Metal Casting

INTRODUCTION

Casting is the oldest and still most widely used process. A mould cavity is created out of sand or some permanent material and liquid metal is pored into this cavity. The product is taken out after solidification. If the mould or pattern is broken after each cast than it is called expendable mould or pattern. If the same mould is used for a number of casting it is called reusable mould/ pattern. Pattern is the replica of the part being produced from the pouring temperature of the liquid metal to the room temperature the material undergoes following shrinkages

1. Liquid from the pouring temperature to liquid at the melting point.
2. Shrinkage during phase change
3. Solid at melting point to solid at room temperature.
   - First two stages shrinkage are compensate by providing a riser.
   - The riser design should be such that it solidify after casting so that liquid metal is available to compensate liquid shrinkage.
   - Third stage of shrinkage is compensated by providing allowance on the pattern.

The casting process is capable of producing intricate shapes in one piece, including those with internal cavity, such as engine blocks. A wide variety of products can be cast.

Many casting process have been developed over many years. As in all manufacturing, each process has its own characteristics, application, advantages, limitations and costs. Casting processes are most often selected over other manufacturing methods for the following reasons.

(a) Casting can produce complex shapes with internal cavities or hollow sections.

(b) It can produces very large parts.

(c) It can utilizes workpiece material that is difficult or uneconomical to process by other means.

(d) Casting is competitive with other processes.

1.1 Type of Allowance

1.1.1 Shrinkage Allowance

To compensate the third stage of shrinkage. (Figure 1.1)

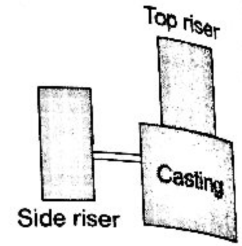

Figure 1.1 Shrinkage Allowance

1.1.2 Machine Allowance

Casting produces poor finish and tolerance. So some margin is given to the pattern for machining parts to produce after solidification. The machining or finishing allowance is provided on the pattern in order to remove some amount of material after the casting has been produce in order to get smooth surface finish.

1.1.3 Draft Allowance

Around 1/2 to 2° (shown in Figure 1.2) tapes is provided over the pattern for easy removal from the sand mould.

Draft or Taper allowances provided for easy removal of pattern without damaging mould

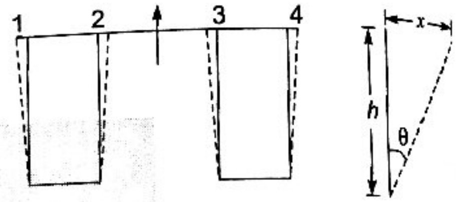

Figure 1.2 Draft Allowance

$$X = h \tan \theta$$

Internal surface require more taper when compared to external surfaces because for the external surfaces the mould strength is more compared to internal surfaces (since dimensions on internal side are uses hence less strength)

1.1.4 Rapping Allowance

Provide to make clearance between pattern and mould walls. Depends on the skill of operator and it is negative in nature.

NOTE

Shrinkage allowances for important material

Material	Allowance
Bismuth	Negligible
Cast iron	10 mm/metre length
Aluminium	12-15 mm/metre length
Bronze	15 mm/metre length
Pure aluminium	17 mm/metre length
Grey C.I.	Negative allowance

Liquid shrinkage > Solid shrinkage > Phase transformation shrinkage

1.2 Terms Associated With Casting

1. Flask

- A moulding flask is one which holds the sand mould intact.
- Depending upon the position of the flask in the mould structure.
- It is made up of wood for temporary applications or more generally of metal for long term use

2. **Core**
   - It is used for making hollow cavities in casting
3. **Pouring Basin**
   - A small funnel shaped cavity at top of the mould into which the molten metal is poured.
4. **Sprue**
   - The passage through which the molten metal from the pouring basin reaches the mould cavity.
   - In many cases it control the flow of metal into the mould.
5. **Runner**
   - The passage ways in the parting plane through which molten metal flow is regulated before they reach the mould cavity.

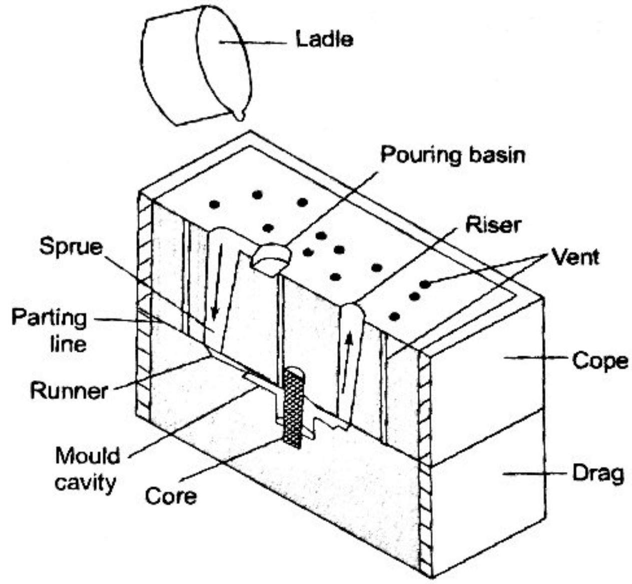

Figure 1.3 Cross section of a sand mould ready for pouring

6. **Gate**
   - The actual entry point through which molten metal enters the mould cavity.
7. **Chaplet**
   - Chaplet are used to support cores inside the mould cavity to take care of its own weight and overcome the metastatic forces.
8. **Chills**
   - Chills are metallic object, which are placed in the mould to increase the **cooling rate** of casting to provide uniform or desired cooling rate.
9. **Riser**
   - It is a reservoir of molten metal in the casting so that hot metal can flow back into the mould cavity when there is **a reduction in volume** of metal due to solidification.
10. **Fluid Flow**

Continuity : The law of mass continuity states that for the incompressible liquids and in a system with impermeable walls, the rate of flow is constant. Thus

$$Q - A_1 v_1 = A_2 V_2$$

Q = Rate of flow (m^3/s)

A = Cross-sectional area of the liquid system

v = Average velocity of the liquid in that cross-sectional location

According to this law, the flow rate must be maintained any where in the system. The permeability of the wall of the system is important because otherwise some liquid will permeate through the wall (such as in sand molds) and the flow rate will decrease as the liquid moves through the system.

Assuming that the pressure at the top of the sprue is equal to the pressure at the bottom and that there is no frictional losses, the relationship between the height and cross-sectional area at any point in the shape is given by the parabolic relationship

$$\frac{A_1}{A_2} = \sqrt{\frac{h_2}{h_1}}$$

Where the subscript 1 denotes the top of the sprue and 2 denotes the bottom moving downward from the top, the cross sectional area of the sprue must decreases. Depending on the assumptions ... ation can also be obtained.

1.3 Type of Pattern

Patterns are used to mold the sand mixture into the shape of the casting. This may be made of wood, plastic or metal. The selection of a pattern depends on the size and shape of the casting, the dimensions accuracy the quantity of casting required and the molding process.

1.3.1 Loose Piece Pattern

These are the single piece pattern but incorporating the allowances, generally these patterns are made up of wood. Gating system is cut from sand manually.

These patterns are also known as one piece patterns or solid pattern. These are generally used for simple shapes and low quantity production.

1.3.2 Gated Patterns

The gating system and runner is the integral part of the pattern. This would eliminated the hand cutting of the runner and gates and hence improved productivity.

1.3.3 Match Plate Pattern

This produce small size complex object in mass production we can use this type of pattern for producing intricate shape. Number of pattern spited along the symmetry and they will be added on both sides of a match plate along with gating elements. This type of pattern will be use in machine moulding technique.

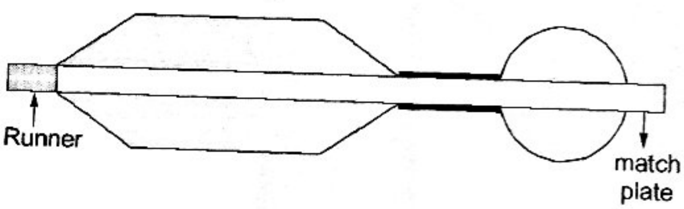

Figure 1.4

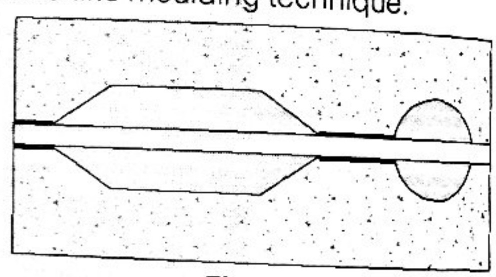

Figure 1.5

The cope and drag portions of the pattern are mounted on the opposite side of wood or metal plate contouring to the parting line. It is used for production of small size precision casting in mass production. Eg. **Piston ring**.

1.3.4 Cope and Drag Pattern

- The cope and drag halves of the mould are made separately.
- It requires accurate alignment by guide and locating pins.
- This types of patterns are used for casting which are heavy and inconvenient for handing and also for continuous production.
- It is used to produced of big size casting.

1.3.5 Sweep Pattern

It is used when 2-D pattern used to produced symmetrical 3-D casting for eg cone, bells, of temples. To produce 3-dimensional complex cavity using two dimensional plane pattern we can select sweep pattern. Two dimension plane pattern will be sweeped inside the mould cavity by 360° by fixing one of its end. Due to this cost of providing 3-dimensional pattern will be reduce.

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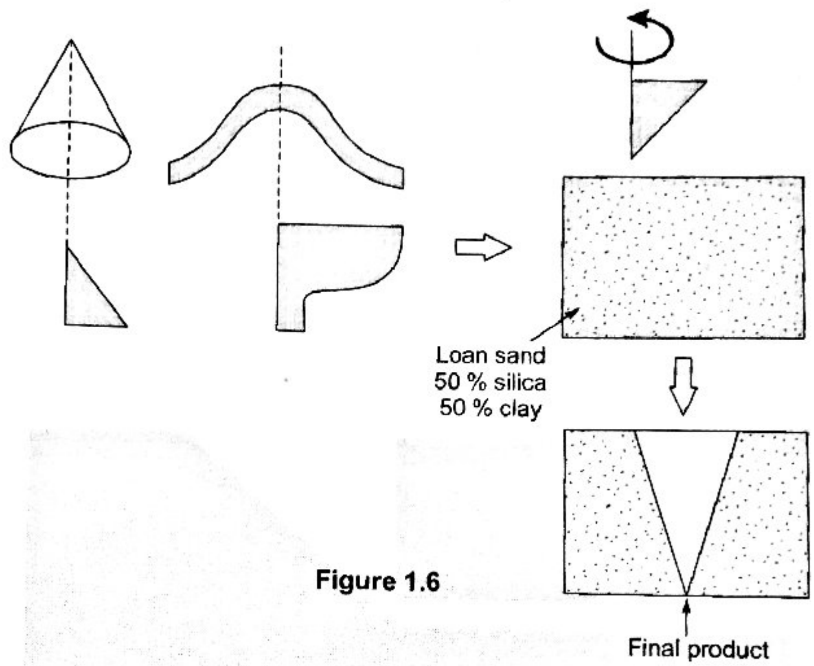

Figure 1.6

1.3.6 Follow board Pattern

- If the pattern is having over hanging portion and lack of strength than due to ramming force, it will distorted. To support the pattern inside the mould fallow board will be use.
- It is used when thin or overhanging sectionizing casting is required. (shown in Figure 1.7 (b))

1.3.7 Skeleton Pattern

- This type of pattern will be used to produced large size sheet and cylinders.
- To produce these object very large size pattern is required.
- To minimize the material consumption on preparing the pattern we can use skeleton pattern

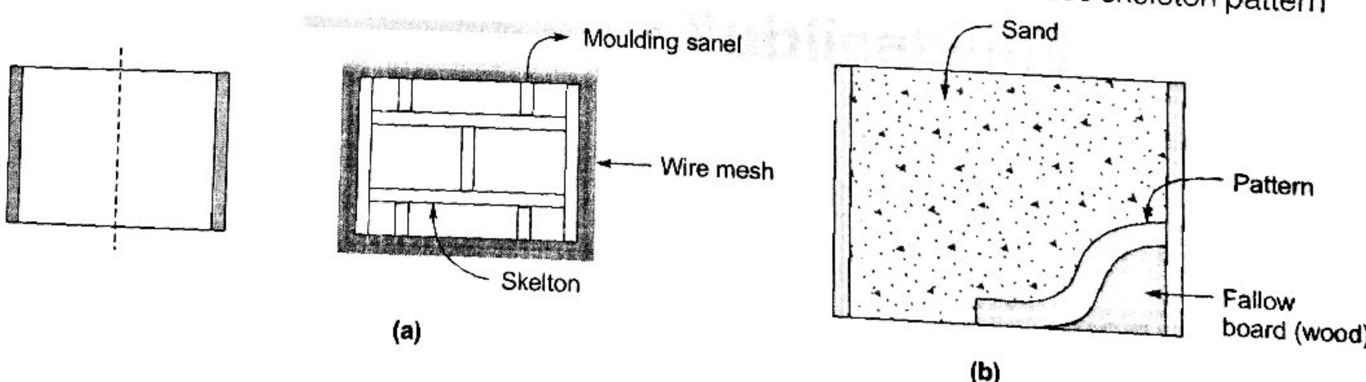

Figure 1.7

- 3 dimensional skeleton is produce using small wooden work piece to get cylinder shape on skeleton wire mesh will be added.
- To get more sand moulding sand will be added to the wire mesh.
- It is used to prepare shells and drums.

1.4 Properties of Moulding Sand

The traditional method of casting metals is in sand molds and had been used for millennia. Simply stated, sand casting consists of

(a) placing a pattern having the shape of the desired casting in sand to make an imprint
(b) incorporating a gating systems
(c) filling the resulting cavity with molten metal
(d) allowing the metal to tool until it solidifies
(e) breaking away the sand mold
(f) removing the casting.

The production steps for a typical sand casting operation are shown below :

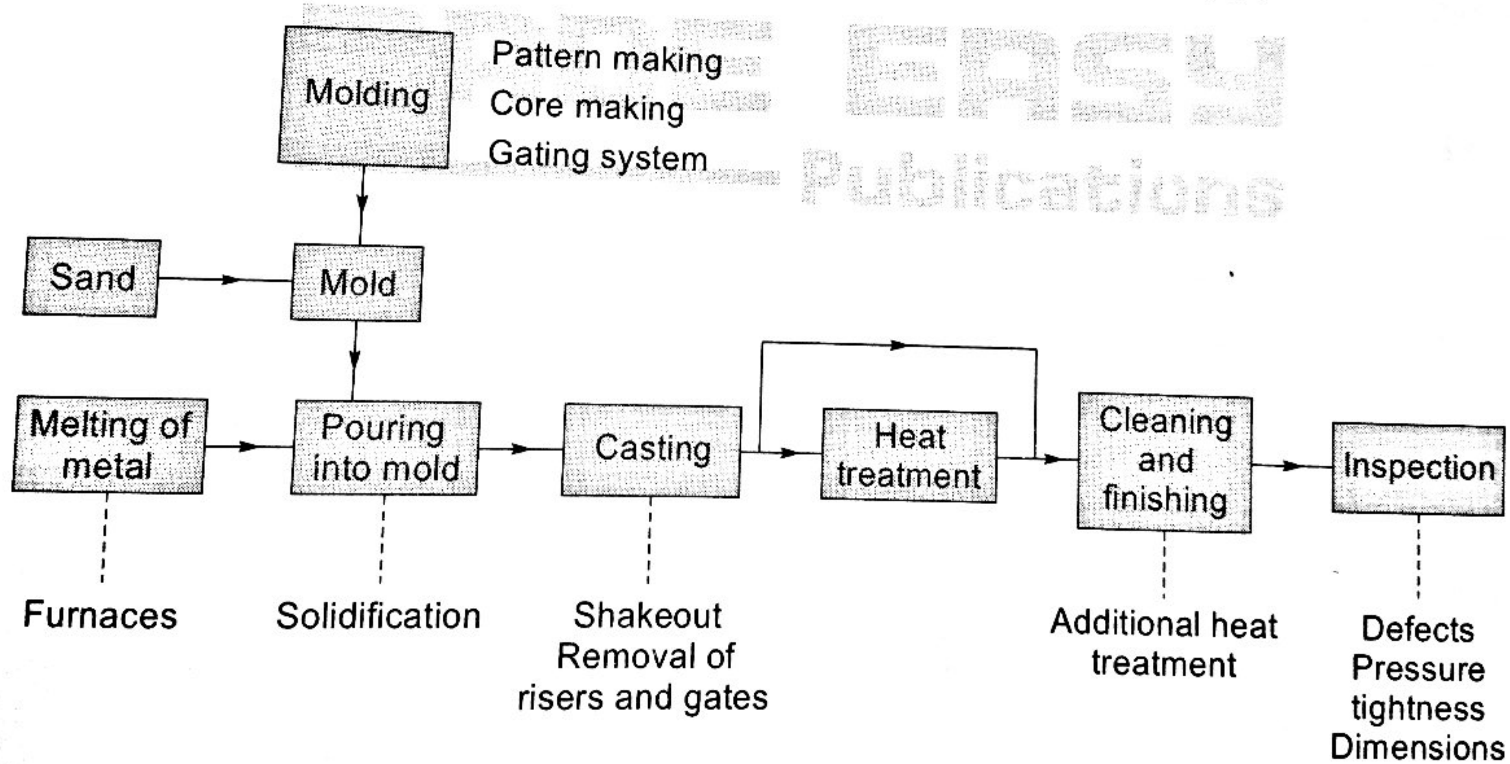

Figure 1.8 Outline of production steps in a typical sand-casting operation

1.4.1 Refractoriness

- It is the ability of moulding sand to withstand the high temperature of molten metals.
- It should be high.

1.4.2 Green Strength

- The moulding sand that contain moisture is termed as green sand.
- The green sand should have enough strength so that the constructed part retain its shape.

1.4.3 Dry Strength

- When molten metal poured into a mould, the sand around the mould cavity is quickly converted in dry sand as the moisture in the sand immediately evaporates due to heat in the molten metal.
- At this stage it should retain the mould cavity and at the same time withstand the metastatic forces.

1.4.4 Hot Strength

It is the strength of the sand that is required to hold the shape of the mould cavity after all the moisture is eliminated.

1.4.5 Permeability

The gas evolving capability of moulding sand is known as permeability. This will be expressed by permeability number.

$$P_n = \frac{VH}{PAT}$$

V = volume of air passing through the specimen

H = Height of standard specimen

P = Pressure of the air passing through the specimen

A = Area of cross section of cylinder.

T = Time required to pass through specimen

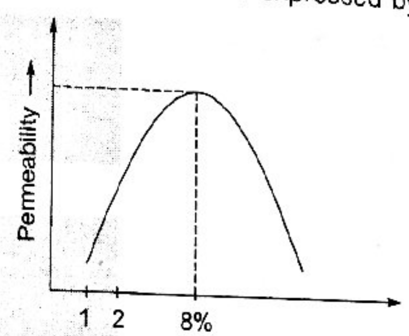

Figure 1.9

By adding water upto 8% the permeability value will be increase, beyond 8% if H_2O is increase its permeability will start decreasing.

1.4.6 Grain Fineness Number (GFN)

- GEN will indicate the average gain size distribution of a given moulding sand.
- Greater the grain fineness number power the grain size.
- GEN can be determine by conducting shieve shaker test.

1.4.7 Flowability

- The ability of sand to flow due to ramming force to fire the mould flask area is known as flowability.

1.4.8 Collapsibility

- Ability of the moulding sand due to which it will offer any resistance against the contraction of casting material is cared collapsibility.
- During the solid contraction of the casting part if the mould creates resistances cracks will appear over the casting.

- High collapsibility is preferred to improve collapsibility.
- Saw dust or wood powder is added to improve collapsibility.
- Since when molten metal poured wood powder burns to ash due to beat and hence shrinks in size causing the mould near casting to easily collapse and provide resistance less shrinkage.

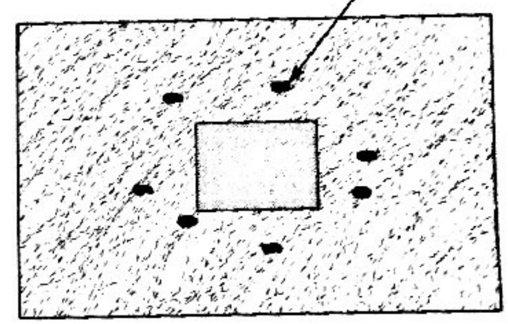

Figure 1.10

1.4.9 Adhesiveness

- The bond formation between two different material i.e moulding sand and mould flask, between mould sand and pattern.

1.4.10 Cohesiveness

- The bond formation between two similar material i.e between 2 sand grains is known as cohesiveness.

1.4.11 Toughness

- Ability to resist impact and shock loads by the moulding sands
- Resistance to stracking, to withstand the force supply by molten liquid metal on the moulds wall is called toughness.
- To get dimensional stability of the casting uniform hardness is require. This can be achieve by uniform ramming.
- Shatter index test is done for toughness testing shocker observed when molten metal is poured.

NOTE

Universal testing machine	:	Used for testing green strength
Sand Muller	:	Used for mixing and preparing moulding sand.

1.5.1 Green Sand

If the sand contains **2.6% of moisture** than the sand is called green sand.

1.5.2 Dry Sand

The moisture available in the moulding sand evaporates cause of high temperature of molten then the sand is called dry sand.

1.5.3 Facing Sand

The sand which is used near the mould cavity with more clay and fine silica sand is called facing sand.

1.5.4 Parting Sand

It is a pure silica sand use to avoid Shrinking of the moulding surfaces with other surfaces.

1.5.5 Baking Sand

Sand which is place at the extreme end of the mould to support the facing sand is known as backing sand. Already used sand can be used as a baking sand.

1.6 Additive Used In Moulding Sand

1.6.1 Wood flour / Saw Dust

It is used in the casting process to improve **green strength** and **collapsibility** of moulding sand.

1.6.2 Starch And Dextrin

- These are used in the casting process as organic binders
- It is used to improve resistance to deformation of the mould and improves the skin hardness of the mould.

1.6.3 Iron Oxide And Aluminium Oxide

- In order to improves hard strength of green iron oxide and aluminium oxide are used in casting process.

1.6.4 Coal Dust, Sea Coal, Silica Flour

- These are carbonous material which are used in the moulding sand to improve **surface finish** and resistance to metal penetration.
- It also increases the fluidity of the moulding sand.

NOTE

Composition of Moulding Sand	
Silica sand	70.85%
Clay	10.20%
Water	3.6%