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CMR Institute of Technology, Bangalore
DEPARTMENT OF MECHANICAL ENGINEERING
II - INTERNAL ASSESSMENT

Semester: 4-CBCS 2018
Subject: METAL CASTING AND WELDING (18ME45B)
Faculty: Ms Shreyas P

Date: 23 Jun 2021
Time: 01:00 PM - 02:00 PM
Max Marks: 50

Instructions to Students :

Answer all the questions

Answer All Questions

Q.No		Marks	CO	PO	BT/CL
1	With a neat sketch explain the construction and working of a Cupola Furnace.	15	CO3	PO1,PO2,PO10,PO11	L2
2	With neat sketches explain slush casting and centrifugal casting.	15	CO4	PO1,PO2,PO10,PO11	L2
3	With a neat graph explain the process of solidification of pure metals.	10	CO4	PO1,PO2,PO10,PO11	L1
4	Explain any 4 sand casting defects with the help of neat sketches, in your explanation include the causes, features and remedies for those defects.	10	CO5	PO1,PO2,PO10,PO11	L1

1.

2.15 CUPOLA FURNACE

A cupola is a vertical cylindrical furnace used for melting ***only*** cast iron. Although other furnaces are capable of melting cast iron, the largest tonnage of cast iron is melted in cupola furnace. Figure 2.15 shows a cupola furnace.

Construction

- Cupola consists of a cylindrical steel shell lined with a refractory material like firebrick and clay.
- The height of the furnace may range from 20 – 35 feet, while its diameter ranges from 10 – 50 inch. The furnace is open at both its top and bottom.
- At the bottom of the furnace, hinged insulated doors are provided, so that after melting is completed, the contents left inside the cupola can be dropped down by opening the hinged doors. The iron prop supports and helps in closing and opening of the hinged doors.
- A coarse refractory sand and clay are rammed slightly on the bottom doors. The sand is rammed in a tapered manner to allow the flow of molten metal easily through the tapping spout.
- Opposite to the tapping spout and little higher is a ***slag hole*** through which the slag *is removed*.
- Slightly above the slag hole is the wind box and tuyeres. The tuyeres are small openings (covered by wind box) through which air under pressure is forced into the furnace from the wind box, via a pipe from the blowing equipment.
- At the top end of the shell, a charging door is provided through which the charge is fed into the furnace.

Working

a) Starting the cupola

Initially, soft and dry wooden pieces are placed on the sand bottom after which coke is charged up to the tuyere level. The wooden pieces are *ignited* through the tap hole and sufficient air is passed through the tuyeres for proper combustion of coke.

b) Charging cupola

The charge used in cupola consists of alternate layers of *coke*, *flux* and *metal (iron)*. These three components are continuously built into the furnace as shown in figure. The most commonly used iron-to-coke ratio is 8:1. The flux may be limestone ($CaCO_3$), fluorspar, sodium carbonate or calcium carbide. Limestone is the commonly employed flux. The total weight of the flux will be approximately 1/5th the weight of the coke charge.

c) Melting

Cupola works on the counter current principle. As the combustion takes place, the charge materials (coke, flux and metal) will be descending downwards, while the hot gases due to combustion will be ascending upwards. Heat exchange takes place between the rising hot gases and the descending charge thereby melting the metal. The liquid metal drops down, while the coke floats up on top of it. The flux also melts and reacts with the impurities of the molten metal forming a slag. The slag floats on the surface of the molten metal thereby preventing oxidation of the metal.

Supply of air at suitable intervals accelerates the combustion process.

d) Tapping slag and molten metal

When sufficient liquid metal is collected in the reservoir, the slag door is opened and the slag floating on the surface of the molten metal is tapped and disposed off. Immediately the tapping spout which was closed with a *bott* (a clay plug) is opened and the liquid metal is tapped into ladles. When the ladle is filled with liquid metal, the tapping spout is again closed with the bott.

The liquid metal from the ladle is poured into the moulds.

e) Dropping down the bottom

When melting is complete and no more liquid metal is required, the charging of cupola is stopped. The prop under the bottom door is knocked down and the bottom door is swung out of the way allowing the contents in the cupola to drop down. The un-melted charge is collected and used during the next melting.

2.15.1 Zones of Cupola Furnace

The various zones in a cupola are shown in figure 2.15 and are discussed as follows :

(a) Well zone

Well zone is the portion situated between the rammed sand bottom and just below the bottom edge of the tuyeres. The molten metal is occupied in this zone.

(b) Combustion zone

The combustion zone or oxidizing zone is situated normally 15 – 30 cm from the bottom edge of the tuyeres. It is in this zone where rapid combustion of coke takes place due to which a lot of heat is

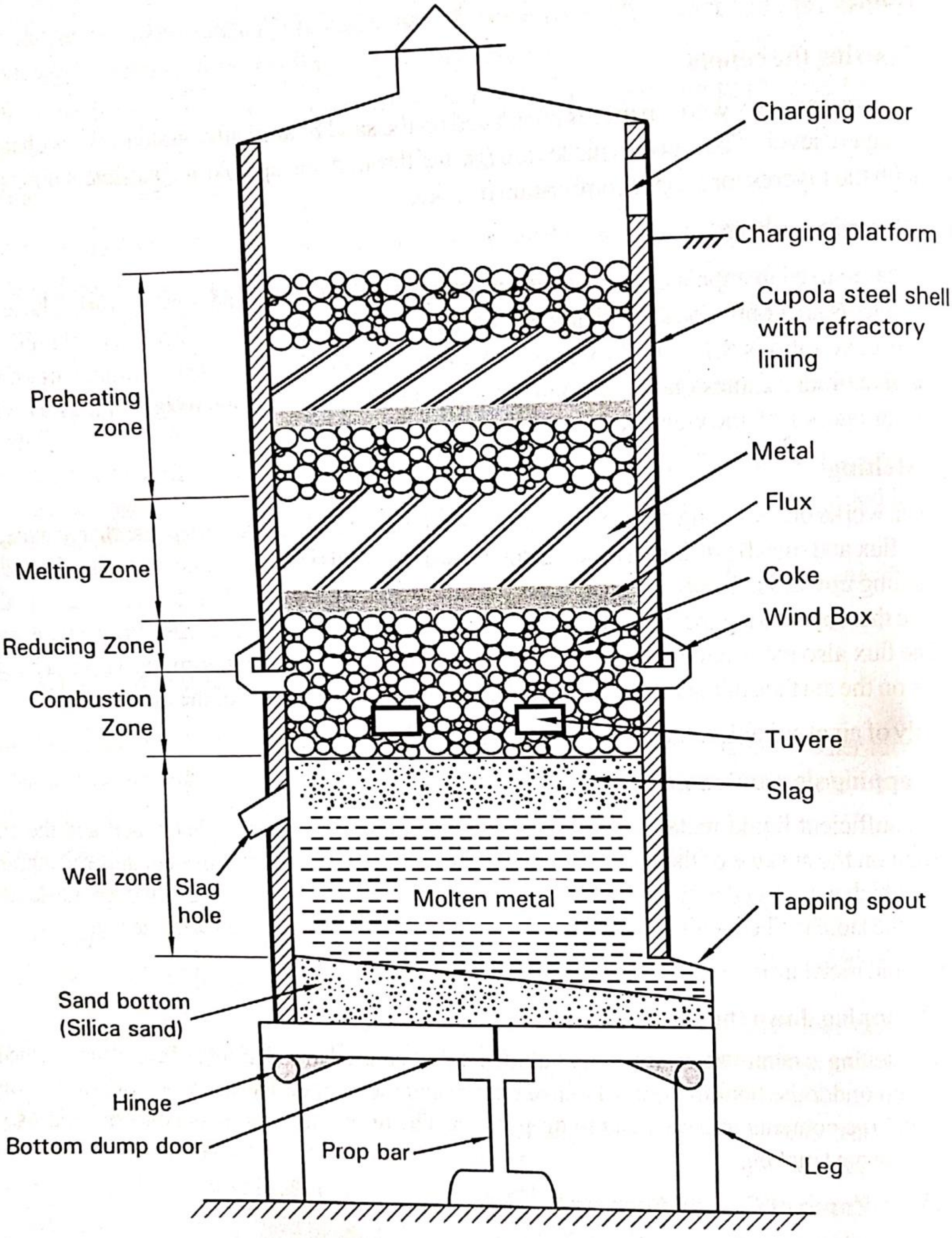


Figure 2.15 Cupola furnace

generated in the furnace. The combustion is rapid due to the supply of blast air through the tuyeres. Oxidation of manganese and silicon evolve still more heat. The reactions that take place in this zone are:

$$C + O_2 \text{ (from air)} \rightarrow CO_2 + \text{heat}$$
$$2Mn + O_2 \rightarrow 2MnO + \text{heat}$$
$$Si + O_2 \rightarrow SiO_2 + \text{heat}$$

The temperature in this zone varies from 1550° – 1850°C.

(c) Reducing zone

Reducing zone or *protection zone* is the portion located from the top of the combustion zone to the top of the coke bed. In this zone, some of the hot CO_2 gas moving upward through the hot coke gets reduced to CO. In other words, reduction of CO_2 to CO occurs in this zone. Due to the reducing atmosphere, the charge is protected from oxidation. The reaction taking place in this zone is given by:

$$CO_2 + C \text{ (coke)} \rightarrow 2CO - \text{heat}$$

Due to the reduction, the temperature reduces to around 1200°C in this zone.

(d) Melting zone

The portion located just above the coke bed to the top of the metal (iron) is called the *melting zone.* The metal starts melting in this zone and trickles down through the coke bed to the well zone. The molten iron while passing down through the reducing zone picks up carbon and the reaction is given by:

$$3Fe + 2CO \rightarrow Fe_3C + CO_2$$

(e) Preheating zone

The portion occupied from the top surface of the melting zone to the charging door is called *preheating zone.* The hot gases rising upwards from the combustion and reducing zone gives its heat to the charge before passing out of the furnace. Thus, the charge is preheated before descending downwards.

2.

2.5.1 True Centrifugal Casting

True centrifugal casting is used to produce parts that are symmetrical about the axis, like that of pipes, tubes, bushings, liners and rings. The outside shape of the casting can be round, octagonal, hexagonal etc., but the inside shape is perfectly (theoretically) round due to radially symmetric forces. Hollow castings can be effeciently produced by this process without the need for cores. Figure 2.5 shows the true centrifugal process.

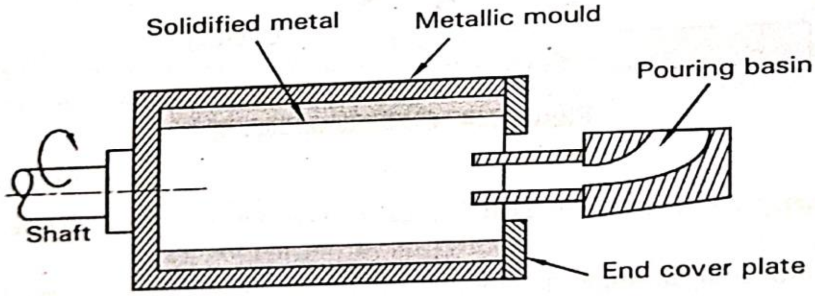


Figure 2.5 True centrifugal process

Steps involved in the process

a) The mould of the desired shape is prepared with metal, and the walls are coated with a refractory ceramic coating.

b) The mould is rotated about its axis at high speeds in the range of 300 – 3000 rpm. A measured quantity of molten metal is poured into the rotating mould.

c) The centrifugal force of the rotating mould throws the liquid metal towards the mould wall and holds the molten metal until it solidifies.

d) The casting cools and solidifies from its outer surface towards the axis of rotation of the mould thereby promoting directional solidification.

e) The thickness of the casting obtained can be controlled by the amount of liquid metal being poured.

An inherent quality of true centrifugal castings is based on the fact that, the non-metallic impurities in castings being less dense than the metal, are forced towards the inner surface (towards the axis) of the casting due to the centrifugal forces. These impurities can be machined later by a suitable process (say boring operation).

Slush casting is a process in which hollow castings are produced without the use of cores. However, the process is *not preferred* to produce objects for engineering use, instead, it is used to make objects like statues, toys, lamp base, candle sticks and others, where only the external features of the object are important. Refer figure 2.9(c).

Steps involved in the process

a) In this process, the molten metal is poured in a metallic mould and permitted to remain in the mould for a short interval of time. Refer figure 2.9(a).

b) Solidification begins at the mould walls, as they are relatively cool, and then progresses inward.

c) When a shell of desired thickness is formed, the mould is inverted, and the metal which is still in the liquid state is drained off. Refer figure 2.9(b). The thickness of the shell obtained depends on the time for which the metal was allowed to remain in the mould, and also the thermal conductivity of the mould.

d) When the mould halves are separated, a hollow casting with good features on its external surfaces, but variable wall thickness is obtained as shown in figure 2.9(c).

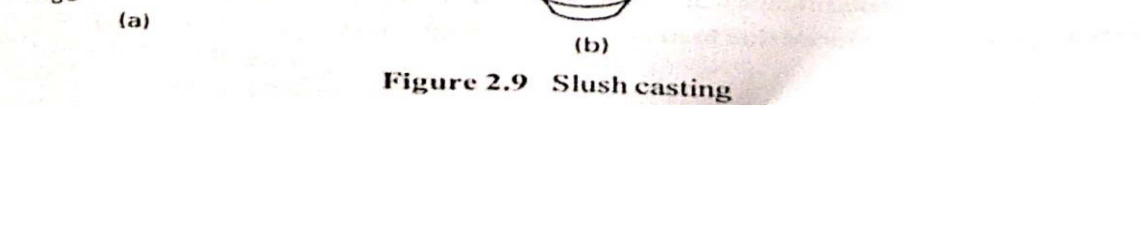
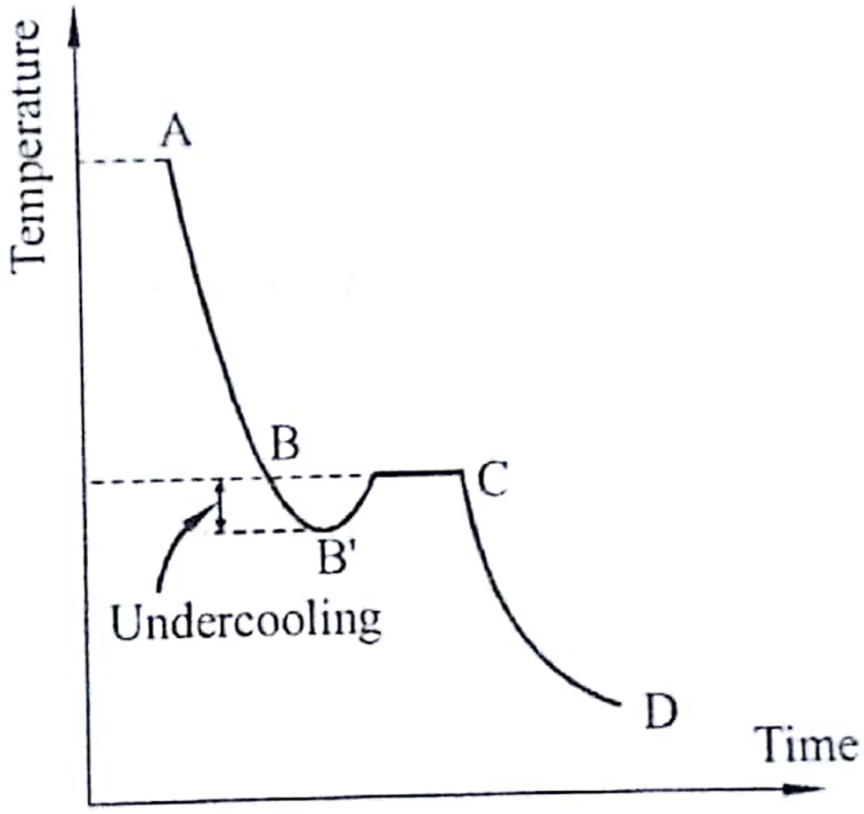


Figure 2.9 Slush casting

3.

When a pure metal is allowed to solidify under equilibrium conditions (slow cooling), the change of state from liquid to solid occurs at a fixed temperature known as the freezing point or solidification point. If the temperature of the metal is recorded at various time intervals during the cooling process, a cooling curve may be obtained as shown in figure 2.1.

Referring to figure 2.1, the point *A* on the curve represents the pouring temperature. At this point, the liquid metal starts giving up its superheat upon cooling. At a particular temperature as indicated by point *B*, the liquid melt begins to solidify. In other words, the liquid crystallizes (crystals starts to grow), and in this condition, there is a two phase mixture consisting of partly liquid and partly solid. As time progresses, a state of point is reached as indicated by point *C*, wherein the liquid is entirely converted to solid. In other words, crystallization completes at point *C*. Solidification begins and completes at constant temperature, because of the evolution of latent heat of fusion by the solidifying crystals. From point *C* to *D*, the solid metal cools to reach room temperature.



4.

Casting process involves a number of variables, and a loss of control in any of these variables can cause defects† under certain circumstances. Some of the common casting defects, their features and remedies to prevent such defects are discussed below.

(a) Shrinkage defect

Shrinkage is a void on the surface of the castings resulting from contraction or shrinkage of metal during solidification. Refer figure 3.7. Although a riser is used to over come the shrinkage effect, in some cases it fails to feed the molten metal efficiently to the casting as it solidifies.

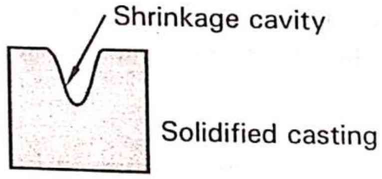


Figure 3.7 Shrinkage defect

Remedies

- Use large sprue and riser to promote directional solidification.
- Locate risers and gating systems in correct positions.
- Gates to be cut as wide as possible.

(b) Porosity defect (Blow hole and Pin hole)

Molten metal absorb gases from various sources such as fluxes, moisture in sand, binders, additives and normal atmospheric gases like oxygen and nitrogen. If these gases are not allowed to escape, they get entrapped in the mould cavity forming small balloon shaped voids or cavities leading to porosity defect in castings. Two types of gas related defects occur in castings. They are: blow hole and pin hole defect.

Blow holes occur below the surface of the castings and are not visible from the outside surface. Refer figure 3.8 (a). On the other hand, pin holes are small gas cavities, many in number at or slightly below the surface of the casting. Refer figure 3.8 (b).

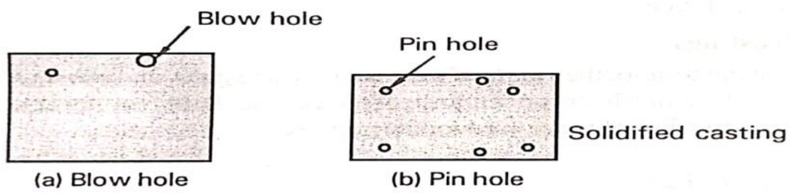


Figure 3.8 Porosity defect

Remedies

- Avoid excess ramming of mould.
- Provide proper vent holes.
- Avoid use of excess carbonaceous or other organic material in the sand/core binders, because these materials react with the molten metal producing large amount of gases.

(c) Misrun

Misrun occur when the mould cavity is not completely filled with molten metal. In other words, it is a defect wherein a casting solidifies before the molten metal completely fills the cavity. Refer figure 3.9.

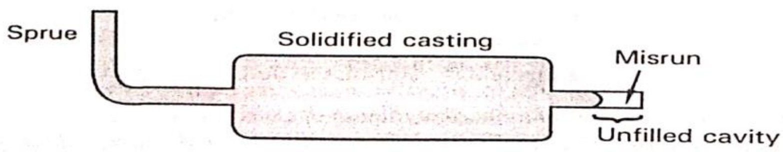


Figure 3.9 Misrun

Remedies

- Fluidity of metal should be maintained suitably.
- Pouring rate and time should be controlled.
- Thin sections should be suitable designed.

(d) Penetration

When fluidity of liquid metal is high, it may penetrate into the sand mould/core (into the voids between the sand particles). A fused aggregate of metal and sand appears on the surface of the casting leading to defect. Refer figure 3.10.

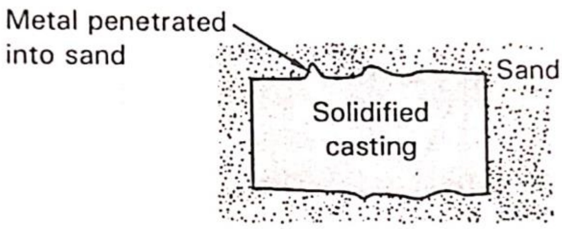


Figure 3.10 Penetration

Remedies

- Sand should be properly rammed.
- Moulding sand/core sand should not be too coarse to promote metal penetration.
- Control proper metal temperature. Fluidity of molten metal should be maintained suitably.