Manufacturing Process

* **Definition** : The process of producing the desired object from the raw material is called manufacturing process

* Classification of Manufacturing Processes :

1. Primary shaping Process.
2. Secondary shaping process.

* Primary shaping process :
(a) Casting (b) forging (c) Smithy (d) Drawing
(e) Rolling (f) Bending (g) extrusion (h) shearing
(i) Embossing (j) Staking (k) ironing etc.

* Secondary shaping Process :
(1) machining (2) joining (3) Surface finishing
(4). Process affecting change in properties.

* Casting Processes : These are the only processes where liquid metal is used. Casting is also the oldest known manufacturing process. It requires preparation of a cavity usually in a refractory material to resemble closly the final object to be made. Molten metal is poured into this refractory mould cavity and is allowed to solidify.
The object after solidification is removed from the mould. Casting processes are universally used to manufacture a wide variety of products.
The principal process among these is sand casting where sand is used as the refractory material.
Some general purpose casting processes are :
- Permanent mould casting.
- Centrifugal Casting.

- Die Casting
- Shell mould casting.
- Precision or investment casting.
- Plaster mould casting.

* Forging : This is a solid state manufacturing process carried out at elevated temperatures to deform metal into desired shapes by the application of steady blows or steady pressure.

* Smithy : This involves the production of small objects from raw material which is done by manual labour heating the material in an apex furnace.

* Drawing : This process produces cup shaped parts from sheet metal blanks by forcing it into a die.

* Rolling : This reduces the thickness of work parts by passing it between the rotating rollers having spacing approximately equal to reduced thickness.

* Bending : This deforms the metal under consideration in both tension and compression at values below the ultimate strength of material.

* Extrusion : In this a heated billet or slug of metal is forced by high pressure through an orifice provided into the die.

* Shearing : This includes the stressing of material being cut above its ultimate strength between the adjacent edges.

* Embossing : This impresses raised letters or other designs in sheet metal.

* Staking : It joins the parts together when one part protrudes through a hole in the other.

* Ironing : It is a thinning process in which the walls of a drawn cylinder are passed between a punch and die whose clearance is less than the original wall thickness.

* Machining Process: In these processes the additional unwanted material is removed in the form of clips from the blank material by a harder tool so as to obtain the final desired shape.

Material removal is normally the most expensive process because more energy is consumed and a lot of waste material is generated still this is widely used because it delivers very good dimensional accuracy and good surface finish.

Machining processes are needed because sometimes we need complex shapes, profiles, contours etc.

Different machining operations are:

- shaping: produces flat surfaces in horizontal, vertical o angular planes by using shapes.
- Milling: removes excess (undesired) metal using milling machine tool.
- Drilling: produces holes in workparts with the help of drill
- Grinding: removes undesired material from the workpiece by a powered abrasive wheel, stone, belt, paste, slurry etc
- Boring: enlarges a hole that already has been drilled or co
- slotting: creates slots, grooves and similar recesses in workpieces, including T-slots and dovetails.
- Broaching: machining a surface with a special multipo tool called a broach, whose teeth remove the whole machining allowing in a single stroke.
- Sawing: It is a machining operation in which conveni length or size for machining is cutting off from the bar stock or raw material.
- knurling: produces a regularly shaped, rough surface on a workpiece.

* Surface Finishing Process: These are used to provide a good surface finish to the metal surface of the product.

Various surface finishing operations are:

- Polishing: It is done with a very fine abrasive in loose form smeared on the polishing wheel with the work rubbing against the flexible wheel. A very small amount of material is removed in polishing.

- Electroplating: An electrical process for depositing metal on a conductive surface that uses a cathode in an electrolytic bath containing desolved salts of the metal being desposited is known as electroplating.

- Lapping: is a finishing operation in which a loose fine grained abrasive in a liquid medium abrades the work piece material. It is an extremely accurate process that corrects minor shape imperfections, refines surface finishes and produces a close fit between mating surfaces.

- Painting: It is an operation to give lustre to the surface by using paints. Paints fill the space between crest and roots of the metallic surface and appears smooth.

* Joining Processes: It essentially involves joining two or more pieces of metal parts. Joining can be either temperory or permanent.

Permanent joining processes are:

- Welding: joins two similar or dissimilar metals by fusion, with or without the application of pressure and with or without the use of filler metal.

  welding may be further classified as:

  1. Arc welding.
  2. Gas welding.
  3. Resistance welding. etc.

- Soldering : joins two pieces of a metal in which a fusibl alloy or metal having melting point below 450°C is introduced in a liquid state between the workpiece to be joined with the help of capilliary action.

- Brazing : joins two pieces of metal in which a non-ferrous alloy having melting point above 450°C (bu lower than the melting temp. of parent metal) is introduced (in a liquid state) and filled by capilliary action between the workpieces to be joined.

- Riveting : In this, holes are created between two part to be joined and rivets are placed in holes. Shank of the rivets are converted into heads by hammering and rivet joint take place.

Temperory joining processes are as follows:

- Nut and Bolts Joints : In this method of fastening, tw or more parts are joined ~~tempe~~rosarily by nut and bolt Bolts shanks are having threads. Nuts are having holes and internal threading. Nut will be tightened by passing over the bolt.

- Screwing : is a joining method in which workparts to be joined are having holes. Screws are passed through that hole and tightened.

- Keys and Cotter Joints : keys and cotters are used to join the two parts temporarily.

* Processes Affecting change in Properties : are used to impar certain specific properties to the metal part for specific conditions of use.

Following processes are used for this purpose:

- Annealing : is the process of heating the steel to about 50° to 60°C above the critical temperature, holding it at this temperature for a sufficient time and then slowly cooling it in the furnace.

- Normalising : This process consists of heating of steel to a point 40 to 50°C above its upper critical temp. Hold at that temp. for a short duration and subsequent cooling it in still air at room temperature.

- Hardening: In this, steel is heated to temperature above the critical point, held at this temperature for a considerable time and then quenched (rapidly cooled) in water, oil or molten salts bath.

- Tempering: Tempering of steel is carried out in liquid baths such as oil, salt or lead. The bath is heated upto an adequate predetermined temperature and metal is immersed in this bath for the determind length of time. After that metal is removed and allowed to cool at room temperature.

PROPERTIES OF MATERIALS

Property of material is a factor that influences quantitativel or qualitatively the response of a given material to imposec stimuli and constraints. Different material properties are physical properties, chemical properties, magnetic properties, electical properties, thermal properties and mechanical properties etc.

Here we are concerned only with mechanical properties of the materials.

MECHANICAL PROPERTIES

The mechanical properties of materials define the behaviou of materials under the action of external forces / Loads.

Various mechanical properties of materials are discussed below.

1. Strength:

Strength of material may be defined as the resistanc offered by material or the ability of material to sustai loads without distortion. The stronger the material, the greater the load it can withstand.

Based on the type of external load applied on the material, the strength of material can be classified as Tensile strength, Compressive strength, Shear strengt Bending strength and Torsional strength.

2. Elasticity:

This is the property of material by virtue of which deformation caused by applied load disappears complete on the removal of Load.

Elastic limit of a material defines the greatest load that a material can withstand without some perman distortion. Beyond the elastic limit, removal of load does not bring the material in its original form.

3. Plasticity:

The plasticity of a material is its ability to undergo some degree of permanent deformation without rupture. Plastic deformation takes place after the elastic limit and is reverse of elasticity.

4. Stiffness:

It is also known as Rigidity. Stiffness is the ability of material to resist change in its shape or size.

The degree of stiffness of material is represented by modulus of elasticity (E), also called as Young's modulus

A material with high value of young's modulus (E) is stiffer than the material with lower value of Young's modulus.

5. Malleability:

It is the ability of metal to withstand deformation under compression without rupture. By the virtue of malleability, a material (metal) can be drawn into thin sheets without rupture. This property generally increases with increase in temperature.

6. Ductility:

It is the ability of a metal to withstand elongation (deformation in longitudional direction) under tensile forces without rupture. By virtue of this property, a metal can be drawn into thin wires.

7. Brittleness:

Brittleness is the property of a material by virtue of which it fails or fractures without any appreciable deformation.

An elongation of less than 5% in a 50 mm gauge length is considered as brittle. This is due to lack of ductility.

Brittle materials are glass, cast iron etc.

8. Toughness:

It is defined as the ability of material to withstand bending on application of shear stress without fracture.

It is also defined as the ability to absorb energy and deform plastically before fracture.

Toughness of a material depends on its tensile strength and ductility. Tougness is related to impact strength i.e. resistance to shock loading. Mild steel absorbs much energy before failure than glass, hence tougher than glass.

9. Hardness :

Hardness is defined as resistance of material to penetration or indentation. It may also be defined as resistance to abrasion, scratching or to wear.

Diamond is the hardest known material.

Hard materials are generally chosen for the manufacturing of cutting tools.

10. Resilience :

It is the ability of a material to absorb energy within an elastic limit. This energy is released when external force is removed.

The case of spring is an example of resilient material.

11. Machinability :

It is the property of a material which defines the ease with which it can be machined. In general, it signifies the amount of force and power required for removing stock from a material.

12. Creep :

Creep is defined as the time dependent strain occurring under stress.

It is also defined as the slow plastic deformation of metal under constant stresses usually at high temperature.

13. Fatigue :

When subjected to fluctuating or repeated Loads, a material tend to develop a characteristic behaviour which is different from that (of the materials) under steady Loads. Fatigue is the phenomenon that leads to fracture under such conditions.

14. Formability :

It is defined as the property of a metal which indicates the ease with which it can be formed (i.e, e.g. pressed by forging) into different shapes and sizes.

CLASSIFICATION OF ENGINEERING MATERIALS

- ENGINEERING MATERIALS
  - METALS
    - Ferrous
      - Steel
        - Plain Carbon Steel
        - Alloy steel
        - Stainless steel
        - Tool Steel
      - Wrought Iron
      - Cast Iron
        - Grey
        - White
        - Mottled
        - Nodular
        - Malleable
        - Alloy.
    - Non-Ferrous
      - Aluminium
      - Copper
      - Magnesium
      - Tin
      - Zinc
      - Lead
      - Nickel
      - and their alloys
  - NON-METALS
    - Organic
      - Plastics
      - Wood
      - Paper
      - Rubber
      - Leather
      - Petroleum Products
    - Inorganic
      - Minerals
      - Cement
      - Glass
      - Ceramic
      - Graphite

In this subject (Manufacturing Process), we are concerned with metals only. (according to syllabus)

* Casting : Casting is one of the oldest manufacturing process by which a liquid material (molten metal) is usually poured into a mould, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as casting (final desired product) which is ejected or broken out of the mould to complete the process.

Casting is, therefore, both a process and a product.

* Steps in Casting
1. Pattern and mould making.
2. Melting and pouring the metal.
3. Cooling and solidification.
4. Removal, cleaning, finishing and inspection.

* Stages in Casting
1. The mould is first preheated, through suitable means like torches, to a temperature of about 400°c, followed by the application of a refractory coating on the surface of mould cavity, runner and riser etc.
2. After attaining the correct mould temperature the first casting is poured.
3. The cores are removed as soon as the metal begins to solidify, otherwise it may shrink on the surface of the metal cores to lock them within the casting.
4. The mould is then cleaned by blowing, coated with refractory coating, cores assembled in position and closed again for pouring.

* Advantages of Casting :

- It is the cheapest and best manufacturing process.
- Since molten metal can flow into any small section in the mould cavity and as such any intricate shape (internal or external) can be made with casting process.
- Since it is possible to place required amount of material exactly, weight reduction in design can be achieved.
- Since casting are cooled uniformly from all sides they are expected to have no directional properties
- It is possible to cast practically any material be it ferrous or non-ferrous.
- There are certain materials ~~and~~ alloys which can only be processed by casting and not by forging etc.
- Casting of any size and wt. even upto 200 tons can be made.
- Since the necessary tools required for casting moulds are very simple and inexpensive, for trial production it is an ideal method.
- It eliminates the necessity of joining process of two products.
- Rate of production is higher.

* Disadvantages of casting:

- Less dimensional accuracy and poor surface finish.
- Too much labour is required (particularly in sand casting)
- It is difficult to remove defects arising out of the moisture present in sand casting.

* Applications of Casting:

- In transportation industries
- In communication industries.
- In construction industries.

- In Agriculture Industries.
- In railway industries
- In aircraft industries (jet engines & blades)
- Power generation Industries (very Large turbines, blades of turbines)

★ Stages of Shrinkage in casting:

There are three stages of shrinkage in casting:

1. Liquid stage: The temperature of liquid metal drops from Pouring to Freezing temperature.
2. Change of phase: When the metal changes from liquid to solid state.
3. Solid stage : The temperature of solid phase drops from freezing to room temperature

Shrinkage during stages 1 and 2 are compensated by providing risers.

The shrinkage for stage 3 is compensated by providing shrinkage allowance on pattern.

Pattern Materials

* Pattern : is a model or replica of the desired object to be casted which is used for forming a impression called mould (cavity) in damp sand.

* Different materials are used for making patterns. The selection of pattern material depends on the factors such as:
  - Design of casting.
  - No. of casting.
  - Quality of casting.
  - Types of moulding process.
  - chances of repeat orders etc.

* Requirements of pattern material:

  To be suitable for use, pattern material should be
  - Easily worked, shaped and joined.
  - Light in weight.
  - Strong, hard and durable.
  - Resistant to wear and abrasion, to corrosion and to chemical reaction.
  - Dimensionally stable.
  - Available at low cost.
  - Having ability to take a good surface finish.

* Materials generally used for making patterns are:
  - wood
  - Metals
    - Cast iron
    - Brass
    - Aluminium alloys
    - white metal.
  - Plaster
  - Plastic compound
  - Wax.

★ Wood : is the most common material used for patterns because it satisfies many of the desired requirement. Wood is used for small no. and bigger size castings.

- Required qualities of wood:
  - should be properly dried
  - straight grained
  - free from knots
  - free from excessive sap wood.
- Common wood used in pattern-making are:
  (i) Pine (ii) Deodar (iii) Mahogany (iv) Sal
  (v) Shisham (vi) kail (v) Teak.
- Advantages:
  - cheap
  - Easily workable
  - Light in weight
  - Easily available
  - Easy to join
  - Easy to obtain good surface finish
  - can be easily repaired.
- Disadvantages:
  - Susceptible to moisture
  - Tends to warp.
  - Wears out quickly due to sand abrasion.
  - Weaker than metallic patterns.

★ Metals: Metallic patterns are used where repetitive production of casting is required in large quantities

- Commonly used metals for pattern making are:
  - cast iron
  - Brass
  - Aluminium alloys
  - white metal.

(a) Cast Iron: is used for highly specialised types of patter

- Advantages:
  - Cheap
  - Easy to file and fit.
  - Strong.
  - Good resistance against sand abrasion.
  - Good surface finish.
- Disadvantages:
  - Heavy
  - Easily broken
  - Rust
  - Brittleness.

(b) Brass : commonly used metal for small patterns.

- Advantages
  - Strong, tough
  - Does not rust
  - Better surface finish than cast iron.
  - very thin sections can be cast.
- Disadvantages:
  - Costly
  - Heavier than cast iron.

(c) Aluminium Alloy (80% Al, 14% Zn, 3% Cu, 1.5% Fe, 1.5% Si

- Advantages
  - Easy to cast
  - Light in weight
  - Easily machined
  - does not rust
  - melts at relatively low temperature.
- Disadvantages
  - Softer than brass and Cast iron
  - Easily damaged by sharp edges
  - Storing and transportation needs proper care.

Larger patterns in metals are usually made from Al or its alloys because of their light weight and low cost.

d) White Metal: is used where intricate and fine shapes are required.

- Advantages:
  - Low melting point 260 °C
  - Best material for lining, stripping plates
  - Can be cast into narrow cavities.
- Disadvantages
  - soft
  - Easily worn away by sand or sharp edges.
  - storing and transportation needs proper care.

* Plaster: Its specific use is in making small pattern and core boxes involving intricate shapes.

- Advantages
  - cheap and easily available.
  - Easily workable.
  - Good surface finish
  - light in weight.
- Disadvantages.
  - Expands on solidification
  - strength is not much.

* Plastics: are gradually gaining favour as pattern materials. It finds application for small size castings.

- Advantages:
  - Light in weight
  - High strength
  - low solid shrinkage
  - Dimensionally stable.
  - High resistance to wear
  - Fine surface finish.
  - High resistance to corrosion and moisture.
- Disadvantages:
  - can not withstand high temperature
  - Fragile in nature.

* Wax: Wax patterns are commonly used in investment casting.

- The waxes commonly chosen are
  - paraffin wax
  - shellac wax
  - bees wax
  - cerasin wax.
- Their use helps in imparting a high degree of surface finish and dimensional accuracy to castings.
- Wax pattern need not be drawn out solid from the mould. After the mould is ready, the wax is poured out by heating the mould and keeping it upside down.
- Disadvantage is that each casting requires different pattern.

* Master Pattern: is used for preparing the moulds for metal castings which are later used as patterns for further moulding work.

Master patterns are accurately finished wooden patterns which carry double shrinkage allowance and the required machining allowance.

Types of Patterns

The type of pattern used for a particular casting depends upon many factors like
- the anticipated difficulty of moulding on account of typical shape or design of casting
- number of castings required.
- type of moulding process.
- the bulk of casting.

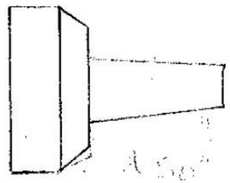
The following types of patterns are commonly used:
1. solid or single piece pattern.
2. Split or two-piece pattern.
3. Multipiece pattern
4. Match plate pattern.
5. Gated pattern.
6. Skeleton pattern.
7. sweep pattern.
8. Pattern with loose pieces
9. Cope and drag pattern
10. segmental pattern
11. Follow board pattern.

* Solid or Single piece pattern:

Patterns made without joints, partings or any loose pieces in its construction is called a single piece or solid pattern.

This is simplest of all the patterns and depending upon the shape, it can be moulded into one or two boxes.

This pattern is cheapest but its use can be done to a limited extent of production only since its moulding involves a large no. of manual operations like gate cutting, providing runners and risers etc. A typical form is shown below

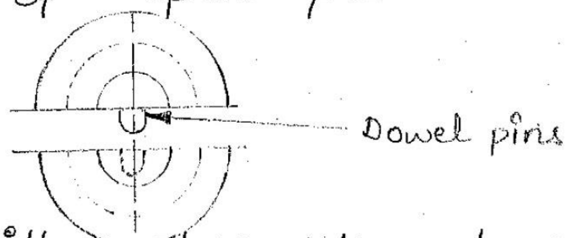


A few examples of castings which are made by making solid patterns are soil tamper, stuffing box and gland of steam engines.

* Split or Two piece pattern:

sometimes patterns can't be made in single piece because of the difficulties encountered in moulding or difficulty in withdrawl from the mould. Because of these, patterns are usually made in two pieces called split patterns.

An example of split pattern is shown below:

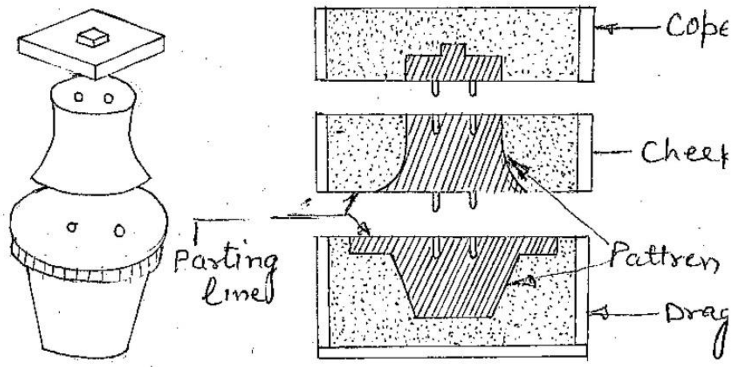


one part will produce the lower half of the mould and the other part will produce the upper half of the mould. These two pieces are held in their proper relative poisition by mean of dowel pins fastened in one piece and fitting holes bored in ~~ano~~other. The surface which is formed at the line of seperation of the two parts, usually at the centre line of pattern is called as parting line or parting surface.

spindles, cylinders, steam valve bodies, water stop cocks and taps are few examples of split patterns.

* Multipiece Pattern :

Castings having a more complicated design require the pattern in more than two parts in order to facilitate an easy moulding and withdrawl from the mould. Their patterns may consist of 3, 4 or more no. of parts depending on their design. A typical example of such a pattern is shown below:

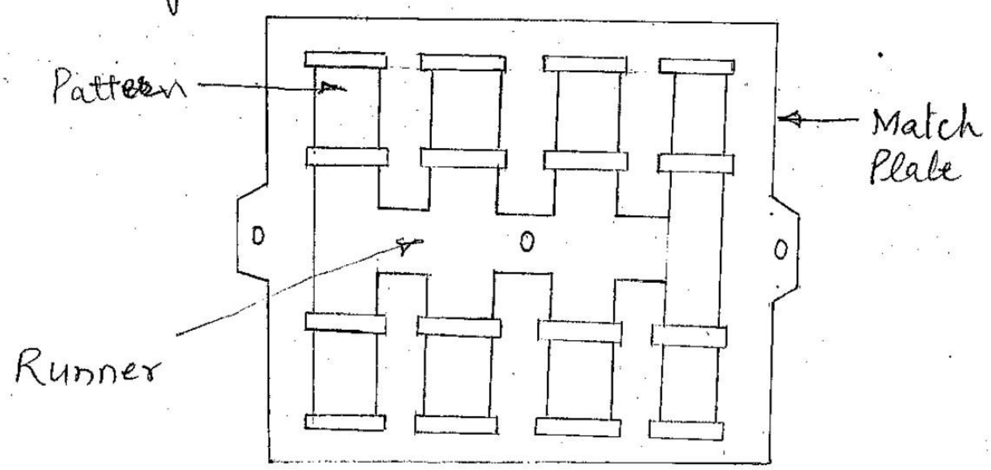


* Match Plate Pattern :

These patterns are used where a rapid production of small and accurate casting is desired on a large scale. These patterns find a great favour in machine moulding and minimum machining requirement. Their construction cost is quite high.

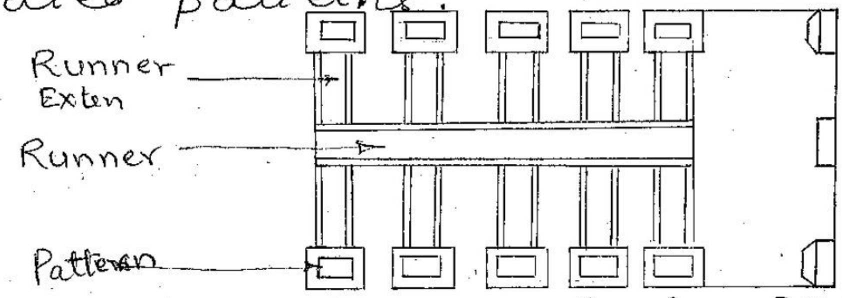
In this split patterns are mounted with one half on one side of a plate (Match plate) and other half directly opposite to the other side of plate, called match plate.

The plate may carry only one pattern or a group of patterns mounted in the same way on its two sides. The plate may be of wood, steel, magnesium or alumininium. Gates and runners are also attached to the plate alongwith pattern.



* Gated Pattern:

They are also used in mass production of small casting. To produce good casting, it is necessary to ensure that full supply of molten metal flows into every part of the mould. Provision for easy passage of the flowing metal in the mould is called gating and is provided in the gated patterns.



In gated patterns, a single sand mould carries a no. of cavities. Patterns for these cavities are connected to each other by means of gate formers which provide suitable channels (path) or gates in sand for feeding the molten metal to these cavities. A single runner can be used for feeding all the cavities.

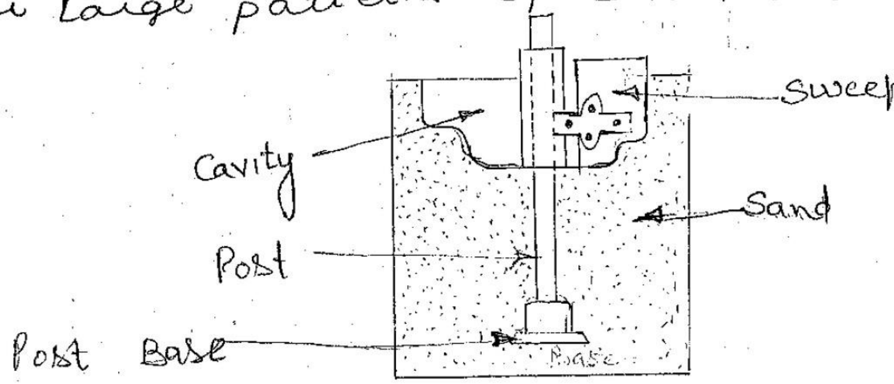
For small quantities, these patterns may be made of wood, but for large production metallic patterns are preferred.

* Sweep Pattern:

Sweeps can be advantageously used for preparing moulds of large symmetrical castings, particularly of circular cross section.

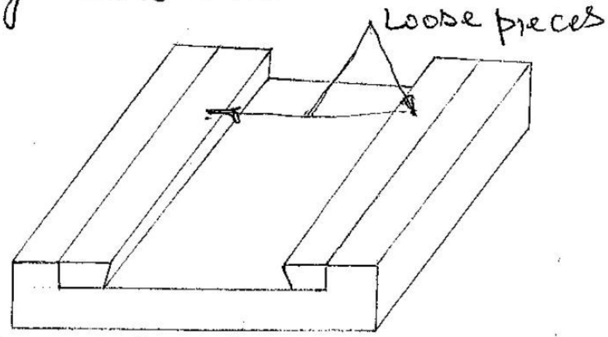
Sweep pattern is just a form made on a wooden board which sweeps the shape of the casting into the sand all around the circumference. The sweep pattern rotates about the post.

Once the mould is ready sweep pattern and the post (spindle) can be removed. These are used for large patterns of cast iron, ridges etc.



* Pattern with Loose Pieces:

Certain patterns can't be withdrawn once they are embedded in the moulding sand. Such patterns are usually made with one or more loose pieces for facilitating their removal from the moulding box and are known as loose piece patterns.



Loose parts or pieces remain attached with the main body of pattern, with the help of dowel pins.

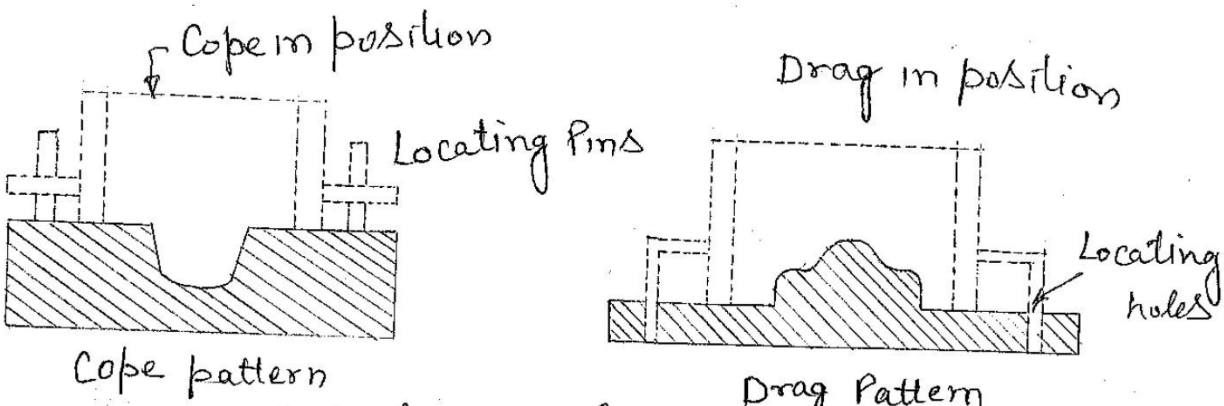
The main body of the pattern is withdrawn leaving the pieces in the sand, which are later withdrawn separately through the cavity formed by the pattern.

Loose piece pattern involves more labour and more cost.

* Cope and Drag Pattern:

It is another form of split pattern but the patterns are very large in size. Each half of the pattern is moulded separately in a seperate moulding box.

Each half of the pattern is fixed to a seperate metal/wood plate.



Cope & Drag Pattern

Each metal plate besides the pattern, has the provision for runner and gates. The two moulds of each half of the pattern are finally assembled and the mould is ready for pouring.

Cope and drag patterns are used for producing big castings which as a whole cannot be conveniently handled by one moulder alone.

* Functions of a Pattern:

- A pattern prepares a mould cavity for the purpose of making a casting.
- To produce seats for cores in the moulds so need core prints on the patterns.
- Runner, gates and risers may form a part of the pattern.
- Pattern establishes the parting line and parting surfaces in the mould.
- Patterns properly made and having finished and smooth surface reduce casting defects.
- A pattern may help in establishing locating pins on the mould and therefore on the casting with a purpose to check the casting dimensions.
- Properly constructed patterns minimize the overall cost of the casting.

Difference between pattern and Casting

- The material of pattern is not necessarily same as that of casting. Pattern may be made from wood.
- The colour of the pattern may not be same as that of casting.
- Pattern carries an additional allowance to compensate for metal shrinkage.
- It carries additional allowance for machining.
- It carries the necessary draft to enable its easy removal from the sand mass.
- It carries distortion allowance. Due to distortion allowance, the shape of pattern is opposite to casting.
- Pattern may carry additional projection called core prints to produce seats for cores.
- Pattern may be in pieces (more than one piece) whereas casting is in single piece.
- sharp changes are not provided on the patterns. These are provided on the casting with the help of machining.
- Surface finish may not be same as that of casting.

* Advantages of Metal Patterns:

1. Unlike wooden patterns, they do not absorb moisture.
2. They retain their shape.
3. They are more stronger and accurate as compared to wooden pattern.
4. They posses life much more longer than wooden patterns.
5. They can withstand rough handling.
6. They do not wrap.
7. They possess greater resistance to abrasion.
8. They are far stable under different environments
9. They have good machinability characteristics

* Limitations:

1. Expensive as compared to wooden patterns
2. Are not easily repaired (Aluminium patterns)
3. Ferrous patterns get rusted.
4. Ferrous patterns are heavier than wooden patterns.

Pattern Allowances.

A pattern is always made larger than the required size of the casting in order to allow for various factors, such as shrinkage, machining, distortion and rapping etc.

The following allowances are provided in a pattern:

1. Shrinkage allowance:
   As a metal solidifies and cools, it shrinks and contracts in size. This contraction takes place in three forms, viz., liquid contractions, solidifying contractions and solid contraction. The first two are compensated by gates and riser and at last one providing adequate allowance in the pattern.
   A pattern is made larger than a finished casting by means of shrinkage or contraction allowance.
   Contraction is different for different metals.

Metal	Allowance mm/metre
cast iron (Grey)	10·5
cast iron (white)	21·5
steel	21·0
Brass	16·0
Aluminium	16·0
zinc	24·0
Lead	24·0
Tin	7·0
silver	10.0
copper, Nickel and Magnesium	16·0

The total contraction is volumetric but the shrinkage allowance is added to the linear dimensions.

2. Machining or Finish Allowance:

For good surface finish, machining of casting is required. For machining, extra metals are needed. This extra metal is called machining or finish allowance.

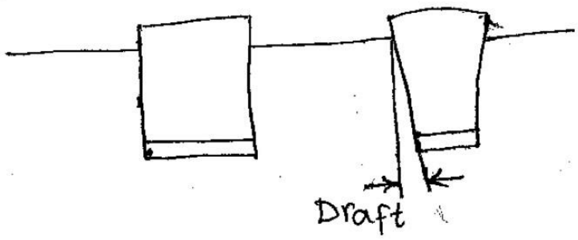
The amount of this allowance varies from 1.5 to 16 mm which depends upon the type of casting metal, size and shape of casting, method of casting used, method of machining to be employed and degree of finish required.

This allowance is given in addition to shrinkage allowance.

3. Draft or taper allowance:

At the time of withdrawing the pattern from the mould, the vertical faces of the pattern are in continual touch/contact with the sand, which may damage the mould cavity. This danger is greatly decreased if the vertical surfaces of a pattern are tapered inward slightly.

The slight taper inward on the vertical surface of a pattern is known as draft.

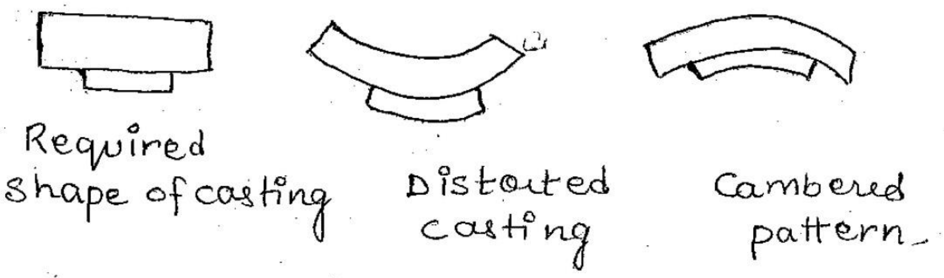


It may be expressed in milimeters per metre on a side or in degrees. The amount of taper varies from ½ to 1½ degrees. The taper on inner surface must be greater than on the outside surfaces.

4. Distortion or Camber Allowance:

If the shape of the casting changes that is called distortion of the casting. A casting will distort or warp, if

- It is of irregular shape.
- All its parts do not shrink uniformly.
- It has long flat casting.
- The arms possess unequal thickness.



Distortion can be practically eliminated by providing an allowance and constructing the pattern initially distorted.

5. Rapping or Shake allowance:

When a pattern is rapped (shaped) in the mould before it is withdrawn, the cavity in the mould is slightly increased. So in order to compensate this, pattern is made slightly smaller than the actual. This is called shaking or rapping allowance.

The magnitude of shake allowance can be reduced by increasing the taper.

6. Mould wall movement Allowance:

Movement of mould wall in sand moulds takes place because of heat and the static pressure exerted on the walls of the mould which comes in contact with molten metal.

Because of this, the size of the mould cavity increases. In order to compensate this, the size of pattern is made smaller so that the casting produced have an accurate size (i.e. desired size)

* All allowances except Shake Allowance and Mould wall movement allowance are positive but both of these are negative.

Size of Pattern may be calculated for a required casting is as given below

Size of casting + Shrinkage allowance + Machining allowance + Taper or draft allowance + Distortion allowance - Shake allowance - Mould wall moment allowance.

Mould

Mould: A mould is a void or cavity created in a compact sand mass with the help of pattern. When filled with molten metal it produces the casting.

Moulding: The process of making a mould is called moul

Moulding materials: A moulding material is one which is used to make the mould.

Moulding materials are classified as;

(a) Metals – include grey cast iron, steel and anodised aluminium.

(b) Non-Metals – include moulding sand, graphite, plaster of paris, ceramic etc.

Moulding Sand: The common sources for collecting moulding sand are rivers, lakes, sea and deserts.

Moulding sand may be classified as:

1. Natural Sand (Green Sand)

   These sands are taken from river beds and are dug from pits and purely natural. They possess an appreciable amount of clay and moisture.

   Due to their low cost and easy availability, these are used for most of the ferrous and non-ferrous castings.

2. Synthetic Sand:

   It is an artificial sand obtained by mixing relatively clay free sand, binder and other materials as required. Its properties can be easily controlled by varying the mixture content and hence it is better moulding sand.

3. Special Sand:

   It contains the mixture of inorganic compounds. Cost of these sands are more but they offer high temperature stability, better cast surface etc. Special sand used are zircon, olivine, chamotte, chromite etc.

The moulding sand according to their use are further classified as below:

1. Green Sand: sand in its natural or moist state. It is a mixture of silica sand with 18 to 30% clay, having total amount of water 6-8%. It is used for simple small and medium size castings.

2. Dry Sand: baked or dried green sand. Excessive moisture is evaporated by drying the green sand in a suitable oven. It has more strength, rigidity and thermal stability as compared to green sand. It is used for large and heavy castings.

3. Loam Sand: It contains much more clay as compared to ordinary moulding sand. The clay content is of the order of 50%. It is used for loam moulding of large grey iron castings.

4. Facing Sand: is used directly next to the surface of pattern and comes in contact with the molten metal. It is fresh sand i.e. without the addition of used sand. It possess high strength and refractoriness. The layer of facing sand ranges from 20 to 30 mm.

5. Backing Sand: backs up the facing sand. It is the floor sand which is repeatedly used. Its color is black due to addition of coal dust.

6. Parting Sand: is clay free and consists of dried silica, sea sand or burnt sand. It is used to keep the green sand from sticking to the pattern and also to allow the sand on the parting surface of cope and drag to seperate without clinging.

7. Core Sand: is used for the preparation of cores. It is also called oil sand. It is silica sand mixed with linseed oil or any other oil as binder.

Main Constituents of Moulding Sand: include

- Silica sand
- Binder
- Additives
- Water

1. Silica Sand: is the major portion of moulding sand(80-8
It contains 80-90% silicon dioxide and is characterised by a high softening temperature and thermal stability.
Silica sand grains imparts refractoriness, chemical resistivity and permeability to sand.

2. Binder: imparts the sufficient strength and cohesiveness to the moulding sand but reduces ~~the~~ permeability.
The common binders used are

 (a) Organic binders: find their use in core making. Examples are Dextrin, Linseed oil, molasses, pitch, cereal binders and resins like phenol and urea formaldehyde.

 (b) Inorganic Binders: are clay, sodium silicate and portland cement. clay is one of the most commonly used binder.

3. Additives: are added to moulding sand to improve the existing properties of sand. Commonly used additives are:

 (a) Sea coal: is added to moulding sand for casting o cast iron to improve the stripping and surface appearance of cast iron.
 It is finely powdered bituminous coal and its amount varies from 1% to 10%.
 It restricts the mould wall movement but reduces permeability and hot strength of the mould.

 (b) Pitch and Asphalt: Pitch is distilled from soft coal at about 600°F and asphalt is a byproduct of petroleum distillation. It improves hot strength and surface finish on ferrous castings. Its amount varies from 0·2–2%.

(c) Silica Flour: is pulverized silica which may be added upto 35%. It improves hot strength, surface finish, resists metal penetration and minimizes sand expansion defects.

(d) Graphite: may be natural or synthetic. It improves surface finish and moldability of sand and may be added from 0.2 to 2%.

e) Wood Flour: may be added from 0·5–2%. It minimizes sand expansion defects, improve flowability, collapsibility

f) Corn Flour: may be added from 0.25–2%. It improves collapsibility, increases green and dry strength of the moulding sand.
But it lowers the flowability and permeability.

4. Water: quantity varies from 2–8%. A suitable quantity of water give required strength to the sand. It helps in improving the plasticity but excess water decreases the strength and flowability.

Properties of Moulding Sand:

1. Porosity or Permeability: is the ability of moulding sand to allow gases to escape.
Moulding sand should have this property so as to provide a path for free escape of the gases which remain dissolved in molten metal and are evolved during solidification.

2. Flowability (Plasticity): is the ability of the moulding sand to get compacted to a uniform density.
Moulding sand should have the property of flowability so that it may retain its shape when the pressure is removed.

3. Refractoriness: is the ability of moulding sand to withstand high temperature of molten metal without

fusion, cracking or buckling.

4. Adhesiveness: is the property of the sand due to whic[h] it adhere or cling to the sides of moulding box. Moulding sand should be adhesive so that it can be successfully held in a moulding box and does not fall out of the box when it is tilted.

5. Cohesiveness: is the ability of sand particles to stick together. Moulding sand should be cohesive so that the mould being prepared is strong.

6. Collapsibility: is the property due to which the sand mould breaks (collapse) automatically (or with very less forces) after the solidification of the casting occur[s]. Moulding sand should be collapsible because if the mould or core does not collapse easily, it may restric[t] free contraction of the solidifying metal and cause the casting to tear or crack.

7. Durability: Moulding sand should possess the capaci[ty] to withstand repeated cycles of heating and cooling during casting operations. This ability of sand is known as durability.

8. Fineness: Sand which is used to prepare the mould should be fine grained in order to resist metal penetration and to produce smooth casting surface.

9. Co-efficient of Expansion: Moulding sand should possess low coefficient of expansion.

10. Moulding sand should be chemically neutral.

11. Moulding sand should be reusable, cheap and easily available.

Types of Moulds:

The various types of moulds are as follows:

1. Green Sand Mould: The word 'green' indicates the

condition of sand i.e. mould is in wet condition i.e. without baking or drying.

A green sand mould possesses lower strength and lower permeability. These moulds contain moisture, therefore certain defects like blow holes may occur in castings. These are suitable for producing small and medium sized castings.

2. Dry Sand Moulds: are prepared from fine grained sand mixed with suitable binder and baking in an oven (at temp. 300 to 650°F) before the molten metal is poured in them.

These evolve less steam and gas thus requiring less permeability but are more expensive and consume more time in making as compared to green sand moulds.

3. Skin Dried Moulds: are made with the moulding sand in the green (moisture) condition and then the skin of mould cavity is dried with the help of gas torches or heat lamps.

These are dried upto a depth varying from 8 mm to 25mm. A skin dried mould is poured immediately after drying otherwise moisture from green backing sand penetrate the dried skin and make the skin dried sand ineffective.

4. Loam Moulds: are used for extremely large castings. They are first built up with bricks and often reinforced with iron plates. A loam mortar is prepared and plastered on the backing made from bricks and iron then they are finished by sweeps or strickles, given a refractory coating and finally baked.

Constuction of these moulds reduce the pattern cost.

5. Plaster Moulds: are used for non-ferrous castings. These are made from the slurry of the mixtures of Gypsum or Plaster of Paris and additives such as talc, silica flour, asbestos fibre etc. with water.

These moulds imparts good surface finish and dimension accuracy to the casting but possess poor permeability which causes several defects.

6. CO_2 Moulds: are made from a mixture of clean and dry silica sand and sodium silicate base binder, in which binder varies from 3 to 7%. CO_2 gas is used as mould hardener.

After preparing the mould from above mixture in the usual manner, the gas is passed through it to obtain the desired hardness.

7. Shell Moulds: are prepared with the help of heated iron or steel patterns. A mixture of fine sand and phenolic resin is used to produce shells.

Shells are assembled to form the mould in which liquid metal is poured.

8. Metallic Moulds: also known as permanent moulds are generally made up of cast iron or steel. These are employed in permanent mould casting, pressure die casting and centrifugal casting.

Classification of Moulding Processes:

1. According to the method used:
   (a) Floor moulding (b) Bench moulding
   (c) Pit moulding (d) Machine moulding.

2. According to the mould materials:
   (a) Sand Moulding
   - Green sand moulding
   - Dry sand moulding
   - Core sand moulding
   - Skin dried moulding.
   - Loam moulding.
   - CO_2 moulding.

   (b) Plaster Moulding.
   (c) Metallic Moulding.

Methods of Moulding.

1. Bench Moulding:

Moulding is carried out on a bench so it is suitable for small and light moulds. Both green and dry sand moulds can be made by bench moulding. Moulds both for ferrous and especially non ferrous castings are made on bench moulds.

Bench moulding is divided into three methods:

(a) Two box moulding: uses two moulding boxes. The upper part is called cope and lower part is called drag. Two moulding boxes are located and clamped by proper fastening devices.

(b) Three box moulding: uses three boxes. This is done to facilitate easy removal of pattern from mould when pattern is of flanged type. Upper part is called cope, middle part is called cheek and lower part is called drag.

(c) stack Moulding: In this method different boxes are stacked one above the other. There is a common passage for the molten metal running through the stack of the intermediate boxes. A no. of parts can be cast in a single pouring operation.

2. Floor Moulding: is done on the foundary floor. The floor itself acts as a drag and it may be covered with a cope or the mould may be cast open. It is used for all medium and large casting

3. Pit Moulding: is done in a pit instead of a flask. It is used for extremely large castings. The mould has its drag part in the pit and a seperate cope is rammed and used above the pit sides of pit are lined with bricks and on the bottom there is a thick layer of binders with connecting vent pipes to the floor level.

gates, runner, pouring basin, sprue etc. are made in the cope.

4. Machine Moulding.

The moulding done by a machine is called machine moulding.

The ramming of sand, rolling over the mould, forming the gate and drawing out of a pattern is done by machines much better and more efficiently than by hand.

This method is preferred for mass production because mostly work is done by machines. Moreover it can produce identical and consistent castings.

CORES

A core can be defined as a body of sand, generally prepared seperately in a core box, which is used to form a cavity of desired shape and size in a casting.

The main characteristics required in a good core are following:

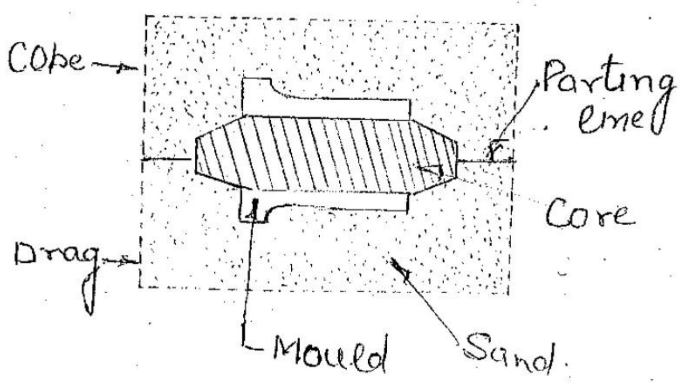
- High permeability to allow an easy escape of gases formed.
- High refractoriness to withstand high temperature of molten metal.
- smooth surface.
- High collapsibility i.e. it should be able to disintegrate quickly after the solidification of the metal is complete.
- Sufficient strength to support itself.

Types of Cores:

According to shapes and position of cores in the prepared moulds, the cores are classified as

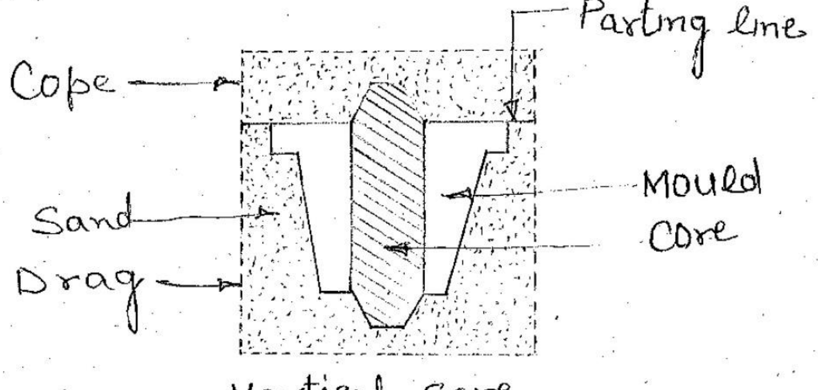
- Horizontal core
- Vertical core
- Balanced core
- Hanging or cover core
- Drop core or stop off core
- Ram up core

1. Horizontal core: is placed horizontally at the parting line of the mould such that one half remains in the cope and other half in the drag.



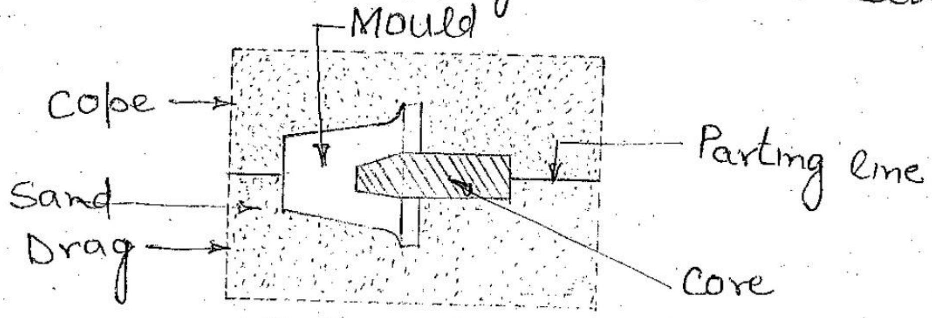
Horizontal Core

2. Vertical Core: is placed in a vertical position both in cope and drag halves of the mould.
Amount of taper at the top is greater than that at the bottom.



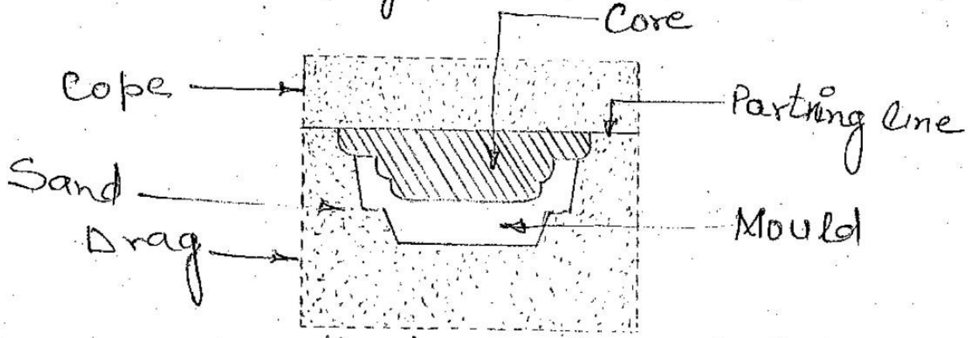
Vertical core

3. Balanced Core: is one which is supported and balanced from its one end only. It is used when the casting does not need a through hole or cavity.



Balanced core

4. Hanging or cover core: hangs from the cope and does not have any support at the bottom of drag. Cover core covers the mould and rests on a seat made in the drag.

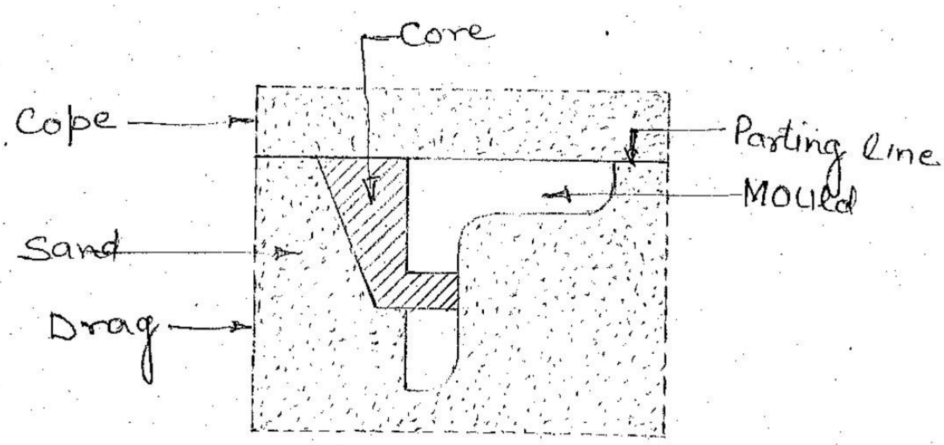


Hanging or Cover core

5. Drop core, stop off or Wing Core:

This is used when a hole, recess or cavity required in a casting is not in line with the parting surface i.e. it is above or below the parting line of the casting.

These are also known as tail core, saddle core or chair core depending upon its shape and position in the mould.

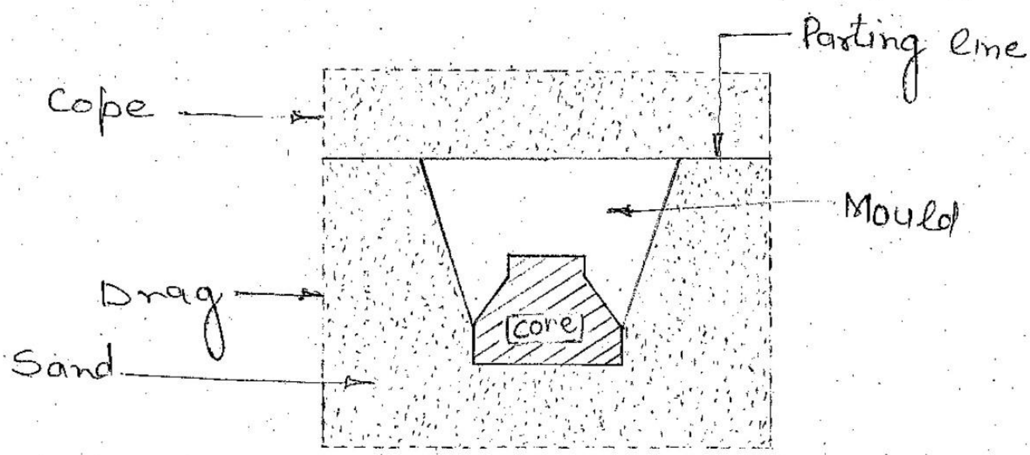


Drop Core

6. Ram up core: is placed with the pattern before the mould is rammed up.

These are used when the core detail (cavity) is located in an inaccessible position.

These are used to produce interior and exterior portions of a casting.



Ram up core

GATING SYSTEM AND ITS ELEMENTS

The term Gating System involves all the passages through which the molten metal enters the mould cavity i.e. it includes the pouring basin, runner, gate an riser etc.

An ideal gating system is expected to meet the following requirements.

1. The velocity of molten metal should be as low as possible so that there is no erosion of mould.
2. Gating system should ensure the proper filling of mould cavity.
3. Gating system should prevent the molten metal from absorbing air or other gases while flowing through it.
4. It should prevent the formation of oxides.
5. It should prevent the entry of oxides, slag, dross etc
6. It should assist in directional solidification of casting.
7. It's design should be practicable and economical.

Elements of gating System :

The various elements connected with gating system are;

1. Pouring basin or pouring cup.
2. Sprue.
3. Sprue base well.
4. Runner
5. Runner extension
6. Ingate
7. Riser.

Pouring Basin: Molten metal is poured into a pouring basin which acts as a reservoir from which it moves smoothly into the sprue.
The pouring basin is also able to stop the slag from entering the mould cavity by means of a skimmer.

Sprue: is the channel through which the molten metal is brought into the parting plane where it enters the runner and then gates.
Sprues are conical in shape because
- molten metal when moving from top ~~of~~ the cope to the parting plane gains in velocity so requires a smaller area of cross section for the same amount of metal to flow at the bottom.
- Liquid tries to attain the minimum area at the bottom so there is an air gap between the liquid jet and sprue wall so air inspiration will be there which causes problem.

Sprue Base Well: This is a reservoir for metal at the bottom of the sprue to reduce the momentum of the molten metal.

Runner: is generally located in the horizontal plane (parting plane) which connects the sprue to its ingates.

Runner Extension: is provided to trap the slag in the molten metal.

gates: are the openings through which the molten metal enters the mould cavity.

Riser: is a reservoir of molten metal from which the metal can flow into the casting during volumetric shrinkage.

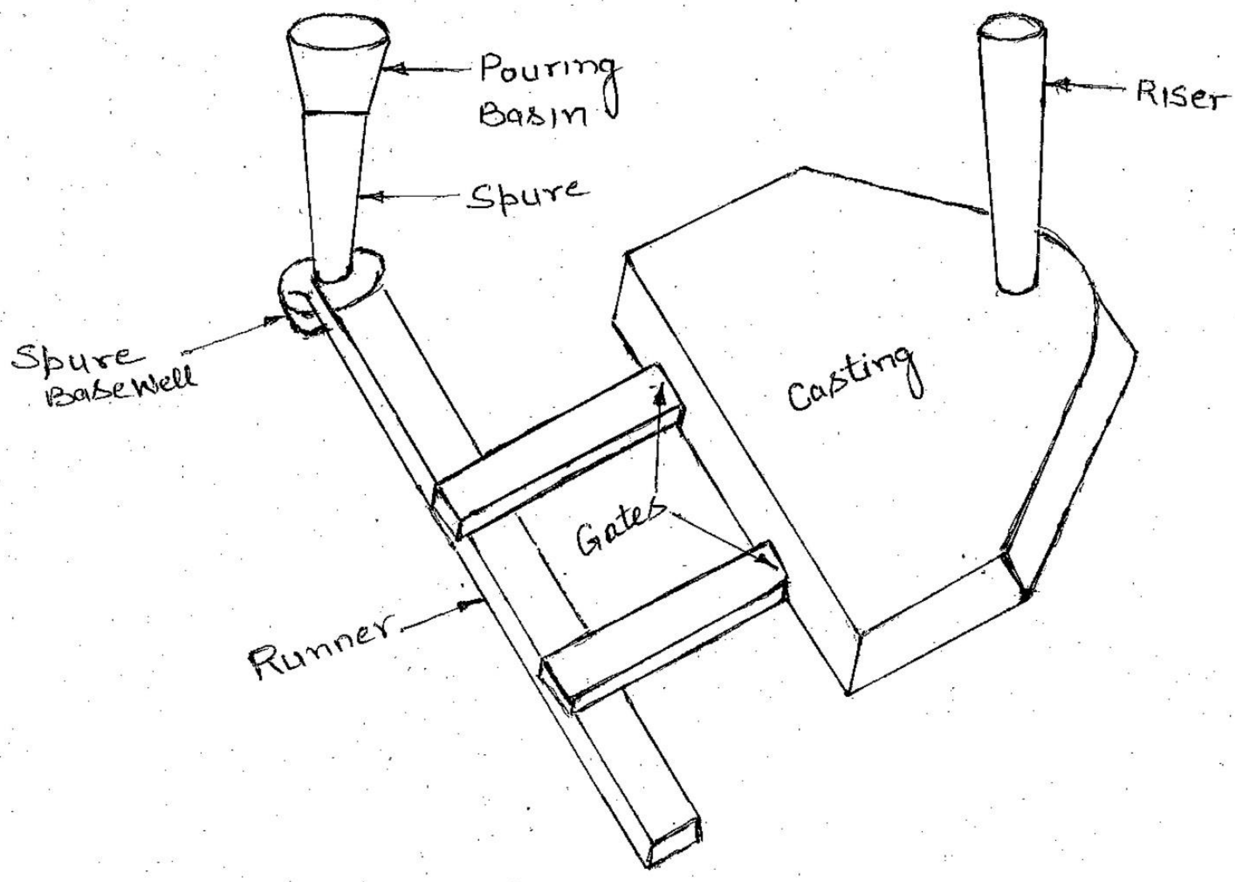
Functions of Riser:

(a) Primary function of riser is to compensate for the shrinkage during solidification of casting.

(b) It permits the escape of air and mould gases as the mould cavity is being filled with molten metal.

(c) It indicates (when full of molten metal) that the cavity has been completely filled up with molten metal.

(d) Riser promote directional solidification.



Various Elements of gating system

Special Casting Methods.

Special casting methods are not commonly employed because of their high initial cost however special casting methods have following advantages over conventional sand casting:

- Greater dimensional accuracy.
- High production rates.
- Lower production cost.
- Better surface finish.
- Denser and fine grain structure.
- Good quality (less defects).

Therefore these methods are used where greater dimensional accuracy better surface finish, High production rate & good quality castings are required.

* Classification of special casting methods:

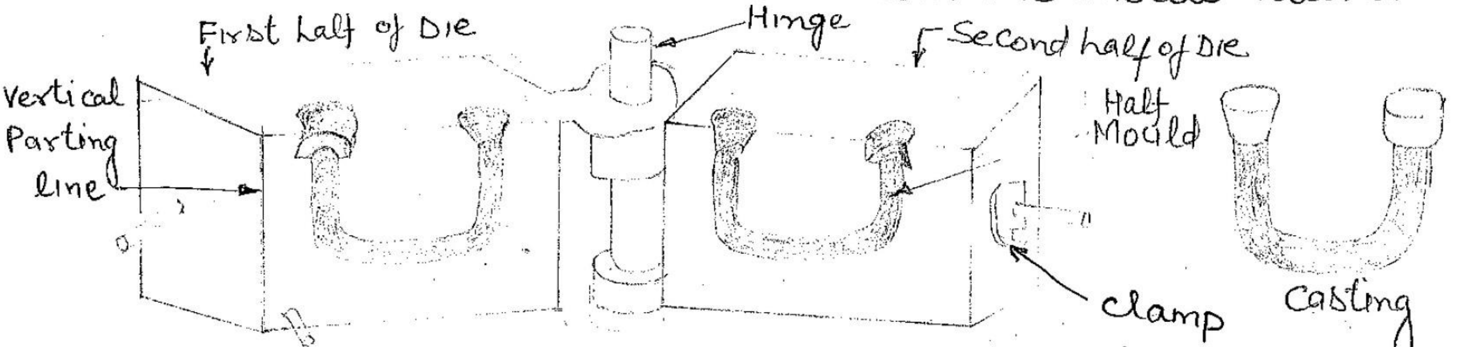
1. Metal mould casting
   (a) gravity die or permanent mould casting.
   (b) Die casting: Hot chamber and cold chamber.
   (c) Slush casting.

2. Non-Metallic mould Casting
   (a) Centrifugal casting
      (i) True centrifugal casting.
      (ii) semi centrifugal casting
      (iii) Centrifuge Casting.
   (b) Investment casting or precision casting.

* Gravity Die or Permanent Mould casting:

gravity die casting is a casting process in which the molten metal is poured into a metallic mould called die under the influence of gravity only; no external pressure is applied to force the liquid metal into mould. Hence the name 'gravity die casting'. The casting is called permanent mould casting because it uses the mould which is permanent i.e. the mould can be reused many times before it is discarded or rebuilt. It is usually made from cast iron, tool steel, copper or aluminium alloys and the choice for a particular material depends on the type of metal to be cast.

A permanent mould is made into two halves which resembles a block. This is done in order to facilitate the removal of casting from the mould.
The mould halves are hinged and can be clamped together to close the mould. Gating and riseing system are machined either in one or both the mould halves.



Working Principle of Gravity die Casting:

- The mould is cleaned using wire brush or compressed air to remove dust and other particles from it.
- It is preheated to a temperature of 200-280°C by gas or oil flame and then the surface is sprayed with a lubricant. The lubricant helps to control the temperature of the die thereby increasing its life and also assist in easy removal of solidified casting.
- The mould is closed tightly and the liquid metal of the desired composition is poured into the mould under gravity.
- After the metal cools and solidifies, the mould is opened and the casting is removed. Gating and riseing systems are seperated from the cast part.
- The mould is sprayed with lubricant and closed for next casting. The mould need not to be preheated since the heat in the previous cast is sufficient to maintain the temperature.

Advantages of gravity die Casting:

- Good surface finish and close dimensional tolerances can be acheived.
- Suitable for mass production.
- Occupies less floor space.
- Thin sections can be easily cast.
- Eliminates skilled operators.

Applications of Gravity die casting:

- Carburetor bodies
- Refrigeration castings
- oil pump bodies
- Typewriter segments
- Automotive pistons etc

Disadvantages:

- Initial cost for manufacturing moulds (dies) is high.
- Not suitable for steel and high melting point metals/alloys
- Un-economical for small productions.
- castings have poor elongation.
- Since the gating system is cut in the mould halves, once machined, it can not be changed.

★ Die Casting (Pressure Die Casting)

It is a casting process in which the molten metal is injected into a die under high pressure. The pressure varies from 25 to 50 kg/cm^2 and is maintained till solidification stage is reached.

The metal being cast must have low melting point that the die material which is usually made from steel and other alloys. Hence this process is best suitable for non-ferrous materials, although a few ferrous materials can be cast.

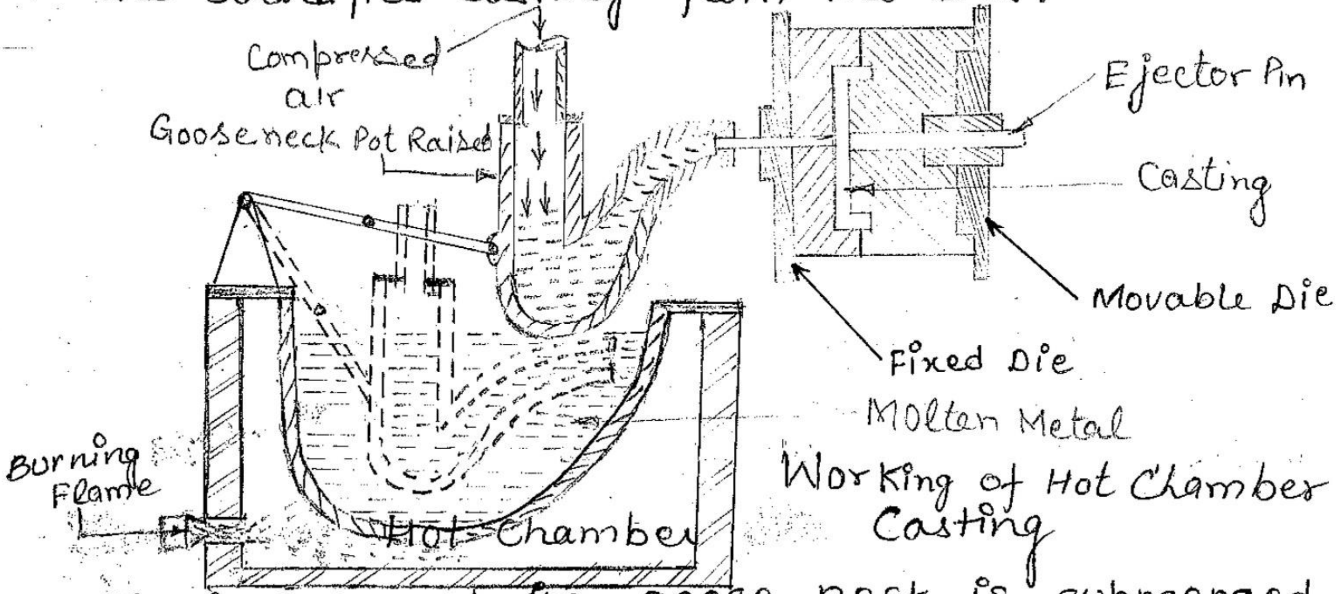
The two basic methods of Pressure Die casting include

- Hot chamber die casting
- Cold chamber die casting.

1. Hot Chamber Die Casting:

In hot chamber die casting machines, the melting unit is in the machine itself. The molten metal posses normal amount of super heat and therefore less pressure is needed to force the liquid metal into die.

In this process, the dies are made into two halves one half called the fixed die or stationary die, while the other half called movable die. The dies are aligned by means of ejector pins which help to eject the solidified casting from the dies.



Working of Hot Chamber Die-Casting

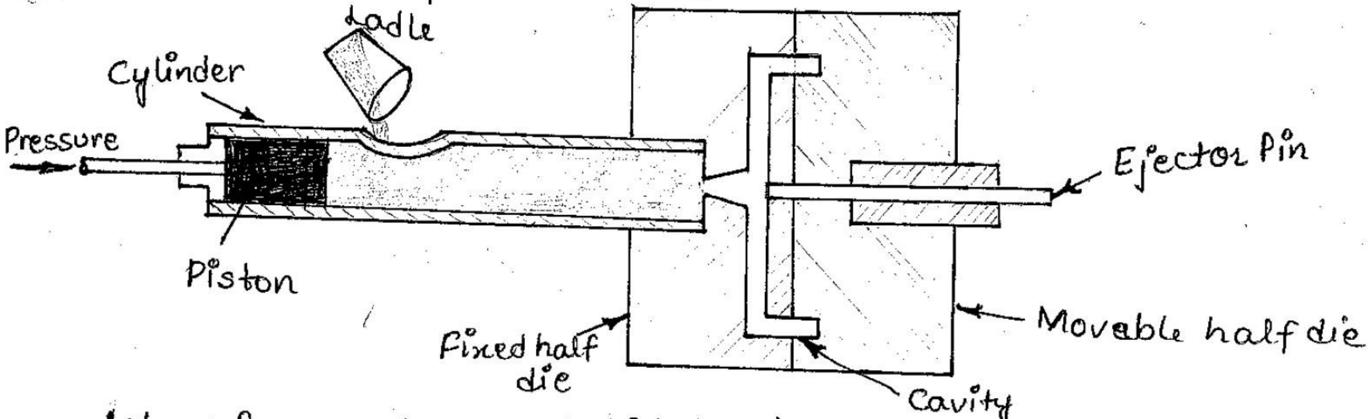
- A pivoted cast iron goose neck is submerged in a reservoir of molten metal where the metal enters and fills the goose neck by gravity.
- The goose neck is raised with the help of a link and then the neck part is positioned in the sprue of the fixed part of the die.
- Compressed air is then blown from the top which forces the liquid metal into die.
- When the solidification is about to complete, the supply of compressed air is stopped and the goose neck is lowered back to receive the molten metal for next cycle. In the meantime, the movable die half opens by means of ejector pins forcing the casting from the die cavity.
- The die halves close to receive the molten metal for the next casting. ~~The~~

The Hot chamber Die Casting is used for casting metals like zinc, tin, magnesium and lead based alloys.

2. Cold Chamber Die Casting

In cold chamber process, the melting chamber is seperate and the molten metal is charged into

the machine by means of ladles.
Cold chamber process is employed for casting materia that are not possible by the hot chamber process. For example, aluminium alloys react with steel structure of the hot chamber machine and as a res there is a considerable iron pick up by aluminium. Th does not happen in the cold chamber process, as the molten metal has a momentary contact with the structure of machine.



Working of Cold Chamber die Casting.

- A cylindrical shaped chamber called cold chamber is fitted with the freely moving piston and is operated by means of hydraulic pressure.
- A measured quantity of molten metal is poured into the cold chamber by means of ladles.
- The plunger of the piston is activated and progresses rapidly forcing the molten metal into the die cavity. The pressure is maintained during the solidification process.
- After the metal cools and solidifies, the plunger moves backward and the movable die half opens by means of ejector pins forcing the casting from the die cavity.

Advantages of Pressure Die Casting:

- Process is economical for large production.
- Good dimensional accuracy and surface finish.
- Thin sections can be easily cast.
- Near net shape can be achieved.
- High production rate.

- The labour cost involved is less.
- Threads can be easily obtained.
- The die has a long life. It is possible to produce 1,00,000 castings in case of zinc base alloys and 75,000 castings in case of copper base alloys.

Disadvantages:

- High initial cost.
- Minimum economic quantity is around 20,000.
- Size of casting is limited.
- Special skill is required for maintainance and supervision of die.
- It requires comparatively a longer period of time for going into production.
- In certain cases, dies may produce an undesirable chilling effect on the die casting.

Applications:

- Automobile parts.
- Marine uses.
- Domestic appliances.
- Instruments.
- Parts of refrigerators, washing machines, television typewriters, projectors, radio, binocular, camera.
- Lead base alloy are used in radiation shielding, battery parts, light duty bearing etc.

★ Slush Casting:

This method is a special application of permanent mould casting in which hollow castings are produced without the use of cores.

The casting produced by this method are not desired for engineering use because wall thickness of the castings are not uniform. External shape is important in these castings.

Working:

- In this method, molten metal is poured into the metal mould and allowed to solidify upto the required thick
- After the skin has frozen, the mould is turned upside down or slung so that remaining liquid metal falls out and casting of desired thickness can be obtained.
- In order to facilitate the removal of casting, the moulds are made into two halves.

Applications:

- In production of toys, ornaments, and lighting fixtures.

Advantages:

- good surface appearance.
- cores are not needed.

Disadvantage:

- Castings are not that much strong.

☆ Centrifugal Casting:

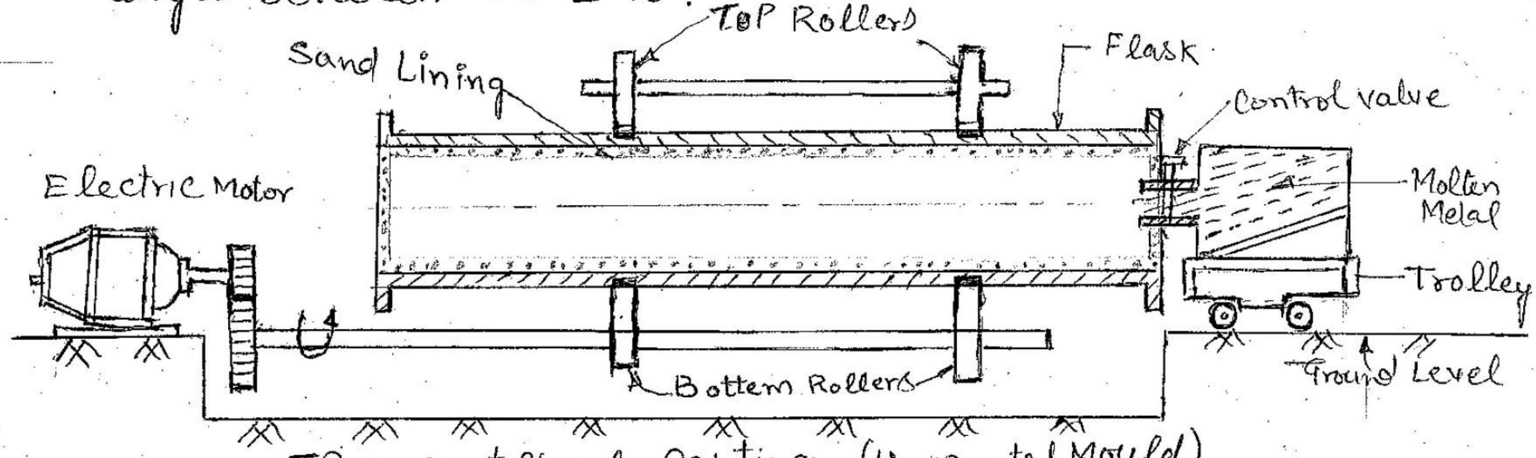
Here centrifugal force plays a major role in shaping and feeding of the casting. The mould is rotated rapidly about its central axis as the metal is poured into it.

There are three main types of centrifugal casting process:

1. True Centrifugal casting.
2. Semi centrifugal casting.
3. Centrifuge casting.

1. True Centrifugal Casting:

This process is used to produce parts that are symmetrical about the axis like pipes, tubes, bushings, liners and rings. Axis of rotation of mould and casting are same. The outside shape of casting can be round, octagonal, hexagonal etc. but the inside shape is perfectly (theoretically) round due to radially symmetric forces. This eliminates the need for cores for producing hollow castings. The axis of rotation of mould may be horizontal, vertical or inclined at any suitable angle between 70° & 90°.



TRUE centrifugal Casting (Horizontal Mould)

Advantages of True Centrifugal Casting:

- No need of core to make a pipe or tube.
- No gates or risers are used so no material is wasted.
- Proper directional solidification is obtained.
- Dense and fined grained casting is obtained.
- It is a quick and economical method.
- Impurities segregate toward the centre from where they can be easily machined.

Disadvantages:

- Limited to symmetrical shaped objects.
- Equipment costs are high.
- Skilled workers are required.

Applications:

- Liners for I.C. engines
- Pipes, rolls, cylinder sleeves, piston ring stocks, bearing, bushing etc.

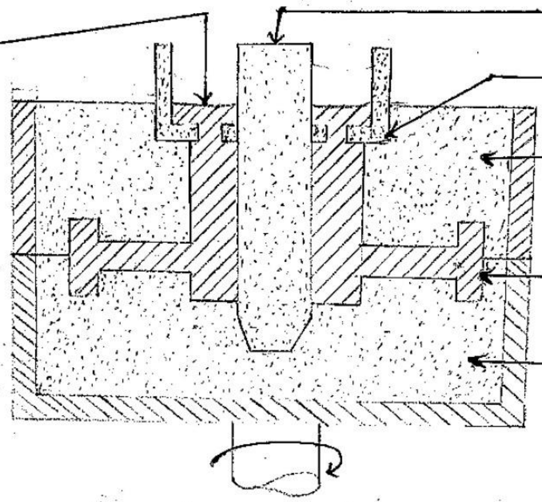
2. Semi Centrifugal Casting:

This method is used to produce solid castings and hence requires a core to produce hollow cavities.

Here axis of rotation of mould is always vertical.

It is used only for symmetrically shaped objects such ~~the axis of rotation~~

as gear blanks, sheaves, wheels and pulleys.



Working Principle:

- The mould is prepared in the usual manner using cope and drag box.
- The mould cavity is prepared with its central axis being vertical and concentric with the axis of rotation.
- The core is placed in position and the mould is rotated. The speed of rotation is such that a linear speed of about 180 m/min is obtained on the outer edge of casting.
- The centrifugal force produced due to the rotation of mould causes the molten metal to fill the cavity to produce the desired shape.

Advantages:

- Spinning speeds need not be as high as required in true centrifugal castings.
- Directional solidification can be obtained by proper gating and selective chilling.
- Casting shapes, more complicated than those possible for true centrifugal casting can be made.
- A no. of moulds can be stacked together, one over the others and can be fed by a common central sprue in order to produce more than one casting at a time.

Disadvantages:

- Here due to lower speed of rotation the impurities are not directed towards the centre as effectively as in true centrifugal casting.

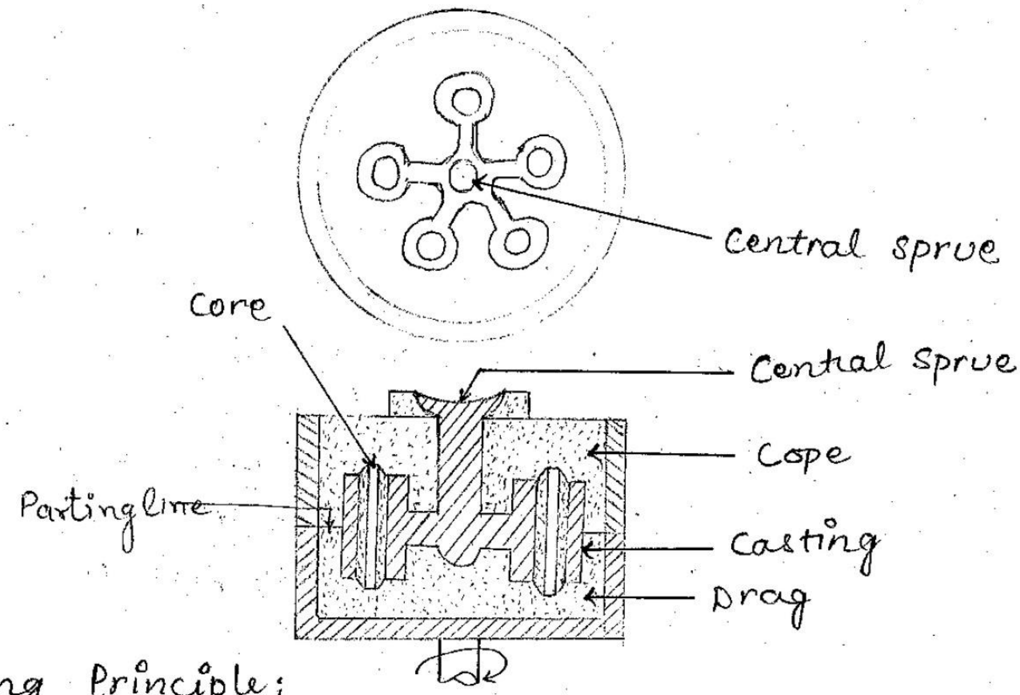
Application:

- Parts such as gears, flywheels and track wheels are produced with the help of this method.

3. Centrifuge Casting: Also known as pressure casting.

In centrifuging process, the axis of mould cavity doesn't concide with the axis of rotation. The mould is designed with part cavities located away from the axis of rotation and hence this is suitable for non-symmetrical castings.

The setup is revolved around the centre to induce pressure on the metal in the mould.



Working Principle:

- Several mould cavities are arranged in a circle and connected to a central down sprue through gates.
- The axis of down sprue is common to the axis of rotation of the mould.
- As the mould is rotated, the liquid metal is poured down the sprue which feeds the metal into the mould cavity under centrifugal force.
- The rotational speed depends on a no. of factors such as, the moulding medium (sand, metal or ceramic), size of casting, type of metal being poured and the distance of cavity from the central axis (sprue axis). Centrifuging is done only about a vertical axis.

Advantages:

- More economical production method.
- Better quality.
- It can cast parts which cannot be satisfactorily

Produced by the other methods.

- Casting shapes imposes no special limitation in this method and almost unlimited variety ~~os~~ of smaller shapes can be cast
- The requirement of core to produce a central hole is avoided in most of the cases.
- The need of separate gates and risers is totally eleminated.
- The production rate is sufficiently high.
- Thin sections and intricate shapes can be easily cast.
- The percentage of rejects is very low.

Disadvantages:

- Initial cost is high.
- operation needs skilled labour
- All types of shapes cannot be casted.
- Maintenance is expensive.

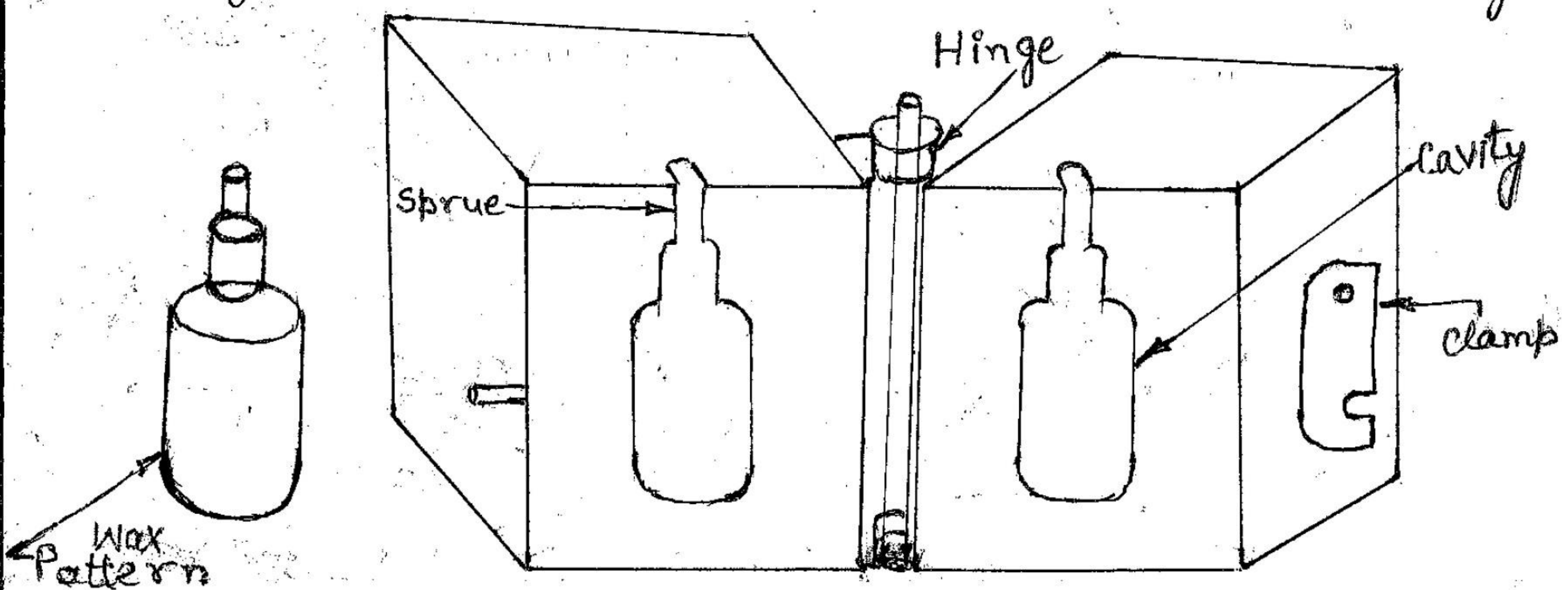
Applications:

Parts produced by this casting are value bodies, value bonnets, Plug yorks, pillow blocks etc.

Investment Casting: This process is also known as Lost Wax process or Precision Casting. It uses a wax pattern which is subsiquently melted from the mould by an appropriate method, leaving a cavity having all the details of original pattern. This cavity is then filled with molten metal & produces casting after solidification.

Procedure:

Selection of suitable pattern: A pattern of requiered size and shape is selected for producing the desired-casting.



Die for making wax Patterns

Producing a die for making wax pattern: A die is made either by machining cavities in two matching blocks or by casting a low melting point alloy around a metalic master pattern of metal having high melting point. Die halves are then properly finished by machining process. A gating system is also prepared by machining process through which wax is to be injected for preparing the pattern of wax or plastic or frozen murcury. Wax is commanly used material for making patterns.

Making wax Patterns: The die halves are cleaned, closed and properly clamped. Molten wax is then injected into the die by means of a wax injecting machine and allowsto solidify. After solidification the die is opened and the pattern is removed. The process is repeated to prepair required number of patterns because one pattern is used for one piece only.

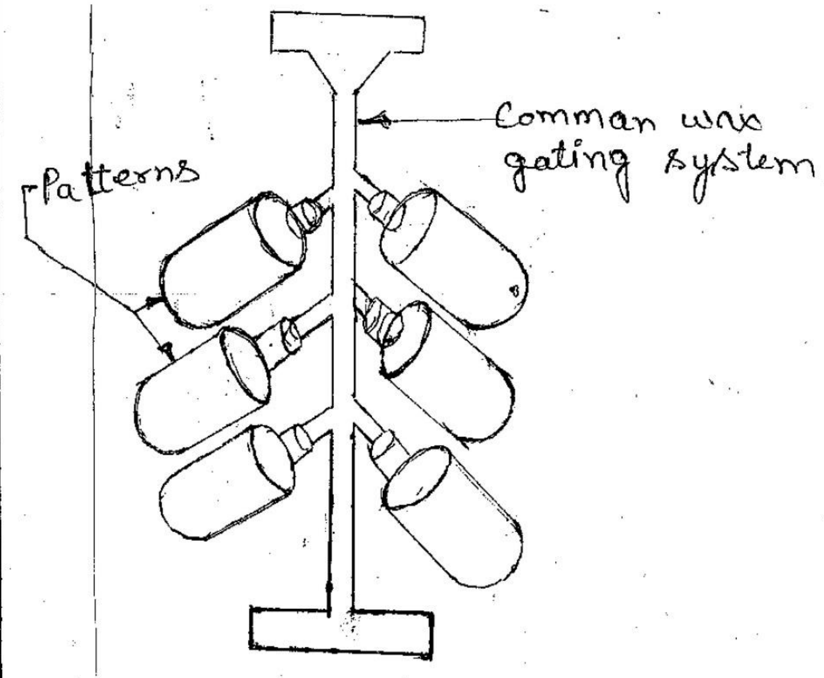
Assembling the wax patterns: A comman wax gating system is then formed and a number of small wax patterns are attached to the gating system so that the whole attachment can be dipped into a container of refractory slurry

Coating the pattern assembly: The wax patten assembly is dipped into a slurry of refractory coating material into a container. A typical slurry consists of 325 mesh silica flour suspended in ethyle silicate or sodium silicate solution. Then wax pattern assembly is sprinkled with powdered refractory materials which may be silica, Aluminaor Zircon and is permitted to dry. After drying the process is repeated till the required thickness of refractory material is actived. This thickness generally should be equal to 8-10 mm. Then the whole assembly is allowed to dry in air about 3 to 4 hours minimum.

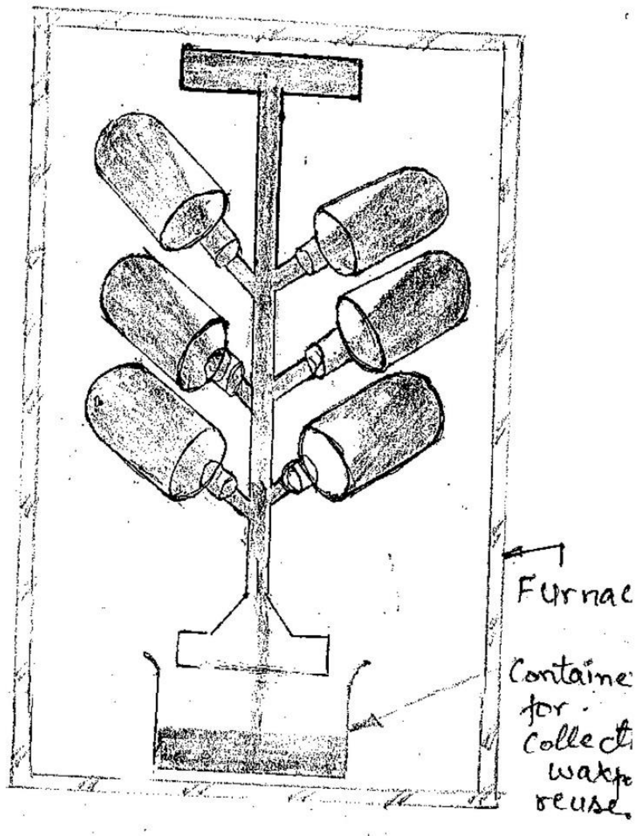
Investing the wax pattern assembly for producing Molds.

Removal of wax patterns: The wax patterns can be removed from the mold cavity by one of the following two methods

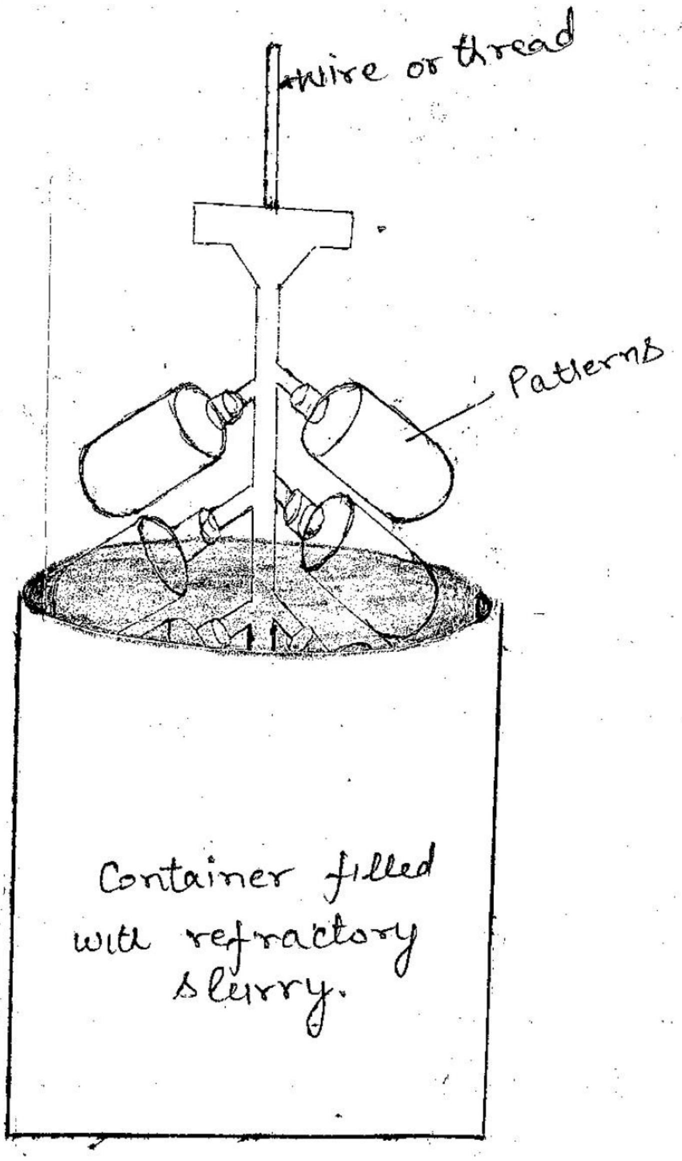
(1) By placing the molds in inverted position in a furnace the wax is melted out due to heat and collected for re-use. The supply of heat is at a slow uniform rate.



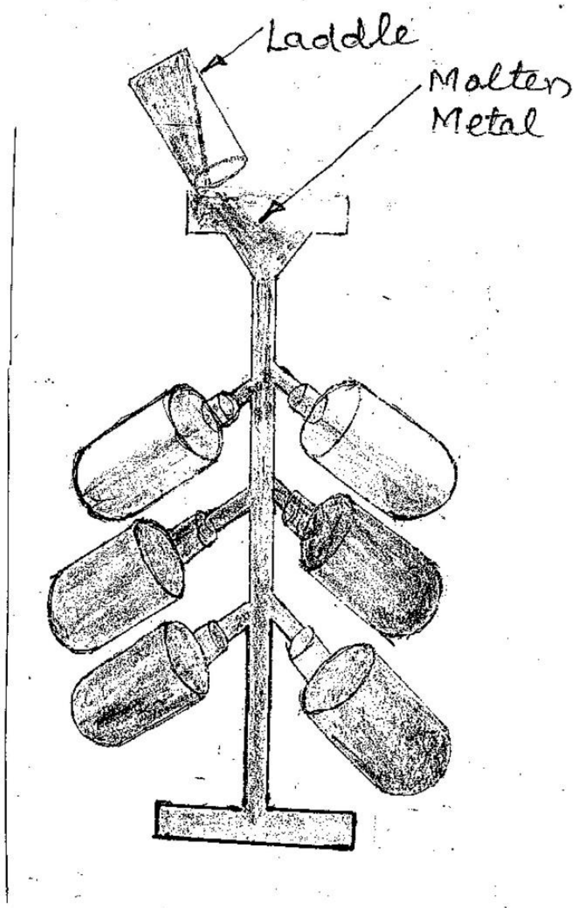
A. sembling a no. of small wax Patterns to a comman wax gating system.



Molds in inverted position in a furnace for removal of wax Patterns.



Dipping the wax pattern assembly into Container of refractory slurry to get appropriate thickness of Coating



Pouring the molten metal into the molds to achive Castings

(ii) in other method by placing the mold assembly in a bath of trichloromethylene vapours which also enable the recovery of wax for re-use.

Pouring and Casting: The molds is then again heated at a rate of 40° to 70°C per hour from 150–900° for ferrous alloys and 650°C for aluminium alloy. This preheating is done to remove the wax if any or to help the material to flow easily and fill up properly or it causes expension of the mold also.
After preheating the mold, the molten metal is poured into the investment molds under gravity or under the force applied air pressure or by centrifugal force.

Removal of Casting: After the solidification of metal the moulds breaked and the casting is removed then casting is separated from the assembly and gates, runners etc are removed. After that inspection and finishing of casting is done.

Advantages:
- High dimensional accuracy of the order of ± 0.08 mm can be attained.
- A very smooth surface without parting line.
- Machining can be eliminated.
- Very thin section can be cast easily (0.76 mm)
- Complex contours and intricate shapes can be easily cast.
- Die castings can be replaced when short runs are involved.
- Castings are sound and have large grains as the rate of cooling is slow.
- Complex shapes are possible because pattern is withdrawn by melting it.

Disadvantages:

- The process is suitable for small size parts.
- This is a more expensive process.
- It is relatively slow.
- Pattern is expendable, one wax pattern is pattern is required to make one investment casting.
- The use of cores make the process more difficult.

Applications:

- In dentistry and surgical implants.
- Parts of gas turbines.
- Parts of sewing machines, locks, rifles, burner nozzles, milling cutters, jewellary and art casting.

Cupola Furnace

A cupola furnace is a vertical cylindrical furnace used for producing only cast iron. Although other furnaces are capable of producing cast iron, the largest tonnage of cast iron is produced in cupola furnace.

The advantages of using cupola are:

(i) The initial cost is comparatively lower than other types of furnace of same capacity.

(ii) Operation and maintinance of this furnace does not involve too many complications.

(iii) Cost of operation and maintenance are comparativ lower.

(iv) The floor area required is hardly a fraction of that required for other furnaces of similar capacity.

(v) It can be operated for a no. of hours at a stretch.

(vi) It consumes the easily available and less expensive fuels.

(vii) Continuous production can be obtained from the cupola furnace once started.

(viii) Temperature control is easier.

(ix) It has a high degree of efficiency.

Disadvantages of cupola furnace are:

(i) The main disadvantage is that it is not possible to produce iron below 2.8% carbon in this furnace. So for producing white cast iron (containing below 2.7% carbon) the duplex process is employed

(ii) Molten metal and coke comes in contact with each other, certain elements such as Si, Mn are lost while others are included in the metal.

* Construction of Cupola:

Shell: The cupola furnace consists of a vertical, cylindrical steel sheet, 6-12 mm thick and lined inside with acid refractory bricks or acid temping clay, known as shell.

The lining is generally thicker in lower region where the temperature encountered are higher than upper region.

cupola diameter varies from 1 to 2 metres and the 4 to 6 times the diameter.

Foundation: The shell is mounted either on a brickworks foundation or on steel columns. The bottom of the shell consists of a drop bottom door, through which debris consisting of coke, slag etc. can be discharged at the end of a melting.

Tuyers: Air for combustion of fuel is delivered through the tuyers which are provided at the height of between 450 to 500mm above the working bottom. or bed of the cupola.

Wind Belt: The air is delivered to the tuyers from a wind belt which is a steel plate duct mounted on the outer shell of cupola.

Blower: A high pressure fan or blower supplies the air to the wind belt through a blast pipe.

slag Hole: It is located at a level about 250 mm below the centres of the tuyers. It is used to remove the slag.

charging door: It is situated 3 to 4 meters above the tuyers. Through this hole, metal, coke and flux are fed into the furnace.

Chimney or Stack: The shell is usually continued for 4 meters to 5 metres above the charging hole to form a chimney.

* Working of Cupola:

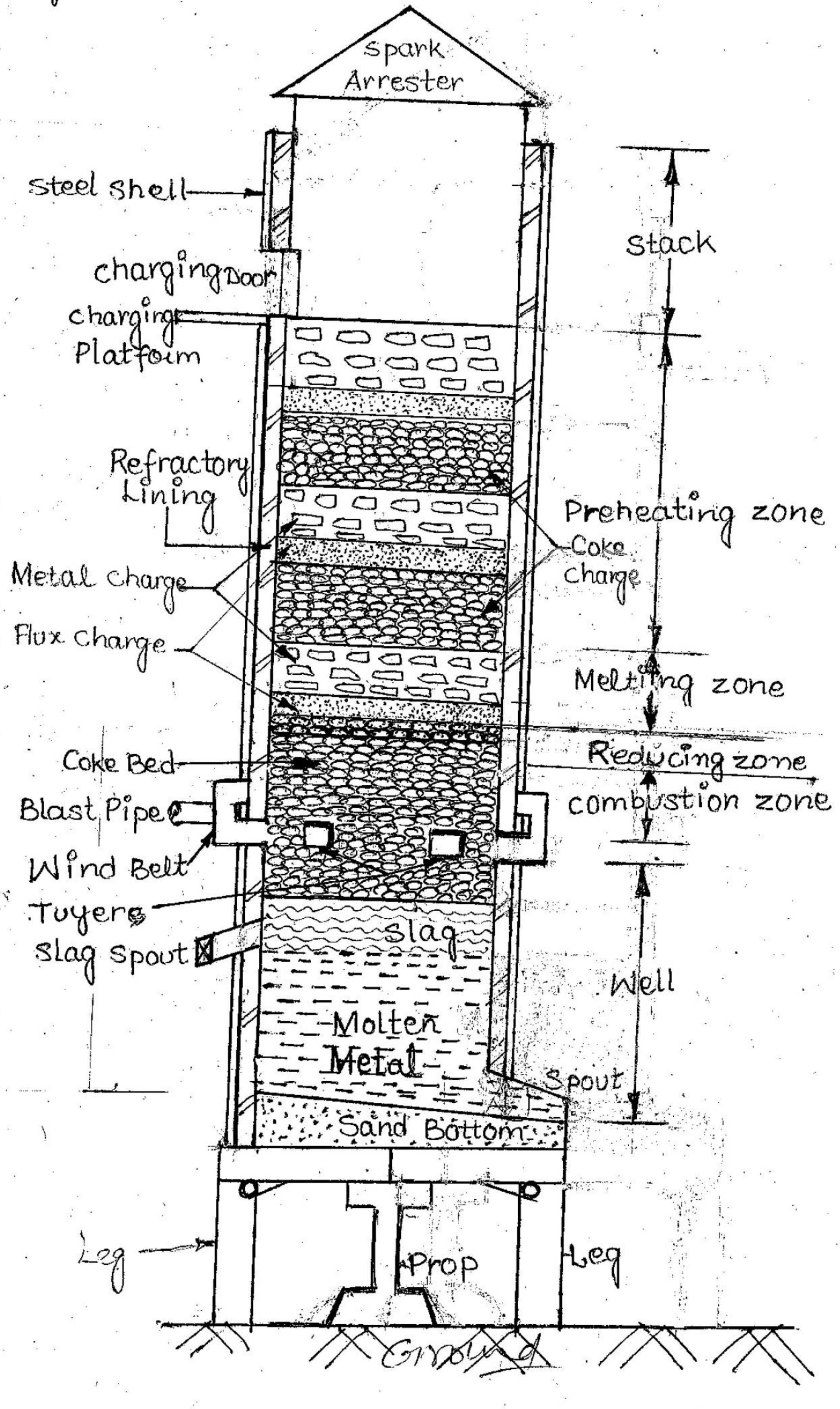
1. Preparation of Cupola: clean out the slag and repair the damages lining with the mixture of fire clay and silica sand. After this bottom doors are raised and held in position by metal props. Bottom sand is introduced through the - charging door and surface of sand bottom is sloped from all directions towards the tap hole. slag hole is also formed to remove the slag.

2. Firing the Cupola: A fire of kindling wood is ignited on the sand bottom. After proper burning of wood, coke is added to a level slightly above the tuyers. Air blast at a slower rate is turn on. After having red spots over the fuel bed, extra coke is added to the predetermined height.

3. Charging the Cupola: After proper burning alternate layers of pig iron, coke and flux (limestone) are charged from the charging door until cupola is full. The height of coke charge in the cupola in each layer generally varies from 10 cms to 15 cms. The quantity of lime stone required may be 30 to 40 kg per tonne of iron melted or 25% by weight of the coke charged.
Suitable quantity Steel scrap is also added along with the pig iron to control the chemical composition of the iron produced.
Flux is added to prevent the oxidation as well as to remove the impurities.

4. Soaking of Iron: After the furnace is charged fully, the charge gets slowly heated up since the air blast is kept shut for about 45 minutes, this causes iron to get soaked.

5. Opening of Air Blast: At the end of the soaking period, the air blast is opened. Tap hole is closed to accumulate the sufficient amount of metal. The rate of charging should be equal to the rate of melting so that the furnace remains full.



6. Tapping the Molten metal : When sufficient metal collects in the well, the slag hole is opened, and the slag is removed. After this tap hole is opened to collect the molten metal.

7. Closing the cupola : At the end of operation, the charge feeding is stopped, air supply is cut off and prop is removed and because of this the door swing down providing a clear space for the coke fire, residue of molten metal with slag and the sand bed to fall down and, thus, the fire inside ceases gradually.

★ ZONES IN CUPOLA :

The entire section of the cupola is divided into following zones :

1. <u>Crucible zone</u> : It is between the top of the sand bed and bottom of the tuyers. The molten metal accumulates here. It is also called the 'well'.

2. <u>Combustion or Oxidizing zone</u> : It is situated normally 150 to 300 mm above the top of the tuyers. Heat is evolved in this zone because of the following oxidation reactions :

$$C + O_2 \longrightarrow CO_2 + \text{Heat}$$

$$Si + O_2 \longrightarrow SiO_2 + \text{Heat}$$

$$2Mn + O_2 \longrightarrow 2MnO + \text{Heat}$$

$$Fe + O \longrightarrow FeO + \text{Heat}$$

3. <u>Reducing Zone</u> : This zone starts from the top of combustion zone and extends upto the top of the coke bed. In this zone, the reduction of CO_2 to CO occurs and temperature drops to about 1200°c

$$CO_2 + C\ (\text{coke}) \longrightarrow 2CO - \text{Heat}$$

4. <u>Melting Zone</u> : The zone starts from the top of the coke bed and extends upto a height of 900 mm. The temperature in this zone is heighest approx. equal to 1600°C.

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

The solid metal charge changes to molten state in this zone and trickles down through the coke to the well. The Molten metal picks up sufficient carbon content here.

5. <u>Preheating zone or Charging zone</u>: It starts from the top of the melting zone and extends upto the charging door. Charging materials are fed in this zone and get preheated.

6. <u>Stack Zone</u>: It starts from the charging zone and extends upto the top of the cupola. The gases generated within the furnace are carried to the atmosphere by this zone.

✱ Cupola Efficiency:

The thermal efficiency of the cupola is given by the ratio of heat actually utilised in melting and superheating the metal to the heat evolved in it through various means.

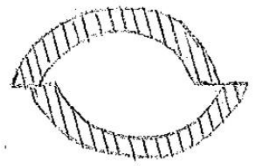
This ratio can be expressed mathematically as follows:

$$\eta_{\text{percent cupola}} = \frac{\text{Heat utilised in melting \& superheating the metal}}{\text{Cal. value of coke + Heat evolved due to oxidation of Fe, Si \& Mn}} \times 100$$

CASTING DEFECTS

* Casting defects may occur due to one or more of the following reasons:
  - Fault in design of casting pattern.
  - Fault in design on mould and core.
  - Fault in design of gating system and rises.
  - Improper choice of moulding sand.
  - Improper metal composition.
  - Inadequate metal temperature and rate of pouring.

* Moulding - related Defects are due to Improper closure:
  - Across parting plane : flash.
  - Along parting line : mismatch.



* Filling related defects are due to
  - Incomplete filling : cold shut, misrun.
  - Gaseous Entrapments : blow hole, gas porosity.
  - Solid Inclusions : sand inclusion, slag inclusion

* Solidification / Cooling - related Defects:
  - Solidification Shrinkage : cavity, porosity, sink.
  - Hindered Cooling Contraction : hot tear, crack, distortion.

* Classification of Casting Defects:

The defects in castings are divided into three categories;

1. Surface defects : eg. Blow, Scar, Blister, Drop, scab, Penetration, Buckle etc.

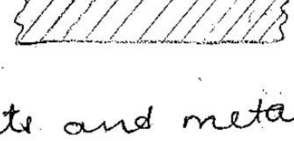
2. Internal Defects : Blow holes, Porosity, Pin holes, Inclusions, Dross etc.

3. Visible Defects : eg. Wash, Rat tail, Swell, Mis run, Cold shut, Hot tear, shrinkage/shift etc.

* Surface Defects:

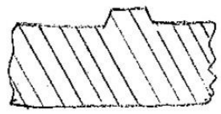
1. Blow: Blow is relatively large cavity produced by gases which displace molten metal from convex surface.

Causes:
- Excessive moisture in the moulding sand.
- Low permeability and excessive fine grain sand
- cores, neither properly baked not adequately vented
- Extra hard rammed sand.
- Rusted and damp chills, chaplets and inserts.
- Excessive use of organic binders.



Remedies:
- Control moisture content.
- Use clean and rust free chills, chaplets and metal inserts.
- Bake cores properly.
- Proper use of organic binders.
- Cores and moulds should be properly vented.
- Moulds should not be rammed excessively hard.

2. <u>Drop</u> : Drop is an irregularly shaped projection on the cope surface caused by dropping of sand in the molten metal.



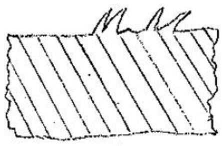
Causes :

- Low green strength in moulding sand and core.
- Too soft ramming.
- Inadequate reinforcement of sand projections and core.

Remedies:

- Modify sand composition to increase the strength.
- Provide harder ramming.
- Provide adequate reinforcement to sand projection

3. <u>Penetration</u> : This defect occurs when molten metal enters into the spaces between the sand grains and holds some of the sand tightly with it even after fettling.



Causes :

- Large grain size of sand.
- Soft ramming.
- Moulding sand or core have low strength.
- Pouring temperature of metal too high.

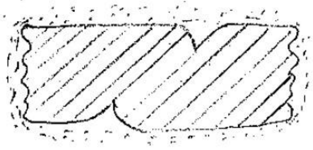
Remedies:

- Use sand having finer grain size
- Provide harder ramming.
- Increase the strength of sand.
- Adjust the proper pouring temperature.

4. <u>Buckles</u> : Buckle is a V-shaped depression on the surface of a flat casting caused by expansion of a thin layer of sand of sand at the mould face.

Causes :

- Excessive mould hardness.
- Large flat surface of casting.



Remedies :

- Reduce mould hardness.
- Break continuity of large flat surface by grooving of depressions.

5. Fusion: Fusion is caused by the fusion of sand grai with the molten metal, giving a brittle, glassy appearence on the casting surface.

Causes:

- Low refractoriness.
- Faulty gating.
- Too high pouring temperature.
- Poor facing sand.

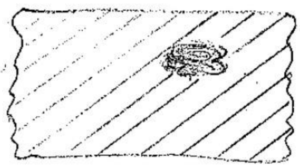
Remedies:

- Improve refractoriness.
- Modify gating system.
- Use lower pouring temperature.

6. Hard Spots: Hard spots on surfaces are generally developed on iron castings rich in silicon content due to local chilling of those spots by moulding sand.

Causes:

- Faulty metal composition
- Faulty casting design.



Remedies:

- Suitable change in metal composition.
- Modify the casting design.

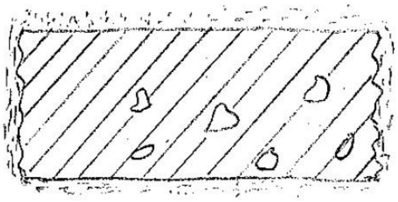
7. Crushes: A crush is a deformation of mould surface due to pressing or scrapping of the sand during setting of core or assembly of the mould boxes.

Causes:
- Careless assembly of cores in the mould.
- Worn out core prints on patterns.
- Defective core boxes.

Remedies:
- Repair or replace core boxes.
- Repair or replace core prints.
- Proper setting of cores.

★ INTERNAL DEFECTS:

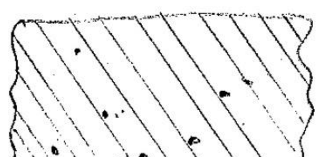
1. Porosity: This defect occurs in the casting in the form of pin hole porosity or gas porosity. Hydrogen is responsible for pin hole porosity. Gases will be absorbed by the liquid metal. When the metal solidifies, the solubility decreases and gases will be released and create small voids throughout the casting called porosity.



Causes:
- High pouring temperature.
- Gas dissolved in metal charge.
- Less flux used.
- High moisture and low permeability in mould.

Remedies:
- Increase flux proportions.
- Ensure effective degassing.
- Reduce moisture and increase permeability.

2. Inclusions: At the time of tapping, if slag is not removed properly and if it gets mixed with the molten metal, defect is called inclusion (slag).

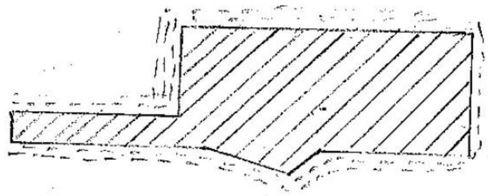


Causes:
- Faulty gating and faulty pouring.
- Inferior moulding or core sand.
- Soft ramming
- Improper flux.

Remedies:
- Improve or modify gating and pouring.
- Use superior sand.
- Provide harder ramming.
- Use proper flux.

3. Cuts and Washes: These defects occur due to the erosion of sand from the mould or core surface by the molten metal.

Causes:
- Low strength of mould and core.
- Lack of binders in facing & core sand.
- Faulty gating.



Remedies:
- Improve collapsibility.
- Modify design.
- Provide soft ramming.

4. Shot Metal: If the molten metal is poured into the mould when its temperature is relatively lower or there is not proper fusing between the main stream and small particles, shot metal defect occurs.

Causes:
- Too low pouring temperature.
- Excess sulphur content in the metal.
- Faulty gating.

Remedies:
- Use higher pouring temperature.
- Reduce sulphur content.
- Modify gating system.

5. Run Outs: A run out occurs when the molten metal leaks out of the mould during pouring, resulting in an incomplete casting.

Causes:
- Faulty moulding.

leaving unfilled portion called Misruns.

A cold shut is called when two metal streams don't fuse together properly.

Causes:

- Lack of fluidity in molten metal.
- Faulty design.
- Faulty gating.

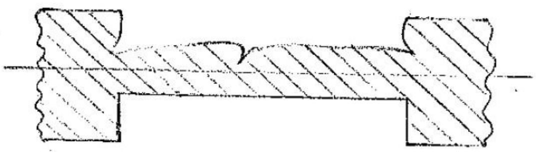
Remedies:

- Adjust proper pouring temperature.
- Modify design.
- Modify gating system.

3. Hot Tears: Since metal has low strength at high temperatures, any unwanted cooling stress may cause the rupture (tear) of the casting called hot tears.

Causes:

- Lack of collapsibility of core and mould.
- Faulty design
- Hard Ramming.



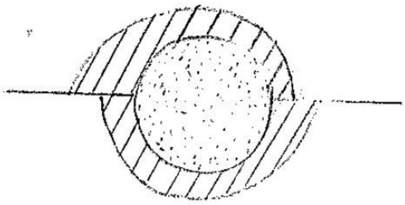
Remedies:

- Improve collapsibility.
- Modify design.
- Provide soft ramming.

4. Shift: A shift is a misalignment between two mating surfaces.

Causes:

- Misalignment
- worn out clamping pins.
- Improper support & location of core.
- Faulty core boxes.



- Defective moulding boxes.

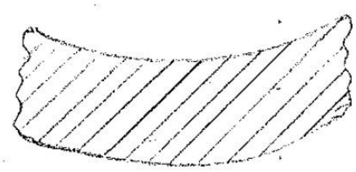
Remedies:

- Improve moulding technique.
- Change the defective moulding boxes.

6. Warpage: If the deformation takes place due to internal stresses developed in the casting or due to differential solidification in different sections, it causes warpage.

Causes:

- Not proper directional solidification.
- Continuous large flat surfaces.



Remedies:

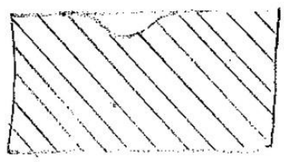
- Facilitate proper directional solidification.
- Modify the casting design to break continuity.

★ VISIBLE DEFECTS:

1. Shrinkage: During solidification of metal, there is volumetric shrinkage. To compensate this, proper feeding of liquid metal is required.

Causes:

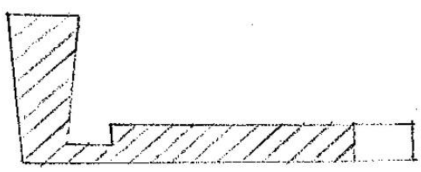
- Faulty gating and risering.
- Improper chilling.

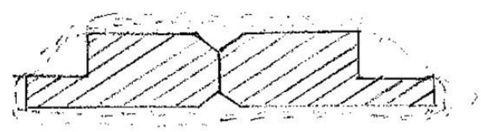


Remedies:

- Ensure proper directional solidification by modifying gating, risering and chilling.

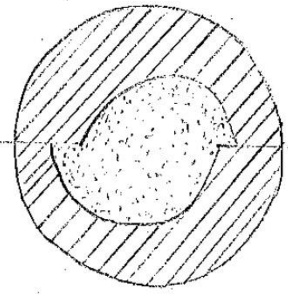
2. Misruns and Cold Shuts: When the metal is unable to fill the mould cavity completely and thus





Remedies:

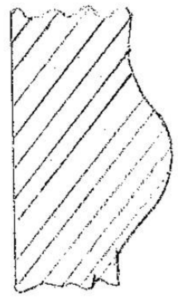
- Repair or replace the pins.
- Provide adequate support to cores.
- Locate the core properly.
- Repair and/or replace the core boxes.



5. Swells: If there is enlargement of casting surface because the mould wall moves backward due to liquid metal pressure and the size of cavity increases that is called swells.

Causes:

- Soft ramming of mould.
- Low strength of mould core.
- Mould not properly supported.



Remedies:

- Provide harder ramming.
- Increase strength of mould and core.
- Provide adequate support to mould.