Lecture Note On
Foundry Technology
[TH-4(A)] (MTPE303)

ORISSA SCHOOL OF MINING ENGINEERING, KEONJHAR

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GOVERNMENT OF ODISHA | ଓଡିଶା ସରକାର

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Vision and Mission of the Department

VISION: To offer quality technical education In the field of Metallurgical Engineering with orientation towards industry, entrepreneurship, higher education and to strive for developing professionally competent technicians meeting the needs of the global economy.

MISSION:

M1 : To develop students in the field of Metallurgical Engineering as highly motivated, skillful and qualified manpower for employment and higher learning

M2 : To promote a conducive environment for all round development of students.

M3 : To promote linkages with external agencies to meet changing needs of industry and society. **M4**

: To Improve Laboratories

Program Education Objectives (PEOs)

PEO 1: Diploma professionals will be able to make a successful career in metallurgical industries or higher studies to meet the needs of future requirements.

PEO 2:Diploma metallurgists will have technical and behavioral competencies through adequate exposure to industry.

PEO 3: To impart technological knowledge and skills for solving real-time engineering problems.

PEO 4: To develop human resources with capabilities of effective communication, moral values and socialresponsible .

SYLLABUS

MODULE	CONTENT	HOUR
Module 1:	**Introduction to Foundry Technology** Definition, Scope, and Applications of Foundry Technology, principles of casting **, basic steps involved in making a casting , advantages &disadvantages of metal casting ,** different types of pattern and different pattern materials , different types of pattern allowances	5
Module 2:	**Foundry Materials & Testing of moulding sand** Types of moulding sand , classification of moulding sand based upon grain size & grain shape , properties desired for moulding sand , facing sand and backing sand , Testing of moulding sand (moisture content test of molding sand , AFS grain fineness number of moulding sand , clay content test of moulding sand , mould hardness test, permeability number of moulding sand, compression strength of moulding sand) , functions of binder & types of binders , Discuss on core , different functions of core & essential characteristics of core	**15**
Module 3:	**Methods of Pouring and Feeding Melting Practice, Special Casting Techniques** Gating system , function of riser & different types of riser , importance of size and shape of riser in metal casting , directional solidification , Chvorinov's rule , the construction and operation of cupola used for cast iron melting, Gravity die casting , Pressure die casting ,Cold chamber process , Hot chamber process, True centrifugal casting , Semi centrifugal casting , Centrifuging , investment casting process, Real World Application Areas of Various Casting Methods	**15**
Module 4:	**Casting Defects Foundry Automation and Modern Trends** Types of casting defects with their remedies (Mismatch or Mold shift , Blow holes ,Pin Holes , Hot tears , Shrinkage defects , Misrun , Coldshut , Porosity , Swell , warpage **Automation in Foundries :** CNC Machines in Pattern Making **,** Automated Sand Mixing and Moulding Machines **Advanced Casting Techniques :** Rapid Prototyping and 3D Printing for Foundries , Thin Wall Casting, Single-crystal casting	**10**

MODULE 01: Introduction to Foundry Technology

Foundry Technology

1. Definition of Foundry Technology

Foundry technology is the branch of manufacturing technology concerned with the production of metal components by melting metal, pouring it into a suitably prepared mould cavity, allowing it to solidify, and removing the casting from the mould.

A foundry is a place where metals and alloys are melted and converted into useful shapes by the casting process.

2. Scope of Foundry Technology

The scope of foundry technology includes all activities involved in producing a sound and accurate casting, such as:

Pattern making – preparation of patterns representing the required component.
Mould making – preparation of the mould cavity.
Core making – production of cores for internal holes and cavities.
Melting of metals – melting metals and alloys in suitable furnaces.
Pouring – transferring molten metal into the mold.
Solidification – controlling cooling and solidification of the molten metal.
Shakeout – removing the solidified casting from the mold.
Cleaning and fettling – removing sand, gates, risers and unwanted metal.
Inspection and testing – checking casting quality and detecting defects.
Heat treatment and finishing – improving mechanical properties and surface quality.

3. Applications of Foundry Technology

Foundry technology is used in almost every major engineering industry.

Automobile Industry
Engine blocks
Cylinder heads
Brake drums
Gear housings
Manifolds

Flywheels
Machine and Manufacturing Industry
Machine-tool beds
Pulleys
Bases and frames
Pump bodies
Valve bodies
Gear boxes
Railway Industry
Railway wheels
Brake components
Couplings
Bogie components
Agricultural Industry
Tractor parts
Plough components
Pump parts
Agricultural machine components
Aerospace and Defence
Engine components
Turbine parts
Structural components
Other Applications
Pipes and pipe fittings
Marine components
Electrical equipment
Household and decorative articles
Construction machinery

4. Principles of Casting

The basic principle of casting is to convert a metal from solid state to liquid state, introduce the molten metal into a mould cavity of the desired shape, and allow it to solidify.

The important principles are:

Melting: The metal is heated above its melting temperature.

Fluid flow: Molten metal must flow properly through the gating system and completely fill the mould cavity.
Mould filling: The metal should fill the cavity without excessive turbulence or air entrapment.
Solidification: The molten metal cools and changes from liquid to solid.
Controlled cooling: Solidification should occur in a controlled manner to minimize shrinkage, porosity and other defects.
Casting removal: After sufficient cooling, the casting is removed from the mould.
Finishing: Extra metal such as gates and risers is removed and the casting is cleaned.

In simple words:

Pattern → Mould → Melting → Pouring → Solidification → Removal → Finishing → Inspection

5. Basic Steps Involved in Making a Casting

Step 1: Preparation of Pattern

A pattern is a replica of the required casting, with suitable allowances provided for shrinkage, machining, etc.

Step 2: Mould Preparation

The pattern is placed in moulding material, usually sand, and a mold cavity is produced.

Step 3: Core Making

If the component contains internal holes or cavities, cores are prepared and placed inside the mold.

Step 4: Melting

The required metal or alloy is melted in a suitable furnace such as a cupola, induction furnace or electric furnace.

Step 5: Pouring

The molten metal is poured into the mould through the gating system.

Step 6: Solidification and Cooling

The molten metal fills the cavity and is allowed to cool and solidify.

Step 7: Shakeout

After solidification, the mould is broken or opened and the casting is removed.

Step 8: Fettling and Cleaning

Sand, cores, gates, risers and other unwanted portions are removed from the casting.

Step 9: Inspection

The finished casting is inspected for:

Dimensional accuracy
Surface defects
Cracks
Blowholes
Porosity
Shrinkage defects
Step 10: Finishing

The casting may undergo machining, grinding, heat treatment, painting or other finishing operations before use.

6. Advantages of Metal Casting

1. **Complex shapes can be produced** relatively easily.
2. **Internal cavities and passages** can be produced using cores.
3. Very **large components** can be manufactured by casting.
4. Very **small components** can also be produced using suitable casting processes.
5. Almost all engineering metals and alloys can be cast.
6. It is economical for **mass production**.
7. Components with complicated geometries can often be produced in **one piece**.
8. Material wastage can be relatively low.

9. Casting can produce parts that would be difficult or expensive to manufacture by machining or forging.
10. It is suitable for both **simple and highly complex components**.

7. Disadvantages of Metal Casting

1. **Casting defects** such as blowholes, porosity, cracks and shrinkage may occur.
2. Surface finish is often poorer than processes such as machining.
3. Dimensional accuracy may be lower in conventional sand casting.
4. Some castings require considerable **cleaning, fettling and machining**.
5. Mechanical properties may be inferior to forged components in some applications.
6. Gas and shrinkage defects can reduce the strength of the casting.
7. Mold and pattern preparation can require considerable time and skill.
8. Some casting processes require expensive equipment and tooling.
9. Handling molten metal involves **high temperatures and safety risks**.
10. Defective castings may have to be completely remade, resulting in material and production losses.

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) oCarries 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 High strength. High resistance to wear. High resistance to corrosion due to moisture. Fine surface finish. 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:

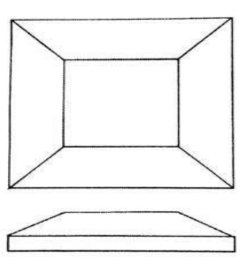
The following factors affect the choice of a pattern.

- 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

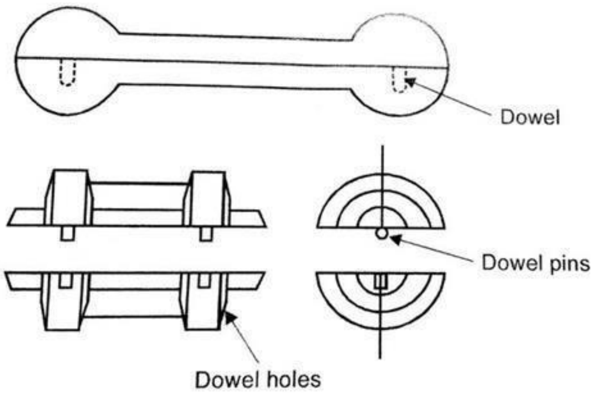
SOLID PATTERN:



(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.

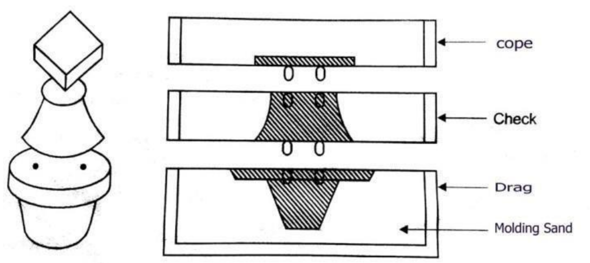
SPLIT PATTERN (OR) TWO PIECE PATTERN



(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.

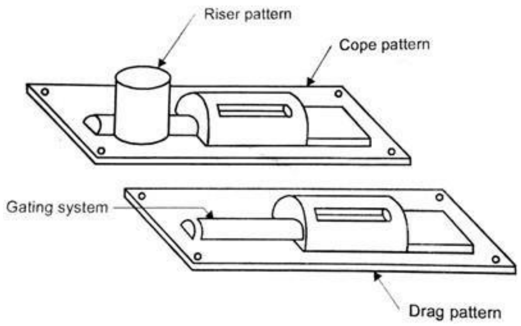
MULTI PIECE PATTERN:



(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.

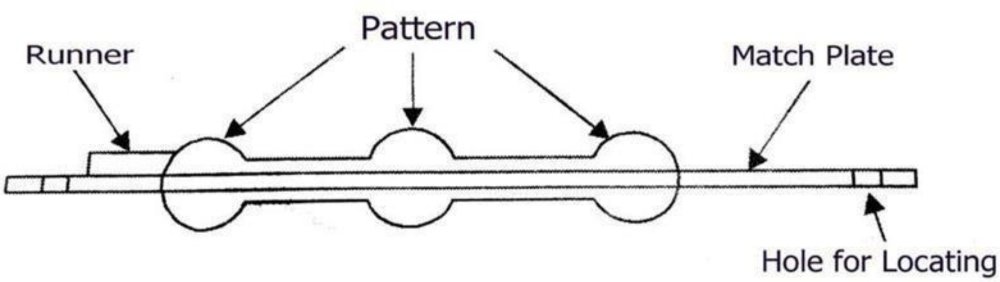
COPE AND DRAG TYPE OF PATTERN:



(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:



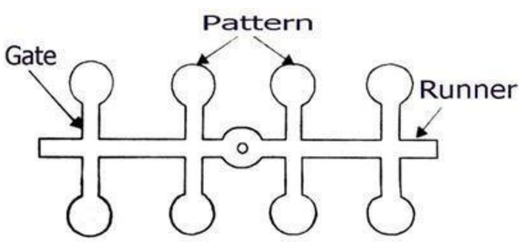
(Match Plate Pattern Diagram)

- 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 aluminumare 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.

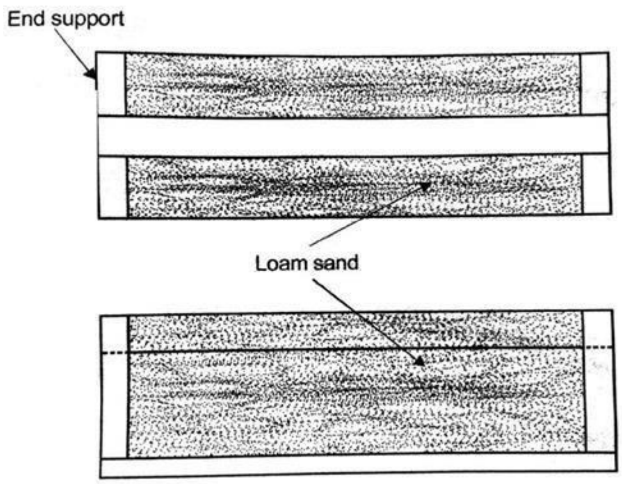
GATED PATTERN:



(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:

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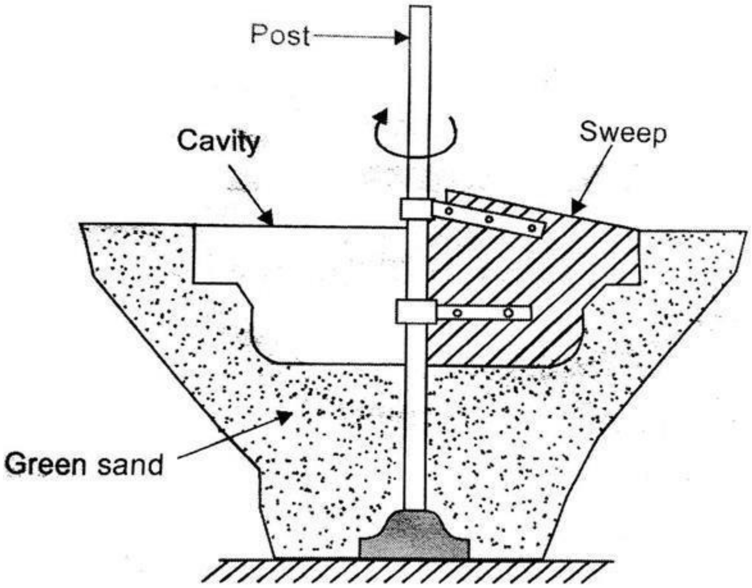
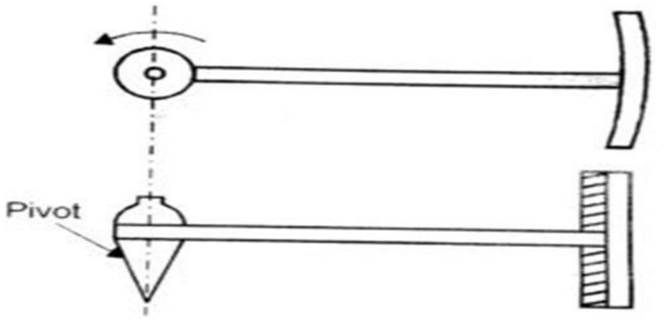


- The plane is rotated about an axis with 360º called symmetry or sweep. In this sweep pattern sand castings prepare the sand mold by using this method. It is called sweep pattern.
  It could be economical to save money and make with full pattern because of symmetry.

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

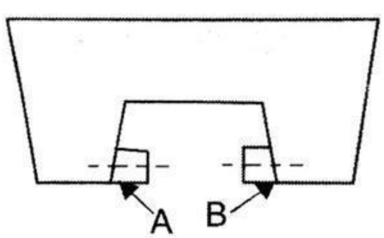
- The sweep pattern sand casting consists of base is placed on the sand mass, vertical spindle and wooden template is called sweep.
- The outer ends of the sweep having corresponding to the shape of require casting.
- The cavity formed together, from sweep is rotated about the axis.
- The sweep and spindle 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.

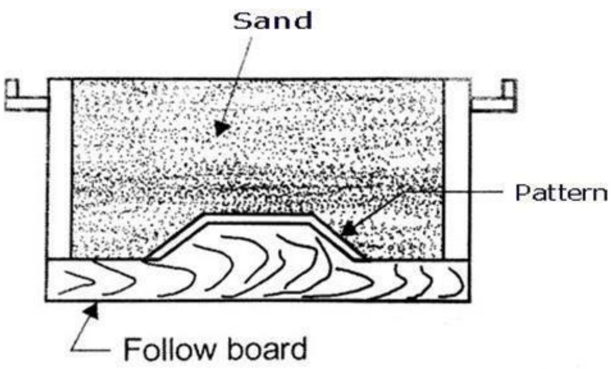
LOOSE PIECE PATTERN:



(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.

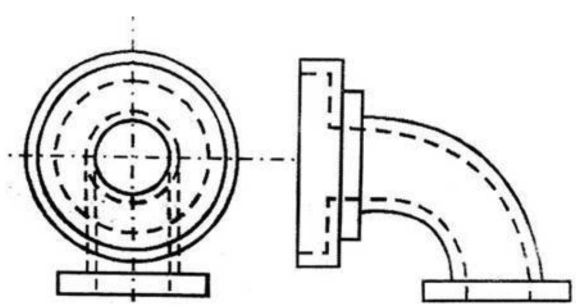
FOLLOW BOARD TYPE PATTERN:



(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.

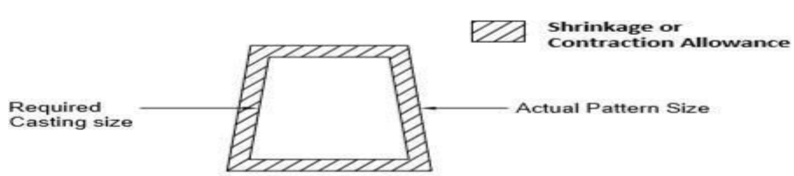


Figure. Shrinkage or contraction Allowance

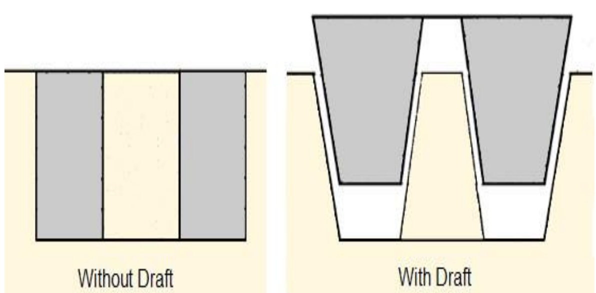
- Riser volume must be sufficient for compensating shrinkage in casting.

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 theree 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:

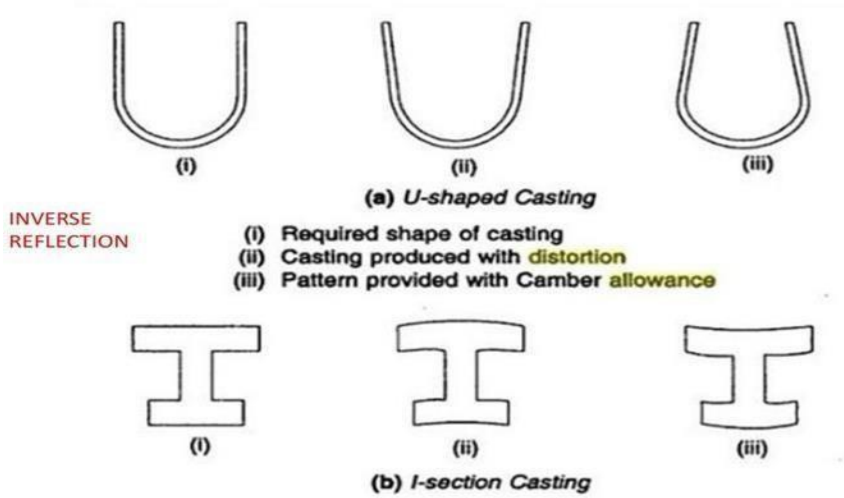
- Taper allowance is also a positive allowance and is given on all the vertical surfaces of pattern so that its withdrawal becomes easier.
- Inner details of the pattern require higher draft than outer surfaces.
- The normal amount of taper on the external surfaces varies from 10 mm to 20mm/mt.
- On 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.

MODULE 02: FOUNDRY MATERIALS AND TESTING OF MOULDING SAND

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 & nonferrous alloy.

LOAM SAND:

- Loam sand contains much more clay as compared to ordinary molding sand.
- 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:

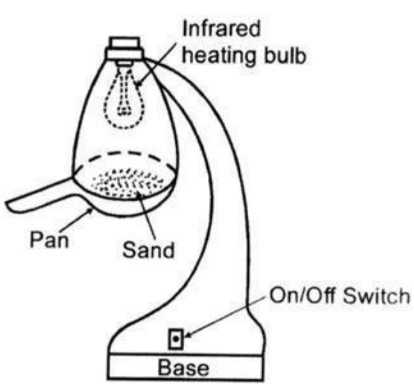
- In mechanized foundries where machine molding is employed.
- System sand is used to fill the whole molding flask. In mechanical sand preparation and handling units, facing sand is not used.
- The used sand is cleaned and re-activated by the addition of water and special additives. This is known as 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.

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^{o}c 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:

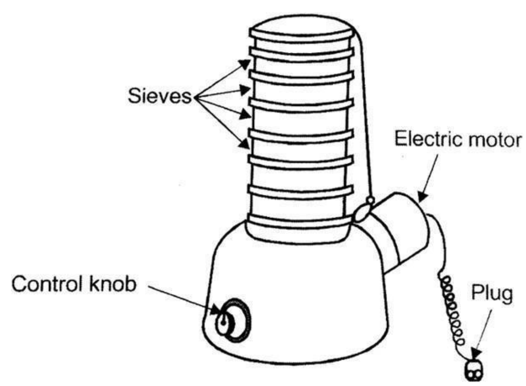
• The clay content test is determined an amount of clay in test process. In this test to take 20 micron clay particles per 0.0008 inch diameter, dried sample such as molding sand with 50 gm., which is put in distilled water with 1% of NaOH solution.

• 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 100ºc to 1300ºc

• And wait 3 minutes and taken from oven for examination use of microscope for evaluate surface characteristic.

•

BINDERS :

✞ **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.

Function of Binder in Foundry

A binder is a material added to molding sand to hold the sand grains together and provide strength to the mold and core.

Main Functions of Binder

Provides strength – Gives the molding sand sufficient strength to maintain the shape of the mold cavity.

Binds sand grains – Holds individual sand particles together.

Improves mold stability – Prevents the mold from breaking or collapsing during handling and pouring.

Improves surface finish – Helps produce a smoother and better-quality casting surface.

Provides resistance to erosion – Prevents molten metal from washing away the mold surface.

Improves core strength – Gives cores adequate strength to withstand handling and molten-metal pressure.

Controls permeability – Helps maintain suitable permeability so gases can escape from the mold.

Improves collapsibility – After solidification, the binder should allow the mold/core to break down easily for removal.

Examples of Binders

Clay (bentonite)

Sodium silicate

Resins

Cement

Oil-based binders

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:

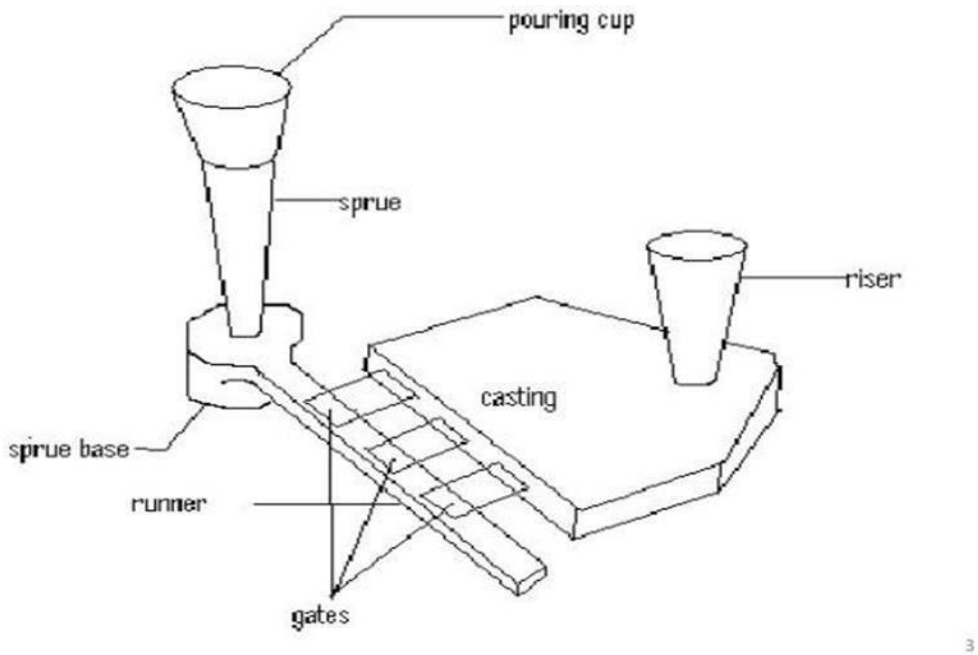
- Good dry strength and hardness after baking
- Sufficient green strength to retain the shape before baking
- Refractoriness
- Surface smoothness
- Permeability
- Lowest possible amount of gas created during the pouring of casting

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.

MODULE :03 METHOD OF POURING AND FEEDING MELTING PRACTICE, SPECIAL CASTING TECHNIQUES:

- 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

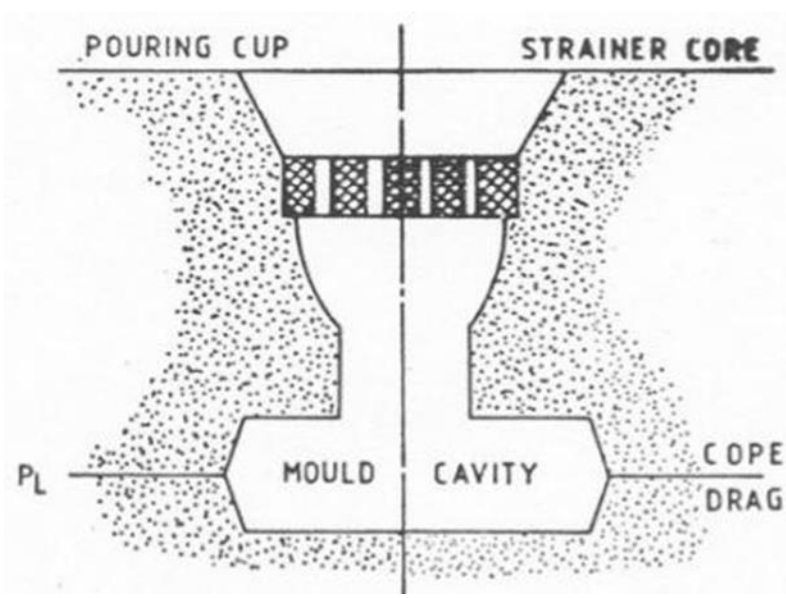
Runner

- 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.

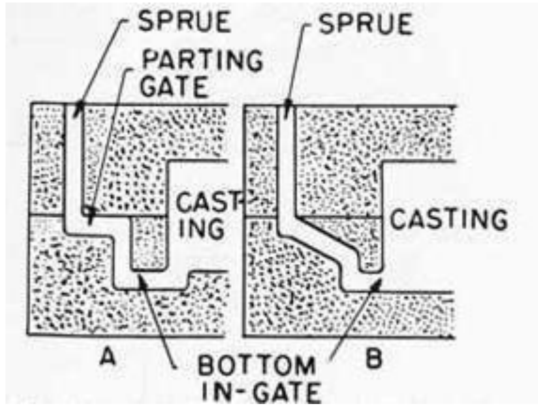
Gate

- 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.

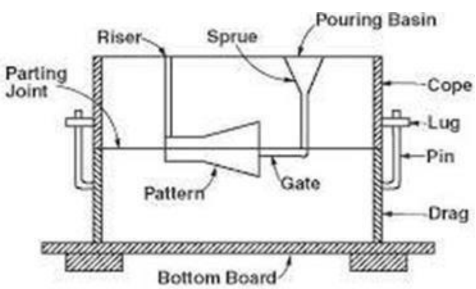
They are shown below



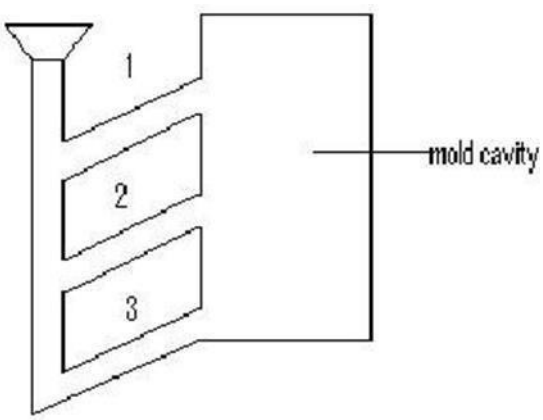
(Top gate)



(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.

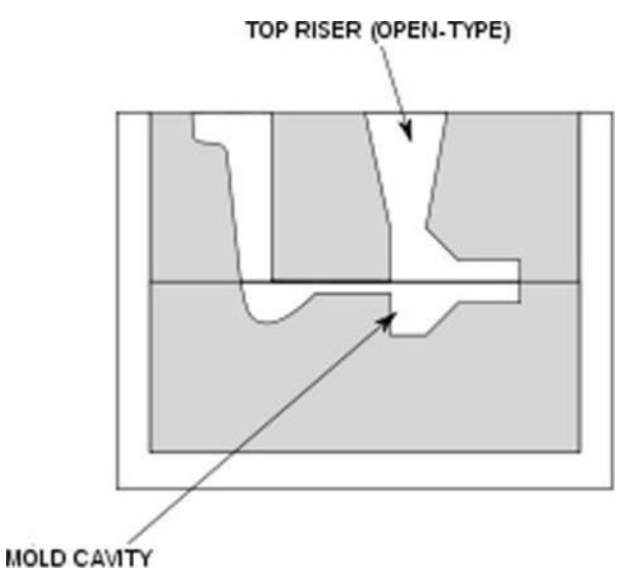
• On the other hand, the connection area should be large enough so that the link does not freeze before solidification of casting. Short-length connections are most desirable.

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:

oLiquid contraction;
oSolidification contraction; and
oSolid 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

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

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

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

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

- 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:

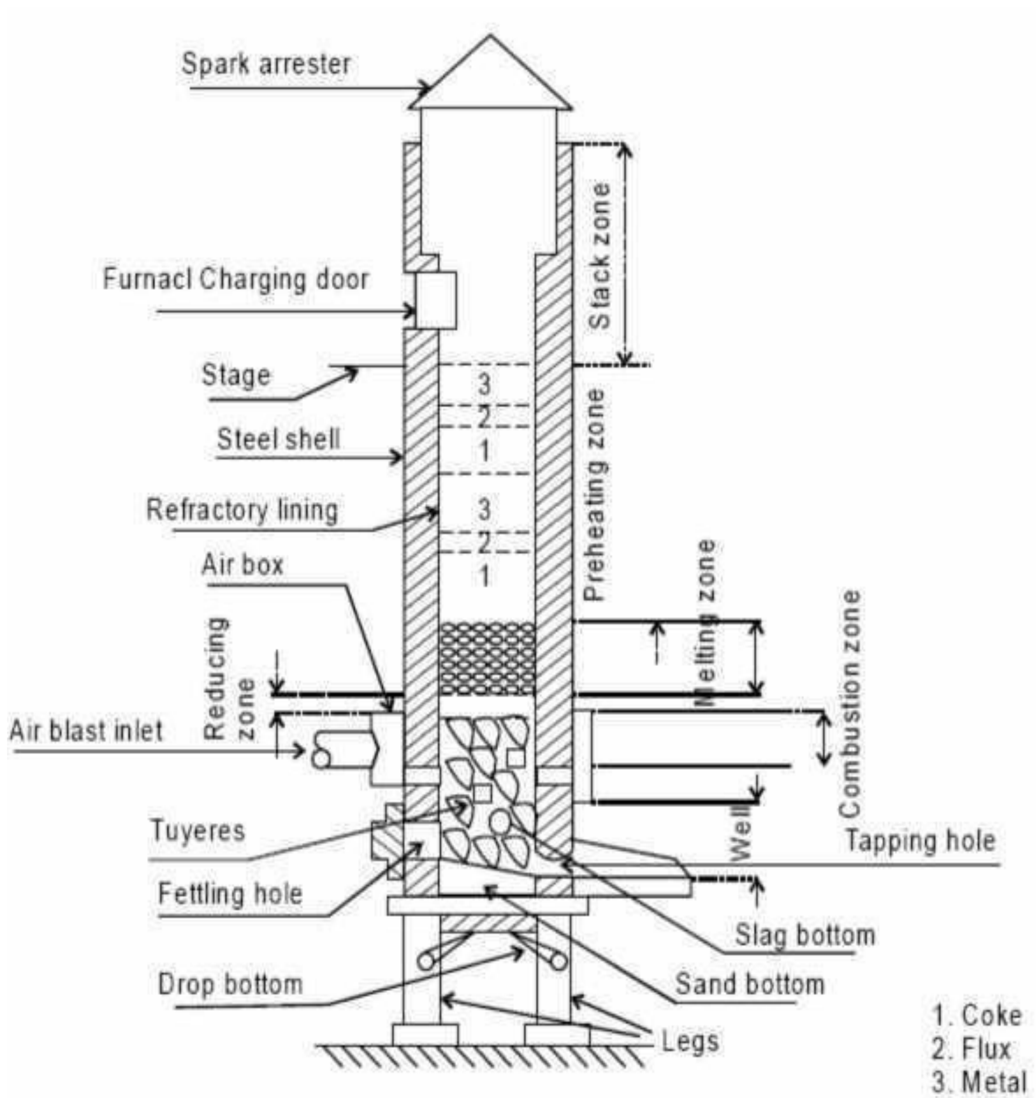
- A cupola is a vertical cylindrical furnace equipped with a tapping spout near its base.
- Cupolas are used only for melting cast irons, and although other furnaces are also used, the largest tonnage of cast iron is melted in cupolas.
- It consists of a large shell of steel plate lined with refractory.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

Gravity Die Casting

Definition: Gravity die casting is a permanent-mould process in which molten metal fills a reusable metal die mainly under gravity. **Steps:**

- Preheat and clean the permanent metal die.
- Apply die coating/release agent.
- Close the die and pour molten metal.
- Metal fills the cavity under gravity and solidifies.
- Open the die, remove the casting and trim the gates/risers.

Advantages: good surface finish, good dimensional accuracy, reusable die and faster production than sand casting.
Limitations: high die cost, not ideal for very complex shapes, and less economical for small quantities.
Applications: aluminium cylinder heads, manifolds, wheels, housings and automotive components.

Exam point: Permanent die + gravity filling = gravity die casting.

Pressure Die Casting

Definition: Pressure die casting is a permanent-mould process in which molten metal is injected into the die cavity under high pressure.
Basic process: Close die → inject metal → maintain pressure → solidify → open die → eject casting.
Advantages: high production rate, good accuracy, good surface finish and thin sections can be produced.
Limitations: high machine/die cost, possible gas porosity, and mainly used for non-ferrous alloys.
Applications: gearbox housings, electronic housings, brackets, handles, appliance parts and automotive components.

Cold Chamber Die Casting

Definition: In cold chamber die casting, the melting furnace is separate from the injection machine. A measured quantity of molten metal is ladled into the shot chamber and injected into the die.

Step	Operation
1	Melt metal in a separate furnace.
2	Transfer a measured amount of molten metal by ladle.
3	Pour it into the shot chamber.
4	Plunger forces the metal into the closed die at high pressure.
5	Maintain pressure while the casting begins to solidify.
6	Open the die and eject the casting.

Common metals: aluminium, magnesium and copper-based alloys.
Advantages: suitable for higher-melting non-ferrous alloys, high pressure and good casting quality.

Disadvantages: metal transfer is required each cycle and cycle time is generally longer than hot chamber.
Applications: aluminium transmission cases, engine covers, pump bodies and structural housings.

Hot Chamber Die Casting

Definition: In hot chamber die casting, the injection mechanism is immersed in or directly connected to the molten metal. **Working:**

- Plunger draws molten metal into the shot chamber.
- Plunger forces metal through the nozzle into the die cavity.
- Pressure is maintained during initial solidification.
- Die opens and ejector pins remove the casting.

Common metals: zinc and other suitable low-melting alloys.
Advantages: very fast cycle, high production rate, easy automation and less metal transfer.
Limitations: unsuitable for many high-melting alloys; injection system is exposed to molten metal.
Applications: zinc locks, fittings, small hardware, electrical parts and automotive components.

Hot Chamber vs Cold Chamber

Point	Hot chamber	Cold chamber
Furnace	Integrated/connected to injection system	Separate furnace
Metal transfer	Little or no ladling each shot	Molten metal is ladled to shot chamber
Cycle	Generally faster	Generally slower
Suitable metals	Lower-melting alloys	Higher-melting non-ferrous alloys such as aluminium
Production	Very high	High

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True Centrifugal Casting

Definition: True centrifugal casting uses a rotating mould. Centrifugal force pushes molten metal against the mould wall and normally produces a hollow cylindrical casting without a conventional core. **Steps:**

- Rotate the mould at the required speed.
- Pour molten metal into the rotating mould.
- Centrifugal force pushes metal outward to the mould wall.

- Metal solidifies from the outer surface toward the inside.
- Stop rotation and remove the casting.

Advantages: good density, good soundness, no conventional core for the bore, and good material economy for cylindrical products.
Limitations: mainly suited to cylindrical/rotational shapes and requires speed control.
Applications: pipes, tubes, cylinder liners, bushings, sleeves and rings.

Semi-Centrifugal Casting

Definition: Semi-centrifugal casting uses rotation to force molten metal toward the outer region, usually producing a solid axis-symmetric part.
Working: Rotate mould → pour metal → centrifugal force moves metal outward → solidify → remove and finish.
Advantages: dense outer region, improved feeding/solidification and good material distribution for rotational parts.
Applications: wheels, pulleys, flywheels, gears and similar solid axis-symmetric components.

Difference: True centrifugal = usually hollow tube; semi-centrifugal = usually solid round/axis-symmetric part.

Investment Casting Process (Lost-Wax Casting)

Definition: Investment casting is a precision casting process in which a wax pattern is coated with ceramic material. The wax is removed before molten metal is poured into the ceramic shell.

Step	Explanation
1. Wax pattern	Make an accurate wax replica of the component.
2. Assembly	Attach wax patterns to a sprue/gating system when required.
3. Ceramic coating	Dip in ceramic slurry and apply refractory material.
4. Drying	Dry each layer and repeat until the shell is strong enough.
5. Dewaxing	Heat the shell to remove the wax.
6. Preheating	Preheat the ceramic shell before pouring.
7. Pouring	Pour molten metal into the shell cavity.
8. Solidification	Allow the metal to cool and solidify.
9. Shell removal	Break/remove the ceramic shell.

10. Finishing	Cut gates, clean, inspect and machine if necessary.

Advantages: excellent accuracy and surface finish, complex shapes, thin sections and fine details, and little parting-line limitation.
Limitations: relatively costly and time-consuming; ceramic shell preparation is delicate.
Applications: aerospace turbine blades, impellers, precision valves, medical parts, jewellery and complex alloy-steel components.

Real-World Applications

Process	Examples
Gravity die casting	Cylinder heads, manifolds, wheels, housings
Pressure die casting	Gearbox housings, brackets, electronic housings
Cold chamber	Aluminium transmission cases, engine covers, pump parts
Hot chamber	Zinc locks, fittings, small hardware, electrical parts
True centrifugal	Pipes, tubes, cylinder liners, bushings
Semi-centrifugal	Wheels, pulleys, flywheels, gears
Investment casting	Turbine blades, impellers, medical parts, precision valves

MODULE :04 CASTING DEFECTS, FOUNDRY AUTOMATION AND MODERN TRENDS

Casting Defects, Foundry Automation and Modern Trends

1. Casting Defects

A casting defect is an unwanted irregularity or imperfection in a casting that occurs due to improper mold preparation, incorrect pouring conditions, poor metal quality, improper solidification, or unsuitable process parameters.

2. Types of Casting Defects and Their Remedies

2.1 Mismatch or Mold Shift

Definition:
Mismatch occurs when the cope and drag portions of the mold are not properly aligned, causing a step or displacement at the parting line.

Causes:

Improper alignment of cope and drag.
Worn or damaged locating pins.
Incorrect positioning of the pattern.
Movement of the mold during closing.

Remedies:

Properly align the cope and drag.
Maintain and replace worn locating pins.
Ensure correct pattern positioning.
Handle and close the mold carefully.

2.2 Blow Holes

Definition:
Blow holes are large cavities or holes caused by trapped gases inside the casting.

Causes:

Excess moisture in molding sand.
Poor mold permeability.
Excessive binder or additives.
Inadequate venting.

High gas generation from the mold or core.

Remedies:

Maintain proper moisture content.
Improve mold permeability.
Provide adequate vents.
Use properly dried and cured cores.
Control the amount of binder and additives.

2.3 Pin Holes

Definition:
Pin holes are very small gas cavities, usually found near or just below the surface of a casting.

Causes:

Excessive dissolved gases, especially hydrogen, in molten metal.
High moisture in the mold.
Poor venting.
Improper melting practice.

Remedies:

Properly degas the molten metal.
Control moisture in molding sand.
Improve mold and core venting.
Avoid unnecessary turbulence during pouring.
Use clean and properly prepared charge materials.

2.4 Hot Tears

Use suitable risering and feeding arrangements. Definition:
Hot tears are cracks formed in a casting during the final stages of solidification when the metal is unable to contract freely.

Causes:

Restricted contraction.
Poor mold/core collapsibility.
Sharp corners and sudden changes in section.
Improper design of the casting.
Incorrect pouring and solidification conditions.

Remedies:

Provide proper fillets and rounded corners.
Improve mold and core collapsibility.
Modify casting design to allow free contraction.
Control pouring and cooling conditions.

2.5 Shrinkage Defects

Definition:
Shrinkage defects are cavities or voids produced because metal contracts as it cools and solidifies.

Causes:

Insufficient feeding of molten metal.
Improper riser design or location.
Poor directional solidification.
Improper casting design.

Remedies:

Provide properly designed and positioned risers.
Use chills where necessary.
Promote directional solidification.
Modify casting design to avoid isolated heavy sections.
Maintain proper pouring temperature.
2.6 Misrun

Definition:
A misrun occurs when the molten metal fails to completely fill the mold cavity before solidification.

Causes:

Low pouring temperature.
Slow pouring.
Poor fluidity of molten metal.
Thin sections in the casting.
Improper gating system.
Excessive heat loss.

Remedies:

Increase pouring temperature within the appropriate range.
Improve the gating system.
Pour at the correct rate.
Increase gate size where appropriate.

Avoid unnecessarily thin sections.
Reduce heat loss during pouring.

2.7 Cold Shut

Definition:
A cold shut is a seam or line formed when two streams of molten metal meet but do not fuse properly.

Causes:

Low metal temperature.
Poor fluidity.
Slow pouring.
Improper gating arrangement.
Oxide films on the molten metal.

Remedies:

Maintain suitable pouring temperature.
Improve the gating system.
Increase pouring speed where appropriate.
Reduce turbulence and oxide formation.
Improve the cleanliness of molten metal.

2.8 Porosity

Definition:
Porosity is the presence of small or large voids within a casting, caused mainly by trapped gases or shrinkage during solidification.

Causes:

Gas dissolved in molten metal.
Poor mold permeability.
Improper feeding.
Turbulent pouring.
Excess moisture.

Remedies:

Degas molten metal.
Improve mold permeability and venting.
Provide proper risers and feeding.
Reduce turbulence in the gating system.
Control moisture in the molding material.

2.9 Swell

Definition:
A swell is an enlargement or bulging of the casting surface caused by the mold wall moving or deforming under the pressure of molten metal.

Causes:

Insufficient mold hardness.
Poor ramming.
Weak molding sand.
Excessive metallostatic pressure.
Improper mold support.

Remedies:

Use proper ramming pressure.
Maintain adequate mold hardness and strength.
Use suitable molding sand and binder.
Properly support the mold.
Avoid excessive metallostatic pressure where possible.

2.10 Warpage

Definition:
Warpage is the distortion or bending of a casting from its intended shape due to uneven or unequal contraction during cooling.

Causes:

Uneven cooling.
Unequal section thickness.
Residual stresses.
Improper casting design.
Improper mold/core conditions.

Remedies:

Maintain uniform section thickness where possible.
Improve casting design.
Control the cooling rate.
Use suitable chills or insulation where required.
Apply suitable stress-relieving heat treatment.

Automation in Foundries

Definition: Foundry automation is the use of CNC machines, sensors, controllers, robots and computercontrolled systems to perform casting operations with minimum manual intervention. It improves productivity, dimensional accuracy, repeatability and workplace safety.

CNC Machines in Pattern Making

CNC (Computer Numerical Control) machines manufacture patterns directly from a programmed digital model. A cutting tool removes material from wood, plastic, foam, aluminium or other pattern materials according to computer-generated tool paths. **Basic sequence:**

- Create the component geometry using CAD software.
- Convert the CAD model into CNC tool paths using CAM software.
- Transfer the program to the CNC machine.
- Clamp the pattern material and set the work coordinates.
- Machine the pattern automatically using suitable cutting tools.
- Inspect the finished pattern and make corrections if required.

Advantages: high dimensional accuracy, excellent repeatability, complex shapes can be produced, reduced manual pattern-making time, easy modification through CAD data, and lower dependence on skilled manual labour.

Applications: automotive castings, aerospace components, pump bodies, dies, mould patterns and prototype castings.

Automated Sand Mixing

Automated sand mixing systems prepare moulding sand by accurately controlling the quantities of sand, binder/clay, water and other additives. The system can automatically measure, mix, transport and deliver prepared sand to the moulding station.

Main operations: batching → mixing → testing/conditioning → conveying → delivery.

Benefits: uniform sand properties, controlled moisture and binder content, consistent mould strength, less material wastage, higher production rate and improved process control.

Automated Moulding Machines

Automated moulding machines produce moulds by compacting prepared moulding sand around a pattern. Modern systems can perform pattern positioning, sand filling, compaction, mould separation and mould transfer automatically.

Common methods: squeeze moulding, jolt-squeeze moulding, high-pressure moulding and flaskless moulding.

Advantages: high production rate, uniform mould hardness, improved dimensional accuracy, reduced labour requirement, better safety and consistent casting quality.

Advanced Casting Techniques

Advanced casting techniques are modern processes developed to produce complex, thin, precise and highperformance components that are difficult or uneconomical to manufacture by conventional casting.

Rapid Prototyping and 3D Printing for Foundries

Rapid prototyping is the quick production of a physical model or prototype directly from a 3D CAD model. In foundries, additive manufacturing can be used to produce patterns, cores, moulds or even metal components.

General process:

- Prepare the 3D CAD model.
- Convert the model into thin digital layers.
- Send the data to the 3D printer.
- Build the pattern, mould, core or component layer by layer.
- Remove support material and perform finishing/post-processing.
- Use the printed pattern/mould/core for casting or inspect the printed part.

Advantages: very short development time, no conventional pattern tooling for many applications, complex internal passages can be produced, easy design modification, reduced material waste and excellent suitability for prototypes and small batches.

Limitations: equipment and material cost can be high, surface finish may require post-processing, build size can be limited, and some printed materials require special process control.

Thin Wall Casting

Thin wall casting produces castings with unusually small wall thickness while maintaining adequate filling, soundness and dimensional accuracy. It is commonly used where low weight and material saving are important.

Important requirements: high fluidity of molten metal, suitable pouring temperature, rapid and controlled filling, proper gating and risering, accurate moulds and good thermal control.

Advantages: lower component weight, reduced metal consumption, faster cooling, improved material efficiency and suitability for lightweight products.

Problems: premature freezing, misrun, cold shut, porosity and dimensional defects can occur if filling and solidification are not properly controlled.

Applications: automobile components, aerospace parts, electronic housings and lightweight engineering components. **2.3 Single-Crystal Casting**

Single-crystal casting is a specialized casting technique in which the entire component solidifies as one crystal, with no grain boundaries across the main body. It is especially important for high-temperature turbine components.

Basic principle: molten alloy is directionally solidified so that only one crystal orientation continues to grow into the component.

Typical method: directional solidification is controlled by a temperature gradient. A specially designed starter section selects one crystal, and a selector geometry eliminates competing grains. The selected crystal then grows through the airfoil/component.
Advantages: elimination of grain-boundary-related weaknesses, improved creep resistance, better fatigue performance at high temperature, and improved resistance to high-temperature deformation.
Applications: gas-turbine and aircraft-engine blades, high-temperature turbine vanes and other components exposed to severe thermal conditions.

Quick Comparison

Technique	Main purpose	Major advantage
CNC pattern making	Accurate pattern production	Precision and repeatability
Automated sand mixing	Uniform moulding sand	Consistent sand properties
Automated moulding	Fast mould production	High production rate
3D printing / rapid prototyping	Rapid patterns, moulds, cores or prototypes	Complex geometry and fast development
Thin wall casting	Lightweight castings	Lower weight/material use
Single-crystal casting	High-temperature components	Excellent creep resistance

***THE END ***