern of exact size. It is similar to sweep pattern, but the difference from Sweep pattern, the sweep pattern is give a continuous revolve motion to generate the part, the segmental pattern itself and mold is prepared.
- In this segmental pattern construction should be save the material for pattern make and easy carried.
- The segmental pattern is mounted on the central pivot and mold in one position for after prepare of mold the segment is moved for next position. That is repeat together the complete mold is done.

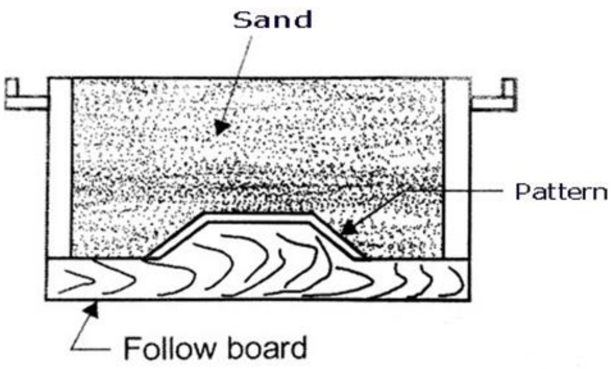
LOOSE PIECE PATTERN:



(Loose Piece Pattern)

- A single piece are made to have loose piece in easy to allow withdrawal from the mold when the molding process are completed, after the main pattern is withdrawn leaving from that piece in the sand.
- After the withdrawal of piece from mold, its cavity separately formed by the pattern.
- Loose piece pattern is highly skilled job and expensive.

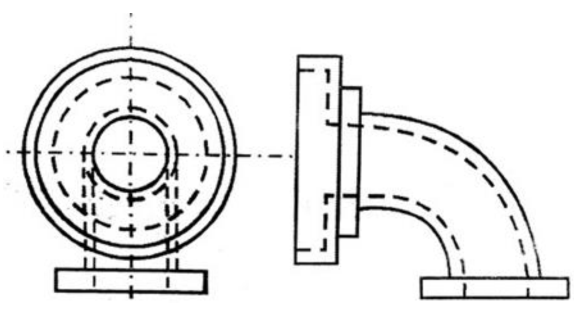
FOLLOW BOARD TYPE PATTERN:



(Follow Board Pattern)

- A follow board is a wooden board & is used for supporting a pattern which is very thin & fragile & which may give way & collapse under the pressure when the sand above the pattern is being rammed.
- It is used for casting master pattern for many applications.

SHELL PATTERN:



(Shell Pattern Diagram)

- Shell pattern is used to molding of hollow shape product with curved or straight.
- It means of pipe work done it process.
- Pattern usually made of metal.
- The pattern parted along with the center line and both halves are doweled.

PATTERN ALLOWANCES:

A pattern is always larger in size as compared to the final casting; because it carries certain allowances due to metallurgical and mechanical reasons. Following are the different types of pattern allowances:

1. Shrinkage or contraction allowances.
2. Machining or finish allowances.
3. Draft or taper allowances.
4. Distortion or camber allowances.
5. Shake or rapping allowances.

SHRINKAGE ALLOWANCES:

- Almost all cast metal shrink volumetrically after solidification & therefore the pattern to obtain a particular shaped casting is made oversized by an amount equal to that of shrinkage.
- Different metal shrink at different rates.
- The metal shrinkage depends upon: the cast metal.
  - (i) Pouring temperature.
  - (ii) Casting dimension
  - (iii) Casting design.
  - (iv) Molding condition

- Shrinkage of metal during casting will takes place in three stages
  - Shrinkage of molten metal when reducing from pouring temp to freezing temp.
  - Shrinkage of molten metal during freezing.
  - Shrinkage solid metal when reducing from freezing temp to room temp
- Liquid shrinkage is always specified by percentage over volume.
- Highest liq. shrinkage = Aluminum (6.60 %)
- Liquid shrinkage is compensated by providing riser during mould making.
- Metal in the riser should solidify in the end.

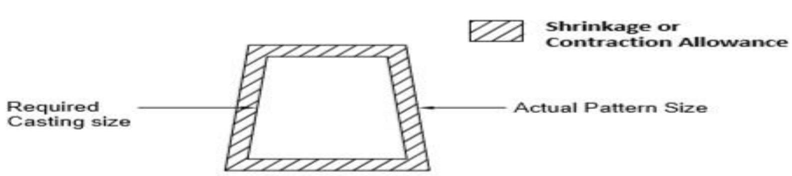


Figure. Shrinkage or contraction Allowance

- Riser volume must be sufficient for compensating shrinkage in casting.

MACHINING ALLOWANCES:

 It is a positive allowance given to compensate for the amount of material that is lost in machining or finishing the casting.

 Casting get oxidized in the mold & during heat treatment thus formed needs to be removed.

 If this allowance is not given, the casting will become undersize after machining.

 The amount of this allowance depends on the size of casting, methods of machining and the degree of finish. In general, however, the value varies from 3mm. to 18 mm.

 How much machining allowances should be provided depends upon the factor listed below.

- Nature of metal
- Size &shape of casting
- Type of machining operation
- Casting condition
- Molding process employed
- Number of cuts to be taken
- The degree of surface finish desired

DRAFT OR TAPPER ALLOWANCES:

 Taper allowance is also a positive allowance and is given on all the vertical surfaces of pattern so that its withdrawal becomes easier.

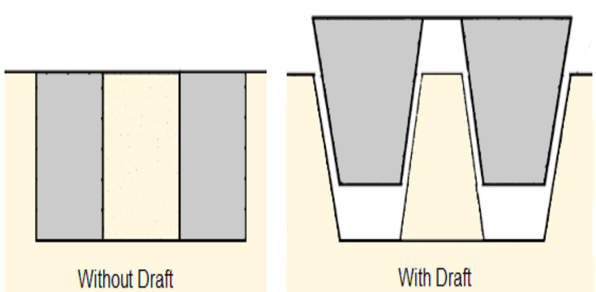
 Inner details of the pattern require higher draft than outer surfaces.

 The normal amount of taper on the external surfaces varies from 10 mm to 20mm/mt.

 On interior holes and recesses which are smaller in size, the taper should be around 60 mm/mt.

 These values are greatly affected by the size of the pattern and the molding method. In machine molding its, value varies from 10 mm to 50 mm/mt.

 Draft allowance varies with the complexity of the job.



 The amount of tapper depends upon:

- Shape & size of the pattern

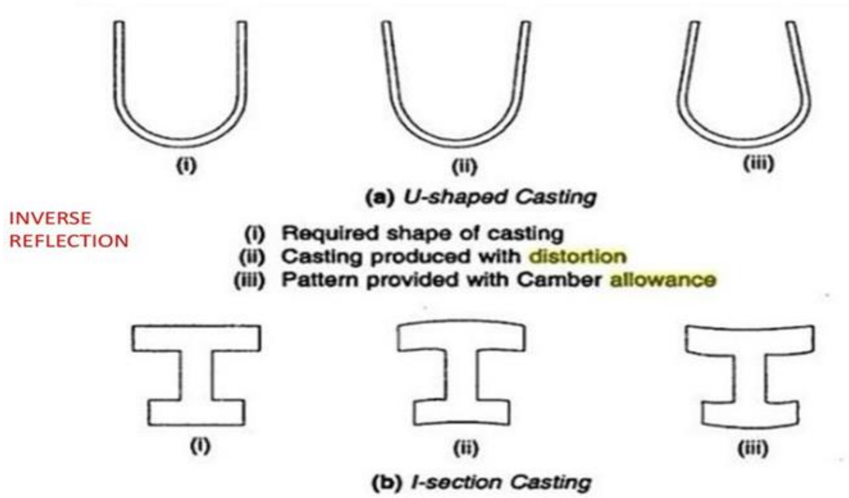
- Molding method
- Mold material

DISTORTION ALLOWANCES OR CAMBER ALLOWANCES

 Does not require on all the castings.

 But it is mainly required in casting of `U' or 'V' shaped castings.

 In case of V or U shape castings because of existence of differential shrinkages at different locations of cavity, the legs will bend outwards producing inclined legs.



 The shape of the pattern itself is given a distortion of equal amount in the opposite direction of the likely distortion direction.

 Done by trial-and-error basis to get the distortion amount.

SHAKE ALLOWANCES:

 Moldings sand adheres to the pattern walls while molding.

 Shake allowance is the wrapping done all around the vertical faces of the pattern.

 It is provided to avoid the damages taking place due to adhering of molding sand to the pattern walls.

 It is highly dependent on mould making person.

 As it reduces the dimension of pattern so it is taken as negative allowance.

 If the pattern is made by using the materials like wax, mercury, polystyrene as Pattern material, no shake allowance to be provided.

CHAPTER 03: MOULDING MATERIAL

A **mold material** should be such that the mold cavity retains its shape till the molten metal has solidified.

SOURCES OF MOLDING SAND:

Following are the Sources of Moulding Sand

- River beds
- Sea
- Lakes
- Desert

TYPES OF MOULDING SAND:

There are basically 3types of molding sand i.e.

1. Natural sand
2. Synthetic sand
3. Loam sand

NATURAL SAND

- Natural sand can be used for making mold as soon as it is received from its sources.
- A natural sand contains binding materials (5-20% clay).
- A natural sand needs only water(5-8%)to mix before making of the mold
- Natural sand can maintain moisture content for a long time.
- Natural sand may contains considerable organic matter.
- Natural sand are employed for casting cast iron & non-ferrous metals.
- Natural sand when mixed with bentonite gets its properties improved & is called as semi synthetic sand.

SYNTHETIC SAND:

A synthetic sand consists of

- Natural sand with or without bentonite
- Binder
- Moisture

Thus a synthetic sand is a formulated sand. It is used for casting steel & other ferrous & non-ferrous alloy.

LOAM SAND:

- Loam sand contains much more clay as compared to ordinary molding sand.
- The clay content is of the order 50% or so.

- The ingredient of loam sand may be
  - ✓ Fine sand
  - ✓ Finely ground refractories
  - ✓ Clay.
  - ✓ Graphite
  - ✓ Fibrous reinforcement
- A typical loam sand mixture contains silica sand20 volumes, clay 5 volumes, manure 1 volumes & moisture 20%.

INGREDIENTS OF MOULDING SAND:

The principal ingredients of moulding sands are:

- Silica sand grains,
- Clay (bond),
- Moisture, and
- Organic additives.

SILICA SAND GRAINS

- ✓ Silica sand grains impart refractoriness, chemical resistivity, and permeability to the sand.
- ✓ They are specified according to their average size and shape.
- ✓ The finer grains would lead to more intimate contact and lower the permeability.
- ✓ However, fine grains tend to fortify the mould and lessen its tendency to get distorted. The shapes of the grain may vary from round to angular.
- ✓ The grains are classified according to their shape as below :
  - Rounded Grain
  - Subangular Grain
  - Angular Grains
  - Compounded Grains

CLAY:

- ➢ Clay is defined as those particles of sand (under 20 microns in diameter) that fails to settle at a rate of 25mm per minute, when suspended in water
- ➢ Clay consists of two ingredients
  - FINE SILT
  - TRUE CLAY.
- ➢ Fine silt is the sort of foreign matter or mineral deposit and has no bonding power. It is the true clay which imparts the necessary bonding strength to the mould sand, so that the mould does not lose its shape after rimming. Most moulding sands for different grades of work contain 5% to 20% clay.

MOISTURE:

- Moisture in requisite amount, furnished the bonding action of clay.
- When water is added to clay, it penetrates the mixture and forms a microfilm which coats the surface of flake-shaped clay particles.
- The bonding quality of clay depends of the maximum thickness of water film it can maintain. The bonding action is considered best if the water added is the exact quantity required to form the film.
- The water should be between 2% to 8%.

ORGANIC ADDITIVES:

1. Miscellaneous materials that are found, in addition to silica and clay in moulding sand are oxide of iron, limestone, magnesia, soda, and potash.
2. The impurities should be below 2%.

PROPERTIES OF MOLDING SAND:

The **basic properties required in molding sand and core sand** are
(i) Adhesiveness
(ii) Cohesiveness
(iii) Collapsibility
(iv) Flow ability,
(v) Dry strength
(vi) Green strength,
Vii) Permeability,
viii) Refractoriness

ADHESIVENESS:

- **Adhesiveness** is a property of molding sand to get the stick or adhere to foreign material such sticking of molding sand with the inner wall of molding box.

COHESIVENESS:

- **Cohesiveness** is property of molding sand by virtue which the sand grain particles interact and attract each other within the molding sand. Thus, the binding capability of the molding sand gets enhanced to increase the green, dry and hot strength property of molding and core sand.

COLLAPSIBILITY:

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

DRY STRENGTH:

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

FLOWABILITY OR PLASTICITY:

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

GREEN STRENGTH:

- The green sand after water has been mixed into it, must have sufficient strength and toughness to permit the making and handling of the mould.
- For this, the sand grains must be adhesive, i.e. they must be capable of attaching themselves to another body and. therefore, and sand grains having high adhesiveness will cling to the sides of the molding box.
- Also, the sand grains must have the property known as cohesiveness i.e. ability of the sand grains to stick to one another. By virtue of this property, the pattern can be taken out from the mould without breaking the mould and also erosion of mould wall surfaces does not occur during the flow of molten metal.
- The green strength also depends upon the grain shape and size, amount and type of clay and the moisture content.

PERMEABILITY:

- Permeability is also termed as porosity of the molding sand in order to allow the escape of any air, gases or moisture present or generated in the mould when the molten metal is poured into it.
- All these gaseous generated during pouring and solidification process must escape otherwise the casting becomes defective. Permeability is a function of grain size, grain shape, and moisture and clay contents in the molding sand.

- The extent of ramming of the sand directly affects the permeability of the mould.
- Permeability of mold can be further increased by venting using vent rods.

REFRACTORINESS:

- **Refractoriness** is defined as the ability of molding sand to withstand high temperatures without breaking down or fusing thus facilitating to get sound casting.
- It is a highly important characteristic of molding sands.
- Refractoriness can only be increased to a limited extent. Molding sand with poor refractoriness may burn on to the casting surface and no smooth casting surface can be obtained.
- The degree of refractoriness depends on the SiO2 i.e. quartz content, and the shape and grain size of the particle.
- The higher the SiO2 content and the rougher the grain volumetric composition the higher is the refractoriness of the molding sand and core sand. Refractoriness is measured by the sinter point of the sand rather than its melting point.

FACING SAND:

- **Facing sand** forms the face of the mould. It is next to the surface of the pattern and it comes into contact with molten metal when the mould is poured.
- Initial coating around the pattern and hence for mold surface is given by facing sand.
- Facing sand have high strength refractoriness.
- Facing sand is made of silica sand and clay, without the use of already used sand.
- Different forms of carbon are used in facing sand to prevent the metal burning into the sand.
- A facing sand mixture for green sand of cast iron may consist of 25% fresh and specially prepared and 5% sea coal.
- They are sometimes mixed with 6-15 times as much fine molding sand to make facings. The layer of facing sand in a mold usually ranges between 20-30 mm. From 10 to 15% of the whole amount of molding sand is the facing sand.

BACKING OR FLOOR SAND:

- The backing sand is old and repeatedly used sand of black colour. It is used to back up the facing sand and to fill the whole volume of the box.
- This sand is accumulated on the floor after casting and hence also known as floor sand.

CORE SAND:

- **Core sand** is used for making cores and it is sometimes also known as oil sand. Core sand is highly rich silica sand mixed with oil binders such as core oil which composed of linseed oil, resin, light mineral oil and other bind materials.
- Pitch or flours and water may also be used in large cores for the sake of economy.

DRY SAND:

- Green sand that has been dried or baked in suitable oven after the making mold and cores is called **dry sand**.
- It possesses more strength, rigidity and thermal stability. Dry sand is mainly used for larger castings.
- Mold prepared in this sand are known as dry sand molds.

PARTING SAND:

- **Parting sand** without binder and moisture is used to keep the green sand not to stick to the pattern and also to allow the sand to the parting surface the cope and drag to separate without clinging.
- Parting sand is clean clay-free silica sand which serves the same purpose as parting dust.

SYSTEM SAND:

- In mechanized foundries where machine molding is employed.
- System sand is used to fill the whole molding flask. In mechanical sand preparation and handling units, facing sand is not used.
- The used sand is cleaned and re-activated by the addition of water and special additives. This is known as system sand.
- Since the whole mold is made of this system sand, the properties such as strength, permeability and refractoriness of the molding sand must be higher than those of backing sand.

SAND PREPARATION:

- Sand preparation means mixing the molding sand ingredients such as sand, binder, moisture, additives.
- The function of sand preparation is to develop optimum properties in molding sand
- And to add adequate amount of water to activate clay binder

SAND CONDITIONING:

- Sand conditioning consists of preparing the mold sand so that it becomes suitable for molding purpose.

SAND RECLAMATION:

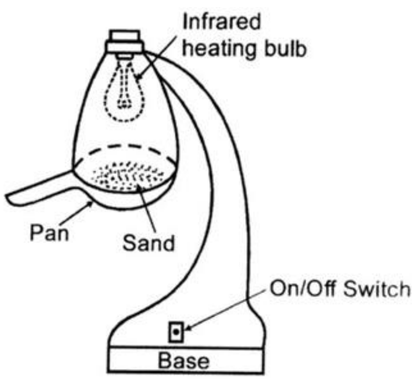
- Sand reclamation means the full recovery of the sand grade for use as a direct substitute for new sand.
- It aims to removing all undesirable objects from the used sand & restores the sand to as nearly its original condition as possible.

TESTING OF MOULDING SAND:

The following sand test method performed to molding.

- Moisture content of sand test
- Clay content test
- Refractoriness sand test
- Strength test
- Permeability test
- Flowability test
- Mould hardness test

MOISTURE CONTENT OF SAND TEST:



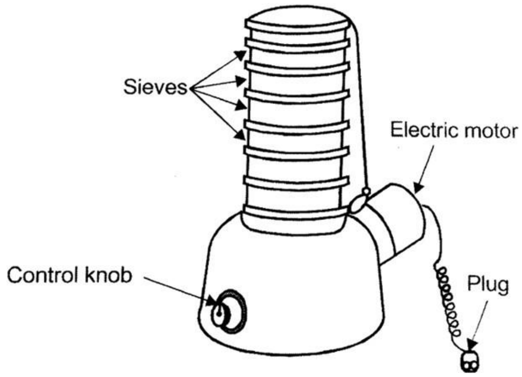
- In this moisture content test method to determine amount of moisture by dry a mold sand weight amount of 20 to 50 grams of mold sand and with constant temperature up to 100^0c above one hour.
- Then cooled with room temperature and reweight the mold sand.
- The moisture content will be evaporated in the sand molding.
- Due to loss of moisture, the weight of molding sand loose together, gives the some amount of moisture expressed as percentage of original sand.
- The moisture content tester as shown in figure. It tester contain the pan with infrared bulb. In this pan above placed weight sand and infrared heating bulb is switched on & determine the time require, the mold sand is weighted together.

CLAY CONTENT TEST:

- The clay content test is determined an amount of clay in test process. In this test to take 20 micron clay particles per 0.0008 inch diameter, dried sample such as molding sand with 50 gm., which is put in distilled water with 1% of NaOH solution.
- In this mixture is stirred for five minutes to allow settle. Then the dirty water is removed together, and process is repeated until to get the clear water.
- In this process washes away all clay in it, the mold sand is dry and weighted the Clay content.

GRAIN FINENESS SAND TEST:

- The grain fineness test method is to find the size of the silica sand particles.



- Fine grain sand associate with good surface finish & strength of mold will high and lower permeability.

- It carried out on dry silica sand weight of 50 gms and free from the clay. When the top sieves of mechanical shaker, the sand is placed with 6, 12, 20, 30, 40, 50, 60, 70, 140, 200 and 270 per mounted on table. In this sieve having meshed together. Its sieve series placed with top to bottom in order of fineness.
- The free silica is shaked together in this shaker within 15 minutes or above after that weight of Sand retained for each sieve is obtains and also retained sand for each sieve multiplied by 2 and give % of weight retained.
- **AFS grain size number=(sum of products/total sum of the percentage of sand retained on pan & each sieve)**

REFRACTORINESS SAND TEST:

- In this test of mold sand is evaluated by heating the standard sand specimen with high temperature based on sand type.
- In this specimen (heated specimen) are to allow cooled to room temperature and it examined along with a microscope for surface characteristic or scratching with steel needle.
- The specimen of sand placed into furnace, then it temperature raise 100^0c to 1300^0c
- And wait 3 minutes and taken from oven for examination use of microscope for evaluate surface characteristic.

CHAPTER 04: BINDERS & ADDITIVES

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

CLAY AS A BINDER:

- When clay is mixed with water it becomes malleable, plastic or liquid, allowing it to be shaped. When drying, clay sets and recovers its cohesive properties, and so can bind the soil together.
- Most soils consist of clay together with proportions of silt, sand and gravel. The larger particles give structure to a soil, while the clay holds it together and to a great extent provides the cohesion.
- The three principal types of clay are:
  - Kaolinite, which is relatively stable and has relatively low cohesion;
  - Illite, which is of average stability and cohesion, and;
  - Montmorillonite, which is highly sensitive to water and has high cohesion.

ADDITIVES:

- Additives are the materials generally added to the molding and core sand mixture to develop some special property in the sand
- Molding and core sands are coal dust, corn flour, dextrin, sea coal, pitch, wood flour, silica flour.

CHAPTER 05: CORE & CORE MAKING

CORE:

- Core is a pre-prepared shape of the mould. It is used to provide internal cavities, recesses, or projections in the casting. It is usually positioned into a mould after the removal of the pattern.
- A core is usually made of the best quality sand and is placed into desired position in the mould cavity. Core prints are added to both sides of the pattern to create impressions that allow the core to be supported and held at both ends.
- Core mix contains clay free silica sand. This is suitably mixed with binders, water and other ingredients to produce a core mix.

CORE CHARACTERISTICS

Good dry sand cores should have the following characteristics:

- Good dry strength and hardness after baking
- Sufficient green strength to retain the shape before baking
- Refractoriness
- Surface smoothness
- Permeability
- Lowest possible amount of gas created during the pouring of casting

FUNCTION OF CORE:

- IT may provide external undercut feature.
- It may form a part of green sand mold.
- It may employed to improve the mold surface.
- It is used to strengthen the mold.

TYPES OF CORES:

- Cores may be classified according to:

A) THE STATE OR CONDITION OF CORE

a) Green sand core:

b) Dry sand core

B) THE NATURE OF CORE MATERIAL EMPLOYED

a) Oil bonded core

b) Resin bonded core

c) Shell core

d) Sodium silicate core

C) THE TYPE OF CORE HARDENING PROCESS EMPLOYED

a. $C0_2$ process
b. The hot box process
c. The cold set process
d. Fluid or castable sand process
e. Nish yam process
f. Furan no bakes system
g. Oil no bake process

D) THE SHAPE & POSITION OF THE CORE

a) Horizontal core
b) Vertical core
c) Hanging core
d) Balanced core
e) Drop core
f) Ram up core

GREEN SAND CORE:

- Green sand cores are formed by pattern itself
- A green sand core is a part of the mold
- It is made out of the same sand from which the rest of mold has been made i.e. the molding sand.

DRY SAND CORE

- Dry sand cores, unlike green sand cores are not produced as a part of the sand.
- Dry sand cores are made separately and independent of that mold
- A dry sand core is made up of core sand which differs very much from the sand out
- A dry sand core is made in a core box and it is baked after ramming.
- A dry sand core is positioned in the mold on core seats formed by core print on the pattern.
- A dry sand core is inserted in the mold before closing the same

OIL BONDED CORE

- Conventional sand cores are produced by mixing silica sand with a small percentage of linseed sand.

RESIN BONDED CORE

- 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

SHELL CORE

 Shell cores can be made manually or on machines

SODIUM SILICATE CORE

 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 is gassed several second with co_2.as a result silica gel is forms which bind the sand grains into a strong solid form Core thus formed posses more strength

HORIZONTAL CORE

- The horizontal core is the most common type of core and is positioned horizontally at the parting surface of the mould.
- The ends of the core rest in the seats provided by the core prints on the pattern.
- This type of core can withstand the turbulence effect of the molten metal poured.

VERTICAL CORE

- The vertical core is placed vertically with some of their portion lies in the sand.
- Usually, top and bottom of the core is kept tapered but taper on the top id greater them at bottom.

HANGING CORE

- The hanging core is suspended vertically in the mould.
- This is achieved either by hanging wires or the core collar rests in the collar cavity created in the upper part of the mould. This type of core does not have bottom support.

BALANCED CORE

- The balance core extends only one side of the mould. Only one core print is available on the pattern for balance core.
- This is best suitable for the casting has only one side opening. This is used for producing blind holes or recesses in the casting.

DROP CORE

 Drop core is used when the core has to be placed either above or below the parting line.

CORE MAKING:

Core making involves the following steps

- Core & sand preparation
- Making the cores

- Baking the cores
- Finishing the cores
- Setting the cores

CORE BAKING:

After cores are made and placed on the core dryer, they are taken to ovens for baking

• Baking removes moisture and hardens core binders

• Generally core sand is a poor conductor of heat and hence heat penetrates slowly into the interior sections of the cores

• In a core having thin and thick sections, the thin sections will be over baked, while thick sections will be optimally baked

• Over baking of cores will result in destroying the binders and hence core will be just a heap of sand

• Large core will be baked differently on the surface and in interiors, especially if the oven is too hot

• Cores that are not baked fully will create an excess of gas and cause blows

EQUIPMENT USED FOR BAKING OF CORES:

IT is categorized as follows

1. Core oven

o Batch type

o Continuous types

2. Dielectric bakers

3. Radiant backers

CORE OVEN:

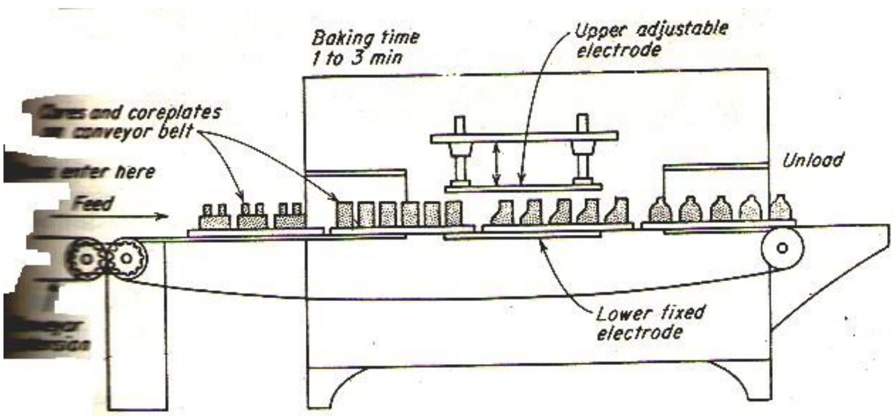
CONTINUOUS OVENS:

- Are those through which the core moves slowly on the conveyor.
- Continuous loading and unloading is followed and hence the baking time is controlled by the rate of travel of the conveyor.
- Generally same sized cores are used in this.

BATCH TYPE OVENS:

- No movement of cores occur
- Electricity, gas, oil are used for heating and temperature is maintained uniformly and closely controlled by suitable instruments.
- Temperature is of the order of 450oF and this depends upon the binder.
- Heating elements are properly spaced to have uniform/same temperature distribution throughout the container.
- Replacing new air from outside is done through blowers so that moisture can be controlled.

DIELECTRIC BAKERS:



• Rapid baking is possible by dielectric heating.
• Induction heating: used for heating materials which are conductors of electricity, like metals, and is done in continuously varying magnetic field.
• Dielectric heating is done for non-conductors of electricity. In this alternating electric field is established between two parallel plates which act as an electric condenser. The material to be heated is placed in between these parallel electrodes
• With a high frequency electric current (15 million times/sec) in ON condition, heat is generated into the molecules.
• IN this case, the interior of the cores are heated rapidly as outer surfaces.
• Thermosetting synthetic resin binders, which cure app. at 250°F and which do not require oxidation are well suited for dielectric heating.
• Small sized samples can be baked within 30 sec, while large sections need few minutes
• Less chance of over baking or under baking.

CHAPTER 06: MOULD & MOULD MAKING

- Molds are negative forms that are used to shape casting materials, creating duplicates of the model (object) the mold was made from. The resulting cast will be an exact likeness of the shape of the hollow mold form.

CHARACTERISTICS OF MOLD:

A mold must:

- Possess refractoriness to bear the high heat of the molten metal
- Possess strength to hold the weight of molten metal.
- Produces a minimum amount of mold gases

DIFFERENT TYPES OF MOLD:

Mold can be classified into following types

1. Green sand mold
2. Dry sand mold
3. Skin dried mold
4. Air dried mold
5. Core sand mold
6. Loam mold
7. Shell mold
8. Cement bonded sand mold
9. Metal mold
10. Investment mold
11. Ceramic mold
12. Plaster mold
13. Graphite mold
14. Sodium silicate mold

METHODES OF MOLDING:

Various methods of molding are as follows:

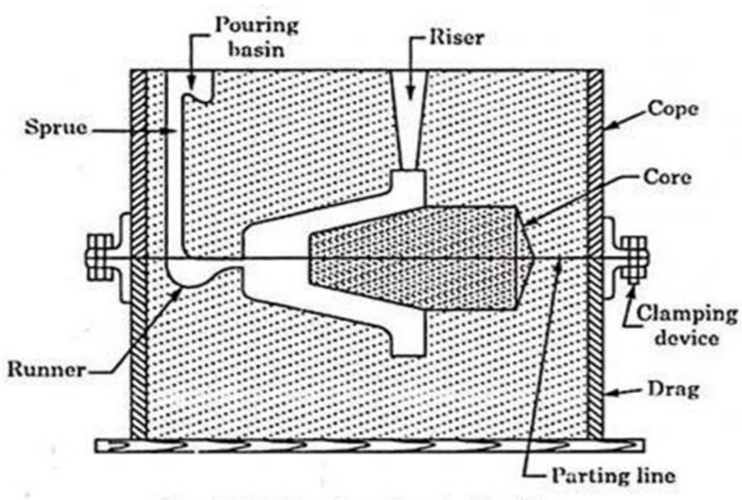
Bench Moulding:

- Bench moulding is carried out on a convenient bench and the moulds prepared are relatively small.
- By bench moulding, green sand, dry sand or skin-dry sand moulds can be made.
- In this, hand ramming with loose patterns is employed and as such, it is a slow and laborious method

Various methods of bench moulding are described below:

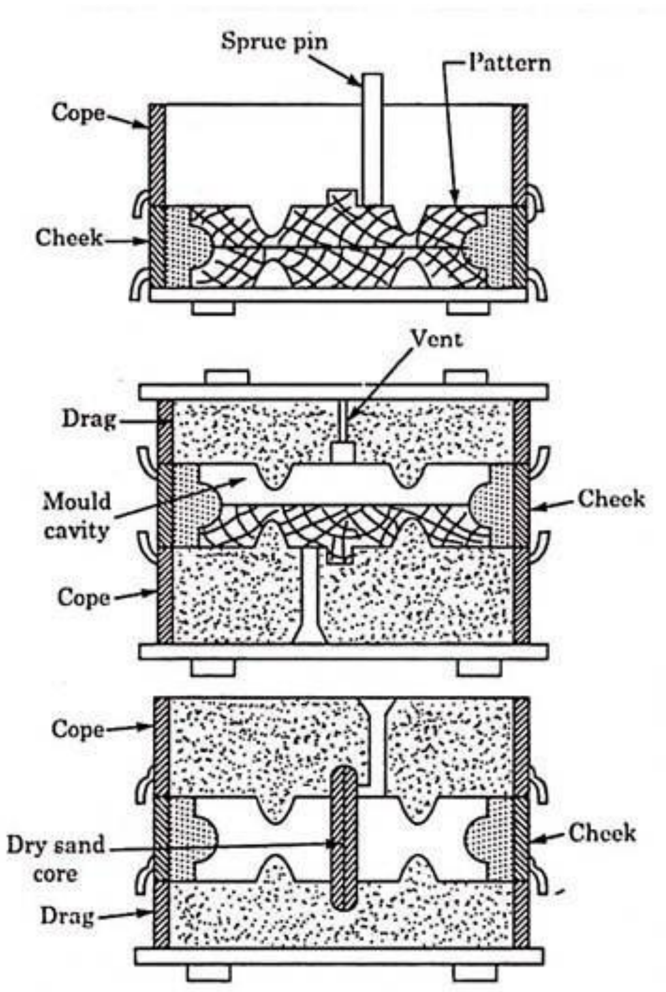
Two Box Moulding:

- It uses the moulding box made in two parts (upper is called cope and lower one drag).
- Two parts are fitted with a suitable clamping and locating device. Clamping prevents the cope from lifting due to the pressure of the molten metal while pouring.
- Locating device enables the two parts to maintain proper alignment at all times.
- In this method, the drag and pattern are placed on the moulding board and the sand is rammed in drag. The drag is then rolled over the board. The other part of the pattern is fitted over bottom one, and cope is placed over the drag.
- Sprue-pin and riser pin are placed in position, and sand filled in the cope and rammed. Mould is vented, sprue and riser pins removed. Mould is then parted off, pattern withdrawn, mould cavity cleaned and gate cut in the drag.
- Core is placed in position and reassembled and clamped to make the mould ready for pouring.



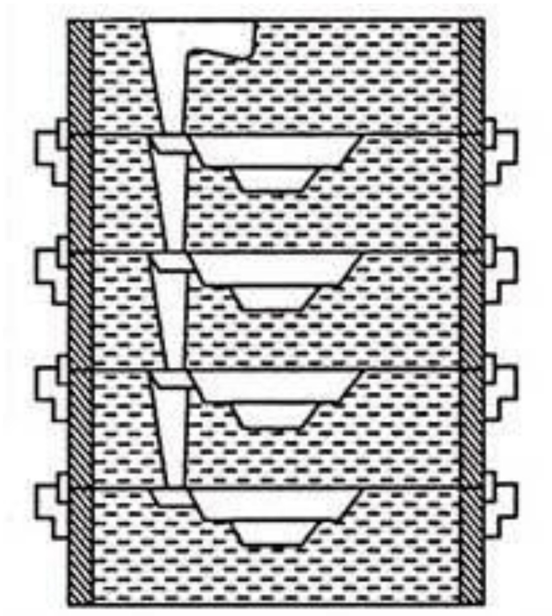
Three-Box Moulding:

- When the pattern is of flanged type, two box moulding becomes inconvenient. To facilitate moulding work in such cases, three boxes are used (middle box being called 'cheek'). During pouring of metal, all the three boxes are clamped properly.



Stacked Moulding:

- When a large number of small size castings are required, each having one flat surface, this method can be used. Both sides of one half of the mould can be made use of by stacking them
- There will be a common passage for the molten metal running through the stock of the intermediate boxes. A number of parts can thus be cast in a single pouring operation



Floor Moulding:

- In this method, the moulding of medium and large moulds is directly carried out on the floor.
- Green sand, dry sand, or skin-dry moulds can be made by this method on the floor with the proper flasks.
- It is also a slow and laborious method as it requires ramming with loose patterns.
- The floor moulding is generally carried out using two part boxes (top and bottom, known as cope and drag). These boxes consist of two stout frames with pins and holes to ensure accurate location. The ground surface is first levelled and half part of pattern placed over it and then box frame is placed around the pattern.
- Box is packed with sand, and sand is rammed and levelled off. The packed box is then turned over and second box placed on top, ensuring correct location by inserting dowel pins into the holes in side lugs on the boxes.
- The other half of pattern is placed over earlier half and sand is filled and rammed in top box and levelled off.
- Two boxes are then opened and pattern is removed. If any repair is required, same is carried out and gates for pouring metal made. If cores have to be located to form holes, these are placed in position.
- Boxes are again put back into position and usually clamped to prevent the upper box floating on the liquid metal.

Plate Moulding:

- The patterns in case of floor moulding are usually constructed of wood and are split on an appropriate horizontal parting-line.
- The two portions of the pattern have to be located together with dowels.
- However, in plate moulding, the pattern consists of a flat plate usually of metal instead of wood for long life, with portions of the pattern permanently assembled in alignment on each side.
- For very large quantity production, and for very heavy castings, two plates may occasionally be used— one to assist in the making of copes, the other for drags.
- The plate incorporates some locating arrangement for the moulding boxes, which could be pegs in the plate, but more usually consists of holes for locating pegs.
- The use of a plate normally calls for moulding boxes which incorporate lugs having holes for location.
- A typical double- sided plate used for hand or machine moulding, and shows how provision is made for six castings from one pouring.
- The plate includes runners, gates, part of pourer and part of riser, thus reducing the time considerably to finish the mould after the extraction of the pattern equipment.
- This method is usually used for large quantity production. The use of a particular plate is restricted to a certain range of moulding boxes.

Pit-Moulding:

- In this method, the moulding is carried out in the pits and generally, very large moulds are made, the pit serving the purpose of flask.
- Generally, green sand is used in pit moulding but cement bonded sand sections may also be used.
- For large moulds, this is the only method of moulding and is quite slow and laborious.

Machine Moulding:

- A variety of machines are used in this method for carrying out the moulding of small, medium and large moulds.
- This method is faster and gives uniform mouldings, but requires mounted patterns. By this method also, green-sand, dry-sand and skin-dry moulds can be prepared.
- Molding machine produce casting of better quality at lower cost.

CHAPTER 07: SPECIAL MOULDING PROCESS

DIFFERENT METHODS OF RAMMING:

- **HAND RAMMING:**
  - IT is used by hand using a rammer.
  - It is laborious &time consuming.
  - It involves low initial cost.
  -
- **SQUEEZING:**
  - A plate is placed on the top of the sand mold and applies the load by using hydraulic or Mechanical press. So, that ramming or compressing of molding sand will be taking place.
  - With the Squeezing operation, higher strength and Hardness of the mold is obtained on **top** and lower strength and hardness is obtained at the bottom**.**

- **JOLTING:**
  - A sand-filled mold is raised to a certain amount of height so that it possesses potential energy.
  - When it is allowed to form freely on to the ground, the Potential energy is converted into Impact energy and Impact loading which is acting on to the ground.
  - Whereas the equal and opposite reaction impact load produced by the ground will be acting on to the mold for ramming and compressing of the mold called as Jolting Operation.
  - Because the force applied by the ground may not be transmitted up to the top of the mold, hence the bottom of the mold is attaining higher strength and hardness.
  - But the top of the mold is possessing lower strength and hardness.

- **SAND SLINGING:**
  - A sand slingers does fast running
  - It rammed uniformly
  - It has high initial cost

CHAPTER 08: MELTING PRACTICES:

- Before pouring into the mould, the metal to be casted has to be in the molten or liquid state. Furnace is used for carrying out not only the basic ore refining process but mainly utilized to melt the metal also.
- A blast furnace performs basic melting (of iron ore) operation to get pig iron, cupola furnace is used for getting cast iron and an electric arc furnace is used for re-melting steel.

FURNACES FOR MELTING DIFFERENT MATERIAL

1. Grey Cast Iron
(a) Cupola
(b) Air furnace (or Reverberatory Furnace)
(c) Rotary furnace
(d) Electric arc furnace

2. Steel
(a) Electric furnaces
(*b*) Open hearth furnace

3. Non-ferrous Metals
(a) Reverberatory furnaces (fuel fired) (Al, Cu)
(i) Stationary
(*ii*) Tilting
(b) Rotary furnaces
(i) Fuel fired
(*ii*) Electrically heated
(c) Induction furnaces (Cu, Al)
(i) Low frequency
(*ii*) High frequency.
(d) Electric Arc furnaces (Cu)
(e) Crucible furnaces (AI, Cu)
(i) Pit type
(ii) Tilting type
(f) Pot furnaces (fuel fired) (Mg and AI)
(i) Stationary
(ii) Tilting

(iii) Non-tilting or bale-out type
(iv) Electric resistance type (Cu

CUPOLA FURNACE:

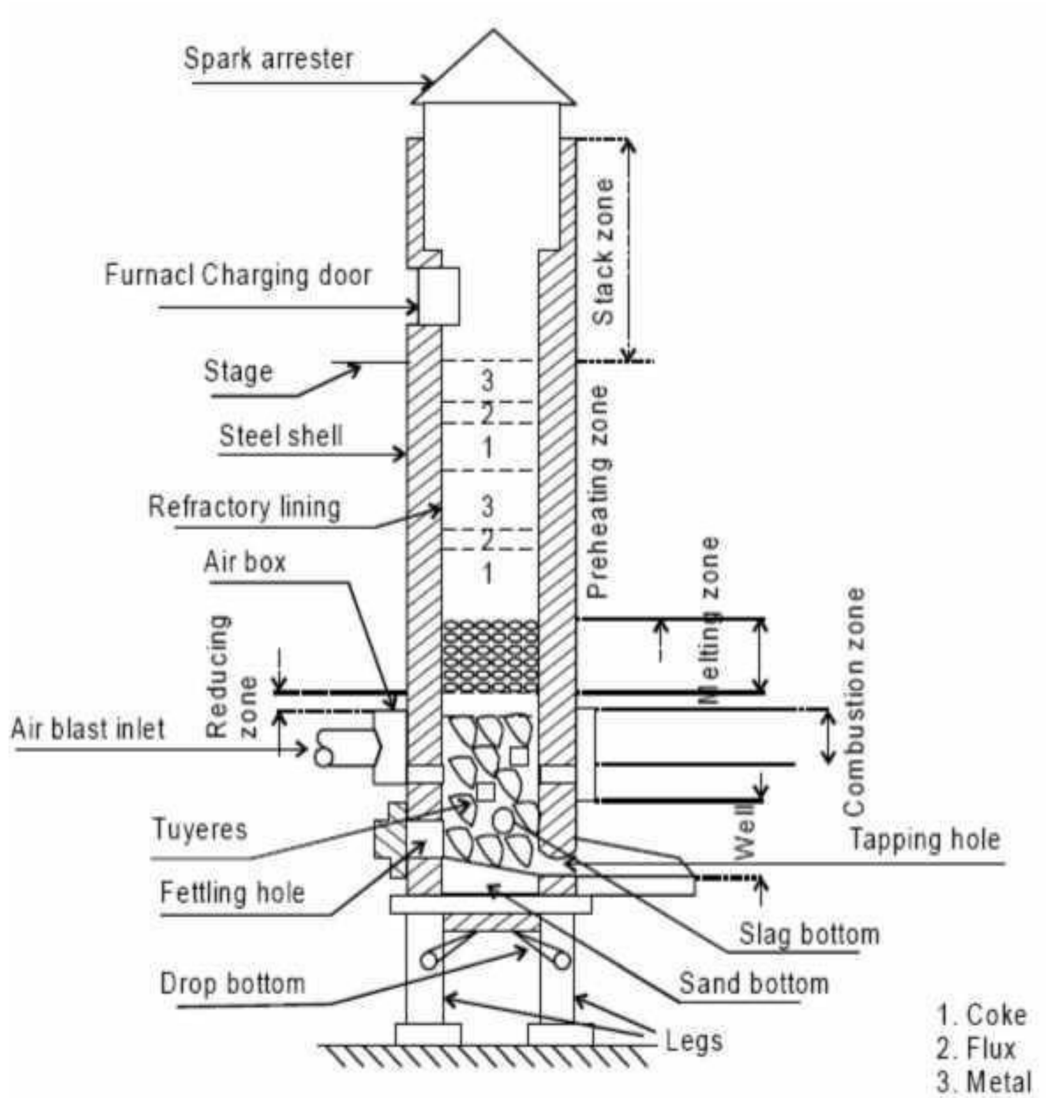
- A cupola is a vertical cylindrical furnace equipped with a tapping spout near its base.
- Cupolas are used only for melting cast irons, and although other furnaces are also used, the largest tonnage of cast iron is melted in cupolas.
- It consists of a large shell of steel plate lined with refractory.
- The charge consisting of 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 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.

DESCRIPTION OF CUPOLA:

- The cupola consists of a vertical cylindrical steel sheet and lined inside with acid refractory bricks. The lining is generally thicker in the lower portion of the cupola as the temperature are higher than in upper portion
- There is a charging door through which coke, pig iron, steel scrap and flux is charged
- The blast is blown through the tuyeres
- These tuyeres are arranged in one or more row around the periphery of cupola
- Hot gases which ascends from the bottom (combustion zone) preheats the iron in the preheating zone
- Cupolas are provided with a drop bottom door through which debris, consisting of coke, slag etc. can be discharged at the end of the melt
- A slag hole is provided to remove the slag from the melt
- Through the tap hole molten metal is poured into the ladle
- At the top conical cap called the spark arrest is provided to prevent the spark emerging to outside

OPERATION OF CUPOLA:

- The cupola is charged with wood at the bottom. On the top of the wood a bed of coke is built.
- Alternating layers of metal and ferrous alloys, coke, and limestone are fed into the furnace from the top.
- The purpose of adding flux is to eliminate the impurities and to protect the metal from oxidation.



- Air blast is opened for the complete combustion of coke.
- When sufficient metal has been melted that slag hole is first opened to remove the slag. Tap hole is then opened to collect the metal in the ladle.

WORKING OF CUPOLA FURNACE:

- Initially the furnace prop is opened to drop the existing earlier charge residue.
- The furnace is then repaired using rich refractory lining. After setting the prop in position, the fire is ignited using firewood and then small amount of coke is used to pick fire.
- The little oxygen is then supplied for combustion. Lime, coke, and metal in balanced proportions are charged through the charging door upon the coke bed and at proper time on starting the blower.
- Air is forced from wind box through tuyers into furnace. The forced air rise upward rough the stack furnaces for combustion of coke. Besides being fuel, the coke supports the charge until melting occurs.
- On increase of temperature, the lime stone melts and forms a flux which protects the metal against from excessive oxidation. Lime also fuses and agglomerates the coke ash.
- The melting occurs and proceeds and molten metal is collected at the bottom.
- Molten metal may be tapped at intervals before each skimming, or the tap-hole may be left open with metal flowing constantly.
- In most cupolas slag is drained from the slag hole at the back of furnace. When metal is melted completely the bottom bar is pulled sharply under the plates and bottom is dropped. All remaining slag, un-burned coke or molten metal drops from the furnace.
- When the melt charge has cooled on closing furnace, it is patched and made ready for the next heat.

ADVANTAGES OF CUPOLA:

- Simple design & easier construction
- Low initial cost
- Simple to operate
- Economy in operation & maintenance
- Less floor space required

DISADVANTAGES OF CUPOLA:

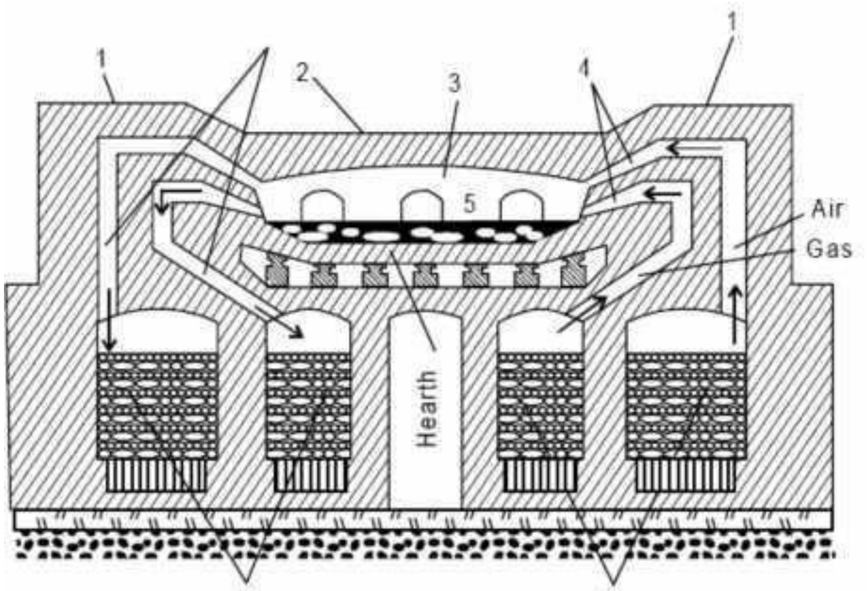
- Close temperature control is not possible
- Carbon & sulphur pickup takes place during melting
- Precise control of composition is difficult

OPEN HEARTH FURNACE:

- In open hearth furnace, pig iron, steel scrap etc. are melted to obtain steel.
- This furnace is widely used in American foundries for steel production.
- The hearth is surrounded by roof and walls of refractory bricks .The charge is fed through a charging door and is heated to 1650°C mainly by radiation of heat from the burning of gaseous fuels above it.

- This heat is obtained by the burning of sufficiently pre-heated air and gas.
- Such pre-heated air of gas is obtained by passing them though arc shaped hot regenerators at a lower level.
- This contains fire bricks which are arranged to extract heat from exhaust gases. In the furnace air and fuel are passed through a honeycomb of hot firebrick, called checkers.
- It preheats the air and fuel so that they are ready for combustion when they enter the hearth. The products of combustion at the same time pass through the checkers at the other end of the furnace.

- The hot gases heat the checkers. The process then reverses itself, and the newly heated checkers now are used to heat the air and the fuel. It is said as a regenerative process.
- The products of combustion after giving up their heat to the checkers pass up through the stack. On firing of coke, the charge is heated. Part of the heat necessary, results from radiation from the low hot roof of the chamber.
- The furnace is raised bricked in with the charging platform, at the rear, also raised so that the charge may be put into the furnace.
- The melt is tapped off the front into large ladles. The chemical composition of the end product depends upon the lining, the charge, and the control impurities added during the melt after the melt has been tapped off into the ladle.
- The lining plays a major role in the control of impurities. For magnetite lined furnace, the charge consists of pig iron, limestone, and scrap iron. The limestone forms a slag.
- This slag and the oxygen in the air combine to remove impurities. The slag reacts with the sulphur and the phosphorus in the metal, while the bubbling air causes oxidation of the carbon and silicon. If too much carbon is present in the melt, iron ore is added.
- The oxygen from the iron oxide burns out the excess carbon. If the carbon content is too low, pig iron is added. This replenishes the carbon. Other alloying elements like Cr, Ni. Co, W, Mo, V etc. are added as needed.
- Ferromanganese may be added to the crucible after tapping. For acid lining furnace, the charge should be scrap iron and low-phosphorus pig iron.
- Limestone is required to keep the slag fluid. As described above, the basic lining burns phosphorus, silicon, and carbon. The slag is tapped off by the molten metal’s being allowed to overflow the sides of the crucible into a slag pot.
- Oxygen is one of the most important elements used in the reduction of the molten metal. Rust, scale, slag, and limestone are some of the sources of oxygen.
- Oxygen is introduced into the furnace with oxygen lances through the roof of the furnace.
- Twice the oxygen input wills double the carbon reduction. This increases the steel production of the furnace.



1. Walls of refractory bricks, 2. Roof, 3. Melting chamber,
4. Air and gas ducts, 5. Charging doors, 6. Checkerwork

ELECTRIC FURNACE:

- Electric arc furnace are employed for the production of high quality casting
- It is used for melting steel
- It has high cost of operation than other but it has to be borne when casting of finest quality is required
- Its furnace atmosphere can be more closely controlled

TYPES:

1. Direct arc furnace

2. Indirect arc furnace

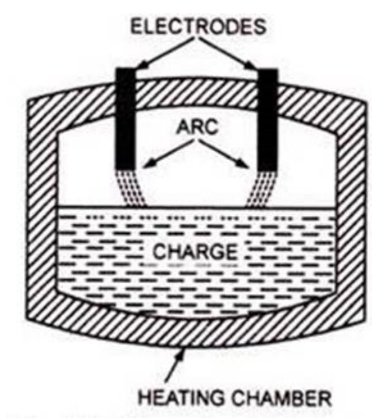
3. Resistance heating

4. Coreless type (or high frequency) induction furnace

5. Core type (low frequency) induction furnace.

DIRECT ARC FURNACE:

- In a direct arc furnace charge acts as one of the electrodes and the charge is heated by producing arc between the electrodes and the charge.
- Since in a direct arc furnace, the arc is in direct contact with the charge and heat is also produced by flow of current through the charge itself, the charge can be, therefore, heated to highest temperature.
- In case of a single phase arc furnace two electrodes are taken vertically downward through the roof of the furnace to the surface of the charge and in a 3- phase furnace three electrodes put at the corners of an equilateral triangle, project on the charge through the roof and three arcs are formed.
- The current passing through the charge develops electromagnetic field and necessary stirring action is automatically obtained by it. Thus uniform heating is obtained.

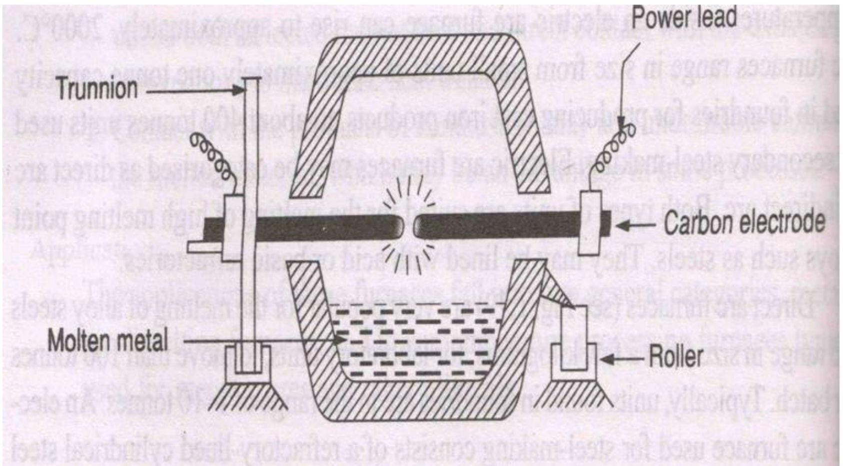


- It is commonly used for production of steel.
- The usually size of such a furnace is between 5 and 10 tonnes, though 50 and 100 tonne arc furnaces have also been developed.

Indirect Arc Furnace:

- An indirect arc furnace consists of a barrel type shell made up of steel plate having refractory lining inside.
- There are 3 opening for the two graphite electrode & the third is the charging door for feeding the metal charge in to the furnace
- Built up with the charging door is pouring spout
- Furnace is mounted on the roller which is driven by a rocking drive unit to rock the furnace back & forth during melting.
- All the pig iron is charged in the furnace & above it scrap is placed.

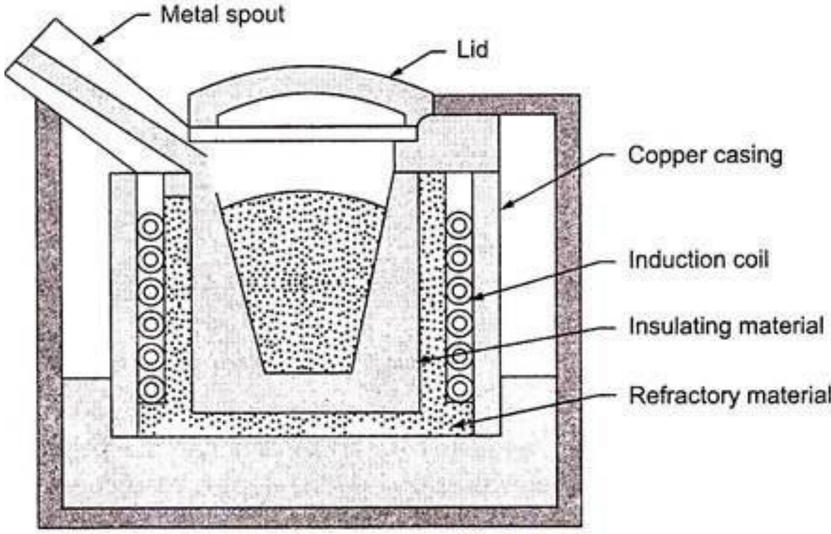
Indirect electric arc furnace



- With electric power on the graphite rod are brought nearer till electric arc set up between them
- The heat is generated & the arc is responsible for melting the charge
- As soon as some metal is melted the furnace is set to rock to & fro for better heat exchange
- When melting is complete the furnace is tilted to permit liquid metal to flow out of the pour

CORELESS TYPE INDUCTION ARC FURNACE:

- A high frequency induction furnace consist of a refractory crucible placed centrally inside water cooled copper coil & packed in to position by ramming dry refractory tightly between the crucible & the copper coil which is recovered with wet refractory dried into hard mass
- Steel scrap is placed in the furnace as metal charge
- A high frequency current is passed through the water cooled copper coil
- Heavy alternating current thus induced in the metal charge by electromagnetic induction which create heat
- The heat developed in the skin of metal charge reaches inside by conduction & melt the charge
- The secondary current associate with it a magnetic field which provide magnetic stirring action on the molten metal speed up the melting process
- Once melted the metal deoxidized & poured into the ladle either tilting or lifting the furnace

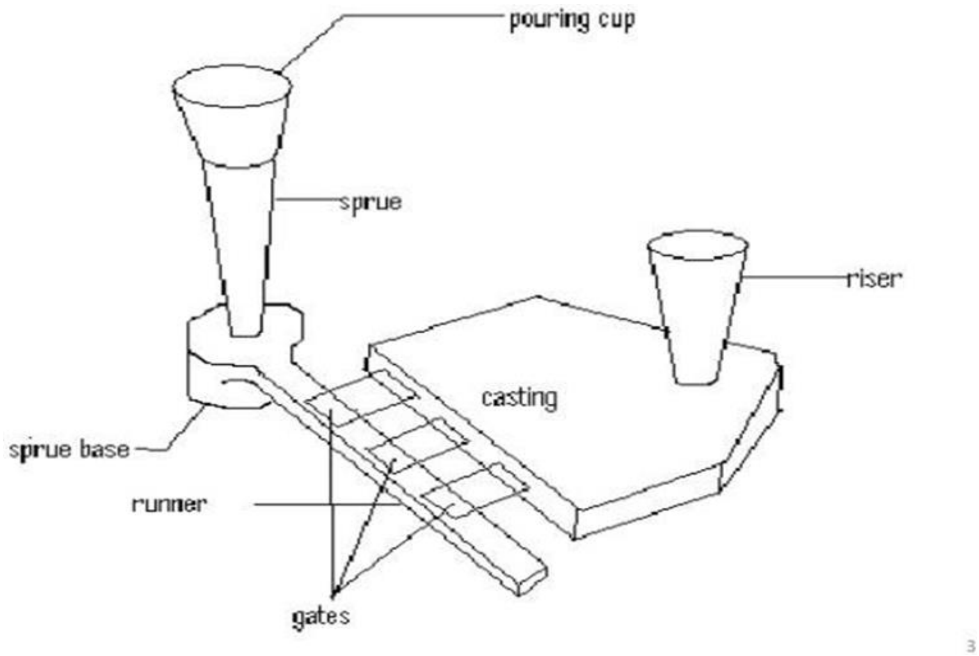


CORE TYPE INDUCTION FURNACE:

- A core type induction furnace operates as an ordinary transformer
- The primary coil has many turn &nit wound on a laminated steel core whereas secondary of the transformer has one turn which is a channel of liquid metal within the furnace
- The furnace uses as alternating current 60cycle per sec
- Secondary current induced in the metal bath around the core & the heat is generated due to electrical resistance of the metal to the flow of secondary current
- Channel of molten metal around the coil connect to the main metal container above which hold the charge
- The metal in channel gets heated ,circulated through & stir the metal in the container &thus melting process proceeds
- Once melted it can be ladled out.

CHAPTER 09: METHODES OF PORING & FEEDING

- Gating system refers to all passageways through which the molten metal passes to enter the mold cavity.
- The main elements needed for the gating system are as follows:
  1. Pouring cup &basin
  2. Sprue
  3. Runner
  4. Gates
  5. Risers



Pouring cup:

- It is circular or rectangular in shape.
- It collects the molten metal, which is poured, from the ladle.
- The main function of a pouring cup is to reduce the momentum of the liquid flowing in to the mould by settling first into it.
- In order that the metal enters into the sprue without any turbulence it is necessary that the pouring basin be deep, also the entrance into the sprue is a smooth radius of at least 25mm.
- The recommended pouring cup depth 2.5 times the sprue entrance diameter is enough for smooth metal flow and to prevent vortex formation.

Sprue:

- It is circular in cross section.
- It leads the molten metal from the pouring cup to the sprue well.
- The sprue should be a vertical taper passage through the cope to gain the velocity of the metal as it flows down reducing the air aspiration and connecting the pouring basin to the runner.
- The taper can obtain by the continuity equation. At Vt = Ac Vc
  Where c = choke section of the sprue t = top section of the sprue

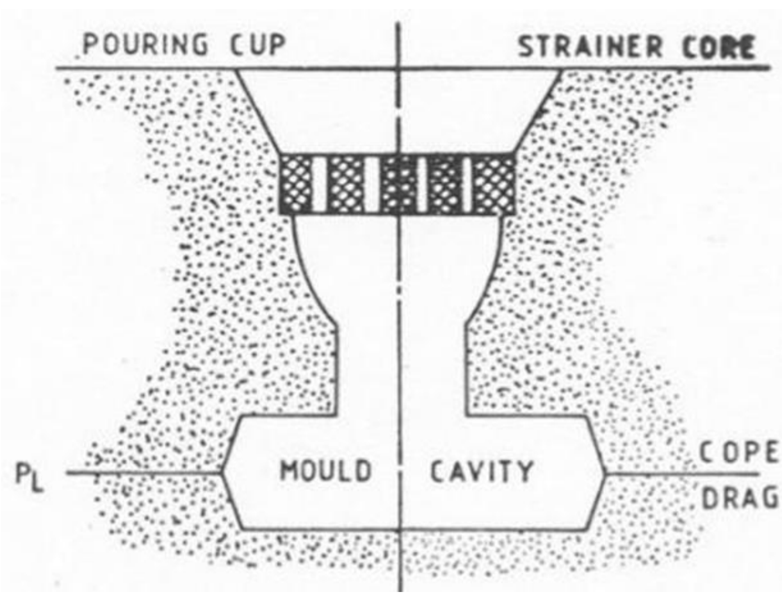
Runner

- The runner takes the molten metal from sprue to the casting.
- This is the final stage where the molten metal moves from the runner to the mold cavity.

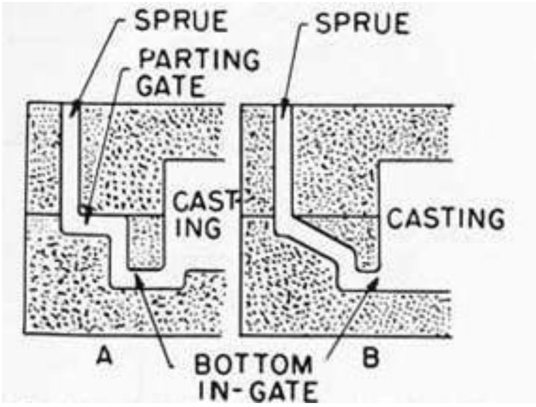
Gate

- This is also called as ingate.
- These are the openings through which the molten metal enters the mould cavity.
- The cross section of the ingate should be such that it can be easily broken off after casting solidification.
- Depending on the application different types of gates are used in casting process.

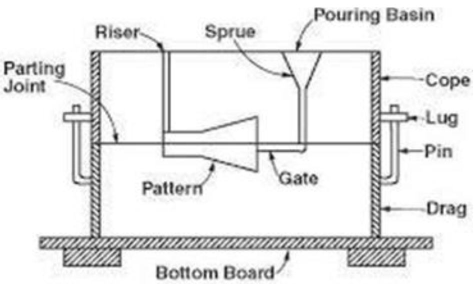
They are shown below



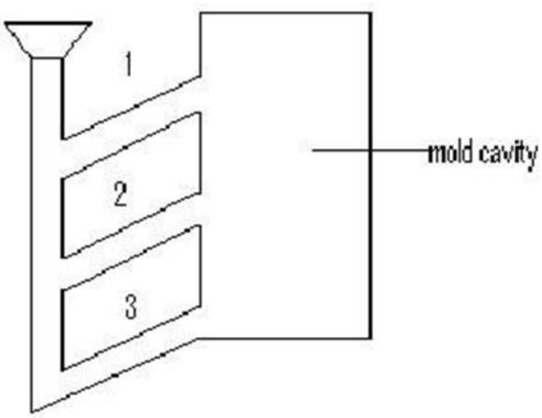
(Top gate)



(Bottom gate)



(Parting line gate)



(Step gate)

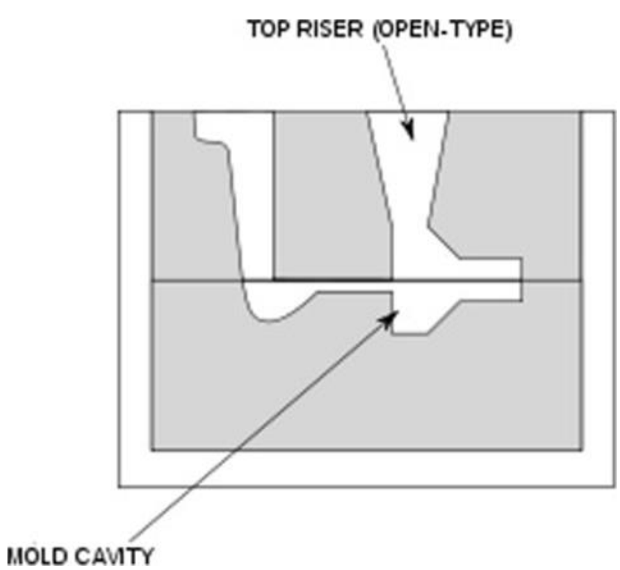
Riser

- Riser is a source of extra metal which flows from riser to mold cavity to compensate for shrinkage which takes place in the casting when it starts solidifying.
- Without a riser heavier parts of the casting will have shrinkage defects, either on the surface or internally.
- Risers are known by different names as metal reservoir, feeders, or headers. The riser must be designed to freeze after the main casting in order to satisfy its function
- The riser must remain molten until after the casting solidifies
- Risers serve dual function, they compensate for solidification shrinkage and heat source. So that they freeze last and promote directional solidification.
- The multiple risers can be provided according to the requirement. The other important aspect of riser design is the connection between the riser and casting. Since it is necessary to separate the riser from casting and it is desirable that the connection area be as small as possible.
- On the other hand, the connection area should be large enough so that the link does not freeze before solidification of casting. Short-length connections are most desirable.

Types of Riser

In casting process there are mainly two types of raisers are used
1. Open riser (Top Riser)
2. Blind riser (Side Riser)

OPEN RISER (TOP RISER):



- The top surface of the riser will be open to the atmosphere.
- The open riser is usually placed on the top of the casting.
- Gravity and atmospheric pressure causes the liquid metal in the riser to flow into the solidifying casting

BLIND RISER (SIDE RISER):

- Blind Riser is completely enclosed in the mould and not exposed to the atmosphere. The metals cool slower and stay longer promoting directional solidification.
- The liquid metal is fed to solidifying casting under the force of gravity alone.
- Blind risers are good design features and maintain heat longer than open risers do

DIRECTIONAL SOLIDIFICATION:

Directional solidification is the solidification of molten metal from the sprue to the mould cavity and then to the riser to produce a casting which is free from voids and internal cavities. As the molten metal cools in the mould and solidifies, it contracts in volume. The contraction of the metal takes place in three stages:

o Liquid contraction;
o Solidification contraction; and
o Solid contraction.

Liquid contraction occurs when the molten metal cools from the temperature at which it is poured to the temperature at which solidification commences.

Solidification contraction takes place during the time the metal changes from the liquid state to the solid, e.g., when the metal loses its latent heat.

Solid contraction spans the period when the solidified metal cools from freezing temperature to room temperature.

Since all the parts of the casting do not cool at the same rate, owing to varying sections and differing rates of heat loss to adjoining mould walls, some parts tend to solidify more quickly than others. This contraction phenomenon causes voids and cavities in certain regions of the casting. These voids must be filled up with liquid metal from the portion of the casting that is still liquid and the solidification should continue progressively from the thinnest part, which solidifies, first, towards the risers, which should be the last to solidify. If the solidification takes place in this manner, the casting will be sound with neither voids nor internal shrinkage. This process is known as **directional solidification**, and ensuring its progress should be a constant endeavor for the production of sound castings. In actual practice, however, it may not always be easy to fully achieve directional solidification owing to the shape and design of the casting, the type of casting process used, and such other factors. In general, directional solidification can be controlled by

- Proper design and positioning of the gating system and risers
- Inserting insulating sleeves for risers
- The use of padding to increase the thickness of certain sections of the casting
- Adding exothermic material in the risers or in the facing sand around certain portions of the castings
- Employing chills in the Moulds
- Providing blind risers

EFFICIENCY OF A RISER:

There are several factor that increase the efficiency of a riser such as

1. Using insulating material
2. Using chills
3. Using exothermic material
4. Use of padding
5. Using chaplet
6. Using moulding material of different chill capacity
7. Using of topping up
8. Using electric arc feeding
9. Proper riser head design

USING INSULATING MATERIAL:

- Solidification in riser or thin section of mold may be delayed by simple insulation
- Insulation can be done by using
- Insulating powder
- Insulating sleeve
- Insulating pad

USING CHILLS

- When the casting consists of both thick and thin sections, the thinner sections tend to solidify earlier than the thicker ones.
- This differential cooling rate produces uneven contraction of parts and gives rise to internal strains in the metal
- It may even produce cracks if the cooling of thinner parts is too severe.

- For rapid solidification of heavy sections and the achievement of directional solidification, which ensures controlled freezing towards the riser, chills are commonly used. Chills, which may be external or internal

USING EXOTHERMIC MATERIAL

- Exothermic materials serve to produce directional solidification by the generation of heat.
- The exothermic material may be added either to the surface of the molten metal in the riser just after pouring or to the sand in the riser walls.
- Due to its contact with molten metal, chemical reaction takes place, producing substantial heat. The metal in the riser thus gets superheated and remains molten for a longer time. It also forms a refractory insulating top on the riser to conserve this heat.
- The exothermic material is a mixture of the oxide of the metal to be cast and aluminum metal in powder form. Each cast metal requires exothermic material which contains its own oxides. A binder-like gelatinous starch is generally used to prepare a self-made mix.
- The exothermic material also serves as an insert in the mould at the desired position to help in controlling directional solidification.
- The material may be molded in the form of a core by mixing it with water and then baking it.
- The exothermic-core is then inserted at a given location. The core retains its shape after the reaction and provides heat insulation to the metal.

PADDING:

- Padding involves modification in the fundamental design of the casting where by thin section are thickened or a taper is introduced to achieve directional solidification
- It involves addition of extra metal to the originally designed section of the casting
- If padding is accepted as design modification it is excellent otherwise the padding provided can be removed by power cutting, grinding or machining.

TOPPING UP:

 Topping up is useful with very heavy casting having long solidification times
 Topping up extends the feeding period
 Topping up involves addition of superheated molten metal into the riser at suitable interval after the mold filled

ELECTRIC ARC FEEDING:

 The metal in an open riser can be kept molten by striking and maintaining an electric arc between a graphite electrode and the riser metal
 Riser metal thus remains in the liquid state and can be fed till the complete casting solidifies.

CHAPLETS

- Chaplets are metal distance pieces inserted in a mould either to prevent shifting of mould or locate core surfaces.
- The distances pieces in form of chaplets are made of parent metal of which the casting is.
- These are placed in mould cavity suitably which positions core and to give extra support to core and mould surfaces.
- Its main objective is to impart good alignment of mould and core surfaces and to achieve directional solidification.
- When the molten metal is poured in the mould cavity, the chaplet melts and fuses itself along with molten metal during solidification and thus forms a part of the cast material

PROPER RISER HEAD DESIGN

Riser Shape and Size

- The most efficient shape a riser can assume is that which will lose a minimum of heat and thereby keep the metal in a molten state as long as possible.
- This condition can be met when the riser is spherical in shape so that its surface area is a minimum.
- For the same volume, the next best shape is a cylinder, and then a square. As it is difficult in practice, to mould a spherical riser, a cylinder is the best shape to employ for the general run of castings.

Riser Location

- The location of the riser should be chosen keeping in view the metal to be cast, the design of the casting, and the feasibility of directional solidification.
- The riser may be located either at the top of the casting or at the side. Top riser is extensively used for light metals as it enables the benefit of metallostatic pressure in the riser.
- Frequently, the number of users has to be more than one so as to derive its most effective use. In such cases, their spacing should be carefully arranged so as to minimize the shrinkage.
- The feeding range, which is the distance a riser can feed the metal in a casting, thus becomes an important consideration in riser design.

CHVORINOVS RULE:

Chvorinov's rule is based on the assumption that freezing time is governed by its (V/A) ratio, where V/A is the ratio of the volume of the casting to its surface area and is known as modulus.
The solidification time of a casting is a function of the volume of a casting and its surface area (**Chvorinov's rule**). Solidification time of a casting is given by the formula:
Where C is the constant that reflects

$$\text{Solidification time} = c\left(\frac{\text{Volume}}{\text{Surface area}}\right)^n$$

(a) The mold material,
(b) The metal properties (including latent heat)
(c) The temperature.

The parameter ‘n’ usually takes the value 2. Sometimes ‘n’ is taken values between 1.5 to 2.

CHAPTER 10: CLEANING OF CASTING

SHAKE OUT:

- ❖ After the molten metal has been poured into the mold it is permitted to cool & solidified, when the casting has solidified it is removed from the molding box. This operation is known as shakeout.

It carried out by following ways

- Dumping the mold assembly upside down on the bench or ground
- Breaking the sand around the casting
- Mechanically shaking out

FETTLING:

❖ Fettling are those operation which helps giving the casting good appearance which when shaken out of the sand mold. It includes

- Removal of the core from the casting
- Removal of adhering sand and oxide scale from the casting surface
- Removal of gate,riser,runner etc. from the casting
- Removal of fins and other unwanted projection from the castings.

CHIPPING BY HAMMER:

- ❖ They are particularly suited in case of grey iron castings and brittle materials.
- ❖ The gates and risers can easily be broken by hitting with the hammer and we when we strike with this hammer.
- ❖ So, these elements of the gating systems can be broken very easily

FLOGGING:

- ❖ Flogging involves the complete elimination of all residual moulding and core sand from the casting surface
- ❖ A small, compressed air power percussion tool is employed to clear the castings hollow part.

SAWING:

- ❖ They are used for cutting the ferrous like steel, malleable iron and for non-ferrous materials except aluminum.
- ❖ Mostly the hand saws are used for small and medium castings, but power saws are used for the heavy castings.

ABRASIVE WHEEL

- ❖ These machines can work with all metals, but are specially designed for hard materials which cannot saw or sheared and it is more expensive than other methods.

FLAME CUTTING:

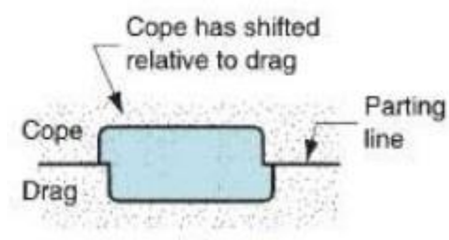
- This type of method is specially used for ferrous materials and large sized castings where the risers and gates are very heavy.
- In this method, the gas cutting flames and arc cutting methods may be employed and it is not for small castings.
- Sometimes there will be heavy castings will be there & the risers may be very big risers with handsaw it may not be possible for to remove that risers at such cases we use the gas cutting flames right.

GOUGING:

- Gouging is an essential part of welding fabrication.
- Used for rapid removal of unwanted metal, the material is locally heated and molten metal ejected - usually by blowing it away.
- Normal oxyfuel gas or arc processes can be used to produce rapid melting and metal removal.

CHAPTER 12: CASTING DEFECT:

MOLD SHIFT:



- Defect caused by displacement of the mold cope in sideward direction relative to the drag. This results in a step in the cast product at the parting line.

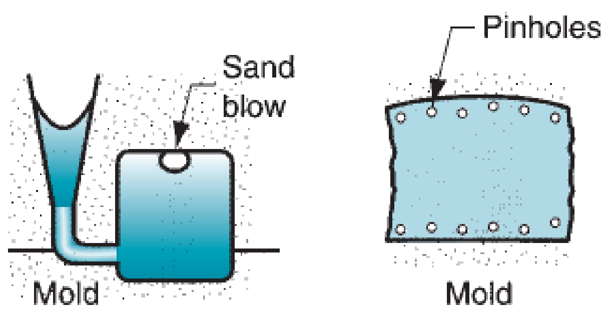
Cause:

- Improper alignment of upper and lower part during mold preparation.
- Misalignment of flask (a flask is type of tool which is used to contain a mold in metal casting. it may be square, round, rectangular or of any convenient shape.)

Remedies:

- Proper alignment of the pattern or die part, molding boxes.
- Correct mountings of pattern on pattern plates.
- Check the alignment of flask

SAND BLOW AND PINHOLES:



- Defect consisting of a balloon-shaped gas cavity or gas cavities caused by release of mold gases during pouring.
- It is present just below the casting top surface.
- Low permeability, bad gas venting, and high moisture content of the sand mold are the usual causes.

Remedies:

- The moisture content in the sand must be controlled and kept at desired level.
- High permeability sand should be used.
- Sand of appropriate grain size should be used.
- Sufficient ramming should be done.
- Adequate venting facility should be provided.

DROP:

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

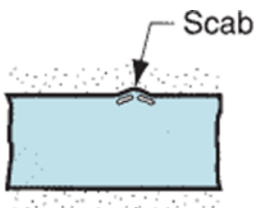
Causes:

- Soft ramming and low strength of sand.
- Insufficient fluxing of molten metal. Fluxing means addition of a substance in molten metal to remove impurities.

Remedies:

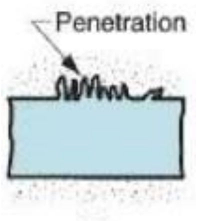
- Sand of high strength should be used with proper ramming (neither too hard nor soft).
- There should be proper fluxing of molten metal, so the impurities present in molten metal is removed easily before pouring it into the mold.
- Sufficient reinforcement of the sand projections in the cope.

SCAB:



It is caused by portions of the mold surface flaking off during solidification and gets embedded in the casting surface.

PENETRATION:



- Surface defect that occurs when the liquid penetrates into the sand mold as the fluidity of liquid metal is high, after solidifying; the casting surface consists of a mixture of sandband metal.
- Harder ramming of sand mold minimizes this defect.

Remedies:

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

Hot Tears or Hot Cracks:

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

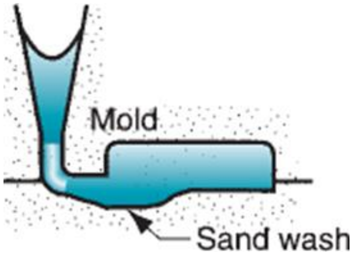
Causes

- Improper mold design.

Remedies

- Proper mold design can easily eliminate these types of casting defects.
- Elimination of residual stress from the material of the casting.

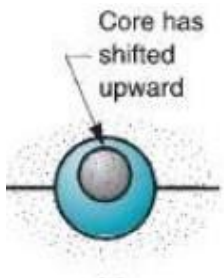
SAND WASH:



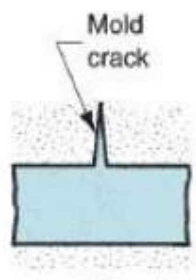
- Surface dips that result from erosion of the sand mold during pouring.
- This contour is formed in the surface of the final cast part.

CORE SHIFT:

Displacement of core vertically. Core shift and mold shift are caused by buoyancy of the molten metal.

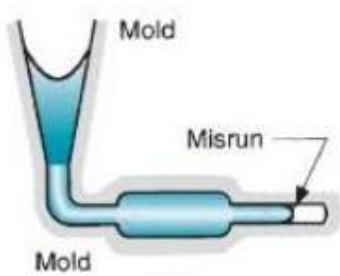


MOLD CRACK:



‘Fin’ like defect in cast part that occurs when mold strength is very less, and a crack develops, through which liquid metal can seep.

MISRUNS:



 Castings that solidify before completely filling the mold cavity.

Causes

 Low fluidity of the molten metal.

 Low temperature of the molten metal which decreases its fluidity.

 Too thin section and improper gating system.

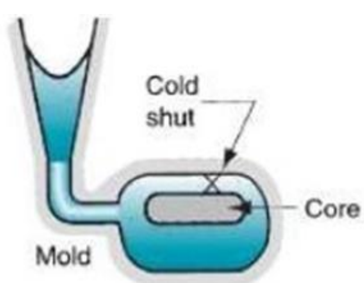
Remedies

 Increasing the pouring temperature of the molten metal increases the fluidity.

 Proper gating system

 Too thin section is avoided.

COLD SHUTS:



 This defect occurs when two portions of the metal flow together but no fusion occurs between them due to premature freezing.

Causes

 Poor gating system

 Low melting temperature

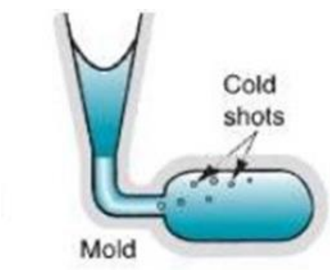
 Lack of fluidity

Remedies

 Improved gating system.

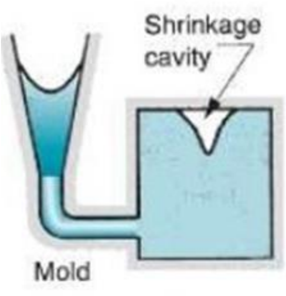
 Proper pouring temperature.

COLD SHOTS:



 Forming of solid globules of metal that are entrapped in the casting. Proper pouring procedures and gating system designs can prevent this defect.

SHRINKAGE CAVITY:



 Cavity in the surface or an internal void in the casting, caused by solidification shrinkage that restricts the amount of molten metal present in the last region to freeze.

 It is sometimes called as ‘pipe’. Proper riser design can solve this problem.

Causes

 Uneven or uncontrolled solidification of molten metal.

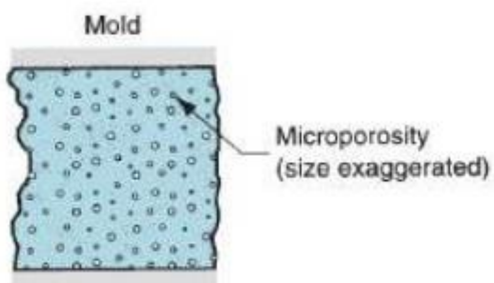
 Pouring temperature is too high.

Remedies

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

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

MICROPOROSITY:



 Network of small voids distributed throughout the casting caused by localized solidification shrinkage of the final molten metal.

HOT SPOT OR HARD SPOT:

 Hot spot defects occur when an area on the casting cools more rapidly than the surrounding materials.

 Hot spot are areas on the casting which is harder than the surrounding area. It is also called as hard spot.

Causes

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

Remedies

 This defect can be avoided by using proper cooling practice.

 By changing the chemical composition of the metal.

DIRT:

 the embedding of particles of dust and sand in the casting surface, results in dirt defect.

Causes:

 Cursing of mold due to improper handling and Sand wash (A sloping surface of sand that spread out by stream of molten metal).

 Presence of slag particles in the molten metal.

Remedies:

 Proper handling of the mold to avoid crushing.

 Sufficient fluxing should be done to remove slag impurities from molten metal.

HONEYCOMBING OR SPONGINESS

 It is an external defect in which there is a number of small cavities in close proximity present in the metal casting.

Causes:

 It is caused due to dirt and scurf held mechanically in the suspension of the molten metal.

 Due to imperfect skimming in the ladle.

Remedies

 Prevent the entry of dirt and scurf in the molten metal.

 Prevent sand wash.

 Remove slag materials from the molten metal by proper skimming in the ladle.

WARPAGE:

 It is an accidental and unwanted deformation in the casting that happens during or after solidification. Due to this defect, the dimension of the final product changes.

Causes:

 Due to different rates of solidification of different sections. This induces stresses in adjoining walls and result in warpage.

 Large and flat sections or intersecting section such as ribs are more prone to these casting defects.

Remedies

 It can be prevented by producing large areas with wavy, corrugated construction, or add sufficient rib-like shape, to provide equal cooling rates in all areas.

 Proper casting designs can reduce these defects more efficiently.

FINS

 A thin projection of metal, not considered as a part of casting is called as fins or fin. It is usually occurs at the parting of the mold or core section.

Causes:

 Incorrect assembling of mold and cores.

 Insufficient weight of the mold or improper clamping of the flask may produce the fins.

Remedies

 Correct assembly of the mold and cores.

 There should be sufficient weight on the top part of the mold so that the two parts

fit together tightly.