Metal casting techniques

Name:

Pin no.

Collage:

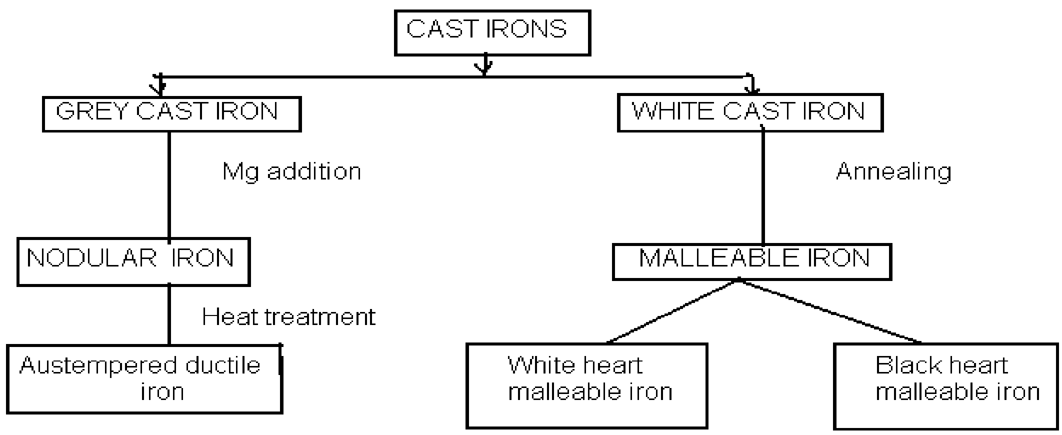
What is cast iron?

- Like steel, cast iron is also a ferrous alloy
- But the basic difference is percentage of carbon In steels the carbon % < 2%, In cast irons the carbon % > 2%,
- In cast irons carbon is present in two forms free form as graphite (C)combined form as carbide (Fe_3C)

Definition of cast iron:

- Cast iron may be defined as an alloy of iron, carbon (up to about 4%) and silicon (up to about 3.5%)
- As the carbon content is high in cast irons, they are very brittle
- They cannot be rolled, forged or extruded
- Therefore, the objects of cast iron can only be obtained by casting

Types of cast irons:



Definition of Grey cast iron:

- It is defined as an iron having a chemical composition such that after solidification, its carbon is distributed throughout casting as free or graphitic carbon in the form of flakes.
- Grey cast iron presents a grey surface when fractured
- The microstructure consists of graphite flakes in a matrix of either ferrite or a combination of ferrite and pearlite

White cast iron:

- It is defined as an iron having a chemical composition such that after solidification, its total carbon is present in a chemically combined form as cementite (iron carbide Fe_3C).
- White cast iron presents a white crystalline surface when fractured
- It has no free carbon or graphite, its entire carbon is in the form of cementite

- The microstructure consists of massive carbides (Fe_3C) in a matrix of pearlite

Nodular iron:

- It is specially prepared iron, treated in the molten condition with a small percentage of Magnesium or Cerium to convert the graphite flakes in to graphite spheroids
- It is also known as ductile cast iron or spheroidal grey iron (S.G. iron)
- The microstructure consists of graphite spheroids in a matrix of ferrite or pearlite or a combination of both ferrite and pearlite

Malleable iron:

- It is defined as an iron, with malleability or ductility, produced by heat treating (malleable) a white cast iron of suitable chemical composition
- The carbon is present as nodular - shaped aggregates of graphite
- The microstructure of malleable iron consists of temper carbon nodules in a matrix of ferrite or pearlite
- If the matrix is ferrite, the malleable irons are known as ferrite malleable irons or white heart malleable irons
- If the matrix is pearlite, the malleable irons are known as pearlitic malleable irons or black heart malleable irons

Chilled iron:

- An iron of such composition that it would normally freeze as grey iron, but which is caused to freeze as white iron in some areas by rapid cooling during solidification i.e. chilling

Types of cast irons and their composition:

- Cast irons are basically two types based on their chemical composition
- White iron - low carbon & low silicon

  - rapid cooling during solidification

- Grey iron - high carbon & high silicon

  - slow cooling during solidification

Composition of grey cast iron:

Element	%
Carbon	2.5 – 4.0
Silicon	1.0 – 3.0
Sulphur	0.05 – 0.25
Manganese	0.40 – 1.0
Phosphorous	0.05 – 1.0

Hardness:

- 170 – 240 BHN

Application:

- Motor blocks
- Piston rings
- Heavy machine bases
- Diesel engine crank shafts
- Machine tools
- Brake drums, clutch plates

Composition of white cast iron:

Element	%
Carbon	1.8 – 3.6
Silicon	0.5 – 1.9
Sulphur	0.25 – 0.80
Manganese	0.05 – 0.20
Phosphorous	0.06 – 0.18

Hardness:

- 240 – 300 BHN

Applications:

- Pipe fittings
- Various truck parts
- Agricultural equipment

Graphitization:

- It is the process of precipitation of free carbon (graphite) during solidification or conversion of combined carbon (Fe_3C) in to free carbon (graphite) during annealing

Factors effecting graphitization:

- <u>Composition:-</u> Carbon and Silicon are the two elements which effect the process of graphitization.
- Silicon is a powerful graphitizer, it causes iron carbide less stable and promotes the formation of graphite
- If either carbon or silicon is held at a constant percentage and the other is Increased, the iron changes from white to grey.
- High carbon and high silicon promote the graphitization process.
- <u>Cooling rate:-</u> Very slow cooling rate during.
- solidification or even in the solid state favors the formation of graphite.
- Where as rapid cooling causes the formation of cementite and a white iron is formed.

- <u>presence of other elements :-</u> Presence of elements like Cr, Mo, W etc. prevents the formation of graphite and favors the formation of carbides.
- Similarly presence of graphitizing elements like Si, Co etc. form the graphite phase

Solidification of grey iron:

- The simplified diagram represents freezing and cooling of cast irons.
- The X- axis represents the composition factor and the Y-axis represents the temperature in degrees centigrade.
- A cast iron with 4.0 composition factor is the eutectic cast iron and has the lowest melting point.
- Cast irons with < 4.0 C.F are known as hypo-eutectic cast irons and with a composition of > 4.0 C.F are known as hyper-eutectic cast irons.
- Now, let us consider a hypo-eutectic cast iron is cooling from its liquid state.
- Liquid melt cools until freezing begins at point 1.
- At point 1 primary dendrites of austenite begin to form and grow until the temperature drops to point 2.
- In case of hyper-eutectic cast irons primary dendrites of graphite begin to form from the liquid under slow cooling conditions.
- At point 2, eutectic freezing begins.
- As the solidification progresses with decreasing temperature, the remaining liquid undergoes eutectic transformation.
- Under slow cooling conditions, the melt transforms in to an eutectic mixture of secondary austenite and graphite.
- Liquid → Austenite + Graphite (C).
- This eutectic transformation is continued until point 3 is reached.
- At point 3, the solidification process is completed.
- At this temperature the structure consists of primary dendrites of austenite and eutectic mixture of secondary austenite & graphite.
- In case of white iron, with low carbon and silicon percentages & rapid cooling conditions, the eutectic transformation proceeds with the formation of secondary austenite and carbides.
- Liquid → Austenite + Carbides (Fe_3C).
- At the end of solidification at point 3, the structure of white iron consists of primary dendrites of austenite and eutectic mixture of secondary austenite and carbides.
- At the eutectic temperature (1090^0 C), the solubility of carbon in austenite is 1.7%.
- With decreasing temperature the solubility also decreases and at the eutectoid temperature (723^0 C) the solubility of carbon in austenite is only 0.6%.
- The excess of carbon i.e.1.7 – 0.6 = 1.1% comes out from the austenite and precipitated as graphite on the existing graphite flakes.
- In case of white irons, the excess carbon in the austenite is precipitated as carbide on the existing carbides.
- This precipitation process is carried until the temperature reaches point 4.
- At point 4, eutectoid transformation begins.
- The austenite is transformed into an eutectoid mixture of ferrite and graphite under slow cooling conditions Austenite → Graphite (C) + Ferrite.
- The eutectoid transformation is completed as the temperature reaches point 5.
- At point 5, the grey iron structure consists of Graphite flakes in a matrix of ferrite if the cooling is very slow.

- If the cooling rate is faster, the austenite is transformed in to an eutectoid mixture of carbide and pearlite Austenite → Carbide (Fe_3C) + Pearlite.
- The eutectoid transformation is completed at point 5.
- At point 5, the white iron structure consists of massive carbides with pearlite areas.
- Cooling below point 5, there is no change in microstructure

Micro constituents:

The important micro constituents of cast irons are:-

- Graphite
- Carbide (Fe_3C)
- Ferrite
- Pearlite
- Austenite
- Steadite

Graphite:

- It is the free or elemental form of carbon.
- It is developed with increasing % of carbon beyond 2% in the presence of graphitizing elements.
- The shape of graphite differs in different cast irons

Grey cast iron	-	flakes
Nodular iron	-	spheroids
Malleable iron	-	Temper carbon nodules

- Flake graphite is responsible for the lack of ductility in grey irons.
- It has low specific gravity and amounts to 6 – 17% of total iron volume.
- The size, shape and distribution of graphite greatly influence their properties.

Carbide:

- It is the chemically combined form of carbon as cementite or iron carbide (Fe_3C).
- It is very hard and brittle.
- Carbides develops during freezing of white or chilled irons, when the C & Si are low and cooling rate is faster.

Ferrite:

- It is an interstitial solid solution of carbon in alpha iron.
- It is soft, ductile and of moderate strength.
- In cast irons ferrite may develop when complete graphitization occurred.

Pearlite:

- It is an eutectoid mixture of ferrite and cementite arranged in alternate lamellae
- Pearlite is strong and moderately hard.
- The amount of pearlite present in cast irons depends on the degree of graphitization of the iron.

Austenite:

- It is an interstitial solid solution of carbon in high-temperature face- centered cubic crystalline form of(gamma) iron.
- It changes to pearlite or ferrite or a mixture of the two during slow cooling.
- Austenite appears at room temperature when cast irons are alloyed with Nickel, etc.

Steadite:

- The phosphorous present in cast irons, especially in grey iron, occurs as steadite.
- It is a eutectic of iron and iron phosphide (Fe_3P).
- It is brittle, very hard and has a low melting point.

Advantages of cupola furnaces:

- Low cost of melting
- Continuous melting
- No power requirement
- As melting unit in low capital cost foundries
- Skilled labor may not be required

Limitations of cupola furnaces:

- Cast irons with <2.8% C, are difficult to produce, due to direct contact of metal with coke.
- Loss of alloying elements due to oxidation.
- Higher temperatures > 1500^0C are difficult to obtain.

Mechanical structure:

- Cupola is a vertical shaft cylinder type furnace.
- It consists of a vertical shell built of 6 – 18 mm steel plate.
- It is lined inside with fireclay refractory bricks.
- A wind box and tuyeres are provided for delivering air into the shaft.
- About > 20 feet above from the bottom an opening is provided for charging the raw materials into the stack from the charging plat form.
- The whole structure of cupola is on the concreted cement foundation.
- The cupola bottom is hinged type so that the furnace may be emptied by dropping the doors.
- The cupola bottom is rammed with sand and inclined towards the tap hole.
- A slab hole is provided above the level of tap hole and opposite side (below the tuyears).
- The stack is topped by a spark arrester.
- The characteristics of various sizes of common cupolas are

- Cupola size :- Cupolas are rated by number from 0 – 12 and the melting rate varies1 - 35 tons per hour
- Shell diameter :- The outer shell diameters of common cupolas ranges from 27 – 108 inches

- Thickness of lower lining:- This is the thickness where maximum erosion occurs and it varies from 4.5 – 12 inches.
- Inside cross- sectional area in the melting zone:-This dimension determines the melting rates of a particular cupola.
- It ranges from 254 sq.inches for a “O” no. cupola to 5542 sq.inches for a 12 no. cupola.
- Total area of tuyers :-The tuyere openings introduce the air for combustion of coke. It varies from 32 – 960 square inches.
- Blast pressure:- The normal air pressure varies from 7 – 20ozs.
- Coke bed height:- It is an important parameter for smooth running of cupola. It varies from 28 – 34 inches for a zero numbered cupola to 47 – 53 for a 12 numbered cupola

Steps in cupola operation:

The important steps are:-

- Preparation of refractory lining of bottom, tap hole and slag hole
- Lighting and burning the coke bed
- Charging
- Melting
- Tapping and slagging
- Dropping the bottom

Preparation of cupola lining:

- It usually begins after dropping the bottom of the previous heat.
- The slag and metal adhere to the side walls, in the melting zone, are chipped away.
- Repair and maintenance of the lining require cupola blocks.
- Fire clay refractories are most commonly used for cupola lining.
- Patch work of lining is done with plastic mixtures of granular refractory, clay and water.
- A mixture of 50% ganister, 30% silica sand and 20% clay is used for ramming the bottom.
- The air gun may be used for patching the melting zone and ramming tap holes and slag holes.

Bottom:-

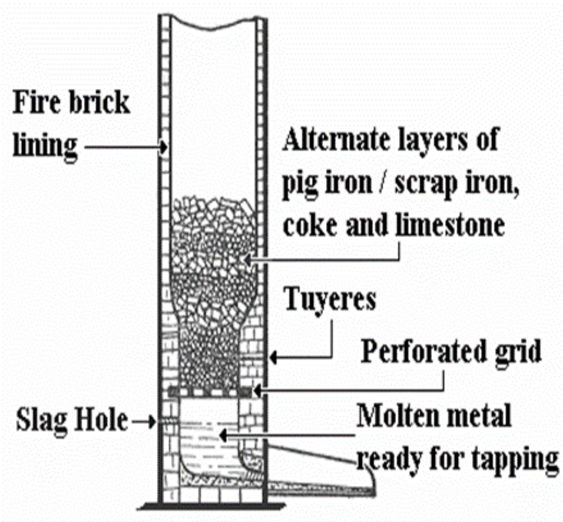
- molding sand may be used for putting in the cupola bottom.
- The bottom is tapered towards the tap hole and it is made hard to prevent any leakage of iron

Tap hole & Slag hole:-

- Tap holes and slag holes are constructed by ramming the plastic mixtures by air gun around a tapered plug.
- The vertical distance from the bottom of the tap hole to the bottom of slag hole, determines the volume of metal in the cupola when slag hole is left open.

Lighting and burning the coke bed:

- After the lining of cupola is fully prepared, the heat begins with the building of the coke bed.\
- The height of coke bed above the tuyere level before commencement of charging is called coke bed height.
- The coke bed height is an important parameter in the operation of cupola.
- If the bed height is low, metal temperature will be low where as if the bed height is high, it results in excessive coke rate.
- Lightening of coke bed is done with gas torches or electric spark igniters.



Charging:

- Charging consists of adding weighed batches of pig iron, foundry returns, coke and flux in alternate layers.
- The weight of one coke charge is approximately produce a layer of 3 – 9 inches deep inside the cupola.
- The function of coke is to maintain the temperature inside the cupola, so that the liquid metal and slag should be in fluid state and readily tapped from the holes.

Melting:

- When the cupola is fully charged, melting can be started.
- First the blowers are started
- After blowing for a few minutes, the coke becomes hot enough to melt the pig iron in the charge
- Droplets of liquid metal can be seen through the tuyere peepholes.
- After 8 – 10 minutes from wind on a trickle of liquid metal appears at the tap hole.
- The time for first iron at the tap hole is an indication of correct coke bed height and smooth running of cupola.
- The pouring temperature should be in the range of 1480 – 1560^{0}C.
- As blowing continues , melting progresses, the cupola charge descends and fresh charges are made into the cupola through the charging door.
- Liquid metal and slag accumulate in the well and may be handled by a sequence of taping and slagging operations.

Tapping and slagging:

- When sufficient amount of liquid metal accumulates in the well, tap hole is opened and the metal is tapped into pouring ladles.
- The intervals of tapping depends on the melting rate and can be predictable.
- Continuous tapping from the cupola is commonly done by some type of dam on the spout.

Various zones of chemical reactions in the cupola:

1. Well Super.
2. Heating zone (combustion or oxidation).
3. Reduction zone.
4. Melting zone.
5. Pre heating.
6. Stack zone.

Well:-

- It acts as a storage of molten iron where it collects before being tapped.
- It is situated between the sand bed and bottom of tuyers.

Super heating zone:-

- It is also known as combustion zone or oxidation zone. The zone lies about 10 – 30 cm above the tuyers.
- Burning of coke, manganese and silicon takes place in this zone with the evolution of heat according to the following reactions.

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

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

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

- O_2 required is supplied from air entering through the tuyers.

- O_2 of the blast is consumed here and this is the zone of maximum temperature, which varies from 1570 – 1820^0 C.

Reducing zone :-

- It is known as protective zone.
- It lies between the combustion zone and top of the coke bed.
- It has a reducing atmosphere and the quantity of heat produced is reduced.
- The main reaction in this zone is

$CO_2 + C \rightarrow 2CO + \text{Heat}$

- This zone protects the metal from oxidation

Melting zone:-

- The melting zone lies above the reducing zone.
- It starts from the first layer of the metal charge above the coke bed and extends up to a height of 90 cm.

- The main reaction in this zone is $3Fe + 2CO \rightarrow Fe_3C + CO_2$.
- The molten iron picks up carbon in this zone. The temperature in this zone is around1600^0 C

Pre heating zone :-

- The zone lies above the melting zone and extends up to the bottom of the charging door.
- It contains alternate layers of charge i.e. coke, flux and iron.
- This charge is preheated up to a temperature of 1000^0 C by the escaping gases rising upward from the melting zone.

Stack zone :-

- This zone extends from the pre heating zone to the top of the cupola.
- The hot gases rising upward through the pre heating zone in to the atmosphere passes through this zone.
- The escaping gases contains 76% nitrogen, 12% carbon monoxide and 12% carbon dioxide.

Heat balance of cupola :-

- The Heat balance of cupola is associated with various zones of cupola.
- Heat is generated by the oxidation of carbon, manganese and silicon.
- Heat is consumed by melting and super heating the metal, calcination of flux, evaporation of moisture and formation of slag.

Principles of cupola operation:

- The successful operation of cupola depends on :-
    - Combustion
    - Blast rate
    - Blast pressure
    - Tuyere size
    - Stack height
    - Well depth

Combustion:

Proper combustion of cupola depends on balanced combination of coke and air supplied

- Coke bed and stack gases

- **<u>1.Coke and air supply :-</u>**
- The rate at which coke is charged and air is delivered must be properly balanced.
- The amount of air required for combustion of 1 kg of coke is 8.4 cu.mts.
- When the coke and air are not proper proportion some problems arise.

Excess of coke results in Wastage of coke, Slow melting rate, High carbon in the iron, Excessive refractory erosion

Over supply of air causes the coke bed burned out and results in Oxidation of iron, Higher losses of Si and Mn, Low carbon in the iron, Low metal temperatures

Blast rate:-

- The blast rate is one of the most important control parameters in a cupola.
- Apart from higher coke consumption, a higher blast rate creates an oxidizing atmosphere, resulting in excess oxidation of iron and elements like silicon and manganese.
- The optimum blast rate has been found to be 115 m^3/min per square meter.
- The blower should be capable of delivering about 15-20% more than the required blast rate, to account for air losses in the blast system.

Blast pressure:-

- Proper blast pressure is required to penetrate the coke bed.
- Incorrect air penetration adversely affects the temperature, carbon pick-up and the melting rate of the cupola.
- The blast pressure is a function of the cupola diameter.
- An empirical correlation is used to determine the blast pressure from cupola diameter is suggested below; $P=0.005D^2-0.0134D+39.45$
  Where, P = Blast pressure, D = Internal diameter at the melting zone

Tuyere size:-

- The tuyere size determines the velocity of the blast air in the bed.
- For a cold blast system, the total area of the tuyeres is about 20% of the melting zone area.
- Size of each tuyere can be calculated by dividing the total tuyere area by the total number of tuyeres.

- The recommended number of tuyeres per row for cupolas of various diameters is as follows.
  Cupola internal diameter < 30 inches :4
  Cupola internal diameter , 30 – 42 inches :6
  Cupola internal diameter , 42 – 60 inches :8
  Cupola internal diameter , 60 – 84 inches :12
- The shape of the tuyers can be either round (preferable) or rectangular.

Stack height:-

- In the cupola, hot gases rising from the melting zone exchange heat with the descending charge materials.
- A stack height between 16 ft to 22 ft is recommended for a cold blast cupola, depending upon its diameter.

Well depth:-

- The well depth influences the carbon pickup and the metal tapping temperature.
- On the flip side, increasing the well depth reduces the tapping temperature of the molten metal.

- As a rule of thumb, there is a drop of 1^0C in the molten metal temperature for every additional inch increase in the well depth.

Chill test:

- Chill testing is a procedure for approximating the graphitizing tendency in iron. A test sample of the iron is taken and poured into a core sand mold or test block.
- The sample is removed from the mold after solidification and is broken, allowing the inspector to view the fracture and measure the chill structure.
- The depth of the chill is measured in increments of 1/32 of an inch.
- Iron composition greatly influences chill depth.
- Low carbon or low silicon content will produce a deep chill, but inoculants can considerably alter iron's chilling tendencies.
- The chill plate test is better adapted to irons with silicon contents exceeding 2.5% and carbon at or above 3.5%.
- As its name implies, the chill plate test specimen is poured against a chilled plate that is usually made of cast iron, graphite, or, water-cooled steel or copper plates.
- The molded chill contains a notch to facilitate breaking of the casting.
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Fluidity test

- Fluidity can be defined as the ability of molten metal to fill the mold cavity completely before freezing commences.
- It can be determined by the spiral fluidity test.
- The fluidity can be expressed in terms of spiral inches.
- Successful production of a gray iron casting depends on the fluidity of the molten metal and on the cooling rate.
- Influenced by the minimum section thickness and on section thickness variations.
- Casting design is often described in terms of section sensitivity.
- Fluidity test is an attempt to correlate properties in critical sections of the casting with the combined effects of composition and cooling rate.
- Fluidity test is performed with the following objects: 1.To find out the cause of misrun 2.To find correct pouring temperature for a particular grade of iron 3.To determine the cross section and length of the cavity for design.
- Test is carried out by pouring molten metal in the standard spiral test pattern and measuring the length of liquid metal flown in inches before it freezes.
- Fluidity is largely effected by the metal composition, pouring temperature

Advantages of induction furnaces:

- Higher yield. The absence of combustion sources reduces oxidation losses.
- Faster startup. Full power from the power supply is available, instantaneously, thus reducing the time to reach working temperature.

- Flexibility. Even a small quantity of metal of any composition can be melted.
- Natural stirring.
- Cleaner melting.
- High melting rates can be obtained from small furnaces
- Precise automatic control
- Reduced refractory costs
- High quality of metals and alloys can be produced

Disadvantages of induction furnace:

- The initial cost is high
- No refining due to hot metal and reactive slag on the metal surface
- Bath sampling cannot be carried

Principle of induction melting:

- The principle of operation of the induction furnace is the phenomena of electro-magnetic induction.
- The induction (generation) of the electrical current in a conductive metal (charge) placed within a coil of conductor carrying electrical current is known as electromagnetic induction of secondary current.
- The alternating current applied to the coil produces a varying magnetic field which is concentrated within the helical coil.
- This magnetic field passing through the charge induces secondary current in the charge piece.
- The current circulating in the charge produces electrical (I^2R) losses which heat the charge and eventually melt it.
- Melting of metal in an induction furnace differs from that of arc furnace.
- In arc furnace the bulk of the heat is generated by an arc and radiated to the charge.
- In induction furnace the heat is generated in the charge itself.
- The furnace contains a crucible or a monolithic lining surrounded by a water cooled copper coil.
- The coil represents the primary to which a high frequency current of 1000 cycles per second is supplied by a motor generator set.
- By induction secondary currents, called eddy currents, are produced in the crucible charge.
- The flow of these currents is motivated by potential difference between the various parts of the charge.

Melting practice of cast iron in induction furnace:

- The normal frequency (mains frequency) medium frequency induction furnace essentially an air transformer in which the primary is a coil of water cooled copper tubing and the secondary is the metal charge.
- The capacity of the furnace rarely ranges from 15 to 200 kgs.
- The shell of the furnace consists of asbestos board, and is supported on trunnions on which the furnace pivots when pouring.
- Inside the shell is placed the circular winding of copper tubing.
- Fire brick is placed on the bottom portion of the shell, and space between that and the coil is rammed with grain refractory.

- The furnace chamber may be a refractory crucible.
- The general practice is to use ganister rammed around a steel shell which melts down with the first heat, leaving a sintered lining.

Operation:-

- The process consists in charging the furnace with steel scrap and then passing a high frequency current through the primary coil, thus inducing a much heavier secondary current in the charge, which results in heating the metal charge by resistance.
- As soon as a pool of metal is formed, very pronounced stirring action in the molten metal takes place, which helps to accelerate melting.
- Melting is so rapid that the loss due to oxidation is very less.
- As melting proceeds, extra scrap may be added, till the required metal temperature is reached.
- The power is then switched off, and alloys are added to adjust the composition of the metal.
- The final deoxidizers i.e. ferro-silicon or aluminium are then added.
- When the alloy additions have been absorbed by the metal and the reactions are complete, a small amount of the slag produced is removed.
- The metal is then tapped in to the ladle by tilting the furnace.
- Aluminium may also be put in the ladle before pouring.
- The time of melting depends upon the size of the furnace and the power input.
- There will be no time for chemical analysis.
- Thus the charge should be carefully selected from scrap of known composition.
- As no refining takes place the sulphur and phosphorous must be with in the limits.

PROPERTIES OF GREY CAST IRON:

- The high carbon content of grey cast iron is responsible for ease of melting and casting in the foundry.
- It has the lowest pouring temperature of the ferrous metals, which is reflected in its high fluidity and its ability to be cast into intricate shapes.
- Gray iron has excellent machining qualities producing easily disposed of chips and yielding a surface with excellent wear characteristics.
- The resistance of gray iron to scoring and galling with proper matrix and graphite structure is universally recognized.
- The low degree or absence of shrinkage and high fluidity provide maximum freedom of design for the engineer.
- Amount of graphite, the length of the flakes and how they are distributed in the matrix directly influence the properties of the iron.
- By suitable adjustment in composition and selection of casting method, tensile strength can be varied from less than 20,000 psi to over 60,000 psi.
- Hardness from 100 to 300 BHN in the as-cast condition. By subsequent heat treatment, the hardness can be increased to 60 HRC.
- The exceptionally high damping capacity of gray cast iron is one of the most valuable qualities of this material.
- The damping capacity of gray iron is considerably greater than that of steel or other kinds of iron.
- This behavior is attributed to the flake graphite structure of the gray iron.

Applications:

- The exceptionally high damping capacity of gray cast iron is ideally suited for machine bases and supports, engine cylinder blocks and brake components.
- The resistance to scaling property of grey iron is advantageous in the use of furnace and stoker parts, melting pots, etc.
- Because of its resistance to the sliding – friction type of wear, especially lubricated, gray iron is used for variety of auto motive parts like brake drums, clutch plates, transmission cases, gear boxes, dies, pistons and rings.
- Motor & Pumps Accessories - For the Motor and Pump industry Pump Castings, Impellers, End Bracket, Flanges, Motor Body Covers for Agriculture, Domestic & Industrial purpose.
- Textile Accessories - Textile machinery spares Roller stand, Arm Bar Slide, Roller Beam, Gearing Unit, Stop Motion Box, Boot, Bearing Stand, Lap Stand, Lap Bracket, Carding Wing (LH & RH), Lickeren Bracket.
- Fire Proof Accessories - Roller Wheels forDoors and Weights.
- Hospital Accessories - wheels for Stretcher & Gear Boxes.
- Kitchen Accessories - wheels for Muruku Preparation Machine and Gear Boxes.
- Burners for all types of Gas Stoves.

Classification of Gray cast Iron:-

- Gray irons may be classified in two ways
    - Based on matrix
    - Based on tensile strength

Based on matrix gray irons may be

- Pearlitic gray irons:-consists of graphite flakes in a matrix of pearlite.
- Ferric gray irons: - consists of graphite flakes in a matrix of ferrite.

Based on tensile strength:

- Generally Gray irons are classified based on tensile strength.
- A class 30 gray iron indicates that it has a nominal tensile strength of 30,000 psi.
- In the International Standard or SI System a similar iron would be of grade 220 with a tensile strength of 220 MPa (N/mm^2).
- However, when the class designation is used in conjunction with a standard specification that requires a minimum tensile strength, then actual tensile tests are made to determine if the metal meets this requirement.

Effect of Si on the Fe – Fe_3C system:

- Silicon is a powerful graphitizing element.
- The important effect of Silicon is its effect on graphitization.

- The increasing percentage of silicon shifts the eutectic point of the iron – carbide diagram to the left.
- The eutectic shift is given by the relationship.Eutectic carbon % = 4.30 – 1/3 X %Si (in Fe-C-Si alloy).
- If the carbon equivalent of a particular iron is calculated to be 4.3, then the iron corresponds to an eutectic iron.
- If the carbon equivalent of an iron is less than 4.3, the alloy is a hypo-eutectic alloy.
- The Silicon in cast irons also shifts the eutectoid point and the solubility limits of carbon in the austenite to the left of equivalent points in the Fe – Fe3C system.
- For this reason the pearlite in a 2.0% Si gray iron contain only about 0.6% carbon rather than 0.8% carbon value in the Fe –Fe3C diagram.
- Micro structurally, silicon dissolves in the ferrite matrix of gray iron.
- It hardens and strengthens the ferrite.

Explain the chemical composition requirements of gray iron:

- Cast irons are alloys of iron, carbon and silicon in which more carbon is present than can be retained in solid solution in austenite at the eutectic temperature.
- In gray cast iron, the carbon that exceeds the solubility in austenite precipitates as flake graphite.
- Gray irons usually contain 2.5 to 4% **C**, 1.5 to 3% **Si**, and additions of manganese, depending on the desired microstructure (as low as 0.1% **Mn** in ferric gray irons and as high as 1.2% in (pearlitics).
- Sulfur and phosphorus are also present in small amounts as residual impurities.

Carbon:

- Carbon in gray iron is present from 2.5 to 4.5 % by weight.
- Two phases present, elemental carbon in the form of graphite and combined carbon as Fe_3C.
- Total carbon = % graphitic carbon + % combined carbon.

Silicon:

- Silicon is present in gray iron from 1.0 – 3.5 %.
- Si promotes graphitization. Low percentages are not sufficient to cause graphitization during solidification, cause nucleation and graphitization in the solid state at high temperature.

Manganese:

- The manganese content varies as a function of the desired matrix.
- Typically, it can be as low as 0.1% for ferric irons and as high as 1.2% for pearlitic irons, because manganese is a strong pearlite promoter.

Sulfur:

- Sulfur is seldom intentionally added to gray iron and usually comes from the coke in the cupola melting process.
- Up to 0.15 percent, sulfur tends to promote the formation of Type A graphite.

- Somewhere beyond about 0.17 percent, sulfur may lead to the formation of blowholes in green sand castings.

- The majority of foundries maintain sulfur content below 0.15 percent with 0.09 to 0.12 % being a common range for cupola melted irons.
- If the sulfur is decreased to a very low value together with low phosphorus and silicon, tougher irons will result and have been designated as "TG," or tough graphite irons.

Phosphorus:

- The phosphorus content of most high-production gray iron castings is less than 0.15 percent however phosphorus contents below 0.10 percent are common.
- Phosphorus generally occurs as an iron, iron-phosphide eutectic, although.
- In some of the higher- carbon irons, the ternary eutectic of iron, iron-phosphide, iron-carbide may form.
- This eutectic will be found in the eutectic cell boundaries, and beyond 0.20 % phosphorus a decrease in machinability may be encountered.
- For increased resistance to wear, phosphorus is often increased to 0.50 % and above as in automotive piston rings.
- At this level, phosphorus also improves the fluidity of the iron and increases the stiffness of the final casting.

Green sand molding:

- If green sand molds are not sufficiently hard or strong, some mold wall movement may take place during solidification, and shrinkage defects develop.
- Although castings up to 100 lb or more can be made in green sand, it generally is used for medium to small size castings

Dry sand molding:

- For the larger castings, the mold surfaces are sometimes sprayed with a blacking mix and skin dried to produce a cleaner surface on the casting.
- This procedure is often used on engine blocks to withstand the higher Ferro static.
- Pressures developed in pouring larger castings dry sand molds are often used.
- In some cases, the same sand as used for green sand molding is employed, although it is common practice to add another binder to increase the dry strength.
- The shell molding process is also used for making cores which are used in other types of molds besides shell molds.
- Its principal advantage is derived from the ability to harden the mold or core in contact with a heated metal pattern.

Shell molding:

- In addition to the improved accuracy, a much cleaner casting is produced than by any other high-production process.
- The techniques and binders for hot box and the newest cold box processes differ from those used for the shell molding process.

- The principles similar in that the core is hardened while in contact with the pattern.

Centrifugal casting:

- Centrifugal casting of iron in water-cooled metal molds is widely used by the cast iron pipe industry as well as for some other applications.
- With sand or other refractory lining of the metal molds, the process is used for making large cylinder liners.

Permanent mold casting machine:

- For some types of castings, the permanent mold process is a very satisfactory one.
- Since the cooling or freezing rate of iron cast into permanent molds is quite high, the thinner sections of the casting will have cementite.

Describe the additives required for ease of molding:

- Additives may be :-
  - Carbonaceous
  - Non – Carbonaceous
- Carbonaceous additives are coal dust, pitch, sea coal, corn floor, dextrin, molasses saw dust, etc.
- Non – Carbonaceous additives are silica floor, alumina, iron oxide, red oxide, etc.

Coal dust:

- Coal dust is produced from bituminous coal and contains 30% volatile matter.
- Coal dust sinters at around 500^0C and begins to burn at 650^0C and completed at 700^0C.
- On further heating, the ash residue melts at 1320^0C .
- Coal dust is widely used in cast iron foundry to improve surface finish and collapsibility of molds and cores.
- It also helps in reducing the scabbing tendency.

Pitch:

- Pitch is a by-product of coke making.
- Coal tar pitch is free flowing powder consisting of spheroidal particles.
- It contains 93% carbon with a total volatile matter of around 50%.
- Coal tar pitch is fluid at 250^0C and burns at 600^0C.
- Small amount of ash fuses at 1300^0C.
- It improves collapsibility and to certain extent dry and hot strengths.
- It is added in the range of 2.0 – 3.0%

Sea – Coal:

- When heated, it changes to coke which fills the pores between the sand grains and is unaffected by water
- Sand grains become restricted to move.
- The addition of 2.0 – 3.0 %of sea coal reduces the mold wall movement and also makes the mold surface clean and smooth.

Saw dust:

- It is fibrous material.
- Addition of saw dust is generally 0.5 – 2.0% and rarely exceeds 3.0%.
- It volatilizes when heated leaving room for expansion of sand grains.
- It improves collapsibility and increases mold wall movement, but decreases expansion defects.

Dextrin:

- The starch is digested in hydrochloric acid, which converts the starch into dextrin.

- Dextrin provides hard surface to green sand molds and increases the green strength of the sand.
- It reduces the deformation of molds during handling.

Molasses:

- It is a byproduct obtained from sugar industry.
- Molasses may be added to molding sands using bentonite or sodium silicate as binder.
- It helps in improving the dry strength and casting finish.
- Addition of Molasses is up to 1.0%.

Silica floor:

- It has good refractoriness.
- Its addition to molding sand mix improves the hot strength and reduces metal penetration in the mold walls.
- The amount of its addition depends on the nature and grain size distribution of the base sands.

Alumina:

- Alumina is used in the sand mix to improve the break down property.
- To certain extent it improves the hot strength.
- Normal addition of alumina is 0.5 – 1.0%.

State the foundry properties of gray iron:

- The high carbon content is responsible for ease of melting and casting in the foundry.
- It has the lowest pouring temperature of the ferrous metals, which is reflected in its high fluidity and its ability to be cast into intricate shapes.
- The important foundry properties are:-1.Fluidity.2.Shrinkage.3.ating & Feeding

Fluidity:

- It is the ability of the metal to fill the mold cavity completely before freezing commences.
- Gray irons are the most fluid of ferrous alloys.
- Intricate and thin section castings may be produced.

- Fluidity of molten gray iron is described in terms of spiral fluidity test, as inches of spiral length for a given chemical composition.
- Fluidity of gray iron is influenced by two factors:-1.Chemical composition.2.Temperature.
- Increasing the percentage of carbon and silicon increases the fluidity of metal.
- A carbon increase of 0.15 – 0.20 percent in the hypo eutectic range will increase the fluidity about 1 inch.
- An increase of temperature of 20^0F will increase the fluidity by 1 inch.

Shrinkage:

- Shrinkage is the volumetric contraction of molten metal during cooling from the pouring temperature to the room temperature.
- Shrinkage is three types:-1.Liquid shrinkage.2.Solidification shrinkage.3.Solid shrinkage.
- Liquid shrinkage is very negligible and Solidification shrinkage can be compensated by providing a suitable size of riser.
- The solid shrinkage can be compensated by providing sufficient allowance to the pattern
- The solidification shrinkage of gray iron can be calculated by:-ΔV, % = 2(% graphitic carbon – 2.80) Where ΔV = % volume change, positive or negative.
- Since, the percentage of graphitic carbon influences the equation, the readily graphitisable irons will have little or no solidification shrinkage.
- Whereas a white iron has 0 % graphitic carbon, it would have considerable shrinkage ΔV, % = 2(% graphitic carbon – 2.80) = 2(0 – 2.80) = - 5.6%.
- The % volume change is negative.
- A normal gray iron of 3.5% C and 2.2% Si, with about 0.4 – 0.6% combined carbon (pearlite) and 2.90 – 3.10% graphitic carbon, have virtually no shrinkage or even expand on solidification.
- ΔV, % = 2(% graphitic carbon – 2.80) = 2(2.90 – 2.80) = 2(0.10) = 0.20 %.
- The percentage volume change is positive.
- Hence, for ordinary gray irons little risering is needed for the purpose of feeding solidification shrinkage.

Calculation of the pouring temperature:

- If we know the composition of a gray iron, we can calculate the appropriate pouring temperature and, the fluidity at that temperature.
- Model problem:- A gray iron has the following composition. C- 3.4%,Si - 2.1%Mn- 0.5% ,P- 0.4%,S- 0.06%.calculate the appropriate pouring temperature and the fluidity of the metal at that pouring temperature.
- From the given composition, we can calculate the composition factor:
- Composition factor, C.F = % C + ½ % P + ¼ % Si: C.F = 3.4 + 0.3 + 0.5: C.F = 4.2.
- The liquidus temperature = 2981 – (218 x C.F): T = 2981 – 915.6: T = 2066^0 F.
- The pouring temperature should be 100 – 150 ^{0} F above the liquidus temperature.

- Therefore, the pouring temperature = Liquidus temp. + 150= 2066 + 150= 2216 ^{0} F or = 1215 ^{0} C.
- The fluidity of the metal can be Calculated by the formula:
- Fluidity, inches = (14.9x C.F) + (0.05 x T) – 155 = 62.58 + 110.8 – 155 = 173.38 – 155 = 18.5 inches.

Explain the effect of alloying elements on the properties and structure of gray iron:

- **Copper and nickel:** Copper and nickel behave in a similar Manner in cast iron.
- They strengthen the matrix and decrease the tendency to form hard edges on castings.
- Since they are mild graphitizes, they are often substituted for some of the silicon in gray iron.
- An austenitic gray iron may be obtained by raising the nickel content to about 15 percent together with about 6 percent copper, or to 20 percent without copper.
- **Chromium:** Chromium is generally present in amounts below 0.10 percent as a residual element carried over from the charge materials.
- Chromium is often added to improve hardness and strength of gray iron.
- For this purpose the chromium level is raised to 0.20 to 0.35 percent.
- Beyond this range, it is necessary to add graphitizes to avoid the formation of carbides and hard edges.
- Chromium improves the elevated temperature properties of gray iron.
- **Molybdenum:** One of the most widely used alloying elements for the purpose of increasing the strength is molybdenum.
- It is added in amounts of 0.20 to 0.75 %although the most common range is 0.35 to 0.55 %.
- Best results are obtained when the phosphorus content is below 0.10 % since molybdenum forms a complex eutectic with P and thus reduces its alloying effect.
- Molybdenum is widely used for improving the elevated temperature properties of gray iron.
- Since the modulus of elasticity of molybdenum is quite high, molybdenum additions to gray iron increase its modulus of elasticity.
- **Vanadium:** Vanadium has an effect on gray iron similar to molybdenum, but the concentration must be limited to less than 0.15 percent if carbides are to be avoided.
- Even in such small amounts, vanadium has a beneficial effect on the elevated temperature properties of gray iron.
- **Tin & antimony:** The beneficial effect of relatively small additions of tin (less than 0.10percent) is particularly helpful in complex castings wherein some sections cool rather slowly through the Ar_3 temperature interval.
- It has been found that additions of up to 0.05 percent antimony have a similar effect.
- In larger amounts, these elements tend to reduce the toughness and impact strength of gray iron, and good supervision over their use is necessary.

What is ductile iron?

- Ductile Cast Iron is also known as Spheroidal or nodular Cast Iron.
- It is specially prepared molten iron with addition of Magnesium or Cerium.
- Graphite Occurs in the form of Spheroids.
- Ductility is due to the spheroidal shape of Graphite.

Ductile Iron Products:

- Heavy motor blacks.
- Heavy duty machinery, dies, gears.
- Motor Frame.
- Axle equalizer beam.
- Diesel engine piston.
- Automotive crank shaft.
- Hot air valves.
- Angle finished roll.

General Properties –

- Low melting, good fluidity, good cast ability, and excellent machinability, good wear resistance.

Engineering Properties:

- High strength, toughness, ductility, and
- Hot workability, harden ability

Uses:

- Heavy duty machinery, gears, dies.
- Rolls for wear resistance and strength.
- Pressure castings, valves, and pump bodies.
- Shock resisting parts, navy ship boards.
- Pinions, gears, crank shafts, cams, guides, truck rollers.

Composition of Ductile cast Iron

- Carbon – 3 to 4 %
- silicon – 1.8 to 2.8 %
- manganese – 0.15 to 0.90%
- Sulphur – 0.03% max.
- Phosphorous – 0.10% max.

Role of Magnesium:

- The most common element added in molten iron is Magnesium or Cerium.
- The magnesium or Cerium transforms graphite to spheroids.
- Magnesium serves as deoxidizer and desulphuriser of molten iron.
- It prevents nucleation of flake graphite's.

Metallurgical process control of Adding of Mg:

- The sherardizing element when added to melt eliminate Sulphur, oxygen.
- Changes solidification characteristics.
- Total Mg recovery depends on the alloy type, method of addition.
- After Mg treatment to determine final chemistry of ductile iron.

- To prepare cast test coupon in one heavy piece in core sand mold.
- Sample is allowed to cool to black heat.
- Allowed to water quenched.
- The sample is allowed to water quench.
- Then the sample Broken off, ground, and polished.
- To see the micro structure of sample on X100.
- Microstructure should reveal Graphite spheroid.

Metallurgical process control of Nodule size and count:

- Different sizes of Graphite spheroids can be observed.
- Nodules count is Nodules per sq. in, in structure.
- Sample of 0.5 bar diameter, in. 465 carbide free, 88 vermicular free nodule are present.
- 1.5 bar diameter, in.80 carbide free, 88vermicular nodules are present.
- Low nodules count are accompanied by a carbide matrix.
- Number of nodules is increases as the amount of ferrite increase.

Metallurgical process control of Graphite shapes:

- 5 types of shapes can be observed in Ductile Iron.
- These are Type -1 Graphite is the accepted form in ductile iron.
- Type -2. Graphite is in little on properties.
- Type -3. is not desirable.
- Type- 4. & 5. Lower mechanical properties.
- Graphite shape depends on
    - Low pouring temperature.
    - Heavy section sizes.
    - Insufficient Mg addition.
    - Lack of inoculation.
    - Low carbon equivalent.

Metallurgical process control of Carbide formation:

- Eutectic carbide formation occur during solidification.
- Eutectic carbide prevented by high carbon equivalent.
- Development of adequate number of spheroids.

Metallurgical process control of Dross formation:

- Mg react with Sulphur, oxygen to form magnesium sulphide, oxide as dross.
- Appears on cope surface of casting.
- Aggravated by high Magnesium addition, high pouring temperature, and turbulence of gating system.

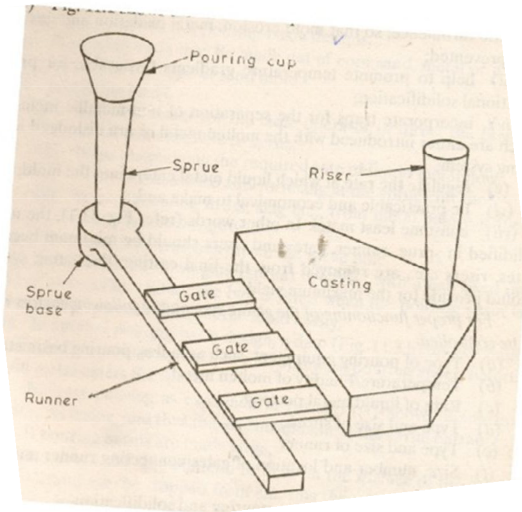
Inoculation:

- Most of castings are made in green or dry sand molds.
- Moist content in the sand should be controlled to avoid Mg oxidizing.

- Total combustible material in sand up to 6 to 7%.
- Type of castings produced depends on sand mixture manufacture of mold.
- The Quality of ductile iron is improved by either inoculation or post inoculation.
- The addition of Fe-Si to the melt to form number spheroid sites.
- Inoculation increases graphitizing tendency of solidifying melt.
- Reduce the chilling tendency.
- Reduce high hardness eutectic carbide formation.
- Most widely used grade of inoculant is Fe-si alloy with 85% Silicon.
- Post Inoculation much more effective than base silicon content of ductile iron.
- About 0.5 to 1.5% silicon is added in the mould immediately after pouring.
- Methods of inoculation
    - Ladle Inoculation
    - Mold Inoculation
- Reloading the iron onto Fe-Si placed in the bottom of the ladle.
- Added to the metal stream.
- Add very small amount to the sprue or runner during pouring

Foundry process control:

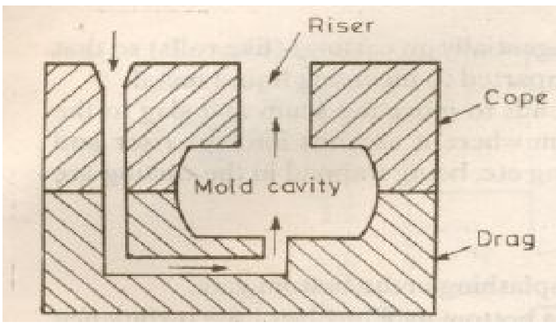
- Mg readily react with oxygen, Sulphur to form dross.
- Pouring carried at about 1400^{0}C above to avoid dross formation.
- Adopt good gating and pouring practice.



Design of gating system:

Requirement of good gating system

- Retain the slag and dirt in the gating system ahead of the mold cavity.
- Introduce the metal into the mold with little turbulence as possible.
- Control the rate of entry of metal into the mold.
- Establish the best possible metal distribution.
- Gating system minimize turbulence in mold cavity.
- Metal introduce number bottom ingrates, with equal amount metal in mold.
- Positive gating ratio 4:8: 3 should be used.



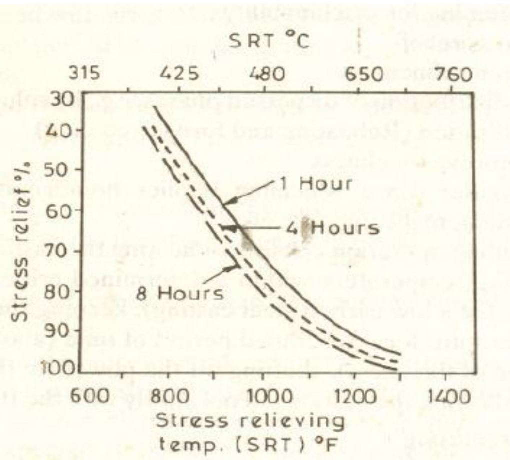
Riser design:

- Ductile iron solidifies by neoeutectic type.
- Larger number of graphite spheroid surrounded by austenite.
- Neoeutectic solidification with liquid and solid metal exist throughout a wide temperature.
- Greater shrinkage of hypoeutectic alloy than hyper eutectic alloy.
- Side, top riser effectively feed the casting.
- Hypereutectic iron in dry sand molds requires less risering.

Stress relieving heat treatment:

- Heating to a temperature at which elastic (residual) stress is completely removed.
- Stress relieve does not affect the metallurgical properties of the casting.
- To relieve internal stresses caused by previous treatment.
- Heat the casting at 538^{0} C to 677^{0}C for 1 hr. plus 1hr per in. of thickness.
- Then followed by very slow cooling as in the furnace.

Stress relieving Cycle:



Annealing treatment:

- Many cast alloys owe their properties mainly to the structure formed during solidification.
- Strength and toughness of the casting may be improved by changing grain size by solution controlled precipitation of phase.

Purpose of annealing treatment:

- Softening for machinability.
- Stress relief.
- Grain refinement.
- Re distribution of dispersed phases.
- Improve toughness.

Types of annealing treatment:

Type-1 annealing:-

- Heating the casting to about 691^{0}C and hold for 5 hr or 1hr in of thickness
- Then uniformly cool to room temperature.

Type- ii annealing:-

- Heat the casting to 899^{0}C and hold for 5 hr, or 1hr per in. of thickness.
- Then furnace cool from 899^{0}C to 649^{0}C at a rate less than 2^{0}C per hr.

Type -3 Subcritical annealing:-

- Heating the casting to 704^0 C and holding for 5hr , or 1hr per in. of thickness.
- Then followed by furnace cool to at least 593^0 C

Normalizing and tempering:

Normalizing:-

- Heating the casting to about 871^0 C to 927^0 C and holding there for definite time.
- Then followed by an air cool.
- Normalizing process is used for 100-70- 03 and120- 90-02 types of ductile cast iron to develop properties as follows.
- Refine the grains.
- Improve substructure by air cooling.
- Improve toughness machinability.
- Relaxes residual stress.

Tempering:-

- Reheating the air quenched ductile casting at a temperature below the transformation range and cool at any rate desired.

Purpose of tempering:-

- Decrease the hardness and increase toughness of casting.
- Retention of pearlite and thereby highest strength and hardness.

Hardening and tempering:

- Heating of casting to 857^0 C to 927^0 C.
- Then cool rapidly enough to obtain Martensite structure.
- Strengthening of casting occurs by non-equilibrium changes.
- Quenching media may be brine solution, water or oil it depends on alloy type.
- Care must require to Quenching of thick and thin section.
- Jigs and fixtures' should be used to hold casting which are liable to wrap or distort during quenching.

Tempering:-

- Reheating hardened casting to427^0 C to 450^0 C.
- To reduce hardness to the desire values.
- Both treatments to produce a maximum tensile strength.

Austempering:

- It is a two stage operation.
- Heat the casting to austenite temperature of 860^0 C to 927^0 C.

- Then hold the casting until completely austenite structure.
- Quenching to 232^0 C- 399^0 C and holding isothermally in salt or oil bath.
- Then allow the austenite to transform to bainitic ferrite and retained austenite.
- Quenching must be rapid to prevent austenite to either ferrite or pearlite.

Mar tempering:

- Casting is cooled rapidly to a temperature just above the M_S and hold until uniform cross section.
- Hold at this time until the temperature is equalized to the section.
- Then the casting is allowed to cool in air through the Martensite range.
- Transformation occur uniformly throughout the section.
- Uniform Martensite occur more or less simultaneously across the section.
- Residual stresses induced are minimum.

Flame hardening:

- It is done by means of an oxyacetylene torch.
- Heating should be done rapidly by the torch and the surface quenched before appreciable heat transfer to core occurs.
- It is applicable to large mill rolls, large gears and complicated cross section.

Induction hardening:

- Enclose the casting to be heat treated in an induction coil.
- Alternating current of high frequency passes through induction coil.
- Induced emf heat the casting.
- Immediately after the heating water jets are activated to quench the surface.
- The hardened depth of casting decreases with increasing frequency.
- The heating time is usually a few seconds.
- Martensite is produced at the surface, making it hard and wear resistant.
- Structure of the core remains unchanged.

Raw material malleable iron:

Material	Batch melting	Duplexing
1)Pig iron %	25—35	12
2)Sprue %	45-55	50
3)Malleable scrap %	5-10	10
4)Steel scrap %	0-10	38
5)Fuel:--		
Coke,lb/ton melt	0	160– 220.
Coal,lb/ton melt	700—1000	180–220.
Electricity,kw/ton melt	0	480.
Flux, lb./ton melt	0	60– 80

Properties of Malleable Iron:

- It possess good wear resistance, vibration damping capacity.
- High yield strength.
- High young's modulus and low coefficient of thermal expansion.
- It possess malleability in process.
- It possess ductility or toughness in service.
- It possess magnetic properties.

Uses of Malleable Iron:--

- Automotive industry.
- Rail road.
- Agricultural implements.
- Electrical line hardware.
- Conveyor chain links.
- Gear cases.
- Universal joint yoke.
- Rear axle banjo housing.
- Truck tandem axle assembly parts.
- Automotive crankshaft.
- Crankshaft sprocket.

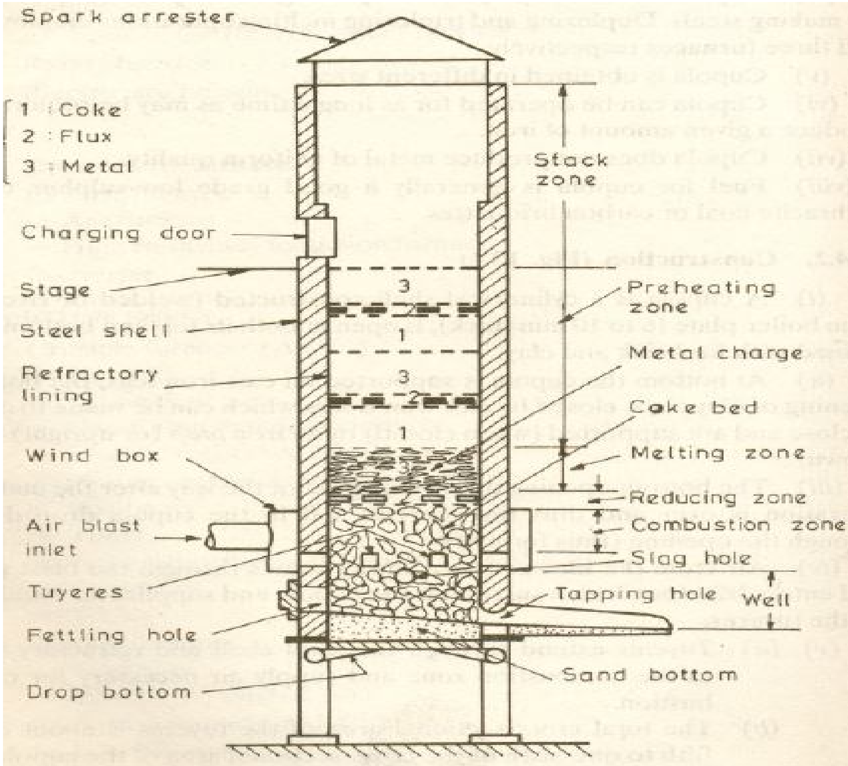
Chemical composition:

- Carbon :--------- 2.16- 2.90 %
- Silicon :-------- 0.90--- 1.90 %
- Manganese :------- 0.15—1.25 %
- Sulphur :-------- 0 .02---0.20 %
- Phosphorus :-------- 0.02-- 0.15 %

Melting practice of white cast iron: **Cupola furnace:**

1) Batch cold melting.

- It is done in coreless or channel-type induction furnaces, electric arc furnace, and cupola furnace.
- Careful selection of charge material is required for melting in cupola.
- Most of process control is done in the primary melting furnace.
- Molds are produced in green sand, silicate bonded or shell molds.
- Metal to be produced having desired composition and properties.



2) Duplex melting:--

- The iron is melted in a cupola or electric arc furnace.
- Molten metal is transferred to a coreless or channel type induction furnace.
- Holding the molten metal.
- Final corrections in composition and pouring temperature are made in the duplex melting.
- Pouring of cast iron in molds is similar to gray iron.

Casting defects:

1) Shrinkage casting

- Solidification shrinkage of white cast iron is about 3 to 6%.
- Primary austenite dendrite formed as temperature fall below 1343^0 c.
- Interlocking of dendrites causes difficulty to feed the liquid metal to the mold.
- Unfed shrinkages shows cavities.
- Shrinkage cavity can be removed by using chills.
- Chills are employed to provide sharp temperature gradient
- They cause rapid solidification by taking out the heat from the metal.
- Directional solidification also eliminates shrinkage cavities.
- Using proper size and shape of riser is also remedy of shrinkage cavity

Malleablisation heat treatment of white cast iron:

- The white iron structure consists of large pearlite areas and massive carbides.
- The Malleablisation converts massive carbide into temper carbon modules $Fe_3C = 3Fe + C$.
- The treatment consists of three stages.
  - Nucleation
  - First stage Graphitization
  - Second stage Graphitization

- The objectives of nucleation is to heat slowly through transition temperature.
- First stage graphitization occur during prolonged holding at the higher temperature. Its objective is elimination of carbide by a process of dissolution and precipitation.
- Second stage graphitization occur during very slow cooling through transition temperature. Its objective is to produce a fully ferrite structure.

Nucleation rate of malleable iron:

- Rapid heating decrease the number of nuclei developed.
- Thin section casting developers more nuclei.
- High % Si proper balance of Mn, and Sulphur favors nucleation.
- Pretreatment at 316^{o}c-649^{0}c for a period of 20hrs increases nucleation subsequent to Malleablisation.
- Slag high in FeO (over 25%) drastically decrease nucleation during Malleablisation.
- Addition of .01 to .003% boron or few %Al or Ti to the molten iron increases nucleation.
- Graphite stabilizing elements promotes nucleation during Malleablisation.
- Oxidizing atmosphere melting decrease nucleation.
- Excess addition of B, and Te decrease nucleation.
- Prequenching of casting increase the nucleation during Malleablisation.
- Heat the white iron castings slowly at lower critical temperature.
- Pearlite changes to grains of austenite.
- On further heating to 900^{0} c, austenite dissolves secondary cementite.
- Microstructure consist of saturated austenite, some secondary cementite, eutectic ferrous cementite.
- At 900^{0} c saturated austenite of the metastable system (Fe—Fe_3c) dissolved in it more carbon than stable system (Fe—G).
- Carbon is precipitated out of austenite as free (temper) graphite.
- The process of solution and precipitation of carbon is known as first stage of graphitization.
- The carbide dissolved in the austenite and diffuses to the nuclei and precipitates as graphite.
- Nucleation of graphite occurs at austenite- cementite interface and sulphide inclusions.
- Due to graphite precipitation carbon depleted from austenite and also same amount of carbon diffuse from cementite.
- Carbon diffuses through austenite to deposit on the original graphite nuclei.
- Growth of temper carbon nodules occurs at the expense of the carbide.
- Graphite nuclei grow at approximately equal rates in all directions.
- It appears as irregular nodules or temper carbon.
- The structure of temper carbon nodules distributed in matrix of saturated austenite.
- The growth occurs till the carbide disappeared from austenite.
- Inoculants in iron increases nucleation and graphitization.
- Increase of temperature increases number of nuclei as well as rate of decomposition of cementite.
- High temperature results in excessive distortion of casting.
- The time required for FSG is function of number of nuclei, solution of carbide, diffusion rate of carbon it is also related to silicon content and temperature.

Nodules counts:

- The number of nodules developed during heat treatment.

- Count the number of noodles under microscope, with magnification X100.
- Number of nodules per square millimeter by dividing it by area observed particular microscope.
- An average value obtain by counts 5 to 10 areas is used.
- The total number of nodules few to $150/sq^2$ mm.
- This is converted by nodules per mm^3 using the graph.
- From this method 2000 to 4200 nodules per mm^3 may be found in annealed iron.

Production of white heart malleable iron:

- It is common method used for thin section castings.
- White iron castings and oxidizing material are packed in boxes.
- The oxidizing material used is hematite ore.
- The packed boxes are heated to 900^0 c-950^0 c.
- Holding the boxes at this temperature for 3– 4 days.
- The castings are cooled very slowly through the transition temperature.
- Carbon oxidized due to oxidizing material.
- The microstructure of casting consists of entirely ferrite.
- It is referred as wieldable iron.

Production of black heart malleable iron:

- White cast iron and neutral material are packed in boxes.
- The neutral material are sand or cinder or mill scale.
- The packed boxes are heated to about 850^{0c} -900^{0C}
- Castings are hold for 50 hrs. at this temperature.
- Cool the castings from above the temperature.
- Only graphitization occurs and little oxidation of carbon takes place.
- Uniform structure of temper carbon nodules in pearlite matrix occur.
- Uniform structure possible with proper balance of Si, C, S and slow cooling.
- Pearlite matrix is obtained by more rapid cooling through the transition
- It is also occur by adding of 1% Mn.
- Second stage of graphitization is prevented completely.

Properties of ferrite malleable iron:

- Ferrite malleable iron properties:-
- Higher ductility than grey iron.
- Good machinability.

Uses of ferrite malleable iron:

- Pipe fittings ,expansion joint
- Railing castings, chain hoist assemblies.
- Breaking blocks, valves, farm equipment's.
- Chains .automobile parts, in general hardware's.
- Reducing gear housings, rear axles housings.
- Hubs, hooks, shackles, leads, yokes.

- Nuts ,mufflers, flanges ,couplings

Properties of pearlitic malleable iron:

- High strength.
- High hardness.

Ferrite malleable iron	**Pearlitic malleable iron**
Temper carbon in ferrite matrix	Temper carbon in pearlite matrix
Obtain by very slow cooling through transition of temp.	Obtained by faster cooling through transition temp.
Heat the castings in oxidize atmosphere	Heat the castings in neutral condition
Iron ore used as oxidizing media	Sand or cinder or mill scale used
More tensile strength	Lesser tensile strength ferrite malleable iron
More elongation	Lesser elongation than ferrite malleable iron
Lesser hardness	Higher hardness

- Comparatively poor ability

Uses of pearlitic malleable iron:

- Camshafts, crank shafts, axles.
- Differential housing in automobile industry.
- Rolls, pumps, nozzles, gears, links, sockets.
- Elevator brackets in conveyer equipment's.

Raw material for Al melting:

- Clean foundry scrap(remelt)
- Prealloyed Al pigs
- Low melting point alloying elements such as zinc and Mg.
- Higher melting point metals such as Cu, Ni, Mn, Si, Ti, and Cr as hardeners.

Comparison of ferrite and pearlitic malleable iron:

Properties of Al:

- Light weight, one third that of steel.
- Good malleability and ductility.
- Good electrical conductivity.
- High thermal conductivity.
- Resistance to atmospheric corrosion.
- Non- toxicity.
- Affinity for oxygen.

- Higher coefficient of expansion as compared to steel.
- Tensile strength as high as those of structural steel.
- It possess minimum solidification shrinkage.
- Adequate fluidity in the molten condition.
- It should not possess a tendency to hot tear or crack.
- The alloy should face minimum problem regarding Drossing and gas absorption.
- It should be possible to produce pressure-tight castings.

Uses of Al:

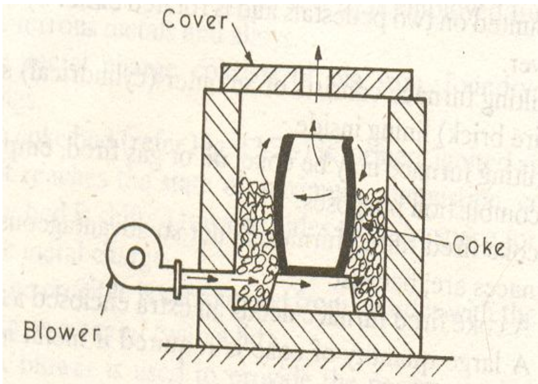
- Used as architectural and decorative parts.
- Cooking utensils and food handling equipment's.
- Building construction.
- Used as rotor bars in induction motors.

Limitations of Al:

- Lack of resistance to abrasion and wear.
- Absence of tensile strength, toughness, and hardness compare to ferrous alloys.
- Lack of resistance to severe corrosion.

Molding methods in Al foundry:

The most commonly used molding processes are.1.Sand molding.2.Permanent mold casting.3.Die casting.



Sanding casting methods. Sand casting is the most versatile process. Almost all sizes and shapes of casting can be produced.

- Large casting are produced in sand molds.
- Section thickness up to 150mm can be cast by sand molding process.
- Castings of any size in small quantities can be produced
- It associates with low cost.
- Sand casting produces rougher casting surfaces.
- Dimensional variations is high.
- Molding sands, molding procedure, pattern practice same as other metals and alloys.
- Core practice and equipment for core and mold making Al alloys are almost same as for sand casting of other metals.

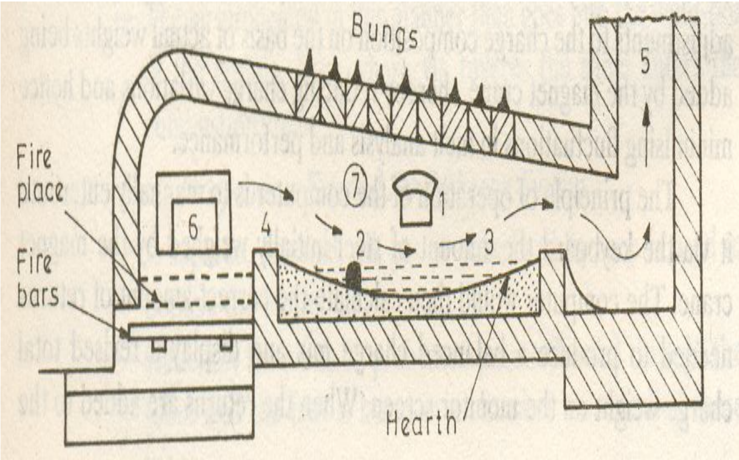
Melting furnaces:

Crucible furnace:-

- The metal charge is placed and melted in a crucible.
- It is made up of silicon carbide, graphite or refractory material.
- It can withstand high temperature.

- They are available in different sizes ranging from 1to 400 tons.
- Each number indicates the amount of metal which can be handled conveniently.

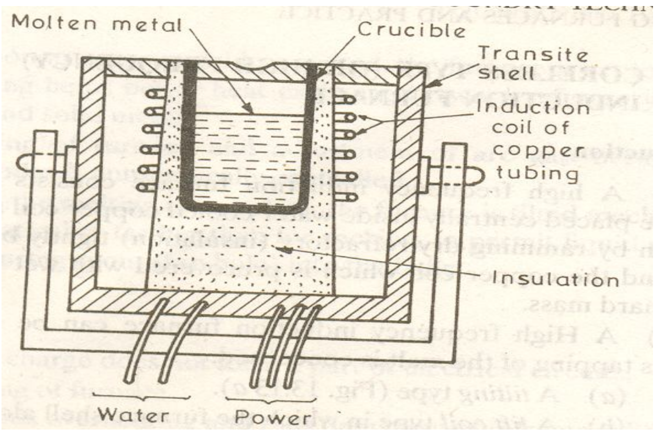
Pot furnace:-



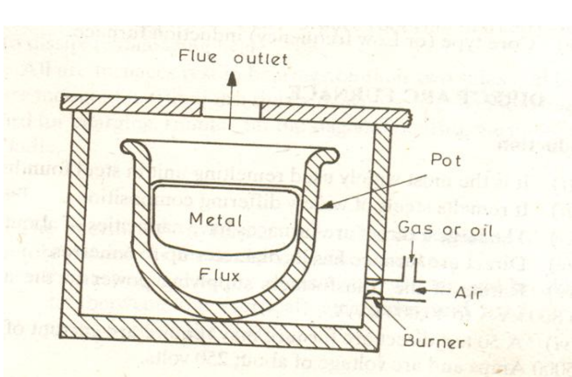
- It is usually an indirect flame furnace.
- It consist of a cast or steel pot in which metal charge is placed.
- The pot is heated by gas, oil or electricity.
- It is used for melting low melting point alloys such as Al, Mg Zn.
- As the metal is melted, it is ladled from the pot for distribution to the mold.
- It is used with permanent mold and die casting machines for producing small castings.
- Its capacity is few kgs.
- Tilting furnace capacity is up to 1500 kg of melt.

Reverberatory furnace:-

- It is a long, rectangular structure.
- It is having removable arched roof section (bungs) over a shallow hearth.



- It is made up of refractory sand dampened with clay wash.
- Metal is charged through the bungs.
- Oil, or pulverized bituminous lump coal used as fuel for heating and melting the metal.
- Air and fuel are blown through one end of the furnace.
- Flame passes over the metal charge lying in the hearth of the furnace.
- The flame and hot gases heat up the furnace roof and wall.



- The heat reflected and radiated from roof and wall is utilized for melting and super heating the metal charge.
- The entire charge material is put into the furnace at a time.
- The charge is melted in batches and drawn out when the correct composition and temperature are obtained.

High frequency induction furnace

- It consists of a refractory crucible placed centrally inside.
- Water cooled copper coil enclosing the crucible.

- A high frequency current is passed through coil.
- The coil act as the primary of a transformer.
- The metal charge act as the secondary.
- Heat is induced in the charge by electromagnetic induction due to high alternating current.
- This heat developed in the skin of metal charge by conduction and melt the charge.
- Melting time of charge is short.

Low frequency induction furnace

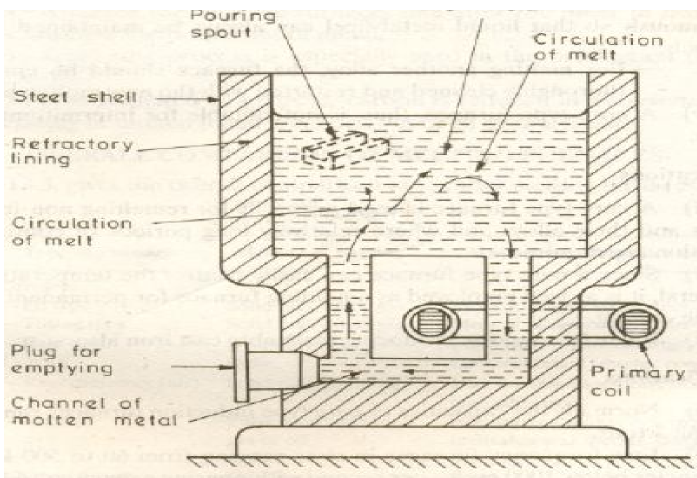
- The steel core is enclosed by a coil
- The steel core act as primary winding.
- A channel or proof of liquid metal act as secondary winding.
- The heat generated due to the electric resistance of the metal.

Drossing:

- Drossing is the formation of aluminum oxide and other oxides.
- Removal of dross from the melt is very difficult due to same specific gravity.
- Some oxides float on the surface.
- Other oxides sink and form a sludge at the bottom of the furnace.
- Minimum dross formation occurred by fast melting.
- Melt is protected from products of combustion.
- Dross can be removed by subsequent fluxing and flushing.

Gas absorption:

- Gases are absorbed in molten, metal from various sources
- Furnace charge (wet metal charge, fluxes).
- Furnace refractories if they are not properly preheated.
- Furnace atmosphere(water vapour,co,co_2,so_2 O_2,N_2)
- Al and its alloys absorb or dissolved harmful quantities of hydrogen gas.
- More gas is absorbed at temperature above the melting point of metal.
- Solubility of gases increases with increasing temperature
- Gas increase with increasing partial pressure of gas in metal.
- Gas evolution results gas or pin holes and microscopic gas porosity.
- Water vapor is particularly harmful in causing gassing of Al and its alloys. $2Al+3H_2O = Al_2O_3 +6H$ (dissolved in Al).



Objectives of Fluxing and flushing:

- To remove dissolved hydrogen from the melt.
- To separate dross from molten metal.

- Gaseous fluxes are used to flush or purge the melt i.e. removal of dissolved hydrogen from the metal.
- The gaseous fluxes are N_2, He, Ar, Cl_2.
- The solid fluxes are Al, and Zinc chlorides are used for easy separation of dross from the melt.
- Fluxing is addition of solid, liquid or gaseous material to molten metal.
- It facilitate to produce sound casting.
- Fluxes may be classified as
- 1) Covering fluxes.
- 2) Cleaning fluxes.
- 3) Drossing fluxes.
- 4) Degassing fluxes.
- 5) Grain refining fluxes.

Grain refining:

- Grain size in cast Al, its alloys can be refined by.
- 1) Chilling.
- 2) Temperature adjustment (pouring lowest possible Pouring temperature).
- 3) Later additions by using boron, Ti, Cr, Columbium and sodium to the melt.
- The addition of .2%Ti or .02% boron to Al alloy to reduce it size from 2.5mm to 125mm in diameter.
- The addition of Fe, nickel (small percentage) to Al bronze to prevent formation of coarse crystalline structure.
- Mg-Al alloys are grain refined by small addition of carbon to the molten metal.
- Al-Si alloys with addition of sodium salt fine dispersion of Si and high physical properties.

Pouring temperature:

- Melt is properly prepared and the temperature is measured by immersion thermocouple.
- The pouring temperature depends upon the casting size and alloy composition.
- The pouring temperature around 677^0 cto760^0 c.
- High pouring temperature create turbulence and form dross.

Gating ratio:

Gating ratio is the ratio of Sprue area: runner area: in gates area =S_A: R_A: G_A

Unpressurised system the ratio are

1. 1:2:2.
2. 1:4:4.
3. 1:6:6

Pressurized system the ratios are

1. 1:2:1

It is not suitable because it encourage turbulence at the in gates.

Gating system:

It refers to all passageways through which the molten metal passes to enter the mold cavity.The gating system composed of

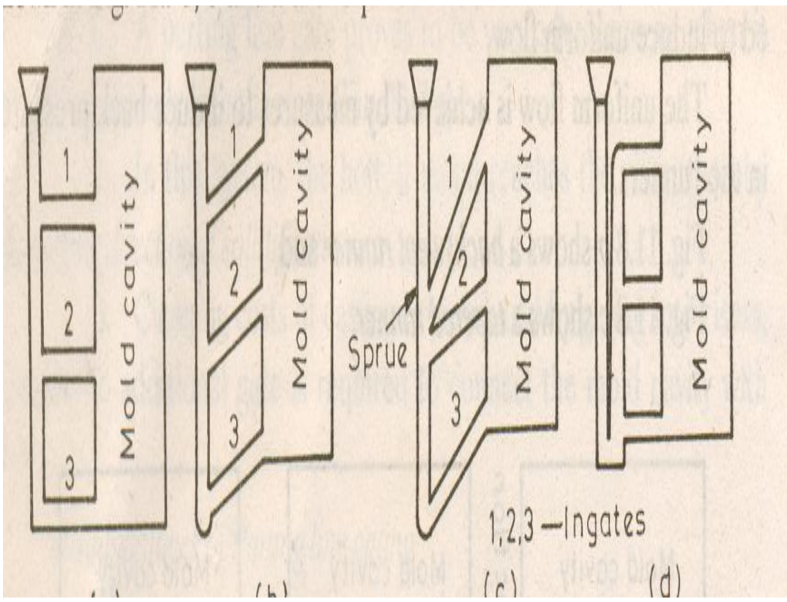
2. Pouring cup and basin
3. Sprue.
4. Runner.
5. Gates.
6. Risers.

Purpose of gating system:

- Fill the mold cavity completely before freezing.
- Introduce the liquid metal into the mold cavity with low velocity and little turbulence to avoid mold erosion.
- To avoid mold erosion, metal oxidation, gas absorption.
- Regulate the rate at which liquid metal enters into the mold.

Importance of multiple ingates:

- In single gate it is not suitable for effective feeding for large casting.
- Hot spot and shrinkage problem is solved by employing multiple gate system having a number of separate ingates.
- A multiple gate system can feed metal at widely separated point in a casting.



Pressurized gating system:

- Gating ratio may be of the order of 1:2:1.
- Back pressure is maintained on the gating system by a fluid flow restriction at the gates.
- Back pressure keeps Sprue full of metal.
- It reduce metal pulling from mold wall and minimizes air aspiration.

- Volume flow of liquid from every ingates is almost equal.
- They are smaller in volume for a given flow rate of metal.
- The casting yield is higher.
- High metal velocities also cause turbulence, mold erosion, dross formation and air aspiration.

Solution treatment of Al alloys:

- Heating an alloy to suitable temperature (below melting point).
- Holding the casting at that temperature long enough.
- One or more constituents to enter into solid solution.
- Cooling rapidly enough to hold the constituents in the solution.
- Solution homogenization treatment is used to eliminate the concentration.
- This treatment improve corrosion resistance of casting.
- Improve ductility especially in ingots required to be worked latter on.
- Makes an alloy amenable to subsequent hardening.

Precipitation treatment (Ageing):

- It produces a change in the properties of metal or alloys.
- The change of properties at a slow rate at room temperature.
- The properties changes in rapidly at high temperature.

Age hardening:-

- It is hardening by ageing usually after rapid cooling or cold working.

Precipitation treatment:-

- It is artificial ageing in which a constituent precipitates.
- The precipitation from a supersaturated solid solution.
- It is a low temperature, time dependent process.

Properties copper alloys:

- Good appearance.
- High thermal conductivity.
- High electrical conductivity.
- Excellent resistance to corrosion.
- Good bearing qualities.
- Easy to work.
- It is ductile and malleable.
- Moderate to high hardness and strength.
- It is easily polished, brazed, or welded..
- Nonmagnetic properties
- Very good machinability.
- Easy of forming alloys with other elements.
- Non-toxicity.
- Act as deoxidizer.

- Resistance to fatigue and abrasion.

Uses copper alloys:

- Electrodes of resistance welding machinery.
- Turbine runners.
- Water-meter housings.
- Bearings.
- Gears and corrosion resistance pumps.
- Marine equipment's.
- Plumbing goods.
- Valves and fittings.
- Steam pipe fittings.
- Hydraulic valves and gears.
- Die cast parts.

Types of copper alloys:

- Tin bronze:- 8 to10% Sn,2 to4%Zn, remain Cu.
- Lead bronze:--6 to 8.5%Sn, 0.5 to 5%Pb, 4% Zn remain Cu.
- High leaded tin bronze: - 5 to10%Sn, 7 to 15%Pb, 1to3%Zn.
- Al bronze:--1 to 4%Fe, 9 to 11%Al, sometimes 4%Ni, remain Cu.
- Leaded nickel bronze:4 to 5% Sn, 1.5 to 4% Pb, 2 to8%Zn,20 to 25%Ni, remain Cu.
- Leaded red brass: - 4 to 5%Sn, 5 to 6%Pb,5 to 7%Zn, remain Cu.
- Leaded yellow brass: - 1%Sn, 1to 3%Pb, 24 to 36%Zn 0.3 %Al, remain Cu.
- Silicon brass: - 1.4%Zn, 3.5 to 4%Si, 0.5%Pb, remain Cu.
- Gun metal: - 5 to 10%Sn, 2 to 5%Zn, remain Cu.

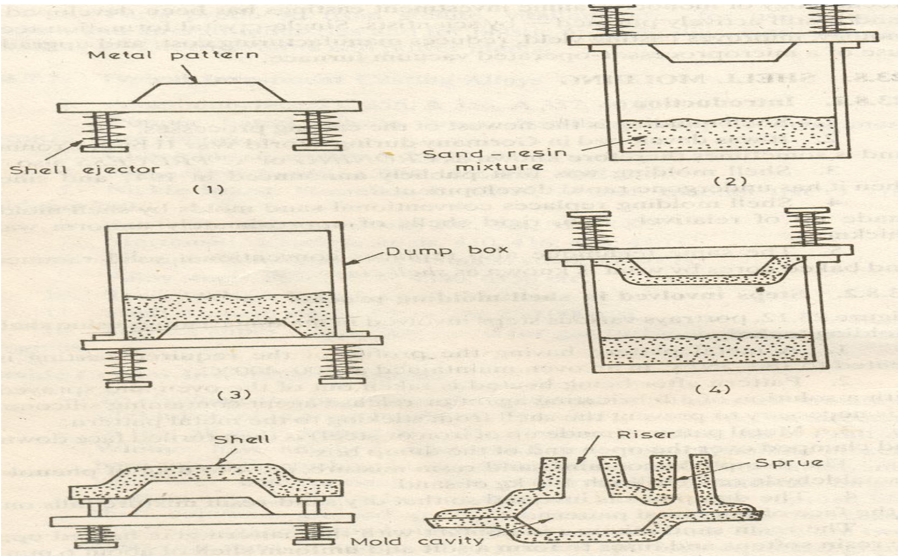
Raw materials copper alloys:

- Foundry scrap (re melt).
- Pig or ingot of the desired analysis.
- Alloying additions such as,
- Zinc
- Tin
- Lead
- Nickel
- Aluminum.

Shell molding method:

- Silica sand is used for making shell mold and core.
- Material % of material.
- Silica sand of 108 ASF fines 60%.
- Silica sand of 137 AFS fines 30%.
- Resign that of soften at 99 to 107^{0}c 6%.
- Treated Bentonite 2.5%.
- Calcium stearate 1.7%

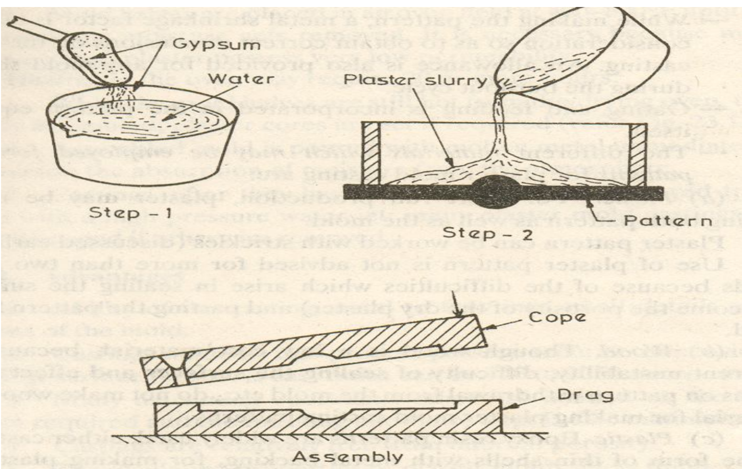
- A metal pattern heated to 180 ^{0}c to 250^{0}c in an oven at 300to 400^{0}c.
- Remove the heated pattern from oven.
- Sprayed with a solution of a lubricating agent or released agent containing silicon
- The pattern is then turned face down and dumped over the open end of the dump box.



- The dump box contain sand resign mixture.
- The dump box is inverted to falls the dry sand on the face of hot pattern.
- The sand is heated up and fuse to form a soft and uniform shell about 6mm.
- The dump box is turned to its original position
- The excess sand and mix, fall back into the dump box.
- The shell is stripped from pattern with help of ejector pins.
- Two matching shells are securely fastened together to form a complete mold.
- The shell is ready for pouring.

Plaster molding method:

- 100 parts gypsum plus 60 parts water mixed to creamy consistency with mixing the plaster.
- Slurry is poured over the pattern on which parting agent has already applied.



Drossing:

- Copper alloys containing readily oxidizable elements such Zn, Sn, Al, Mg, Mn.
- The oxides separate more or less completely from the melt and form dross.
- The oxides has a low specific gravity.
- Due to low specific gravity it may float on the melt surface.
- The float of oxides difficult due to surface tension and other factors.
- The dross contain considerable metal causing high melting losses.
- Remedies for minimize dross:
- A cover of fluxes or charcoal covers are employed to minimize dross.
- A cover of bottle glass thin with borax
- A minimum of agitation.
- Melting under favorable combustion condition.

Oxygen in copper melting:

- Cu is an element which is readily oxidized in the molten condition.
- The solubility of O_2 in molten Cu increases rapidly with temperature above its melting point.
- In the solid state copper can dissolve up to about 0.0035% of O_2
- Melting of copper in the presence of free O_2 or an oxidizing gas such as CO_2, favors oxidation.
- O_2 dissolves in pure copper up to 0.04 to 0.05%.
- The deoxidizers in Cu alloys reduces the oxygen in melt.

Hydrogen in Cu melting:

- It is increases markedly with temperature in Cu alloys.
- The solubility of hydrogen increase above the melting point of copper.
- Solubility of hydrogen is lower in Cu-Sn alloy than in pure copper.
- H_2 pick up by from the
- Furnace atmosphere
- Oils
- Moisture on the furnace charge.
- Hydrogen causes gas holes, and micro porosity.
- The gas will readily diffuse to cavities precipitate as dispersed shrinkage.
- The dispersed shrinkage appear as swell on the riser top.

Reaction of impurities:

- Both the gases oxygen and hydrogen have a regularly effect on each other's solubility
- The reaction of O_2 and H_2 to form steam or water vapour.
- $H_2+O_2 = 2H_2O$.
- If the O_2 solubility of the metal is high, it prevents the solubility of H_2 in the metal
- The high O_2 is produced by melting under an oxidizing
- Most foundry men prefer melting of copper under an oxidizing atmosphere.
- Or adding solid CuO to the melt.
- The hydrogen content of the metal is low by the water vapour reaction.
- Reducing atmosphere, containing a high CO%, promote porosity and poor properties.
- To remove the H_2 from melt by purging and flushing with N_2 gas as in Al alloys.

- Zn flaring is another mean of reducing H_2 of
- Yellow brass, Mn bronze and high Zn, Cu base alloys.
- Flaring is due to the vapour pressure –temperature relationships of zinc in these alloys.
- Zinc vapour distills from the brass more readily as
- Temperature increases to the point where
- The vapour pressure equals barometric pressure.
- The zinc vapour reacting with O2 forms a brilliant white flame or flare.
- It is occur when the temperature is raised to the point
- Where boiling is incipient or occurs.
- The loss of Zn about 1 to 1.5lb zinc per 100lb melt.
- H_2 porosity may occur due to dirty charges
- Melting in reducing atmosphere
- Improper flaring used to flush out hydrogen.
- C (dissolved) + O (dissolved) CO (gas) - 1.
- S(dissolved)+2O(dissolved) SO_2(gas)- 2
- The reaction causes gas holes defect.
- The above reaction occurs more readily as
- Temperature drops, when a casting freezes.
- Solubility of carbon in copper is very low (0.004%).
- The reactions of C, S, removed by using de-oxidizer.
- Considerable S present in copper alloys as impurities.
- The limit is 0.005 to 0.08% Sulphur.

Defects of due to impurities:

- Lead sweat is a defect which may be caused by Si and Al in lead alloys.
- It is an exudation of lead from the casting during the last stage of solidification.
- The above impurities form lead silicate as white scum on the casting.
- It is a wormy or wrinkly surface.
- Phosphorus acts as de-oxidizer and also promotes fluidity.
- Excessive fluidity of P Wet the molding sand and gives a rougher surface.
- The iron amount over 0.15 to 0.25 form the hard spots in the melt.
- It is also used as grain refining, hardening, and strengthening in Mn and Al bronzes. (Below the above).

De-oxidizers:

- Element which combine more effectively with O_2 than Cu is used as de oxidizer.
- The deoxidizers are P, Lithium, boron, Ca, Mg, Al, Si, and beryllium.
- Most commonly employed elements are P, Cu.
- 0.02% P as residual is fully reduce the O_2 to a low value.

Control of gases:

- Hydrogen is controlled by an oxidizing stage during melting and heating.
- Oxygen is controlled by practice de-oxidation.
- Flushing and flaring employed to control hydrogen.
- Hydrogen removal can be carried out by just before pouring by adding copper oxide ladle

- The de-oxidation practice of adding phosphor copper.

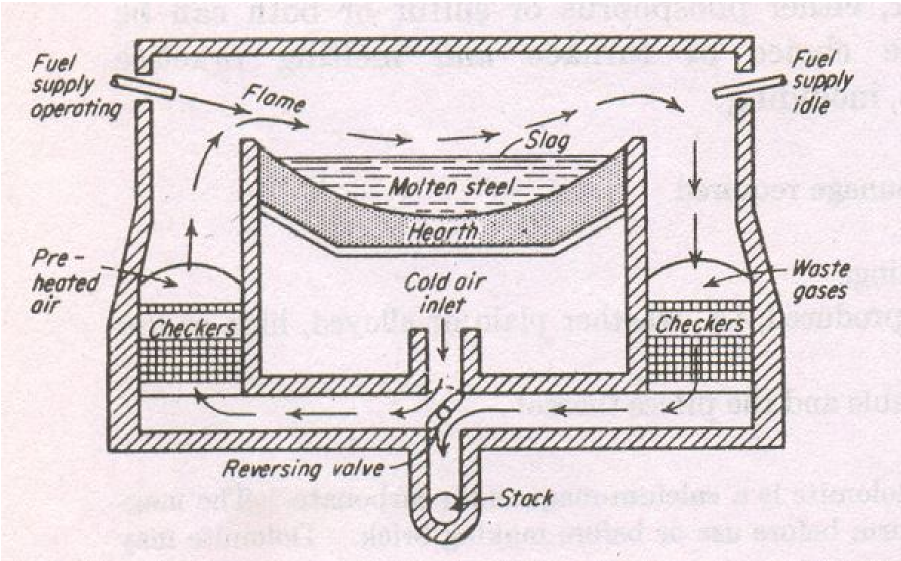
Temperature control:

- High temperatures encourage the aspiration of gases into the melt (prolonged heating).
- Pouring the melt below 50 to 100^0 c of melt temperature.
- Pouring too cold may results in misruns.
- Shrinkage and as porosity are also developed.
- High pouring temperature may causes
- Damaged metal due to gasses during melting.
- Increased possibility of reaction between mold sand and metal.
- Excessive dross in the gating system.
- Development of porosity because of increased feeding requirement.

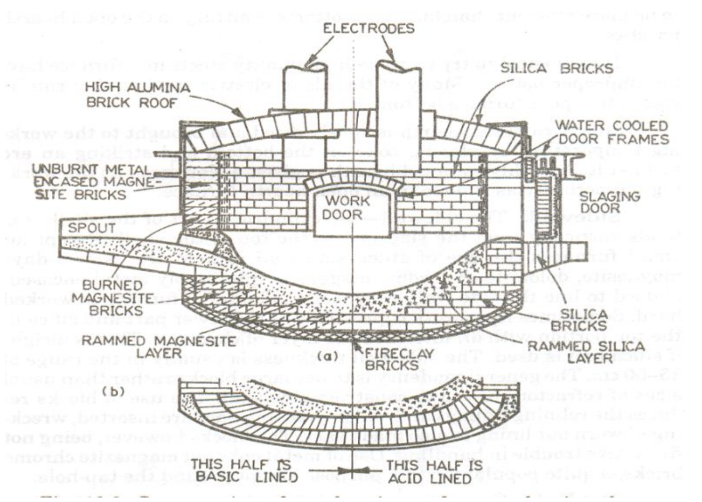
Raw materials for steel castings:

- Basic open hearth :
- Pig iron(c- 3.5 to 4.4%, Mn– 1.5 to2%, Si– 1.25% max,S-0.06%, p- 0.35% max).
- Purchased scrap, foundry scrap return, lime and ore.
- Gas or oil.
- Additions– Mn ore.
- Acid open hearth:-
- Foundry scarp (low S, P between0.04%) Si- 0.6 to 1% Mn-0.4 to 1.75%.
- Purchased scrap.
- Fuels --- gas/ oil.
- Acid electric arc furnace:-
- Foundry scrap, purchased scrap (low p, s).
- Basic electric arc furnace:---
- Alloy scrap.
- Lime.
- Iron ore.
- Fluorspar.
- Induction furnace:---
- Steel scrap
- Alloy steel scrap
- Ferro – alloys etc.

Open hearth furnace:



Electric arc furnace:



Induction furnace

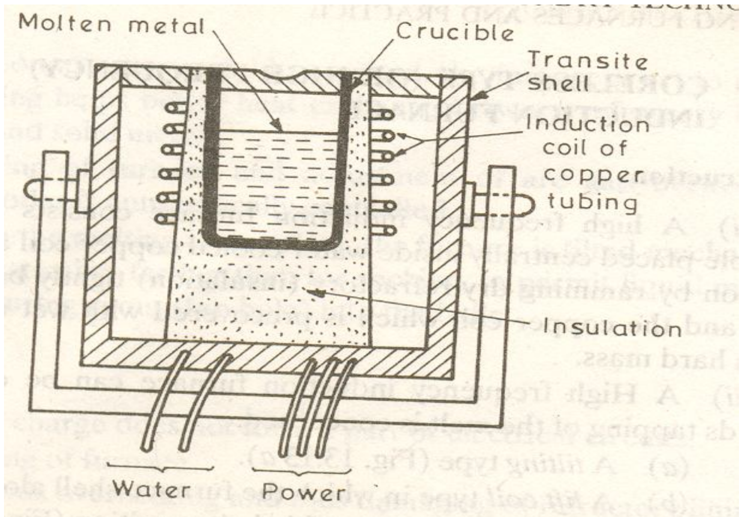
Molding methods:

Steel castings can be made by using:-

1. Green sand molding.
2. Dry sand molding.
3. Skin – dried molding.
4. Core (sand) molding.
5. Shell molding.
6. Investment molding.
7. Ceramic molding.

Green sand molding:

- Sand mixture:-
- Silica sand, AFS fineness 40 to 60 content 96.4%.
- Bentonite 1.5%.
- Cornstarch (dextrin) 0.7%.
- Soda ash 0.04%.
- Moisture 3.5 to 4%.
- Mold coating: - Zircon flour 200 mesh or finer.
- More steel castings are produced in green sand molding.
- Only synthetic sands are used in mold mixture for steel.
- Facing sand and backing sands (reused facing sand)
- Are compounded to produce desired properties.



- More venting is needed for escape of gas
- Mold coating by spraying or brushing of Bentonite.
- The mold surface is dried with a gas torch or hot air.

Dry sand and skin- dried sand molding:

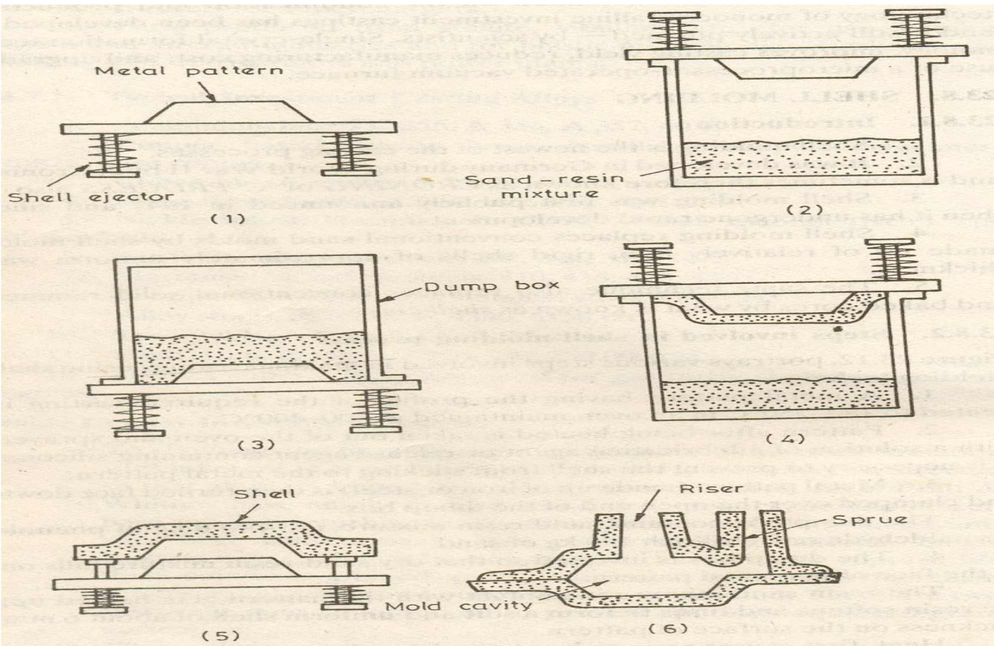
- This type of molds superior to green sand molds.
- They are stronger and withstand handling.
- They ensure closer dimensional tolerances and avoid pinhole porosity.
- Large steel castings weighing up to several tons are commonly produced in dry sand molds.
- Sand preparation for dry sand molding are similar to those for green sand molding except that:
- Moisture content is somewhat higher to get greater mold ability and greater dry strength.
- Addition of silica flour to increase the rammed density of the mold.
- A thermosetting resin is also added in the mix.
- Molds are coated with a mold wash.
- The molds are dried for 10 to 40 hrs. at 316^0c to 371^0c .

Core (sand) molding:

- Core molds are made of:
    1. Air- setting resin- bonded sand.
    2. Conventional oil- bonded core sands(required baking)
    3. Sodium- silicate bonded sands (harden by co_2 gas)
- Individually made cores are assembled to form molds.
- This method is used for medium and large steel castings.

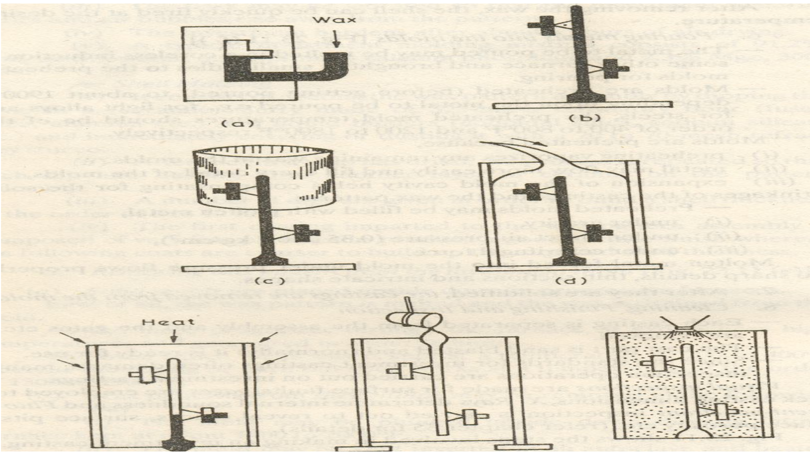
Shell moulding:

- Carbon, low alloy steel casting are produced by this method.
- Casting thickness from 6 to 50 mm and weighing up to 150kg.
- The molding mixtures are :
- Silica sand 63 parts (AFS 140).
- Zircon sand 30 parts.
- Resin 6%.
- Silica flour 2%.



Investment molding:

- Steel castings weighing up to 4.5kg have been produced
- It producing casting having close tolerance of intricate designs.
- High temperature service alloys and shapes (turbine blades) are produced.



Ceramic molding:

- It produced intricate shaped castings.
- It produced good dimensional accuracy and smooth surfaces of castings.
- This methods to make casting that are larger than those made by investment molding.
- It is a cope and drag process.

Importance of zircon sand:

- These sands are ideal for achieving special characteristics.
- Zircon sand in chemically called as zircon is zirconium silicate ($ZrSiO_4$).
- The special characteristics are as follows.

- Low thermal expansion.
- Chemical inertness to the action of molten metal.
- High heat conductivity.
- Greater density.
- High sintering temperature.
- High refractoriness.
- Greater density than that of silica sand, which prevents metal penetration.
- High sintering temperature.
- High refractoriness, which hinders sand burns.
- Low thermal expansion.
- Being only 1/6th that of silica sand.
- Which strengthens mould against thermal and mechanical stresses.
- Helps in producing accurate castings.
- Free from scabbing defects.
- Chemical inertness to the action of molten metals.
- This enhance the finish of castings.
- Protecting the castings from sand burns.
- Useful for high alloys steels such as chrome steels and manganese steels.
- High heat conductivity.
- About double that of silica sand.
- Promotes quick formation of a solidified metal layer.
- Helps in producing casting with a fine grained structure.
- Zircon sand is required in greater volume than silica.
- Mixing times are longer.
- Good venting is necessary.
- The unit cost of this sand is very high.
- Find use only as facing sand.

Effects of fluidity in gate design:

- Fluidity of molten cast steel depends upon pouring temperature, and steel composition.
- Particularly the silicon content has a more noticeable influence on fluidity.
- Chromium steels possess a very poor fluidity.
- In order to retain fluidity, ladling, pouring and handling of molten steel should be done with a minimum of temperature drop.
- Proper gating design helps in compensating relatively low fluidity steel.
- The following types of ladles are used for pouring steel castings.

    1. The bottom pour ladle.
    2. The tea pot ladle.
    3. The lip pour ladle.

- The gating system for pouring should help, fill the mold quickly.
- Molten metal heat the mold by radiation when it rises in mold cavity.
- This heat can destroy the binders in the molding sand.
- The heated mold collapse, unless the metal rises rapidly
- Design of the gating system will largely determine
- The manner in which molten steel is fed into the mold as well as the rate of feeding.
- A gating system having several gates will influence the distribution of the flow between gates.

- A good design of gating will ensure even distribution of
- Metal between gates, both initially and while the mold is filling.
- Various gating system used in steel foundries includes
- Finger ingates: - it fed the metal to casting above the parting line.

Solidification in gate design:

- Temperature level of solidification.
- Temperature range for solidification.
- Thermal conductivity of the mold.
- Thermal conductivity of steel.
- Gravity and convection effects.
- Solidification time.
- Shape factor.
- Temperature level of solidification.
- Because of its high solidification temperature,
- A large temperature difference between the casting and the mold wall.
- The steep thermal gradient that favour progressive solidification.
- Temperature range of solidification.
- It is primarily influenced by the carbon content
- Secondarily by other alloying elements in low alloy steel.
- In high- alloy steel, the effects of elements other than carbon may predominate.
- The solidification range increases with the carbon content.
- Solidification time:---
- The modification of chorine' s rule relating freezing time to surface area and volume of the casting.
- $V = qA. \sqrt{t}$
- q = solidification constant
- q = 2.09 for steel

Shrinkage in gate design:

- The proper understanding of the solidification.
- Mechanism is essential for preventing defects due to shrinkage of the metal.
- During solidification, cast form develops cohesion and acquires structural characteristics.
- As soon as the metal is poured in a sand mold, the process of solidification starts.
- Besides structure, the soundness of a casting also depends upon the solidification mechanism.
- Soundness implies the degree of true metallic continuity
- A casting will be sound if volume shrinkage accompanying the change of state of metal to solid is
- Compensated by liquid metal with help of riser.
- Volume shrinkage occurs in three stages.
- Liquid contraction occurs when the metal in liquid state.
- Solidification contraction occur during the change from liquid to solid.
- Solid contraction occur in three stages.

    1. It is occurs when the metal is solid.
    2. It is occurs after solidification.

3. It does not influence shrinkage defects.

Purpose of a riser:

- A riser or a feeder head is a passage of metals made in the cope.
- The molten metal rises in the feeder head after the mold cavity is filled up.
- This metal in the feeder head compensates the shrinkage as the casting solidifies.
- It promote directional solidification.
- The primary function of the riser is to feed metal to the solidifying casting so that shrinkage cavities are get rid of.
- A riser permits the escape of air and mold gases as the mold cavity is being filled with the molten.

Effective feeding distance of a riser:

- In addition to its adequate size, a riser must be properly located to obtain a sound casting.
- It may be located at the top of the casting or at in the side of the casting.
- Top riser is extensively used for light metals.
- It enables the benefits of metallostatic pressure.
- Riser spacing should be carefully arranged to minimize shrinkage.
- The feeding range which is the distance of a riser can feed the metal in a casting
- Riser diameter and height have a limited effect on it.
- 4.5 x T is preferred for plate type castings.
- T is the thickness of casting.
- 2 – 2.5 T or 6 $\sqrt{T}$ for bar type castings.
- In case of an exothermic riser, the feeding distance can be 50 – 70 % more.
- Advisable to reduce the diameter of the riser at the neck by 30 – 40 %.
- It improves feeding range.
- Helps in easy knocking of the riser from the casting.
- Shrinkage occurs in parallel walled casting as in the following.
- When a long horizontal bar without riser is poured the maximum heat is extracted from the ends.
- The solidification proceeds from the ends towards the center.
- The casting is sound at the ends but develops some shrinkage in the center (end effects).
- A long bar is cast horizontally with one riser at the center.
- The casting will be sound under and near the riser.
- This sound casting cause riser know as riser effect.
- Beyond this riser effect, shrinkage may occur.
- The temperature distribution and center- line shrinkage
- In case of a long bar fed with an end riser.
- The center- line shrinkage in horizontal bar or plate
- Avoided by reducing its length to some extent.
- The center-line shrinkage eliminate by using end, riser effect.
- The both effects promote directional solidification in the casting.
- The directional solidification can be promoted by
- The relation between D, the feeding distance for the riser
- T, is the minimum bar or plate thickness.
- Chills have a powerful influence in extending the feeding

- Of risers.
- The distance between two risers can be more than doubled by placing a chill in between.

Hot tear:

- They are internal or external ragged discontinuities are cracks on the casting surface.
- Caused by hindered contraction occurring immediately after the metal has solidified.
- They may produce when.
- The casting is poorly designed.
- Abrupt sectional changes.
- No proper fillets and corner radii.
- Inappropriate placing of chills.

Causes of hot tear:

- Very hard ramming and thereby under severe strain during cooling.
- Poor collapsibility of core and mold.
- Improper placement of gates and risers.
- Incorrect pouring temperature.

Remedies of hot tear:

- By improving the casting design.
- Achieving directional solidification.
- Even rate of cooling all over.
- Selecting proper mold and core materials.
- Controlling the mold hardness.

Metal penetration:

- Molten metal enters the space between the sand grains.
- And results in an uneven and rough external surface.

Causes: -

- High permeability.
- Large grain sized sands.
- Low dry strength of sand.
- Soft ramming.

Different techniques to removal of gates and risers:

A few commonly used methods are given below

- Chipping hammers.
- Flogging (knocking off).
- Shearing.
- Sawing a) Band saw b) Hack saw c) Circular saw.

- Abrasive wheel slitting.
- Machining.
- Flame cutting.
- Plasma cutting.
- Chipping hammers:----
- It is an air driven chisel as the cutting tool.
- Geometry of the chisel tip and its inclination to the casting influence cutting efficiency of the chisel.
- The cutting operation can be improved by keeping the cutting tip of chisel wet with oil.

Stages of fettling:

- Knocking out of dry sand cores.
- Removal of gates and risers.
- Removal of fins and unwanted projections.
- Cleaning and smoothening the surface.
- Repairing casting to fill up blow holes and straightening the warped or deformed casting.
- Inspection.

Cleaning and smoothening castings:

- In as cast state fused sand particles adhering to their surface.
- A scale is also formed during heat treatment.
- The adhering sand particles and scale as to be removed.
- Cleaning of the surface can be done by :

1. Tumbling.
2. Blasting.

Tumbling:

- Castings to be cleaned put in a large shell or barrel.
- Closed at its ends by cast iron lids.
- Barrel is supported on horizontal trunions.
- Rotate at a speed of 25 – 50 rpm.
- Small piece of white iron called “stars” are also charged.
- These helps in cleaning and polishing operations.
- Rotation, causes the casting to tumble over and over again rubbing against each other.
- Thus by tumbling.
- Castings get clean and polished.
- Sharp edges and fins get eliminated.
- Internal stresses in the casting are relieved.
- Fragile nature castings not suitable for tumbling.

Blasting:

- Cleaning with compressed air impact (sand blasting).
- Cleaning with mechanical impact (shot blasting).

Difference between tumbling and blasting:

S.No.	Tumbling	Blasting
1	Sand, scale and some fine and wires may be removed.	Sand and scales may be removed.
2	The mill is filled with casting and some jack stars.	Abrasive media are sand, metal grit and metal shot.
3	The rotation of the casting and stars to cause tumble and abrade each other.	The media (air, metallic particle) force on to the casting.
4	The operation time around 25 to 60 minutes.	It is faster than tumbling.
5	Corners rounded by burning action on the casting surface.	Not rounded at the corners.

Trimming operations:

- Either after, before , or during the initial surface cleaning,
- The castings are trimmed to remove fins, gate.
- Riser pads protruding beyond the casting surface.
- Chaplets, wires, parting-line flash to the casting.
- Which are not a part of its final dimensions.

Chipping: -

- Pneumatic chipping hammers may be used to remove.
- 1) Fins 2) Gate and riser pads 3) wires 4) cores.
- A variety of hammer and chisel sizes are used for various casting alloys.
- Chipping operations may be speeded up by having.
- Chipping stations at conveyors used to transport casting in the cleaning room.
- Much chipping may be done most conveniently by hand with a hammer.
- Hand chipping is carried out on light- gray and white- iron castings.
- Pneumatic chipping is applied on to the heavier and more difficult to trim.

Grinding: -

- It is to remove excess metal from casting.
- Three types of grinders are employed for this purpose.
- These are 1) Floor or bench- stand grinders,
- 2) Portable grinders, 3) Swing- frame grinders.
- The specialized machines such as disk grinders, belts, and cutoffs may be used.

Finishing operations:

- Finishing of castings is latter stage in cleaning of the castings.
- The finishing of castings carried out after cleaning of castings (removal of gates riser etc.,) .
- The finishing is resorted in order.

- Remove any excess metal if left on the casting.
- Improve surface finish and appearance.
- The finishing operation are as follows.
- 1) Grinding 2) Rotary filing 3) Machining 4) polishing.
- 5) Chemical treatment 6) Brushing 7) Buffing.
- 8) Blasting blast cleaning 9) Painting.

Machining: -

- As per their requirement, castings may be given a
- Treatment on lathe, shaper, milling machine etc.
- Polishing: -Castings may be polished to obtain smooth surface finish.
- It can be carried out on abrasive belt machine using a fine grit (80 to 400 mesh).

Chemical treatment: -

- Both ferrous and non-ferrous castings may be given this Treatment to make their surfaces attractive.
- A molten salt bath of sodium hydroxide (95%), sodium Nitrates and nitrates (5%) at 427^0 C is used for cleaning gray iron castings.

Brushing: -

- It imparts a smooth surface finish to castings.
- Rotary wire or fiber brushes may be employed to remove burrs and grinding marks from the surfaces of a casting.

Buffing: -

- It provides an exceptionally higher luster on cast surfaces.
- A buff is a disk of muslin sewn together.
- It is mounted on the axle of a buffing machine.

Painting: -

- Many ferrous castings do not need fine finish,
- Rather they are painted after initial cleaning so that
- The objects acquire a suitable appearance for sale and
- Are at the same time protected from rust etc.

Salvage of defective castings:

- Salvage means repairing of defective castings by suitable means and put to use
- All castings cannot be produced defective free at all times.
- In the mass production of the light castings, defective
- Castings can be scrapped and replaced because the

- Cost of material is less than the salvage of the defective castings.

Factor affecting salvage of casting: -

- Composition of casting alloy.
- Size and shape of casting.
- Relative cost of new casting versus repairing the defective casting.
- Difficulty of salvaging the defective casting.
- Availability of repair equipment's and methods.
- Quality requirements.
- Performance level of salvaged castings.
- Any agreement between manufacture and user for salvage the defective casting.
- Various salvaging techniques employed for repairing defective castings are

1. Welding (The most common technique).
2. Brazing, braze welding and soldering.
3. Burning on.
4. Patches and plugs.
5. Caulking and impregnation.

Visual inspection methods:

Inspection means check the quality of the castings acceptance or rejection. They are as follows

1. Visual, surface inspection for foundry defects.
2. Dimensional, requiring gauges for measurements.
3. Metallurgical, requiring chemical, physical, and other tests for metal quality.

Visual inspection:

- Certain defects such as cracked castings, tears.
- Dirt, blowholes, scabs, run outs swells etc. are visualized by the inspector.
- The defects caused by defective molds, cores, flask equipment.
- Inspector identify the casting defects and assign their causes.

Dimensional inspection:

- It involves the principles of gauging.
- When precision castings are produced by processes.
- such as investment casting , shell moulding etc.,
- Dimensions need to be closely checked.
- The inspection of castings are conducted by the following methods.
- Standard measuring instrument to check the size.
- These are rulers, vernier calipers etc.
- Templates and contour gauge for the checking of profile, curves and intricate shapes.
- The CMM accuracy range from .001mm to .05mm.
- It is also used for marking in three dimension on metallic or non-metallic surfaces.
- Once the machine is set, all measurements can be

- Carried out in a programmed sequence automatically.

Metallurgical inspection:

Casting soundness: ---

- The casting defects are greater or lesser importance
- Depending on the casting application.
- The casting for aircraft, ordnance, and precision
- Engineering required high degree of metallurgical quality.
- **Pressure testing:--**
- It is used to locate leakage in a casting or check the
- Over- all strength of a casting in resistance to bursting
- Under hydraulic pressure.
- Proof loading by hydraulic pressure involves introduce
- A fluid , oil or water, into the casting
- **Sectioning:--**
- Casting may be sawed up, and the sections examined for soundness.
- To obtain the section thickness, as well as soundness.
- Micro etching may be conducted to locate suspected shrinkage, porosity, or cracks.

Other inspections tests are:

- Radiography
- Magnetic particle testing
- Penetrate test
- Ultrasonic testing

Radiographic inspection: -

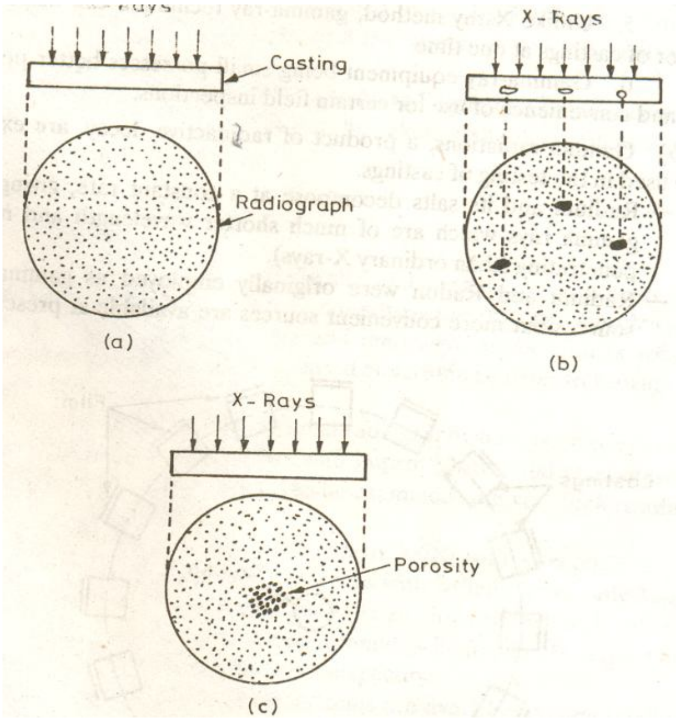
- The casting soundness may be determined by X- ray radiography.
- The short wave length rays which penetrate metals.
- The rays generated from a radium capsule, a cobalt -60 capsule, etc.,
- The photographic film behind the casting section being radiographed.
- The film is darkened more where the defects are in the line of the X- ray beam.

Radiographic inspection: -

- To obtain better results to select proper casting.
- Thickness, exposure to x- rays, time etc.

Magnetic- particle inspection: -

- It is used on ferrous casting for detecting invisible.
- Surface or slightly sub –surface defects.
- The object is magnetized, and magnetic particle powder is applied to the casting.
- When magnetizing force is passed through the metal, field are set up.
- Polar effects exist at the defects, which cause magnetic
- Particles aligned around the defect.
- The magnetic flux equipment is portable to carry anywhere.



a) Sound casting.

b) Blow casting

c) porosity

Circular magnetizing: