**Introduction to cast irons (1 Short)**

**1.1** **Define the terms cast iron, grey cast iron, white cast iron, chilled cast iron, malleable iron, nodular iron and compacted gray iron**

**Cast iron:** Cast iron may be defined as an alloy of iron, carbon (up to 4%) and silicon (up to 3%).

**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.

**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 Fe3C).

**Chilled cast 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.

**Malleable iron:** It is defined as an iron, with malleability, produced by heat treating (malleableizing) a white cast iron of suitable chemical composition.

**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.

**Compacted grey iron (CGI):**

In this grey iron, graphite occurs as blunt flakes that are interconnected within each cell. This graphite structure and the resulting properties of the iron are intermediate between gray and ductile irons. Its production is similar to that for ductile iron in requiring close metallurgical control and addition of alloying elements such as titanium to minimize the formation of spheroidal graphite. CGI retains castability of gray iron, but has a higher tensile strength and some ductility.

**1.2** **Express the composition of various cast irons**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Cast iron | % C | % Si | % Mn | % S | % P | % Fe | Spec additives |
| Grey cast iron | 2.5-4.0 | 1.0-3.0 | 0.4-1.0 | 0.05-0.25 | 0.05-1.0 | Bal | - |
| White cast iron | 1.8-3.6 | 0.5-1.9 | 0.25-0.8 | 0.05-0.20 | 0.06-0.18 | Bal | - |
| Nodular iron | 3.0-4.0 | 1.8-2.8 | 0.15-0.9 | 0.03 max | 0.10 max | Bal | Mg: 0.03 -0.04% |
| Malleable iron | Same as White cast iron | | | | | | |

**1.3**  **Define graphitisation**.

It is the process of precipitation of free carbon (graphite) during solidification or conversion of combined carbon (Fe3C) in to free carbon (graphite) during annealing.

**1.4 State the factors effecting graphitisation.**

**1. Composition: -** Carbon and Silicon are the two elements which effect the process of graphitization. High carbon and high silicon promote the graphitization process. 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 iron.

**2. Cooling rate: -** 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.

**3. Presence of other elements: -** Presence of elements like Cr, Mo, and W etc prevents the formation of graphite and favors the formation of carbides. Similarly presence of graphitizing elements like Si, Co etc forms the graphite phase.

**1.5 State the micro constituents present in cast irons.**

The important micro constituents of cast irons are:

* Graphite
* Carbide (Fe3C)
* Ferrite
* Pearlite
* Austenite
* Steadite

**2. Melting of cast irons (1 short and 1 essay)**

**2.1 State the advantages & limitations of cupola.**

Cupola is the most common type of melting furnace used in foundry industry,

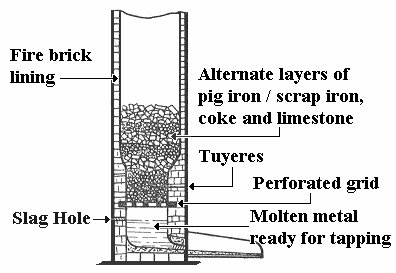
**Advantages of cupola:-**

* 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:**

* 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 > 15000 C are difficult to obtain

**2.2 Describe the mechanical structure of cupola with a sketch.**

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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 slag hole is provided above the level of tap hole and opposite side (below the tuyeres). 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 varies 1 - 35 tons per hour.

**Shell diameter:** The outer shell diameter 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 “O” no. cupola to 5542 sq.inches for a 12 no. cupola.

**Total area of tuyeres**: The tuyeres openings introduce the air for combustion of coke. It varies from 32 – 960 square inches

**Blast pressure**: The normal air pressure varies from 7 – 20 ozs

**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.

**2.3 Explain various steps in the operation of cupola.**

The important steps are:

* **Preparation of refractory lining of bottom, tap hole and slag hole:**

It usually begins after dropping the bottom of the previous heat. The slag and metal adhere to the side walls, an 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.

* **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 producing 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. The flux is usually lime stone and is about 20% of the weight of coke. The main function of flux is to form the slag from coke ash, refractory erosion and metal oxidation.

* **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 – 15600 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.

* **Dropping the bottom:**

The end of cupola heat begins with stopping the charging. The materials inside the cupola are allowed to melt until it descends up to the melting zone. The supply of air is put off. All the liquid metal and slag are tapped out from the cupola. The bottom doors are opened and the materials inside the cupola are dropped on to the floor. Water is sprayed to cool the dropped materials.

**2.4 Describe various zones with chemical reactions.**

The various zones of chemical reactions in the cupola are:

* **Well:**

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

* **Super heating zone (combustion or oxidation zone):**

The zone lies about 10 – 30 cm above the tuyeres. Burning of coke, manganese and silicon takes place in this zone with the evolution of heat according to the following reactions.

C + O2  → CO2 + Heat

Si + O2  → SiO2 + Heat

2Mn + O2 → MnO + Heat

O2 required is supplied from air entering through the tuyeres. O2 of the blast is consumed here and this is the zone of maximum temperature, which varies from 1570 – 18200 C.

* **Reduction 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 :

CO2 + C → 2CO + 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 → Fe3C + CO2

The molten iron picks up carbon in this zone. The temperature in this zone is around16000 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 10000 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 contain 76% nitrogen, 12% carbon monoxide and 12% carbon dioxide.

**2.5 Explain the principles of cupola operation.**

The successful operation of cupola depends on the following principles:

* **Combustion:**

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

The amount of air required for combustion of 1 kg of coke is 8.4 cu.mts. Excess of coke results in wastage of coke, slow melting rate, high carbon in the iron, and 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, and 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. Too little blast air does not generate enough heat for efficient combustion and leads to lower metal temperature, slower melting and higher coke consumption. The optimum blast rate has been found to be 115 m3/min per square meter cross-sectional area of cupola at the tuyers area.

* **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 = 0.005 D2 - 0.0134 D + 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.

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 tuyere 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. Increasing the well depth reduces the tapping temperature of the molten metal. As a rule of thumb, there is a drop of 10C in the molten metal temperature for every additional inch increase in the well depth.

**2.6 Explain the melt control tests**

**(a) Chill test (b) Spiral fluidity test.**

**Chill test:**

Chill test 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 the chill depth. Increase in carbon equivalent will reduce chill depth.

**Spiral 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. Fluidity test is performed with the following objects:

- To find out the cause of misrun

- To find correct pouring temperature for a particular grade of iron

- To determine the cross section and length of the cavity for design

This 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 affected by the metal composition and pouring temperature.

**2.7 Calculate the molten metal analysis from the given charge analysis.**

The Loss and gain of elements during melting are as follows:

|  |  |
| --- | --- |
| element | Loss/ gain |
| Carbon | 20% gain |
| Silicon | 10% loss |
| Manganese | 15%loss |
| Sulphur | 0.03% gain |
| phosphorous | No loss/no gain |

**Model Problem:-** A cupola has been charged with the following materials. Calculate the analysis of molten metal at the cupola spout by assuming suitable losses and gains

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Wt.% charge | Material | % C | %Si | %Mn | %P | %S |
| 25 | Pig iron – 1 | 3.6 | 3.1 | 0.9 | 0.2 | 0.03 |
| 35 | Pig iron - 2 | 3.0 | 2.8 | 0.8 | 0.3 | 0.12 |
| 25 | Remelts | 3.5 | 2.9 | 0.7 | 0.2 | 0.12 |
| 15 | Steel scrap | 0.4 | 0.2 | 0.3 | 0.05 | 0.02 |

**2.8 State the advantages and disadvantages of Induction furnace.**

**Advantages:**

**-** Higher yield

- Faster startup

- Flexibility

- 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

**Limitations:**

- The initial cost is high

- No refining due to hot metal and reactive slag on the metal surface

- Bath sampling cannot be carried

**2.9 List out different types of Induction furnaces.**

There are two main types of induction furnace:

a. Channel or core type

b. Coreless

Based on the currents used, the induction furnaces may be classified in to :

- Low frequency furnaces (<200Hz)

- Medium frequency furnaces (200-5000Hz)

- High frequency furnaces (>500≤10,000Hz)

**2.10 State the 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 current circulating in the charge produces electrical (I**2**R) losses which heat the charge and eventually melt it.

**2.11 Explain the melting practice of cast iron in induction furnace.**

The furnace contains a crucible or a monolithic lining surrounded by water cooled copper coil. The coil represents the primary to which a high frequency current of 1000 cycles per second is supplied by a power source. By induction, secondary currents (or 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. Resistivity of metal causes current losses, which are dissipated into heat energy, results in melting the metal.

The cored furnace is generally used for melting of cast irons. It carries an induction coil, which is immersed within the metal bath and acts as a core for the eddy currents to flow. The electromagnetic induction effect causes the liquid to move around the secondary coil.

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 aluminum 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.

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 within the limits.

**3. Grey iron (2 short and 1 essays)**

**3.1 State the properties and applications of Grey iron.**

**Properties:**

* Ease of melting and casting. It has the lowest pouring temperature of the ferrous metals, so it has high fluidity and can cast into intricate shapes.
* It has excellent machinability and wear resistance.
* Volumetric shrinkage is very low or almost nil during solidification.
* Tensile strength is in the range of 20,000 psi to 60,000 psi.
* Hardness is in the range of 100 to 300 BHN in cast condition.
* It has exceptional damping capacity.
* It has high dimensional stability.
* It has resistance to scaling.

**Applications:**

* Exceptionally high damping capacity is suited for machine bases and supports, engine cylinder blocks and brake components.
* The resistance to scaling property is advantageous in the use of furnace and stoker parts, melting pots, etc.,
* Due to the resistance to the sliding wear, grey iron is used for making of automotive parts like brake drums, clutch plates, transmission cases, gear boxes, dies, pistons and rings.

**3.2 Classify the Grey irons.**

Grey irons are classified in two ways.

**Based on matrix:**

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

- Ferritic gray irons: - consists of graphite flakes in a matrix of ferrite.

**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 Sl System a similar iron would be of grade 220 with a tensile strength of 220 MPa.

**3.3 State the effect of Silicon on the iron-iron carbide system.**

Silicon is a powerful graphitizing element. 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)

The Silicon in cast irons also shifts the eutectoid point and the solubility limits of carbon in the austenite to the left in the iron – carbide diagram. For this reason the pearlite in a 2.0% Si grey iron contain only about 0.6% carbon rather than 0.8% carbon value in the iron – carbide diagram.

Microstructurally, silicon dissolves in the ferrite matrix of gray iron. It hardens and strengthens the ferrite.

**3.4 Explain the chemical composition requirements of Grey iron.**

Grey 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 ferritic grey iron and as high as 1.2% in pearlitic grey iron). Sulfur and phosphorus are also present in small amounts as residual impurities.

The composition of grey iron must be selected in such a way to satisfy three basic structural requirements:

The graphite size, shape and distribution

The carbide-free (chill-free) structure

The matrix of ferrite or ferrite and pearlite

**Carbon:**

It presents in two phases - elemental carbon in the form of graphite and combined carbon as Fe3C. If graphitization is complete, the % of total carbon and the % of graphitic carbon are equal. If no graphitization has occurred, the % of graphitic carbon is zero. Certain minimum total carbon content is necessary to develop sufficient graphitization during solidification,

**Silicon:**

It promotes graphitization. The combined influence of carbon and silicon on the structure is usually taken into account by the carbon equivalent (CE).

CE = %C + 0.3x (%Si) + 0.33x (%P)

Increasing the carbon and silicon contents improves the graphitization potential and decreases the chilling tendency. Strength is adversely affected by silicon addition due to ferrite promotion and the coarsening of pearlite.

**Manganese:**

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

The effect of sulfur must be balanced by the effect of manganese. Without manganese in the iron, undesired iron sulfide (FeS) will form at grain boundaries and make it prone for hot shortness. The optimum ratio between manganese and sulfur for a FeS-free structure and maximum amount of ferrite is:

%Mn = 1.7x (%S) + 0.15

**Sulfur:**

Sulfur is seldom intentionally added to grey iron and usually comes from the coke. 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.

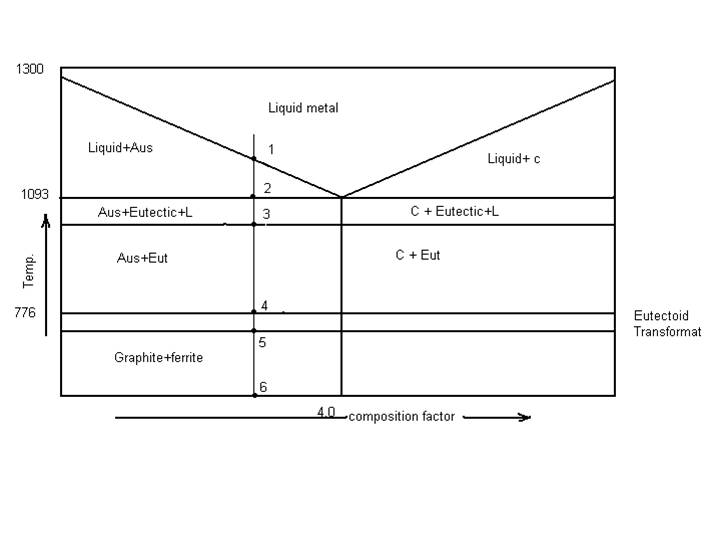
**Phosphorus:**

The phosphorus content of most grey iron castings is less than 0.10 wt%. It occurs as an eutectic of iron, iron-phosphide. This eutectic will be found in the grain boundaries, and beyond 0.20 % phosphorus a decrease in machinability may be encountered. The iron phosphide is hard and brittle. Increasing the % of phosphorous in the iron causes a proportional increase in the hard constituent, and therefore increases the hardness and brittleness of the iron.

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.

**3.5 Explain the solidification of Grey iron w.r.t Graphitisation.**



Freezing processes of Fe-C-Si alloy (3.5% C and 2% Si)

Under equilibrium freezing conditions primary austenite dendrites are formed in the temperature range about 1260 – 11260C. Simultaneous solidification of the eutectic austenite plus graphite completes the freezing process.

In the solidification of Fe – C – Si alloy, the graphitization occurs in two stages

**Graphitization during solidification:**

As cooling progresses, the austenite dendrites grow, and the remaining liquid becomes enriched in carbon until the eutectic composition of 4.3 percent carbon equivalent is reached. This occurs at a temperature of approximately 11400C depending on the silicon content. At this temperature, eutectic austenite and graphite in the form of flakes are deposited simultaneously. The austenite-graphite deposition occurs at a number of centers or nuclei, and these grow in size until all of the liquid is complete creating a cell-type structure. During this period of cell growth, the phosphorus is rejected toward the cell boundaries and freezes as a eutectic at about 9780C.

The eutectic freezing occurs in the temperature range 1140 – 11150 C. When solidification is complete, the microstructure consists of about 20% primary austenite dendrites and 80% austenite plus graphite eutectic.

The changes of graphite size, number of flakes and their distribution are related to metallurgical nucleation and growth principles. The type of graphite depends on:

* Section size and cooling rate
* Super heating
* Inoculation

Graphitization in the solid state:

Further decrease in temperature is accompanied by rejection of carbon from austenite as graphite and its precipitation on the graphite flakes in the eutectic carbon precipitation continues until the eutectoid temperature range of about 7850 C is reached. At the eutectoid temperature the 2.0% Si austenite contains about 0.6% carbon. Equilibrium cooling through the range results in the transformation of austenite to ferrite and precipitation of the remaining carbon on the graphite flakes.

The final microstructure consists of isolated areas of ferrite originating in the primary austenite dendrites areas of mixed ferrite and flake graphite having their origin in the austenite – graphite eutectic are also present.

**3.6 List out the molding methods used in Grey iron foundry.**

Some of moulding methods used in Grey iron foundry are:

- Green sand molding,

- Dry sand molding,

- CO2 molding,

- Shell molding,

- Permanent mold casting, and

- Centrifugal casting

**3.7 Describe the additives required for ease of moulding.**

Additives are the materials added to the different types of sand mixes to develop special properties such as collapsibility, hot strength, surface finish of the molds and cores. There are two types of sand additives.

Carbonaceous additives: coal dust, pitch, sea coal, saw dust, dextrin, molasses, etc.,

- Coal dust is used in cast iron foundry to improve surface finish and collapsibility of molds and cores.

- Pitch improves collapsibility and to certain extent dry and hot strengths of molds

- Sea coal reduces the mold wall movement and also makes the mold surface clean and smooth

- Saw dust improves collapsibility and increases mold wall movement, but decreases expansion defects

- Dextrin provides hard surface to green sand molds and increases the green strength of the sand

- Molasses improves the dry strength and casting finish

Non – Carbonaceous additives: silica floor, alumina, iron oxide, red oxide, etc.,

- Silica floor addition to molding sand mix improves the hot strength and reduces metal penetration in the mold walls

- Alumina is used in the sand mix to improve the break down property and hot strength

**3.8 State the foundry properties of Grey iron.**

- The high carbon content of grey 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

- Liquid shrinkage of grey iron is very negligible. A normal gray iron of 3.5% C and 2.2% Si, have virtually no shrinkage or even expand on solidification

**3.9 Calculate the pouring temperature and fluidity for a given composition of grey iron.**

If we know the composition of a gray iron, we can calculate the

* + - appropriate pouring temperature, and
    - fluidity of grey iron at that temperature

From the given composition, can calculate the composition factor.

Composition factor, C.F = % C + ½ % P + ¼ % Si

The liquidus temperature = 2981 – (218 x C.F)

The pouring temperature should be 100 – 150 0F above the liquidus temperature.

The fluidity of the metal can be calculated by the formula:

Fluidity, inches = (14.9x C.F) + (0.05 x T) – 155

Where, T is the pouring temperature in 0F.

**3.10 State different heat treatments of Grey iron.**

Different heat treatments of grey iron are:

- Stress relief annealing

- Ferritizing annealing

- Full annealing

- Graphitizing annealing

- Normalizing

- Hardening

**3.11 Explain the effect of alloying elements on the properties and structure of grey iron.**

In general, alloying elements added in grey iron are classified into three categories.

**Strong graphitizes: Silicon and aluminum**

* Increase the graphitization potential for both the eutectic and eutectoid transformations
* Increase the number of graphite particles.
* Increase the ferrite/Pearlite ratio
* lower strength and hardness

**Mild graphitizes: Nickel, copper, and tin**

* Increase the graphitization potential during the eutectic transformation and decrease it during the eutectoid transformation.
* This second effect is due to the retardation of carbon diffusion.
* These elements form solid solution in the matrix.
* Raising the Pearlite/ferrite ratio.
* Since they increase the amount of Pearlite, they raise strength and hardness.
* 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

**Carbide formers: Chromium, molybdenum, tungsten, and vanadium**

* Decrease the graphitization potential at both stages.
* Increase the amount of carbides and Pearlite.
* As long as carbide formation does not occur, these elements increase strength and hardness.
* Chromium is often added to improve hardness and strength of gray iron.

**4. Ductile iron (1 short and 1 essay)**

**4.1 State the properties and uses of ductile iron.**

**Properties of ductile iron:**

* + Low melting point
  + Good fluidity and good cast ability
  + Excellent machinability
  + Good wear resistance
  + High strength and toughness, and
  + High ductility

**Uses of ductile iron:**

* + 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 etc.,

**4.2 Explain the composition requirements for ductile iron.**

Composition: Same as grey iron. Apart of normal composition, a little amount of Magnesium or Cerium (0.03 – 0.04%) is added. Graphite Occurs in the form of Spheroids. Ductility is due to the spheroidal shape of Graphite.

**4.3 State the role of Mg.**

Magnesium transforms graphite to spheroids. It prevents nucleation of flake graphite. Magnesium serves as deoxidizer and desulphuriser of molten iron.

**4.4 Explain various Magnesium treatment methods.**

Amount of Magnesium added depends on % of Sulphur & oxygen content. Magnesium is added in the alloy form such as Mg-Ni alloy, Mg- Si alloy, and Mg-Ferro silicon alloys.

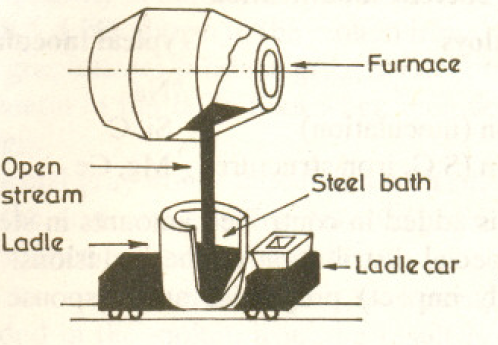
Types of Magnesium treatment methods are:

* + Open ladle method
  + Sandwich method
  + Plunging technique
  + Mechanical feeder method

**Open ladle method:**

Deep and narrow ladles (height to diameter ratio 2:1) are used in this case. Mg alloy is placed at the ladle bottom. Molten metal is tapped on to Mg alloy. Reactions between Mg vapor & iron are confined to the ladle.

Advantages are flexible, low equipment cost, and low temperature losses.



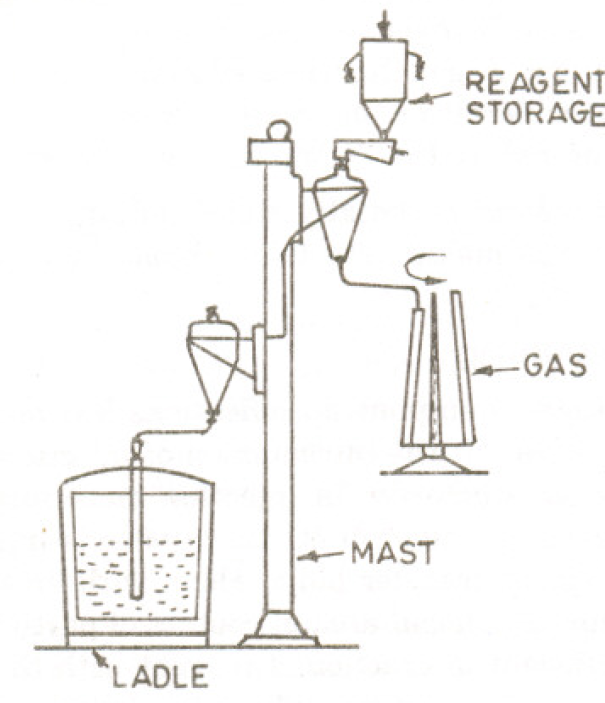
Open ladle method

**Sandwich method:**

It is same as open ladle method. Mg alloy is placed at the refractory bottom of the ladle. These alloys are covered by a steel plate or inert material. Molten metal is tapped in the ladle. Reaction time between Mg alloy and molten metal may be delayed until ladle is partially filled with molten metal.

Mg recovery is more compared to open ladle method.

**Plunging technique:**

****

Mg alloy is placed in the container and it is connected to the vented graphite or refractory bell. Plunging action of the bell is controlled by connecting rod. Vented refractory bell is plunged into the ladle filled with molten iron for reaction between Magnesium and iron. Advantages of this technique are good control over the reaction between Mg and iron; high Mg recovery.

**Mechanical Feeder Method:**

In this method, Mg alloy is added continuously to the molten metal stream emitting from the furnace through mechanical feeder. It is a continuous process and gives uniform Magnesium treatment. Mg recovery is also high.

**4.5 Describe the metallurgical process control-**

**4.6 Adding of Mg. (b) Nodule size and count. (c) Carbide formation.**

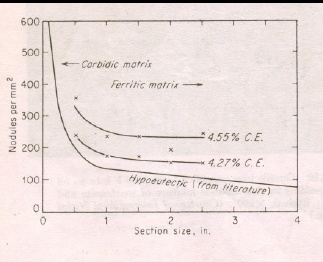
**Adding of Magnesium:**

Magnesium is a spherodizing element and added to molten metal of iron to eliminate sulphur, oxygen. It changes the solidification characteristics of molten iron. It prevents nucleation of flake graphite and promotes spheroid graphite. Total Mg recovery depends on the alloy type, and method of addition. After Mg treatment, samples are prepared to determine final chemistry and microstructure of ductile iron.

**Nodule size and count:**

Different sizes of graphite spheroids can be observed in ductile iron.

Nodules count is nodules per sq mm in microstructure of a given ductile iron. Nodules count depends on the size of casting. Nodules count decreases with increase of casting section size. The following graph gives the relation between nodules count and casting section size. Number of nodules is increases as the amount of ferrite increase.



**Carbide formation:**

Eutectic carbide formation occurs during solidification of molten cast iron. This formation is prevented by high carbon equivalent of the cast iron. Slow cooling will also promotes graphite formation by reducing the chilling tendency of cast iron.

**4.7 State the inoculation process.**

Inoculation is a process of late additions to the molten metal which refines the grain size of casting without any change in chemical composition. Most widely used inoculant is Fe-Si alloy with 85% Silicon. The addition of Fe-Si to the melt will increase number spheroid nucleation sites.

Inoculation increases graphitizing tendency of solidifying melt by reducing its chilling tendency. Inoculation also reduces eutectic carbide formation.

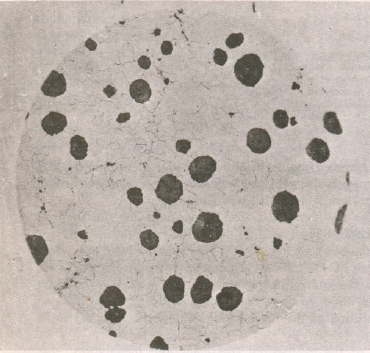
**4.8 State different heat treatments of ductile iron.**

Different heat treatments of ductile iron are:

* + Stress relieving
  + Annealing
  + Normalizing
  + Quenching and tempering
  + Martempering
  + Austempering
  + Flame and Induction hardening

4.9 Draw the microstructure & identify the phases of ductile iron.

Class room practice



**5. Malleable iron (1 short and 1 essay)**

**5.1 State the properties & uses of malleable iron.**

**Properties:**

* + High malleability compare with all cast irons.
  + Good wear resistance
  + Good vibration damping capacity
  + High yield strength
  + Low coefficient of thermal expansion

**Uses:**

* Automotive industry
* Rail road
* Agricultural implements
* Conveyor chain links.
* Gear cases
* Axle assembly parts
* Automotive crankshafts etc.,

**5.2 Mention the composition of white iron (in wt %)**

C: 1.8-3.6%; Si: 0.5-1.9%; Mn: 0.25-0.8%; S: 0.05-0.20%; P: 0.06-0.18%; Balance: Fe

**5.3 Draw the microstructure & identify of phases of white iron.**

Class room practice

**5.4 Explain the Malleabilisation treatment of white iron for the production of malleable iron with reference to micro structural changes**

The white iron structure consists of large pearlite areas and massive carbides. The malleablisation converts massive carbide into temper carbon modules by the reaction: Fe3C → 3Fe + C.

Malleabilisation treatment consists of three stages

* + Nucleation
  + First stage graphitization
  + Second stage graphitization

**Nucleation:**

The success of malleablisation treatment depends on nucleation of graphite. During the heating pearlite changes completely to austenite at above 900 0 C. Holding the casting at that temperature for a longer period. The first nuclei are appeared at the interface of carbide-austenite or non metallic inclusion.

Addition of .01 to .003% boron or Al or Ti to the molten iron increases the nucleation. Graphite stabilizing elements promotes nucleation during Malleablisation.

**First stage of graphitization (FSG):**

It occurs during prolonged holding at the higher temperature (9000 C). Its objective is elimination of carbide by a process of dissolution and precipitation

Nucleation of graphite occurs at austenite- cementite interface and sulphide inclusions. Carbon diffuses from cementite and diffuses through austenite to deposit on the graphite nuclei. Growth of temper carbon nodules occurs at the expense of the carbide. 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. But, high temperature results in excessive distortion of casting.

The time required for FSG is function of number of nuclei, amount of carbide, diffusion rate of carbon

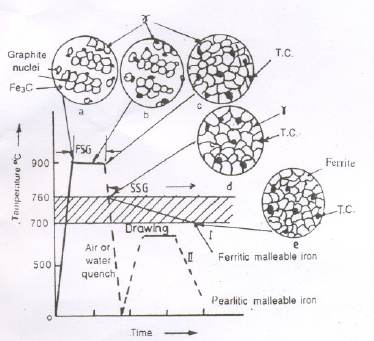
**Second stage of graphitization (SSG):**

It occurs during very slow cooling through austenite transition temperature range (7600 C - 7000 C). Its objective is to produce a fully ferritic structure. In this stage, austenite is converted into pearlite, excess carbon dissolve in austenite changed to graphite. The cementite of pearlite also decomposes to graphite and ferrite.

After second stage of graphitization, the structure is composed of temper carbon nodules embedded in ferrite matrix.

Moderately fast cooling through SSG transforms austenite to pearlite. It gives pearlite matrix of malleable iron.

The intermediate cooling rate may result in a part graphitization of pearlite. It produces the structure of temper carbon embedded in ferrite and pearlite.



Malleabilisation heat treatment cycle

**5.5 List out the types of malleable iron.**

Based on matrix, malleable irons are of 2 types:

* + Pearlitic malleable iron or black heart malleable iron
  + Ferritic malleable iron or white heart malleable iron

**5.6 Draw the microstructure of white & black heart malleable iron.**

Class room practice

**5.7 List the methods of producing black heart malleable iron.**

Black heart malleable iron is produced by one of the following methods:

* + Malleabilisation treatment in closed boxes packed with inert materials
  + Fast cooling through eutectoid transition temperature range (7600 C - 7000 C)
  + By adding of 1% Mn
  + Complete prevention of second stage of graphitization

**5.8 Explain the method of producing black heart malleable iron**

Black heart malleable iron consists of temper carbon in the matrix of pearlite.

White cast iron and neutral material are packed in boxes. Generally sand is used as neutral material. The packed boxes are heated to about 8500 C -9000 C. Castings are hold for 50 hrs at this temperature. Cool the castings from above the temperature. Uniform structure of temper carbon nodules in pearlite matrix will produce by this treatment.

Also, Pearlite matrix is obtained by more rapid cooling through the eutectoid transition temperature range (7600 C - 7000 C). Adding of 1% Mn will also produce pearlite matrix. Complete prevention of second stage of graphitization results in producing black heart malleable iron.

**6. Aluminium Foundry Practice (1 short and 1 essay)**

**6.1 List the uses of Aluminium castings.**

* Used as architectural and decorative parts.
* Cooking utensils and food handling equipments.
* Building construction.
* Used as rotor bars in induction motors.

**6.2 State the different moulding methods used in an aluminium foundry.**

* Sand molding
  + Green sand molding
  + Dry sand molding
* Permanent mold casting
* Die casting

**6.3 Explain the melting procedure of aluminium alloys with respect to drossing, gas absorption, fluxing and flushing, grain refining and pouring temperature.**

Furnaces used for melting of Al and its alloys are Crucible furnace, Reveraberatory furnace, Pot furnace, and Induction furnaces. Following are the salient features w.r.t. melting of aluminum alloys.

**Drossing:**

Drossing is the formation of aluminum oxide and other oxides. Removal of the dross from the melt is very difficult due to same specific gravity. Minimum dross formation occurred by fast melting. Melt is protected from products of combustion for minimum dross formation. Dross can be removed by subsequent fluxing and flushing.

**Gas absorption:**

Gases are absorbed in molten metal from various sources. Furnace charge, wet furnace refractories, furnace atmosphere are some of sources for absorption of gases in molten metal. Al and its alloys absorb harmful quantities of hydrogen gas. Solubility of gases increases with increasing temperature. During cooling, gases are evolved from the metal. Gas evolution results gas or pin holes and microscopic gas porosity in castings. Water vapor is particularly harmful in causing gassing of Al and its alloys.

2Al+3H2O → Al2O3 +6H (dissolved in Al)

**Fluxing and Flushing:**

The objectives of Fluxing and Flushing are:

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

Two types of fluxes are used in Al foundry. They are: Gaseous fluxes and solid fluxes.

Gaseous fluxes are used to flush the melt i.e. removal of dissolved hydrogen from the metal. The gaseous fluxes are N2, He, Ar, Cl2.

The solid fluxes are Al, and Zinc chloride. They are used for easy separation of dross from the melt. After flushing the temperature is raised for pouring.

**Grain refining:**

Grain size in cast Aluminum and its alloys can be refined by.

* Chilling (fast cooling)
* Temperature adjustment (pouring at lowest possible temperature)
* Later additions of boron, Ti, Cr, Columbium and sodium to the melt (inoculation)

**Pouring temperature:**

Temperatures of molten Al alloys are measured by immersion thermocouple. The pouring temperature of Al alloys depends upon the casting size and alloy composition. The pouring temperature is around 6770 C to7600 C. High pouring temperatures create turbulence and form dross.

**6.4 state suitable Gating ratios for aluminium alloys.**

Gating ratio is the ratio of Sprue area: runner area: total in gates area of molding. For aluminum alloys, unpressurised gating system (the ratios are 1:2:2; 1:4:4; 1:6:6) are used for filling of molten metal into the mold cavity. Pressurized gating system (the ratio is 1:2:1) is not suitable because it encourage turbulence at the gates.

6.5 State the methods of Gating &Risering of aluminium alloys.

Same as copper alloy foundry practice (Ref. 7.4)

**6.6 State the importance of Multiple-ingating.**

Single gate is not suitable for fast and effective feeding of large castings. Multiple-ingating system (having a number of small gates) can feed large size castings effectively. Hot spot and shrinkage problems are solved by employing multiple-ingating system. A multiple gate system can feed metal at widely separated points in a casting.

**6.7 State effect of unpressurised gating systems for aluminium castings**

Unpressurised gating system (the ratios are 1:2:2; 1:4:4; 1:6:6) does not create the turbulence at the in gates. Mold erosion and dross formation can be minimized by unpressurised gating system. But, back pressure is not maintained on the gating system due to lack of flow restriction at the gates. So, it does not keep Sprue full of metal. Air aspiration is high in the molten metal passing through unpressurised gating system. Volume flow of molten metal from ingates is different at different ingates. The casting yield is lower because of large size of runner and ingates.

6.8 Explain the different casting defects in aluminium castings with remedial measures

Same as copper alloy foundry practice (Ref. 7.6)

**7. Copper alloy foundry practice (1 short and 1 essay)**

**7.1 State the uses of copper alloy castings.**

**Uses:**

* Electrodes of resistance welding machinery
* Turbine runners
* Bearings
* Gears and corrosion resistance pumps
* Marine equipment
* Valves and fittings
* Steam pipe fittings
* Die cast parts etc.,

**7.2 state the moulding procedures used in a copper alloy foundry**

* Sand casting
* Permanent mold casting
* Die casting
* Plaster of paris mold casting
* Shell mold casting

**7.3 Explain the melting procedure of copper alloys with respect to drossing, oxygen and Hydrogen in copper melting, reaction of impurities, de-oxidation, control of gases and temperature control.**

Furnaces used for melting of Cu and its alloys are Crucible furnace, Reveraberatory furnace, Electric arc furnace, and Induction furnaces. Following are the salient features w.r.t. melting of copper alloys.

**Drossing:**

Copper alloys containing oxidizing elements such Zn, Sn, Al, Mg, Mn. These elements form oxides during melting and form dross. The oxides have low specific gravity, so they float on the melt surface. The dross contains considerable metal causing high melting losses.

Remedies for minimizing the dross:

* A cover of fluxes or charcoal are employed to minimize the dross
* A minimum of agitation during melting
* Melting under favorable combustion conditions

**Oxygen and Hydrogen in copper melting:**

Cu is an element which is readily oxidized in the molten conditions. The solubility of O2 in molten Cu increases rapidly with temperature above its melting point. In the solid state copper can dissolve up to about 0.0035% of O2. Melting of copper in the presence of free O2 or an oxidizing gas such as CO2, favors oxidation. The deoxidizers in Cu alloys reduce the oxygen in melt.

Solubility of hydrogen is increases markedly with increase temperature in Cu alloys. H2 pick up in copper alloys occurs from the furnace atmosphere, moisture on the furnace charge.

Hydrogen and oxygen causes gas holes, micro porosity, and shrinkage.

**Reaction of impurities:**

The reaction of O2 and H2 forms steam or water vapor: H2+O2 → 2H2O

If the O2 solubility of the metal is high, it prevents the solubility of H2 in the metal. So, most foundry men prefer melting of copper under an oxidizing atmosphere.

Also, H2 from melt is reduced by flushing with N2 gas.

Also, following reactions can observe during melting of copper alloys:

C (dissolved) +O (dissolved) → CO (gas)

S (dissolved) +2O (dissolved) → SO2 (gas)

The reaction causes formation of gas holes in castings. The reactions of C, S are removed by using de-oxidizers.

**De-oxidation:**

Elements which have more chemical affinity with O2 than Cu are used as de oxidizers. Most used deoxidizers are P, B, Ca, Mg, Al, and Si.

0.02% P as residual is fully reducing the O2 from copper alloys.

**Control of gases:**

Oxygen is controlled by de-oxidation practice.

Hydrogen is controlled by an oxidizing during melting and heating.

Flushing and Zn flaring employed to control hydrogen.

CO, SO2 formation is controlled by adding de-oxidizers.

**Temperature control:**

High pouring temperatures encourage the aspiration of gases into the melt. Also, it results in excessive dross formation, and mold erosion.

Low pouring temperatures may results in misruns, porosity and shrinkage.

Pouring the melt just 50 to 1000 C above the melting temperature is preferable for copper alloy castings.

**7.4 State the design of gating & Risering system in the case of copper alloy casting**

**Design of gating system:**

A pouring basin should be preferred, rather than to pour the molten metal straight down in the sprue. The dam in the pouring basin promotes a more even flow.

Sprue should maintain desired flow rate of molten metal. A sprue should have a well at the base. It reduces velocity of the vertical flow of metal.

Runners are commonly placed in the drag and the gates in the cope. Runner provides uniform flow into the casting cavity. It have rectangular cross-section. Its maximum cross- sectional area should be 4 to 6 times that of the sprue exit. Inadequate cross- section of a runner can cause premature chilling of the metal and result in misruns.

The alloy of copper readily oxidizes in the liquid state. Time logging in filling of mold cavity with molten metal may cause more oxidation. So, quick filling of molten metal into mold cavity is essentially a requirement in the case of copper alloys. The gating system must provide a quiet filling of the mold cavity.

Gating ratios used in copper alloys are: 1:2:2 or 1:4:4 (cross- section area of the sprue, runner and total in- gate areas)

Cu base alloy containing Zn, Sn, and Al are readily formed dross. Gating arrangements for catching the dross and prevent its entry into the casting is a requirement in the design of gating system for copper alloy castings.

**Design of Risering system:**

Cu base alloys do not have favorable solidification characteristics. They show high solidification contraction and have long freezing range. They freeze dendritically and this makes the transfer of molten metal to casting more difficult. Because of their dendritic form solidification, dispersed shrinkage may be formed in castings. This shrinkage is eliminated by using risers of sufficient size and number. Risers also produce directional solidification. The later portions of castings are fed by risers. Both open and blind risers are used in pouring Cu alloys. When open riser are used it is often possible to pour through the riser, thereby ensuring that the hottest metal will be in the riser.

**7.5 Define the term reverse shrinkage**

Evaluation of gases in later stages of solidification causes to expansion of the solidified metal and it counter acts the normal shrinkage. This phenomenon is called reverse shrinkage. Phase changes also sometimes cause to occurrence of reverse shrinkage.

**7.6 Explain the different casting defects in copper castings with remedial measures**

**Blowhole:**

Blowhole is a kind of cavities defect. Gases entrapped by solidifying metal on the surface of the casting, which results in a rounded or oval blowhole as a cavity. It is frequently associated with slags or oxides.

Causes:

* Inadequate core and mold venting
* Excessive release of gas from core and molds
* Excessive moisture absorption by the cores and molds
* Low gas permeability of the core and mold sand

Remedies:

* Improve venting of cores and molds by providing venting channels
* Reduce amount of gas by reducing the quantity of binder
* Use coarser sand for improving of permeability of molds and cores
* Use dry cores

**Sand burning and Metal Penetration:**

Thin sand crusts firmly adhering to the casting. The defect occurs to a greater extent in the case of thick-walled castings and at high temperatures.

Causes:

* Uneven mould compaction
* Uneven distribution of inflowing metal with resultant over-heating
* Temperature of liquid metal too high

Remedies:

* + Ensure uniform compaction.
  + Even out incoming metal flow
  + Reduce pouring rate
  + Reduce liquid metal temperature

**Sand and slag inclusions or scabs:**

Causes:

Uneven compaction of moulds

Low compactability

Pouring rate too high, with heavy impact against mould wall surface resulting in erosion Ladle too far above pouring basin

Pouring time too long

Remedies:

Raise compactability and thus plasticity of the sand

Avoid high pouring rates and impact of metal stream against mould walls

Shorten pouring times

Improve metal distribution at gates

**Cold shut and Mis-runs:**

Cold shut and mis-runs are round cracks or voids in castings formed due to faulty feeding system of the castings. Cold shut is because of low melting temperature or poor gating system. When the metal is unable to fill the mould cavity completely and thus leaving unfilled portion called mis-run. A cold shunt is called when two metal streams do not fuse together properly.

Causes:

Lack of fluidity in molten metal

Faulty design

Faulty gating system

Remedies:

Adjust proper pouring temperature

Modify design of the castings

Modify gating system

**Gas porosity:**

The gas can be from trapped air, hydrogen dissolved in molten metal, moisture from molds and cores produce small gas holes (i.e. porosity) in the casting.

Causes:

Metal pouring temperature too low

Insufficient metal fluidity e.g. carbon equivalent too low

Pouring too slow

Interruption to pouring during filling of the mould

High gas pressure in the mould arising from molding material having high moisture and/or volatile content

Low permeability of the molds

Metal section too thin

Inadequately pre-heated metallic moulds

Remedies:

Increase metal pouring temperature

Modify metal composition to improve fluidity

Pour metal as rapidly as possible without interruption

Improve mould filling by modification to running and gating system

Reduce gas pressure in the mould

Adequate venting of moulds and cores

Modify casting design to avoid thin sections

Ensure metal moulds are adequately pre-heated and use insulating coatings.

**Shrinkage:**

Shrinkage defects occur when feed metal is not available to compensate for shrinkage as the metal solidifies.

Causes:

Volumetric contraction during solidification causes to form shrinkage. Most of the non ferrous metals show more shrinkage than ferrous metals due to high freezing range.

Faulty molding design and gating system also cause to form more shrinkage.

Remedies:

Use of risers

Adopt directional solidification

Proper casting design and gating design

**8. Steel Foundry Practice (1 short and 1 essay)**

**8.1 State the moulding processes used in steel foundry.**

Moulding processes used in foundry are:

* + Green sand molding
  + Dry sand molding
  + Core sand molding
  + Shell molding
  + Investment molding
  + Ceramic molding

**8.2 State the importance of Zircon sands.**

Zircon sand (ZrSiO4) has high refractoriness, low thermal expansion, chemical inertness to the action of molten metal, high heat conductivity, and high density than silica sands.

High density prevents metal penetration. High refractoriness avoids sand burns. Low thermal expansion strengthens mould against thermal and mechanical stresses. Chemical inertness to the action of molten metal’s enhancing the finish of castings. High heat conductivity promotes quick formation of a solidified metal layer and helps in producing casting with a fine grained structure.

The unit cost of zircon sand is very high compare with silica sand, so that it is used as facing sand only.

**8.3 State the importance of mould coating in steel foundry**

The following are the advantages of mould coating in steel foundry:

* Increase the refractoriness of the mould walls
* Improves the surface finish of the mould and castings
* Reduce metal penetration and scabbing defects
* Lowers the thermal expansion of moulds and reduce mould wall movements

**8.4 State the effects of fluidity and shrinkage in the design of gates**

Fluidity of molten cast steel depends upon pouring temperature, and steel composition. Silicon improves the fluidity and chromium decreases the fluidity. Fluidity is high at higher temperatures. In general, steels have low fluidity compare with cast irons.

Proper gating design helps in compensating relatively low fluidity steel. The gating system for pouring should help to fill the mold quickly. 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. Multiple gating systems are used in steel foundry for quick fed of molten metal into mold cavity.

As soon as the metal is poured in a sand mold, the process of solidification starts. Solidification mechanism results in volumetric contraction (shrinkage) of steel castings. Liquid shrinkage of steel is compensated by liquid metal with the help of riser.

Gating system used in steel foundry by considering its low fluidity and high shrinkage are:

* + Finger ingates
  + Bottom gates
  + Step gates

Also, following rules are used in design of gates for steel castings.

* + Use gates and runners of round cross- section. They cause less surface friction and thus pass more metal per unit time than square cross- section.
  + If possible, the casting pattern should have a provision to form gates also. As compared to cut gates, gates made with pattern are less susceptible to erosion.
  + Molten steel should enter the mold cavity at as many points as possible, to minimize hot spots and to quick fill of mold cavity.

**8.5 State the 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. Some of riser functions are:

* Molten metal in the riser compensates the shrinkage as the casting solidifies.
* Promotes directional solidification
* Permits the escape of air and mold gases form the mold cavity
* Pourer can see whether the mold cavity is filled with molten metal or not

**8.6 Give the 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. Riser spacing should be carefully arranged to minimize shrinkage.

The feeding range of riser is the distance of feeding of the metal in a casting by a given riser. Riser diameter and height have effect on its feeding distance. It is also affected by end effects of casting, type of casting and its thickness. The following table gives feeding distance of riser with respect to type of casting, end effects of casting.

|  |  |
| --- | --- |
| **Description** | **Feeding distance of riser** |
| Plate ,no end effect | D= 3.6 √ T , where T is the thickness of casting |
| Bar no end effect | D= 3.6 √ T |
| Plate with end effect | 11.6 √T-5.2 |
| Bar with end effect | D=6√T |

**8.7 Explain the defects caused due to cores.**

**(a) Hot tear formation (b) Metal penetration.**

**Hot tear formation:**

They are internal or external ragged discontinuities or cracks on the internal or external surface of the castings.

**Causes:**

* Very hard molds and cores cause arising of severe stresses in the surrounding solidified steel metal leads to formation of cracks.
* Poor collapsibility of cores and molds
* Improper placement of gates and risers
* Incorrect pouring temperature
* Abrupt sectional changes of castings

**Remedies:**

* Controlling the mold and core hardness
* By improving the casting design
* Even rate of cooling all over the casting
* Selecting proper mold and core materials

**Metal penetration:**

Molten metal enters the space between the sand grains and results in an uneven and rough external surface – called metal penetration.

**Causes:**

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

**Remedies:**

* Permeability of molding sands should not be very high
* Mixed grain sized sands are used in molding
* Improves the dry strength of molding sand
* Soft ramming of molding sand should be avoided

**9. Cleaning of casting (1 short and 1 essay)**

* 1. **List out the various cleaning or fettling operations.**

Various cleaning or fettling operations of the casting are:

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

**9.2 Explain different techniques employed in removal of gates, risers.**

Different techniques employed in removal of gates and risers of the casting are:

**Chipping:**

Pneumatic (air driven) chisel hammer is used as the cutting tool. Geometry of the chisel tip and its inclination to the casting influence the cutting efficiency of the chisel. Chipping hammers are used for cutting of Cu, Brass, Bronze, Ductile cast iron, Medium and low carbon steels. Instead of an air driven (pneumatic) hammer, a chisel and a hand hammer are preferred for thin intricate jobs.

**Flogging (knocking off):**

It implies removing gates and risers from a casting by impact striking with a hammer. It is very suitable for brittle material such as gray and white iron. Since gates are broken by impact there is a danger of break extending into the casting. The break extending can be avoided by notching the ingate ahead of the casting.

**Shearing:**

The removal of gates and risers are carried out on a shearing machine. It can take up only small castings. It is fast and economical. Shearing can be used for the castings of Brass, Bronze, Aluminum, Magnesium, and Malleable iron.

**Sawing:**

Different kinds of saws are used for removing of gates and risers from the casting. Hand operated hack saw is employed in small non ferrous foundries. Other types of saws are power hack saws, band saws, and circular saws. These are used for large size castings.

**Abrasive wheel slitting:**

Abrasive cut–off wheels are employed for removing of gates and risers of castings. They cut hard or difficult to saw alloys as well as more common foundry alloys, such as Gray cast iron, Malleable cast iron, Ductile iron, and Steel. This process is very rapid and results in smooth cuts. But, It is more expensive as compared to other methods.

**Machining:**

Gates and risers are conveniently removed by machining. Much smoother cuts can be obtained with machine cutting. Machine cuts need no further finishing. It is very suitable for removing large size gates and risers.

**Flame cutting:**

Large size and irregular shape gates and risers are very conveniently removed by Oxyacetylene cutting torches. The torch can be easily manipulated at different angles and positions. Cutting by this method is a combination of melting and oxidation to form slag. This process used for metals such as Steel, gray cast iron, malleable, ductile cast iron.

**Plasma cutting:**

It is now being increasingly used to removing of gates and risers of castings. It cut gates and risers of plate shaped castings. This operation is fast, clean and accurate. Programmable robots for handling and manipulating the casting can be adopted in this process.

**9.3 Explain the various surface cleaning operations.**

Castings are trimmed to remove fins, chaplets, and wires from the casting surface. The following methods are to clean surface of the casting.

**Tumbling:**

Castings to be cleaned put in a large shell or barrel. It is closed at its ends by cast iron lids. Barrel is supported on horizontal trunions. Barrel is rotated at a speed of 25 – 50 rpm. Small piece of white iron called “stars” are charged along with castings. These stars help in cleaning and polishing of the castings. 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 of castings are getting eliminated. Internal stresses in the casting are relieved. Fragile nature castings not suitable for tumbling

**Blasting:**

It is of 2 types:

* Cleaning with impact of compressed air (sand blasting)
* Cleaning with mechanical impact (shot blasting)

A high velocity stream of compressed air along with the sand or steel grit is blasted against the casting surface. The castings are mounted on a rotating table. Sand or Steel shots with very high velocity hitting the casting surface with enormous impact. This is more efficient and gives good polish of the castings. It is adopted for both fragile and large size castings.

**9.4 Differentiate between Tumbling & 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 shots |
| 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. |

**9.5 Describe the Trimming operations.**

After initial surface cleaning, the castings are trimmed to remove fins, gate and riser pads protruding beyond the casting surface. Trimming is carried out either by chipping or grinding.

**Chipping:**

Pneumatic chipping hammers are used to remove fins, gate and riser pads, wires and cores. A variety of hammers and chisels with different sizes are used for various casting alloys. Conveyors are used to transport the castings to chipping stations. 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 the 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, sand belts, and cutoffs may be used for trimming of castings.

**9.6 Mention the Finishing operations.**

Finishing of castings is latter stage in cleaning of the castings. The finishing is resorted in order to remove any excess metal if left on the casting. Finishing improve surface finish and appearance.

Different finishing operations are:

* Grinding
* Rotary filing
* Machining
* Polishing
* Chemical treatment
* Brushing
* Buffing
* Blasting
* Painting.

**9.7 Define the term Salvage of castings.**

Salvage of casting means repairing of defective castings by suitable means and put to use. All castings cannot be produced defective free at all times. Factor affecting salvage of casting are composition of casting alloy, size and shape of casting, and relative cost of the new casting versus repairing the defective casting.

**9.8 List out various Salvage Techniques.**

Various salvaging techniques employed for repairing defective castings are:

* + Welding (The most common technique)
  + Brazing, braze welding and soldering
  + Burning on
  + Patches and plugs
  + Caulking and impregnation

**9.9 State different inspection methods**

Inspection means check the quality of the castings for their acceptance or rejection. Different inspection methods are:

* + Visual, surface inspection for foundry defects
  + Dimensional, requiring gauges for measurements
  + Metallurgical inspection of castings
  + Non-destructive testings such as Radiography, Magnetic particle testing, Penetrate test, Ultrasonic testing