Ch-1: Casting

1.1 Introduction to casting

- Casting is One of the oldest materials shaping methods carried out in the foundry and the product of casting process is called as casting.
- In casting process molten metal is poured into cavity (called as mould) of required shape & size 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.

1.2 **History**

Refers Page no 61, Ch-6: Metal casting process, Book: Manufacturing Technology by P N Rao, TMH Pub.

1.3 **Advantage & Limitations**

Advantages:

- Molten material can flow into very small sections so that intricate shapes can be made by this process.
- 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.
- Size and weight of the product is not a limitation for the casting process.

Limitations:

Poor Dimensional accuracy and surface finish of the castings

Application:

Typical application of sand casting process are cylinder block, liners, machine tool bed, piston, piston rings, mill rolls, wheels, housing, water supply pipes and bells

1.4 **Pattern**

- A Pattern is a replica of the object to be made by the casting process, with some modifications. The main modification are:

a) Addition of pattern allowances

b) The provision of core prints

c) Elimination of fine details which cannot be obtained by casting

- **Pattern Allowances:** The dimensions of the pattern are different from the final dimensions of the casting required. This is required because of shrinkage of metal when cooling.
- Shrinkage: Almost all the metal shrink when cooling. This is because of the inter-atomic vibrations which are amplified by an increase in temperature.

➢ Liquid Shrinkage

➢ Solid Shrinkage

Draft Allowance: Vertical faces of the pattern are to be made tapered to reduce the chances of damage to the mould cavity. It varies with the complexity of the job. Inner details require more allowance than outer. This allowance is more for hand moulding than machine moulding

Finish or machining allowance:

➢ In casting process, extra material is to be provided which is to be subsequently removed by marching or cleaning process for good surface finish or dimensionally accurate casting is known as machining allowance.

➢ This depends upon dimensions, type of casting materials and the finish required. It may range from 2 to 20 mm.

Shake allowance: This is a negative allowance. Applied to those dimensions which are parallel to parting plane.

Distortion allowance: Metals just solidified are very weak, which may be distorted. This allowance is given to the weaker sections like long flat portion, U & V sections, complicated casing, thin & long sections connected to thick sections. This is a trial and error method.

Master Pattern: This is a type of pattern and used in the process of investment casting for making of wax patterns.

Pattern materials: The patterns are generally made from following materials:

(i) Wood (ii) Metals (iii) Cast iron (iv) Brass (v) Plaster of Paris (vi) Plastic (vii) Wax

Wood:

➢ pine, mahogany, teak, walnut and deodar

➢ Easily availability and low weight

- Easily shaped and relatively cheap
- Disadvantage is Absorption of moisture results in distortions and dimensional changes occurs

Metals:

- cast iron, brass, aluminum etc.
- Higher durability and smooth surface finish
- Used for large scale casting production and for closed dimensional tolerances

Plastics:

- generally used plastics pattern are cold setting epoxy resins with suitable fillers and also used polyurethane foam as pattern materials
- Low weight, easier formability, smooth surfaces and durability
- It Does not absorb moisture so dimensionally stable and cleaned easily

Core Prints: Core prints are required for casting where coring is required.

Elimination of fine details:-

Type of details to be eliminated depends on

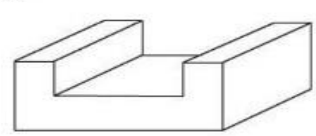
- Required accuracy
- Capability of the chosen casting process
- Moulding method employed

1.4 **Pattern types**

TYPES OF PATTERNS:-

Various types of patterns depends on
- Complexity of the job
- No of castings required
- Moulding procedure adopted

(a) ***Single piece pattern*** – Inexpensive and simplest one
Single piece
Simple job
Useful for Small scale production
Pattern will be entirely in the drag
One surface is flat and at the parting line
Used for very small scale production



(b) ***Split or two piece pattern*** – Used for intricate casting
Split along the parting line
Used where depth of job is too high
Aligned with dowel pins fitted to cope

(c) ***Gated pattern –*** Gating and runner system are integrated with the pattern
Improves productivity

(d) ***Cope and drag pattern -*** Similar to split pattern
For cope and drag, separately attached gating system to metal plate
Heavy and inconvenient for handling
Useful for Continuous production

(e) ***Match plate pattern –*** Similar to cope and drag patterns with gating and risering system mounted on a single matching plate
Pattern and match plate are made up of metal (Al)
Useful for small casting with high dimensional accuracy
Suitable for large scale production
Gating system is attached to the match plate
Expensive

(f) ***Loose piece pattern –*** Withdrawing of the pattern from the mould is difficult
Useful for highly skilled job
Expensive

(g) ***Follow board pattern –*** Used for structurally weak portions
Bottom board is modified as follow board

(h) ***Sweep pattern –*** Useful for axi-symmetrical and prismatic shape
Suitable for large scale production

(i) ***Skeleton pattern –*** Stripes of wood are used for building final pattern
Suitable for large casting

1.5 **Steps involved in the making of casting process:**

Making a pattern

⇩

Preparing Molding Sand

⇩

Preparing a mould and core

⇩

Melting the Metal

⇩

Pouring the metal into the mould

⇩

Cooling i.e., Solidification

⇩

Removing the Solidified casting from the mould

⇩

Fettling OR Cleaning

⇩

Heat Treatment

⇩

Testing and Inspection

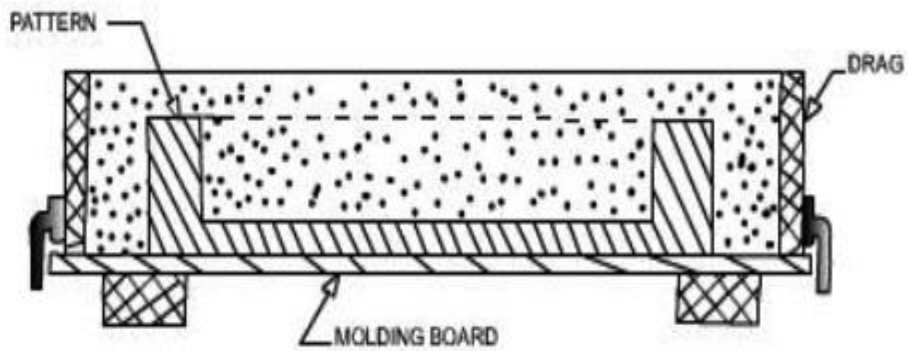
<u>The flow chart indicating the main steps in the making of a casting</u>

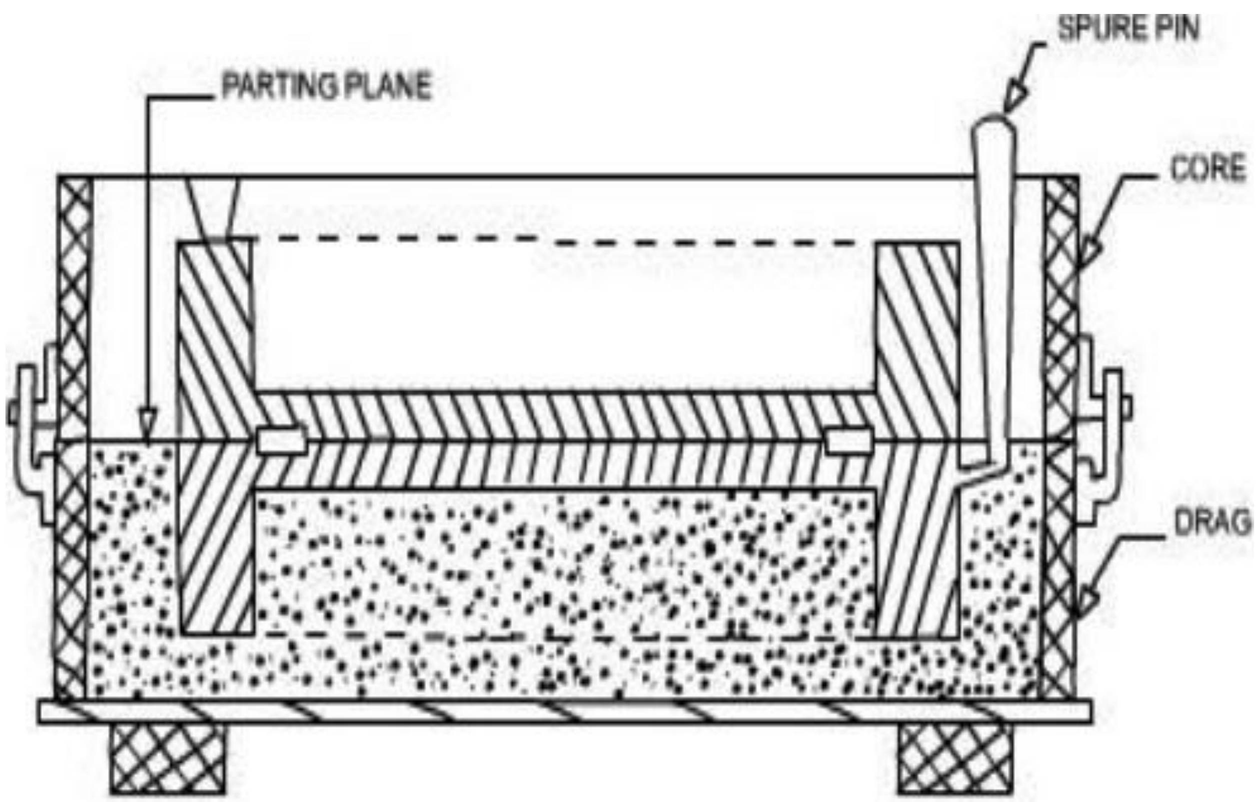
Casting process comprises of the following steps:

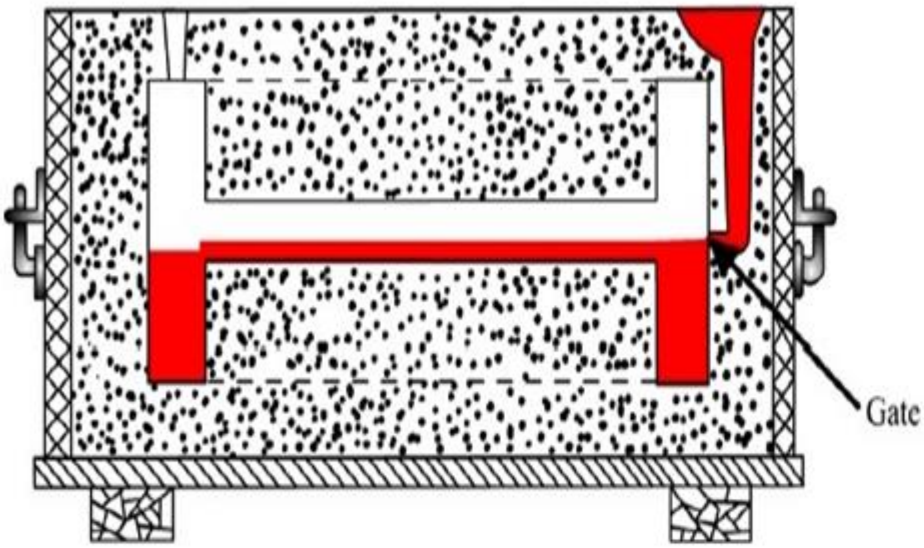
1) **Making a pattern**: Pattern is the model/ replica/ duplicate of the desired product (called casting), constructed in such a way that it can be used for forming an impression/ cavity called mould (cavity) in damp sand. Various allowances such as shrinkage, machining, draft, shaking, distortion etc., are provided. Sometimes core prints are also provided to the patterns to make a core seat in the damp sand.
2) **Preparing Molding Sand**: Sand is the principal molding material in a foundry shop. The quality of the casting depends upon be the selection and mixing of sand, which may be natural or synthetic and is used for mould and core making.
3) **Preparing a mould and core making**: Moulds are prepared with the help of pattern to produce a cavity of desired shape. Usually the mould is made of sand is used only once. But sometimes permanent metal moulds are also used. For obtaining hollow portions, cores are prepared separately in core boxes. Moulds and cores are baked to impart strength.
4) **Melting the Metal**: The required quantity of the metal with proper composition is melted in a suitable furnace.
5) **Pouring the metal into the mould**: When the molten metal attains pouring temperature, it is taken into ladles and poured into the moulds.
6) **Cooling i.e., Solidification**: After pouring the molten metal into the mould cavity it is allowed to cool down so that the metal solidifies.
7) **Removing the Solidified casting from the mould**: The solidified casting are extracted by breaking the mould and cleaned by removing adhering sand.
8) **Fettling**: The unwanted projection in the form of gates, risers etc. are cut off and the entire surface is cleaned and made uniform.
9) **Heat Treatment**: The castings may need heat treatment depending on the specific properties required.
10) **Testing and Inspection**: Finally the casting is inspected to ensure that it is free from casting defects and is as per desired specifications.

1.6 **Sand mould making procedure:-**

The first step in making mould is to place the pattern on the moulding board. The drag is placed on the board shown in fig.(a). Dry facing sand is sprinkled over the board and pattern to provide a non sticky layer. Moulding sand is then riddled in to cover the pattern with the fingers; then the drag is completely filled. The sand is then firmly packed in the drag by means of hand rammers. The ramming must be proper i.e. it must neither be too hard or soft. After the ramming is over, the excess sand is levelled off with a straight bar known as a strike rod. With the help of vent rod, vent holes are made in the drag to the full depth of the flask as well as to the pattern to facilitate the removal of gases during pouring and solidification. The finished drag flask is now rolled over to the bottom board exposing the pattern


PATTERN
DRAG
MOLDING BOARD


SPURE PIN
PARTING PLANE
CORE
DRAG



Casting terms:-

Flask- It holds the sand mould intact. It is made up of wood for temporary application and metal for long term use.

Drag- Lower moulding flask

Cope – Upper moulding flask

Cheek – Intermediate moulding flask used in three piece moulding.

Pattern - Replica of final object to be made with some modifications. Mould cavity is made with the help of pattern.

Parting line – Dividing line between two moulding flasks.

Bottom board – Board used to start mould making (wood)

Facing sand - Small amount of carboneous material sprinkled on the inner surface of the mould cavity to give better surface finish to casting.

Moulding sand – Freshly prepared refractory material used for making the mould cavity. (Mixture of silica, clay & moisture)

Backing sand – used and burnt sand

Core – Used for making hollow cavities in the casting

Pouring basin – Funnel shaped cavity on the top of the mould into which molten metal is poured

Sprue – Passage from pouring basin to the mould cavity. It controls the flow of molten metal into the mould.

1.6 Moulding Materials

MOULDING MATERIALS

Different types of moulding materials are

- -moulding sand
- -system sand (backing sand)
- -rebonded sand
- -facing sand
- -parting sand
- -core sand

Choice of moulding materials depends on processing properties.

Properties_-

1) Refractoriness- Ability to withstand high temperature of molten metal so that it does not cause fusion
   Refractory materials - silica, zirconia, alumina
2) Green strength- Moulding sand containing moisture is known as green sand. The strength of the green sand is known as green strength.
3) Dry strength- When moisture is completely expelled from the moulding sand, it is known as dry sand and the strength of the sand is the dry strength.
4) Hot strength- After moisture elimination, the sand is exposed to higher temperature of molten material. Strength of sand to hold the shape of mould cavity at this higher temperature is known as hot strength.
5) Permeability – Moulding sand is porous, so it escapes gases through it. This gas evolution capability of moulding sand is known as permeability.

Other properties include collapsibility, reusable, good thermal conductivity etc.

MOULDING SAND COMPOSITION-

Main ingredients of moulding sand are silica grain (SiO_2), Clay (binder) and moisture (to activate clay and provide plasticity)

(a) Silica sand- this is the major portion of the moulding sand. About 96% of this sand is silica grain. Rests are oxides (Al_2O_3), sodium ($Na_2O + K_2O$) and magnesium oxide ($MgO + CaO$). Main source of silica sand is river sand (with /without washing). Fusion point of sand is 1450^{0}C for cast iron and 1550^{0}C for steels. Grain size varies from micrometer to millimetre. The shape of the grains may be round, angular, sub angular or very angular.

(b) Zircon sand- The main composition is zirconium silicate ($ZrSiO_2$).

Composition- ZrO_2- 66.25%
SiO_2-30.96%
Al_2O_3-1.92%
Fe_2O_3-0.74%
Other - oxides

It is very expensive. In India, it is available at quilon beach, kerela. The fusion point of the sand is 2400°C.

Advantage - High thermal conductivity
High chilling power
High density
Requires very small amount of binder (3%)

Use - Precision steel casting
Precision investment casting

(c) Chromite sand – The sand is crushed from the chrome ore. The fusion point of the sand is 1800^{0}C. It requires very small amount of binder (3%).

Composition- Cr_2O_3 - 44%
Fe_2O_3 -28%
SiO_2 -2.5%
CaO -0.5%
Al_2O_3 +MgO -25%

Use – heavy steel castings
Austenitic manganese steel castings

(d) Olivine sand- This sand composed of the minerals of fosterite (Mg_2SiO_4) and fayalite (Fe_2SiO_4). It is versatile in nature.

CLAY :–

Clay is a binding agent mixed to the moulding sand to provide strength. Popular types of clay used are kaolinite or fire clay (Al_2O_3.2 SiO_2.2H_2O) and Bentonite (Al_2O_3.4 SiO_2.H_2O nH_2O). Kaolinite has a melting point from 1750 to 1787^{0}C where as Bentonite has a melting temperature range of 1250 to 1300^{0}C. Bentonite clay absorbs more water and has increased bonding power. To reduce refractoriness, extra mixtures like lime, alkalis and other oxides are added.
Bentonite is further of two types. (a) Western bentonite and (b) southern bentonite

Western bentonite – It is rich with sodium ion
It has better swelling properties
When it mixes with sand, the volume increases 10 to 20 times.
High dry strength, so lower risk of erosion
Better tolerance of variation in water content
Low green strength
High resistance to burn out

Southern Bentonite - It is rich with calcium ion
It has low dry strength and high green strength
Its properties can be improved by treating it with soda ash (sodium carbonate)

Water:- Used to activate the clay
Generally 2 to 8% of water is required

Other materials added:- Cereal binder – (2%) – to increase the strength
Pitch (by product of coke) – (3%) – to improve hot strength
Saw dust (2%) – To increase permeability

Testing sand properties:-

Sample preparation can be done by mixing various ingredients like sand, clay and moisture.

During mixing, the lump present in sand should be broken up properly. The clay should be uniformly enveloped and the moisture should be uniformly distributed.

The equipment used for preparation of moulding sand is known as Mueller. This is of two types.

(i) Batch Mueller- Consists of one/two wheels and equal no. of blades connected to a single driving source. The wheels are large and heavy.
(ii) Continuous Mueller- In this type, there are two bowls with wheel and ploughs. The mixture is fed through hopper in one bowl. After muelled, it is moved to another bowl. This type of Mueller is suitable for large scale production.

Moisture content:-

1st method - 50g of moulding sand sample is dried at 105^0C to 110^0C for 2hrs. The sample is then weighed.

Wt. diff * 2= % of moisture content

2nd method - Moisture teller can be used for measuring moisture content.

The Sand is dried suspending sample on fine metallic screen allowing hot air to flow through sample. This method takes less time in comparison to the previous one.

3rd method - A measured amount of calcium carbide along with moulding sand in a separate cap is kept in the moisture teller. Both should not come in contact with each other. Apparatus should be shaken vigorously such that the following reaction takes place.

$$CaC_2 + 2H_2O - C_2H_2 + Ca(OH)_2$$

The acetylene coming out will be collected in space above the sand raising the pressure. A pressure gauge connected to the apparatus would give directly the amount of acetylene generated, which is proportional to the moisture present.

Clay content:-

A 50g of sand sample is dried at 105^0C to 110^0C and is taken in a 1lt. glass flask. 475ml distilled water and 25ml of a 1% solution of caustic soda (NaOH 25g/l) is added to it. The sample is thoroughly stirred (5 mins). The sample is then diluted with fresh water upto 150 mm mark and then left undisturbed for 10mins to settle. The sand settles at bottom and the clay floats. 125mm of this water is siphoned off and again topped to the same level. The process is repeated till water above the sand becomes clear. Then the sand is removed and dried by heating. The difference in weight multiplied by 2 will give the clay % of sand.

Sand grain size:-

For sand grain size measurement, the moulding sand sample should be free from moisture and clay. The dried clay free sand grains are place on the top sieve of sieve shaker (gradually decreasing mesh size). The sieves are shaken continuously for 15 mins. After this the sieves are taken apart and the sand over each sieve is weighed. The amount retained on each sieve is multiplied by the respective weightage factor, summed up and then divided by the total mass f the sample which gives the grain fineness number.

$$GFN = \Sigma M_i f_i / \Sigma f_i$$

M_i= multiplying factor for the i^{th} sieve

F_i= amount of sand retained on the i^{th} sieve

Permeability:-

Rate of flow of air passing through a standard specimen under a standard pressure is known as permeability number.

$$P = V H / p A T$$

V= volume of air= 2000cm^3

H= height of sand specimen= 5.08cm

P= air pressure, 980Pa (10g/cm^2)

A= cross sectional area of sand specimen= 20.268 cm^2

T= time in min. for the complete air to pass through

Inserting the above standard values in the expression we get, P= 501.28/ P.T

Permeability test is conducted for two types of sands

(a) Green permeability – permeability of green sand

(b) Dry permeability – permeability of the moulding sand dried at 105^{0}C to 110^{0}C to remove the moisture completely

Strength:-

Measurement of strength of moulding sand is carried out on the universal sand- strength testing M/C. The strength can be measured in compression, shear & tension. The types of sand that can be tested are green, dry, core sands.

Green compressive strength:-

Stress required to rupture the sand specimen under compressive loading refers to the green compressive strength. It is generally in the range of 30 to 160KPa.

Green shear strength:-

The stress required to shear the specimen along the axis is represented as green shear strength. The range is 10 to 50 KPa.

Dry strength:-

The test is carried out with a standard specimen dried between 105 to 110°C for 2 hours. The range found is from 140 to 1800KPa.

Mould hardness:-

A spring loaded steel ball (0.9kg) is indented into standard sand specimen prepared. If no penetration occurs, then the hardness will be 100. And when it sinks completely, the hardness will be 0 indicating a very soft mould.

Moulding sand properties:-

The properties of moulding sand depends upon the variables like –

- sand grain shape and size
- Clay types and amount
- moisture content
- method of preparing sand mould

Sand grains:-

The grain shape could be round or angular. Angular sand grains require high amount of binder, where as round sand grains have low permeability.

Similarly the grain size could be of coarse or fine. Coarse grains have more void space which increases the permeability. Fine grains have low permeability, but provide better surface finish to the casting produced. The higher the grain size of the sand, higher will be the refractoriness.

Clay and water:-

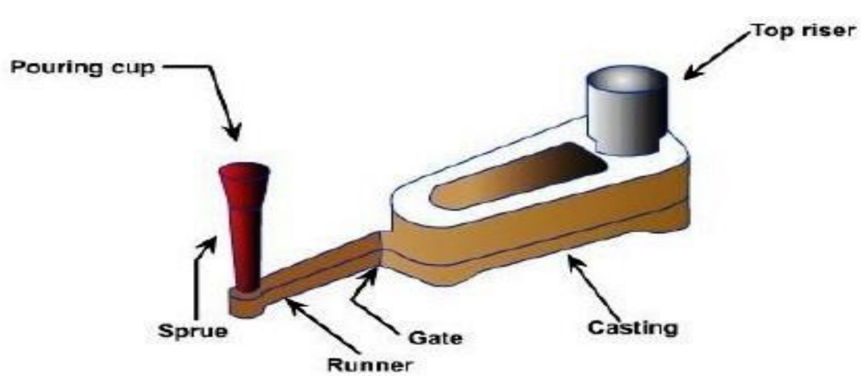
Optimum amount water is used for a clay content to obtain maximum green strength. During sand preparation, clay is uniformly coated around sand grains. Water reacts with the clay to form a linkage of silica - water – clay- water- silica throughout the moulding sand. Amount of water required depends on the type and amount of clay present. Additional water increases the plasticity and dry strength, but decreases the green strength. There is a maximum limit of green compression strength. This type of sand is known as clay saturated sand and used for cast iron and heavy non ferrous metal casting. This type of sand reduces some of the casting defects like erosion, sand expansion, cuts & washes. These sands have green compression strength in a range of 100 to 250 KPa.

1.7 Gating System

Gating System For Casting

Gating system:- It refers to all those elements connected with the flow of molten metal from ladle to mould cavity.
Various elements:-

- pouring basin
- sprue
- sprue base well
- Runner runner extension
- Ingate
- Riser



Requirements for defect free casting :-

- Mould should be filled in smallest time
- Metal should flow without turbulence
- Unwanted material should not enter into the cavity
- Atmospheric air should be prevented
- Proper thermal gradient should be maintained
- No gating or mould erosion should take place
- Enough metal should be there inside the mould cavity
- Economical
- Casting yield should be maximized

Elements

Pouring basin:- The molten metal is entered into the pouring basin, which acts as a reservoir from which it moves into the sprue. The pouring basin stops the slag from entering into the mould cavity by the help of skimmer or skim core. It holds the slag and dirt which floats on top and only allows the clean metal. It should be always full during pouring and one wall should be inclined 45^0 to the horizontal.

Function:-This will reduce the momentum of liquid flowing into mould

Design:- Pouring basin should be deep enough. Entrance into sprue be a smooth radius of 25mm. pouring basin depth should be 2.5 times the sprue entrance diameter. A stainer core restricts the flow of metal into the sprue and thus helps in quick filling of the pouring basin. It is a ceramic coated screen with many small holes.

Sprue:-

It is a channel through which molten metal is pours into the parting plane where it enters into the runner and gates to reach the mould cavity. When molten metal is moving from top to the cope, it gains velocity and requires a smaller amount of area of cross-section for the same amount of metal to flow. If the sprue is straight and cylindrical, then a low pressure area will be created at the bottom of the sprue. Since the sand is permeable, it will aspire atmospheric air into the mould cavity causing defects in the casting. That is why the sprue is generally made tapered to gradually reduce the cross-section.

Exact tapering can be obtained by equation of continuity

$A_tV_t = A_cV_c$ t denotes top section

$\Rightarrow A_t = Ac\frac{Vc}{Vt}$ c denotes choke section

By Bernoulli's equation

$A_t = Ac\sqrt{\frac{hc}{ht}}$ velocity α (potential head)^2

The profile of the sprue should be parabolic. Metal at entry of the sprue is moving with a velocity of

$V=\sqrt{2gh}$. Hence $A_t = Ac\sqrt{\frac{ht}{h}}$

H= actual sprue height

$h_t = h + H$

<u>Sprue Base Well</u> :-

This is the reservoir for the metal at the bottom of sprue to reduce the momentum of the molten metal. Sprue base well area should be 5 times the sprue choke area and well depth should be approximately equal to that of the runner.

Runner:-

It is located at the parting plane which connects the sprue to its ingates. It traps the slag & dross from moving into the mould cavity. This is normally made trapezoidal in cross section. For ferrous metals, the runners should be kept in cope and ingates in drag.

Runner extension:-
This is provided to trap the slag in the molten metal.

GATES/ IN-GATES:-

These are the opening through which molten metal enters into the mould cavity. Depending on the application, the various types of gates are

Top gate:- The molten metal enters into the mould cavity from the top. These are only used for ferrous alloys. Suitable for simple casting shape. There may be chance of mould erosion.

Bottom gate:- This type of gating system is used for very deep moulds. It takes higher time for filling of the mould cavity.

Parting gate:- This is most widely used gate in sand casting. The metal enters into the mould at the parting plane. This is easiest and most economical.

Step gate:- These types of gates are used for heavy and large casting. The molten metal enters into the mould cavity through a number of ingates arranged in vertical steps. The size of ingates are increased from top to bottom ensuring a gradual filling of mould cavity.

RISER:-

Most alloys shrink during solidification. As a result of this volumetric shrinkage, voids are formed which are known as hot spots. So a reservoir of molten metal is maintained from which the metal can flow steadily into the casting. These reservoirs are known as risers. Design considerations:- The metal in riser should solidify at the end and the riser volume should be sufficient for compensating the shrinkage in the casting. To solve this problem, the riser should have highervolume.

Types:-

(a) top riser- This type of riser is open to the atmosphere. It is very conventional & convenient to make. It looses heat to the atmosphere by radiation & convention. To reduce this, insulation is provided on top such as plaster of paris and asbestos sheets.
(b) blind riser :- This type of riser is surrounded by the moulding sand and looses heat very slowly.

(c) Internal rise:- It is surrounded on all sides by casting such that heat from casting keeps the metal in the riser hot for a longer time. These are used for cylindrical shapes or hollow cylindrical portions casting.

Chill:- Metallic chills are used to provide progressive solidification or to avoid the shrinkage cavities. These are large heat sinks. Use of chill will form a hard spots, which needs further machining.

1.8 Design of Gating system for casting

- Pouring Time
- Choke area
- Sprue
- Gating ratios

GATING SYSTEM DESIGN:-

The Liquid metal that runs through various channels, obeys Bernoullis equation according to which the total energy head remains constant.

$$h + \frac{P}{W} + \frac{V2}{2g} = \text{constant (ignore frictional losses)}$$

h = Potential head, m
P = pressure, Pa
V = liquid velocity, m/s
W= sp. wt. of liquid, N/m^3
g = gravitational constant, 9.8 m/s^2

According to the Law of continuity, the volume of metal flow at any section is constant.

$$Q = A_1V_1 = A_2V_2$$

Q= rate of flow, m^3/s
A = Area, m^2
V = Velocity, m/s

Pouring time:-

It is the time required for complete filing of mould cavity. If it is too long, then it requires a higher pouring temp. and if is too short, there will be turbulent flow, which will cause defective casting. So the pouring time depends on casting material, complexity of casting, section thickness and casting size. Ferrous material requires less pouring time where as non-Ferrous materials require higher pouring time.

Some Standard methods for pouring time :-

(1) Grey cast iron, mass< 450 kg

$$t = K\left(1.41 + \frac{T}{14.59}\right)\sqrt{W},\ s$$

K= fluidity of iron, inches/40

T = avg. section thickness, mm

W = Mass of casting, kg

Pouring time for cast iron	
Casting mass	Pouring time, s
20 kg	6 to 10
100 kg	15 – 30
100000 kg	60 – 180

(2) Grey cast iron, mass> 450 kg

$$t = K\left(1.236 + \frac{T}{16.65}\right)\sqrt[3]{W},\ s$$

(3) Steel casting

$$t = (2.4335 - 0.3953 \log W)\sqrt{W},\ s$$

(4) Shell moulded ductile iron, (Vertical pouring)

$$t = K_1\sqrt{W},\ s$$

K_1 = 2.080 for thin section

= 2.670 for 10 – 25 mm thick sections

= 2.970 for heavier section

(5) Cu alloy castings

$$t = K_2\sqrt[3]{W},\ s$$

K_2 = constant given by

Top gating – 1. 30

Bottom gating – 1.80

Brass – 1.90

Tin bronze – 2.80

(6) Intricately shaped thin walled casting – upto 450 kg

$$t = K_3\sqrt[3]{W'},\ s$$

W' =mass of casting with gates and risers, kg

K_3 = constant

T (mm)	K_3
1.5 – 2.5	1.62
2.5 – 3.5	1.68
3.5 – 8	1.85
8 – 15	2.2

(7) Above 450 kg &upto 1000 kg

$$t = K_4\sqrt[3]{W'},\ s$$

T (mm)	K_4
Upto 10	1
10 – 20	1.35
20 – 40	1.4
Above 40	1.7

for mass< 200kg; avg.section thickness – 25mm

grey cast iron	40s
steel	20s
brass	15 – 45s

Choke area:-

The control area which meters the metal flow into the mould cavity so that the mould is completely filled up within the calculated pouring time is known as choke area. It is mainly considered at the bottom of the sprue.

The choke area by using Bernoulli's equation,

$$A = \frac{1}{dtC\sqrt{2gH}}$$

A = choke area

W = casting mass, kg

t = Pouring time, s

d = mass density of molten metal, kg/mm^3

g = acceleration due to gravity, mm/s^2

H = sprue height, mm

C = efficiency factor

The effective sprue height, H depends on type of gating system.

Top gate, $H = h$ Bottom, $H = h - \frac{C}{2}$ Parting, $H = h - \frac{P^2}{2C}$

h = height of sprue

P = height of mould cavity in sprue

C = total height of mould cavity

$$C = \frac{1}{\sqrt{1+K_1\frac{A^2}{A_1^2}+K_2\frac{A^2}{A_2^2}+\text{-----}}}$$

K_1, K_2 = loss coeff. – at changes of direction

A_1, A_2 = area down the stream from changes

A = choke area

Gating ratios:-

The gating ratios refers to the proportion of the cross-sectional areas between sprue, runner and ingate.

There can be Two types of gating system.

(a) Non pressurized gating system:-

This has a choke at bottom of the sprue having total runner area and in gates area >sprue area. This reduces the turbulence. This is useful for Al and Mg alloys. These have tapered sprue, sprue base well and pouring basin.

Sprue : runner : ingate :: 1:4:4

Disadvantages :-

-Air inspiration

-casting yield- less

(b) Pressurized gating system:-

In this type, the in gate areas are smallest, thus maintaining a back pressure. Beacause of this, the metal is more turbulent and flows full with a minimum air aspiration. This has a higher casting yield. Mostly useful for ferrous castings.

Sprue : runner : ingate :: 1:2:1

1.9 CASTING DEFECTS:-

a) Gas defects
b) Shrinkage cavities
c) Moulding material defects
d) Pouring metal defects
e) Metallurgical defects

(a) Gas defects:

A condition existing in a casting caused by the trapping of gas in the molten metal or by mould gases evolved during the pouring of the casting. The defects in this category can be classified into blowholes and pinhole porosity. Blowholes are spherical or elongated cavities present in the casting on the surface or inside the casting. Pinhole porosity occurs due to the dissolution of hydrogen gas, which gets entrapped during heating of molten metal.

Causes:

The lower gas-passing tendency of the mould, which may be due to lower venting, lower permeability of the mould or improper design of the casting. The lower permeability is caused by finer grain size of the sand, high percentage of clay in mould mixture, and excessive moisture present in the mould.

- Metal contains gas
- Mould is too hot

(b) 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 mould. 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.

(c) Molding Material Defects

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

Cut and washes

These appear as rough spots and areas of excess metal, and are caused by erosion of moulding sand by the flowing metal. This is caused by the moulding sand not having enough strength and the molten metal flowing at high velocity. The former can be taken care of by the proper choice of moulding sand and the latter can be overcome by the proper design of the gating system.

Metal penetration

When molten metal enters into the gaps between sand grains, the result is a rough casting surface. This occurs because the sand is coarse or no mould wash was applied on the surface of the mould. The coarser the sand grains more the metal penetration.

Fusion

This is caused by the fusion of the sand grains with the molten metal, giving a brittle, glassyappearance on the casting surface. The main reason for this is that the clay or the sand particles are of lower refractoriness or that the pouring temperature is too high.

Swell

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

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 mould can prevent this defect.

(d) Pouring Metal Defects

The likely defects in this category are

- Mis-runs and
- Cold shuts.

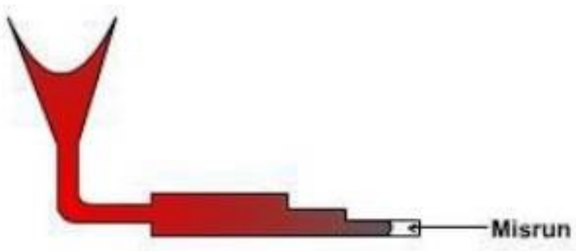
A mis-run is caused when the metal is unable to fill the mould cavity completely and thus leaves unfilled cavities. A mis-run results when the metal is too cold to flow to the extremities of the mould cavity before freezing. Long, thin sections are subject to this defect and should be avoided in casting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

A cold shut is caused when two streams while meeting in the mould cavity, do not fuse together properly thus forming a discontinuity in the casting. When the molten metal is poured into the mould cavity through more-than-one gate, multiple liquid fronts will have to flow together and become one solid. If the flowing metal fronts are too cool, they may not flow together, but will leave a seam in the part. Such a seam is called a cold shut, and can be prevented by assuring sufficient superheat in the poured metal and thick enough walls in the casting design.

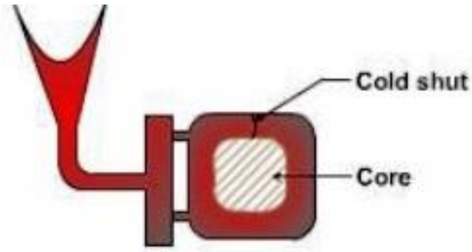
The mis-run and cold shut defects are caused either by a lower fluidity of the mould or when the section thickness of the casting is very small. Fluidity can be improved by changing the composition of the metal and by increasing the pouring temperature of the metal.

Mould Shift

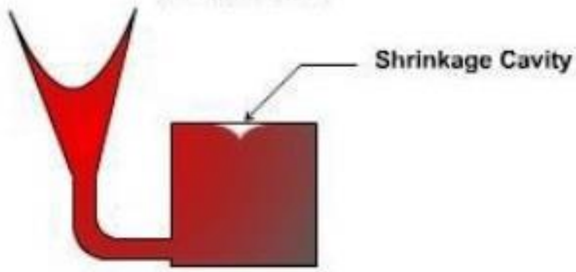
The mould shift defect occurs when cope and drag or moulding boxes have not been properly aligned.



Misruns

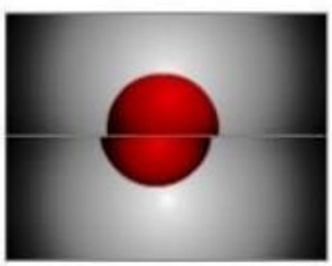


Cold shut

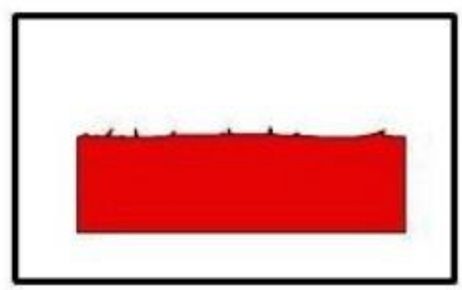


Shrinkage Cavity

Microporosity



Mismatch



Metal Peneration

1.10 Other casting process

(a) PRECESSION INVESTMENT CASTING:

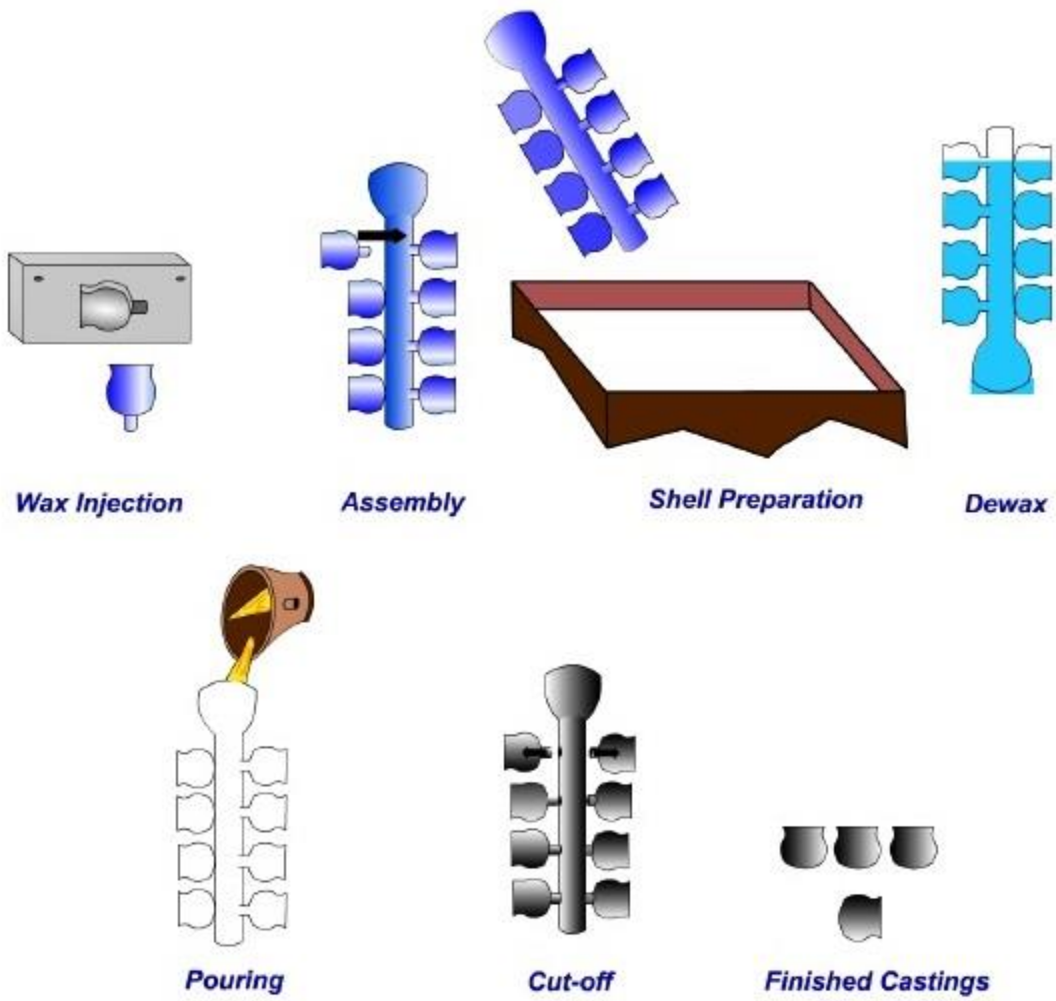
The investment casting process also called lost wax process begins with the production of wax replicas or patterns of the desired shape of the castings. A pattern is needed for every casting to be produced. The patterns are prepared by injecting wax or polystyrene in a metal dies. A number of patterns are attached to a central wax sprue to form an assembly. The mould is prepared by surrounding the pattern with refractory slurry that can set at room temperature. The mould is then heated so that pattern melts and flows out, leaving a clean cavity behind. The mould is further hardened by heating and the molten metal is poured while it is still hot. When the casting is solidified, the mould is broken and the casting taken out.

The basic steps of the investment casting process are:

1. Production of heat-disposable wax, plastic, or polystyrene patterns

2. Assembly of these patterns onto a gating system
3. “Investing,” or covering the pattern assembly with refractory slurry
4. Melting the pattern assembly to remove the pattern material
5. Firing the mould to remove the last traces of the pattern material
6. Pouring
7. Knockout, cut off and finishing.

Adv: complex shapes, very fine details, close tolerance, better surface finish, no machining
Limitation: size and mass – maximum 5 kg
-expensive
Application: jewellery, surgical instruments, vanes and blades of gas turbine, impellers, claws of movie camera



(b) **SHELL MOULD CASTING:**

It is a process in which, the sand mixed with a thermosetting resin is allowed to come in contact with aheated pattern plate (200 $_{o}$C), this causes a skin (Shell) of about 3.5 mm of sand/plastic mixture to adhere to the pattern.. Then the shell is removed from the pattern. The cope and drag shells are kept in a flask with necessary backup material and the molten metal is poured into the mould. This process can produce complex parts with good surface finish 1.25 µm to 3.75 µm, and dimensional tolerance of 0.5 %. A good surface finish and good size tolerance reduce the need for machining. The process overall is quite cost effective due to reduced machining and cleanup costs.

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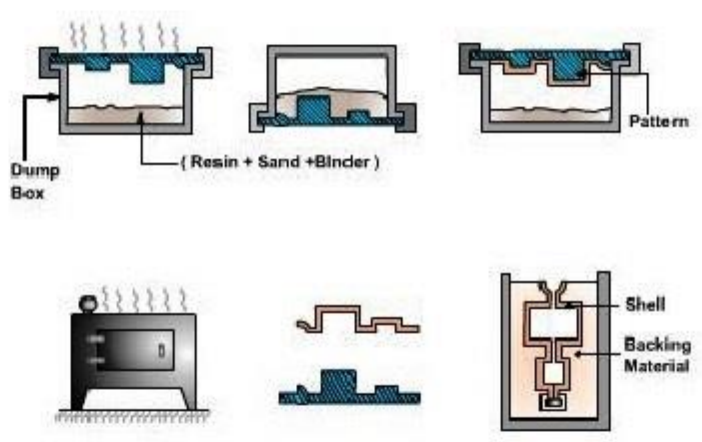

(C) CENTRIFUGAL CASTING:

In this process, the mould is rotated rapidly about its central axis as the metal is poured into it. Because of the centrifugal force, a continuous pressure will be acting on the metal as it solidifies. The slag, oxides and other inclusions being lighter, get separated from the metal and segregate towards the center. This process is normally used for the making of hollow pipes, tubes, hollow bushes, etc., which are axisymmetric with a concentric hole. Since the metal is always pushed outward because of the centrifugal force, no core needs to be used for making the concentric hole. The mould can be rotated about a vertical, horizontal or an inclined axis or about its horizontal and vertical axes simultaneously. The length and outside diameter are fixed by the mould cavity dimensions while the inside diameter is determined by the amount of molten metal poured into the mould.

There are three types of centrifugal casting.

a) True centrifugal casting
b) Semi centrifugal casting
c) Centrifuging

a) True centrifugal casting:

- Hollow pipes, tubes, hollow bushes – axi-symmetric with concentric holes
- Axis of rotation – horizontal, vertical or any angle.

- Sand moulds/ metal moulds
- Water cooling

Adv: superior mechanical properties
Directional solidification
No cores
No gates and runners

Limitation: - only for axi-symmetric concentric holes
- Expensive

b) Semi-centrifugal casting:
- More complicated- axi-symmetric jobs
- Vertical

c) Centrifuging:
- Not axi-symmetrical jobs
- Small jobs of any shape – joined by radial runners with a central sprue on revolving table.

(D) Die casting

Die casting involves preparation of components by injecting molten metal at high pressure into a metallic dies. It is also known as pressure die casting. Narrow sections, complex shapes, fine surface details can be produced by using this casting process. The dies have two parts. 1st one is a stationary half (cover die) which is fixed to die casting m/c. The other one is a moving half (ejector die) which is moved out for extraction of casting. At the starting of the process, two halves of the die should be placed apart. The lubricant is sprayed on die cavity and then the dies are closed and clamped. The metal is injected into the die. After solidification, the die will be opened and the casting will be ejected.

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