Metal Casting

Introduction

- ✓ Metal Casting is one of the oldest materials shaping methods known.
- ✓ Casting means pouring molten metal into a mold with a cavity of the shape to be made, and allowing it to solidify. When solidified, the desired metal object is taken out from the mold either by breaking the mold or taking the mold apart. The solidified object is called the casting.
- ✓ By this process, intricate parts can be given strength and rigidity frequently not obtainable by any other manufacturing process.
- ✓ The mold, into which the metal is poured, is made of some heat resisting material.
- ✓ Sand is most often used as it resists the high temperature of the molten metal.
- ✓ Permanent molds of metal can also be used to cast products.

Advantages

- ✓ The metal casting process is extensively used in manufacturing because of its many advantages.
- ✓ Molten material can flow into very small sections so that intricate shapes can be made by this process. As a result, many other operations, such as machining, forging, and welding, can be minimized or eliminated.
- ✓ It is possible to cast practically any material that is ferrous or non-ferrous.
- ✓ As the metal can be placed exactly where it is required, large saving in weight can be achieved.
- ✓ The necessary tools required for casting molds are very simple and inexpensive. As a result, for production of a small lot, it is the ideal process.

- ✓ There are certain parts made from metals and alloys that can only be processed this way.
- ✓ Size and weight of the product is not a limitation for the casting process.

Limitations

- ✓ Dimensional accuracy and surface finish of the castings made by sand casting processes are a limitation to this technique.
- ✓ Many new casting processes have been developed which can take into consideration the aspects of dimensional accuracy and surface finish.
- ✓ The metal casting process is a labor intensive process.

Pattern:-

The pattern is the principal tool during the casting process. Pattern is a replica of the final object to be made with some modifications. The main modifications are the addition of pattern allowances, and the provision of core prints. If the casting is to be hollow, additional patterns called cores are used to create these cavities in the finished product. The mould cavity is made with the help of pattern.

Function of pattern:

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

Patterns material:

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

- ✓ Easily worked, shaped and joined
- ✓ Light in weight
- ✓ Strong, hard and durable
- ✓ Resistant to wear and abrasion
- ✓ Resistant to corrosion, and to chemical reactions
- ✓ Dimensionally stable and unaffected by variations in temperature and humidity.
- ✓ Available at low cost

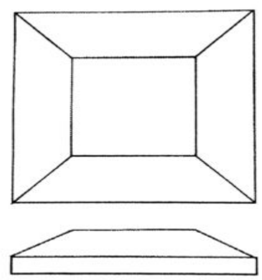
The important pattern types in casting:

The pattern types in casting process depend on the part to be manufactured. The sand casting pattern making will be easy remove from the mold without any damage in the mold product. It is based on design patterns material and more. The different types of pattern as follows,

- ✓ Solid or single piece pattern
- ✓ Split pattern or two piece pattern
- ✓ Multi-piece pattern
- ✓ Cope and drag pattern
- ✓ Match plate pattern
- ✓ Gated pattern
- ✓ Skeleton pattern

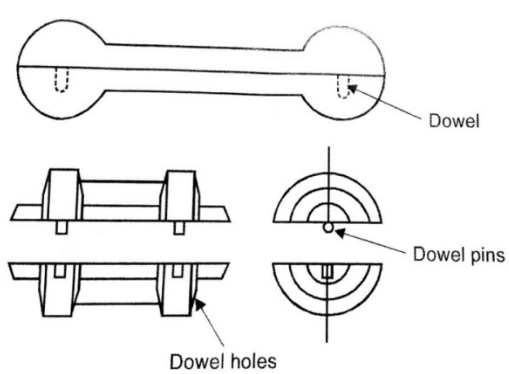
- ✓ sweep pattern sand casting
- ✓ Loose piece pattern
- ✓ Follow board pattern

1. Single Piece pattern or Solid pattern:



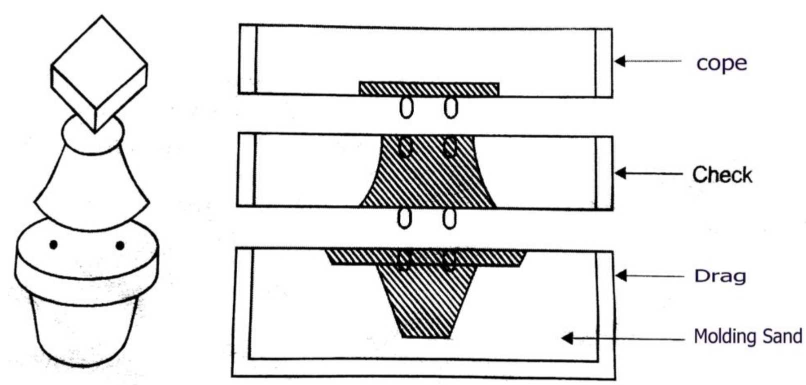
- ✓ The solid pattern types is a most and simple method for simple shape casting.
- ✓ It pattern can make without any sub-part or joint in the mold part.
- ✓ In this type of pattern only produce simple shape and withdrawn for very easily from the mold.
- ✓ The solid pattern placed in the drag position.

2. Split pattern (or) two piece pattern:



- ✓ The split pattern is a 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. The split pattern is above figure.
- ✓ 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.

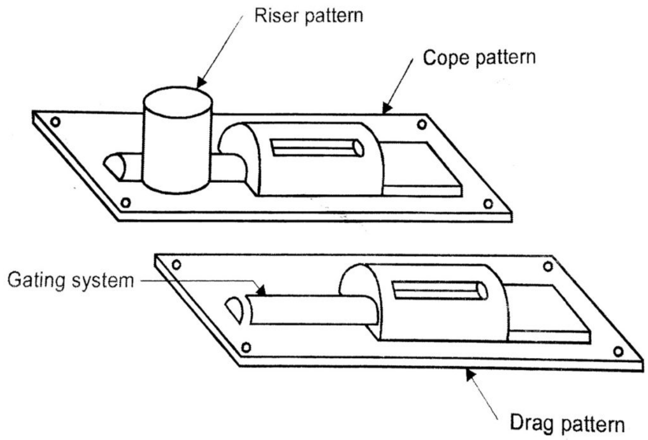
3. Multi piece pattern:



- ✓ 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.
- ✓ They are three pattern will be connected by using dowel pins and molding box clamped by using clamp.

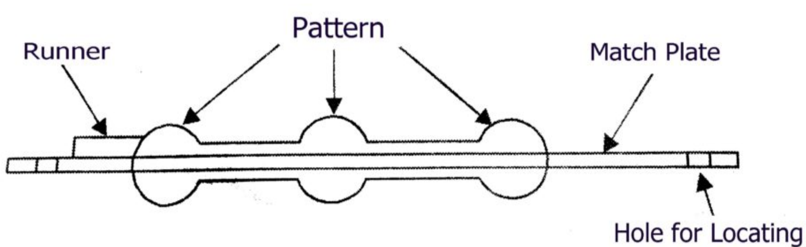
4. Cope and drag type of pattern:

- ✓ These are similar to split patterns.



- ✓ In addition to splitting the pattern, the cope and drag halves of the pattern along with the gating and risering systems are attached separately to the metals or wooden plate along with the alignment pins. They are called cope and drag pattern.

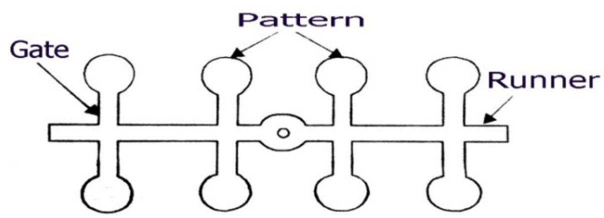
5. Match plate type pattern:



- ✓ The match plate pattern are having two parts, one side of match plate the cope flask is prepared and on the other the drag flask.
- ✓ The molding process completed after that match plate removed together, the gating is obtained for joining the cope and drag.
- ✓ It pattern is mainly used for casting of metal, usually aluminum are machined in this method with light weight and machinability.
- ✓ It should be possible for mass production of small casting with high dimensional accuracy.

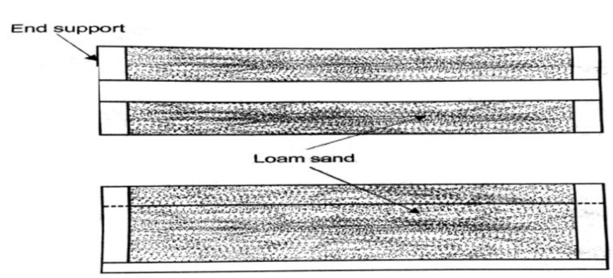
- ✓ They are also used for machine molding. The cost will be high of molding but it is easily compensated by high rate of production and more accuracy.

6. Gated pattern:



- ✓ 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.

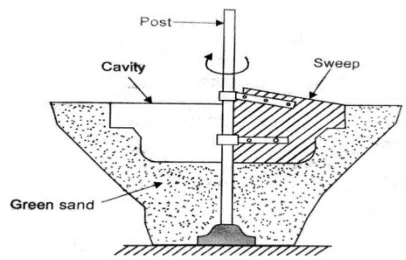
7. Skeleton pattern:



- ✓ When the size of casting is very large, but easy to shape and only a few 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.

8. Sweep pattern sand casting Method:



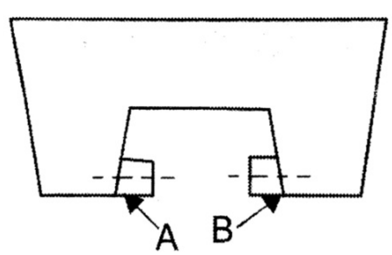
- ✓ A sweep pattern is a section or board made of wood or metal to required cross section that is rotated about one edge to shape mould cavity having shapes of rational symmetry.

- ✓ The plane is rotated about an axis with 360^0 called symmetry or sweep..

- ✓ It could be economical and make with full pattern because of symmetry.

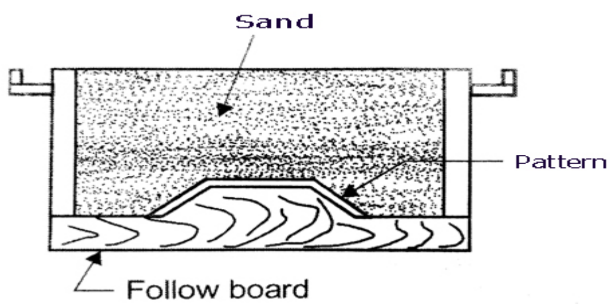
- ✓ In this pattern used for prepare the mold of large symmetrical casting by mean of circular cross section.

9. Loose piece pattern:



- ✓ A single piece are made to have loose piece in easy to allow withdrawal from the mold 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, it cavity separately formed by the pattern. It loose piece pattern is highly skilled job and expensive.

10. Follow board type pattern:



- ✓ In casting process some portions are structurally weak.
- ✓ It is not supported properly and may be break under the force of ramming.
- ✓ In this stage the special pattern to allow the mold may be such as wooden material.

Pattern Allowances

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

    1. Shrinkage or contraction allowance

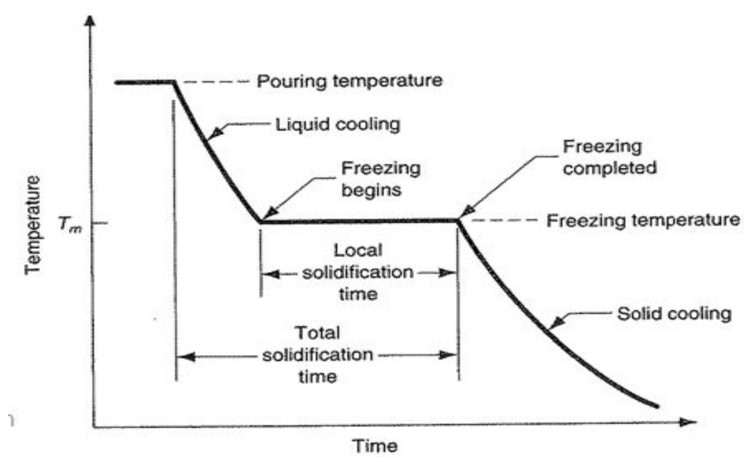
2. Draft or taper allowance
3. Machining or finish allowance
4. Distortion or camber allowance
5. Rapping allowance

1. Shrinkage or Contraction Allowance

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

- ✓ **Liquid Shrinkage**: it refers to the reduction in volume when the metal changes from liquid state to solid state at the solidus temperature. To account for this shrinkage; riser, which feed the liquid metal to the casting, are provided in the mold.

- ✓ **Solid Shrinkage:** it refers to the reduction in volume caused when metal loses temperature in solid state. To account for this, shrinkage allowance is provided on the patterns.



2. Draft or Taper Allowance

- ✓ By draft is meant the taper provided by the pattern maker on all vertical surfaces of the pattern so that it can be removed from the sand without tearing away the sides of the sand mold and without excessive rapping by the molder.

- ✓ **Figure 1** shows a pattern having no draft allowance being removed from the pattern. In this case, till the pattern is completely lifted out, its sides will remain in contact with the walls of the mold, thus tending to break it.

- ✓ **Figure 2** is an illustration of a pattern having proper draft allowance. Here, the moment the pattern lifting commences, all of its surfaces are well away from the sand surface. Thus the pattern can be removed without damaging the mold cavity.

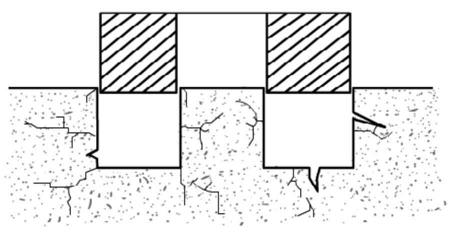


Figure 1

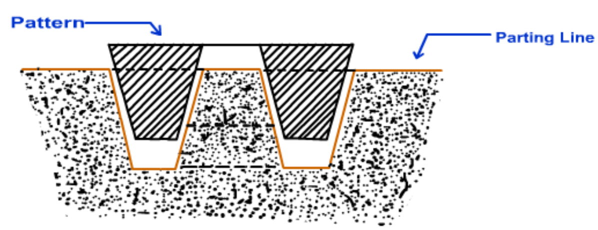


Figure 2

3. Machining or Finish Allowance

- ✓ The finish and accuracy achieved in sand casting are generally poor and therefore when the casting is functionally required to be of good surface finish or dimensionally accurate, it is generally achieved by subsequent machining.

- ✓ Machining or finish allowances are therefore added in the pattern dimension.

4. Distortion or Camber Allowance

- ✓ Sometimes castings get distorted, during solidification, due to their typical shape. For example, if the casting has the form of the letter U, V, T, or L etc. it will tend to contract at the closed end causing the vertical legs to look slightly inclined.

- ✓ This can be prevented by making the legs of the U, V, T, or L shaped pattern converge slightly (inward) so that the casting after distortion will have its sides vertical (Figure).

- ✓ The distortion in casting may occur due to internal stresses.

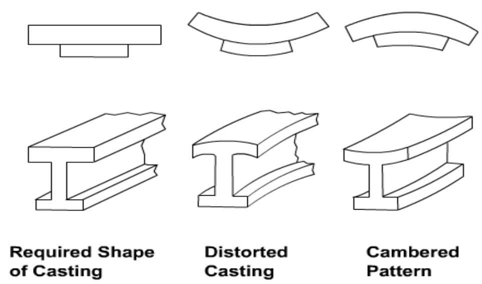


Figure: Distortions in Casting

5. Shake Allowance or Rapping Allowance

- ✓ Before the withdrawal from the sand mold, the pattern is rapped all around the vertical faces to enlarge the mold cavity slightly, which facilitate its removal.

- ✓ Since it enlarges the final casting made, it is desirable that the original pattern dimension should be reduced to account for this increase.

Core and Core Prints:

- ✓ Castings are often required to have holes, recesses, etc. of various sizes and shapes.

- ✓ These impressions can be obtained by using cores. So where coring is required, provision should be made to support the core inside the mold cavity.
- ✓ Core prints are used to serve this purpose. The core print is an added projection on the pattern and it forms a seat in the mold on which the sand core rests during pouring of the mold.
- ✓ The core print must be of adequate size and shape so that it can support the weight of the core during the casting operation.
- ✓ Depending upon the requirement a core can be placed horizontal, vertical and can be hanged inside the mold cavity. A typical job, its pattern and the mold cavity with core and core print is shown in Figure.

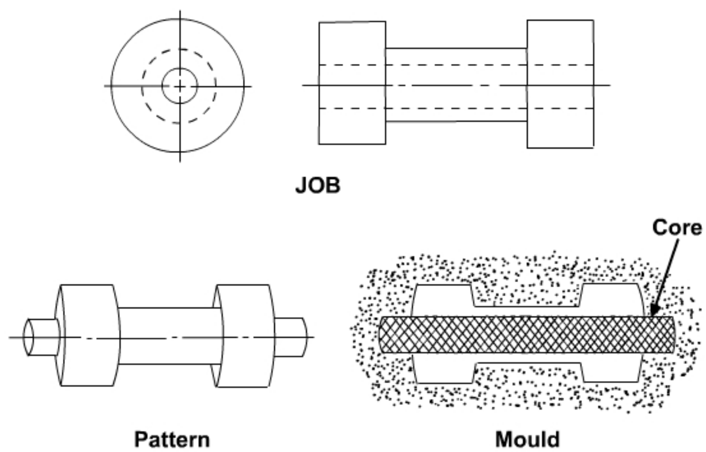


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Figure: A Typical Job, its Pattern and the Mold Cavity

Molding Material and Properties:

A large variety of molding materials is used in foundries for manufacturing molds and cores. They include molding sand, system sand or backing sand, facing sand, parting sand, and core sand. The choice of molding materials is based on their processing properties. The properties that are generally required in molding materials are:

1. Refractoriness

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

2. Permeability or Porosity

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

3. Strength

- ✓ To avoid pouring defects, the sand should be of sufficient strength to produce mold of desired shape and also retain this shaped even when the molten metal is poured in the moulding cavity.

A. Green Strength

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

B. Dry Strength

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

C. Hot Strength

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

4. Collapsibility

- ✓ The ability of the molding sand to collapse after solidification of the molten metal is called collapsibility.
- ✓ The molding sand should also have collapsibility so that during the contraction of the solidified casting it does not provide any resistance, which may result in cracks in the castings. Besides these specific properties the molding material should be cheap, reusable and should have good thermal conductivity.

5. Cohesiveness

- ✓ The ability of the sand particles to stick with each other is called cohesiveness.
- ✓ The strength of the sand depends upon how cohesive the sand particles are.

6. Adhesiveness

- ✓ The ability of the sand particles to get stick with another body is called adhesiveness.

- ✓ The sand should have sufficient adhesiveness so that it can easily get cling to the sides of the molding boxes and does not fall out to the box when it is removed.

7. Flowability

- ✓ It is the measure of the molding sand to flow around and over a pattern during ramming and to uniformly fill the molding flask.
- ✓ Due to this property the sand can easily occupy the space in molding box and take up its shape.
- ✓ The sand should be of high flowability, so that it can be easily compacted for uniform density and to obtain a good impression of the pattern in the mould.

Molding Sand Composition

The main ingredients of any molding sand are:

- ✓ **Base sand,**
- ✓ **Binder, and**
- ✓ **Moisture**
- ✓ **Additives**

A. Base Sand

- ✓ Silica sand is most commonly used base sand. Other base sands that are also used for making mold are zircon sand, Chromite sand, and olivine sand. Silica sand is cheapest among all types of base sand and it is easily available.

B. Binder

Binders are of many types such as:

I. Clay binders,

II. Organic binders and

III. Inorganic binders

- ✓ Clay binders are most commonly used binding agents mixed with the molding sands to provide the strength.
- ✓ The most popular clay types are:
- ✓ Kaolinite or fire clay (Al2O3 2 SiO2 2 H2O) and Bentonite (Al2O3 4 SiO2 nH2O) of the two the Bentonite can absorb more water which increases its bonding power.

C. Moisture

- ✓ Clay acquires its bonding action only in the presence of the required amount of moisture.
- ✓ When water is added to clay, it penetrates the mixture and forms a microfilm, which coats the surface of each flake of the clay.
- ✓ The amount of water used should be properly controlled.
- ✓ This is because a part of the water, which coats the surface of the clay flakes, helps in bonding, while the remainder helps in improving the plasticity.

D. Additives

- ✓ Additives are the materials generally added to the molding and core sand mixture to develop some special property in the sand.
- ✓ Some commonly used additives for enhancing the properties of molding and core sands are coal dust, corn flour, dextrin, sea coal, pitch, wood flour, silica flour.

Types of Molding Sand

The various types of molding sand are

1. Green sand
2. Dry sand
3. Loam sand
4. Parting sand
5. Facing sand
6. Backing sand
7. System sand
8. Core sand

1. Green Sand

- ✓ Green sand is a mixture of silica sand and clay. It constitutes 18 % to 30 % clay and 6 % to 8 % water.
- ✓ The water and clay present is responsible for furnishing bonds for the green sand.
- ✓ It is slightly wet when squeezed with hand. It has the ability to retain the shape and impression given to it under pressure.
- ✓ It is easily available and has low cost.
- ✓ The mould which is prepared in this sand is called green sand mould.
- ✓ It is commonly used for producing ferrous and non-ferrous castings

2. Dry Sand

- ✓ After making the mould in green sand, when it is dried or baked is called dry sand.
- ✓ It is suitable for making large castings.
- ✓ The mould which is prepared in dry sand is known as dry sand moulds.

3. Loam Sand

- ✓ It is a type of molding sand in which 50 % of clay is present.
- ✓ It is mixture of sand and clay and water is present in such a quantity, to make it a thin plastic paste.
- ✓ In loam molding patterns are not used.
- ✓ It is used to produce large casting.

4. Parting Sand

- ✓ Parting sand is used to prevent the sticking of green sand to the pattern and also to allow the sand on the parting surface of the cope and drag to separate without clinging.
- ✓ It is clean clay free silica sand.

5. Facing Sand

- ✓ The face of the mould is formed by facing sand.
- ✓ Facing sand is used directly next to the surface of the pattern and it comes in direct contact with the molten metal, when the molten metal is poured into the mould.
- ✓ It possesses high strength and refractoriness as it comes in contact with the molten metal.
- ✓ It is made of clay and silica sand without addition of any used sand.

6. Backing Sand

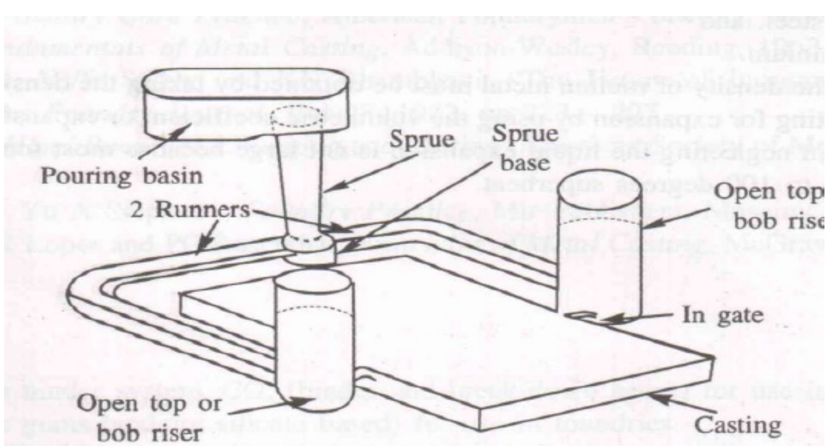
- ✓ Backing sand or flour sand is used to back up facing sand.
- ✓ Old and repeatedly used molding sand is used for the backing purpose.
- ✓ It is also sometimes called black sand because of the addition of coal dust and burning when it comes in contact with the molten metal.

7. Core Sand

- ✓ The sand which is used to make core is called core sand.
- ✓ It is also called as oil sand.
- ✓ It is a mixture of silica sand and core oil. Core oil is mixture of linseed oil, resin, light mineral oil and other binding materials.
- ✓ For the sake of economy, pitch or flours and water may be used in making of large cores.

Elements of Gating System

The gating systems refer to all those elements which are connected with the flow of molten metal from the ladle to the mould cavity. The elements of gating systems are



- ✓ **Pouring basin:** This is otherwise called as bush or cup. It is circular or rectangular in shape. It collects the molten metal, which is poured, from the ladle.
- ✓ **Sprue :** It is circular in cross section. It leads the molten metal from the pouring basin to the sprue well.
- ✓ **Sprue Well:** It changes the direction of flow of the molten metal to right angle and passes it to the runner.
- ✓ **Runner:** The runner takes the molten metal from sprue to the casting.
- ✓ **Ingate**: This is the final stage where the molten metal moves from the runner to the mold cavity.
- ✓ **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.

Goals of Gating System

- ✓ To minimize turbulence to avoid trapping gasses into the mold
- ✓ To get enough metal into the mold cavity before the metal starts to solidify
- ✓ To avoid shrinkage
- ✓ Establish the best possible temperature gradient in the solidifying casting so that the shrinkage if occurs must be in the gating system not in the required cast part.
- ✓ Incorporates a system for trapping the non-metallic inclusions
- ✓ Gating system refers to all the sections, through which the molten metal passes, while entering into the mould cavity.

Casting Defects

1. **Gas Defects**

   ✓ A condition existing in a casting caused by the trapping of gas in the molten metal or by mold gases evolved during the pouring of the casting.

   ✓ The defects in this category can be classified into blowholes and pinhole porosity.

   a. **Blowholes** It is fairly large, well- rounded cavity produced by the gases which displace the molten metal at the cope surface of a casting.

   b. **Pinhole** porosity occurs due to the dissolution of hydrogen gas, which gets entrapped during heating of molten metal.

2. **Shrinkage Cavities**

   ✓ These are caused by liquid shrinkage occurring during the solidification of the casting. To compensate for this, proper feeding of liquid metal is required.

   ✓ For this reason risers are placed at the appropriate places in the mold.

   ✓ Sprues may be too thin, too long or not attached in the proper location, causing shrinkage cavities.

   ✓ It is recommended to use thick sprues to avoid shrinkage cavities.

3. **Molding Material Defects**

   The defects in this category are cuts and washes, metal penetration, fusion, and swell.

   a. **Cut and washes**

   ✓ These appear as rough spots and areas of excess metal, and are caused by erosion of molding sand by the flowing metal.

   ✓ This is caused by the molding sand not having enough strength and the molten metal flowing at high velocity.

   b. **Metal penetration**

- ✓ When molten metal enters into the gaps between sand grains, the result is a rough casting surface.

c. Swell

- ✓ Under the influence of metallostatic forces, the mold wall may move back causing a swell in the dimension of the casting.
- ✓ A proper ramming of the mold will correct this defect.

d. Inclusions

- ✓ Particles of slag, refractory materials sand or deoxidation products are trapped in the casting during pouring solidification.
- ✓ The provision of choke in the gating system and the pouring basin at the top of the mold can prevent this defect.

4. Pouring Metal Defects

The likely defects in this category are

A. Mis-runs and

B. Cold shuts.

A. Mis-run:

- ✓ A mis-run is caused when the metal is unable to fill the mold cavity completely and thus leaves unfilled cavities.
- ✓ A mis-run results when the metal is too cold to flow to the extremities of the mold cavity before freezing.
- ✓ Long, thin sections are subject to this defect and should be avoided in casting design.

B. Cold shut:

- ✓ A cold shut is caused when two streams while meeting in the mold cavity, do not fuse together properly thus forming a discontinuity in the casting.

- ✓ When the molten metal is poured into the mold cavity through more-than-one gate, multiple liquid fronts will have to flow together and become one solid.

5. Shift

A. **Mold shift:** The mold shift defect occurs when cope and drag or molding boxes have not been properly aligned.

B. **Core Shift:** A misalignment between cores may give rise to defective casting.

6. Hot Tear

- ✓ A crack develops in a casting due to high residual stresses is called hot tear.

7. Porosity

- ✓ This indicates very small holes uniformly dispersed throughout the casting.
- ✓ It arises when there is a decrease in gas solubility during the solidification.

8. Scar

- ✓ A shallow blow, usually found on the flat casting surface is referred to as a scar.

9. Drop

- ✓ An irregular shaped projection on the cope surface of a casting is called Drop**.**

10. Dross

- ✓ Lighter impurities appearing on the top of the surface of the casting are called dross.

11. Dirt

- ✓ Sometimes sand particle dropping out of the cope get embedded on the top of a casting. When removed, these leave small angular holes known as dirt.

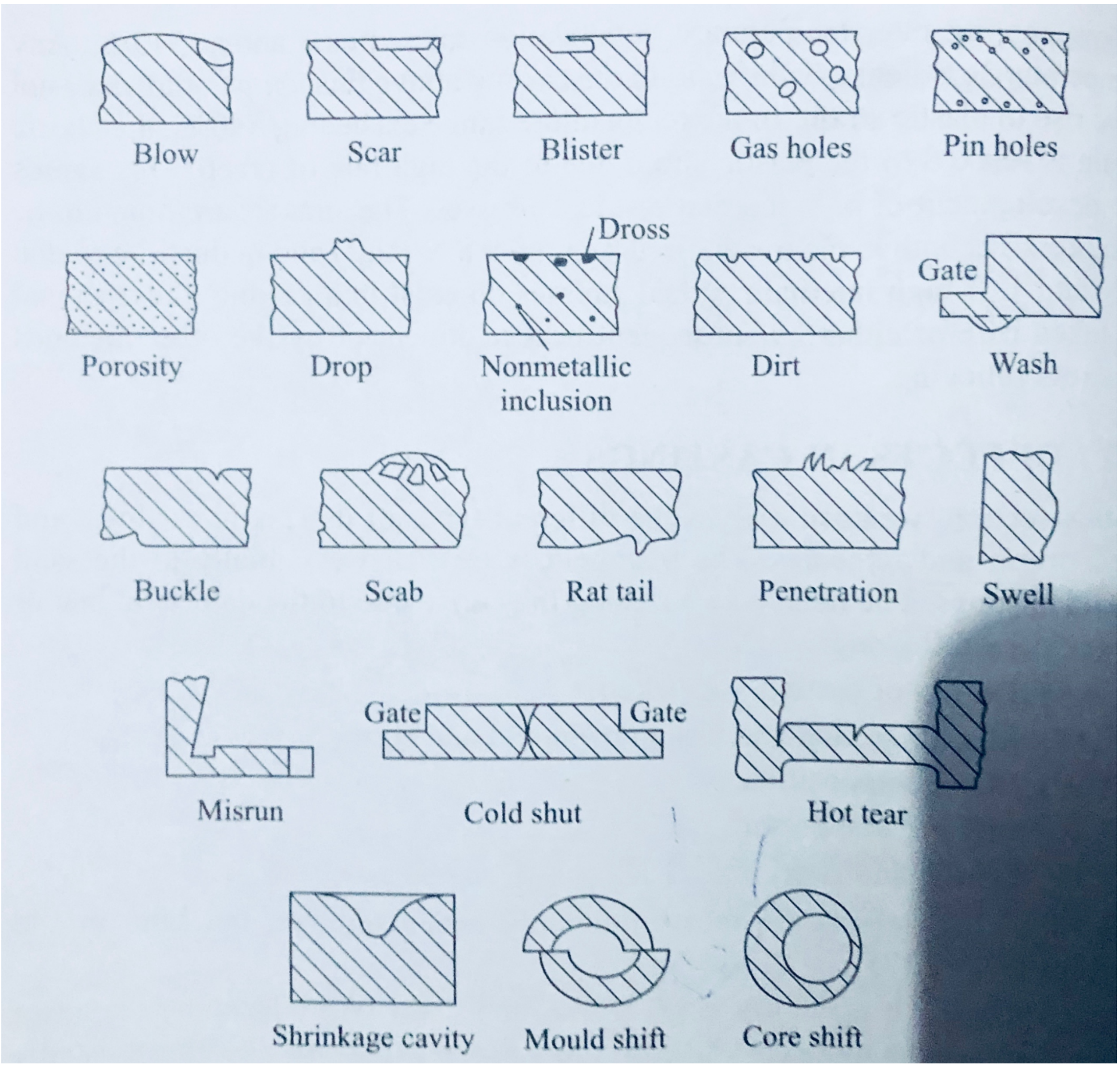


Figure: Casting Defects