CBCS SCHEME

17ME35A

USN 1CR17ME015

Third Semester B.E. Degree Examination, Dec.2018/Jan.2019
Metal Casting and Welding

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. Define casting process. Explain steps involved in casting process. (10 Marks)
b. What is pattern? Discuss the importance of providing various allowances to the pattern. (06 Marks)
c. Define core. Give its classification. (04 Marks)

OR

2 a. With a neat sketch explain the working of Jolt moulding machine. (08 Marks)
b. Explain investment moulding process with necessary sketches listing its advantages and disadvantages. (10 Marks)
c. List the functions of a Riser. (02 Marks)

Module-2

3 a. Explain Hot chamber pressure die casting process with a neat sketch. (08 Marks)
b. Explain continuous casting process with a neat sketch. (08 Marks)
c. Classify melting furnaces. (04 Marks)

OR

4 a. With a neat sketch describe the construction and working of cupola furnace. (10 Marks)
b. Describe the construction and working of Direct Arc Electric furnace with neat sketches. (10 Marks)

Module-3

5 a. Define solidification. List solidification variables. (04 Marks)
b. List and explain the methods of achieving directional solidification. (08 Marks)
c. Why the degasification in liquid metals is necessary? Discuss briefly the methods of removing entrapped gases in liquid metals. (08 Marks)

OR

6 a. Name the casting defects. Explain their causes and remedies. (08 Marks)
b. With a neat sketch explain the stir casting process. (08 Marks)
c. Mention the advantages and limitations of casting process. (04 Marks)

Module-4

7 a. Define welding. Classify the welding processes. (04 Marks)
b. Explain Metal-Inert-Gas (MIG) welding process with a neat diagram. (08 Marks)
c. Explain spot welding process mentioning its applications. (08 Marks)

OR

8 a. Explain the thermit welding process with sketch listing its advantages and applications. **(10 Marks)**

b. With a neat diagram, explain electron beam welding process. Mention its advantages, disadvantages and applications. **(10 Marks)**

Module-5

9 a. Brief about formation of different zones in welding process. **(05 Marks)**

b. Define Brazing. Brief about Torch brazing process. **(07 Marks)**

c. Explain Oxy-acetylene welding process with a neat sketch. **(08 Marks)**

OR

10 a. With a neat sketch explain magnetic particle inspection method and list its advantages. **(10 Marks)**

b. Explain Radiography inspection method with its advantages and disadvantages. **(10 Marks)**

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MODULE 1

1. a.

Casting is one of the earliest metal-shaping methods known to human beings. It can also be defined as a primary shaping process, where solid metal is melted to proper temperature and is then poured into a refractory mould with a cavity of the shape to be made and allowing it to solidify for pre-determined time so as to take the shape of the mould.

- Mould sand preparation:

Mould sand mixture is prepared by using base sand, binder, water and other ingredients and this mixture is used to prepare mould cavity with the help of pattern.

- Pattern making.

It is the duplicate copy of the object to be cast and is made up of wood, metal, wax or other materials with the help of special tools. During solidification, the molten metal undergoes reduction in volume thus the size of the pattern is made larger than the product.

Patterns are required to make moulds. The mould is made by packing molding sand around the pattern.

- Preparation of mould:

Mould is produced by ramming sand mixture around a pattern placed in a support or flask, for easy removal of pattern the mould is made into two parts.

- In horizontal molding, top half box in called the cope and bottom half box is called the drag.
- In vertical molding, the leading half box is called the swing and the back half box is called the ram.

When the pattern is removed from the molding box by leaving the imprints called cavity and creating the gating/feeding system to direct the molten metal into the mould cavity.

- Core preparation:

If the casting is to be hollow, additional patterns called as core that are placed in the mould cavity to form the interior surfaces and sometimes the external surfaces as well of the casting. The shape of the core corresponds to the shape of the hollow required.

- Melting and pouring:

Metal is melted in the melting furnace. The molten metal is poured into the mould cavity and allowed to solidify. The solidification process allows the product to gain the desired properties and strength. The shrinkage in casting is controlled by the riser and proper design of the mould. The solidified metal is removed from the cavity by destroying the mould.

- Cleaning:

Includes all the operations required to remove the gates and risers that constitute the gating/feeding system and to remove the adhering sand, scale, parting fins, and other foreign material that must be removed before the casting is ready for shipment or other processing.

- Inspection & Testing
  - Inspection follows, to check for defects in the casting as well as tonsure that the casting has the dimensions specified on the drawing and/or specifications.
  - Inspection for internal defects may be quite involved, depending on the quality specified for the casting.

- The inspected and accepted casting sometimes is used as is, but often it is subject to further processing which may include heat treatment, painting, rust preventive oils, other surface treatment (e.g., hot-dip galvanizing), and machining.
- Final operations may include electrodeposited plated metals for either cosmetic or operational requirements.

b. A pattern is a replica of the product, constructed in such a way that it can be used for forming an impression of required shape and size called mould cavity in sand damp.

Pattern allowance is a vital feature as it affects the dimensional characteristics of the casting. Thus, when the pattern is produced, certain allowances must be given on the sizes specified in the finished component drawing so that a casting with the particular specification can be made. The selection of correct allowances greatly helps to reduce machining costs and avoid rejections. The allowances usually considered on patterns and core boxes are as follows:

- Shrinkage or Contraction allowance
- Draft or Taper allowance
- Machining or Finish allowance
- Distortion or Camber allowance
- Rapping or Shaking allowance

Shrinkage or Contraction Allowance

In casting process, solidification of the molten metal takes place. All the metals or alloys undergo decrease in volume during solidification. This change in volume is known as shrinkage. Shrinkage of molten metal takes place in three stages. First stage, period in which temperature falls from the pouring temperature to the liquids temperature called Liquid contraction. Second stage, period in temperature falls from liquids temperature to solidus temperature called Solidifying contraction. Third stage, period from solidus temperature to the temperature reaches to room condition called Solid contraction.

The contraction of metal during first and second stage is taken care of by providing proper gating and risering. But contraction of metal at third stage is taken care by providing positive shrinkage allowance to the pattern. Shrinkage allowance is an allowance added to the pattern, to compensate for the metal shrinkage that takes place while the metal solidifies”

Draft Allowance

Draft is meant the taper provided by the pattern maker on all vertical surfaces of the pattern so that pattern can be removed from the sand without tearing away the sides of the sand mold. Figure a. shows a pattern without draft allowance being removed from the pattern. In this case, till the pattern is completely lifted out, its sides will remain in contact with the walls of the mold, thus tending to break it. Figure b. is an illustration of a pattern with proper draft allowance. Here, the moment pattern lifting commences, all of its surfaces are well away from the sand surface.

Draft allowance varies with the complexity of the sand job. But in general inner surface details of the pattern require higher draft than outer surfaces. The amount of taper varies from 0.5^0 to 1.5^0. It may be reduced to less than 0.5^0 for larger castings. The wooden pattern required more taper than metal patterns because of the greater fractional resistance.

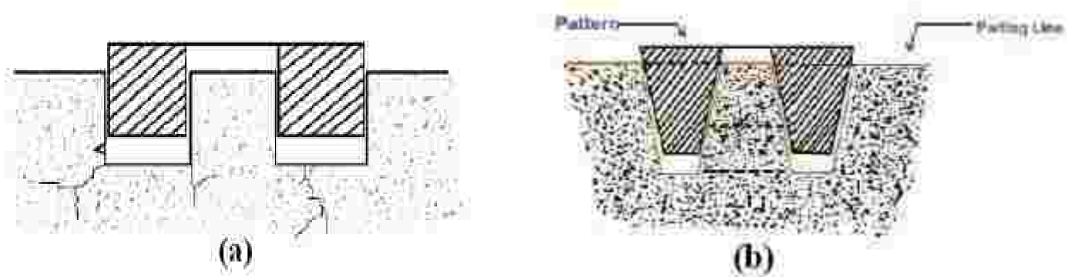


Fig- Draft allowance in pattern

Machining Allowance

For good surface finish, machining of casting is required. The dimensions gets reduces after machining. Hence the size of the pattern is made larger than the required. For machining extra metals are needed. This extra metal is called machining allowance. This allowance is given in addition to shrinkage allowance. The amount of this allowance varies from 1.6 to 12.5 mm which depends upon the following

1. Type of casting metal
2. Size and shape of casting
3. Method of casting used
4. Method of machining employed
5. Degree of finish.

Distortion Allowance

Sometimes castings get distorted, during solidification, due to their typical shape. For example, if the casting has the form of the letter U, V, T, or L etc. It will tend to contract at the closed end causing the vertical legs to look slightly inclined outward. This can be prevented by making the legs of the U, V, T, or L shaped pattern converge slightly (inward) so that the casting after distortion will have its sides vertical.

The distortion in casting may occur due to internal stresses. These internal stresses are caused on account of unequal cooling of different section of the casting and hindered contraction. Measure taken to prevent the distortion in casting includes:

- Modification of casting design
- Providing sufficient machining allowance to cover the distortion affect
- Providing suitable allowance on the pattern, called camber or distortion allowance (inverse reflection)

Rapping or Shaking Allowance

To remove the pattern from the mould cavity, pattern is rapped with the help of draw spike so that they can be detached from the mould. But due to excessive rapping the size of the cavity in mould gets enlarged. Therefore the size of the pattern is made smaller than the casting, which is known as rapping allowance. In small and medium size casting, this allowance can be neglected. But in larger casting this allowance is considered by making the part slightly smaller than required size. This is negative allowance.

c.

Core is a body made of refractory material (sand) which is used for to produce the hollow interior in the castings. Core is prepared individually in a core box, which is inserted into the prepared mould before closing and pouring molten metal into it, for forming the holes, recesses, projections, undercuts and internal cavities.

The cores may be classified as follows

I. According to state of the core:

i. Green sand cores
ii. Dry sand cores
iii. Oil sand cores
iv. Loam cores
v. Metal cores

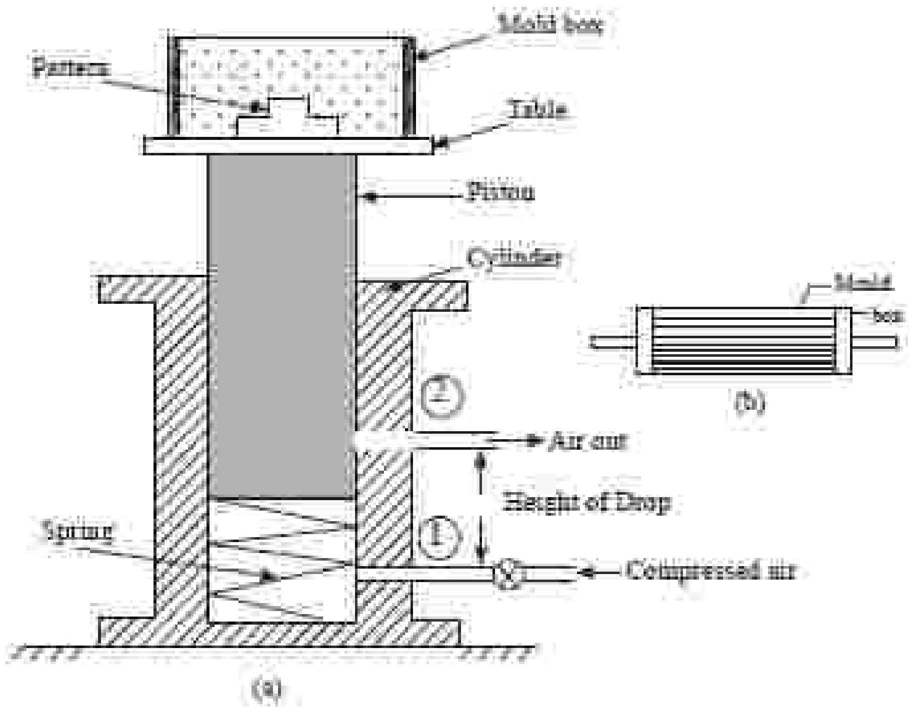
II. According to the position of the core in the mould.

i. Horizontal core
ii. Vertical core
iii. Balanced core
iv. Hanging core
v. Drop core
vi. Kiss core

2. **a**. The jolting machine consists of a piston and cylinder mechanism. The piston is located inside the cylinder that can move up and down. The cylinder is provided with two passages, one is at the bottom through which compressed air is allowed to flow into the cylinder and other at the top through which air pressure is letting out from the cylinder. The pattern plate and mould box are clamped to the flat table and the table along with mould boxes are mounted on a piston. The machine is firmly fixed on concrete base. Schematic arrangement of jolting machine is shown in Fig.

Operation

1. Initially, the flask with pattern is filled with Molding sand completely up to the top surface.
2. Compressed air is supplied to the cylinder through the bottom passage, it raises the piston.
3. When the piston base passes the top passage, air escapes out causing drop of pressure inside the cylinder.
4. Then the piston drops down to the initial position due to its own weight (under gravity).
5. Because of sudden drop of piston, jolting action takes place on the sand and then sand in flask gets compacted. The process is repeated several times to achieve a desired hardness in the mould.
6. In this machine the maximum hardness is achieved nearest to the pattern plate, but molding sand at the top does not get fully compacted as shown in Fig 1.16 (b). Similarly cope box is also prepared by this way.



b.

This process is also known as low wax process or precision casting. In this process a disposal type of pattern is used like wax pattern which subsequently melted from the mould, leaving a cavity having all the details of the original pattern. In this process, refractory sand slurry is prepared by using -325 mesh silica flour with a binder ethyl silicate or colloidal silica etc., accelerator (HCL) and water.

Steps involved in process

1. Pattern making: The investment casting process begins with the production of wax pattern of the desired casting. Pattern is prepared by injecting molten wax into the metallic mould and allows cooling for some time as shown in Fig a. After solidification the wax takes the shape of the cavity. Metallic mould gives a smooth surface finish and long life.
2. Assemble the wax patterns*:* Depending on the application multiple wax patterns may be created and then assembled into one complex pattern so that they can all be cast at once. These multiple patterns are attached to a common wax sprue, and gating system which forms the cluster or tree of patterns as shown in Fig.b.
3. Investment**:** The ceramic mould, known as the *investment*, is produced by three repeating steps: coating, stuccoing, and hardening.
   I. The first step involves dipping the cluster of patterns into slurry of fine refractory material and then letting any excess drain off, so a uniform surface is produced. This fine material is used first to give a smooth surface finish and reproduce fine details.
   II. In the second step, the cluster is *stuccoed* with a coarse ceramic particle, by dipping it into a fluidized bed, placing it in a rainfall-sander, or by applying by hand.
   III. Finally, the coating is allowed to harden.

   These steps are repeated (6-8 times) until enough layers (5-15 mm thickness) must be formed to build a shell strong enough to with stand subsequent operations as shown in Fig c.

4. Dewaxing: The investment is then allowed to completely dry, which can take 16 to 48 hours. Drying can be enhanced by applying a vacuum or minimizing the environmental humidity. The coated wax assembly is inverted and the shell is heated around 1000^0C to 1200^0C to remove wax as well as to improve the strength of shell as shown in Fig d. The collected wax is then reused.
5. Mould preparation: The prepared investment mould shell is placed in a flask and the backing sand material is rammed around the shell to give support in a flask. Now the mould is completely ready to receive the molten metal.
6. Pouring: The molten metal is poured into the shell through a funnel- shaped pour cup and flows down by gravity, through the gates and into the part cavities as shown in Fig e. As the metal cools, the parts, gates, sprue and pouring cup become one solid casting. After the casting has cooled, the ceramic shell is broken off and the parts are cut from the sprue.

Advantages

1. Gives smooth surface finish
2. High dimensional accuracy.
3. All metals or alloys can be cast.
4. Completely machining is eliminated
5. Casting produces are defect free
6. Very thin sections and complex shape can be easily produced

Dis-advantages

1. Suitable only for small size casting and expensive.
2. Process is relatively slow
3. Process is expensive
4. Difficult to separate the refractory from the casting

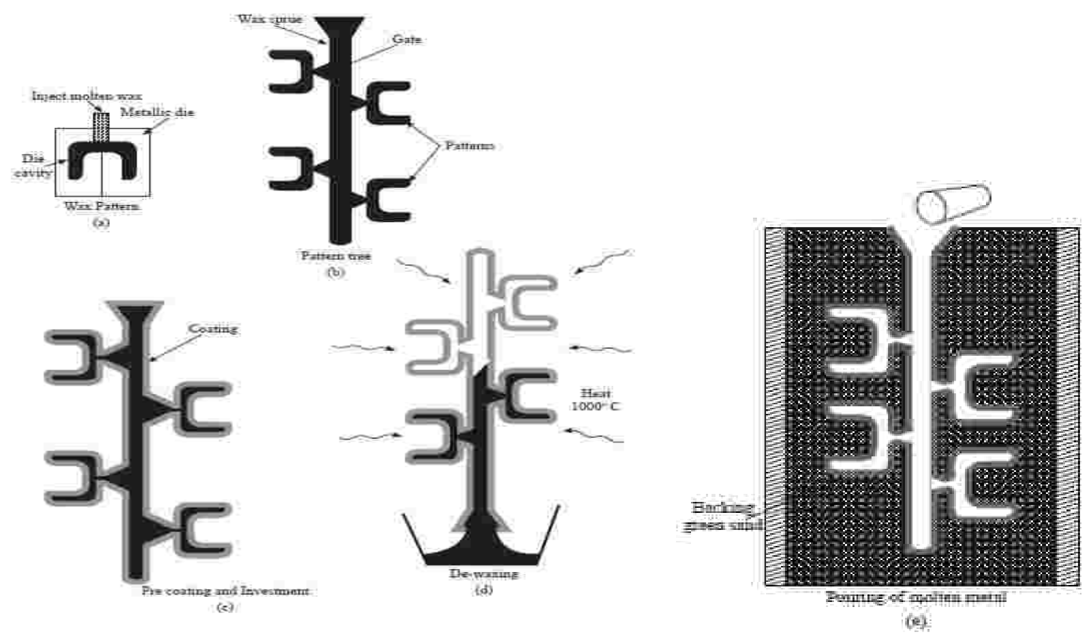


Fig -Investment Mold Process

c.

- Provide extra metal to compensate for the volumetric shrinkage.
- Allow mold gases to escape
- Provide extra metal pressure on the solidifying mold to reproduce mold details more exact

MODULE 2

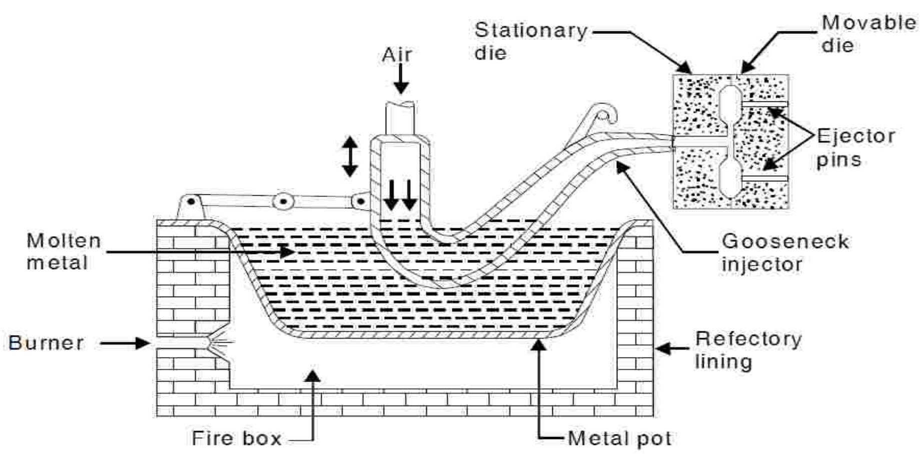
3. a.

In hot chamber die casting process, molten metal container is placed inside the machine itself and the container is heated continuously so as to keep the metal in a molten state throughout the operation, hence the name hot chamber die casting. It consists of metallic dies are made into two halves, in which one half is fixed die and other half is movable die. Both dies are aligned in position with the help of ejector pins. In this method, less pressure is required to force the molten metal into mould cavity because molten metal possesses normal amount of superheat.

Hot chamber die casting method uses two different arrangements to force the molten metal into mould cavity are as follows.

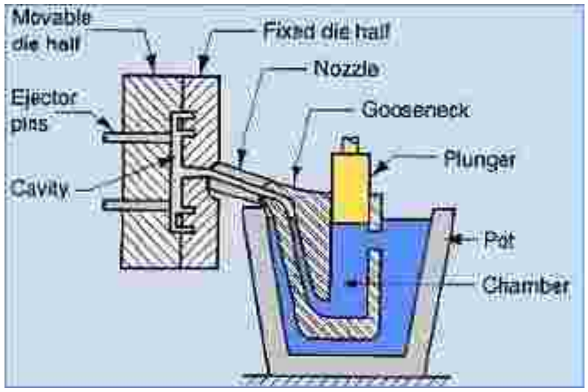
I. Goose neck or air injection type
II. Submerged plunger type

I. Goose neck or air neck injection type: In hot chamber die casting method, the goose neck melting pot is included within the machine and it is operated by a lifting mechanism. Initially goose neck is immersed in the molten metal and is filled by gravity. Then it is raised so as to bring the nozzle in contact with die opening and is locked in that position. Compressed air is then supplied from the top of the neck to force the molten metal into the mould and pressure is maintained till solidification. When solidification is complete, goose neck is lowered down to eject the casting with the help of ejector pins. Figure shows goose neck type hot chamber die casting.



II. Submerged plunger type

Figure shows submerged plunger type casting machine, the goose neck melting pot is always immersed within the machine and the molten metal from the container is forced into the mould by plunger pressure. It is operated either by air pressure or hydraulic pressure. Initially plunger is moved up, fills the container with molten metal and is then moves down, which forces the metal into the mould cavity. The metal is held under pressure until it solidifies. When solidification is complete, casting is ejected out with the help of ejector pins.



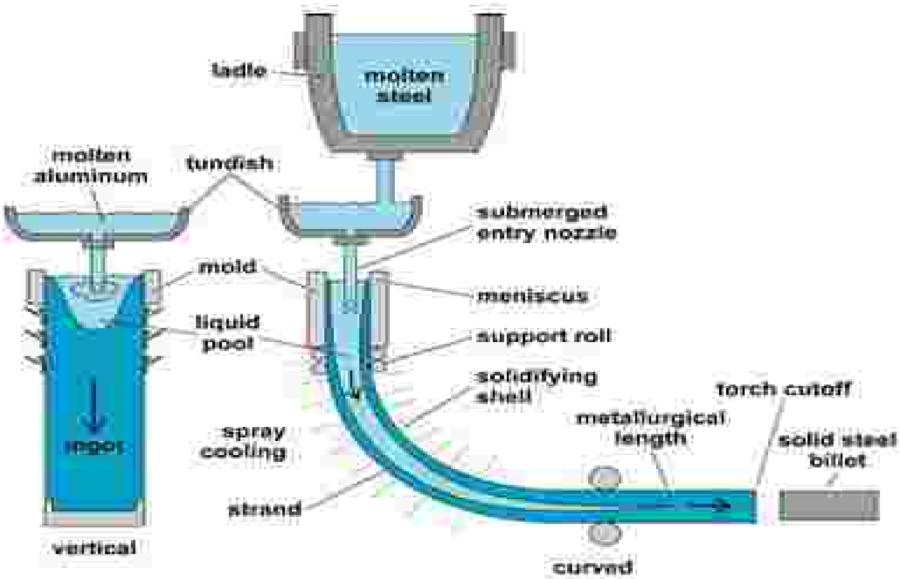
b.

In this method, molten metal is continuously poured into the mould at one end and solid metal is drawn from the other end. Solidified metal is continuously cut to the desired length. The following processes are commonly used for continuous casting of various metals and alloys.

a) Asarco process
b) Reciprocating process
c) Direct sheet moulding

A continuous casting produces higher quality steels for less cost. Normally the continuous casting arrangement is vertical and it involves the following procedure. Figure shows continuous casting process.

1. The molten metal is prepared by conventional melting process and is transferred to ladle, where it is cleaned and equalized in temperature by blowing nitrogen gas through it for 5 to 10 minutes.
2. Intermediate ladle called tundish is used and lined with insulating boards, where impurities are skimmed off, which allows controlled flow of molten metal into the mould and is located above the mould.
3. Mould used is made up of copper or graphite and is open at both ends. Water cooling arrangement is provided to extract heat from the molten metal.
4. In operation, before the casting process start, bottom of the mould is covered by a dummy bar. Molten metal from the tundish enters the mould and it falls on the bar.
5. Then molten metal starts filling into the mould. The water is continuously extracting the heat from the molten metal, so that it solidifies before it leaves the mould. A skin of solid metal forms at the mould metal interface.
6. First metal on the dummy bar forms a solid mass of metal and as the bar moves downward further metal starts solidifying and is pulled out of the mould.
7. The solidified metal is continuously extracted with the help of dummy bar and it is made to pass through the pinch rollers. Finally the solid metal is cut into the desired lengths by shearing or torch cutting.



- Advantages
  1. No wastage of metal.
  2. No riser, no runner and no gates used
  3. Continuously casting process takes place which is not possible from other process.
  4. Process is complete automatic.
  5. Directional solidification is present; the casting will have superior properties.
- Dis-advantages
  1. Continuous and capable cooling of moulds is required; else, center-line shrinkage develops.
  2. Just simple shapes can cast, which should have a stable cross-section.
  3. High capital investment is necessary to set up process.
  4. Not suitable for small quantity production.
  5. Required more floor space.
  6. Cost of produce is in the higher ride.

c.

A) Based on type of metal to be melted

I. Ferrous metals & alloys
- Cast iron
  1. Cupola
  2. Reverberatory furnace
  3. Rotary furnace
  4. Electric arc furnace
- Steel
  1. Open hearth furnace
  2. Electric arc furnace
  3. Converter

II. Non-ferrous metals & alloys

- Fuel fired furnaces
  1. Crucible furnace
     - Pit furnace (oil, coke & gas fired)
     - Tilting & Non tilting type
     - Electric resistance type
  2. Reverberatory furnace stationary & tilting
  3. Rotary furnace
  4. Induction furnace
     - Low frequency
     - High frequency
  5. Electric arc furnace

III. Based on the type of heat furnace

- Fuel fired furnace
  1. Coke fired pit furnace
  2. Gas fires pit furnace
  3. Oil fired pit furnace
  4. Cupola
- Electrical furnaces
  1. Electric resistance furnace
  2. Electric arc furnace
     - Direct arc furnace
     - Indirect arc furnace
  3. Induction furnace
     - Low frequency
     - High frequency

4. a.

Constructional Features

- The cupola consists of a vertical cylindrical shell made of 10 mm thick steel plate. The furnace is lined inside with acid refractory bricks. The lining is generally thicker in the lower portion of the cupola as the temperature is higher than in upper portion.
- The diameter of the furnace varies from 1 to 2 meters and the height of cupola ranges from 5-10 meters.
- The bottom of the cupola is provided with two drop doors, which are hinged on two sides and are supported by a vertical rod called prop.
- On the drop bottom doors the base is prepared thoroughly ramming refractory moulding sand and clay and is made with tapered manner to allow the flow of molten metal easily thoroughly the tapping spout. Prop rod is used to open the doors to remove out the waste contents.
- A slag hole is provided to remove the slag from the molten metal and is located opposite to the tapping spout.
- There is a charging door near to the top through which coke, pig iron, steel scrap and flux is charged. At the top conical cap called the spark arrest is provided to prevent the spark emerging to outside
- The air blast is blown through the tuyeres and wind box. These tuyeres are arranged in one or more row around the periphery of cupola and are placed just above the slag hole.

Cupola zones

1. Combustion or Oxidizing zone: It is the zone where combustion takes place. It extends from the top of the tuyeres to a surface boundary below which all the Oxygen of air is consumed by combustion, chemical reaction that takes place in the zone is

$$C \text{ (coke)} + 0_2 \text{ (from air)} \rightarrow C0_2 + \text{Heat}$$

The temperature in this zone is about 1800°C.
2. Reducing zone: It extends from the top of the combustion zone to the top of the initial coke bed. The CO2 produced in the combustion zone moves up and is reduced to CO. The temperature also drops to 1650°C.

$$C0_2 + C_2 \text{ -» } CO - \text{Heat}$$

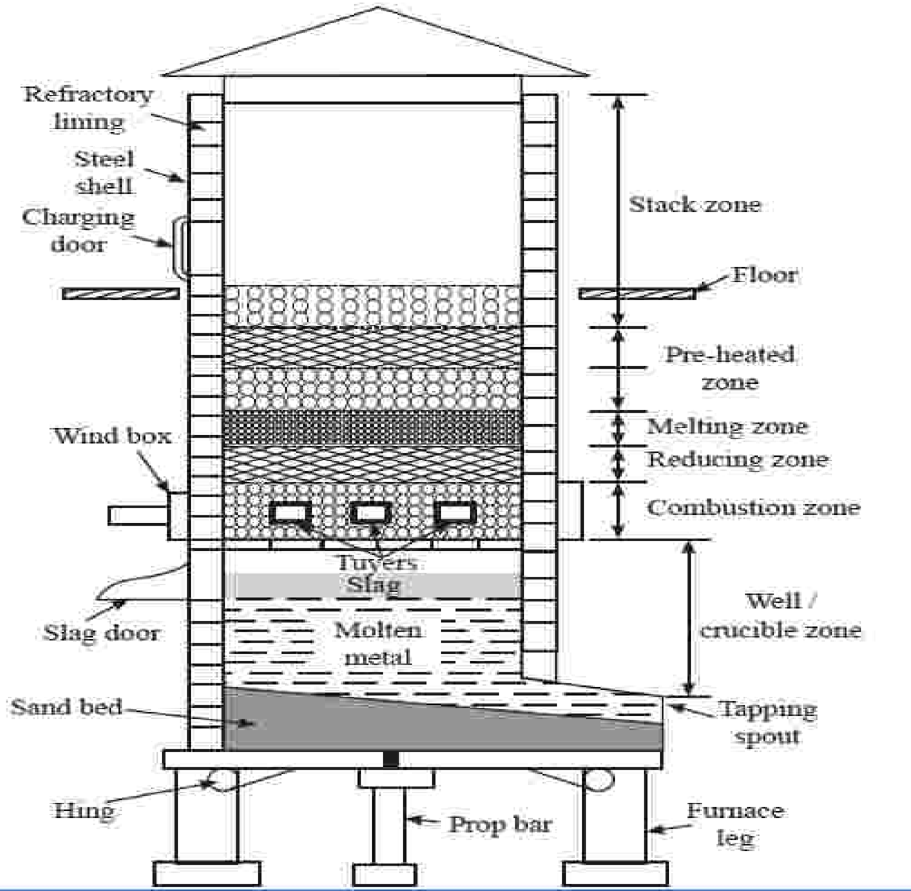
3. Melting zone: It includes the first layer of pig iron above the initial coke bed. In this zone, the pig iron is melted. The following reaction takes place.

$$3\ Fe + 2\ CO \text{ -» } Fe_3C + C0_2$$

4. Preheating zone: It includes all the layers of cupola charges placed above the melting zone to the top of the last charge. The layers of charges are heated by the out-going gases. The temperature in the zone may be up to 1050°C.
5. Stack: It is the zone beyond the pre-heating zone, through which the hot gases go to the atmosphere

Operation

1. Preparation: The slag and waste from previous melting is cleaned. The bottom doors are closed. A sand bottom is prepared sloping towards tap spout. The height of sand bed is to be about 200 mm. a tap spout is formed and lined with clay. A slag hole is prepared. The cupola is dried thoroughly.
2. Firing**:** Oiled waste and wooden pieces are placed at the bottom and fire is started. Now air is supplied into the furnace. When the wood starts burning, coke is charged in several portions. When the coke burns, more coke is added up to the tuyere level. The blast is turned off. Again coke is added upto the level of bed charge. When the coke bed burns for half an hour, the charging is done.
3. Charging: Alternative layers of coke, flux and iron metal is charged through the charging door. The metal to coke ratio by weight is about 8:1 is maintained. The commonly used flux is limestone and is added upto 25-50% by weight of the coke charged.
4. Melting: After charging the cupola with alternative layer of coke, flux and metal, the charge is allowed to preheat of about 30-45 minutes and preheating of charge takes place by heat from the burnt coke, which is supplied during firing stage. Once the coke becomes hot, it melts the metal charge. The tap spout is kept closed by a plug. The liquid metal falls down and the coke floats up on top of it. The flux also melts and reacts with the impurities of the molten metal forming a slag over a liquid metal.
5. Slagging and Tapping: when sufficient amount of liquid metal collected, slag formed on the surface of the molten metal is removed through the slag door. The tapping spout is opened and the molten metal is collected out in ladle. As the charge is melted and tapped, the charge will descending downwards and subsequent charging of coke and metal with flux is made.
6. Dropping the bottom: after completion of melting process, the air blast is shut off and the prop rod is removed, so contents in the cupola to drop down. The un-melted metal is separated out and is re-used.



Advantages

1. Charging and melting is continuous and metal is tapped out regular interval.
2. Low cost of operation
3. Low maintenance cost
4. Easy to operate
5. Construction is simple

Limitations

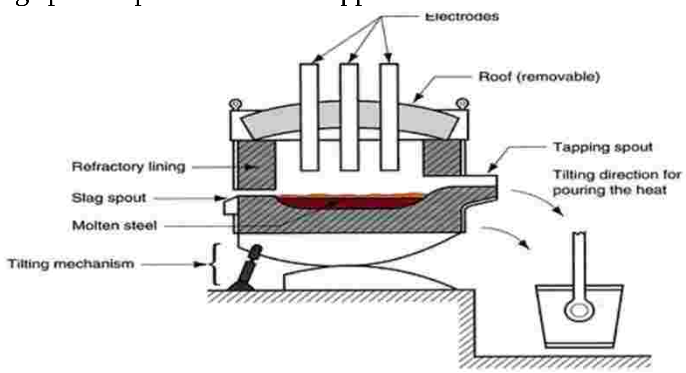
1. Difficult to attain low carbon percentage below 2.8% because of the direct contact of molten metal with fuel.
2. Temperature above 2000^0 cannot be attained.

b.

Construction

1) This furnace consists of a cylindrical shell with hemispherical bottom made of thick mild steel shell. The furnace shell is lined in the side, bottom and roof with refractory bricks to protect it from internal heat. Fig shows direct arc electric furnace.
2) The base is mounted on rollers to enable tilting of the furnace forward for pouring molten metal into ladle through pouring spout and can also tilt backward to remove slag through charging door.
3) The roof is a dished dome made of steel shell lined inside with refractory bricks, which can be opened to charge the raw materials into the furnace.

4) The roof is provided with three holes, through which non-consumable graphite electrodes are inserted into the furnace and these electrodes which in turn are connected to the 3-phase power supply.
5) The charging door is provided in the front side for observation, minor charging, slagging etc., while a pouring spout is provided on the opposite side to remove molten metal.



Working

1) The furnace is charged with raw materials through the charging door. The electrodes are lowered down and fixed at proper position.
2) The arc is produced, when the tip of the electrodes are struck with the charge metal, on supplying necessary current.
3) The suitable gap is maintained between electrodes and charge metals by regulating the movement of the electrodes so that stabilised arc is maintained between them.
4) The heat is generated by resistance offered by the charge metals to the flow of current. The arcing temperature is of about 3000^0 C, thus sufficient heat can be generated.
5) The metal below the electrodes starts melting; gradually it melts remaining metal in the furnace. As the charge starts melting, the flux reacts to form slag containing all the impurities. Once the metal reaches the required pouring temperature, the arc is disconnected by raising the electrodes.
6) Slag is removed through the charging door by tilting the furnace backward and also clean molten metal is removed through spout by tilting it forward.

Advantages

1) It has faster melting rate compared to arc furnace.
2) Energy consumption per ton melted metal is much lower.
3) Simple mechanism and lower maintenance cost.
4) Lower pollution and better working condition.

Dis-advantages

1) Refining of metal is difficult
2) Need high quality scrap
3) Need of costly capacitor bank

MODULE 3

5. a.

Solidification, also known as freezing, is a phase change of matter that results in the production of a solid. Generally, this occurs when the temperature of a liquid is lowered below its freezing point.

- Solidification time
- Solidification rate
- Temperature gradient
- Cooling rate

b.

Need for directional Solidification

To control the shrinkage, the directional solidification of metal is required. Solidification of metal should takes place from one end and progress towards the riser end. This is required to helps to feed the molten metal by the riser.

Methods of achieving Directional Solidification

Only through the directional solidification it is possible to get sound castings. Following are the methods that are employed to achieve directional solidification:

1) Use of riser to the casting
2) By use of insulating material
3) By using chills
4) By padding the casting
5) Using Exothermic compounds
6) Use of an arc over the riser.

Use of proper Riser to the casting

To obtain proper directional solidification the casting is achieved by providing proper riser system to the casting. Riser retains the molten metal for a longer time than the casting, the surface area through which heat transfer takes place must be minimum for a given volume of the riser. Fig shows this.

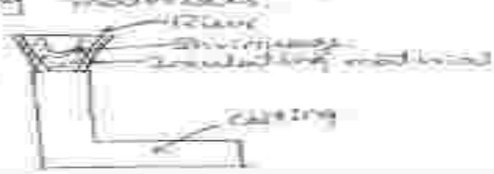
.

Casting without Riser

Casting with Riser

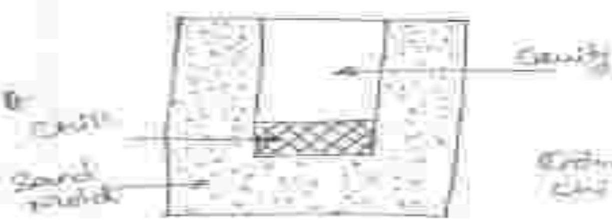
(b) Use of insulating material

To enhance the directional solidification of the casting is achieved by providing the riser system with insulating materials. Risers can be made more efficient by ~~wrapping~~ coating with insulating material which keeps the molten metal more hot compared to the freezing metal. Fig shows Riser with insulating materials.

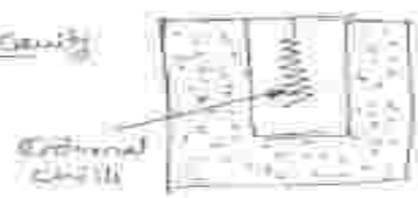


Use of chills

Some of the castings will not support the riser system, where it is not possible to locate the riser on the castings. To promote directional solidification of the castings are provided with chills. Chills are placed at an proper location in the mold to speed up the directional solidification. Fig shows this. Chills ~~may be classified as~~



(a) External chills



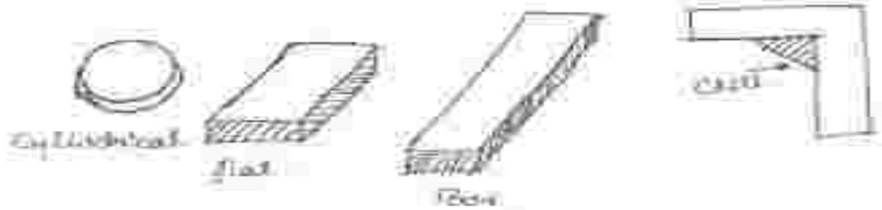
(b) External chills

Chills are of two categories

1) External chills
2) Internal chills

External chills.

These metal inserts are made of steel, cast iron & copper. It extracts the heat at faster rate. Fig. shows the different chills.



Internal Chills

External chills are not possible to locate within the castings internal chills are used and are placed at surface level. Internal chills are made up of same metal as that of casting because chills will fuse and become a part of casting. It alters the physical properties of casting. Fig. shows some of the internal chills.

c.

Minimizing Gas Dissolution

gas dissolution may be minimized by

1) charge used for melt preparation must free from rust, moisture etc,
2) keeping the furnace atmosphere clean.
3) keeping the ladle free from moisture
4) Protecting the molten metal using flux, slag, etc.

Degasification Methods.

Degasification is the process of removal of gas from molten metals or alloys.

Degasification may be carried out in different ways:

* Use of flux
* Flux washing process
* Vacuum degassing
* Degassing using inert gases
* Use of solid degassers
* others

Use of Flux

Fluxes are employed to remove the gases from the molten metal. Degasification by using flux is suitable only for non-ferrous metals.

The surface of molten metal is covered with fluxes and gas dissolution can be prevented. Mixture of alkali chloride with or without fluorides are used as fluxes.

The commonly used flux material is the ~~eutec~~ mixture of NaCl + KCl. This mixture is employed with aluminium alloy. flux lowers the surface tension of oxide films and get in between Al_2O_3 and aluminium interface. This flux mixture prevents the aluminium alloys from oxidation and forms covering layer on the molten metal and absorb gases from the molten metal.

Flux washing Process.

In this process gases from the molten metal is removed by dissolution of fluxes. Here molten metal is subjected to the agitation with flux and ensure proper dissolution of flux within molten metal. The dissolved flux material removes the gases from metal.

Ex - Flux materials which contain chlorides and fluorides of Na & Ca. The process shown in fig

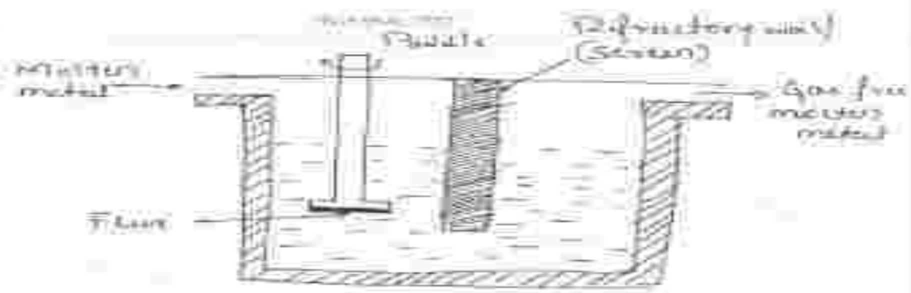


Fig: Flux washing Process

Vaccum Degassing

The gases from the molten metal can also be removed by vaccum degassing method.

The amount of gas dissolved in the molten metal is a function of partial pressure of the surrounding atmosphere.

i.e. $S \propto \sqrt{P}$

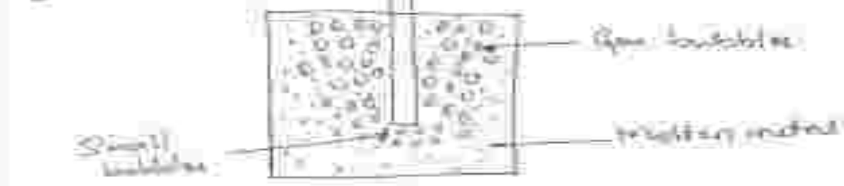
Gases from the molten metal can be removed by reducing surrounded atmospheric pressure.

Degassing Using Inert gases

Dissolved gases from the molten metal can be removed by using inert gases. Inert gases introduced into the molten metal under pressure results formation of large numbers of small bubbles within the molten metal. These bubbles creates low pressure region into which the dissolved gases gets diffuses. Bubbles along with dissolved gases floats to the top are also removed during the process.

This process is also referred as flushing of dissolved gases by inert gases is shown in fig.

Gases like nitrogen, chlorine, flourine, argon, helium are used as inert gases.



6. a.

Sand blow and Pinholes: defect consisting of a balloon-shaped gas cavity or gas cavities caused by release of mold gases during pouring. It is present just below the casting top surface.

Low permeability, bad gas venting, and high moisture content of the sand mold are the usual causes. Sand wash: surface dip that results from erosion of the sand mold during pouring. This contour is formed in the surface of the final cast part.

Scab: It is caused by portions of the mold surface flaking off during solidification and gets embedded in the casting surface.

Penetration: surface defect that occurs when the liquid penetrates into the sand mold as the fluidity of liquid metal is high, After solidifying, the casting surface consists of a mixture of sand and metal. Harder ramming of sand mold minimize this defect.

Mold shift: defect caused by displacement of the mold cope in sideward direction relative to the drag. This results in a step in the cast product at the parting line.

Core shift: displacement of core vertically. Core shift and mold shift are caused by buoyancy of the molten metal.

Mold crack: ‘fin’ like defect in cast part that occurs when mold strength is very less, and a crack develops, through which liquid metal can seep.

Misruns: castings that solidify before completely filling the mold cavity. This occurs because of (1) low fluidity of the molten metal, (2) low pouring temperature, (3) slow pouring, (4) thinner cross-section of the mold cavity.

Cold Shuts: This defect occurs when two portions of the metal flow together but no fusion occurs between them due to premature freezing.

Cold shots: forming of solid globules of metal that are entrapped in the casting. Proper pouring procedures and gating system designs can prevent this defect.

Shrinkage cavity: cavity in the surface or an internal void in the casting, caused by solidification shrinkage that restricts the amount of molten metal present in the last region to freeze. It is sometimes called as ‘pipe’. Proper riser design can solve this problem.

Microporosity: network of small voids distributed throughout the casting caused by localized solidification shrinkage of the final molten metal.

b.

c.

Advanatges

- Molten metal flows into small ant section in the molten cavity. Hence any complex shape can be easily produced.
- Practically any material can be casted.
- Ideal method is by producing small quantities
- Due to small cooling rate from all directions, the properties of casting are same in all directions.
- Any size of casting can be produced up to 200 tons.
- Casting is the often cheapest and most direct way of producing a shape with certain desired mechanical properties.
- Certain metals and alloys such as highly creep resistant metal-based alloys for gas turbines cannot be worked mechanically and can be cast only.
- Heavy equipment like machine leads, ship's propeller, etc. can be thrown easily in the required size rather than fabricating them by joining several small pieces.
- Casting is best suited for composite components requiring different properties in various direction. These are made by incorporating preferable inserts in a casting. For example, aluminum conductors into slots in iron armature for electric motors, wear resistant skins onto shock resistant components.

Disadvantages

- With normal sand casting process, the dimensional accuracies and surface finish is less.
- Defects are unavoidable.
- Sand casting is labor intensive.

MODULE 4

7. a.

Welding is a process of joining two similar or dissimilar metals by fusion. It joins different metals/alloys, with or without the application of pressure and with or without the use of filler metal.

Welding process can be classified into different categories depending upon the following criteria:

1. Oxy-Fuel Gas Welding

- Air-acetylene welding
- Oxy-acetylene welding
- Oxy-hydrogen welding
- Pressure gas welding

2.Arc Welding

- Carbon Arc Welding
- Shielded Metal Arc Welding
- Submerged Arc Welding
- Gas Tungsten Arc Welding
- Gas Metal Arc Welding
- Plasma Arc Welding
- Atomic Hydrogen Welding
- Stud Arc Welding
- Electro-gas Welding

3. Resistance Welding

- Spot Welding
- Seam Welding
- Projection Welding
- Resistance Butt Welding
- Flash Butt Welding
- Percussion Welding
- High Frequency Resistance Welding
- High Frequency Induction Welding

4. Solid-State Welding Processes

- Forge Welding
- Cold Pressure Welding
- Friction Welding
- Explosive Welding
- Diffusion Welding
- Cold Pressure Welding
- Thermo-compression Welding

5. Thermit Welding

- Thermit Welding
- Pressure Thermit Welding

6. Radiant Energy Welding Processes

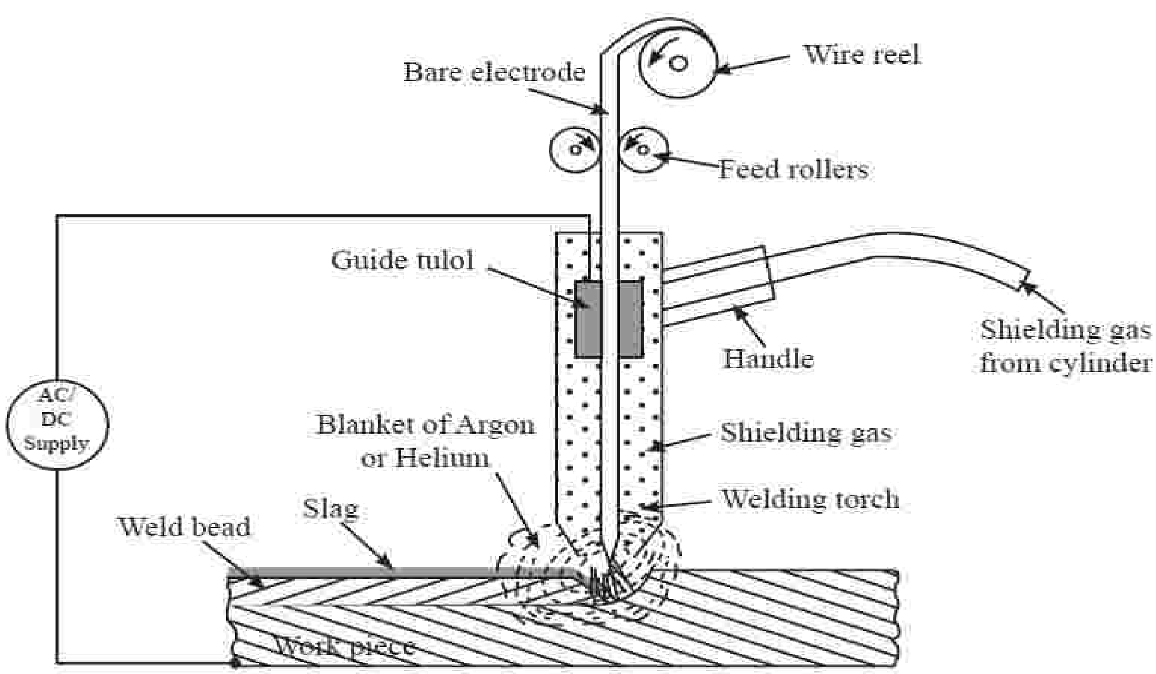
- Laser Welding

- Electron Beam Welding

b.

Main component of MIG

1. **A consumable electrode** wire of diameter 0.6 to 2.5 mm is used and is coiled on a spool.
2. **Welding torch** is used to hold the wire electrode through the contact nozzle and guided by guide tube. The electrode is fed continuously at a constant rate through the feed roller driven by an electric motor.
3. **Shielding gas cylinder:** shielding gas is flows from the cylinder to the torch, through the passage provided in the torch and then impinges on the workpiece through the torch nozzle.
4. **Welding power**: The electrode wire is connected to the positive polarity of DC source through the contact nozzle and work piece to negative polarity. The power source could be constant voltage DC power source, with electrode positive and it yields a stable arc and smooth metal transfer with least spatter for the entire current range. AC power source gives the problem of erratic arc. Figure 4.5 shows schematic arrangement of metal inert gas welding process.



Operation

1. At first the job is cleaned and all types of contaminants like grease, oil, dirt, scale and paint are removed. The surfaces of the electrodes are also made very clean.
2. Power connections and electrode feeder motor are switched ON. The inert gas supply is turned ON through the regulator.

3. An arc is then struck with the actual workpiece to be welded and instantaneously the electrode is separated from the workpiece by a small distance of about 2-4 mm so that. arc remains between the electrode and the workpiece

4. The arc thus struck both workpiece and the electrode tip melts simultaneously. The molten electrode material is combines with the molten metal of the workpiece, fills the gap between workpiece and forms the globules of molten metal.
5. Simultaneously shielding gas is impinges on the workpiece through the torch nozzle and covered the molten pool completely to protect it from atmospheric contamination.
6. The welding head is moved along the surface to be welded and the electrode at a predetermined speed is continuously fed to the joint to complete the weld.
7. As the welding is continued forward, the preceding molten metal starts solidifying and forms the strong joint between the workpiece.

Advantages of Metal Inert Gas Welding (MIG, GMAW):

- Continuous weld may be produced (no interruptions);
- High level of operators skill is not required;
- Slag removal is not required (no slag);
- Thin and thick metals can be welded.
- Suitable for welding both ferrous and non-ferrous metals.
- Process can be semi-automatic, faster and results in quality welds.
- There are no weld cracks and no weld spatter.

Disadvantages of Metal Inert Gas Welding (MIG, GMAW)

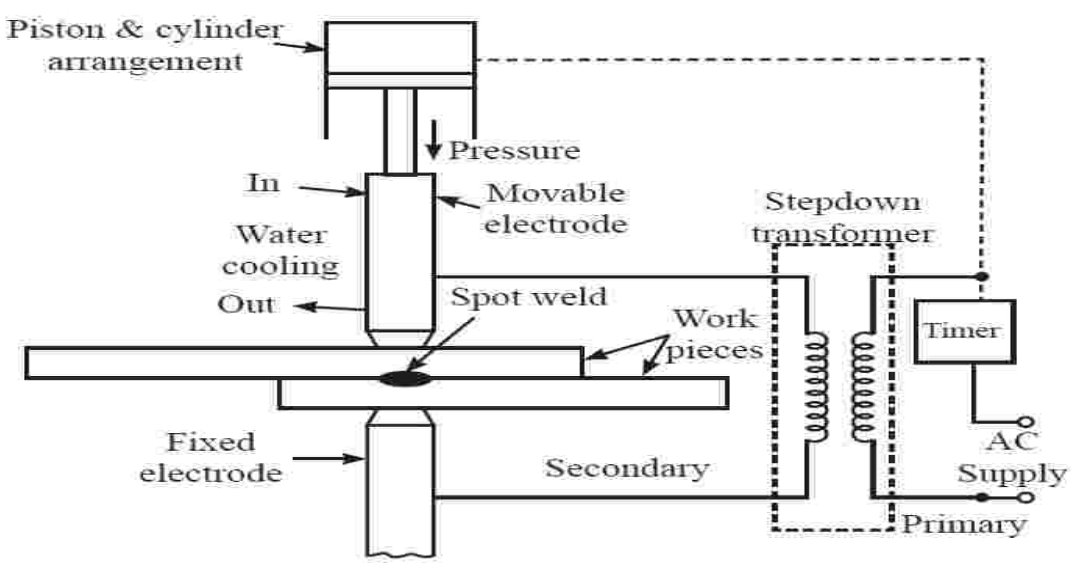
- Expensive and non-portable equipment is required;
- Outdoor applications are limited because of effect of wind, dispersing the shielding gas.

c.

Resistance spot welding (RSW) is a resistance welding process in which fusion of two or more overlapping sheets of metal are held between electrodes through which welding current is supplied for a definite time and also force is exerted on work pieces. The resistance to this current flow by weld metal causes the fusion at held region and forms a joint at localized point called spot weld. The principle is illustrated in Figure 4.8.

It consists of following parts

1. Two **water cooled cylindrical electrodes made** of alloyed **copper**, in which upper electrode is movable and lower electrode is stationary.
2. These electrodes are connected to **secondary step down transformer** with a current controlling device, which converts low current high voltage supply into high current low voltage supply.
3. **Hydraulic or mechanical or pneumatic type of Piston-cylinder** mechanism is used to apply the external pressure/force on the movable electrode.
4. **Timer,** used to control duration of flow of current to the electrodes and also controls the pressure apply.



Operation

1. The two workpieces to be joined are properly cleaned so that surfaces to be welded are free from rust, dust, oil and grease. For this purpose components may be given pickling treatment i.e. dipping in diluted acid bath and then washing in hot water bath and then in the cold water bath. After that components may be dried through the jet of compressed air.

2. Welding cycle starts with the placing an overlapped workpieces in between the electrodes and are held under pressure.

3. The welding current is switched ON and heavy current is passed between the electrodes for preset time.

4. For the current flow, heat at the area of metals in contact shall be rapidly raised to welding temperature varying from 800^0 to 950^0 C, due to maximum resistance is exists at the contact surfaces of the workpieces.

5. The heat developed fuses the workpieces at the electrode spot and in order to obtain a strong joint, external pressure is applied on the electrodes by piston-cylinder mechanism which squeezes the hot metal together thus completing the weld. In some cases external pressure is not required, holding pressure of electrodes is sufficient to create good joint.

6. The weld nugget formed is allowed to cool under pressure and then pressure is released and workpiece is moved to the next spot to make a weld. This total cycle is known as resistance spot welding cycle.

Application

1. The most common application of spot welding is in the automobile car manufacturing industry, where it is used to weld the sheet metal to form a car body and other parts. It is frequently used in the place of riveting.

2. Another application is in dental prosthesis (Orthodontics), where small scale spot welding equipment is used.

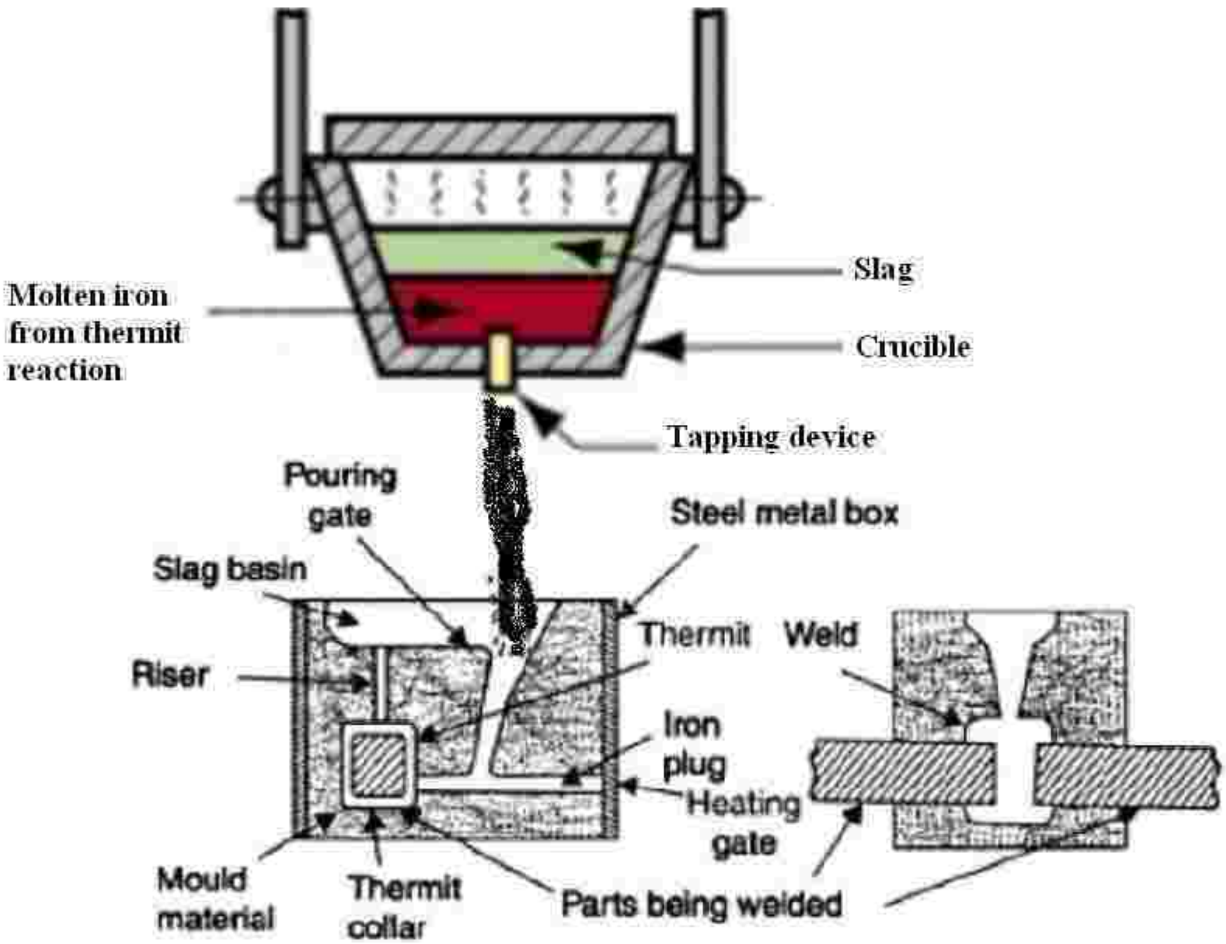
8. a.

It is a fusion welding process that makes use of intense heat generated by exothermic chemical reaction of the thermit mixture (a mixture of a metal oxide and aluminum powder). Thermit is a non-explosive mixture consists primarily of finely divided aluminium and iron oxide in the ratio of about 1: 3 by weight. Other metal oxides that can be used in place of iron oxide include oxides of Copper, Nickel, Chromium or Manganese but Iron oxide Thermit is the most commonly used. The thermit mixture is kept in a refractory lined crucible and the mixture is ignited with a highly inflammable powder consisting of Barium Peroxide, an ignition temperature of 1150^0 C is attained which initiates the main thermit reaction. The reaction is self sustaining and very rapid as it is exothermic, producing molten iron and slag releases high heat of order of 3000^0 C. the reaction is as follows.

$8Al + 3Fe_3O_4$ – -> $9Fe + 4Al_2O_3$ (Slag) + Heat

Slag being very light floats over the thermit steel thereby protecting the metal from

atmospheric gases. Apart from the basic ingredients of the thermit mixture other materials may be added to produce a desired thermit melt for any specific application. The molten metal, produced by the reaction, acts as a filler material joining the work pieces after Solidification. The process is thus essentially a combination of casting and welding processes. The process of welding is illustrated in Figure.



Working Operation:

1. In operation the workpiece edges are cut to provide a gap with parallel faces and are cleaned to remove grease, dirt.
2. Here a wax pattern of desire shape is prepared and placed in a gap.
3. The wax pattern is then surrounded by sheet iron box and the space between box and the pattern is filled and rammed with moulding sand and care is taken to provide openings for the runner, riser and a heating gate.

4. Flame is directed into the heating gate due to which the wax pattern melts and drains out, the heating is continued to raise the temperature of the parts to be welded. The heating gate is then closed with an iron plug or sand core to prevent flow of thermit metal.

5. Thermit reaction is started in the crucible and is placed above the pouring cup, the resulting molten iron is then run into the mould and fuses with the parts to be welded and forms the thermit collar at the joint. allowed to flow into the mould, from the bottom of the crucible and it

6. The slag being lighter floats over the molten metal in the crucible. It flows last and remains at the top of the mould where it solidifies. Clean metal enters the mould around the sections to be welded.

Advantages:

1. The heat necessary for welding is obtained from a chemical reaction and thus no costly power supply is required. Therefore broken parts (rails etc.) can be welded on the site itself.

Limitations:

1. Thermit welding is applicable only to ferrous metal parts of heavy sections, i.e., mill housing and heavy rails sections.
2. The process is uneconomical If used to weld cheap metals or light parts

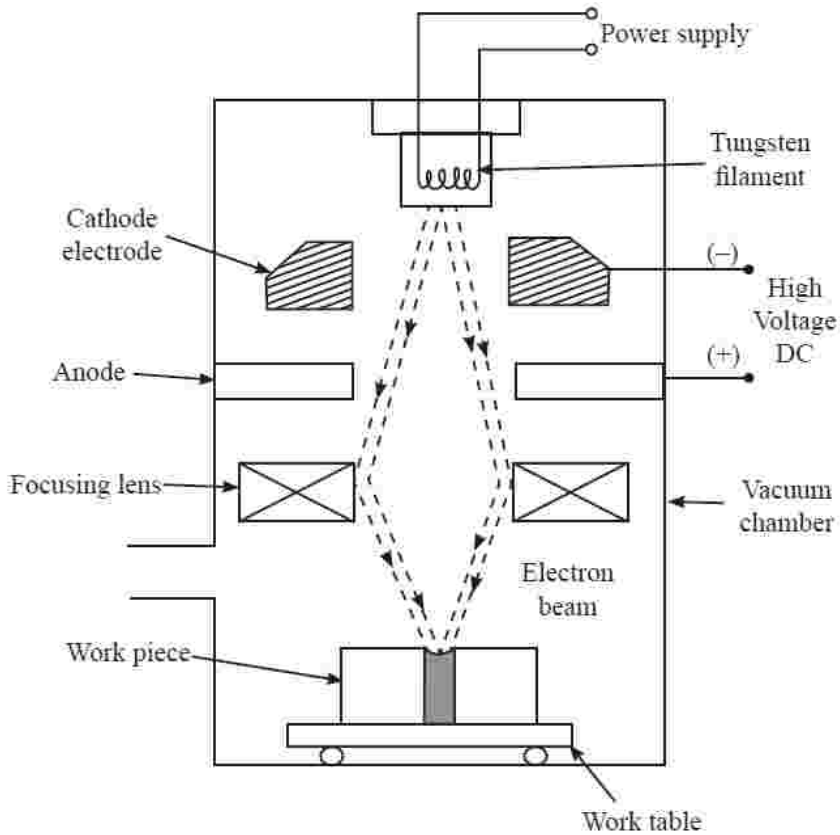
b.

It is a welding process utilizing a heat generated by a beam of high energy electrons. The electrons strike the work piece and their kinetic energy converts into thermal energy heating the metal so that the edges of work piece are fused and joined together forming a weld after Solidification. The process of welding is illustrated in Figure

Equipment:

An EBW set up consists of the following major equipment:

1. **Electron gun-** an electron gun generates accelerates and aligns the electron beam in required direction and spot onto the workpiece.
2. **Power supply-** In emitter power supply, AC or DC current is required to heat th0e filament for emission of electrons. The amount of current depends upon the diameter and type of the filament. The current and voltage varies from 25-70 A and 5-30 V respectively
3. **Vacuum Chamber-** The process is carried out in a vacuum chamber at a pressure of about 0.13-133 mPa). Such high vacuum is required in order to prevent loss of the electrons energy in collisions with air molecules.



4. **Workpiece handling device-** Quality and precision of the weld profile depends upon the accuracy of the movement of work piece. There is also provision for the movement of the work piece to control the welding speed. The movements of the work piece are easily adaptable to computer numerical control.

Principles:

1. The workpieces to be joined are cleaned to remove dirt and placed on the table within the vacuum chamber.
2. In this process, electrons are emitted from the heated tungsten filament called electrode.

   These electrons are accelerated towards the anode by applying high potential difference (30 kV to 175 kV) between cathode and anode. The higher the potential difference, the higher would be the acceleration of the electrons.
3. The electron beam is focused by means of electromagnetic lenses. When this high kinetic energy electron beam strikes on the workpiece and penetrate slightly below the base surface. The kinetic energy of the electrons is converted into heat energy.
4. Continuously the electron beams strikes the same place on the work piece resulting in melting of the work material.
5. Molten metal fills into the gap between parts to be joined and subsequently it gets solidified and forms the weld join

Advantages of EBW:

1. High penetration to width can be obtained, which is difficult with other welding processes.

2. High welding speed is obtained.
3. Material of high melting temperature can be welded.
4. Superior weld quality due to welding in vacuum.
5. High precision of the welding is obtained.
6. Dissimilar materials can be welded.

Disadvantages

1. Very high equipment cost.
2. High vacuum is required.
3. High safety measures are required.
4. Large jobs are difficult to.
5. Skilled man power is required.

Applications

1. Electron beam welding process is mostly used in joining of refractive materials like columbium, tungsten, ceramic etc. which are used in missiles.
2. In space shuttle applications wherein reactive materials like beryllium, zirconium, titanium etc. are used.
3. In high precession welding for electronic components, nuclear fuel elements, special alloy jet engine components and pressure vessels for rocket plants.
4. Dissimilar material can be welded like invar with stainless steel.

MODULE 5

9. a.

Welding is a high temperature process, thus many metallurgical changes takes place during the process. These metallurgical changes are different for different welding processes and they depend largely on the composition of the material, the weld structure, the time of the welding process and the cooling conditions. A typical fusion welded joint varies in metallurgical structure from the fusion zone to the base material with consequential variations in mechanical properties. This is because of the fact that fusion welding processes result in melting and solidification with very high temperature gradient within a small zone with the peak temperature at the center of the fusion zone. In general, a weld can be divided in four different zones as shown schematically in Fig

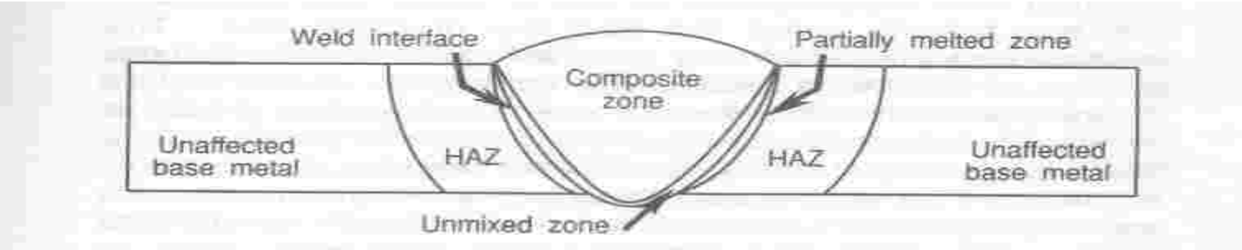


Figure 19 Weld metallurgical zones.

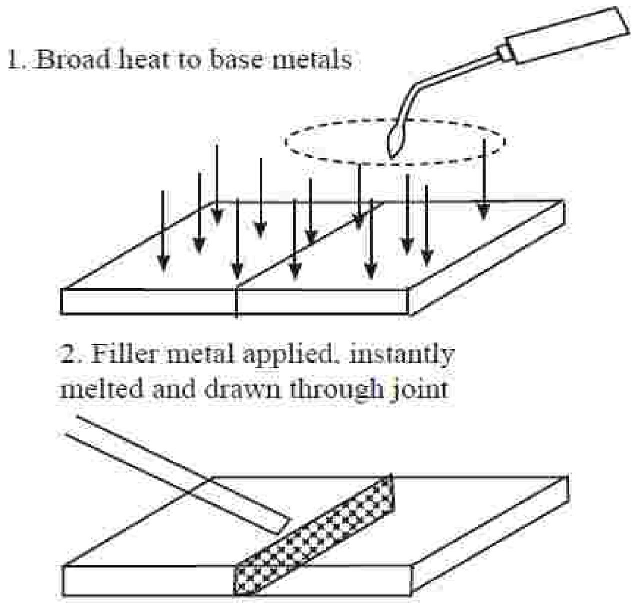
1. The **fusion zone (referred to as FZ)** is the **center zone,** can be characterized as a mixture of completely molten base metal with molten metal of filler rod (filler metal if consumable electrodes are in use) and it is termed the **weld bead**. Fusion welding is similar to casting process, wherein under high welding temperature base metal reaches the molten state, forms the pool of molten metal and on solidification it becomes a strong joint. The main driving forces for convective transport of heat and resulting mixing of molten metal in weld pool are: (1) buoyancy force, (2) surface tension gradient force, (3) electromagnetic force, (4) friction force. Similar to a casting process, the microstructure in the weld fusion zone is expected to change significantly due to re-melting and solidification of metal at the temperature beyond the effective liquidus temperature.
2. The **weld interface,** which is also referred to as **mushy zone**, is a narrow zone consisting of partially melted base material which has not got an opportunity for mixing. This zone separates the **fusion zone** and **heat affected zone.**
3. The **heat affected zone (HAZ)** is the region next to weld interface zone and surround the fusion zone. This zone is not the fused zone but experiences an elevated temperature that is well below the solidus temperature while high enough that can change the microstructure of the material. The amount of change in microstructure in **HAZ** depends on the amount of heat input, peak temp reached, time at the elevated temp, and the rate of cooling. As a result of the marked change in the microstructure, the mechanical properties also change in **HAZ** and the metal in this zone remains as the weakest section in a weldment.
4. The **unaffected base metal zone** is the last zone and it is surrounding the HAZ is likely to be in a state of high residual stress, due to the shrinkage in the fusion zone. However, metal in this zone remains unaffected as it does not heat sufficiently to undergo any change in the microstructure.

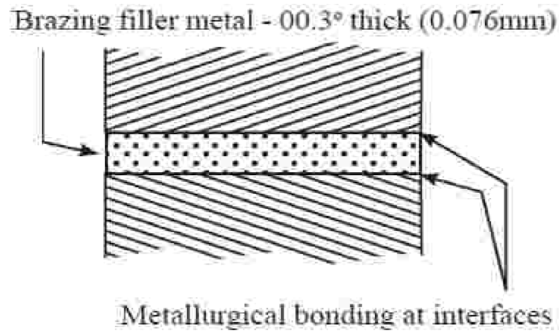
b.

Before brazing, the surfaces of the parts are cleaned removing oxides and grease. After cleaning, a flux is applied at the place of the joint. Common borax and mixture of borax and boric acid have been used as flux. After the flux is applied, the joints and the filler material are heated by an oxy-acetylene welding torch to the temperature above the melting temperature of the filler material. The molten filler material flows by capillary action into the joint space and after cooling produce a strong joint.

Torch Brazing

In case of torch brazing, flux is applied to the part surfaces and a torch is used to focus flame against the work at the joint. A reducing flame is used to prevent the oxidation. Filler metal wire or rod is added to the joint. Torch uses mixture of two gases, oxygen and acetylene, as a fuel like gas welding.





c.

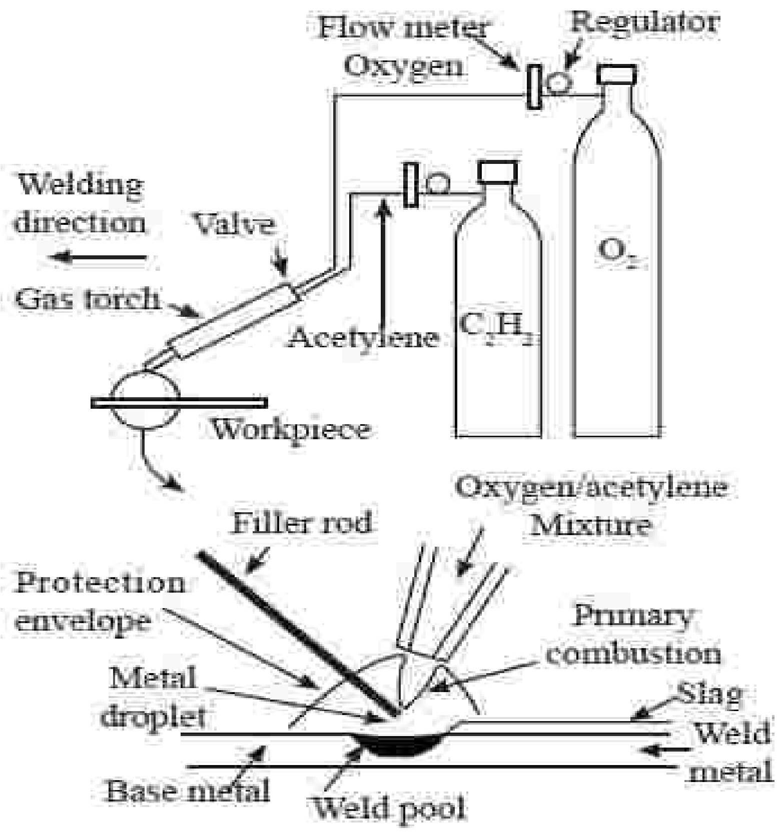
Principle and working

In this process, acetylene is mixed with oxygen in correct proportions in the welding torch and ignited. The flame resulting at the tip of the torch is sufficiently hot to melt and join the parent metal. The oxy-acetylene flame reaches a temperature of about 3300°C and thus can melt most of the ferrous and non-ferrous metals in common use. A filler metal rod or welding rod is generally

It consists of two sets of large cylinders in which one cylinder consist oxygen at high pressure and other contains acetylene gas. Welding torch device is used to mix both oxygen and acetylene gases at required proportion and it will burn the mixture at the tip as shown in figure. The pressure at which both gasses supplied to the torch are controlled by the pressure regulators.

Operation

A mixture of acetylene gas (C2H2) and oxygen gas are mixed; acetylene is highly flammable, so the mixture can be ignited and burns generating very high temperatures of up to 3000°C. The flame is used to melt the metal at the joint, along with a filler rod to provide some extra material to fill the gap. The filler rod is coated with flux. The flux is a chemical with two uses: part of it evaporates, and the vapor surrounds the region around the molten metal, preventing oxidation. Another part of the flux melts, and dissolves impurities and metal oxides; since these are lighter than the molten metal, they float to the surface and can be removed by a finishing process later.



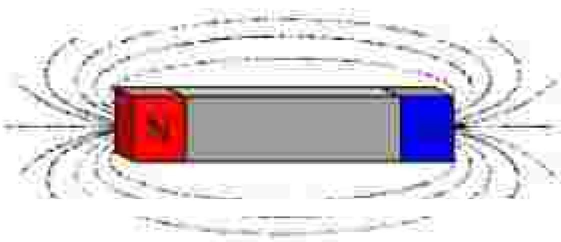
10. a.

Magnetic particle testing is one of the most widely utilized NDT methods. This method uses magnetic fields and small magnetic particles (i.e. iron filings) to detect surface defects or near- surface defects in ferromagnetic components (materials such as iron, nickel, cobalt, or some of their alloys).

Basic Principles

In theory, magnetic particle testing has a relatively simple concept. It can be considered as a combination of two nondestructive testing methods: magnetic flux leakage testing and visual testing. For the case of a bar magnet, the magnetic field is in and around the magnet. Any place that a magnetic line of force exits or enters the magnet is called a "**pole**" refer fig.A (magnetic lines of force exit the magnet from North Pole and enter from the South Pole).

When a bar magnet is broken in the center of its length, two complete bar magnets with magnetic poles on each end of each piece will result. If the magnet is just cracked but not broken .B. The magnetic field exits the North Pole and reenters at the South Pole. The magnetic field spreads out when it encounters the small air gap created by the crack because the air cannot support as much magnetic field per unit volume as the magnet can. When the field spreads out, it appears to leak out of the material and, thus is called a **flux leakage field.**



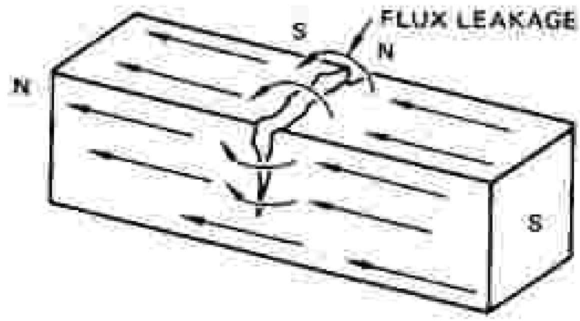
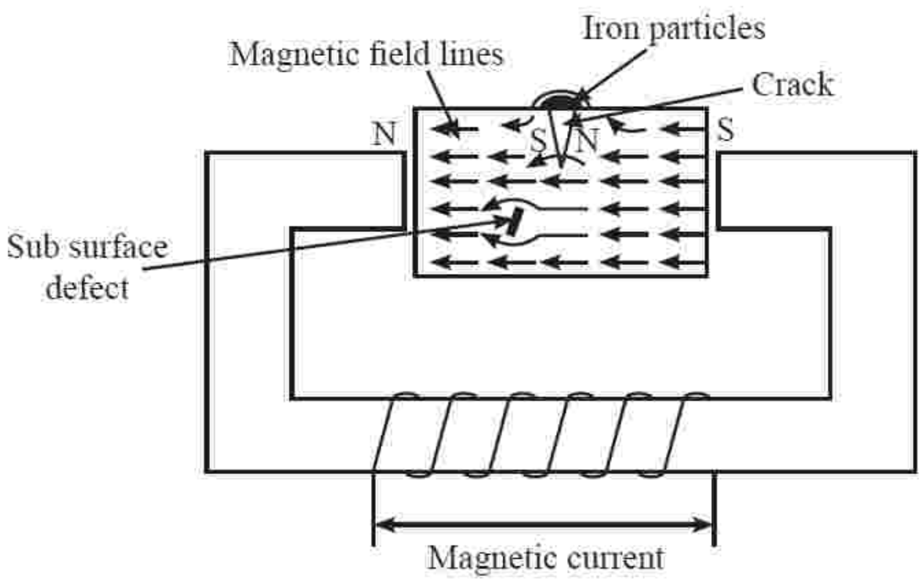


Fig A. Magnet with magnetic lines

Fig B. Magnet with flux leakage field



Steps involved in the inspection method

1. The first step in a magnetic particle testing is to magnetize the component that is to be inspected as shown in figure
2. If any defects on or near the surface are present, the defects will create a leakage field.
3. After the component has been magnetized, iron particles, either in a dry or wet suspended form, are applied to the surface of the magnetized part.
4. The particles will be attracted and cluster at the flux leakage fields, thus forming a visible indication that the inspector can detect.

Advantages

1. High sensitivity (small discontinuities can be detected).
2. Indications are produced directly on the surface of the part and constitute a visual representation of the flaw.
3. Minimal surface preparation (no need for paint removal)
4. Portable (small portable equipment & materials available in spray cans)
5. Low cost (materials and associated equipment are relatively inexpensive)

b.

In NDT, radiography is one of the most important and widely used methods for detecting internal defects for both ferrous and nonferrous metals and other materials. In general, RT is method of inspecting materials for hidden flaws by using the ability of short wavelength electromagnetic radiation (high energy photons) to penetrate various materials. The intensity of the radiation that penetrates and passes through the material is either captured by a radiation sensitive film. **Fig** shows schematic arrangement of Ultrasonic inspection

Radiography inspection

1. The equipment consists of a **filament** acts as cathode and **target** act as anode, which in turn are placed in **evacuated glass bulb**.
2. The filament is heated by passing an electric current through cathode and anode.
3. When the filament reaches the elevated temperature causes release of electrons and are accelerated towards the target by maintaining high voltage difference between cathode and anode.
4. When electrons collide with target a part of kinetic energy is converted into energy of radiation or **X-rays.**
5. In **operation**, the part to be inspected is placed between the radiation source and a piece of radiation sensitive film.
6. When X-rays are passes through the material containing a defect, the sound part of the workpiece possesses thicker and denser area will stop more radiations.
7. The unsound (defects like cracks, inclusion, blow hole, etc.,) part of the workpiece possesses thinner and less denser area, which stops less radiation.

8. The radiation that passes through the workpiece will expose the film and forms a shadowgraph of the part. The image darkness (density) will vary with the amount of radiation reaching the film through the test object where darker areas indicate more exposure (higher radiation intensity) and liter areas indicate less exposure (lower radiation intensity).

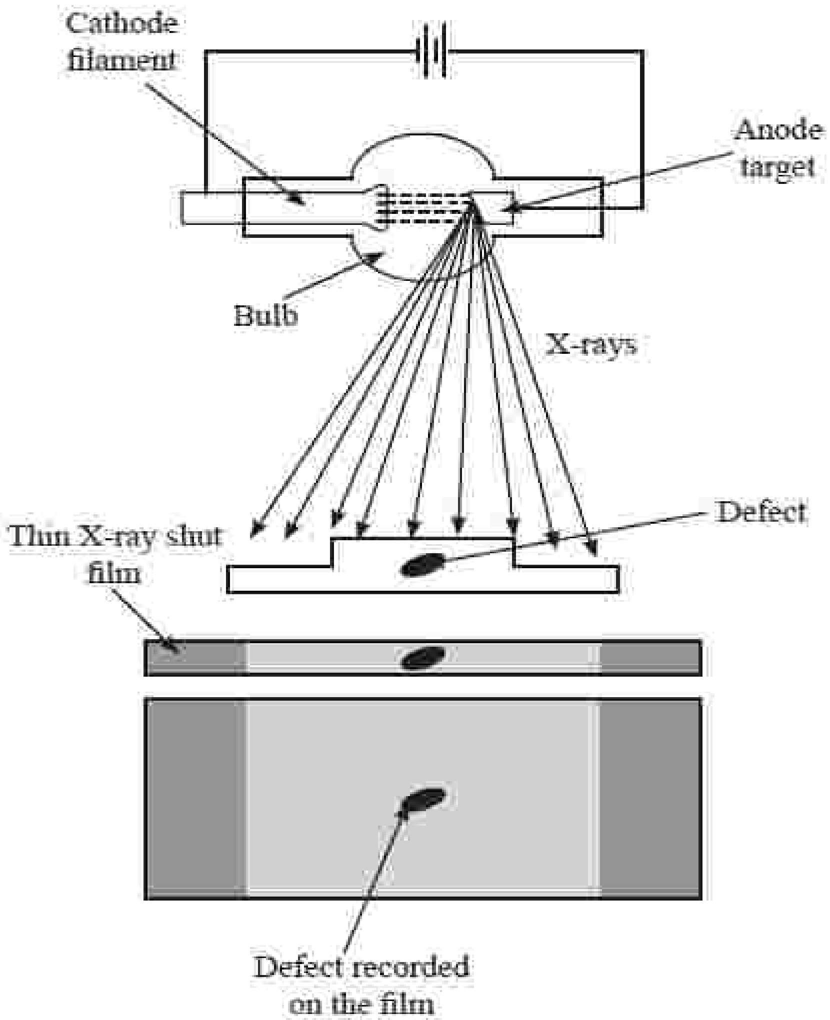
9. This variation in the image darkness can be used to determine thickness or composition of material and would also reveal the presence of any flaws or discontinuities inside the material.

Advantages

1. Both surface and internal discontinuities can be detected.
2. Significant variations in composition can be detected.
3. It has a very few material limitations.
4. Can be used for inspecting hidden areas (direct access to surface is not required)
5. Very minimal or no part preparation is required.
6. Permanent test record is obtained.
7. Good portability especially for gamma-ray sources.

Disadvantages

1. Hazardous to operators and other nearby personnel.
2. High degree of skill and experience is required for exposure and interpretation.
3. The equipment is relatively expensive (especially for x-ray sources).
4. The process is generally slow.
5. Highly directional (sensitive to flaw orientation).
6. Depth of discontinuity is not indicated.
7. It requires a two-sided access to the component.


Cathode
filament
Anode
target
Bulb
X-rays
Defect
Thin X-ray shut
film
Defect recorded
on the film