GOVT. POLYTECHNIC SIRSA

BRANCH :MECHANICAL ENGINEERING

SUBJECT :WORKSHOP TECHNOLOGY-I

SEMESTER :3rd

CONTENTS

1.4 OTHER WELDING PROCESSES

- **1.4.1** Resistance welding: Principle, advantages, limitations
- **1.4.2** Spot welding: Principle, advantages, limitations
- **1.4.3** Seam welding: Principle, advantages, limitations
- **1.4.4** Projection welding: Principle, advantages, limitations
- **1.4.5** Percussion welding: Principle, advantages, limitations
- **1.4.6** Atomic hydrogen welding: Principle, advantages, limitations
- **1.4.7** Shielded metal arc welding: Principle, advantages, limitations
- **1.4.8** Submerged arc welding: Principle, advantages, limitations
- **1.4.9** Welding distortion: Principle, advantages, limitations

1.5 MODERN WELDING METHODS

- **1.5.1** Methods, Principle of operation, advantages, disadvantages and applications of Tungsten inert gas (TIG) welding
- **1.5.2** Methods, Principle of operation, advantages, disadvantages and applications of Metal inert gas (MIG) welding
- **1.5.3** Methods, Principle of operation, advantages, disadvantages and applications of Thermit welding
- **1.5.4** Methods, Principle of operation, advantages, disadvantages and applications of Electro slag welding
- **1.5.5** Methods, Principle of operation, advantages, disadvantages and applications of Electron beam welding
- **1.5.6** Methods, Principle of operation, advantages, disadvantages and applications of Laser beam welding
- **1.5.7** Methods, Principle of operation, advantages, disadvantages and applications of Ultrasonic welding
- **1.5.8** Methods, Principle of operation, advantages, disadvantages and applications of Robotic welding

2. FOUNDRY TECHNIQUES

2.1 PATTERN MAKING

- **2.1.1** Types of pattern
- **2.1.2** Pattern material

2.1.3 Pattern allowances

2.1.4 Pattern codes as per B.I.S.

2.1.5 Introduction to cores

2.1.6 Core boxes and core materials

2.1.7 Core making procedure

2.1.8 Core prints, positioning of cores

2.2 MOULDING AND CASTING

2.2.1 Moulding sand and properties

2.2.2 Their impact and control of properties viz. permeability, refractoriness, adhesiveness, cohesiveness, strength, flow ability, collapsibility

2.2.3 Types of moulding sand

2.2.4 Testing of moulding sand and Safety precautions in foundry

2.2.5 Mould making: Types of moulds

2.2.6 Step involved in making a mould

2.2.7 Molding boxes

2.2.8 Hand tools used for mould making

2.2.9 Molding processes: Bench molding, floor molding, pit molding and machine molding

2.2.10 Molding machines

2.2.11 Squeeze machine

2.2.12 Jolt squeeze machine

2.2.13 Sand slinger

2.3 CASTING PROCESSES

2.3.1 Charging a furnace

2.3.2 Melting and pouring both ferrous and non-ferrous metals

2.3.3 Cleaning of castings

2.3.4 Principle, working and applications of Die casting: hot chamber

2.3.5 Principle, working and applications of Die casting: cold chamber

2.3.6 Centrifugal casting

2.4 GATING AND RISERING SYSTEM

- **2.4.1** Elements of gating system, Pouring basin, sprue, runner, gates
- **2.4.2** Types of risers
- **2.4.3** location of risers
- **2.2.4** Directional solidification

2.5 MELTING FURNACES

- **2.5.1** Construction and working of Pit furnace
- **2.5.2** Construction and working of Cupola furnace
- **2.5.3** Construction and working of Crucible furnace – tilting type
- **2.5.4** Construction and working of Crucible furnace - Electric furnace

CHAPTER 1
WELDING

1.1 WELDING PROCESS

It is a process of joining two similar or dissimilar metals by fusion, with or without the application of pressure and with or without the use of filler metal. The assemblage of parts that are joined by welding is called a weldment. Welding is more economical and a much faster process as compared to casting and riveting.

1.1.1 PRINCIPLE OF WELDING

Welding involves the use of four components: the metals, a heat source, filler metal, and some kind of shield from the air. The metals are heated to their melting point while being shielded from the air, and then a filler metal is added to the heated area to produce a single piece of metal. It can be performed with or without filler metal and with or without pressure.

1.1.2 CLASSIFICATION OF WELDING PROCESSES

Welding processes are broadly divided into two types;

1. **Forage or pressure welding**

   In forage or pressure welding the weld is produced by without melting the base material and without the addition of a filler metal. Pressure is always employed, and generally some heat is provided. Frictional heat is developed in ultrasonic and friction joining, and furnace heating is usually employed in diffusion bonding. The various type of forage welding is shown in fig.1.

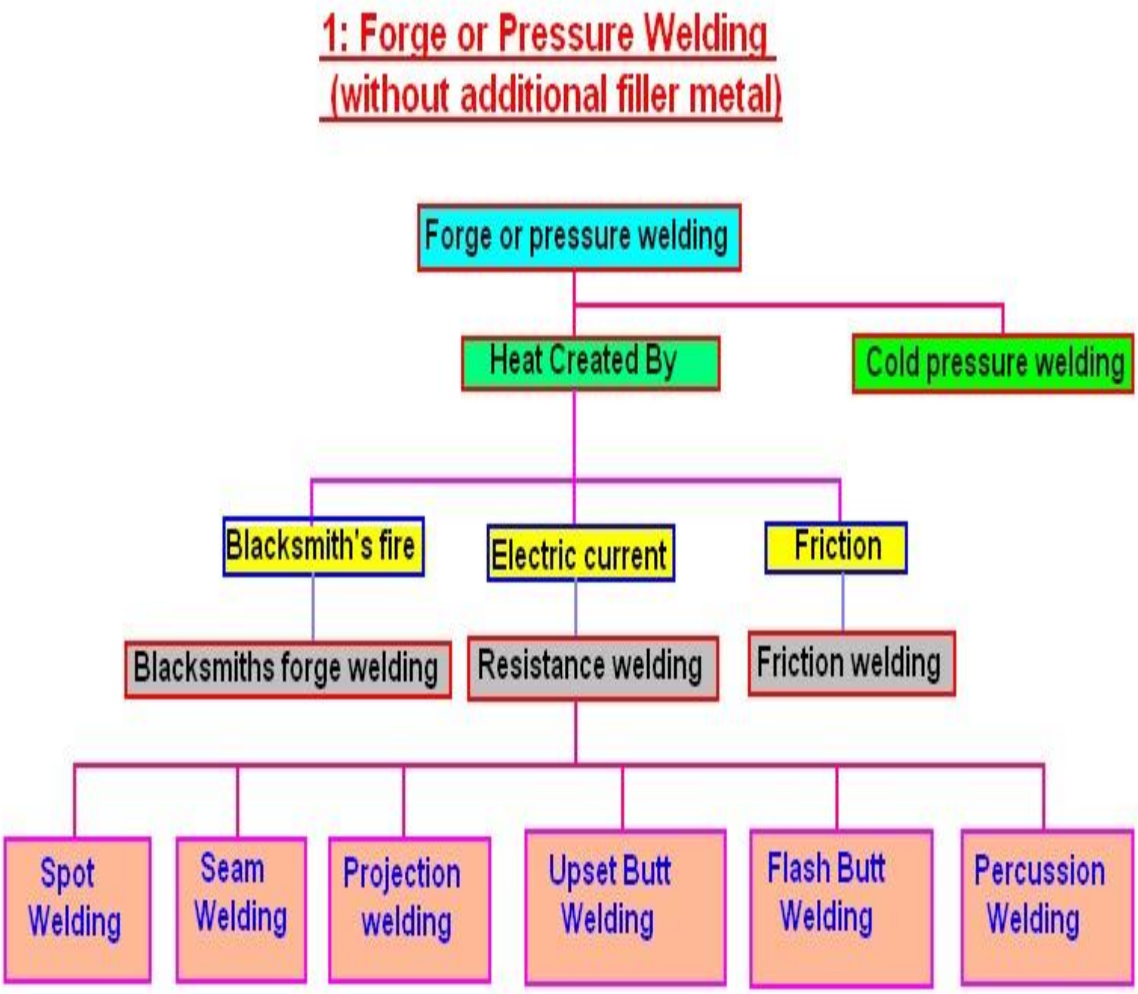


Fig.1: Various types of forage welding

2. Fusion or non-pressure welding

A fusion welding process in which coalescence of the metals is achieved by the heat from an electric arc between an electrode and the work with use of additional filler metal and without the application of pressure. The various type of fusion welding is shown in fig.2.

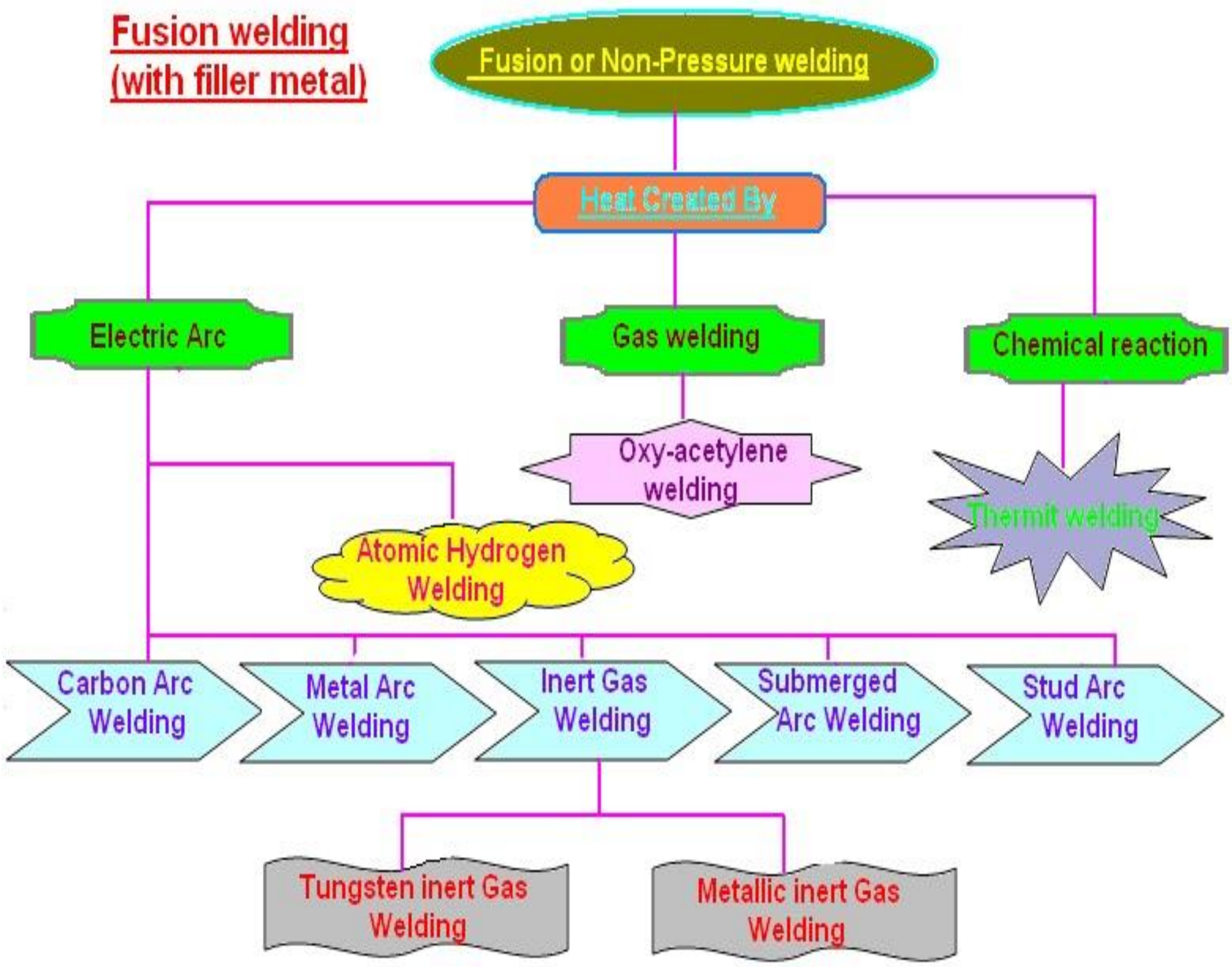


Fig.2: Various types of fusion welding

1.1.3 ADVANTAGES AND LIMITATIONS OF WELDING

Advantages of welding

1. Low manufacturing cost.
2. Different material can be welded.
3. Repair by welding is very easy.
4. Provide a complete rigid joint.
5. It can be automated.
6. Welding results in a good saving material and reduces labour content of production.

Limitations of welding

1. Welding joints have poor fatigue resistance due to residual stresses, stress concentration etc.
2. It is impossible to disassemble joints without destroying detail parts.
3. More safety devices are needed.
4. A skilled welder is required.
5. Welding heat produces metallurgical changes.
6. Welding produces the harmful radiations, fumes and spatter.
7. Jig and fixture are required to hold the parts to be welded.
8. Looking at an electric arc can blind you instantly and permanently.

1.1.4 INDUSTRIAL APPLICATION OF WELDING

The welding process finds wide-spread applications in all branches of industry and construction. Welding is extensively employed in regular fabrication of automobile cars, aircrafts, bridges and building construction and refrigerators etc. It is also used in repair and maintenance of work. Welding processes are also used for cutting purpose, thus saving the cost of expensive cutting dies.

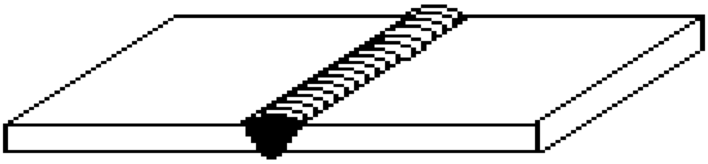
1.1.5 WELDING POSITION AND WELDING TECHNIQUE

Welding position

The welding position refers to the position of the welding operator towards the workpiece to be welded. Because of gravity, the welding position affects the flow of molten filler metal. It’s important to understand the types of welding positions as different welding processes require to be performed at a certain position of the welder. The welding positions are classified as follow:

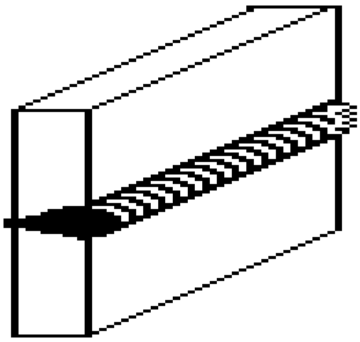
1. Flat position

This type of welding is performed from the upper side of the joint. The face of the weld is approximately horizontal. The axis of a weld is a line through the length of the weld, perpendicular to the cross section at its center of gravity.



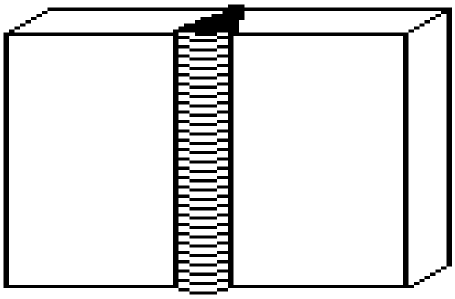
2. Horizontal position

In this welding position, the filler material is deposited on a vertical surface in a horizontal direction as shown in fig



3. Vertical position

In vertical position welding, the axis of the weld is approximately vertical. When welding is done on a vertical surface, the molten metal has a tendency to run downward and pile up.

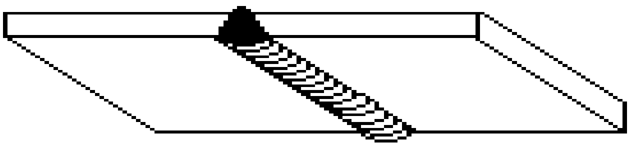


4. Inclined position

In this welding position, the filler material is deposited up or down on an inclined surface as shown in fig

5. Overhead position

Overhead welding is performed from the underside of a joint. In this, the metal deposited tends to drop or sag on the plate, causing the bead to have a high crown.



WELDING TECHNIQUE

1. Leftward or forward welding

In this technique, the torch is held in the right hand and the filler rod is in the left hand of the operator. The welding is started from the right hand end of the plate and travels towards left hand as shown in fig.3. The torch tip makes an angle of 60-70° and the filler rod makes an angle of 30-40° with the work surface.

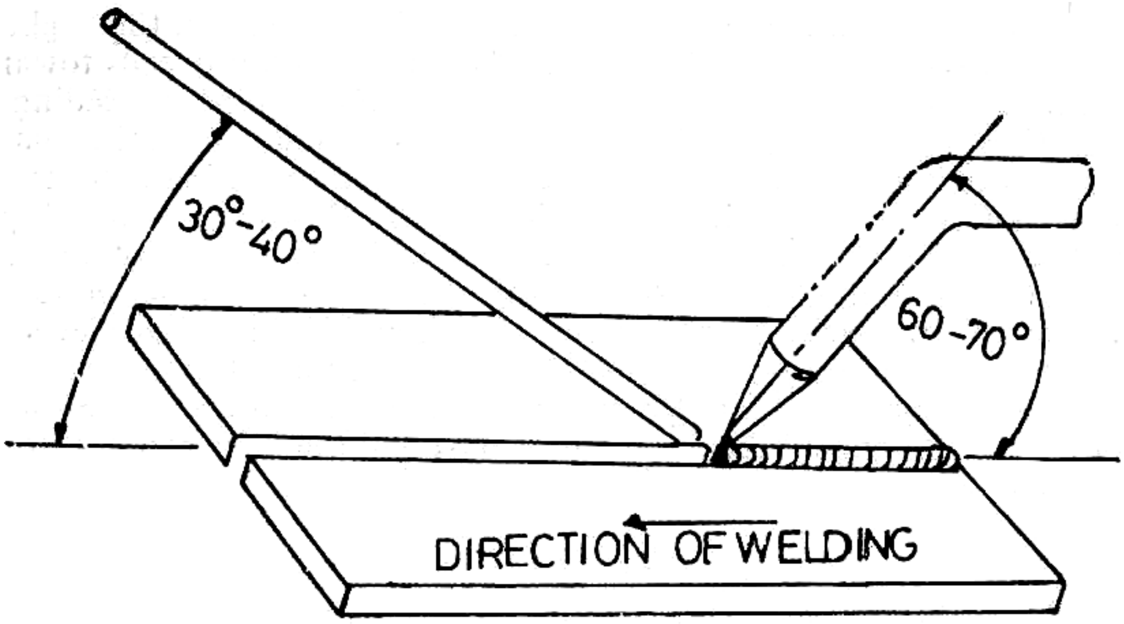


Fig.3: Leftward or forward welding

2. Rightward or backward welding

In this technique, the welding torch is held in the right hand and the filler rod is in the left hand. The welding is started from the left hand end of the plate and travels towards right hand as shown in fig.4. The torch tip makes an angle of 40-50° and the filler rod makes an angle of 30-40° with the work surface.

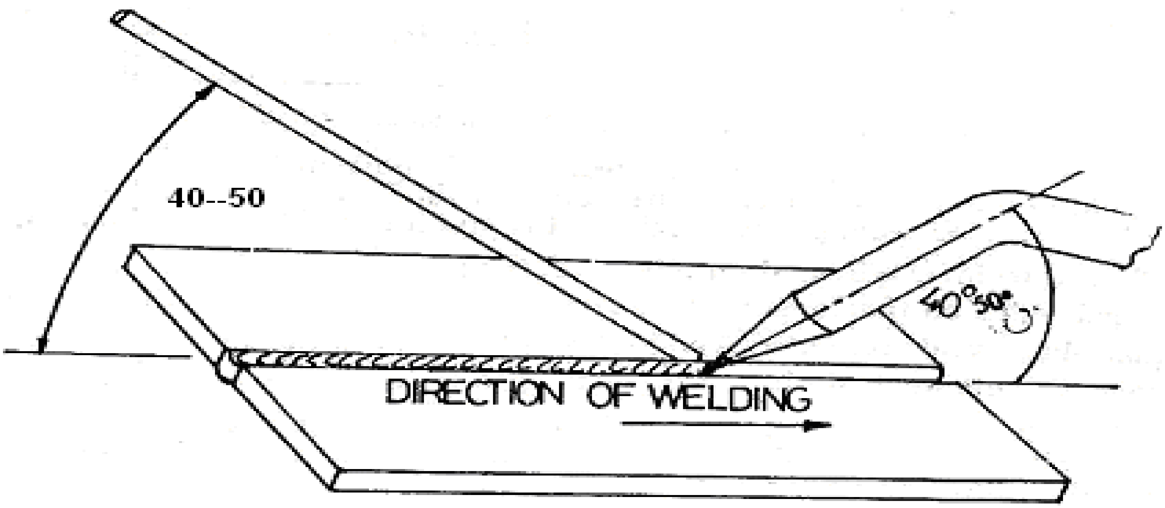


Fig.4: Rightward or backward welding

1.1.6 BASIC WELD SYMBOLS

Fig.5 shows various types of basic weld symbols and their sectional representation according to ISI and SP: 46 – 1988.

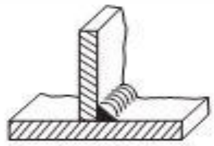
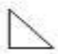
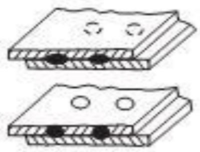
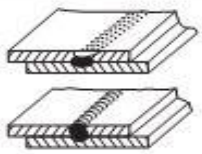
No.	*Designation*	*Illustration*	*Symbol*
1.	Butt weld between plates with raised edges (the raised edges being melted down completely)		
2.	Square butt weld		
3.	Single-V butt weld		
4.	Single-bevel butt weld		
5.	Single-V butt weld with broad root face		
6.	Single-bevel butt weld with broad root face		
7.	Single-U butt weld (parallel or sloping sides)		
8.	Single-U butt weld		
9.	Backing run; back or backing weld		
10.	Fillet weld		
11.	Plug weld; plug or slot weld		
12.	Spot weld		
13.	Seam weld		

Fig. 5: Basic weld symbols

1.1.7 SAFETY PRECAUTIONS IN WELDING

Always weld in a well-ventilated place. Fumes given off from welding are unpleasant and in some cases may be injurious, particularly from galvanized or zinc coated parts.

1. Do not weld around combustible or inflammable materials, where sparks may cause a fire.
2. Never weld containers, which have been used for storing gasoline, oil or similar materials, without first having them thoroughly cleaned.
3. Check the welding machine to make sure that it is properly grounded and that all leads properly insulated.
4. Never look at the arc with the naked eye.
5. The arc can burn your eyes. Always use a face shield while welding.
6. Prevent welding cables from coming in contact with hot metal, water, oil and grease. Avoid dragging the cables around the sharp corners.
7. Ensure proper insulation of the cable and check for openings.
8. Always wear safety hand gloves, apron and leather shoes.
9. Always turn off the machine when leaving work.
10. Apply eye drop after welding is over for the day, to relive the strain on the eye.
11. While welding, stand on dry place and keep the body insulated from the electrode any other parts of electrode holder.

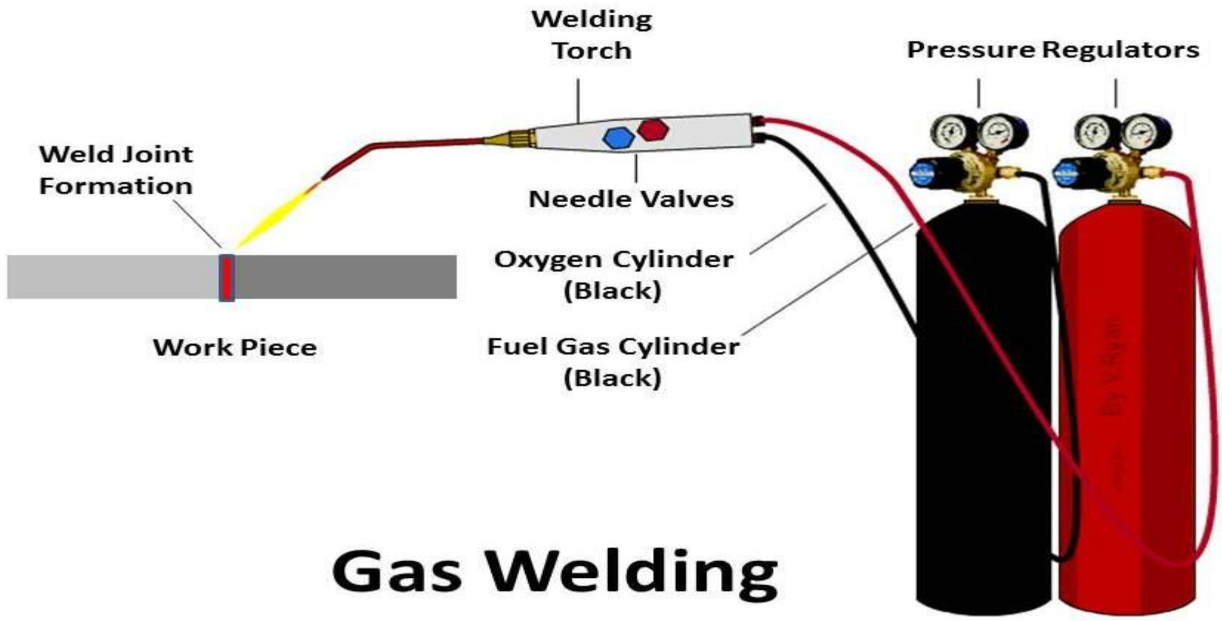
1.2 GAS WELDING

Oxyacetylene welding, commonly referred to as gas welding, is a process which relies on combustion of oxygen and acetylene. When mixed together in correct proportions within a hand-held torch or blowpipe, a relatively hot flame is produced with a temperature of about 3200 °C. The chemical action of the oxyacetylene flame can be adjusted by changing the ratio of the volume of oxygen to acetylene.

1.2.1 PRINCIPLE OF OPERATION

It is done by burning of fuel gases with the help of oxygen which forms a concentrated flame of high temperature. This flame directly strikes the weld area and melts the weld surface and filler material. The melted parts of welding plates diffused in one another and create a weld joint after cooling. This welding method can be used to join most of common metals used in daily life.

1.2.2 EQUIPMENT



1. **Welding Torch**

Welding torches are most important part of gas welding. Both the fuel gas and oxygen at suitable pressure fed through hoses to the welding torch. There are valves for each gas witch control the flow of gases inside the torch. Both gases mixed there and form a flammable mixture. These gases ignite to burn at the nozzle. The fire flame flow through the nozzle and strikes at welding plate surface. The nozzle thickness depends on the size of the welding plates and material to be welded.

2. **Oxygen Cylinder**

For proper burning of fuel, appropriate amount of oxygen required. This oxygen supplied by an oxygen cylinder. A black line is used to indicate oxygen cylinder.

3. **Fuel Gas Cylinder**

Gas cylinder is filled either by oxy acetylene gas, hydrogen gas, natural gas or other flammable gas. The fuel gas selection is depends on the welding material. Mostly oxy acetylene gas is used for all general purpose of welding. Normally these cylinders have Maroon line to indicate it. The fuel gases passes through it.

4. **Pressure regulator**

Both oxygen and fuel gases are filled in cylinder at high pressure. These gases cannot use at this high pressure for welding work so a pressure regulator is used between flow. It supplies oxygen at pressure about 70-130 kN / m^2 and gas at 7-103 kN / m^2 to the welding torch.

5. **Goggles and Gloves**

These are used for safety purpose of welder. It protects eyes and hand from radiation and flame of fire.

WORKING OF GAS WELDING

Gas welding process is quite simpler compare to arc welding. In this process all the equipment are connected carefully. The gas cylinder and oxygen cylinder connected to the welding torch through pressure regulators. Now the regulate pressure of gas and oxygen supplied to the torch where they properly mixed. The flame is ignited by a striker. Take care the tip of torch is pointing downward. Now the flame is controlled through valves situated in welding torch. The flame is set at natural flame or carburizing flame or oxidizing flame according to the welding condition. Now the welding torch moved along the line where joint to be created. This will melt the interface part and join them permanently.

APPLICATIONS

1. It is used to join thin metal plates.
2. It can used to join both ferrous and non-ferrous metals.

3. Gas welding mostly used in fabrication of sheet metal.
4. It is widely used in automobile and aircraft industries.

ADVANTAGES

1. It is easy to operate and dose not required high skill operator.
2. Equipment cost is low compare to other welding processes like MIG, TIG etc.
3. It can be used at site.
4. Equipment's are more portable than other type of welding.
5. It can also be used as gas cutting.

DISADVANTAGES

1. It provides low surface finish. This process needs a finishing operation after welding.
2. Gas welding have large heat affected zone which can cause change in mechanical properties of parent material.
3. Higher safety issue due to naked flame of high temperature.
4. It is Suitable only for soft and thin sheets.
5. Slow metal joining rate.
6. No shielding area which causes more welding defects.

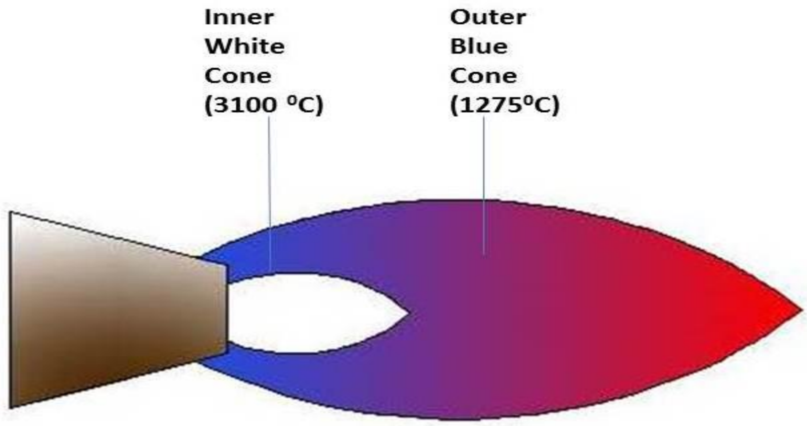
1.2.3 TYPES OF GAS WELDING FLAME AND THEIR APPLICATIONS

There are three basic flame types: neutral (balanced), excess acetylene (carburizing), and excess oxygen (oxidizing).

1. Natural flame

As the name implies, this flame has equal amount of oxygen and gases fuel by the volume. This flame burns fuel completely and does not produce any chemical effect on metal to be welded. It is mostly used for welding mild steal, stainless steel, cast iron etc. It produces little smoke. This flame has two zones.

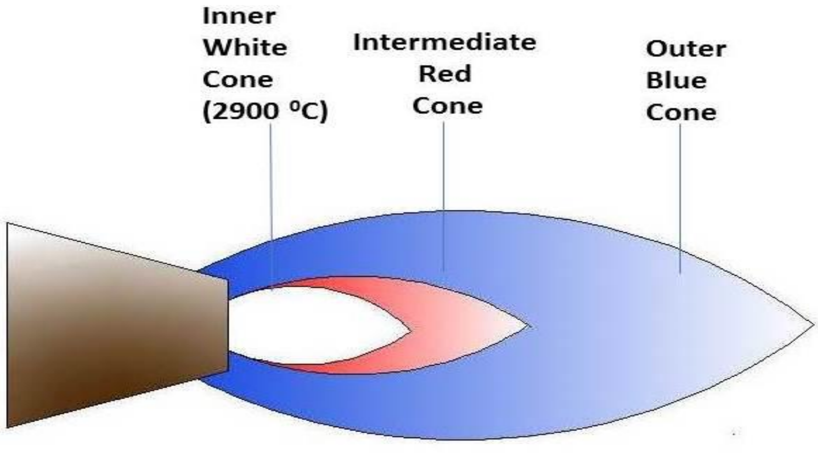
The inner zone has white in color and has temperature about 3100 degree centigrade and outer zone has blue color and have temperature about 1275 degree centigrade.



Natural Flame

2. Carburizing flame

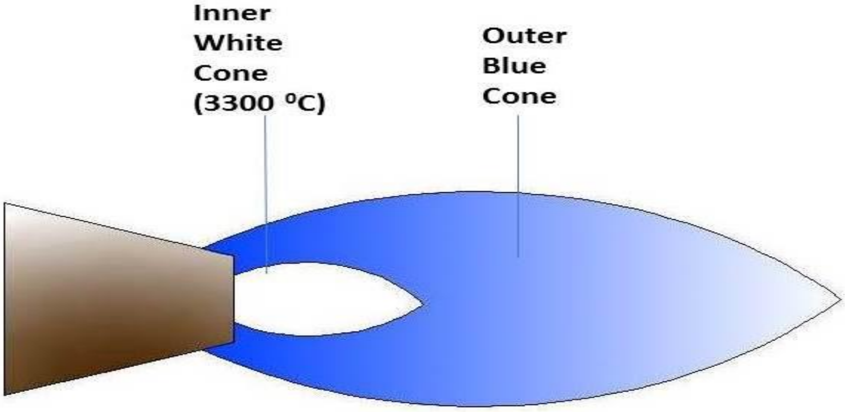
This flame has excess of fuel gas. This flame chemically reacts with metal and form metal carbide. Due to this reason, this flame does not used with metal which absorb carbon. It is smoky and quiet flame. This flame has three regions. The inner zone has white color, the intermediate zone which is red in color and outer cone has blue color. The inner cone temperature is about 2900 degree centigrade. This flame is used to weld medium carbon steel, nickel etc.



Carburizing Flame

3. Oxidizing flame

When the amount of acetylene reduces from natural flame or amount of oxygen increases, the inner cone tend to disappear and the flame obtain is known as oxidizing flame. It is hotter than natural flame and has clearly defined two zones. The inner zone has very bright white color and has temperature of about 3300 degree centigrade. The outer flame has blue in color. This flame is used to weld oxygen free copper alloy like brass, bronze etc.



Oxidizing Flame

1.2.4 FILLER RODS AND FLUXES

Filler rods used in gas welding provide extra metal to the weld by melting the end of the rod. The filler rods used in welding should have a chemical composition similar to that of the base metal. The diameter of the filler rod is selected to suit the thickness of the base metal. Some typical composition of filler rods for gas welding are given below:

Sr. No.	Material to be welded	Chemical composition of filler rod
1.	L-C steels	0.8%C, 0.36%Mn, 0.13%Cr, 0.13%Ni, 0.20%P
2.	Mn- steels	0.14%C, 0.12%Si, 0.81%Mn, 0.25%Ni
3.	Cr - steels	0.24%C, 0.21%Si, 0.42%Mn, 0.96%Cr, 0.17%Ni, 0.35%S

FLUXES

A flux is a chemical substance used to prevent, dissolve or remove the oxides formed during welding. It is fusible and non-metallic chemical compound.

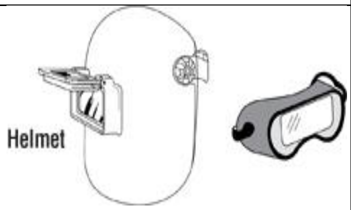
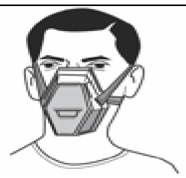
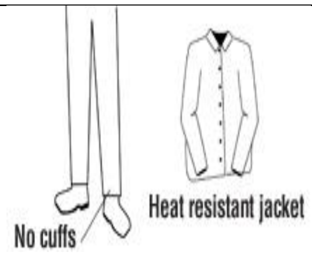
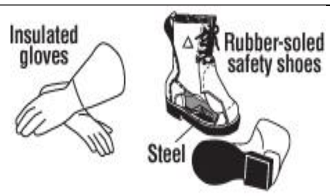
Fluxes are available in several forms, such as dry powders, a paste, liquids, or coatings on welding rod. In gas welding, the borax, sodium chloride are commonly used as flux material. The dry flux is applied by heating the end of the welding rod and dipping it into the powdered material. A single flux is not suitable for welding all metals. The type of flux used depends on operation and the base metal being welded.

Sr. No.	Material to be weld	Flux material
1.	Ferrous metals	Borax, carbonate, bicarbonate and silicates of sodium.
2.	Copper and its alloys	Boric acid, mixture of sodium and potassium, borates, carbonates, sulphates etc.
3.	Aluminium and its alloys	Alkaline chlorides, fluorides and bisulphates.
4.	Magnesium and its alloys	Same as used for aluminium and its alloys.

Function of fluxes

1. The flux prevents the formation of oxides, nitrides and other undesirable material in the weld pool.
2. The flux protects the molten metal from atmospheric oxygen to go inside.
3. The flux chemically reacts with the oxides present and forms a low melting temperature fusible slag, the slag floats during the welding and deposited on the top surface of the joint after Solidification of metal. It can be easily brushed off by brush and chipping hammer.
4. The flux acts as better cleaning agent. It helps to clean and protect the surface of the base metal.

1.2.5 PERSONAL SAFETY EQUIPMENT FOR WELDING

Body Part	**Equipment**	**Illustration**	**Reason**
Eyes and face	Welding helmet, hand shield, or goggles		Protects from: - Radiation - Flying particles, debris - Hot slag, sparks - Intense light - Irritation and chemical burns Wear fire resistant head coverings under the helmet where appropriate
Lungs (breathing)	Respirators		Protects against: - Fumes and oxides
Exposed skin (other than feet, hands, and head)	Fire/Flame resistant clothing and aprons		Protects against: - Heat, fires - Burns - Radiation Notes: pants should not have cuffs, shirts should have flaps over pockets or be taped closed
Ears- hearing	Ear muffs, ear plugs		Protects against: - Noise Use fire resistant ear muffs where sparks or splatter may enter the ear, rather than plugs.
Feet and hands	Boots, gloves		Protects against: - Electric shock - Heat - Burns - Fires

1.3 ARC WELDING

Arc welding is a type of fusion welding in which an electric arc is set up between the metal electrode or welding rod and the workpiece. An electric arc is generated when the two conductors are placed within a distance of 2-4 mm so that there will be continuity in current flow all the way through the air. Electric arc generates temperature in the range of 4000ºC to 6000ºC. The various arc welding processes are as follow:

1. Metal arc welding
2. Carbon arc welding
3. TIG welding
4. MIG welding
5. Electro gas welding
6. Plasma arc welding

1.3.1 PRINCIPLE OF OPERATION OF ARC WELDING

Principle of operation of arc welding consists of the following steps:

1. **Preparation of edges of workpieces**

Edges of the workpieces are suitably prepared before welding. No matter what type of joint is used, proper cleaning of the workpieces prior to welding is essential if welds of good appearance and physical properties are to be obtained. On small assemblies, manual cleaning with a wire brush, steel wool, or a chemical solvent is usually sufficient. For large assemblies or for cleaning on a production basis, vapor degreasing or tank cleaning may be more economical. In any case, be sure to remove completely all oxide, scale, oil, grease, dirt, rust, and other foreign matter from the work surfaces.

2. **Striking the arc**

After connecting the work to the welding circuit, the electrode is brought in contact with the work at the point where the welding is to be started. After a light contact, the electrode is immediately withdrawn to a distance of 2 to 4mm from the work. Comparatively, a low voltage is required between the electrode and the work to strike an arc. 80 to 100 V is usually sufficient for A.C. arc welding and 60 to 80 V for D.C. arc welding. The voltage available at the output terminals of a welding set, before the arc is struck, is known as open circuit voltage (OCV). A stable arc can be maintained between a metal electrode and the workpiece with a voltage of 15 to 30V, while 30 to 35V are needed to strike an arc between non-consumable electrode and the work.

1.3.2 D.C. AND A.C. ARC WELDING & ARC WELDING MACHINE

With direct current, greater heat is generated at the positive pole of the arc. In metal arc welding, it is the general practice to connect the work to the positive pole of the DC generator and filler rod to the negative pole so that the larger mass of metal is melted on base metal.

An alternating current is an electric current that reverses its direction many times per second. A 60-hertz current will change its polarity 120 times per second. With AC welding, because the magnetic field and current rapidly reverse-direction, there is no net deflection of the arc.

COMPARISON OF AC AND DC ARC WELDING

Sr. No.	AC arc welding	DC arc welding
1	Alternating current is used.	Direct current is used.
2	Transformer is cheaper and simple in operation.	DC generator costlier and more cumbersome in operation.
3	Maintenance of transformer is easier because of no moving parts	Maintenance cost is more because of many moving parts.

4	Efficiency of transformer is high.	Efficiency of transformer is low.
5	Striking the arc particularly with electrodes is relatively difficult.	It is easier to strike an arc even with thin electrodes.
6	Arc blow is not there.	Arc blow is there.
7	Bare electrodes cannot be used in AC arc welding.	Both bare and coated electrodes can be used.
8	Polarity concept is not presents.	Polarity concept is used.
9	Welding of non-ferrous metal is not possible.	Welding of non-ferrous metal is possible.
10	AC is more dangerous.	DC is comparatively less dangerous.

ARC WELDING MACHINE

A source is used to provide both AC and DC to meet the complex variables of the arc. This source is called welding machine. Two types of welding machine may be used:

1. Direct current welding machines
2. Alternating current machines

1. DC welding machines

DC welding machines are of following types:

1. Motor generator welding machine
2. Engine driven generator welding machine
3. Rectifier welding machine

1. Motor generator welding machine

A motor generator consists of an electric motor and a generator mounted on a common shaft with separate or same housing in horizontal or vertical position. Welding current is supplied by the generator which is driven by the motor. The open circuit voltage of the generator varies from 50-100V. a polarity switch is generally provided on the machine gives straight or reverse polarity.

2. Engine driven generator welding machine

Petrol, diesel or compressed air is used to drive the engine which drives the generator. This is quite useful in areas where electric power is not available as it is independent of external power supply.

3. Rectifier welding machine

A rectifier is a device which permits current flow in one direction only and can therefore be used to convert AC to DC. They can be supplied as an individual unit, but most often are incorporated into the welding power source. The rectifier consists of metal plates coated with a selenium compound, or of silicon diodes- each having the special property of allowing the current to flow in one direction only. This means that when an alternating voltage is applied, only the positive half-cycles are effective. This 'half wave rectification' is undesirable and uneconomical, so the rectifier units are arranged in the form of a bridge to achieve 'full wave rectification'.

2. AC welding machines

When an AC mains supply is available, it is possible to use a step-down transformer to reduce the supply voltage of 415 V to a safe OCV of around 70–80 volts. At the same time current is increased so as to provide sufficient heat for welding.

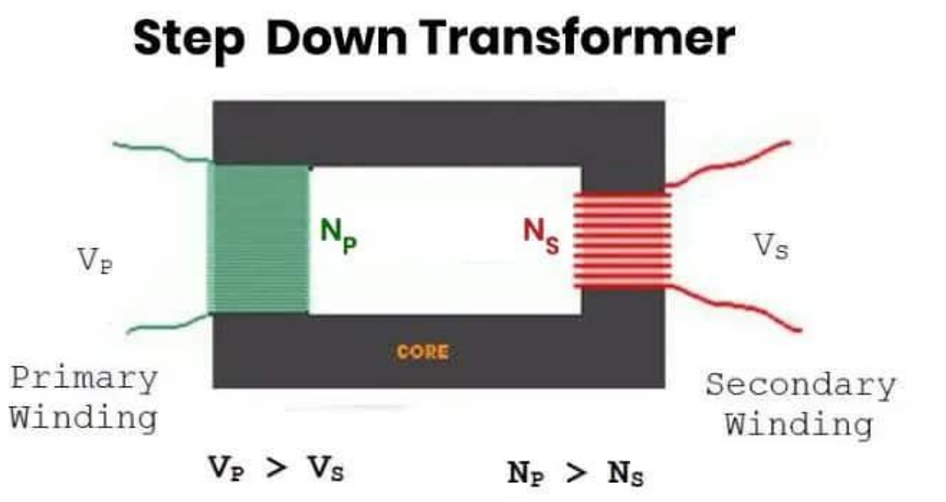


Fig. 6 : Step-down transformer

The step-down welding transformer consists of a laminated, soft iron core carrying two coils which are not electrically connected as shown in fig. 6. The first is connected to the supply (primary). Voltage applied across the first coil will produce, by induction, a voltage in the second coil. The value of this secondary (induced) voltage will be proportional to the ratio between the turns in the two coils. If each coil has an equal number of turns, equal voltage will appear at the secondary connections. If, however, a transformer has 400 turns in the primary coil, and 50 turns in the secondary coil, then a primary voltage of 400 V will induce 50 V to appear at the secondary connections. The power into the welding machine is calculated by multiplying the volts by the amps and is expressed as volt-amps (VA). This figure is generally quite large and is usually divided by 1000 and expressed as kilovolt amperes (kVA). The transformer welding machine is equipped with a regulator to control the current for the size of the electrode being used by the operator. The regulator may work on either of the following principles:

1. Moving core principle
2. Moving coil principle
3. Trapped choke principle
4. Magnetic amplifier principle

1.3.3 POLARITY IN ARC WELDING

The type of potential is given to the workpiece or electrode. In case of DC power source, positive and negative terminals are fixed, whereas, in case of AC power source, positive and negative terminals are not fixed. Polarities are of following two types:

1. Straight polarity
2. Reverse polarity

1. **Straight polarity:** The electrode is connected to negative terminal, whereas the workpiece is connected to the positive terminal of the direct current source.
2. **Reverse polarity:** The electrode is connected to positive terminal, whereas the workpiece is connected to the negative terminal of the direct current source.

EFFECT OF POLARITY

Straight polarity or DCEN (Direct current electrode negative) is a situation where the electrode is made negative and the work is made positive. Since, electrons flow from negative to positive, a large amount of heat appears on the work, usually 2/3rd of total heat. More heat implies deeper penetration. DCEN is required for thicker plates and materials of higher thermal conductivity.

Reverse polarity or DCEP (Direct current electrode positive) is a situation where the electrode is made positive and the work is made negative. So, a large amount of heat appears at the electrode here (not on the work). This is done for the purpose of welding thinner plates. Weld penetration is less due to less amount of heat available to the work.

1.3.4 CURRENT AND VOLTAGE REGULATION IN ARC WELDING

The alternating current for arc is obtained from a step down transformer. The transformer receives current from the main supply at 220 to 440 volts and step down to required voltage i.e., 80 to 100 volts. The direct current for arc is usually obtained from a generator driven by either an electric motor, or petrol or diesel engine.

An open circuit voltage (for striking of arc) in case of DC welding is 60 to 80 volts while a closed circuit voltage (for maintaining the arc) is 15 to 25 volts.

1.3.5 ELECTRODES

An electrode is a metallic or non-metallic wire rod which is used as a terminal or terminals in an electric circuit to produce an electric arc. The electrodes are also used as filler rods in the metal arc welding process.

TYPES OF WELDING ELECTRODES

Basically, depending upon the process there are two types of welding electrodes:

1. Consumable electrodes
2. Non-consumable electrodes

1. Consumable electrodes

Consumable electrodes have low melting point. These types of welding electrodes are preferred to use in Metal Inert Gas (MIG) welding. For making consumable electrodes, materials such as mild steel and nickel steel are used. The one precaution that you must take is to replace consumable electrodes after regular intervals. The only disadvantage of using such electrodes is that they don’t have a large number of industry applications but at the same time they are easy to use and maintain.

Consumable electrodes are categorized as:

a. Bare Electrodes
b. Coated Electrodes

a. Bare electrodes

Bare electrodes are electrodes without any type of coating and mostly used in applications where there is no need of coated electrode.

b. Coated electrodes

Coated electrodes are classified according to the coating factor. Coating factor is the ratio of the diameter of the electrode to the diameter of the core wire.

So, following are sub types of coated electrodes:

1. **Light coated electrodes** with coating factor of 1.25. Light coating applied to electrodes helps to remove impurities such as oxides and phosphorous. Light coating also helps in enhancing arc stability.
2. **Medium coated electrodes** with coating factor of 1.45.
3. **Shielded arc or heavily coated electrodes** with coating factor ranging in between 1.6 to 2.2. These electrodes have a proper and well defined composition. The heavily coated electrodes are designed in three types- electrodes with cellulose coating, electrodes with mineral coating and the electrodes with coating of both cellulose as well as mineral coating.

2. Non-consumable electrodes

These types of welding electrodes are also referred to as Refractory electrodes. There are again two sub-types of non-consumable electrodes:

a. **Carbon or Graphite electrodes:** It is made up of carbon and graphite and mostly used in the applications of cutting and arc welding.
b. **Tungsten electrodes:** Basically, it is consists of tungsten as the name itself suggests and it is a non-filler metal electrode.

As the name suggests, these types of welding electrodes are not consumed in the entire welding process or we can say more appropriately that they do not melt during welding. But practically, due to the vaporization and oxidation processes taking place during welding there is a little bit reduction in the length of the electrode. The non-consumable electrodes have high melting point and are unable to fill the gap in the workpiece. Non-consumable electrodes are made from materials such as pure tungsten, graphite or carbon coated with copper. The melting point of carbon is 3350 degree Celsius and that of Tungsten is 3422 degree Celsius. Non-consumable electrodes are used in Tungsten inert gas welding (TIG) and carbon arc welding.

1.3.6 BIS CODING OF ELECTRODES & SELECTION OF ELECTRODE

A coding system is used to indicate some characteristics of the electrodes. It is printed on each packet of the electrodes. The details of the coding system are as given below:

1. **Prefix letter:** Prefix letter indicates the method of manufacturing of electrode.
2. **First digit:** The first digit of the numeric code indicates the types of covering.
3. **Second digit:** The second digit of the numeric code indicates the position or position in which the electrodes may be used.
4. **Third digit:** The third digit of the numeric code indicates the welding current conditions recommended by the manufacturer of the electrode.
5. **Fourth and fifth digits:** Fourth and fifth digits indicate mechanical properties such as tensile strength and the appropriate yield stress.
6. **Sixth digit:** The sixth digit of numeric code indicates the percentage elongation in combination with impact value of the deposited metal.

Selection of electrode

The selection of an electrode for a job is made on basis of following considerations:

1. The electrode diameter should not to be more than the thickness of the base plate.
2. The maximum diameter of the electrode for vertical and overhead position is 5 mm.
3. A thin electrode is recommended for making first run of a thick metal job for better penetration.
4. It is economical to use larger diameter electrodes, but it is difficult to control the arc.

1.3.7 FLUX FOR ARC WELDING

A flux is a substance used to prevent the formation of oxides and the other unwanted contaminations, or to dissolve them and facilitate removal. During welding the flux melts and becomes a liquid slag, Covering the operation and protecting the molten weld metal. The slag hardens upon cooling and must be removed later by Chipping or brushing. The type of flux used depends on operation and the base metal being welded.

Sr. No.	Material to be weld	Flux material
1.	Ferrous metals	Borax, carbonate, bicarbonate and silicates of sodium.
2.	Copper and its alloys	Boric acid, mixture of sodium and potassium, borates, carbonates, sulphates etc.
3.	Aluminium and its alloys	Alkaline chlorides, fluorides and bisulphates.
4.	Magnesium and its alloys	Same as used for aluminium and its alloys.

1.3.8 REQUIREMENT OF PREHEATING & POST HEATING

Requirement of Preheating

Preheating the steel to be welded slows the cooling rate in the weld area. This may be necessary to avoid cracking of the weld metal or heat affected zone. The need for preheat increases with steel thickness, weld restraint, the alloy content of the steel, and the diffusible hydrogen of the weld metal. Preheat is commonly applied with fuel gas torches or electrical resistance heaters.

Requirement of Post Heating

Post-weld heat treatment is most generally used for stress relief. The purpose of stress relieving is to remove any internal or residual stresses that may be present from the welding operation. Stress relief after welding may be necessary in order to reduce the risk of brittle fracture, to avoid subsequent distortion on machining, or to eradicate the risk of stress corrosion.

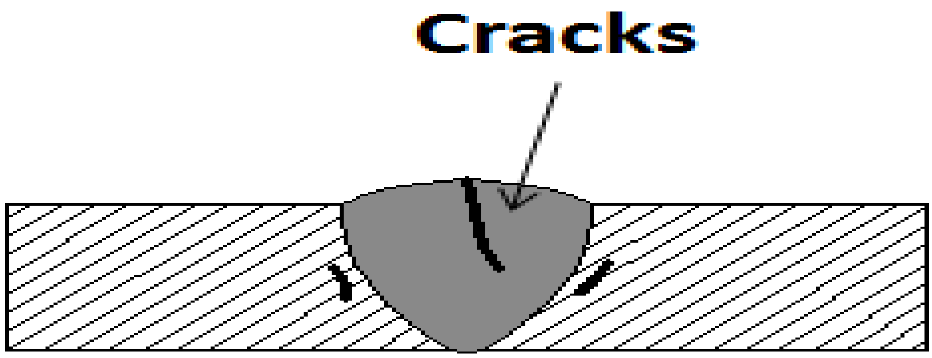
1.3.9 WELDING DEFECTS

Defects are common in any type of manufacturing, welding including. In the process, there can be deviations in the shape and size of the metal structure. It can be caused by the use of the incorrect welding process or wrong welding technique.

1. Weld crack

The most serious type of welding defect is a weld crack and it's not accepted almost by all standards in the industry. It can appear on the surface, in the weld metal or the area affected by the intense heat.

There are different types of cracks, depending on the temperature at which they occur:



- **Hot cracks:** These can occur during the welding process or during the crystallization process of the weld joint. The temperature at this point can rise over 10,000 C.
- **Cold cracks:** These cracks appear after the weld has been completed and the temperature of the metal has gone down. They can form hours or even

days after welding. It mostly happens when welding steel. The cause of this defect is usually deformities in the structure of steel.

- **Crater cracks:** These occur at the end of the welding process before the operator finishes a pass on the weld joint. They usually form near the end of the weld. When the weld pool cools and solidifies, it needs to have enough volume to overcome shrinkage of the weld metal. Otherwise, it will form a crater crack.

Causes of cracks:

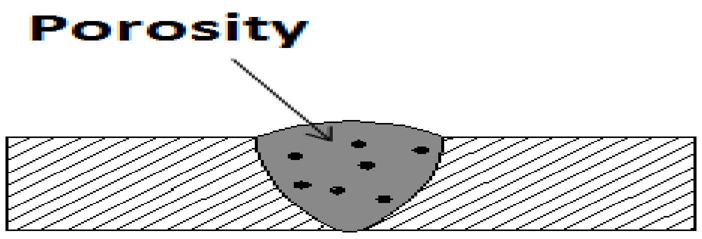
- Use of hydrogen when welding ferrous metals.
- Residual stress caused by the solidification shrinkage.
- Base metal contamination.
- High welding speed but low current.
- No preheat before starting welding.
- Poor joint design.
- A high content of sulfur and carbon in the metal.

Remedies:

- Preheat the metal as required.
- Provide proper cooling of the weld area.
- Use proper joint design.
- Remove impurities.
- Use appropriate metal.
- Make sure to weld a sufficient sectional area.
- Use proper welding speed and amperage current.
- To prevent crater cracks make sure that the crater is properly filled.

2. Porosity

Porosity occurs as a result of weld metal contamination. The trapped gases create a bubble-filled weld that becomes weak and can with time collapse.



Causes of porosity:

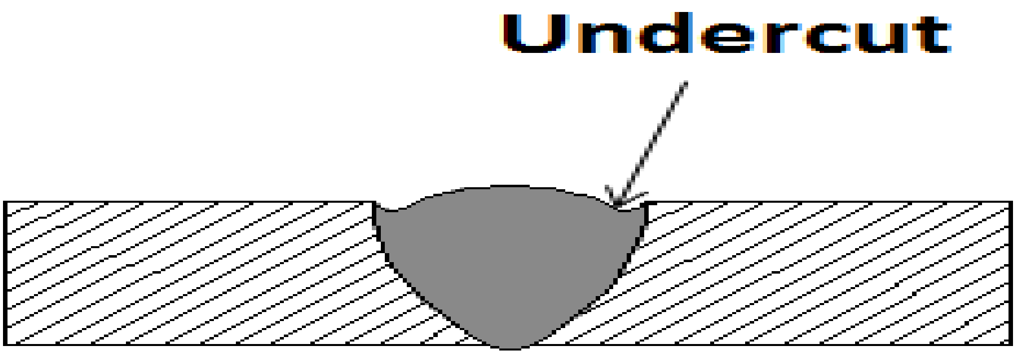
- Inadequate electrode de-oxidant.
- Using a longer arc.
- The presence of moisture.
- Improper gas shield.
- Incorrect surface treatment.
- Use of too high gas flow.
- Contaminated surface.
- Presence of rust, paint, grease or oil.

Remedies:

- Clean the materials before you begin welding.
- Use dry electrodes and materials.
- Use correct arc distance.
- Check the gas flow meter and make sure that it’s optimized as required with proper with pressure and flow settings.
- Reduce arc travel speed, which will allow the gases to escape.
- Use the right electrodes.
- Use a proper weld technique.

3. Undercut

This welding imperfection is the groove formation at the weld toe, reducing the cross-sectional thickness of the base metal. The result is the weakened weld and workpiece.



Causes:

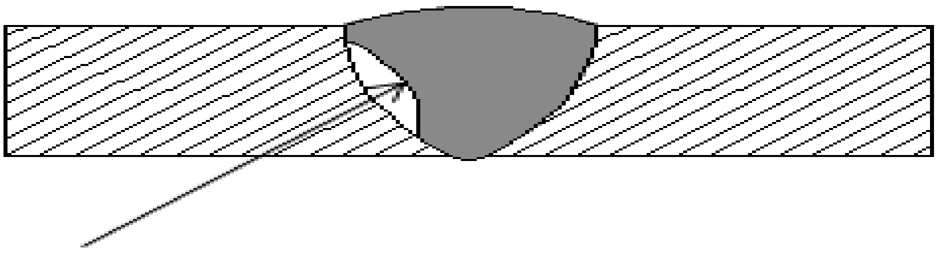
- Too high weld current.
- Too fast weld speed.
- The use of an incorrect angle, which will direct more heat to free edges.
- The electrode is too large.
- Incorrect usage of gas shielding.
- Incorrect filler metal.
- Poor weld technique.

Remedies:

- Use proper electrode angle.
- Reduce the arc length.
- Reduce the electrode's travel speed, but it also shouldn't be too slow.
- Choose shielding gas with the correct composition for the material type you'll be welding.
- Use of proper electrode angle, with more heat directed towards thicker components.
- Use of proper current, reducing it when approaching thinner areas and free edges.
- Choose a correct welding technique that doesn't involve excessive weaving.
- Use the multi-pass technique.

4. Incomplete fusion

This type of welding defect occurs when there's a lack of proper fusion between the base metal and the weld metal. It can also appear between adjoining weld beads. This creates a gap in the joint that is not filled with molten metal.



Incomplete Fusion

Causes:

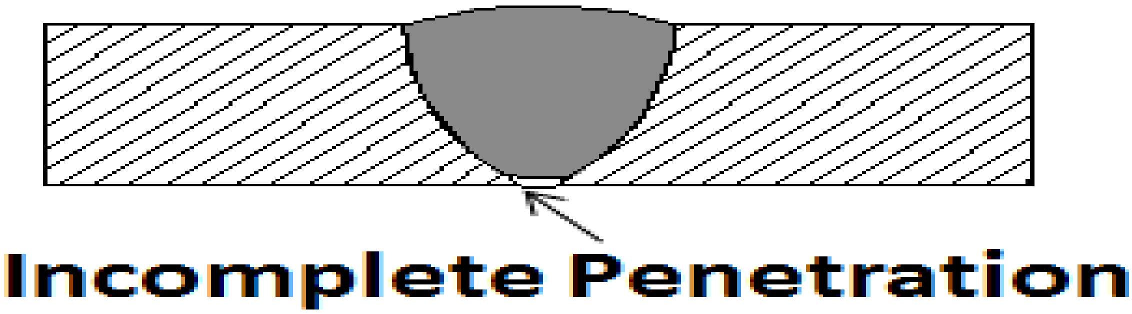
- Low heat input.
- Surface contamination.
- Electrode angle is incorrect.
- The electrode diameter is incorrect for the material thickness.
- Travel speed is too fast.
- The weld pool is too large and it runs ahead of the arc.

Remedies:

- Use a sufficiently high welding current with the appropriate arc voltage.
- Before you begin welding, clean the metal.
- Avoid molten pool from flooding the arc.
- Use correct electrode diameter and angle.
- Reduce deposition rate.

5. Incomplete penetration

Incomplete penetration occurs when the groove of the metal is not filled completely, meaning the weld metal doesn't fully extend through the joint thickness.



Causes:

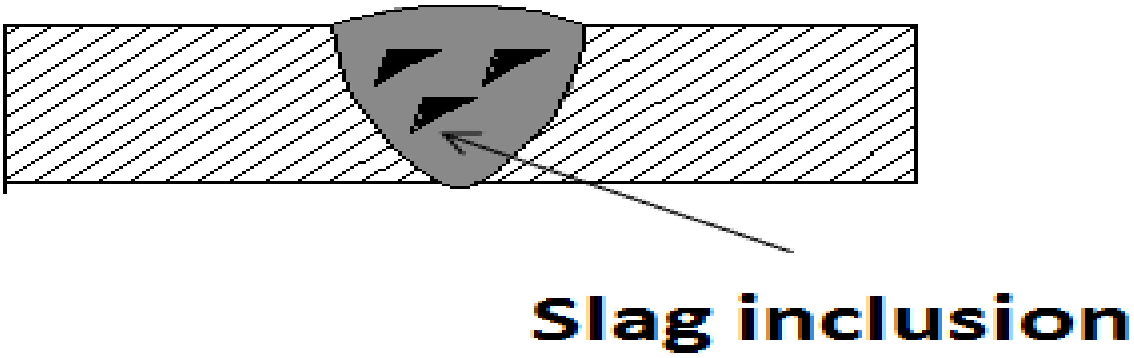
- There was too much space between the metal where welding together.
- If we moving the bead too quickly, which doesn't allow enough metal to be deposited in the joint.
- Use of too low amperage setting, which results in the current not being strong enough to properly melt the metal.
- Large electrode diameter.
- Misalignment.
- Improper joint.

Remedies:

- Use proper joint geometry.
- Use a properly sized electrode.
- Reduce arc travel speed.
- Choose proper welding current.
- Check for proper alignment.

6. Slag Inclusion

Slag inclusion is one of the welding defects that are usually easily visible in the weld. Slag is a vitreous material that occurs as a byproduct of stick welding, flux-cored arc welding and submerged arc welding. Its can occur when the flux, which is the solid shielding material used when welding, melts in the weld or on the surface of the weld zone.



Causes:

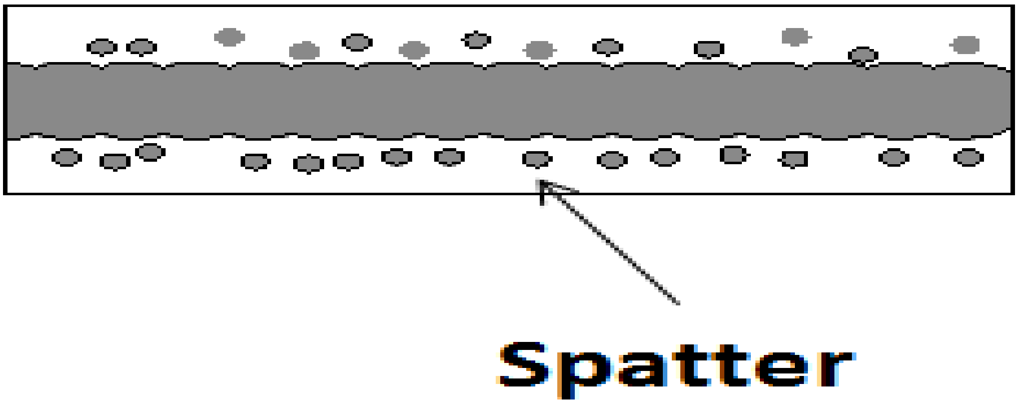
- Improper cleaning.
- The weld speed is too fast.
- Not cleaning the weld pass before starting a new one.
- Incorrect welding angle.
- The weld pool cools down too fast.
- Welding current is too low.

Remedies:

- Increase current density.
- Reduce rapid cooling.
- Adjust the electrode angle.
- Remove any slag from the previous bead.
- Adjust the welding speed.

7. Spatter

Spatter occurs when small particles from the weld attach themselves to the surrounding surface. It is an especially common occurrence in gas metal arc welding. No matter how hard you try, it can't be completely eliminated. However, there are a few ways that can keep it to a minimum.



Causes:

- The running amperage is too high.
- Voltage setting is too low.
- The work angle of the electrode is too steep.
- The surface is contaminated.
- The arc is too long.
- Incorrect polarity.
- Erratic wire feeding.

Remedies:

- Clean surfaces prior to welding.
- Reduce the arc length.
- Adjust the weld current.
- Increase the electrode angle.
- Use proper polarity.
- Make sure don’t have any feeding issues.

1.3.9 INSPECTION AND TESTING OF WELDED JOINTS

a. Destructive Tests

Some of these tests, such as tensile and bending tests, are destructive, in that the test Specimens are loaded until they fail, so the desired information can be gained. Destructive tests are in two categories:

1. Workshop based tests

2. Laboratory tests (corrosive, chemical, microscopic, macroscopic/magnifying glass)

b. Non-destructive tests (NDT)

Other testing methods, such as the X-ray and hydrostatic tests are not destructive (NDT). This type of testing is also referred to as NDE or nondestructive examination and NDI or nondestructive inspection. The goal of these methods is to exam the welds without causing any damage.

1. Magnetic particle test

This is a physical weld testing or inspection method used on welds and parts made of magnetic alloy steels. It is applicable only to ferromagnetic materials in which the deposited weld is also ferromagnetic. A strong magnetic field is set up in the piece being inspected by means of high amperage electric currents as shown in fig.7.

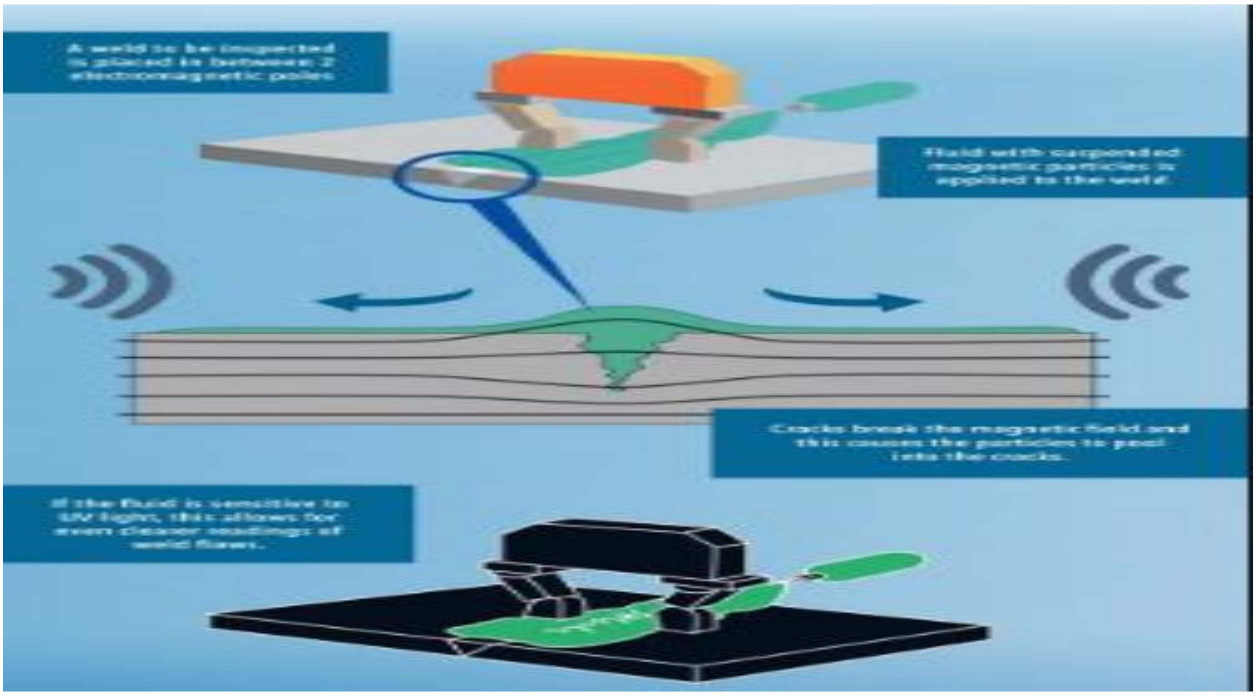


Fig. 7: Magnetic particle test

A leakage field will be set up by any discontinuity that intercepts this field in the part. Local poles are produced by the leakage field. These poles attract and hold magnetic particles that are placed on the surface for this purpose. The particle pattern produced on the surface indicates the presence of a discontinuity or defect on or close to the surface of the part.

2. X-Ray Testing

This is a radiographic physical weld testing method used to reveal the presence and nature of internal defects in a weld, such as cracks, slag, blowholes, and zones where proper fusion is lacking as shown in fig. 8. In practice, an X-ray tube is placed on one side of the welded plate and an X-ray film, with a special sensitive emulsion, on the other side. When developed, the defects in the metal show up as dark spots and bands, which can be interpreted by an operator experienced in this inspection method.

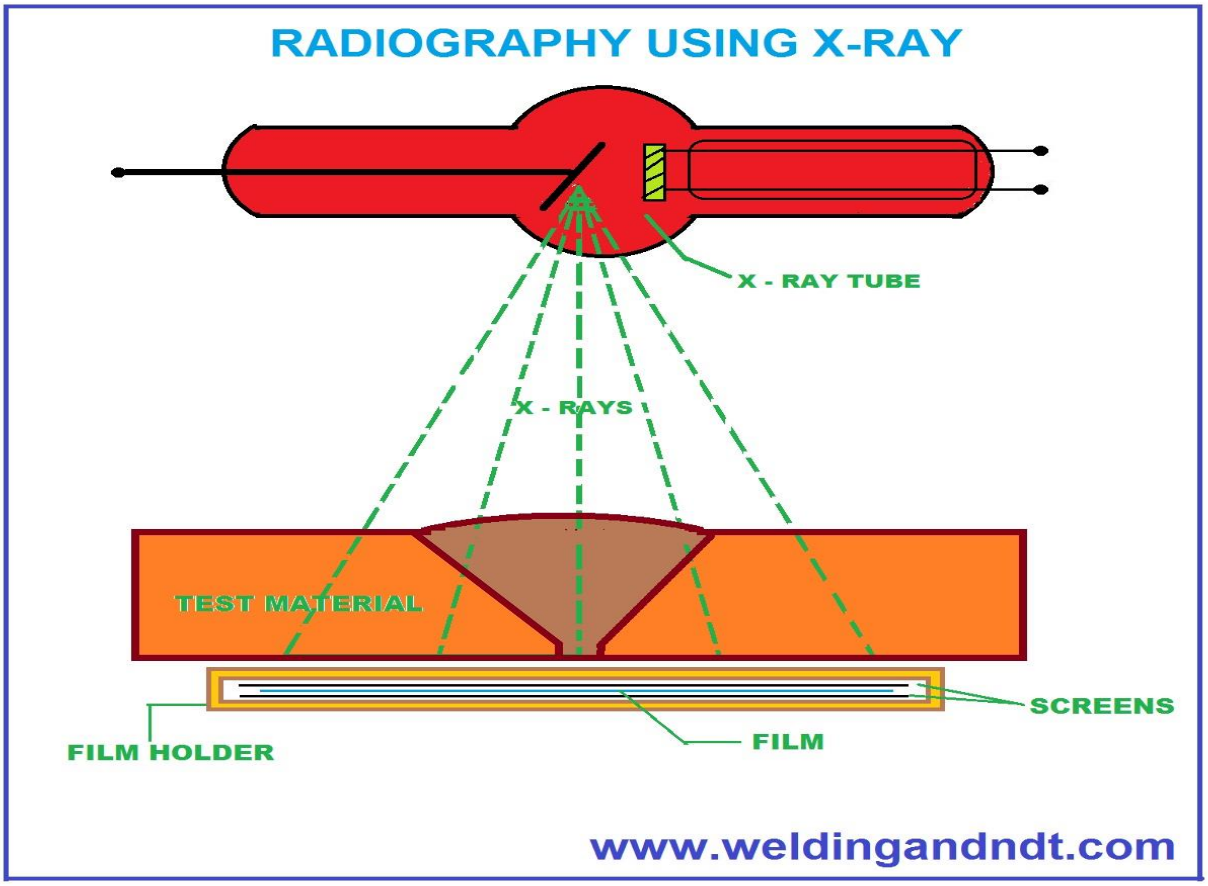


Fig. 8: X-ray testing

1.4.1 RESISTANCE WELDING

It is a welding process in which metal pieces to be welded are first heated to the fusion temperature by the resistance of these to the flow of electric current and then squeezed by mechanical pressure to accomplish weld. No filler material or flux is added.

PRINCIPLE OF RESISTANCE WELDING

The working principle of resistance welding is the generation of heat because of electric resistance. The resistance welding such as seam, spot, protection works on the same principle as shown in fig. 9. Whenever the current flows through electric resistance, then heat will be generated. The same working principle can be used within the electric coil. The generated heat will depend on material's resistance, applied current, conditions of a surface, and applied the current time period. The heat generation takes place because of the energy conversion from electric to thermal. The resistance welding formula for heat generation is

$$H = I^2RT$$

Where H – total heat generated (J),

I – electric current (A),

T – Time for which electric current is passed through the joint (s),

R – Resistance of the joint (Ohm)

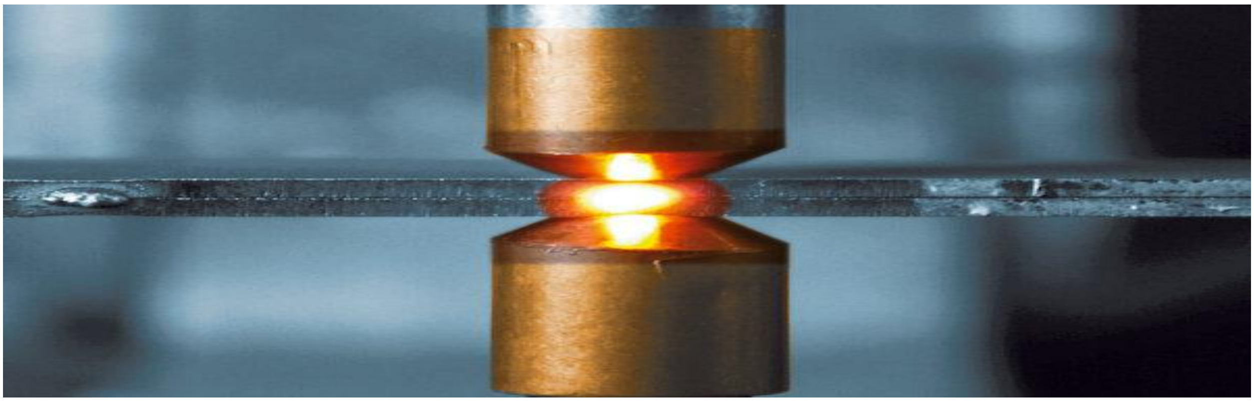


Fig. 9: Resistance welding

ADVANTAGES

1. This method is simple and does not necessary high expert labor.

2. The resistance welding metal thickness is 20mm, & thinness is 0.1 mm.
3. Automated simply
4. The rate of production is high
5. Both related & different metals can be weld.
6. Welding speed will be high
7. It does not need any flux, filler metal & protecting gases.

DISADVANTAGES

1. Tools cost will be high.
2. The work section thickness is limited because of the current requirement.
3. It is less proficient for high-conductive equipment.
4. It consumes high electric-power.
5. Weld joints contain small tensile & fatigue power.

APPLICATIONS

1. Joining sheets, bars and tubes.
2. Making containers.
3. Making metal furniture.
4. Making fuel tanks in cars, tractors etc.
5. Welding aircraft and automobile parts.

TYPES OF RESISTANCE WELDING

The various types of resistance welding processes are as follow:

- Spot welding
- Seam welding
- Projection welding
- Flash welding
- Butt welding
- Percussion welding

1.4.2 SPOT WELDING

Spot welding is the simplest type of welding where the work portions are held jointly below the force of anvil face. The copper (Cu) electrodes will make contact with the work portion & the flow of current through it. The work portion material applies a few resistances within current flow which will cause limited heat production. The resistance is high at the edge surfaces because of the air gap. The current begins to supply through it, then it will reduce the edge surface. As shown in fig.10.

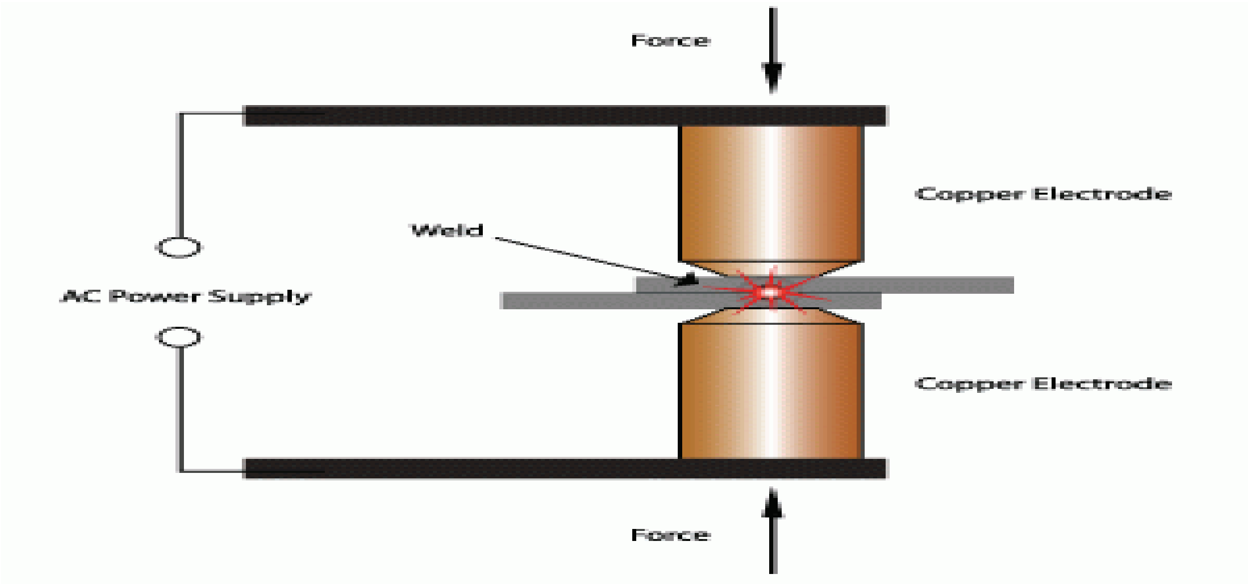


Fig.10: Spot welding

The current supply & the time must be enough for the correct dissolving of edge faces. Now the flow of current will be stopped however the force applied with electrode continued for a second, whereas the weld quickly cooled. Later, the electrodes eliminate as well as get in touch with new spot to create a circular piece. The piece size mainly depends on electrode size (4-7 mm).

Application of spot welding

1. Automobile and aircraft industries.
2. Household steel furniture.
3. Welding of low carbon steels, HSS, SS and Al, Cu and nickel alloys.
4. Containers etc.

1.4.3 SEAM WELDING

This type of welding is also known as continuous spot welding where a roller form electrode can be utilized to supply current throughout work parts. Initially, the roller electrodes are getting in touch with the work part. High current can be supplied through these electrode rollers to melt the edge surfaces & shape a weld joint. It is shown in fig.11.

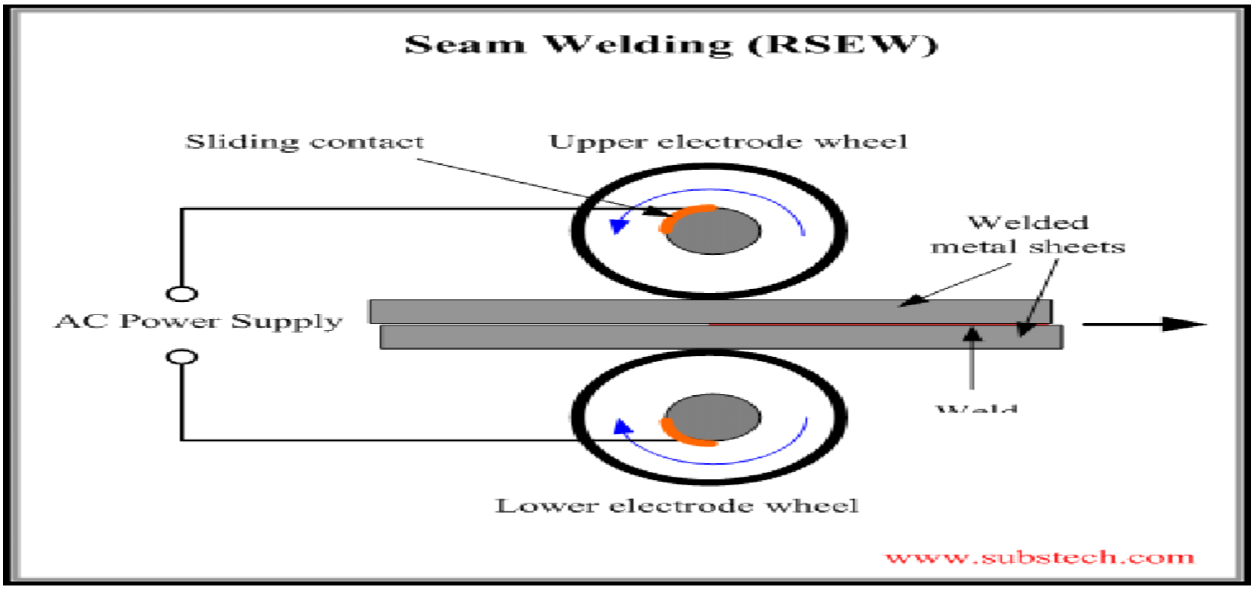


Fig. 11: Seam welding

At present, the electrode rollers will begin rolling on work plates to make a permanent weld joint. The weld timing & electrode movement can be controlled to guarantee that the weld overlap and work part doesn’t acquire too warm. The speed of the welding can be about 60 in per min within seam welding, which is used to make airtight joints.

Application of seam welding

It is used for welding of stainless steel, Al and its alloys, nickel and its alloys etc.

1.4.4 PROJECTION WELDING

It is in fact a modified form of the spot welding. One of the pieces to be welded this way has projections produced by pressure. The electrodes are flat. The electrodes are placed on work piece and current passed between them. Heat is produced at the contacts and work piece gets welded at these points as shown in fig.12.

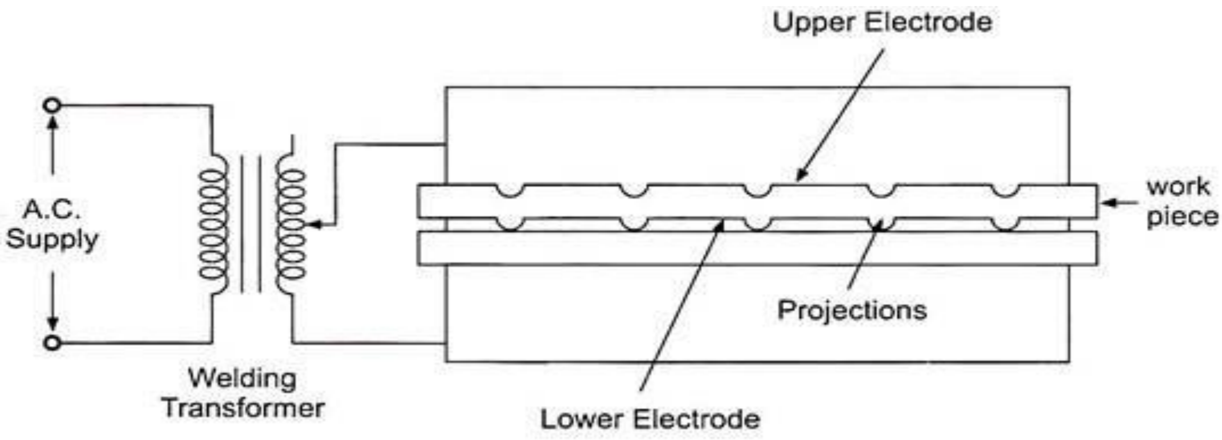


Fig.12: Projection welding

It is easy to weld certain parts which cannot be welded by spot welding. When two plates to be welded are of different cross-section then in order to obtain desirable strength it is necessary to have the projections on the thicker plate.

Application of projection welding

It is widely used in electrical, electronics, automotive and construction industries, and manufacturing of sensors, valves and pumps etc.

1.4.5 PERCUSSION WELDING

It is one type of resistance butt-welding process. The parts to be welded are clamped in copper jaws of the welding machine in which one clamp is fixed and other one is movable. The movable clamp is backed up against the pressure from a heavy spring. The jaws act as electrodes. Heavy electric current is connected to the workpieces. Now, the movable clamp is released rapidly and it moves forward at high velocity. When the two parts are approximately 1.6 mm apart, a sudden discharge of electrical energy is released thereby causing an intense arc between two surfaces. The arc is extinguished by the percussion blow of the two parts coming together with sufficient force to complete in 0.1 second. No upset or flash occurs at the weld. This method is primarily employed to join dissimilar metals.

Application of percussion welding

1. It is used in telephone industries.
2. It is used for welding stellite tips to tools, silver contact tips to copper etc.
3. It is also used for welding fine wire leads to filaments in lamps etc.

1.4.6 ATOMIC HYDROGEN WELDING

Atomic hydrogen or tungsten arc welding is a fusion process in which an arc is created between two tungsten electrodes. A stream of hydrogen is passed through an arc between two Tungsten electrodes. A.C. is used at the time of welding. The energy of the arc is created by the electrodes splits up the molecules of hydrogen into atomic state with the absorption of a large amount of heat as shown in fig 13.

The atoms recombine when they reach the slightly cooler regions. While recombining atoms to molecular state, intense heat is released. The temperature of the heat is about 4000°C. Transformers of movable primary coil are used for regulation with an open circuit voltage of about 300 volts & stepping down to maintain the arc to 70–90 volts. The pri-coil connected to power supply through fused switch & sec-coil through magnetic contactor which open when the arc is broken. The flow of hydrogen is connected to the tubular clamps. One clamp is fixed. Others are movable, connected to the start & stop button through which electrodes are brought together & separates the electrode. The clamps are so arranged that the electrodes converge at an angle of about 30–40°. Hydrogen gas is supplied from the cylinder. The regulator is similar to an acetylene regulator.

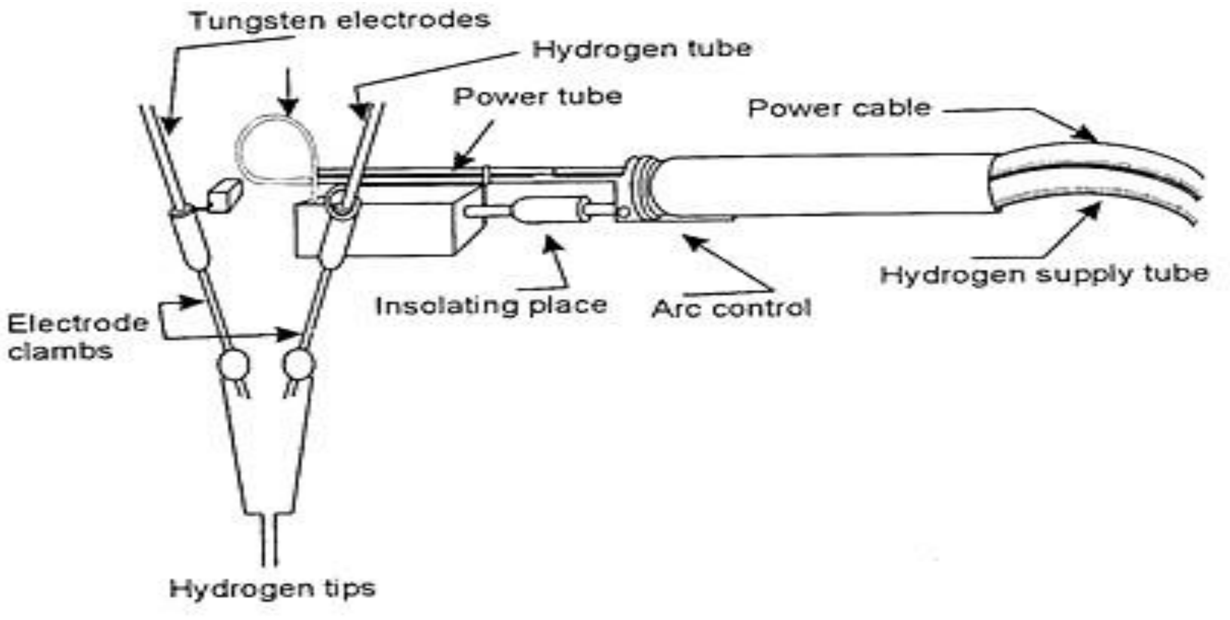


Fig.13: Atomic hydrogen welding

The electrode becomes shorter due to its slow consumption, it should be readjusted. A filler rod, when required, should be used as in oxy-acetylene welding. The filler rods shouldn't contract the hot electrodes. Atomic hydrogen welding is applicable practically in all commercial metals & alloys.

1.4.7 SHIELDED METAL ARC WELDING

Shielded metal arc welding (Stick welding, manual metal arc welding) uses a metallic consumable electrode of a proper composition for generating arc between itself and the parent work piece. The molten electrode metal fills the weld gap and joins the work pieces as shown in fig. 15.

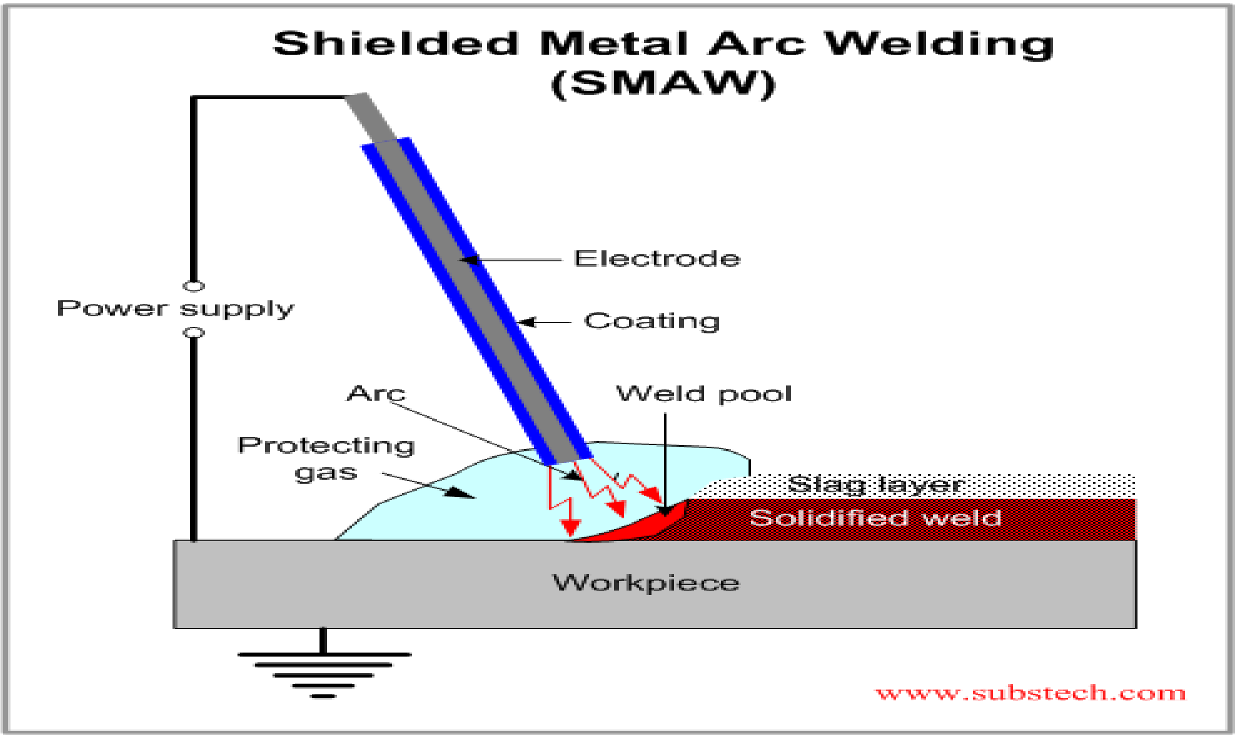


Fig. 15: Shielded metal arc welding

The electrodes are coated with a shielding flux of a suitable composition. The flux melts together with the electrode metallic core, forming a gas and a slag, shielding the arc and the weld pool. The flux cleans the metal surface, supplies some alloying elements to the weld, protects the molten metal from oxidation and stabilizes the arc. The slag is removed after Solidification.

Advantages

1. Simple, portable and inexpensive equipment;
2. Wide variety of metals, welding positions and electrodes are applicable.
3. Suitable for outdoor applications.

Disadvantages

1. The process is discontinuous due to limited length of the electrodes.
2. Weld may contain slag inclusions.
3. Fumes make difficult the process control.

1.4.8 SUBMERGED ARC WELDING (SAW)

In this welding, arc can travel under a layer of granular flux. In this type of welding, a tubular electrode otherwise consumable solid can be fed constantly to the weld region. At the same time, a layer of granular fusible flux can be poured over the weld zone which immersed the welding arc as well as defends it from atmospheric pollution as shown in fig 14.

In this kind of welding, the flux begins for depositing on the joint to be welded. Whenever the flux is cold, then it acts as an insulator. The arc can be started by moving the tool by the work portion. The arc struck will constantly remain below a wide coating of flux, and the generated heat by the arc softens the granular flux.

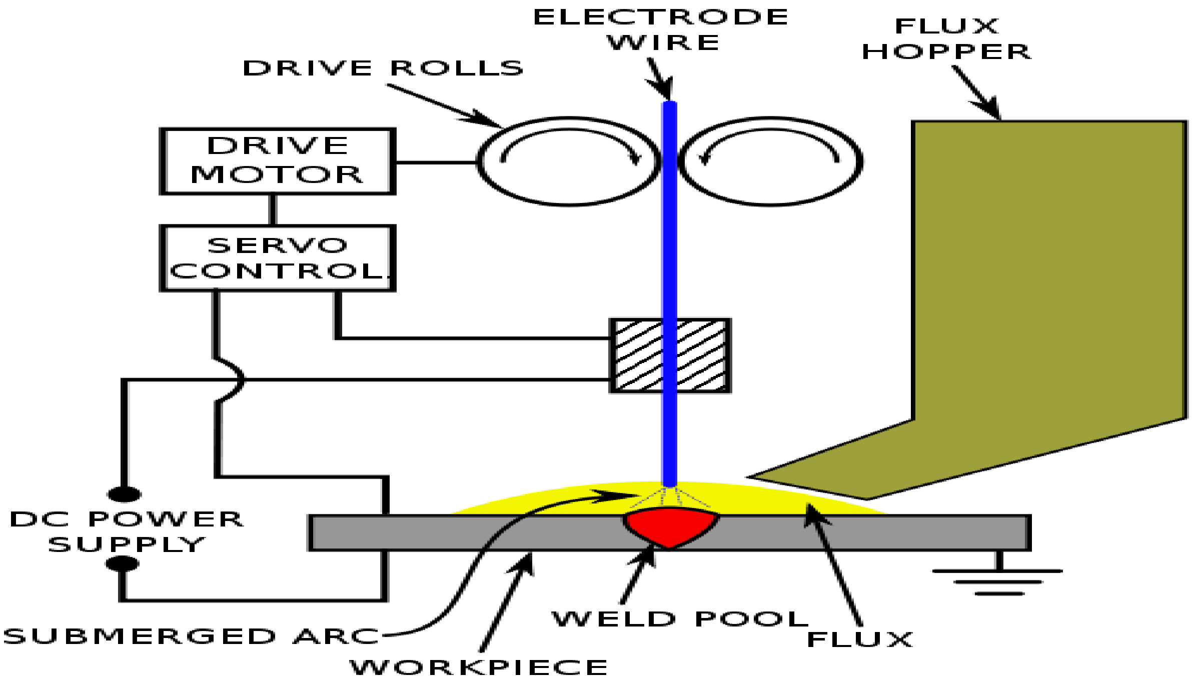


Fig. 14: Submerged arc welding

Once the flux is melted by the heat of the arc, then it will become highly conductive. The flow of current begins to flow the electrode through the melted flux that can be in contact by the atmosphere. The minor dissolved flux alters to wastage slag & which is detached after welding method finished.

At a fixed speed, the electrode from the roll is constantly fed toward the joint to be linked. If linking is partially automatic, then the top of the welding can be moved physically along with the connection. In an automatic submerged arc welding, a separate drive can be used to move the welding top above the stationary job otherwise job moves beneath the head of the stationary welding.

With the help of the self-adjusting arc principle, the length of the arc is kept stable. When the arc length reduces, the arc voltages will increase & this will increase the arc current. Because of this, the rates of burn-off will increase & the arc length will be increased. The reverse phenomenon arises when the arc length rises more than the regular length. For straight penetration as well as for supporting the huge quantity of melted metal a support steel plate otherwise copper may be used.

Advantages

1. Submerged arc welding process has high (45kg/h) deposit rate.
2. In automatic applications.
3. Very small welding smoke can be observed.
4. No edge training is required.
5. It is used in indoor, and outdoor.
6. No chance of weld sprinkles because it is submerged within flux blanket.

Disadvantages

1. The process is incomplete to some particular metals.
2. The application is imperfect to direct seams vessels, and pipes.
3. The flux usage is hard.
4. A health problem can be occurred due to the flux.
5. Slag elimination is desirable after welding.

Applications of submerged arc welding

1. The Submerged Arc Welding can be used to weld pressure vessels like boilers.

2. A lot of structural outlines, pipes, earth moving tools, shipbuilding, railroad construction, and locomotives.
3. This type of welding can be used to repair machine parts.

1.5 MODERN WELDING METHODS

1.5.1 TUNGSTEN INERT GAS WELDING (TIG)

In TIG Welding Process, TIG stands for Tungsten Inert Gas. TIG is also known as Gas Tungsten Arc Welding (GTAW). It is a process that uses a non-consumable tungsten electrode to form the weld. Generally, it uses filler metal but in some autogenous weld, it does not require it. To protect the weld area from atmospheric contamination, helium or argon is used as a shielding gas. A constant-current welding power supply is used to produce the arc between the electrode and the workpiece as shown in fig. 16.

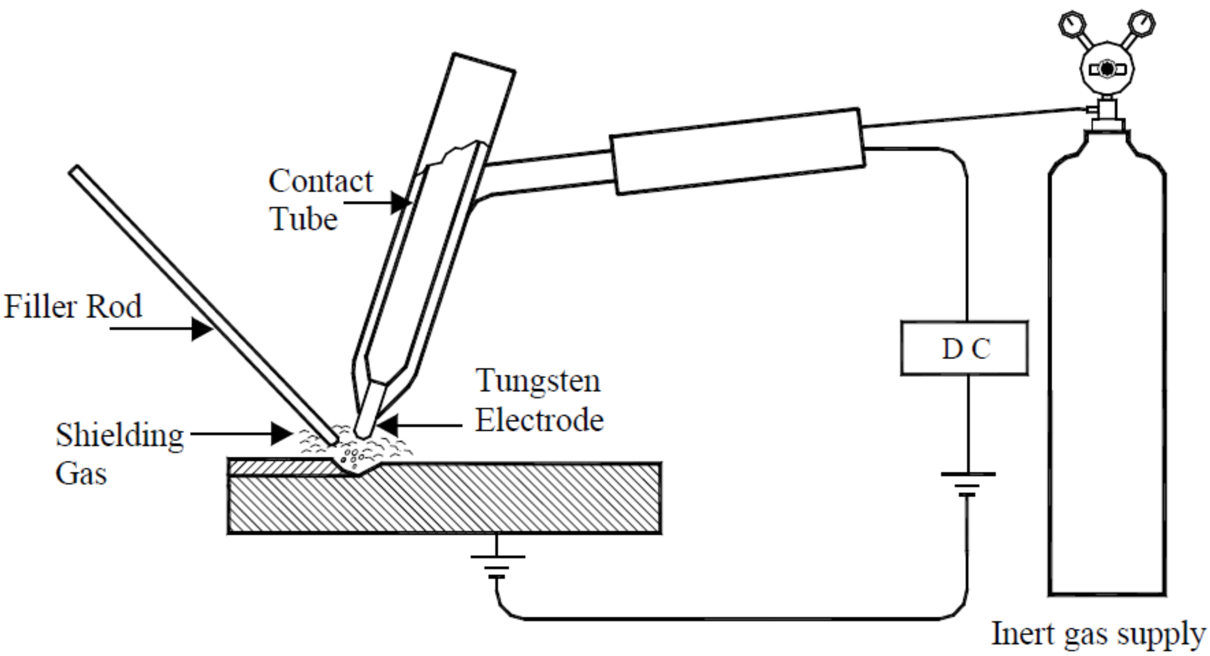


Fig. 16: TIG welding

WORKING OF TIG WELDING

In the TIG welding process or Gas Tungsten Arc Welding, the welding torch is connected to a constant current welding power supply and shielding gas source.

With the help of the constant current supply, the electric arc is produced between the electrode and two metal workpieces which are to be joined.

A filler metal is used to join the two metal pieces together. As the spark is struck, the filler metal is inserted in the cavity, and due to intense heat, the filler metal melts and fills the cavity between the two metal pieces and forms a strong weld.

A shielding gas (He or Ar) is used to protect the weld from atmospheric contaminations. As the arc is produced, simultaneously the shielding gas also starts to spread near the weld area and avoids the weld to combine with atmospheric air and protect it from contaminations.

The welding is performed by a highly-skilled operator. The operator has better control over the weld. He can use both hands to control heat generated and filler metal. From one hand he controls the arc produced and with the other hand he controls the feed of filler metal.

ADVANTAGES

1. Almost all metals can be welded by this technique. But most commonly it is used to weld stainless steel, Al, Mg, and Cu alloys.
2. It allows better control over the weld. This is because the operator uses both the hand to perform the operation, one hand to control the arc and other to control the feed of filler metal.
3. The welds formed are highly resistant to corrosion.
4. Welds thin metal sheets.
5. Produces good quality welds with precision.
6. It is a clean process because of less emission of fumes, sparks, spatter and smoke.

7. It is suitable for work in any position.
8. It offers greater visibility during the operation due to less emission of smoke and fumes.

DISADVANTAGES

1. It is a complex process and difficult to master.
2. It is not portable and hence suitable for welding shops only.
3. It is a slower welding process as compared with other welding processes.

APPLICATION

TIG welding process is used in aerospace industries, used to weld thin metal sheets, especially non-ferrous metals. It is used to manufacture of space vehicles, in bicycle industries to weld small diameter and thin wall tubing. It is often used to make root or first-pass welds for piping of various sizes. It is used in maintenance and repair work.

1.5.2 METAL INERT GAS WELDING (MIG)

MIG Welding, also known as Gas Metal Arc Welding (GMAW), is a process that utilizes a continuously fed solid electrode, shielding gas from an externally supplied source, and electrical power to melt the electrode and deposit this molten material in the weld joint. The equipment used automatically regulates the electrical characteristics of the arc. The only manual controls required of the welder for semi-automatic operation are travel speed, travel direction and gun (torch) positioning. Given proper equipment settings, the power supply will provide the necessary amperage to melt the electrode at the rate required to maintain the pre-selected arc length (voltage).

WORKING PRINCIPLE

This welding process is achieved when a cable from either AC or DC power supply is connected to a consumable electrode (welding gun) and the earth cable is placed on the workpiece. At this point, the welding gun is carrying current.

Whenever it is placed closed to the workpiece, an arc is produced. This arc melts the base metals. Inert gas supply is provided around the electrode during the process. This gas shield is around the arc and the weld pool, helping to protect the weld from the external atmospheres. At this point, it solidifies and the joint is obtained as shown in fig.17.

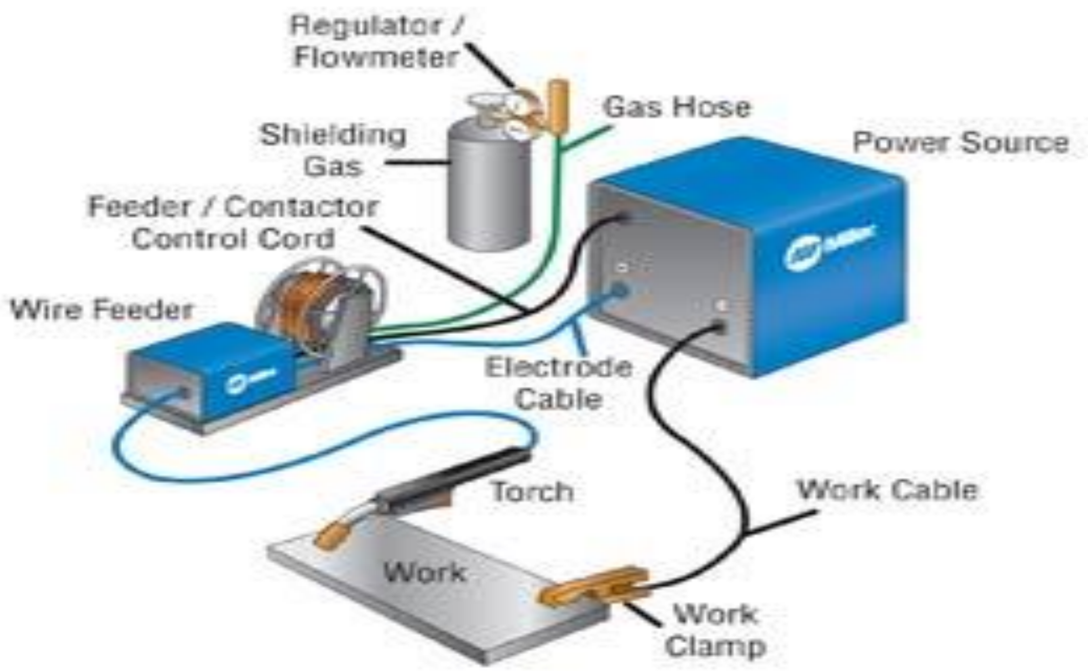


Fig. 17: Metal inert gas welding

ADVANTAGES

1. It is easy and simple
2. Filler material is not needed
3. The gas is protected automatically
4. Continuous electrode is easy to feed
5. It does not produce slag

DISADVANTAGES

1. The welder is exposed to hazardous gases
2. Weld becomes porous if the welding gun is not properly handled

3. Improper welding may lead to the floating of solid impurities over the liquid welding
4. It is expensive and the equipment is not portable
5. It cannot be done outdoor because of effect of wind, dispersing the shielding gas.

APPLICATIONS

1. Fabrication of sheet metal.
2. Automobile and aircraft industries.
3. Joining ferrous and non-ferrous metals.
4. Joining thin metals.

DIFFERENCE BETWEEN MIG AND TIG WELDING

Sr. No.	MIG welding	TIG welding
1	Metal inert gas (MIG) welding utilizes a consumable electrode that is continuously fed into the welding zone from a wire pool.	Tungsten inert gas (TIG) welding utilizes a non-consumable electrode (so it remains static and intact during welding).
2	The electrode itself melts down to supply necessary filler metal required to fill the root gap between base metals. So electrode acts as filler metal (no additional filler is required).	If required, filler metal is supplied additionally by feeding a small diameter filler rod into the arc. So filler metal is supplied separately.
3	Composition of electrode metal is selected based on parent metal. Usually, metallurgical composition of electrode metal is similar to that of base metal.	Electrode is always made of tungsten with small proportion of other alloying elements (like thorium).
4	It is suitable for homogeneous welding. It cannot be carried out in autogenous mode welding as filler is applied inherently.	It is particularly suitable for autogenous mode welding. However, it can also be employed for homogeneous or heterogeneous mode by supplying additional filler.
5	The electrode-cum-filler for MIG welding comes in the	TIG welding filler typically comes in the form of small diameter (1 – 3 mm)

	form of a small diameter (0.5 – 2 mm) and very long (several hundred meters) wire that is wound in a wire-pool.	and short length (60 – 180 mm) rod.
6	Due to very large length, the filler electrode can be fed for a longer duration without replacement.	Due to short length, frequent replacement of filler is required. This interrupts the welding process unintentionally.
7	MIG welding is commonly carried out either in AC or in DCEP polarity so that electrode can be melted and deposited at a faster rate.	TIG welding is commonly carried out either in AC or DCEN polarity to increase electrode life.
8	Filler deposition rate is very high, so the process is highly productive.	Filler deposition rate is low. In this sense, it is not very productive.
9	MIG welding usually produce spatter. This causes loss of costly filler metal.	TIG welding is mostly free from spatter.
10	Quality and appearance of weld bead are not very good.	It can easily produce defect-free reliable joint with good appearance.
11	It does not lead to tungsten inclusion defect.	TIG welding sometimes leads to tungsten inclusion defect (occurred when a melted/broken part of the tungsten electrode gets embedded into weld bead).

1.5.3 THERMIT WELDING

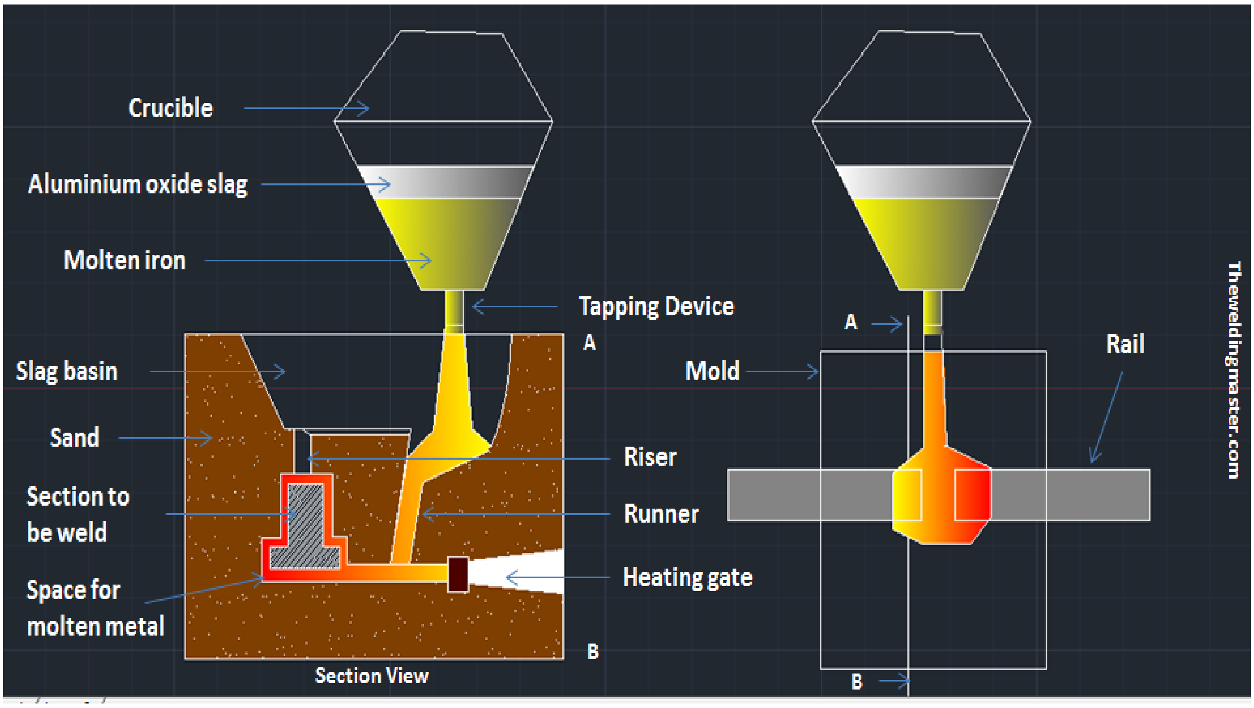
Thermit welding is a chemical welding process in which an exothermic chemical reaction is used to supply the essential heat energy. That reaction involves the burning of thermit which is a mixture of fine aluminum powder and iron oxide in the ratio of about 1:3 by weight.

Although a temperature of 3000°C may be attained as a result of the reaction, preheating of the thermit mixture up to about 1300°C is essential in order to start the reaction. There are different Thermit mixtures available for welding different metals, such as copper and chromium. They use different metal oxides in place of ferrous oxide.

WORKING PRINCIPLE

In thermit welding process, a thermite material which is a composition of a metal oxide, aluminium and fuel is used to achieve exothermic reaction. A reaction between the metal oxide and aluminium powder is takes place.

During reaction the metal oxide reduces to free elemental metal and aluminium get oxidized to aluminium oxide with production of a large amount of heat (about 3310 °C). The heat generated melts the elemental metal (Fe) and then this molten metal poured into the mold to join the two metal pieces together.



Thermit Welding Process

During the alumino-thermic reaction, the reduction of iron oxide and oxidation of Al takes place. The large amount of heat generated during the process melts the iron and aluminium oxide and get molten iron and refractory slag of aluminium oxide. The density of the aluminium oxide slag is much less than the liquid iron, so it floats above the molten iron. So during the welding process, the molten iron present at the bottom of the crucible and slag floats above it.

APPLICATIONS

1. It is traditionally used for the welding of very thick and heavy plates.
2. It is used in joining rail roads, pipes and thick steel sections.
3. It is also used in repairing heavy castings and gears.
4. It is suitable to weld large sections such as locomotive rails, ship hulls etc.
5. It is used for welding cables made of copper.

ADVANTAGES

1. It is a simple and fast process of joining similar or dissimilar metals.
2. This process is cheap, as no costly power supply is required.
3. This process can be used at the places where power supply is not available.

DISADVANTAGES

1. It is essentially used for ferrous metal parts of heavy sections.
2. It is uneconomical for welding cheap metals and light parts.

1.5.4 ELECTRO SLAG WELDING

In which the job is welded through the molten slag covering which is a result of a high quantity of heat which is generated by the circulation of electric current through the electrode and the workpiece.

WORKING PRINCIPLE

Electro slag welding process works on the principle of heat generation due to arc and electric resistance. Arc is made between the welding electrode and the workpiece which starts melting the filler metal to fill the filler cavity. Now the heat is produced due to electric resistance when the current passes through the surface. The heat further starts melting the filler metal which is continuously fed from the roller. This filler wire melts and fills the weld and makes it a strong joint as shown in fig. 18.

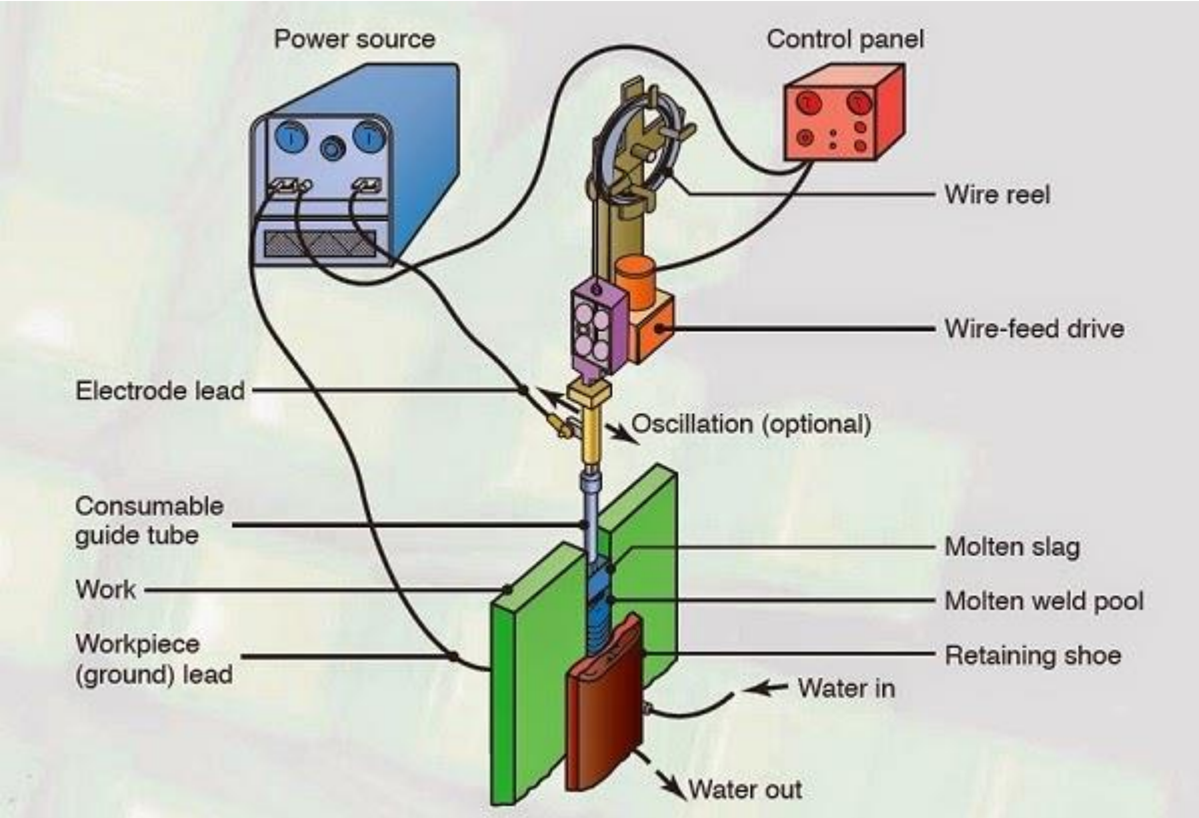


Fig. 18: Electro slag welding

ADVANTAGES OF ELECTRO SLAG WELDING

1. The cooling rate is very low so there is no problem of cold cracking.
2. There is no problem of slag inclusion or porosity.
3. The process is semi-automatic and faster.
4. Heavier section can be welded in a single pass.
5. High productivity can be achieved.
6. Low cost for joint preparation.

DISADVANTAGES OF ELECTRO SLAG WELDING

1. Too high heat input to base.
2. High temperature of welding needs cooling arrangement.
3. Slow rate of cooling give columnar grain in weld.

4. When the heat input is very high then the weld quality can be poor, including low toughness caused by the coarse grains in the fusion zone and the heat-affected zone.
5. It is restricted to vertical position welding, because of large molten metal pools and slag.
6. It is difficult to close cylindrical welds
7. It tends to produce large grain sizes.

APPLICATIONS OF ELECTRO SLAG WELDING

1. It is used in heavy industries where plate thickness is up to 80 mm to be joined.
2. Welding of thick walled large diameter pipes is done by this welding process.
3. Welding of storage tanks is done by it.
4. It is used to construct big and thick parts of ships.

1.5.5 ELECTRON BEAM WELDING

Electron Beam Welding Process is a fusion welding process in which a high-velocity electron beam is used to join two metals together. The high-velocity electron beam when strikes the weld area of two metal pieces and very intense heat is generated which melts the metal and they fuse together to form a strong weld. The whole process is carried out in a vacuum chamber to prevent it from contamination.

WORKING PRINCIPLE

It works on the principle that when a high-velocity beams of electron that has Kinetic energy strikes the two metal pieces, the kinetic energy of the electron transformed into heat. The intensity of heat produced is so much that it melts the two metal pieces and fuse them together to form a strong weld.

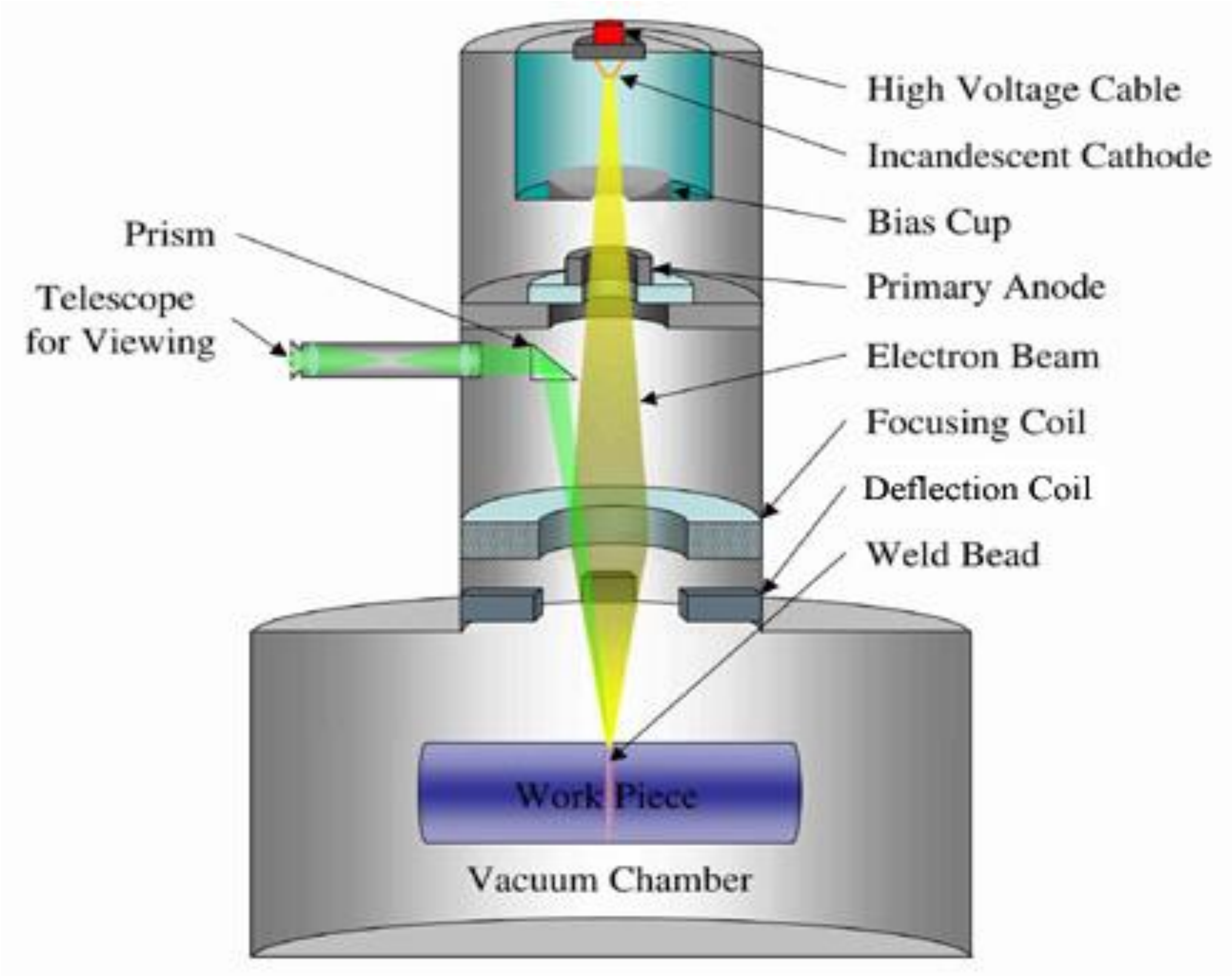


Fig. 19: Electron beam welding

In Electron Beam welding, the electron is produced by the cathode of the electron gun as shown in fig.19. After cathode, a cup grid is provided. It prevents the divergence of electron and controls it. Because of the high voltage applied across the cathode and anode. The anode which is positively charged attracts the electron from the cup grid. The anode accelerates the electron and its velocity increases and reaches the range of 50000 – 200000 km/s. From the anode, the high-velocity electron beam is passed through the magnetic lens and deflector coils. The magnetic lens focuses the electron beam to the desired location on the workpiece. And the deflector coil deflects the beam to the required weld area. As the high-velocity electron beam strikes the workpiece, intense heat is produced and it melts the metal of the two workpieces and fills the weld area. The molten weld solidifies and forms a strong weld joint.

ADVANTAGES

1. High welding speed.
2. Welding of dissimilar metal can be done.
3. High weld quality and precision.
4. Less operating cost.
5. Materials with high welding temperatures can be welded easily.
6. Less distortion due to less affected heat zone.
7. The cost of cleaning is negligible.
8. It welds thicker sheets, ranges from .025 mm to 100 mm.
9. It is capable of welding inaccessible joints.

DISADVANTAGES

1. The cost of equipment is very high.
2. High skilled operator is required to operate it.
3. A high vacuum is required.
4. Due to operation in vacuum, large jobs cannot be welded.
5. High safety measures are needed to work with it.

APPLICATIONS

1. It is used in aerospace industries for manufacturing jet components, parts of structures, transmission parts and sensors.
2. It is used in power generation industries.
3. It is used in space industries to build titanium tanks and sensors.
4. It is used in automobile industries to manufactures transmission systems, gears, and turbochargers.
5. It used in electrical and electronic industries to manufactures parts of copper structures.

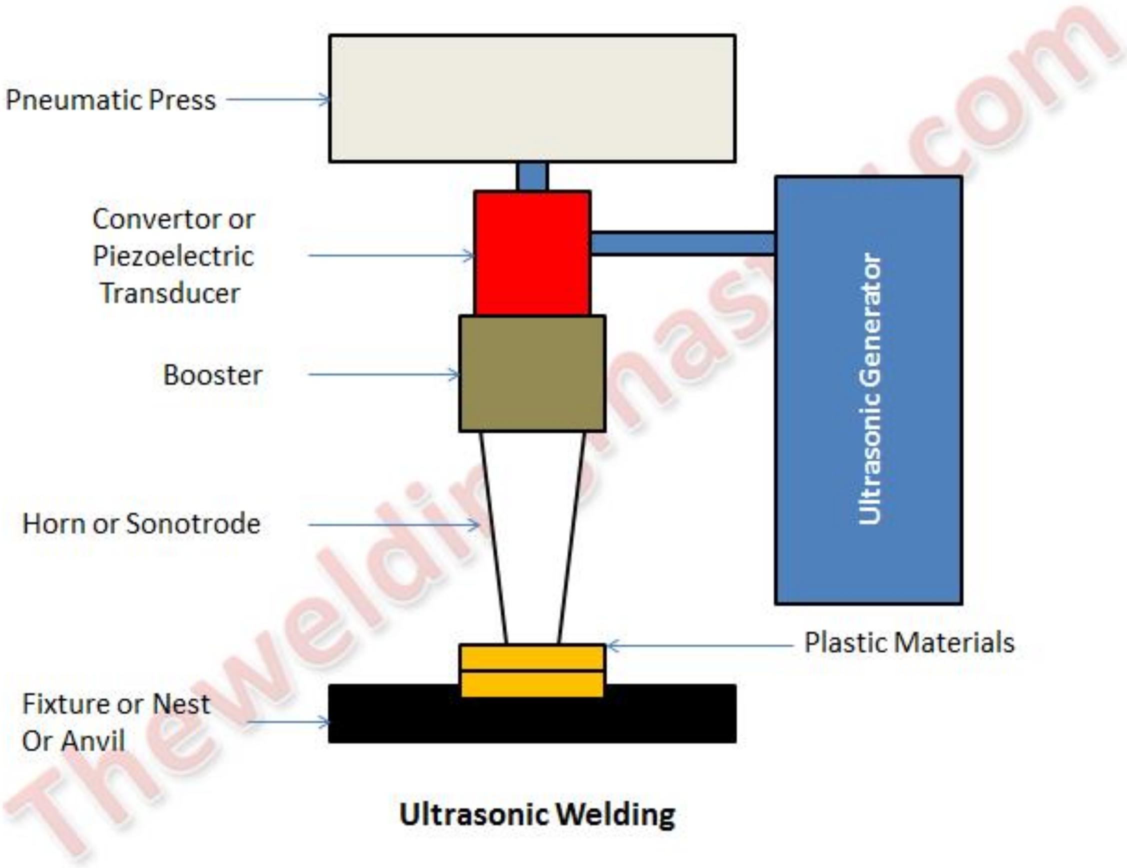
6. The other areas where it is used are nuclear industries, medical, research centers, etc.

1.5.6 ULTRASONIC WELDING (USW)

It is a welding technique that uses ultrasonic vibration of high frequency to weld the two pieces together. It is most commonly used to weld thermoplastic materials and dissimilar materials. Metal with a thin section can also be welded with USW.

WORKING PRINCIPLE

A high frequency (20 kHz to 40 kHz) ultrasonic vibration is used to join two plastic pieces together. The high-frequency vibration generates heat energy at the interface of the two pieces and melts the material. The melted material fused with each other to form a strong weld on cooling and solidification. The typical frequency used is 15, 20, 30, 35 or 40 kHz.



Ultrasonic Welding

The two plastic pieces to be joined are assembled in the nest (anvil or fixture). The horn is made to contact at upper part of the piece. A pressure is applied to the two pieces against the fixture. The pressure is applied through the pneumatic or electric driven press. Horn is vibrated vertically at very high frequency (20 kHz to 40 kHz), transmits the mechanical vibration to the two plastic pieces. This generates heat energy at the contact tip of the two surfaces and melts them. A clamping force is applied to the two pieces for a predetermined amount of time to fuse them together to form a strong weld on cooling and solidification. After solidification, the clamping force is removed and horn retracted. The welded plastic part is taken out of the fixture as one piece.

APPLICATIONS

It is mostly used in computer and electrical, aerospace and automotive, medical, and packaging industries.

ADVANTAGES

1. It is a fast welding process.
2. It has Quick drying time i.e. the pieces do not remain for a long time in the fixtures to dry
3. It can be easily automated.
4. It produces a clean and precise joint.
5. It exhibits clean weld sites and does not require and touch-up work.
6. It produces a low thermal impact on the materials.

DISADVANTAGES

1. It cannot be used to produce large joints (greater than 250 x 300 mm).
2. It requires specially designed joints, so it can make tip contact during the welding process.
3. High tooling cost for the fixtures.
4. The ultrasonic welding process is restricted to the lap joints.

1.5.7 LASER BEAM WELDING

It is a fusion welding process in which two metal pieces are joined together by the use of laser. The laser beams are focused to the cavity between the two metal pieces to be joined. The laser beams have enough energy and when it strikes the metal pieces produce heat that melts the material from the two metal pieces and fills the cavity. After cooling a strong weld is formed between the two pieces.

WORKING PRINCIPLE

It works on the principle that when electrons of an atom gets excited by absorbing some energy. And then after some time when it returns back to its ground state, it emits a photon of light. The concentration of this emitted photon increased by stimulated emission of radiation and we get a high energy concentrated laser beam.

Light amplification by stimulated emission of radiation is called laser.

First, the setup of welding machine at the desired location (in between the two metal pieces to be joined) is done. After setup, a high voltage power supply is applied to the laser machine. This starts the flash lamps of the machine and it emits light photons. The energy of the light photon is absorbed by the atoms of ruby crystal and electrons get excited to their higher energy level. When they return back to their ground state (lower Energy state) they emit a photon of light. This light photon again stimulates the excited electrons of the atom and produces two photons. This process keeps continue and we get a concentrated laser beam.

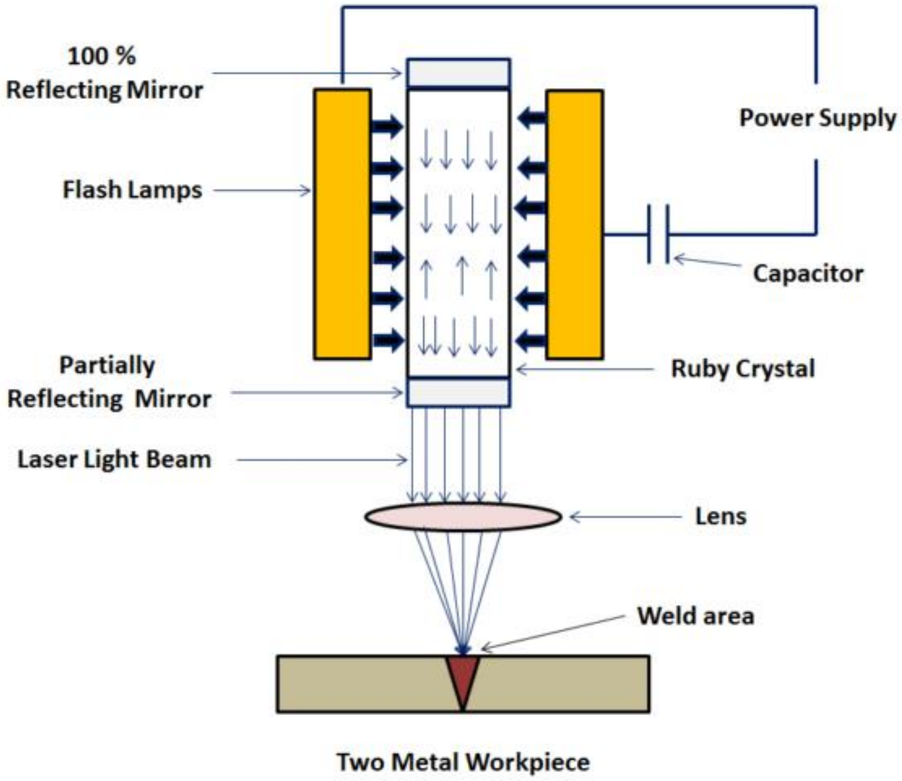


Fig. 20: Laser beam welding

This high concentrated laser beam is focused to the desired location for the welding of the multiple pieces together as shown in fig. 20. Lens is used to focus the laser to the area where welding is needed. CAM is used to control the motion of the laser and workpiece table during the welding process.

As the laser beam strikes the cavity between the two metal pieces to be joined, it melts the base metal from both the pieces and fuses them together.

ADVANTAGES

1. It produces high weld quality.
2. LBW can be easily automated with robotic machinery for large volume production.
3. No electrode is required.
4. No tool wears because it is a non-contact process.
5. The time taken for welding thick section is reduced.
6. It is capable of welding in those areas which are not easily accessible.

7. It has the ability to weld metals with dissimilar physical properties.
8. It can be weld through air and no vacuum is required.
9. X-Ray shielding is not required as it does not produce any X-Rays.
10. It can be focused on small areas for welding. This is because of its narrower beam of high energy.
11. A wide variety of materials can be welded by using laser beam welding.

DISADVANTAGES

1. The initial cost is high. The equipment used in LBW has a high cost.
2. High maintenance cost.
3. Due to the rapid rate of cooling, cracks may be produced in some metals.
4. High skilled labor is required to operate LBW.
5. The welding thickness is limited to 19 mm.
6. The energy conversion efficiency in LBW is very low.

APPLICATIONS

The laser beam welding is dominant in the automotive industry. It is used in the area where large volume production is required.

1.5.8 ROBOTIC WELDING

Robot welding is the use of mechanized programmable tools (robots), which completely automate a welding process by both performing the weld and handling the part. Processes such as gas metal arc welding, while often automated, are not necessarily equivalent to robot welding, since a human operator sometimes prepares the materials to be welded. Robot welding is commonly used for resistance spot welding and arc welding in high production applications, such as the automotive industry as shown in fig. 21.

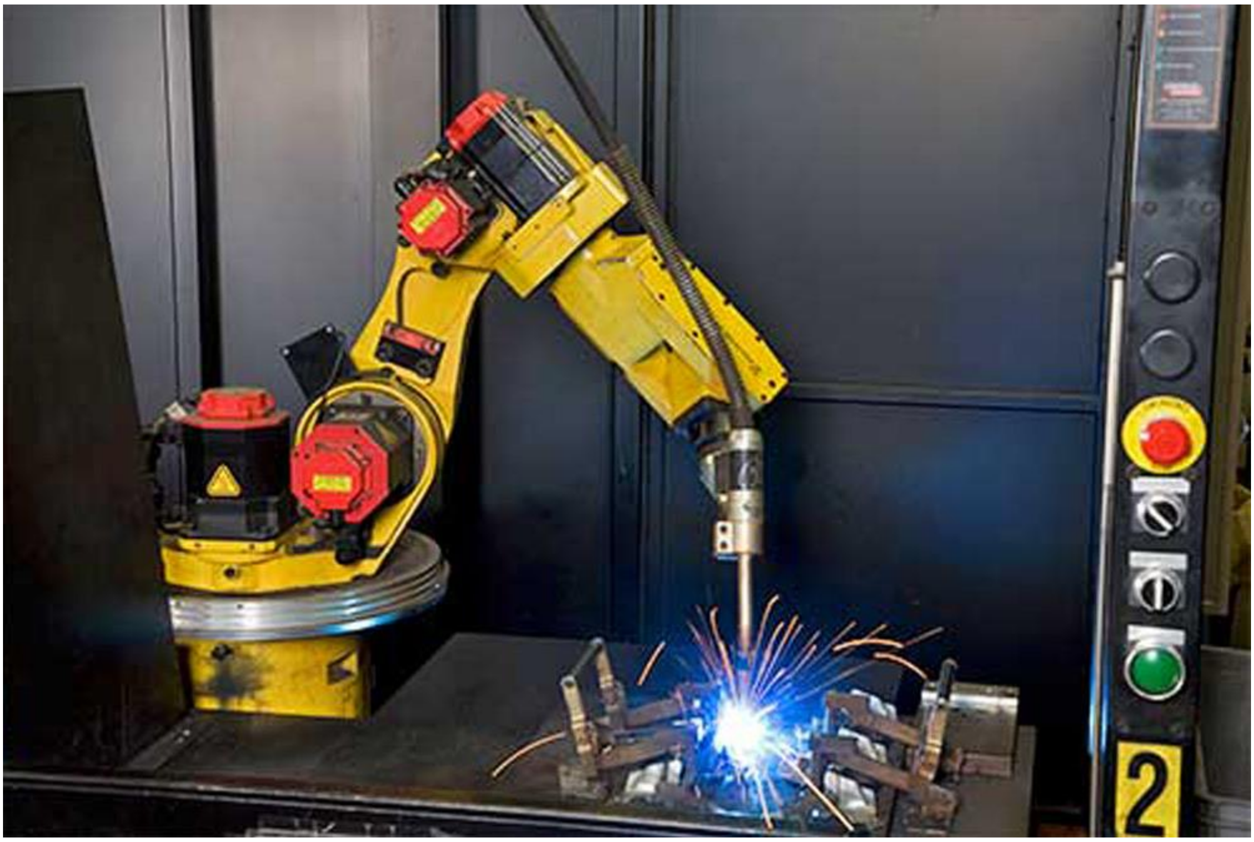


Fig. 21: Robotic welding

2.1 PATTERN

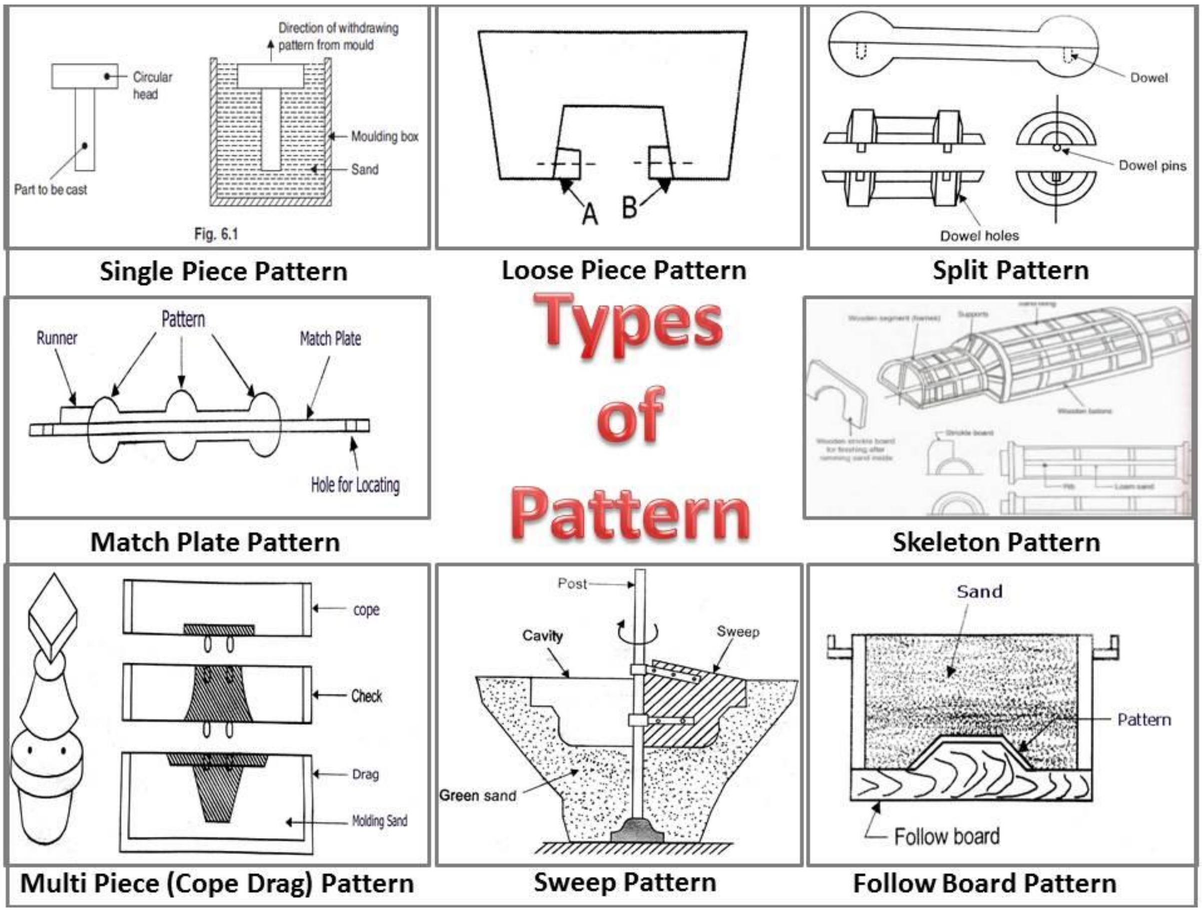
Pattern is replica or model of object which to be created. It is used to make hollow cavity in sand mold in which molten metal is poured and allow solidifying to create object. The size and shape of cast object is highly depends of shape and size of pattern. Mostly pattern are made by aluminum, wood, wax etc. Metal pattern are used for mass production. The pattern making is most critical work in casting because the object is highly depended on it.

2.1.1 TYPES OF PATTERN

The common types of patterns are as follow:

1. Single piece pattern
2. Split pattern or multi piece pattern
3. Cope and drag pattern

4. Match plate pattern
5. Loose piece pattern
6. Gated pattern
7. Sweep pattern
8. Skeleton pattern
9. Segmental pattern
10. Follow board pattern



1. Single piece pattern

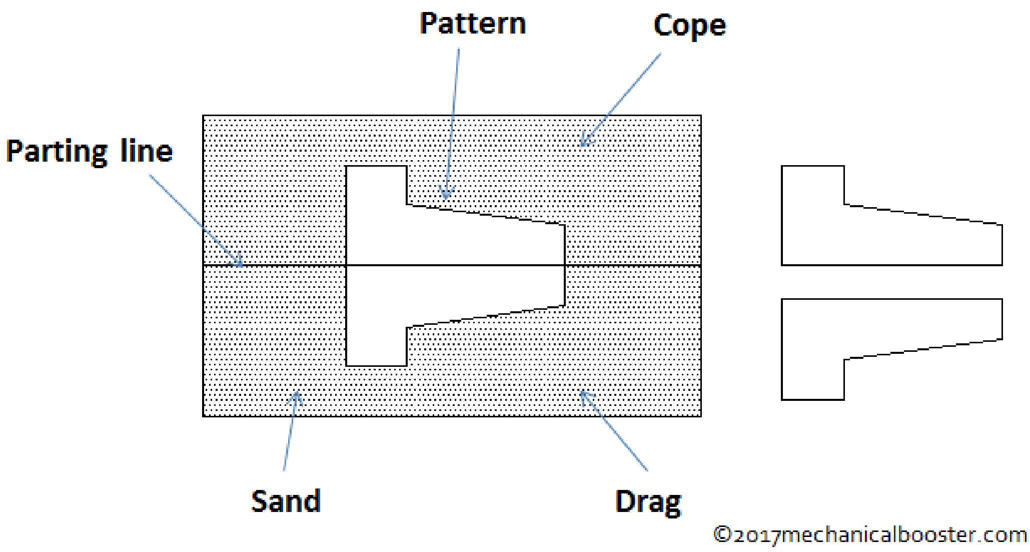
It is simplest type of pattern which is made in single piece. It is used for simple objects. It is either placed into cope or in drag according to the simplicity of operation. It is used to cast stuffing box of steam engines.

2. Split pattern or Multi piece pattern

These patterns are made into two or more pieces. The first half of pattern placed into cope and other half into drag. It is used for complex objects where removal of single piece pattern from mould is impossible. When pattern is made in more than three parts cheeks are also used for easy removal.

3. Cope and drag pattern

A cope and drag pattern is a split pattern having the cope and drag portions each mounted on separate match plates. These patterns are used when in the production of large castings; the complete moulds are too heavy and unwieldy to be handled by a single worker.



Cope and Drag Pattern

4. Match plate pattern

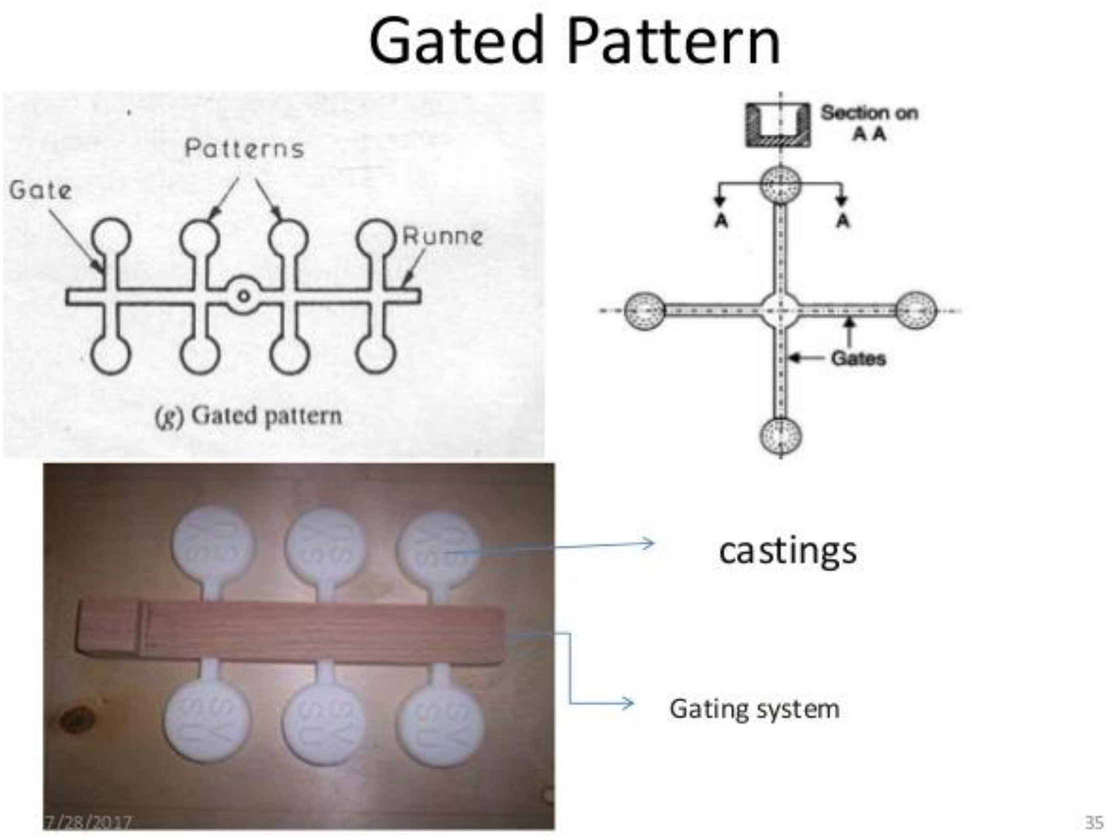
Match plate pattern is a split pattern in which cope and drag section mounted on opposite sides of a plate. The plate is known as match plate. These will make easy to cast any shape with high production rate. Mostly runner, gates etc. are also mounted on same plate which will easy to mould making work. These patterns are used for mass production.

5. Loose piece pattern

When removal of pattern is impossible due to an extended surface at either upper half or lower half, the extended part made as loose piece so this extended part can be removed first before removal of whole pattern. This will make easy removal of pattern without effect on the cavity. These patterns are known as loose piece pattern.

6. Gated Pattern

These are simply more than one loose piece which is attached with a common gating system. These are used for mass production. It is used to produce small size cavities into one mould.



7. Sweep pattern

These patterns are used for large rotational symmetrical casting. A sweep is a section of large symmetrical object which is rotated along a edge into sand which make a large symmetrical mould. These patterns makes easy pattern making work of large objects.

8. Skeleton pattern

A Skeleton pattern is a hollow form of pattern, consisting of a wooden frame and ribs. The hollow portion is filled with loam sand or clayed sand. The skeleton pattern is made in two halves; one is placed in the cope and other in the drag. A stickle board is used to scrap the surplus sand out of the spaces between the ribs. The material cost is reduced for this pattern. The skeleton pattern is used when a few and large-sized castings are required. Hollow cast iron pipes, boxes, valve bodies and bends are casted with these types of patterns.

9. Segmental pattern

It is used for preparing circular castings such as rings, gears, wheels. In this type it does not revolve continuously like sweep pattern, instead prepares the mould by parts. It completes one portion of the mold and then moves to next position to make the next part of the mold and so on till the mold is completed.

10. Follow board pattern

Follow board is a wooden board which is used to support pattern during moulding. It acts as sit for pattern.

2.1.2 MATERIAL FOR PATTERN MAKING

The materials used for pattern making should be

1. The materials used in the pattern should be cheap in cost and easily available in the market.
2. The material should have a good surface finish.
3. The material should have withstood high temperatures and does not change its shape at high temperatures.

Base on the above factors we can choose the following materials for pattern making.

1. Wood
2. Metals
3. Plaster of Paris
4. Plastics
5. Wax

1. Wood

As we all know woods are easily available, and the price is quite low so it is satisfied some basic criteria. Also, there are some advantages using wood in pattern and those are:

1. Wood is light in weight.
2. Easily available in the market.
3. It can make any shape using wood.
4. Woods gives good surface finish.

However wood is attracted to moisture and sometimes it can change shape on high temperature or after dry out from moisture, this is an important con of using wood as a pattern. Not only this reason woods are very weak in strength, and it wears out quickly due to its low resistance to sand abrasion. For these above reasons, it is not used for very big product casting. Generally, **pines deodar, walnut, teaks** are used for making a pattern.

2. Metals

In metals, cast iron, brass, aluminum are generally used in patterns. It gives smooth surface finish; this is the only reason that metals are used in large production casting workshops.

These are some advantages of using metal pattern:

1. Smooth surface finish can be obtained by metal patterns.
2. Deformation is less.
3. Closer dimensional tolerance.

Although there are some disadvantages of using this type of pattern like it is a little bit costlier, heavy, sometimes rusting effect occurred on the surfaces of the metals.

3. Plaster of Paris

It is generally used if you need to set up the pattern quickly. The main advantage of this pattern is it can easily cast into intricate shapes. However, it is not for repetitive usages as it is fragile.

4. Plastics

Different types of plastics are nowadays used in pattern because of their lighter weight, strength, and dimensionally stable and also for cheap in cost. Thermoplastics and polystyrene are commonly used for making pattern, and thermosetting plastics such as phenolic and epoxies are also used in a pattern.

There are few advantages of using pattern and those are:

1. Light in weight.
2. Cheap in price.
3. It possesses good compressive strength.
4. No tension of rusting or moisture absorbing.

However, they are a little weak in strength and not good abrasion-resistant.

5. Wax

A wax pattern is used in the investment casting process. By using this pattern we get a high degree of accuracy and have an excellent surface finish. However it needs little care handling otherwise it can be broken, and it is used in small casting.

2.1.3 PATTERN ALLOWANCES

To make a casting perfect we need to consider the allowances because after cooling the molten metal it can shrink and makes any distortion. So there are 5-types of allowance we are considering when designing a pattern and those are:

1. Shrinkage/contraction allowance
2. Draft allowance
3. Machining/finishing allowance
4. Shake/rapping allowance
5. Distortion allowance

1. Shrinkage /contraction allowance

Shrinkage is defined as reduction is the dimension of the cast during the cooling or solidification process. This is a general property of all materials as shown in fig. 22. The magnitude of shrinkage varies from material to material but every material shrinks. The contraction allowance depends on:

1. The type of casting method used.
2. The type of material used for casting.

It can be also divided into two types:

a. Liquid shrinkage

When the metal is in the liquid stage, the liquid shrinkage occurred. To encounter the shrinkage we generally provide a riser that supplied the extra molten metal to the cavity.

b. Solid shrinkage

It's occurred when the metal is in the solid stage, to encounter this situation we can provide the shrinkage allowances.

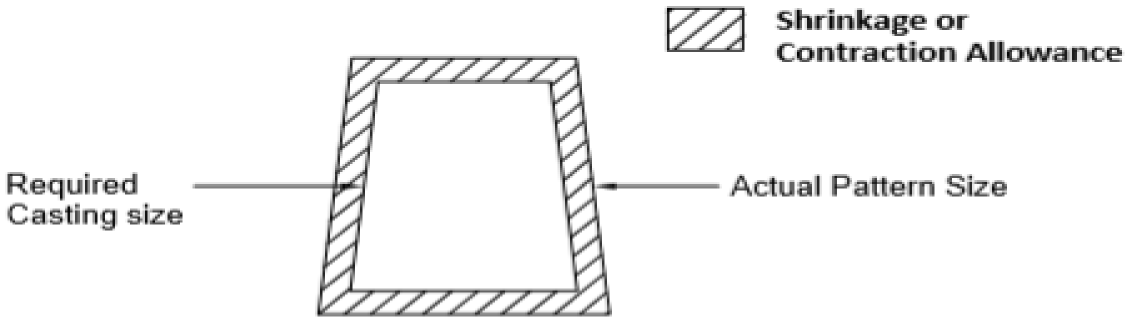


Fig. 22: Shrinkage allowance

2. Draft allowance

When the casting is done, due to the removal of the pattern sometimes the edges of the casting brake, to overcome this situation sometimes we provide a taper for easy removal of the pattern from the mold as shown in fig. 23. Generally, a 1-3 degree draft is provided with the outer surface of the pattern to overcome this brokerage.

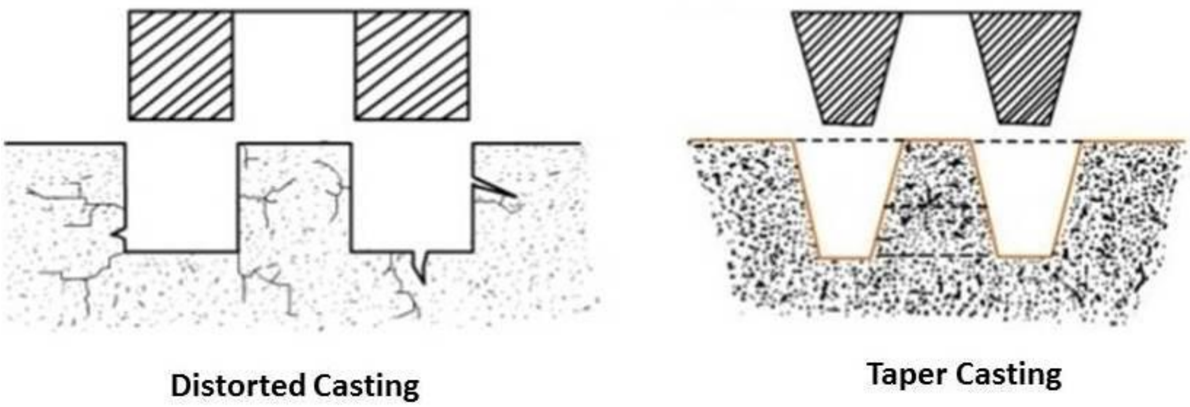


Fig. 23: Draft allowance

3. Machining/finishing allowance

After casting we need to do some machining operations, may grinding, or surface finishing operation, these all operations are metal removal operation, so we need to keep the size of the pattern little bigger than the actual size so that after removal of some material, it will perfectly be shaped.

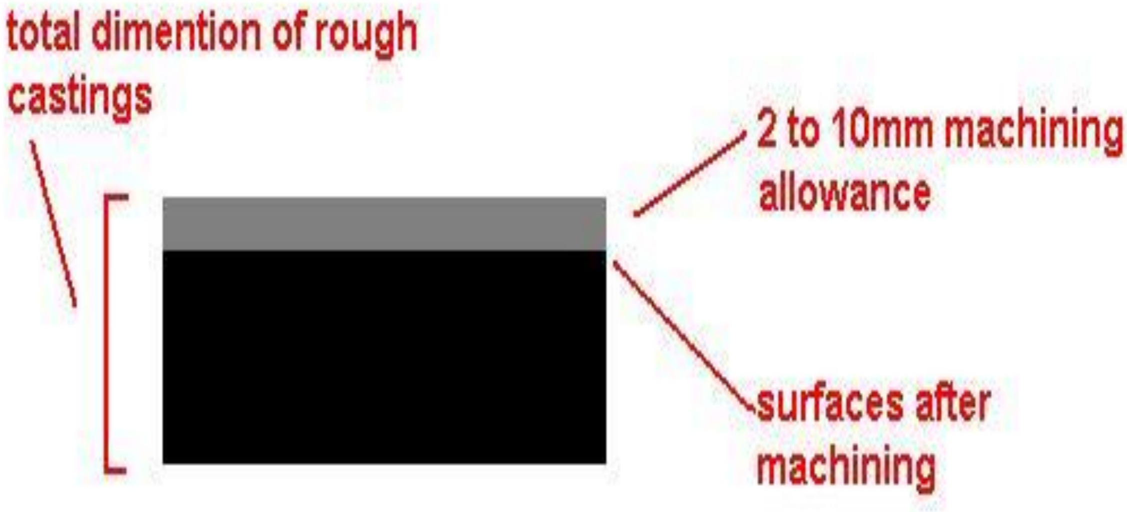


Fig. 24: Machining allowance

4. Shake/rapping allowance

When the pattern is to be removed from the sand of casting, the pattern will have to be shaken slightly to remove it from the sand and this will cause a slight increase in dimension of casting as shown in fig. 25. To compensate this increase in dimension of casting, the patterns are made slightly smaller from casting. This change in dimension of pattern is known as shaking or rapping allowances.

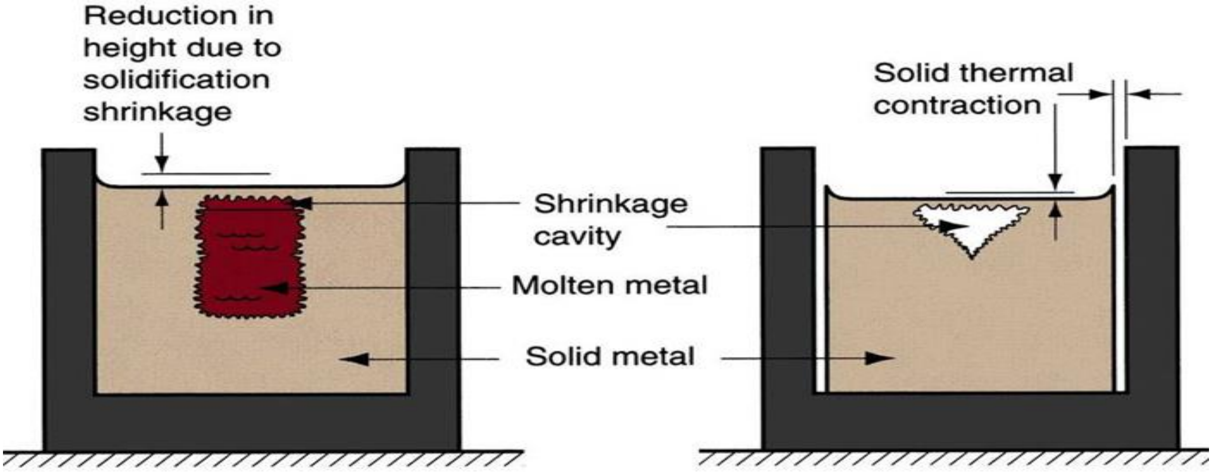


Fig. 25: Rapping allowance

5. Distortion/camber allowance

When the metal is in cooling process, stress is developed in the solid metal due to uneven metal thickness in the casting process. This stress may cause distortion or bending in the casting. To avoid this bending or distortion in casting, camber is provided in the opposite direction so that when bending occurs due to uneven thickness of metal, casting becomes straight. This change in pattern shape to compensate bending while casting is known as bending allowances as shown in fig. 26.

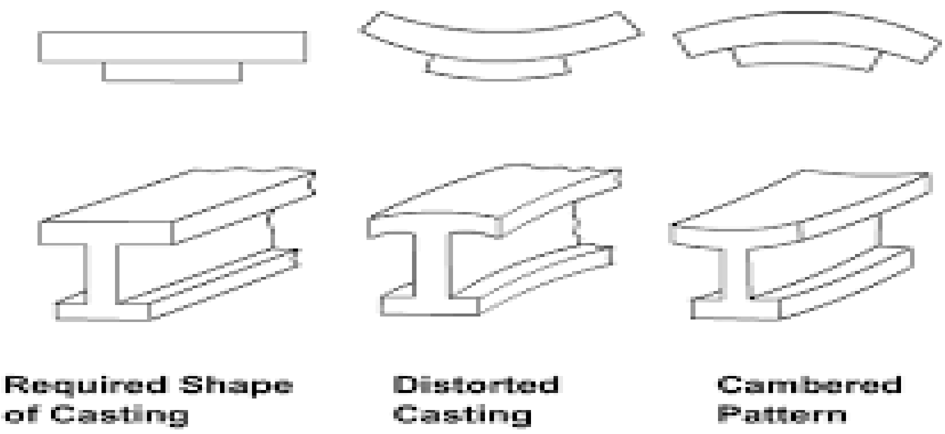


Fig. 26: Distortion allowance

2.1.4 PATTERN CODE AS PER B.I.S.

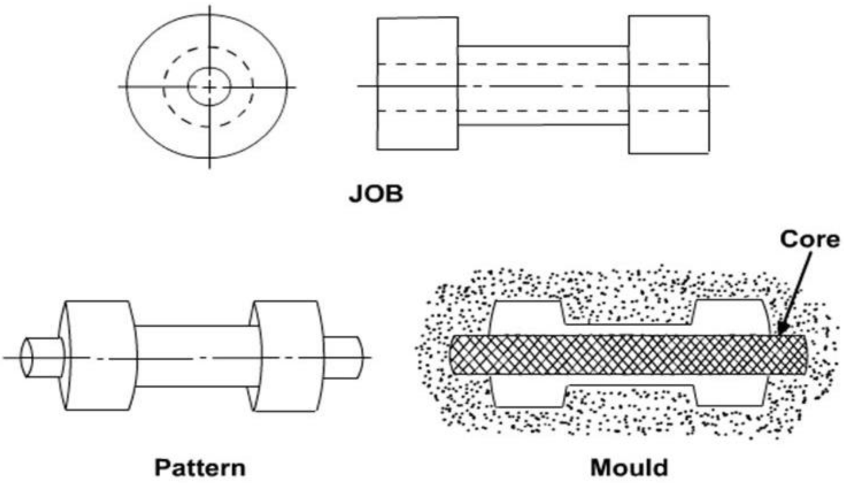
Different color is used to paint pattern so that person making mold comes to know how to treat a particular surface. There is no universal standard for color code but there is commonly and widely used color code in pattern as given below:

1. **Black colour:** The surfaces which are to be left un-machined are painted with black colour.
2. **Red colour:** The surfaces which are to be machined are painted with Red colour.
3. **Yellow colour:** The core prints and seats for loose core prints are painted with Yellow colour.
4. **Yellow base with Red stripes**: The seats for loose pieces are marked with red strips on yellow base.
5. **Yellow base with Black strips:** The stop offs are indicated by diagonal black strips on yellow base.
6. **No colour:** The parting surfaces are indicated by a colour.

2.1.5 INTRODUCTION TO CORES

A core is a device used in casting and moulding processes to produce internal cavities and reentrant angles (an interior angle that is greater than 180°). The core is normally a disposable item that is destroyed to get it out of the piece. They are most commonly used in sand casting, but are also used in die casting and injection moulding.

Core & Core Prints



2.1.6 CORE BOXES AND CORE MATERIALS

The core is a chemically bonded sand shape that creates the interior surfaces of an iron casting. A core box is the tooling used to create the core. High-quality cores are essential to the iron casting process. The common types of core boxes are as follows:

1. Half core box

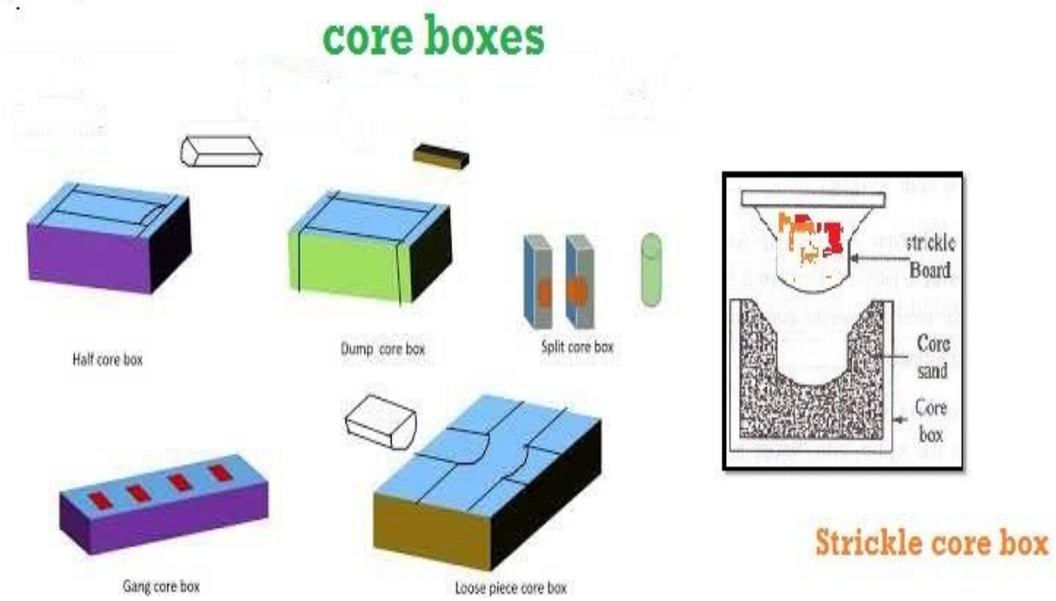
A half core box is most common type of core box. It is used for making the two identical halves of a symmetrical core. These two half portions are pasted together after backing, thus makes a complete core.

2. Dump core box

A dump core box is similar to half core box in construction but produces a full core at a time. This box is commonly used for making rectangular, square, slab, triangular and trapezoidal cores. Dump core box sometimes is also known as slab core box.

3. Split core box

A split core box consists of two parts, joined together with the help of dowel pins and hole. A complete core is produced in single operation. In its operation, the two boxes are properly aligned and the core sand is rammed from one side. After ramming, the surplus sand is strickled off. The clamps are opened and the core-boxes are withdrawn carefully leaving the core.



4. Strickle core box

A strickle core box is used when the core is required to have an irregular shape. It consists of a strickle wooden board and a core box. The sand is dumped in a core box and rammed. The top surface of the core in the core box is given the desired shape with the help of strickle board. The strickle board is made to a desired shape and moved over top of the rammed sand.

5. Loose piece core box

A loose piece core box is used for making cores when provision for bosses, hubs etc., is needed. Both halves of the left and right core can be made from a single core box with the help of loose pieces. Different shapes may be obtained by inserting loose wooden pieces in the core box thus changing the symmetry of core box.

6. Gang core box

A gang core box is employed when a large number of small sized cores are required in a single operation.

Core materials

The compositions of core material are the mixture of sand, binders and additives. Core sands are silica, zircon, Olivine etc. and core binders are core oils, resins, molasses, dextrin etc., are generally used for preparation of core materials. Sand contains more than 5% clay reduces not only permeability but also collapsibility and hence not suitable for core making. The commonly used core sand is a mixture of following items:

a) Core sand

The sand may be green sand for smaller castings and mixture of fire clay, green sand and betonies for heavier casting. The cores are oven backed to dry away its moisture. The dry sand cores are strong than green and cores. Also, the sand with rounded grains is best suitable for core making as they have better permeability than the angular grains sand.

b) Oil sand

Oil sand can be used for almost any sand casting application.

A typical composition of oil sand is:

a. Sand 95-96%,
b. Cereal flour 1-1.05%,
c. Core oil 1-1.5%,
d. Water 1-2%,
e. Bentonite 0.1-0.3%.

c) Resin sand

These are thermosetting or thermoplastic binders such as rosin, phenol, urea, furan, formaldehyde etc. are used to obtain good bonds to sand. They are becoming common in use due to their high strength, low gas formation, excellent collapsibility, resistance to moisture absorption, better dimensional accuracy to casting, etc.

d) CO_2 – Sodium silicate sand

Silica sand and sodium silicate (3-4%) is rammed in the core and then CO_2 gas is passed through sand to make the core hard. Such types of cores are used for very large castings. They do not need to dry and hence is very fast method of core making.

e) Core binders

Natural sand has not sufficient binding properties and hence some binders are used to improve the binding strength of core sand. The functions of binders are to hold the sand grains together and to provide better strength to the core. There are two types of binders used are:

1. Inorganic binders

They include fire clay, bentonite, limonite, silica powder, iron oxide, aluminum oxide, etc. They are very fine powder and popularly used.

2. Organic binders

They include core oils like petroleum oil, vegetable oil, linseed oil, corn oil, malasses and dextrin. Organic binders get harder rapidly and provide good strength.

f) Core additives

In addition to core sand and core binder, some additives are used to improve the special properties of the core. The additives are:

1. Kaolin or fire clay to improve stability.
2. Iron oxide (Fe2O3) and aluminum oxide (Al2O3) to improve hot strength.
3. Zircon flour and pitch flour to improve refractoriness.
4. Molasses to improve binding properties.
5. Organic additives to improve collapsibility like raw dust.
6. Silica powder, paints and graphite bonded with resin are used to improve the surface finish.

2.1.7 PROCEDURE FOR CORE MAKING

The complete core making procedure consists of the following eight steps:

1. Mixing of core sand
2. Ramming of core sand
3. Venting of core
4. Reinforcing of core
5. Baking of core
6. Cleaning and finishing of core
7. Sizing of cores
8. Joining of cores

1. Mixing of core sand

First of all, the tore sand particles are mix thoroughly in order to obtain best cores. Binders are then mixed with sand before any moisture is added. The mixture must be homogeneous and uniform. This mixing is performed in paddle mixtures or mullers.

2. Ramming of core sand

The mixture of core sand is rammed into the core boxes. The surplus sand is stuck-off with stickles. The ramming may be done with machines or by manually.

3. Venting of core

Because a core is surrounded by molten metal from all sides during casting, gases have only a small area through which to escape. Therefore, good permeability is obtained by providing special vent holes to allow gases to escape easily.

4. Reinforcing of core

Sometimes, cores are reinforced with annealed low-carbon steel wires or even cast iron grids (in case of heavy cores) to ensure coherence and stability. Otherwise, the core may shift from its original position when the molten metal is poured. This is shown in Fig. 3.12.

5. Baking of core

Now, the cores are placed on the baking plates and put into the baking furnace. During baking, moisture is driven out at 100°C. On further increasing the temperature of about 200-270°C, some chemical changes also occur in the core oil and binders which strengthens the core sand. The baking period of about 3 to 6 hours are quite common.

The proper baking of the core is essential and judged by the brown colour. An under-baking core will generate a large amount of gases, which produces blow holes in the casting, while over-baking will burn the binders completely and may collapse too soon and break before solidification of casting. Oil fired ovens, gas fired ovens, dielectric bakers or radiant bakers are used for this purpose.

6. Cleaning and finishing of core

After baking of core in oven, the cores are properly finished by following operations:

(a) Trimming

Trimming involves rubbing or filling of cores with emery stone. It is required to remove the loose pieces and other undesirable sand projections.

(b) Brushing

Brushing involves removing of loose sand with the help of smooth wire brush.

(c) Coating

Coating involves depositing a layer of refractory or protective material which improves their heating resistance. It is applied by spraying or by dipping method.

(d) Muddling

Muddling involves localized coating of graphite or red talc to fill up any cavity, rough spots, joining lines of assembled cores, etc.

7. Sizing of cores

Sizing of core involves to checking and correcting the various dimensions by inserting fixture. Oversized cores may be ground to correct size.

8. Joining of cores

Cores made in two or three piece required joining before use. This may be achieved by pasting (in case of small work) or by bolting (in case of large work). Core pasting uses a mixture of talc, dextrine, flour, molasses, water and other ingredients, at the surfaces to be joined.

2.1.8 CORE PRINTS AND POSITIONING OF CORES

Core prints

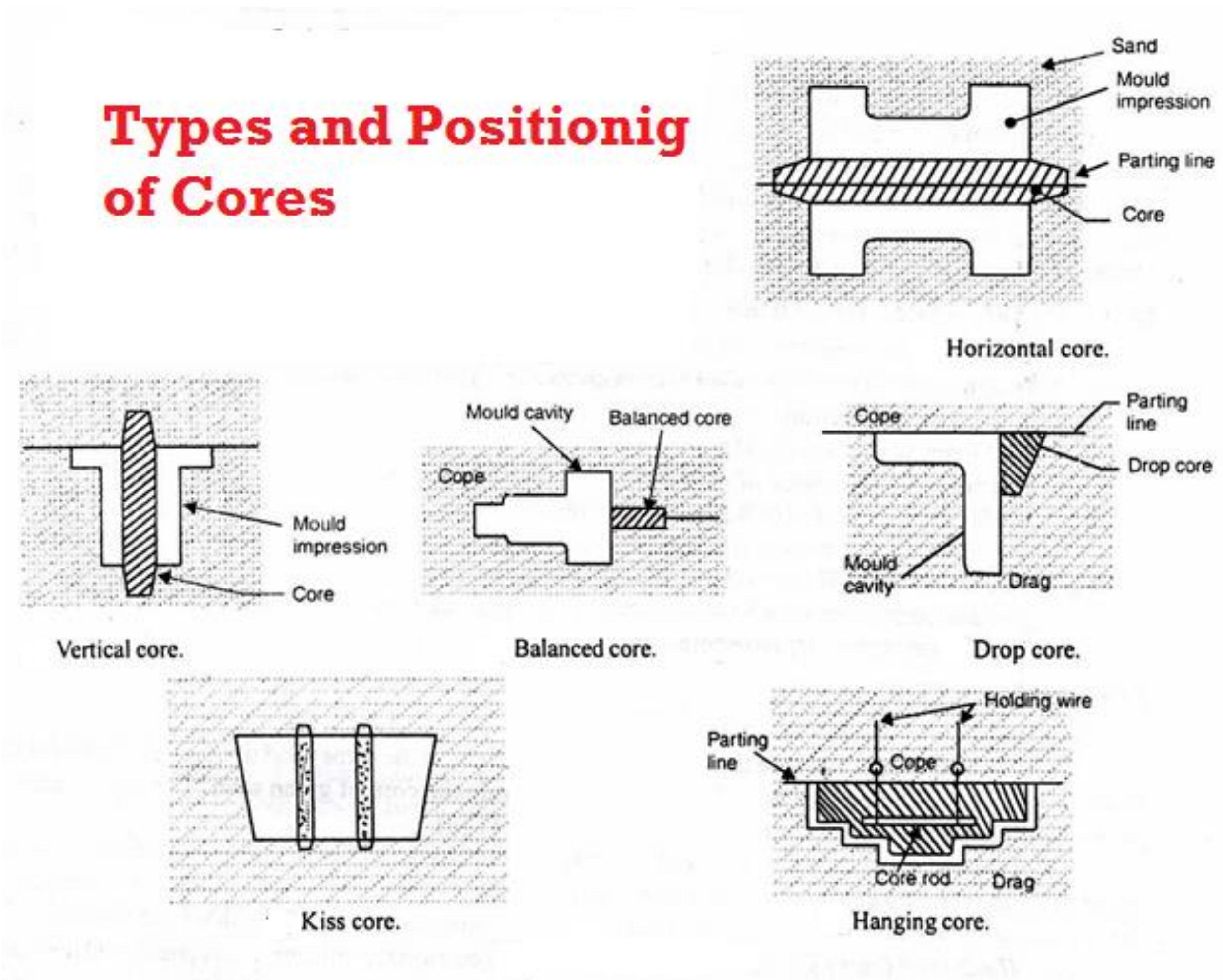
Core print is an open space provided in the mold for locating, positioning and supporting the core. The core cannot be suspended inside the cavity without any support. So the space in the mold is needed. The core print is prepared with the help of projections on the pattern. But the problem is, while removing the pattern; the mold will get damaged due to the presence of projections on the pattern. Hence split pattern is used for casting process in which the core is used.

Positioning of cores

Cores are of various types depending upon their shapes and position in the mould. The various types of cores and their positions are as follow:

1. Horizontal core

The horizontal core is the most common type of core and is positioned horizontally at the parting surface of the mould. The ends of the core rest in the seats provided by the core prints on the pattern. This type of core can withstand the turbulence effect of the molten metal poured.



2. Vertical core

The vertical core is placed vertically with some of their portion lies in the sand. Usually, top and bottom of the core is kept tapered but taper on the top id greater them at bottom.

3. Balance core

The balance core extends only one side of the mould. Only one core print is available on the pattern for balance core. This is best suitable for the casting has only one side opening. This is used for producing blind holes or recesses in the casting.

4. Hanging core

The hanging core is suspended vertically in the mould. This is achieved either by hanging wires or the core collar rests in the collar cavity created in the upper part of the mould. This type of core does not have bottom support.

5. Drop core

The drop core is used when the core has to be placed either above or below the parting line. This core is also known as wing core, tail core, chair core, etc.

6. Kiss core

The kiss core is used when a number of holes of less dimensional accuracy are required. In this case, no core prints are provided and consequentially, no seat is available for the core. The core is held in position approximately between the cope and drag and hence referred as kiss core.

2.2 MOULDING SAND

A mould can be described as a void or cavity in a compact sand mass with the help of pattern which, when filled with molten metal, will produce a casting. Moulding is a process of making moulds from which castings are obtained. The moulding sand is used as a raw material to making mould.

2.2.1 PROPERTIES OF MOULDING SAND

Following are the important properties of moulding sand:

1. Porosity

Porosity also known as permeability is the most important property of the moulding sand. It is the ability of the moulding sand to allow gasses to pass through. Gasses and steam are generated during the pouring of molten metal into the sand cavity. This property depends not only on the shape and size of the particles of the sand but also on the amount of the clay, binding material, and moisture contents in the mixture.

2. Cohesiveness

Cohesiveness is the property of sand to hold its particles together. It may be defined as the strength of the moulding sand. This property plays a vital role in retaining intricate shapes of the mould. Insufficient strength may lead to a collapse in the mould particles during handling, turning over, or closing. Clay and bentonite improves the cohesiveness.

3. Adhesiveness

Adhesiveness is the property of sand due to which the sand particles sticks to the sides of the moulding box. Adhesiveness of sand enables the proper lifting of cope along with the sand.

4. Plasticity

Plasticity is the property of the moulding sand by virtue of which it flows to all corners around the mould when rammed, thus not providing any possibility of left out spaces, and acquires a predetermined shape under ramming pressure.

5. Flow-ability

Flow-ability is the ability of moulding sand to free flow and fill the recesses and the fine details in the pattern. It varies with moisture content.

6. Collapsibility

Collapsibility is the property of sand due to which the sand mould collapse automatically after the solidification of the casting. The mould should disintegrate into small particles of moulding sand with minimum force after the casting is removed from it.

7. Refractoriness

It is the property of sand to withstand high temperature of molten metal without fusion or soften. Moulding sand with poor refractoriness may burn when the molten metal is poured into the mould. Usually, sand should be able to withstand up to 1650 ºC

2.2.2 TYPES OF MOULDING SAND

According to the use, moulding sand may be classified as below:

1. Green sand

The green sand is the natural sand containing sufficient moisture in it. It is mixture of silica and 15 to 30% clay with about 8% water. Clay and water act as a bonding material to give strength. Molds made from this sand are known as green sand mould. The green sand is used only for simple and rough casting products. It is used for both ferrous and non-ferrous metals.

2. Dry sand

When the moisture is removed from green sand, it is known as dry sand. The mould produced by dry sand has greater strength, rigidity and thermal stability. This sand is used for large and heavy castings.

3. Loam sand

Loam sand is a mixture of 50 percent sand and 50 percent clay. Water is added in sufficient amount. It is used for large and heavy moulds e.g., turbine parts, hoppers etc.

4. Facing sand

Sand used for facing of the mould is known as facing sand. It consists of silica sand and clay, without addition of used sand. It is used directly next to the surface of the pattern. Facing sand comes in direct contact with the hot molten metal; therefore it must have high refractoriness and strength. It has very fine grains.

5. Parting sand

Pure silica sand employed on the faces of the pattern before moulding is known as parting sand. When the pattern is withdrawn from the mould, the moulding sand sticks to it. To avoid sticking, parting sand is sprinkled on the pattern before it is embedded in the moulding sand. Parting sand is also sprinkled on the contact surface of cope, drag and cheek.

6. Backing or Floor sand

The backing sand is old and repeatedly used sand of black colour. It is used to back up the facing sand and to fill the whole volume of the box. This sand is accumulated on the floor after casting and hence also known as floor sand.

7. System sand

The sand employed in mechanical heavy castings and has high strength, permeability and refractoriness, is known as system sand. It is used for machine moulding to fill the whole flask. In machine moulding no facing sand is used. The system sand is cleaned and has special additives.

8. Core sand

The sand used for making cores is known as core sand. It is silica sand mixed with core oil (linseed oil, resin, mineral oil) and other binding materials (dextrine, corn flour, sodium silicate). It has remarkable compressive strength.

9. Molasses sand

A sand which carries molasses as a binder is known as molasses sand. It is used for core making and small castings of intricate shapes.

2.2.3 TESTING OF MOULDING SAND AND SAFETY PRECAUTIONS IN FOUNDRY

The following points highlight the six main tests done to determine the essential qualities of sand. The tests are:

1. Grain fineness test
2. Permeability test
3. Sand mould strength test
4. Moisture content test
5. Clay content test
6. Hardness test.

1. Grain Fineness Test:

Granular particles of various sizes and shapes provide variable interstices (space between grains) and hence, are directly responsible for permeability and compactness of the sand. Granular particles have higher- strength but lower permeability, whereas round grains have high permeability and lower strength.

To carry out this test, a sample of dry sand weighing 50 grams, free from clay is placed on the topmost sieve bearing U.S. series equivalent number 6. A set of standard testing sieves having U.S. Bureau of Standard Meshes 6, 12, 20, 30, 40,50, 70,100,140,200 and 270 are mounted on a mechanical shaker. The above sample is shaking for about 15 minutes. After this, weight of the sand retained on each sieve can be obtained. To obtain the grain-fineness, weight of the sand retained by each sieve is multiplied by 2, which gives the percentage of weight retained by each sieve. This percentage is again multiplied by a multiplying factor given in the example solved below: The A.F.S. (American Foundry Men's Society) grain fineness number will be,

$$= \frac{\text{Total product}}{\text{Total sum of percentages of sand retained by different sieves}}.$$

Table 3.1. Calculation for AFS Grain Fineness Number

Sieve number	Sieve size (microns)	Sand retained: Weight	Sand retained: % wt. retained (2 × Wt.)	Multiplier	Product (4) × (5)
6	3,360	—	—	3	—
12	1,680	—	—	5	—
20	840	—	—	10	—
30	590	—	—	20	—
40	420	0.20	0.40	30	12
50	297	0.65	1.30	40	52
70	210	1.20	2.40	50	120
100	149	2.25	4.50	70	315
140	105	8.55	17.10	100	1,710
200	74	11.05	22.10	140	3,094
270	53	10.85	21.70	200	4,360
Pan	—	9.35	18.70	300	5,580
Total		44.10	88.20		15,243

$$\text{Grain-fineness number} = \frac{\text{total product}}{\text{\% sand ratained}} = \frac{15,243}{88.2} = 173.$$

2. Permeability test

Permeability is a condition of porosity and thus is related to the passage of gaseous materials through the sand. It is expressed as the volume of air in cubic centimeter that will pass per minute under a pressure of 10 kg/m^2 through a specimen of sand 1 square centimeter of cross-sectional area and one centimeter in height. There are four conditions of permeability:

(a) Base permeability is the permeability measured in a specimen of packed dry sharp sand.

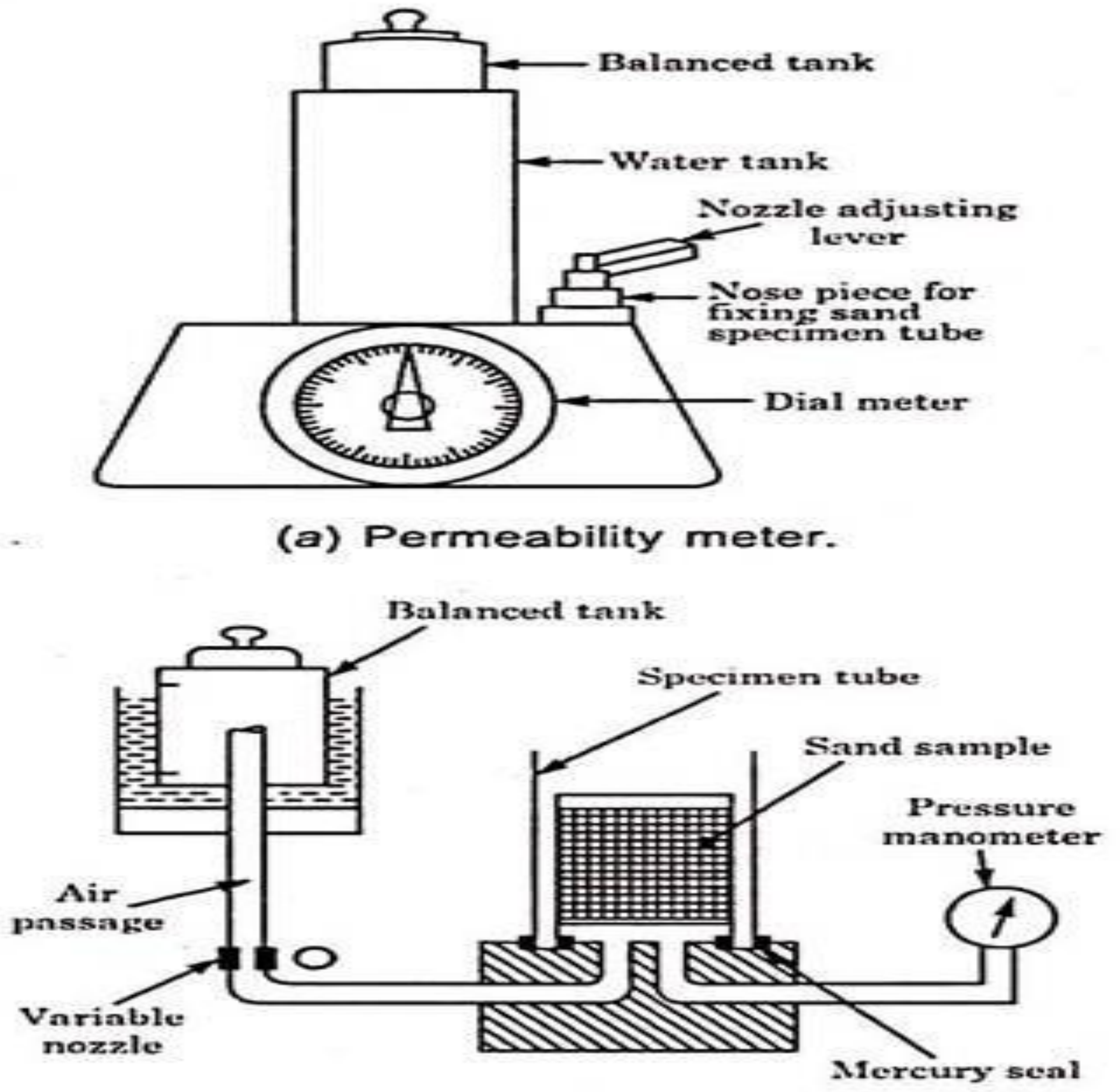
Table 3.2. Foundry Sand Grading Classification

Grain Fineness		*Clay Content*	
Grain Class	*Fineness Zone*	*Clay Class*	*Clay Zone*
1	200 to and including 300	A	0.0 to but not including 0.5
2	140 to but not including 200	B	0.5 to but not including 2.0
3	100 to but not including 140	C	2.0 to but not including 5.0
4	70 to but not including 100	D	5.0 to but not including 10.0
5	50 to but not including 70	E	10.0 to but not including 15.0
6	40 to but not including 50	F	15.0 to but not including 20.0
7	30 to but not including 40	G	20.0 to but not including 30.0
8	20 to but not including 30	H	30.0 to but not including 45.0
9	15 to but not including 20		
10	10 to but not including 15		

(b) Green permeability is the permeability measured in a specimen made of moist moulding sand.

(c) Dry permeability is the permeability measured in a specimen made of moulding sand and dried at about 100 to 110°C.

(d) Baked permeability is the permeability measured in a specimen made of sand with thermo-setting binder and backed at some temperature above 105°C.



(a) Permeability meter.

(b) Schematic sketch of permeability meter.
Fig. 3.25

Permeability test is carried out by using a permeability meter consisting of an aluminium casting in the form of a water tank and a base. A balanced tank floats inside the water tank. A specimen tube extends down to the specimen and opens into the air space.

The sand specimen is placed at the base and is sealed with mercury. Lowering of the floating tank makes air to pass through the sand specimen. Air is passed through a nozzle to adjust the flow rate. For fine sand, flow rate should be slow.

Permeability test is conducted with the specimen usually of 20.26 cm^2 cross-sectional area and 5.08 cm height, placed in the instrument cup, which provides a mercury seal, and a predetermined amount of air is forced through the specimen under controlled conditions.

The permeability reading is taken by noting the time in which 2000 c.c. of air is passed through the specimen at constant pressure. Then permeability number is obtained by dividing 3007.2 by the time in seconds.

This permeability number is a relative number. It does not necessarily tell the permeability of a mould made with the same sand, which depends on the compactness of the sand. The unit can be made direct reading, if an electric timer unit and a direct reading dial are provided.

The permeability number P can be found mathematically, by the formula given below:

$$P = \frac{v.h}{p.a.t}$$

P = permeability number to be determined.

v = volume of air passing through the specimen in cm^3.

h = height of the specimen in cm (5.08 cm).

p = pressure of air in gm/cm^2 (10 gm/cm^2).

a = cross-sectional area of specimen in cm^2. (A standard value of 20.26 cm^2 is generally adopted).

t = time for air to pass in minutes.

$$P = \frac{200 \times 5.08 \times 60}{10 \times 20.26 \times t} = \frac{3007.2}{\text{Time in seconds}}$$

Table 3.3 shows the ranges for green permeability for moulding mixtures used for different metals.

Table 3.3. Ranges for Green Permeability for Moulding Mixtures Used for Different Metals

S. No.	Type of Sand	A.F.A. Green Permeability No.
1.	Loam (15% moisture)	less than 5
2.	Moulding mixture for Cast iron	0 to 80
3.	Moulding mixture for Bronze	35
4.	Moulding mixture for Aluminium	20 to 40
5.	Dry sand for steel	60 to 100
6.	Green sand for steel	150 to 300

3. Sand mould strength test

Permeability and strength, the most important factors, depend on size and shape of sand grains provided, the correct quantity of water is used in mixing the sand and also on the degree of hardness to which the sand in rammed.

If the sand hardness number does not exceed 85, it is observed that the product of hardness number and permeability number remains constant.

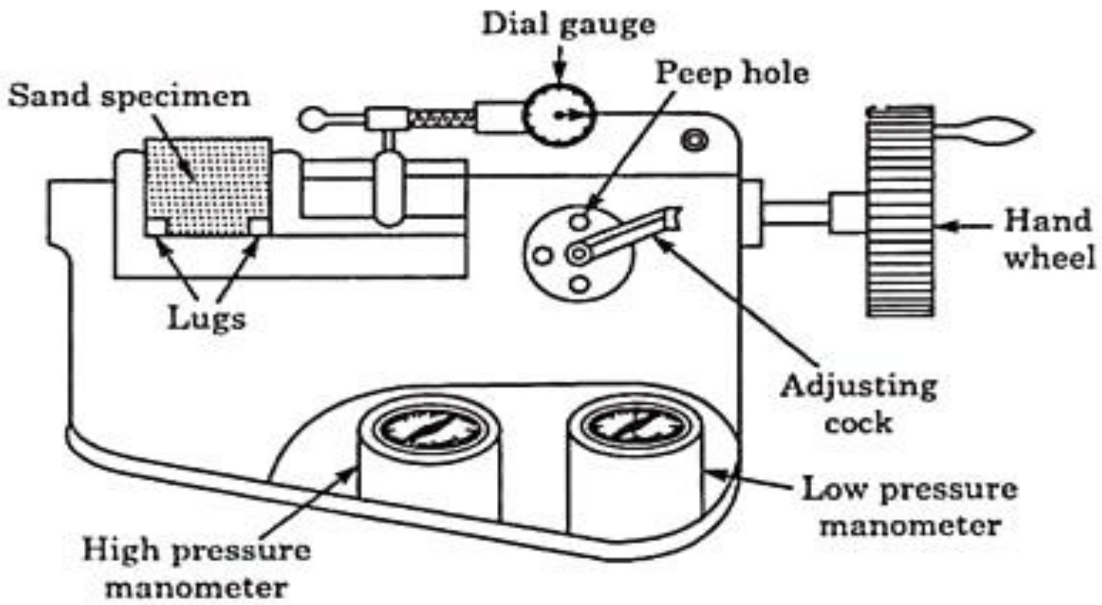


Fig. 3.26. Strength tester.

To find out the holding power of various bonding materials in green and dry sand moulds, strength tests are performed. Compression tests are most commonly performed, although tensile, shear and transverse tests are also sometimes performed. A typical strength tester is shown in Fig. 3.26.

The strength test is performed on the horizontal hydraulic press. The specimen of cylindrical shape, whose strength is to be found out is placed on the lugs and pressure is applied, slowly by hand wheel until the specimen breaks. The reading of the needle on high pressure and low pressure manometer indicates the compressive strength of the specimen.

These manometers are graduated in four different scales each for compressive, shear, tensile and bending in kg/cm^2. Dial gauge is used, when the deformation tests are to be performed. Table 3.4 gives the compressive strength of the sand to be used for different casting materials.

Table 3.4

S. No.	*Metal*	*Compressive Strength kg/cm^2*	
		Green	*Dry*
1.	Cast iron :		
	(a) Light Castings	0.42	1.41
	(b) Medium Castings	0.49	3.52
2.	Steel :		
	(a) Green sand	0.56	4.92
	(b) Dry sand	0.63	10.55
	(c) Oil sand	0.21 to 0.35	21 to 70
3.	Copper base alloy	0.49 to 0.7	2.8 to 4.2
4.	Aluminium	0.35	1.4 to 2.1
5.	Magnesium	0.56	7

4. Moisture content test

Moisture content may be determined by the loss of weight, after evaporation. A sample of tempered sand weighing 50 gm. is dried at 110 to 115°C, and then cooled to room temperature in desiccator and re- weighed. The difference in weight, before and after heating gives the moisture content in the sample. The moisture content can be expressed in percentage by the formula % Moisture content. Other methods of finding the moisture content are based on the principle of reaction and electrical conductivity. In the former method, weighed amounts of sand sample and calcium carbide are mixed by shaking and the resultant pressure of acetylene gas generated indicates the percentage of moisture.

5. Clay content test

Clay content is determined by finding the loss of weight after washing of sample. A 50 gm sample of previously dried sand is weighed, placed in the mixing device and treated with a standard sodium hydroxide solution consisting of 475 c.c. of water and 25 c.c. of NaOH standard solution under controlled conditions. Such a testing apparatus consists of jar, which is securely covered and sealed, and rotated at 60 rpm by electric motor for about an hour.

After it, the sand adhering to cover or sides is washed into jar. After thorough washing, residue is dried and reweighed. Actually, residue is obtained only after ensuring that it settles into water depth of 125 mm in 5 minutes time. The material, which is not able to settle through 125 mm depth in 5 minutes is clay and should be removed. Loss of weight in the sample before and after it is dried gives the clay content.

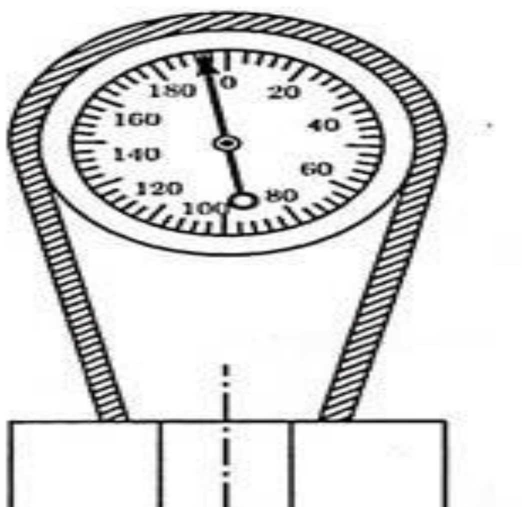


Fig. 3.27. Mould hardness tester.

6. Hardness test

Mould and core hardness can be found out by the hardness-tester, which is based on the same principle as Brinell hardness tester. A steel ball of 50 mm diameter weighing 237 gm is pressed on the mould surface.

The depth of penetration of steel ball will give the hardness of mould surface on the direct reading dial. This hardness test is useful in finding out the mould uniformity. The following are the moulding hardness numbers for moulding:

sand $\left(1 \text{ number} = \frac{1}{100} \text{ mm}\right)$

Soft rammed moulds	= 100
Medium rammed moulds	= 125
Hard rammed mould	= 175.

Safety precautions in foundry

1. Dress properly while working with molten metal.
2. Wear a pair of clear goggles and asbestos gloves.
3. Do not make the sand too wet because water is enemy to the molten metal.
4. Never look over the sand mould during the pouring of molten metal.
5. Do not light the furnace without permission.
6. If a cold metal is to be added to the molten metal, ensure that it is perfectly dry.

2.2.4 MOULD MAKING

A mould can be described as a void or cavity in a compact sand mass with the help of pattern which, when filled with molten metal, will produce a casting. Moulding is a process of making moulds from which castings are obtained.

Types of moulds

The various types of moulds are as follow:

1. Green sand moulds
2. Dry sand mould
3. Skin dried moulds
4. Air dried moulds
5. Loam moulds
6. Cement bonded sand moulds
7. Plaster moulds
8. Shell moulds
9. Metallic moulds

1. Green sand moulds

The green word indicates that the moulding sand is in moist state at the time of pouring of metal. Infact a green sand mould is that mould in which the molten metal is poured immediately after the mould is ready. The main ingradient of green sand moulds are silica sand - 92%, binder (clay) - 8% and moisture (water) - 4%. This mold is using for casting small components and can be taken out within 8 - 10 hrs approximately. The best advantage of this type of sand is that it is almost 95% re-usable and hence is economically very feasible.

2. Dry sand mould

The word 'dry' signifies that at the time of pouring of metal, the mould is in dry state. Dry sand mould is a sophisticated form of green sand mould, in which the sand mould is baked at a given temperature to make it stronger. This mould is mostly used in large foundries to produce big ferrous and non-ferrous castings like engine blocks, construction parts, etc.

3. Skin dried moulds

These are made of green sand with dry sand baking. In some cases, moisture is dried from the surface layer of rammed sand to a depth of 25 mm by heater or gas torches. These are more common in large moulds and can be used for casting, practically all ferrous and non-ferrous alloys.

These are less expensive to construct than dry-sand moulds but more expensive than green sand moulds of given size. It has the advantages of less equip-ment, cheaper materials, less time for preparation, and less floor space in comparison to dry sand moulding. However, these are not as strong as dry sand moulds and cannot be stored for long time as moisture may migrate through the dry skin.

4. Air dried moulds

These moulds are similar to skin dried moulds in the sense that their skin is dried, but they are not artificially heated. After the mould has been made in the green state, it is kept open to the atmospheric air for a certain period of time, during which some of the moisture from the mould surfaces gets evaporated and consequently, the mould skin dries and thereby increases the strength and hardness of mould surface.

5. Loam moulds

Loam is one type of clay which is made with sand mixed with water to form a thin plastic mixture from which moulds are made. Loam sand also contains ganisters or fire clay. A loam mould is preferred for making large castings.

6. Cement bonded moulds

In these moulds, silica sand bonded with portland cement is used as the moulding material, which dries up in air. These moulds are most com-monly used for very large ferrous work and pit moulding and in other cases, where baking is impossible. It has high strength and possesses all advantages of dry sand. For these moulds, extra space for air drying operation has to be pro-vided. The materials used in these moulds cannot be used again like other moulds, thus the process becomes expensive.

7. Plaster moulds

In this, slurry made up of Plaster of Paris with water is poured over a permanent pattern that is contained inside a molding box. After the setting process, a rigid mold is produced. The pattern is then stripped, dried at a high temperature to remove watery part. The metal is then cast into the mold. The mold here is strong and dense but impermeable in nature. So vacuum or pressure assistance is needed for complete filling of the mold by the metal. Plaster mold is created by using of a mixture of gypsum, strengthening compounds, and water. The plaster used is not pure plaster of Paris. Instead, it has additives that improve green strength, dry strength, permeability, and castability. It can only be used with non-ferrous materials.

8. Shell moulds

The shell moulds are produced with the help of heated iron or steel patterns. These mould are prepared by heating a mixture of sand and phenolic resin over the surface of a metallic pattern. Shell mold casting allows the use of both ferrous and non-ferrous metals, most commonly using cast iron, carbon steel, alloy steel, stainless steel, aluminum alloys, and copper alloys. Typical parts are small-to-medium in size and require high accuracy, such as gear housings, cylinder heads, connecting rods, and lever arms.

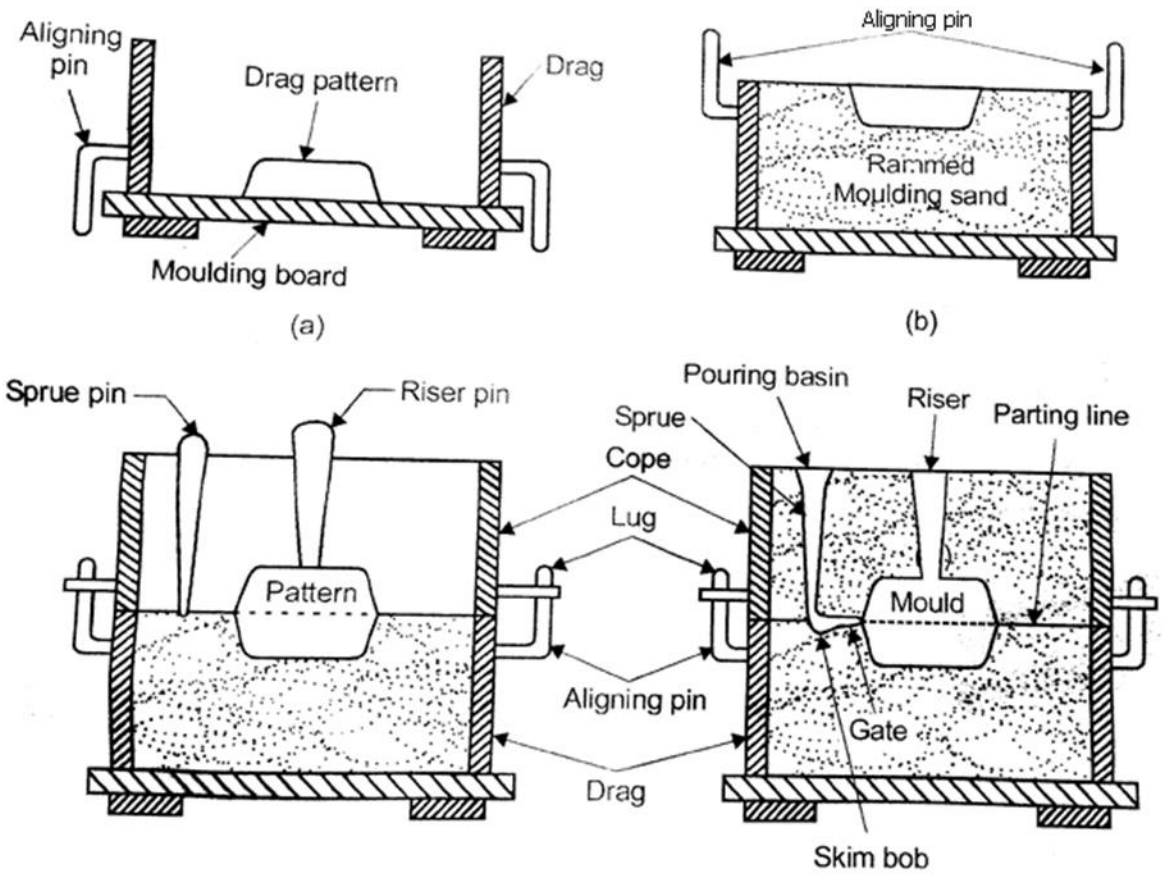
9. Metallic moulds

Metallic moulds are also known as permanent moulds because of their long life. These are generally made in two halves and they are clamped to get the proper mould cavity. Usually the metallic moulds are called dies. These moulds can be used both ferrous and non-ferrous casting.

2.2.5 STEPS INVOLVED IN MAKING A MOLD

1. Firstly a suitable moulding box is selected which accommodate the pattern, riser, gating system.
2. Mould cavity should have sufficient wall thickness as it will have to hold molten metal.
3. A bottom board is placed either on the mold platform.

4. Place the drag pattern with parting surface down on the bottom board.
5. Facing sand is sprinkled carefully all around the pattern.
6. The drag is then filled with ordinary moulding sand and rammed properly.
7. The excess sand is struck off to bring it at the same level of the flask height.
8. Now with a vent wire, vent hole is made in the drag.
9. Parting sand is sprinkled all around the cope pattern.
10. Runner and riser are put in position and supported vertically.



11. Set the gaggers in the cope.
12. Remove sprue and riser pins and vent the cope with vent wire.
13. The pattern parts are then removed from both the drag and cope.
14. Repair the mould if necessary.
15. Cut the gate connecting the sprue basin with mould cavity.
16. Apply mould coating with a swab.

17. Set the cores in the mould if required.
18. Close the mould by inverting cope over drag.
19. Now clamp cope with drag and the mould is ready for pouring.

2.2.6 MOULDING BOXES OR FLASKS

A moulding box or flask is a container in which sand is packed and rammed. Following three types of flasks are widely used in foundary:

1. Box type moulding box
2. Snap type moulding box
3. Wooden moulding box

1. Box type moulding box

A box type moulding box is also known as permanent flask, these flasks should not be removed till the pouring of molten metal is completed. These boxes are generally made of steel and used for small and medium-sized castings.

2. Snap type moulding box

These boxes are fitted with a hinge at one corner and a fastener at the diagonally opposite corner. After the mould has been made, it is moved to the position where it is to be cast. These boxes are used for production of small castings and in machine moulding.

(a) Box type of flask. (b) Snap flask. (c) Wooden moulding box.

Moulding boxes or flasks

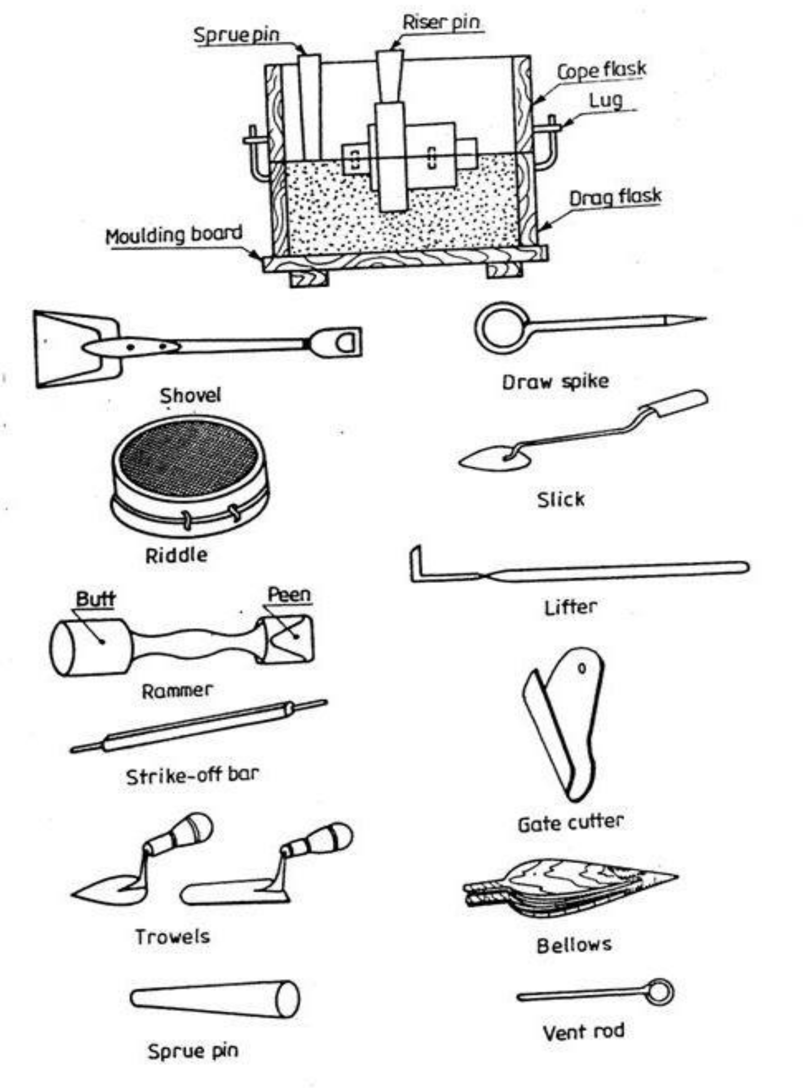
3. Wooden moulding box

In wooden moulding box, handles are an integral part of the boxes and are provided at the extended sides. The upper part known as cope has cross wooden partition but not the drag. These partitions help in supporting the sand when the cope is lifted. For accurate placing of cope and drag together, steel lugs are provided. The clamps and wedges are used for holding the lugs at their position.

2.2.7 HAND TOOL USED FOR MOULD MAKING

In moulding process all the moulding operations such as ramming the sand, placing and drawing the pattern, turning over the moulding boxes etc. are performed by hand. So a number of hand tools are required which are as follow:

1. Shovel
2. Riddle
3. Rammers
4. Trowels
5. Strike-off bar
6. Vent wire
7. Lifter
8. Slick
9. Swab
10. Bellow
11. Gate cutter
12. Sprue cutter
13. Draw screw
14. Mallet
15. Gagger
16. Rapping plate
17. Clamps
18. Sprit level



1. Shovel

A shovel is used for mixing the sand with other ingredients. It is also used for handling the sand from one place to another in the foundary shop. It consists of a square metal pan fitted with a wooden handle.

2. Riddle

A riddle is used for cleaning the moulding sand. It removes the unwanted material like metal scrap, iron and other metal parts, pebbles etc.

3. Rammers

A rammer is a wood or metal tool used for ramming or packing the sand in the moulding box. It has two parts peen and butt. Rammers are available in different designs and constructions. The popular and widely used rammers are peen-rammer, bench-rammer, and floor-rammer etc.

4. Trowels

A trowel is used for finishing and repairing a mould. It consists of a metal-flat with different shapes and wooden handle. It is also used for smoothen the mould surfaces, shaping the square corners, finishing the parting surfaces. It is available in different shapes like rectangular, triangular, square, round etc.

5. Strike-off bar

A strike-off bar is used for striking off the excess sand from the mould to provide a smooth surface. It is a straight bar of wood or steel and usually have rectangular cross-section.

6. Vent wire

A vent wire is used to form vents or holes in the rammed sand to provide easy escape of gases or steam formed during pouring of molten metal. It is a circular or rectangular long needle tool, pointed edge at one end and handle at the other end.

7. Lifter

A lifter is used for picking up the unwanted dust and damaged parts of the mould. It is an L- shaped steel tool with long holding shank and a small toe. It is available in thin sections of various width and lengths, according to the shape of the mould.

8. Slick

A slick is used for repair and finishing the mould surface after the removal of pattern. It is a double ended tool having a spoon on one end and a flat on the other end.

9. Swab

A swab is used for moistening the sand around the edge before the pattern is withdrawn. It consists of soft hair brush to hold water at one end, and a rubber buld at the other end.

10. Bellow

A bellow is used to blow loose particles of sand from the cavity and surface of the mould. Sometimes, a compress jet of air is used for this purpose.

11. Gate cutter

A gate cutter is used for cutting the gate in the mould which acts as a passage for the hot metal. It is U-shaped piece of thin sheet metal.

12. Sprue cutter

A sprue cutter is used for creating a run-through or sprue for the molten metal in the cope. It has tapered cylindrical shape and made from wood.

13. Draw screw

A draw screw is used for drawn out the pattern embedded in the moulding sand. It is a pointed steel rod, with a loop at one end. Wooden mallet is used for striking the draw screw, also called draw spike.

14. Mallet

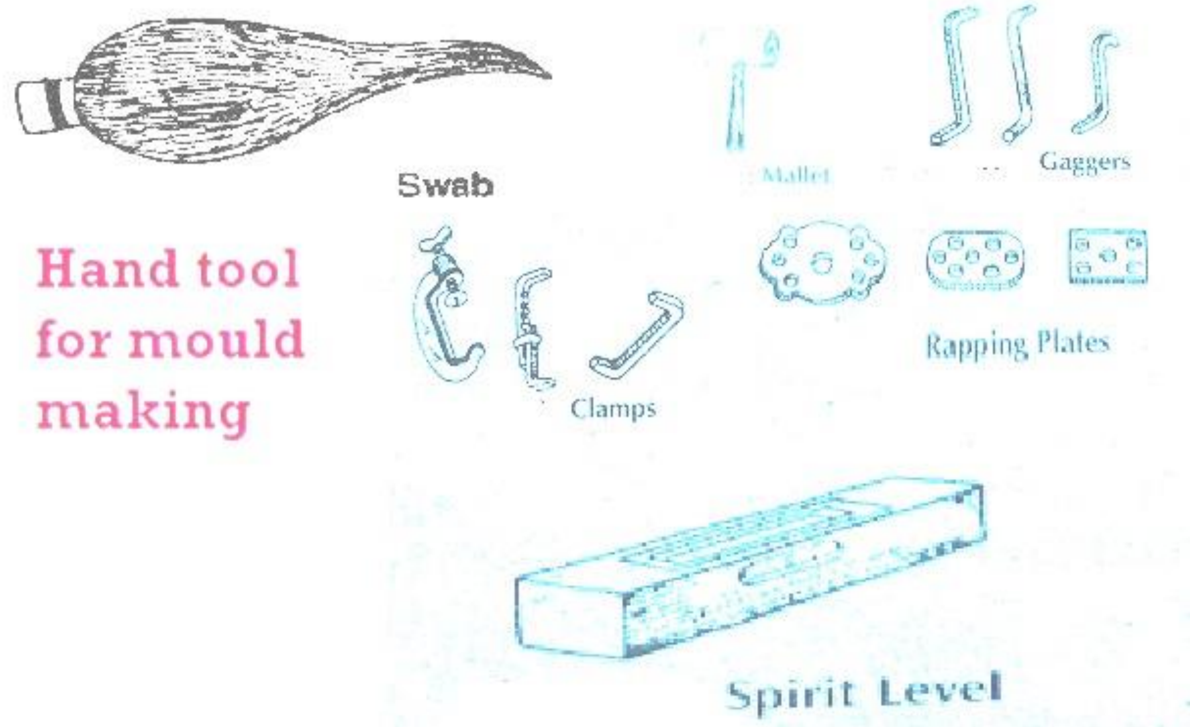
A mallet is used to loosen the pattern in the mould so that it can be removed easily. It is used together with draw spike.

15. Gagger

A gagger is used for reinforcing the moulding sand in the cope part of the moulding box. These are the iron rods or thick wires bent at one or both the ends. The bottom end of the gagger must be kept 5 to 8 mm away from the embedded pattern.

16. Rapping plate

A rapping plate is used for lift the large and heavy pattern from the mould. It is a steel plate and firmly fixed to the top of the pattern by means of bolts and screw. Rapping plates are available in many shapes.



17. Clamps

The clamps are used for holding the top and bottom parts of the mould so that the cope should not rise when the molten metal is poured into the mould cavity.

18. Sprit level

A sprit level is used to keep sand bed, moulding box and table in horizontal position. It consists of an air bubble inside a curved glass tube.

2.2.8 MOULDING PROCESSES

The various moulding processes are used in industries. These are:

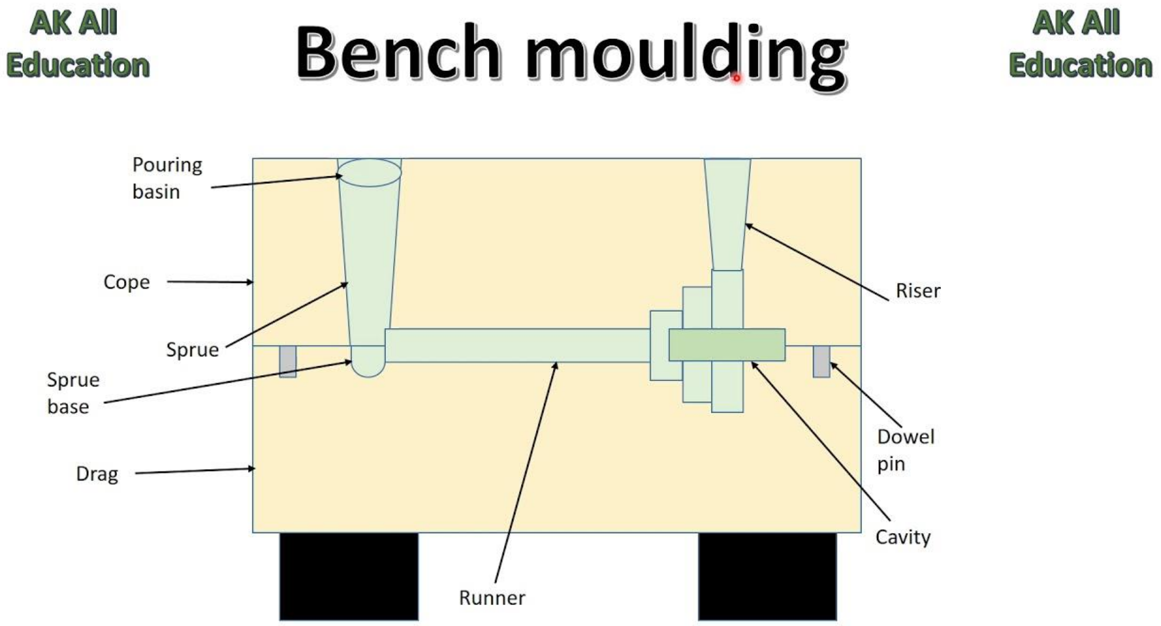
1. Bench moulding

2. Floor moulding
3. Pit-moulding
4. Machine moulding.

1. Bench moulding

Bench moulding is carried out on a convenient bench and the moulds prepared are relatively small. By bench moulding, green sand, dry sand or skin-dry sand moulds can be made. In this, hand ramming with loose patterns is employed and as such, it is a slow and laborious method.

It uses the moulding box made in two parts (upper is called cope and lower one drag). Two parts are fitted with a suitable clamping and locating device. Clamping prevents the cope from lifting due to the pressure of the molten metal while pouring. Locating device enables the two parts to maintain proper alignment at all times.



In this method, the drag and pattern are placed on the moulding board and the sand is rammed in drag. The drag is then rolled over the board. The other part of the pattern is fitted over bottom one, and cope is placed over the drag.

Sprue-pin and riser pin are placed in position, and sand filled in the cope and rammed. Mould is vented, sprue and riser pins removed. Mould is then parted off, pattern withdrawn, mould cavity cleaned and gate cut in the drag. Core is placed in position and reassembled and clamped to make the mould ready for pouring.

2. Floor moulding

In this method, the moulding of medium and large moulds is directly carried out on the floor. Green sand, dry sand, or skin-dry moulds can be made by this method on the floor with the proper flasks. It is also a slow and laborious method as it requires ramming with loose patterns as shown fig. 27.

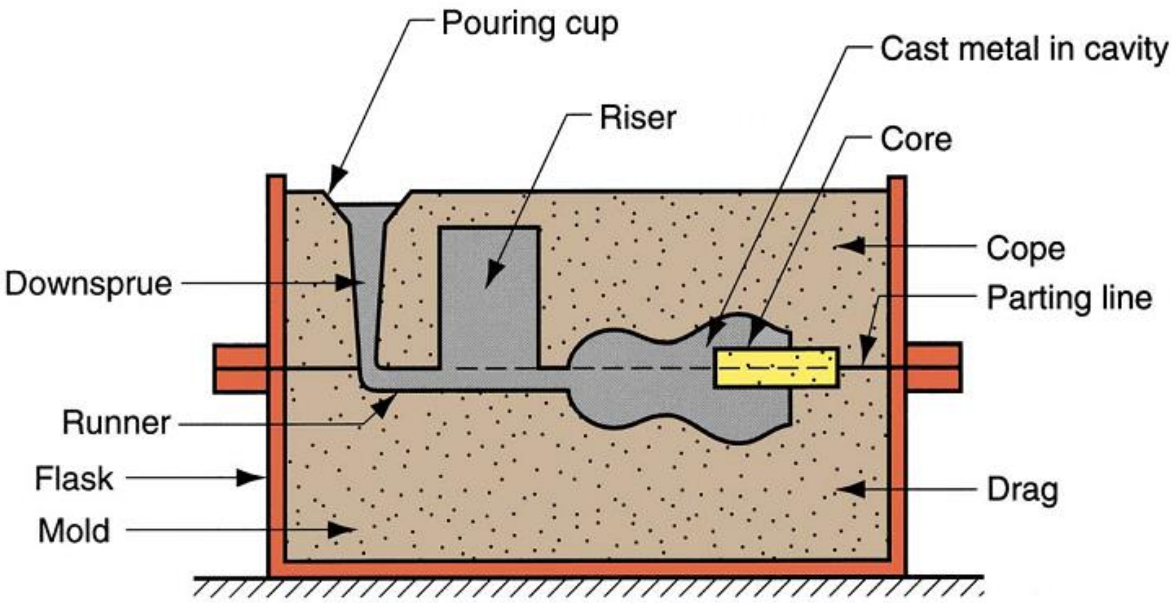


Fig. 27: Floor moulding

The floor moulding is generally carried out using two part boxes (top and bottom, known as cope and drag). These boxes consist of two stout frames with pins and holes to ensure accurate location. The ground surface is first levelled and half part of pattern placed over it and then box frame is placed around the pattern. Box is packed with sand, and sand is rammed and levelled off. The packed box is then turned over and second box placed on top, ensuring correct location by inserting dowel pins into the holes in side lugs on the boxes. The other half of pattern is placed over earlier half and sand is filled and rammed in top box and leveled off.

Two boxes are then opened and pattern is removed. If any repair is required, same is carried out and gates for pouring metal made. If cores have to be located to form holes, these are placed in position. Boxes are again put back into position and usually clamped to prevent the upper box floating on the liquid metal.

3. Pit-moulding

In this method, the moulding is carried out in the pits and generally, very large moulds are made, the pit serving the purpose of flask. Generally, green sand is used in pit moulding but cement bonded sand sections may also be used. For large moulds, this is the only method of moulding and is quite slow and laborious as shown in fig. 28.

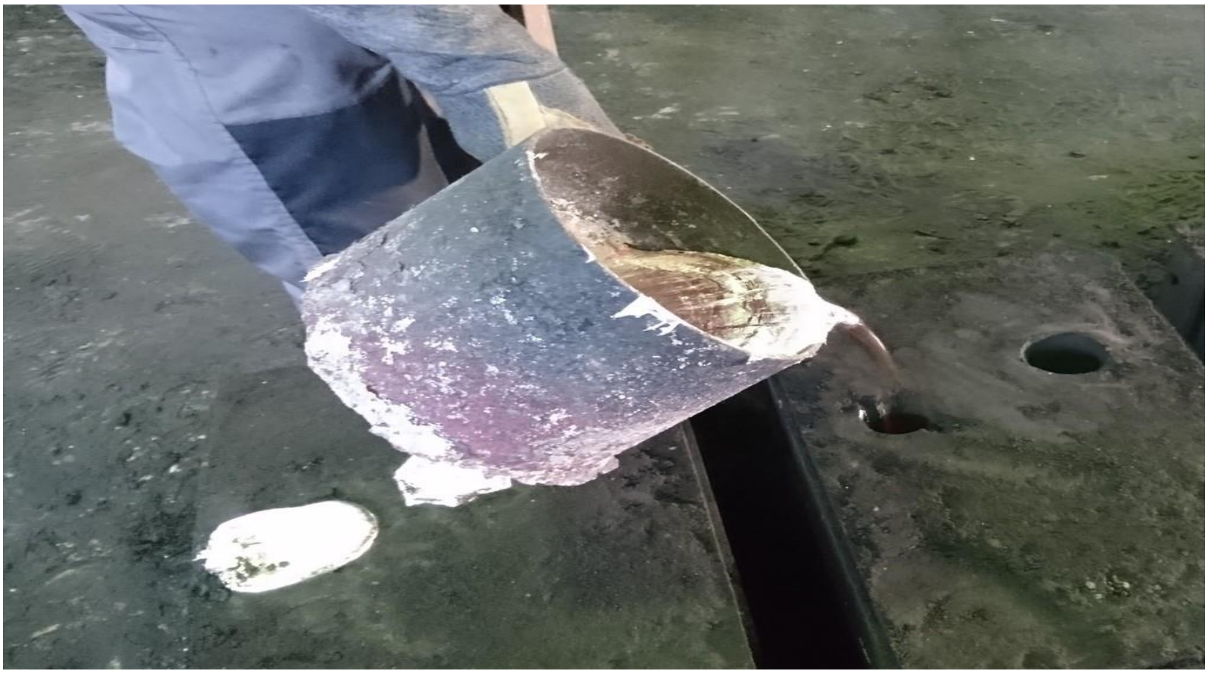


Fig. 28: Pit-moulding

4. Machine moulding

A variety of machines are used in this method for carrying out the moulding of small medium and large moulds. This method is faster and gives uniform mouldings, but requires mounted patterns. By this method also, green-sand, dry-sand and skin-dry moulds can be prepared.

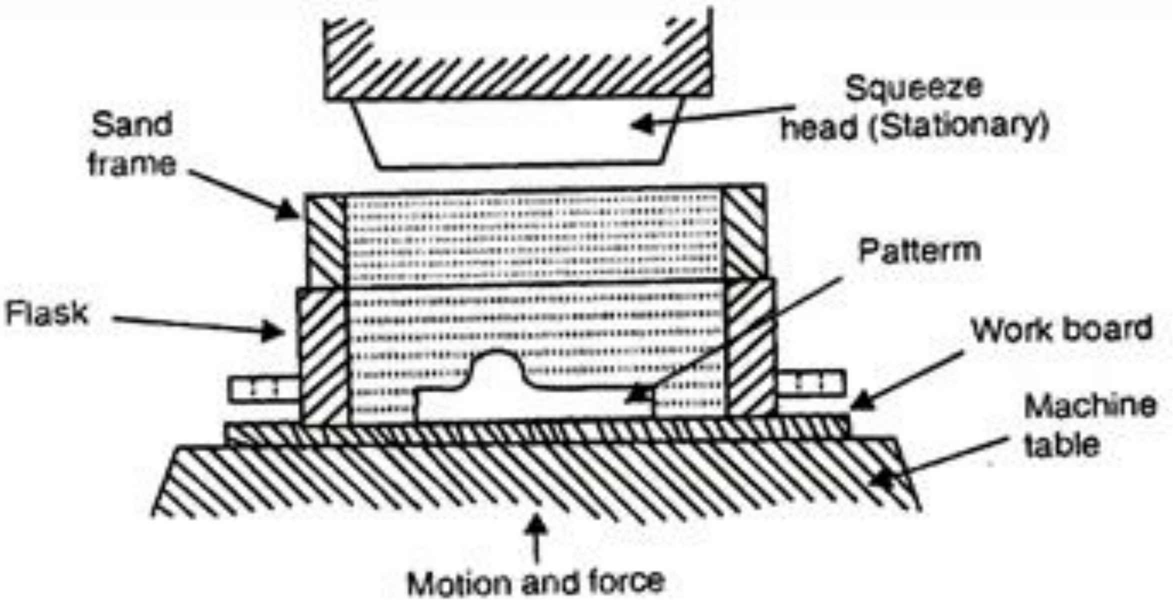
2.2.9 MOULDING MACHINES

A moulding machine is device consisting of a large number of parts and mechanisms which transmits and directs various forces and motions in required

- Squeezing machine
- Jolt Machines
- Jolt-squeeze machine
- Sand Slingers

2.2.10 SQUEEZING MACHINE

In this machine, pattern plate is clamped on the machine table, and a flask is put into position. A sand frame is placed on the flask, and both are then filled with sand from a hopper.

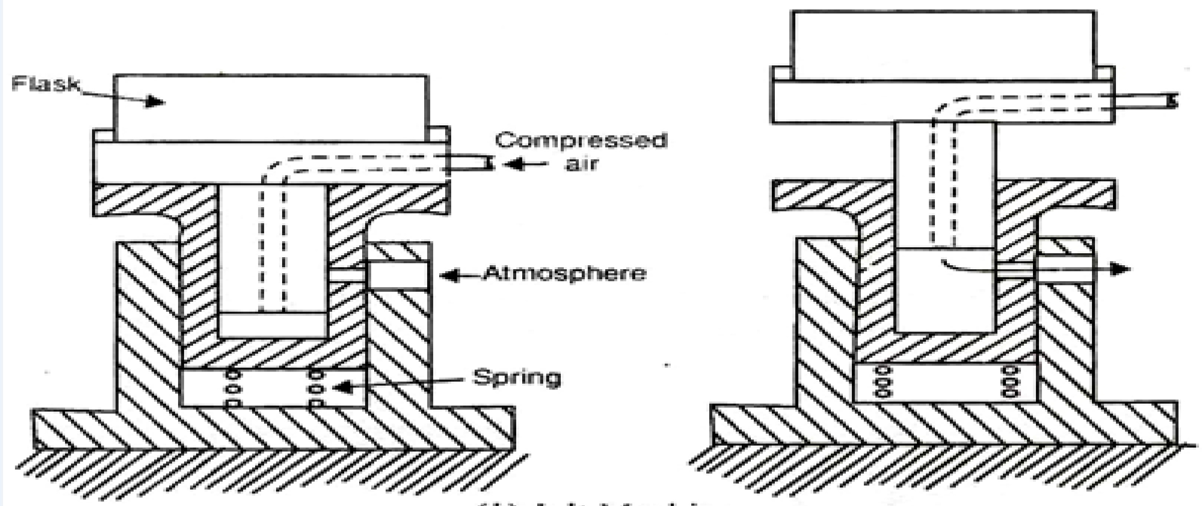


(*a*) Squeezer.

Next, the machine table travels upward to squeeze the sand between the pattern plate and a stationary squeeze head. The squeeze head enters into the sand frame and compact the sand so that it is level with the edge of the flask. These machines rammed the sand harder at the back of the mould and softer on the pattern face. Squeezer machines are very useful for shallow patterns.

JOLT MACHINES

The working principle of jolt type of moulding machine is shown in Fig. 4.11 (b). As can be seen, compressed air admitted through the hose to a pressure cylinder to lift the plunger and the flask, which is full of sand, up to a certain height, where the side hole is uncovered to exhaust the compressed air.



(b) Jolt Machine.

Fig. 4.11. Molding machines.

The plunger then falls down and strikes the stationary guiding cylinder. The shock waves generating from each of successive impacts contributes to packing or ramming the moulding sand in the flask.

2.2.11 JOLT-SQUEEZE MACHINE

Jolt squeeze machine combines the operating principles of 'jolt' and 'squeeze' machines resulting in uniform ramming of the sand in all portions of the moulds. The machine makes use of a match plate pattern placed between the cope and the drag box. The whole assembly is placed on the table with the drag box on it. The table is actuated by two pistons in air cylinders, one inside the other. One piston called 'Jolt piston' raises and drops the table repeatedly for a predetermined number of times, while the other piston called 'squeeze piston' pushes the table upward to squeeze the sand in the flask against the squeeze plate. In operation, sand is filled in the drag box and jolted repeatedly by operating the jolt piston.

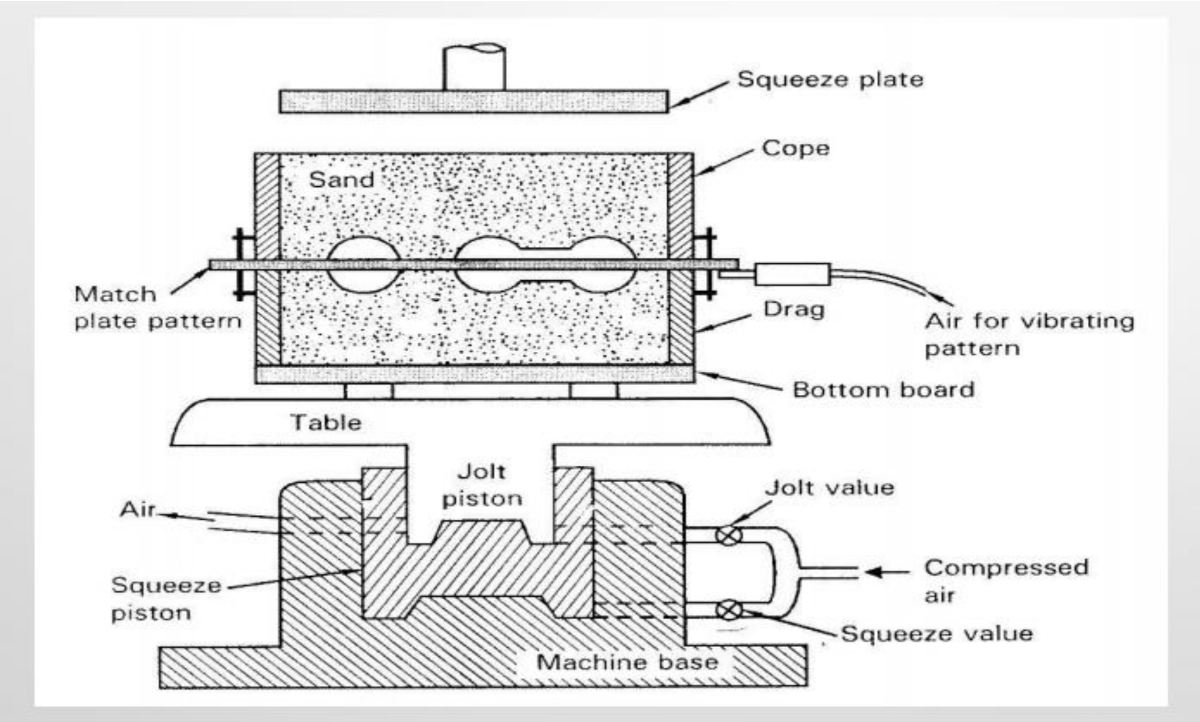


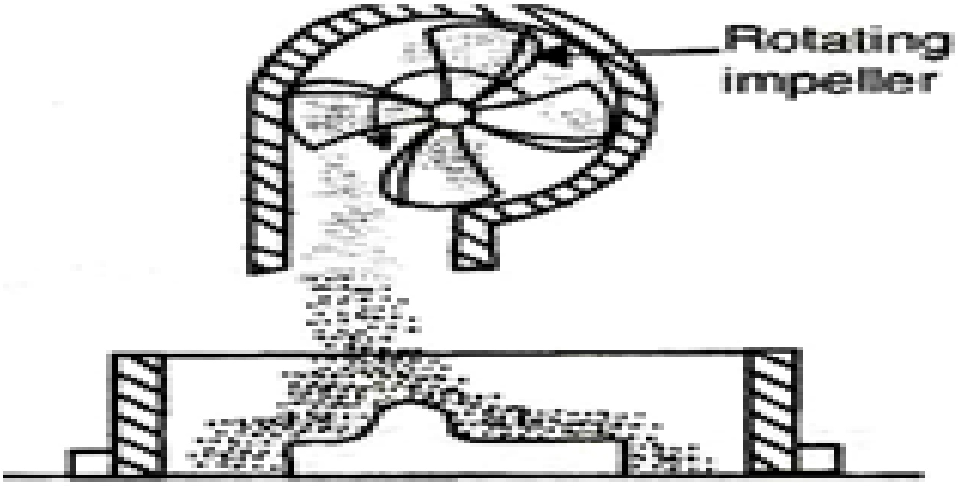
Fig. 29: Jolt-squeeze machine

After jolting, the complete mould assembly is rolled over by hand. The cope is now filled with sand and by operating the squeeze piston; the mould assembly is raised against the squeeze plate. By the end of this operation, the sand in the mould box is uniformly packed. The match plate is now vibrated and removed. The mould is finished and made ready for pouring.

2.2.12 SAND SLINGER MACHINE

The working principle of a sand slinger machine is shown in Fig. 4.11 (c). As can be seen, moulding sand is fed into a housing containing an impeller that rotates rapidly around a horizontal axis.

Sand particles are picked up by the rotating blades and thrown at a high speed through an opening onto the pattern, which is positioned in the flask.



(c) Sand slinger.

This type of machine is employed in moulding sand in flasks of any size, whether for mass production of moulds or individual mould.

2.3 CASTING PROCESSES

2.3.1CHARGING A FURNACE

Charging a furnace depends upon the casting to be obtained. To obtain sound casting, care must be taken in the selection of charge. For producing cast iron castings, pig iron, steel scrap, foundry returns such as gates, risers etc. are melted in the furnace named cupola. After igniting the coke bed of cupola, alternate layers of pig iron mixed with steel scrap and returns, coke and lime stone are charged from the charging door till the cupola is full. A typical metal charge consists of 30% pig iron, 30% steel scrap and 40% returns of foundry. The function of flux is to remove oxides and other impurities.

2.3.2 MELTING AND POURING THE METAL

1. **Melting the metal**

To produce casting first of all metal is melted in the melting furnace. Metal composition must be effectively controlled during melting. Melting losses must be minimum. Melting losses are the losses of alloying elements during melting because of oxidation.

2. **Treatment of molten metal**

Before pouring the molten metal into mould, refining of melt is carried out. Refining can be done by adding oxidizing agents such as active flux and gaseous oxygen during the early stage of melting to ensure low hydrogen content. Molten metal absorbs oxygen and therefore, de-oxidation is essential. The commonly used deoxidizing agents are manganese, silicon, aluminium for steel and nickel base alloy.

3. **Pouring the metal**

Pouring of metal must be carefully controlled during the process of casting. The temperature of molten metal must be proper. The excessively high temperature produces blow holes, while if the temperature is excessively low, the metal solidifies prematurely and does not fill the entire cavity, due to which the defects like mis-run and cold shut occur.

2.3.3 CLEANING OF CASTINGS

The process refers to different activities that are performed to remove the sand, scale and excess metal from the casting. Some of the activities performed in cleaning are:

1. The casting is separated from the mold and transported to the cleaning department.
2. Burned-on sand and scale are removed.
3. Excess metal is removed (fins, wires, parting line fins, and gates).

4. Subsequently the casting can be upgraded using welding or other such as procedures.
5. Final testing and inspection to check for any defects.

DIE CASTING

Die casting is a metal casting process that is characterized by forcing molten metal under high pressure into a mould cavity. The mould cavity is created using two hardened tool steel dies which have been machined into shape and work similarly to an injection mould during the process.

2.3.4 HOT CHAMBER DIE CASTING MACHINE

Hot chamber die casting machines are primarily used for zinc, copper, lead, and other low melting point alloys. The injection mechanism of a hot chamber machine is immersed in a molten metal bath of a metal holding furnace. The furnace is attached to the machine by a metal feeding system called the gooseneck. As the injection cylinder plunger rises, a port in the injection cylinder opens allowing the molten metal to fill the cylinder. As the plunger moves downward, it seals the port and forces metal to fill the cavity through the gooseneck and nozzle to the die cavity as shown in fig. 31.

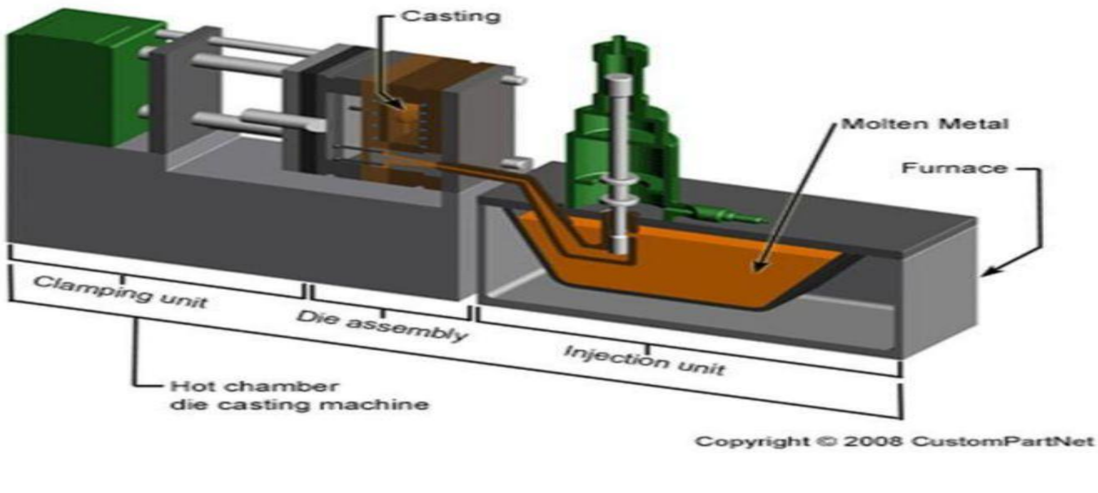


Fig. 31: Hot chamber die casting

After the metal has solidified in the cavity, the plunger is withdrawn. The die opens and the casting ejected.

2.3.5 COLD CHAMBER DIE CASTING MACHINE

The cold chamber die casting process is a preferred manufacturing method for metals that have high melting points. Typically, this will include metal alloys of aluminum, brass, and copper. The requirements for cold chamber die casting include an outside furnace and a ladle to pour the molten metal. Cold chamber die casting methods are known for their ability to produce denser metal castings as shown in fig. 32.

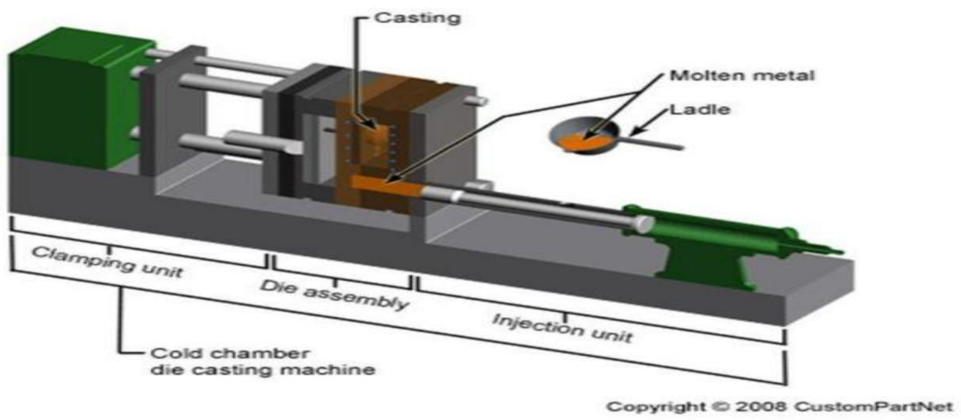


Fig. 32: Cold chamber die casting

Advantages of die-casting

1. High productivity.
2. Good dimensional accuracy.
3. Good surface finish
4. Thin wall parts may be cast.
5. Very economical process at high volume production.
6. Fine Grain structure and good mechanical properties are achieved.
7. Intricate shapes may be cast.
8. Small size parts may be produced.

Disadvantages of die-casting

1. All metals and alloys cannot be achieved.
2. The cost of machines, dies and other equipment used is high.
3. It is not cheap to start with small quantity production.
4. Special precautions are necessary for evacuation of air from die cavity, otherwise cause porosity.
5. It is impossible to get a die casting prototype when product development process.

Application of die-casting

Die-casting is the largest casting technique that is used to manufacture consumer, commercial and industrial products like automobiles, toys, parts of sink faucet, connector housing, gears, etc. Most die castings are done from non-ferrous metals like aluminum, magnesium, etc.

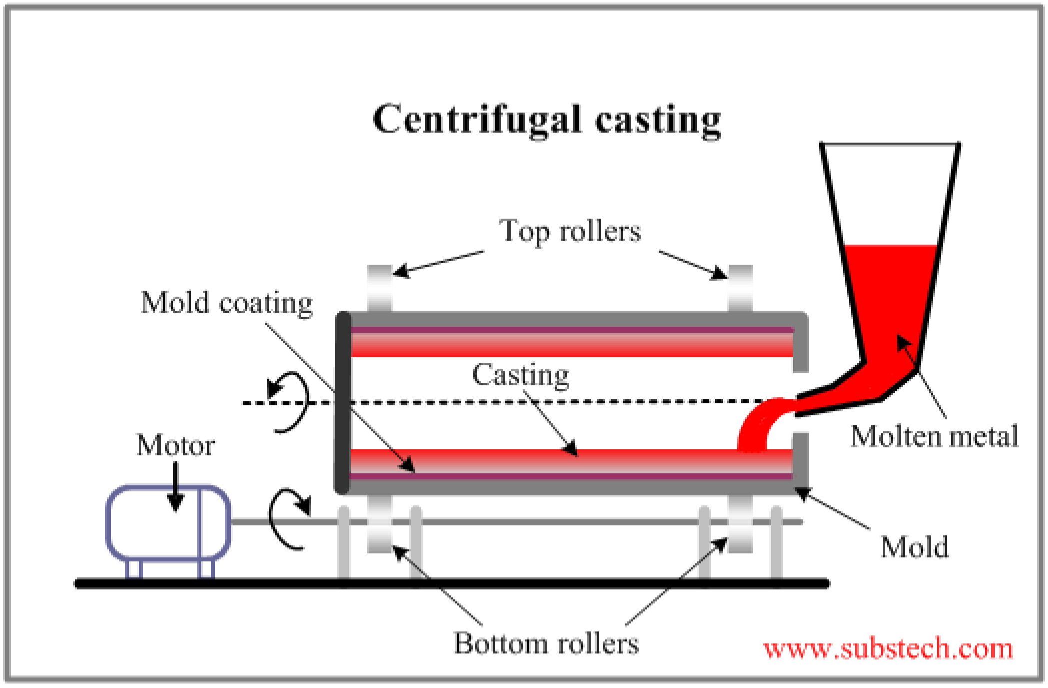
2.3.6 CENTRIFUGAL CASTING

In the centrifugal casting process, molten liquid metal is poured into a spinning die. During the metal casting process, the die can be spinning either on a vertical or horizontal axis depending on the configuration of the desired part. Ring and cylinder type shapes are cast vertically; tubular shapes are made with the horizontal centrifugal process. According to the shape of the mould, the centrifugal casting methods can be classified as follow:

1. True-centrifugal
2. Semi-centrifugal
3. Centrifuge casting

1. True centrifugal casting

It is a method of casting parts having axial symmetry. The method involves pouring molten metal into a cylindrical mold spinning about its axis of symmetry. The mold is kept rotating till the metal has solidified. As the mold material steels, Cast irons, Graphite or sand may be used. The rotation speed of centrifugal mold is commonly about 1000 rpm (may vary from 250 rpm to 3600 rpm).



2. Semi-centrifugal casting

In this process the mold is rotated about the central vertical axis and casting is symmetrical about the axis of rotation, the process is semi centrifugal casting. The molds are either permanent or expandable. It may have cores also. The shape of the rotating mold gives the shape of the casting.

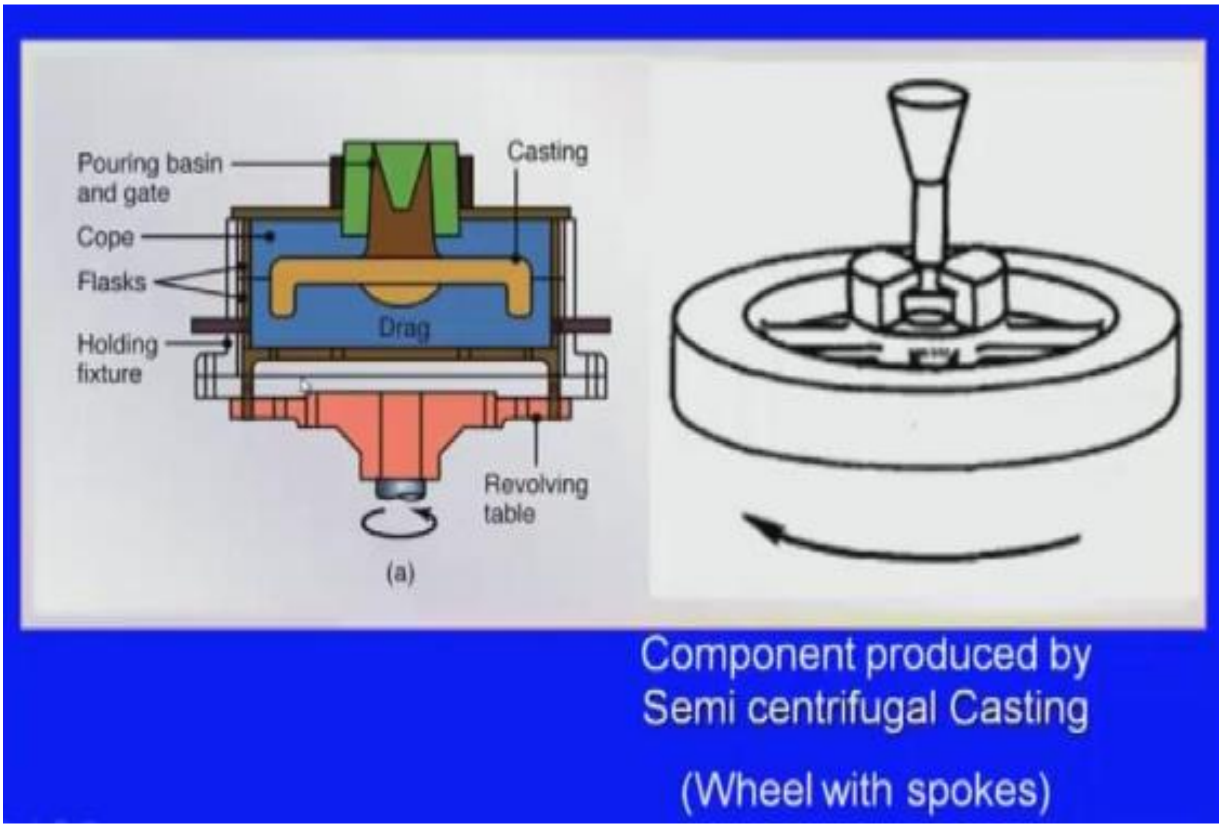


Fig. 33: Semi-centrifugal casting

The centrifugal force is put to good use for the processes of slag separation, melt refilling and increasing the filling power to cast components with thin sections as shown in fig. 33. However this process can suffer from inclusion defects as well as porosity. Thus, suitable only for parts where this can be machined away. This process is used for making wheels, nozzles and similar parts.

3. Centrifuge casting

In this, the axis of the mold and that of the rotation do not coincide with each other. Parts are not symmetrical about any axis of rotation and cast in group of moulds arranged in a circle. The setup is revolved around the center of the circle to induce pressure on the metal in the mould. Mould cavities are fed by a central sprue under the action of centrifugal force as shown in fig. 34.

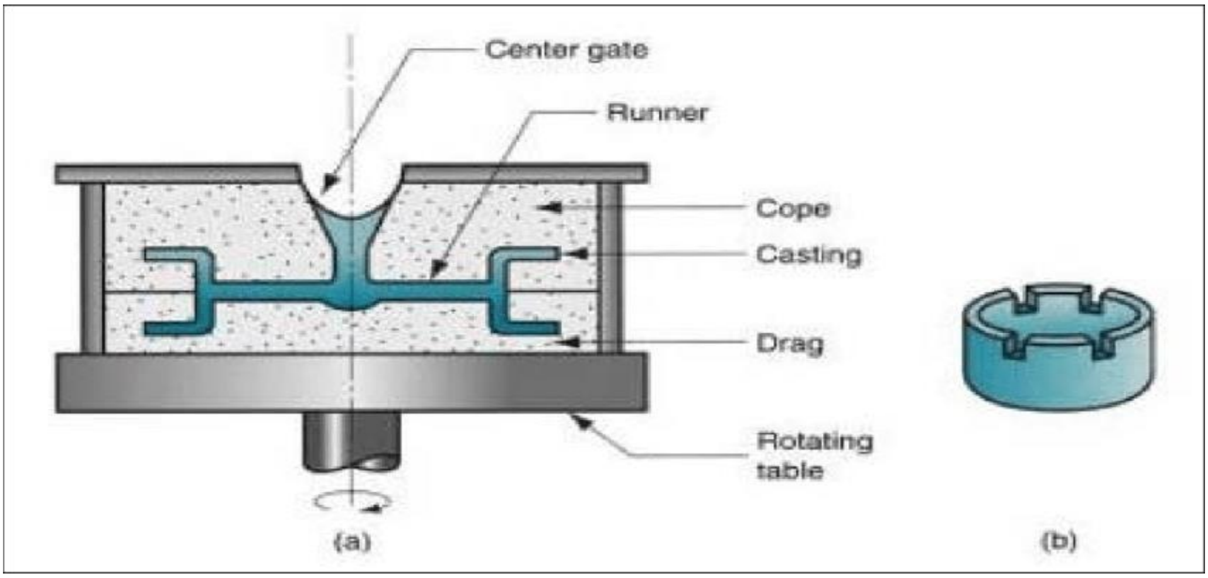
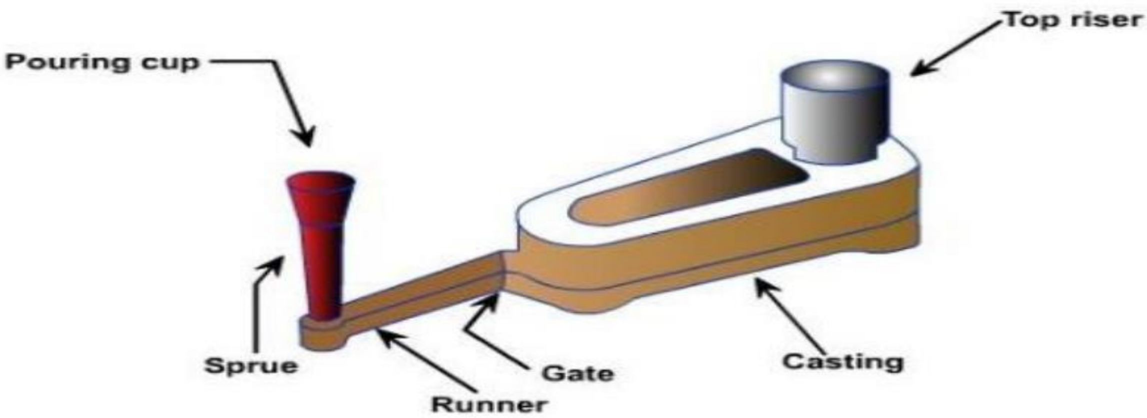


Fig. 34: Centrifuge casting

The metal is introduced at the center and fed into the mould through radial ingates. Centrifuging is possible only in vertical direction. The parts produced are valve bodies, valve bonnets, plugs, yokes, pillow blocks etc.

2.4 GATING AND RISERING SYSTEM

The term gating system refers to all passageways through which the molten metal passes to enter the mould cavity.



Components of Gating System

2.4.1 ELEMENTS OF A CASTING SYSTEM

The main elements of a gating system are as follow:

1. Pouring basin
2. Sprue
3. Runner
4. Gates
5. Risers

1. Pouring basin

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

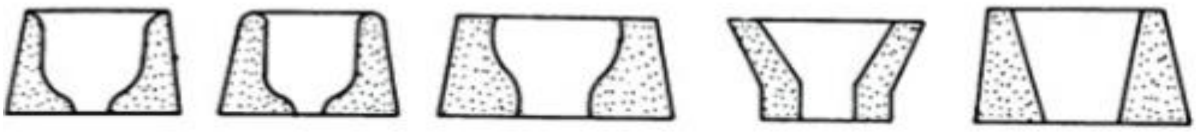


Fig. 11.2. Pouring Cups

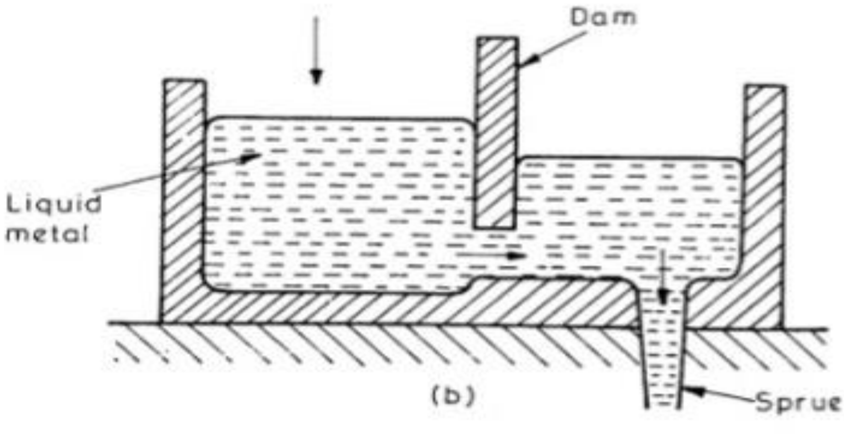
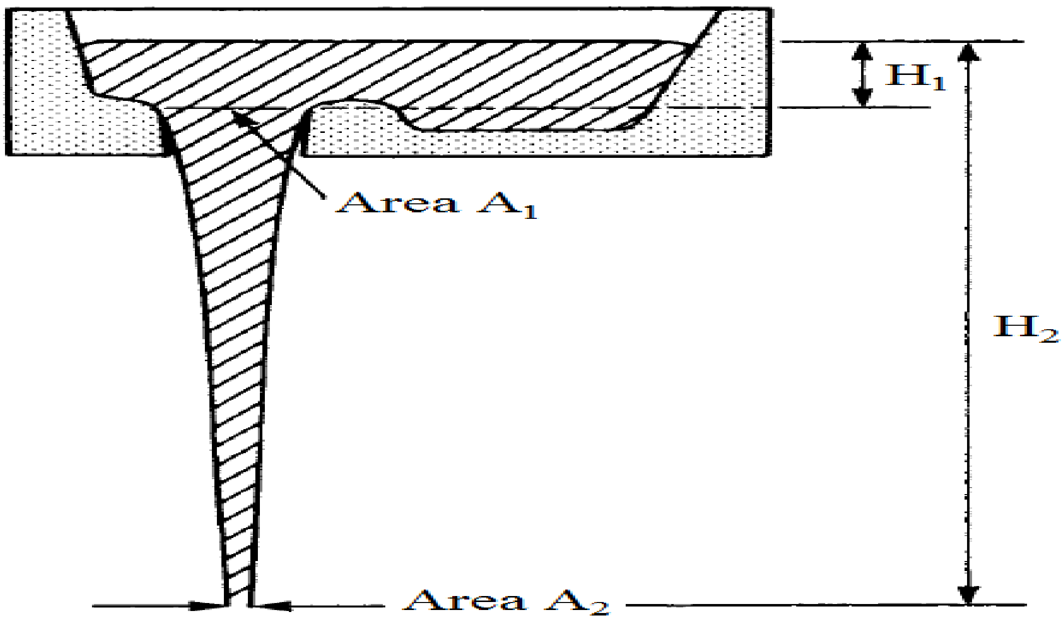


Fig. 11.3. Pouring basin designs

Pouring basin depth should be 2.5 times the sprue entrance diameter. A stainer core restricts the flow of metal into the sprue and thus helps in quick filling of the pouring basin. It is a ceramic coated screen with many small holes.

2. Sprue

It is a channel through which molten metal is pours into the parting plane where it enters into the runner and gates to reach the mould cavity. When molten metal is moving from top to the cope, it gains velocity and requires a smaller amount of area of cross-section for the same amount of metal to flow.



Tapered Sprue

If the sprue is straight and cylindrical, then a low pressure area will be created at the bottom of the sprue. Since the sand is permeable, it will aspire atmospheric air into the mould cavity causing defects in the casting. That is why the sprue is generally made tapered to gradually reduce the cross-section.

3. Runner

It is located at the parting plane which connects the sprue to its ingates. It traps the slag & dross from moving into the mould cavity. This is normally made trapezoidal in cross section. For ferrous metals, the runners should be kept in cope and ingates in drag as shown in fig. 35.

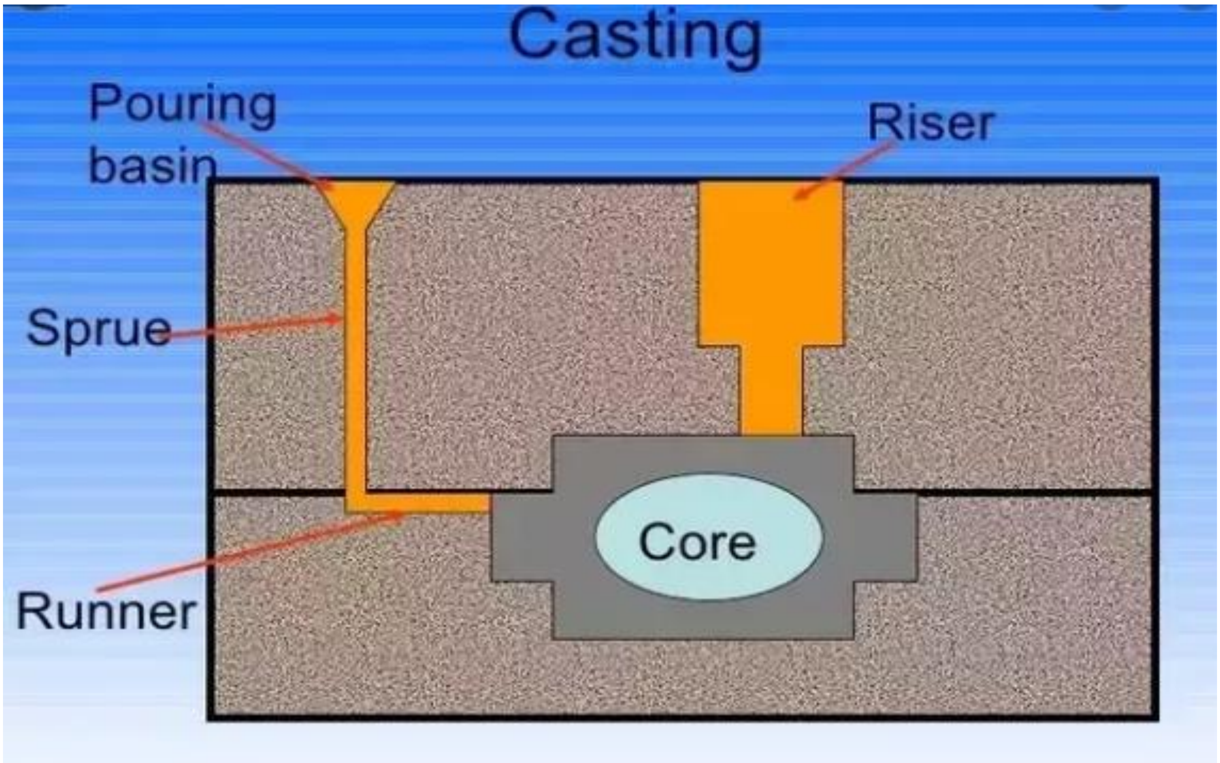


Fig. 35: Runner

4. Gates

A gate is a channel which connects runner with the mould cavity and through which molten metal flows to fill the mould cavity. A small gate is used for a casting which solidifies slowly and vice versa. It should not have sharp edges as they may break during pouring and sand pieces thus may be carried with the molten metal in the mould cavity. Types of gates are

1. Top gate
2. Bottom gate
3. Parting line side gate

1. Top gate

A top gate is made in the cope portion of the mould. In this, the molten metal enters the mould cavity from the top. Top gate involves high turbulence and sand erosion. So it is produces poor casting surfaces as shown in fig.36.

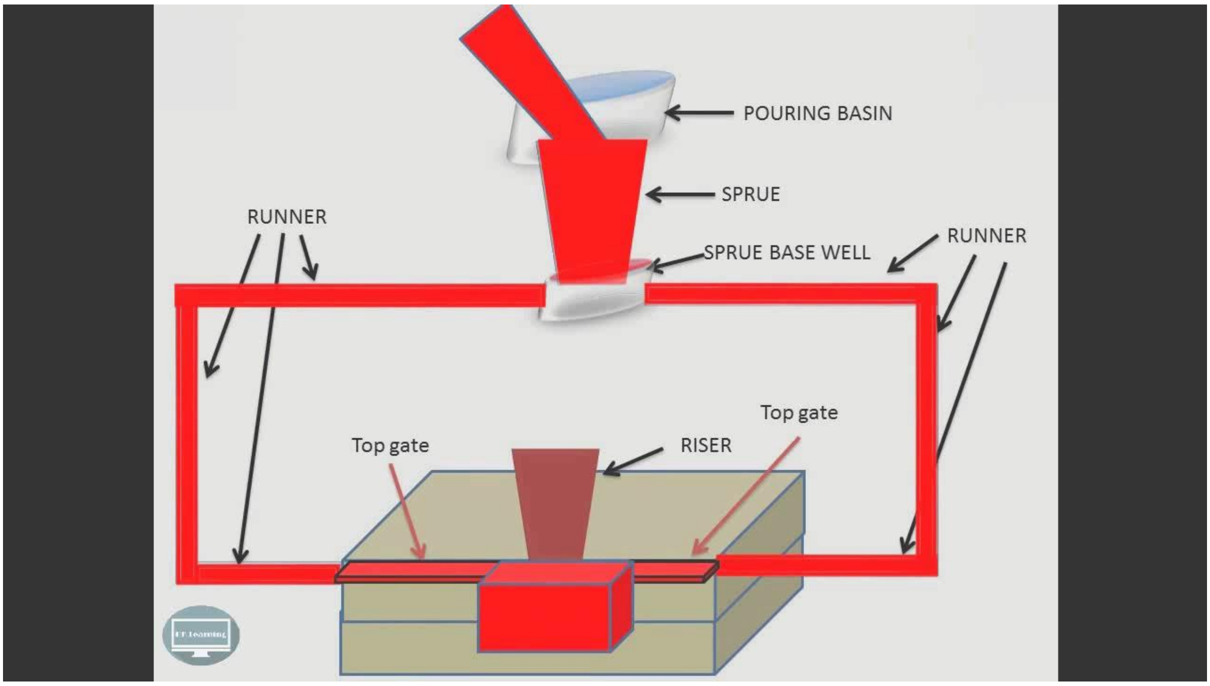
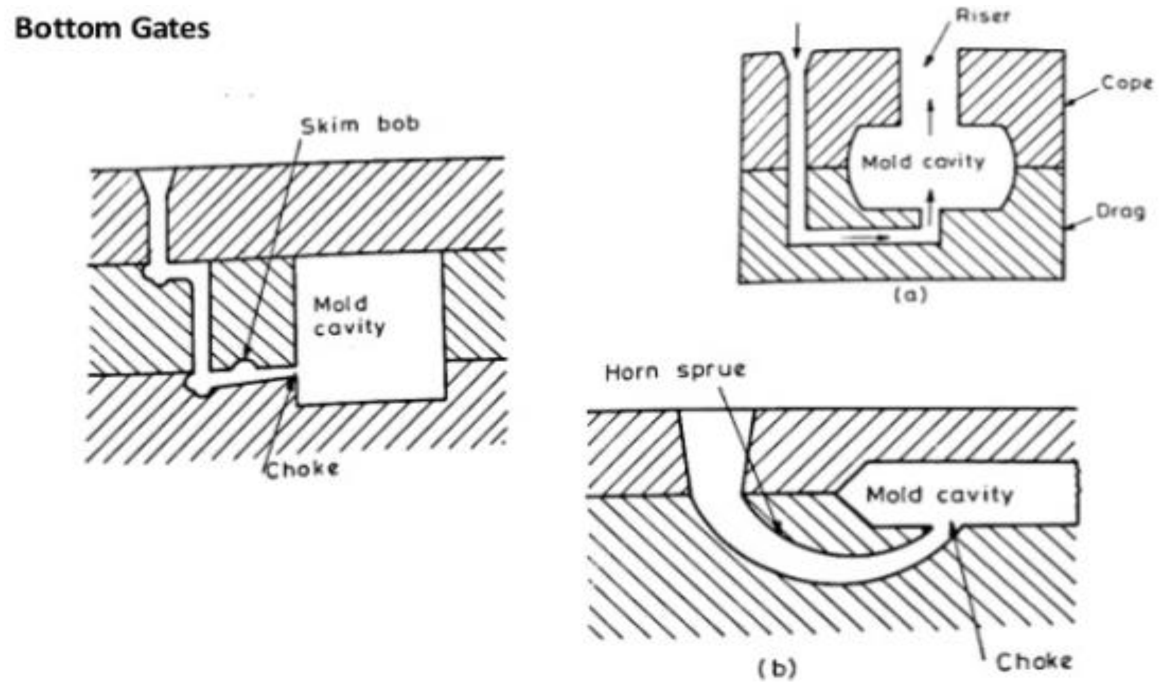


Fig. 36: Top gate

2. **Bottom gate**

A bottom gate is made in the drag portion. In this, liquid metal fills rapidly the bottom portion of the mould cavity and rises steadily and gently up the mould walls.



As comparison to top gate, bottom gate involves little turbulence and sand erosion. So that it produces good casting surfaces. If freezing takes place at the bottom, it could choke off the metal flow before the mould is full. Creates an unfavorable temperature gradient and makes it difficult to achieve directional solidification.

3. **Parting line side gate**

Middle or side or parting gating systems combine the characteristics of top and bottom gating systems. Gate is provided along the parting line such that some portion of the mould cavity will be below the parting line and some portion will be above it.

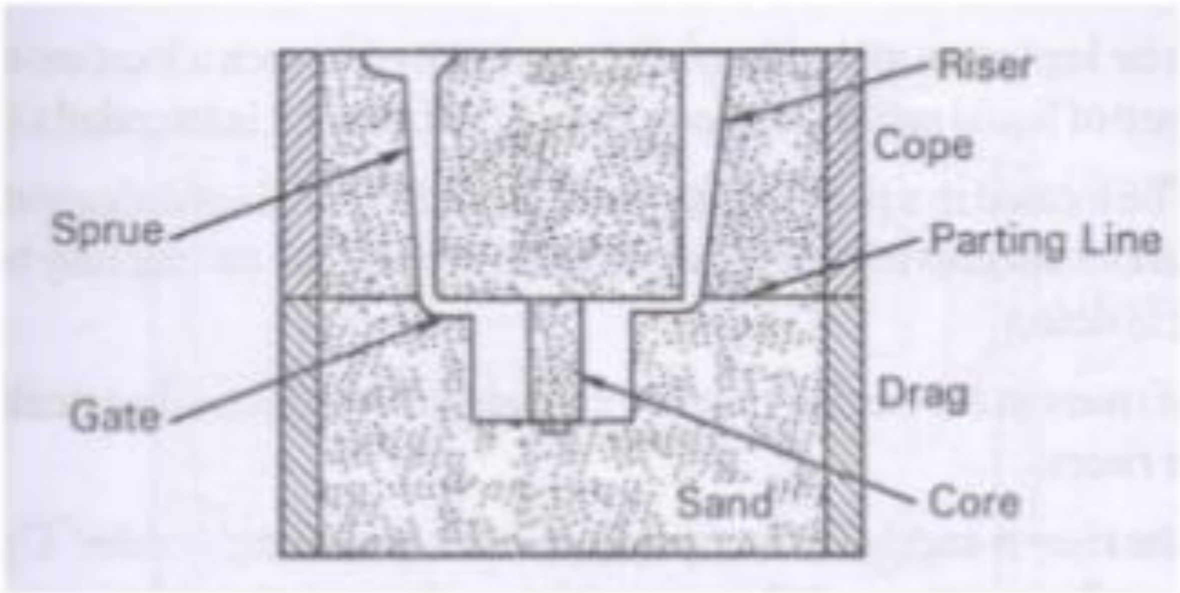


Fig. 37: Parting line side gate

The cavity below the parting line will be filled by assuming top gating and the cavity above the parting line will be filled by assuming bottom gating.

2.4.2 TYPES OF RISERS

A riser or feeder head is a vertical passage made in the cope to store the liquid metal and supply the same to the casting as it solidifies. It is function to store sufficient liquid metal and supply the same to the casting it solidifies there by avoiding volumetric shrinkage of the casting. The riser must be kept open to the atmosphere and placed in such a location that it maintains a positive pressure of liquid metal on all portions of the casting it is intended to feed. The cylindrical shaped riser are generally recommended compared to spherical shaped risers which although consider as the best. Types of riser are:

1. **Open riser**

The top surface of the riser will be open to the atmosphere. It is usually placed on the top of the casting. Gravity and atmospheric pressure causes the liquid metal in the riser to flow into the solidifying casting as shown in fig. 38.

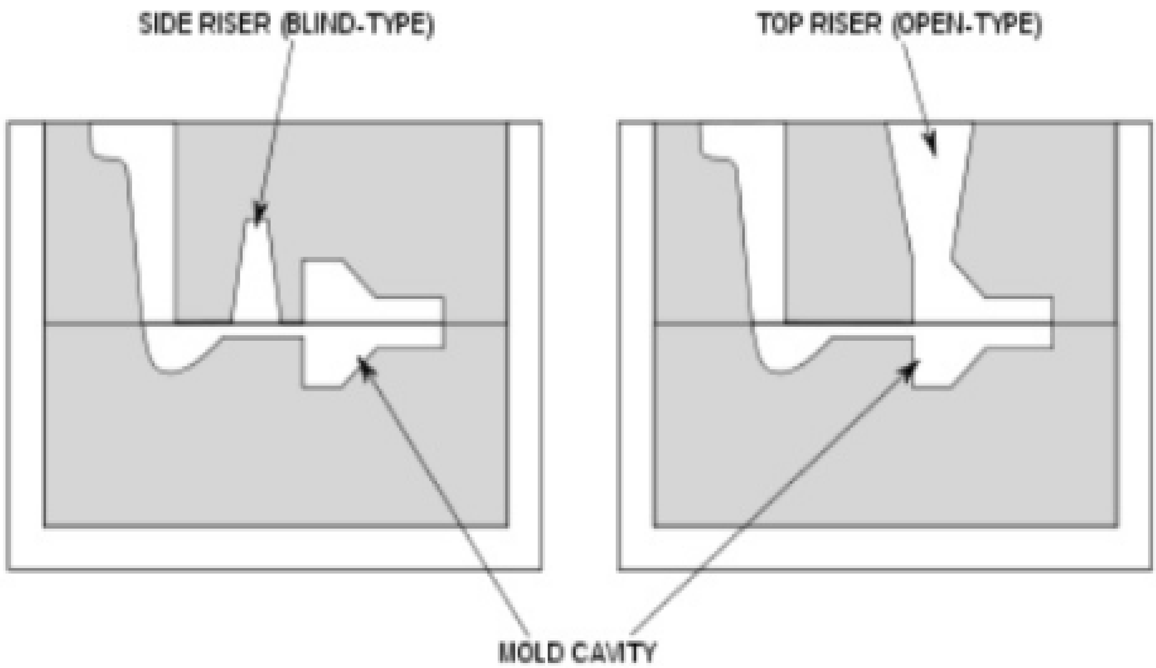


Fig. 38: Riser

2. **Blinder riser**

It is completely enclosed in the mould and not exposed to the atmosphere. The metal is cools slower and stays longer promoting directional solidification. The liquid metal is fed to solidifying casting under the force of gravity alone.

2.4.3 RISER LOCATION

Before the shape and size of the riser is determined, its location must be specified. A riser should be located in a position that will cause directional solidification from the casting towards it. Top risering is advisable for light metals as it develops feeding pressure due to the metallstatic pressure in the riser.

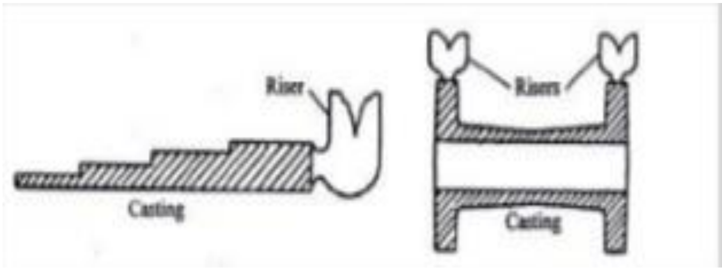


Fig. 39: Riser location

2.4.4 DIRECTIONAL SOLIDIFICATION

When pure metals are allowed to solidify in a mould, the portion of molten metal next to the mould wall begins to solidify. This metal solidifies in the form of solid skin and then the liquid metal tends to freeze on to it. The skin progresses towards the center of the mould from all mould walls. This is called progressive solidification.

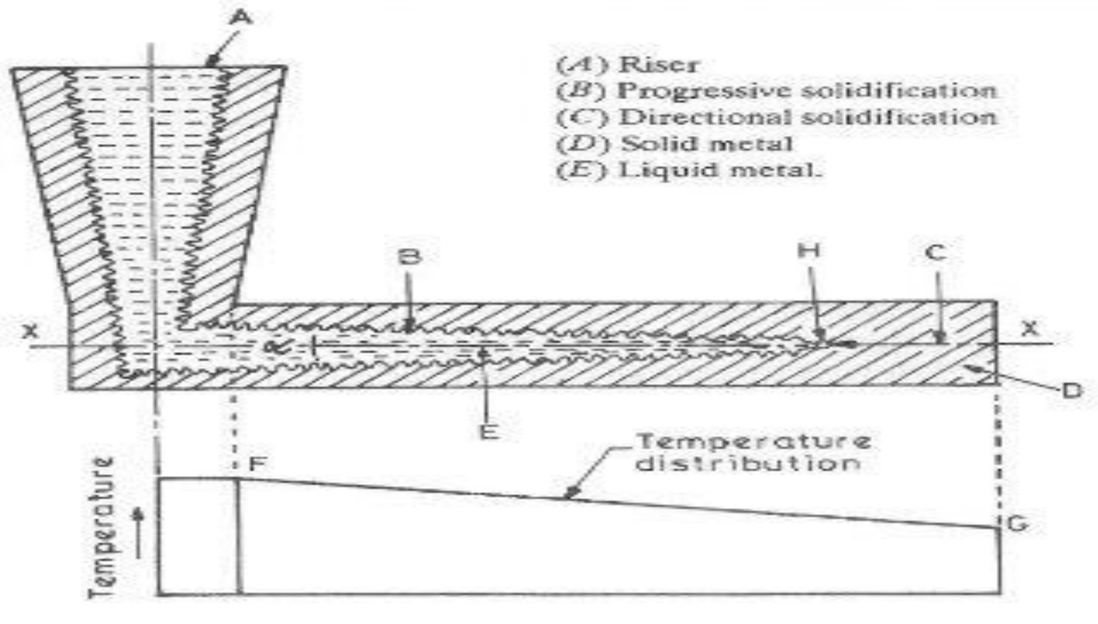


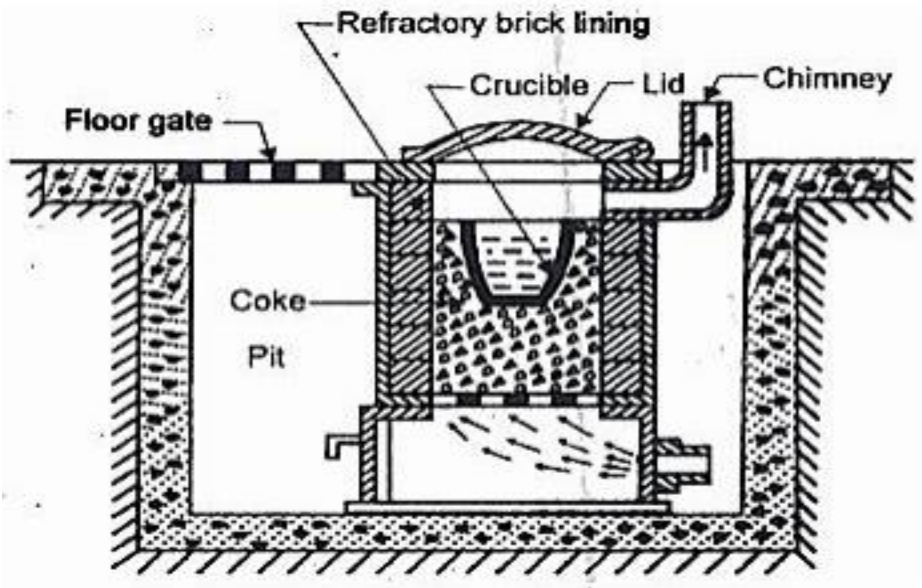
Fig. 40: Directional solidification

When gating design controls this progressive solidification is such a way that no portion of the casting is isolated from liquid metal feeding channels, during the complete solidification cycle; this is referred to as differential solidification. A solidification which is made to occurs in a particular direction. It is occurs from the farthest end of the casting and works its way towards the sprue as shown in fig. 40.

2.5 MELTING FURNACES

2.5.1 PIT FURNACE

Furnaces which are constructed in a pit and extend to floor level or slightly above are called pit furnaces. Workpieces can be suspended from fixtures, held in baskets or placed on bases in the furnace. Pit furnaces are suited to heating long tubes, shafts and rods by holding them in a vertical position. This manner of loading provides minimal distortion.



Pit furnace is a type of a furnace bath which is installed in the form of a pit and is used for melting small quantities of ferrous and non-ferrous metals for production of castings. It is provided with refractory inside and chimney at the top. Generally coke is used as fuel. It is provided with refractory lining inside and chimney at the top. Natural and artificial draught can be used for increasing the capability towards smooth operation of the furnace. Fig. shows the typical pit furnace. The pit furnace is a vertical orientation batch furnace used for a variety of processes. Designs can be provided for atmosphere or direct fired processes.

2.5.2 CUPOLA FURNACE

Cupola furnace is a melting device. It is used in forging operation where Cast Iron, Bronze, and other alloying elements are melted.

This is a very old device that used in manufacturing for melting because this system produces good cast iron from Pig Iron. The shape of this device is cylindrical but others size is also available.

Construction of cupola furnace

The Cupola Furnace is consists of:

Legs:

Legs are provided for supporting purposes.

Slag Hole or Slag spout:

The slag hole is used for removing or extracting the slag from the melting iron.

Sand Bed:

This is in taper shape and the melted iron comes out easily.

Tuyeres:

By tuyeres, we enter the gas to the proper burn of fuel.

Preheating Zone:

In the Preheating zone, the heating process started and heats the metal charge about 1090 degrees Celsius.

Melting Zone:

In the melting zone, we do not provide much heat to melt the metal charge because it’s already melted in the preheating zone with a temperature of about 1090 degrees Celsius.

Charging door:

From here we supply the charge to the furnace. The various charges are for the cupola furnace are Pig Iron, Coke and limestone.

Brick lining and Steel shell:

The shell of the cupola furnace is being usually made of steel and it's called a steel shell.

Spark Arrester:

This device used in the system for preventing the emission from the fireplace.

Working principle of cupola furnace

The Cupola furnace works on the principle where we generate heat from burning coke and when the temperature of the furnace is above the melting point of the metal then the metal is melt.

The charge introduced in the cupola consists of pig iron, scrap, casting rejection, coke, and flux. Coke is the fuel and limestone is added as a flux to remove undesirable materials like ash and dirt. The scrap consists of Steel and cast iron rejections.

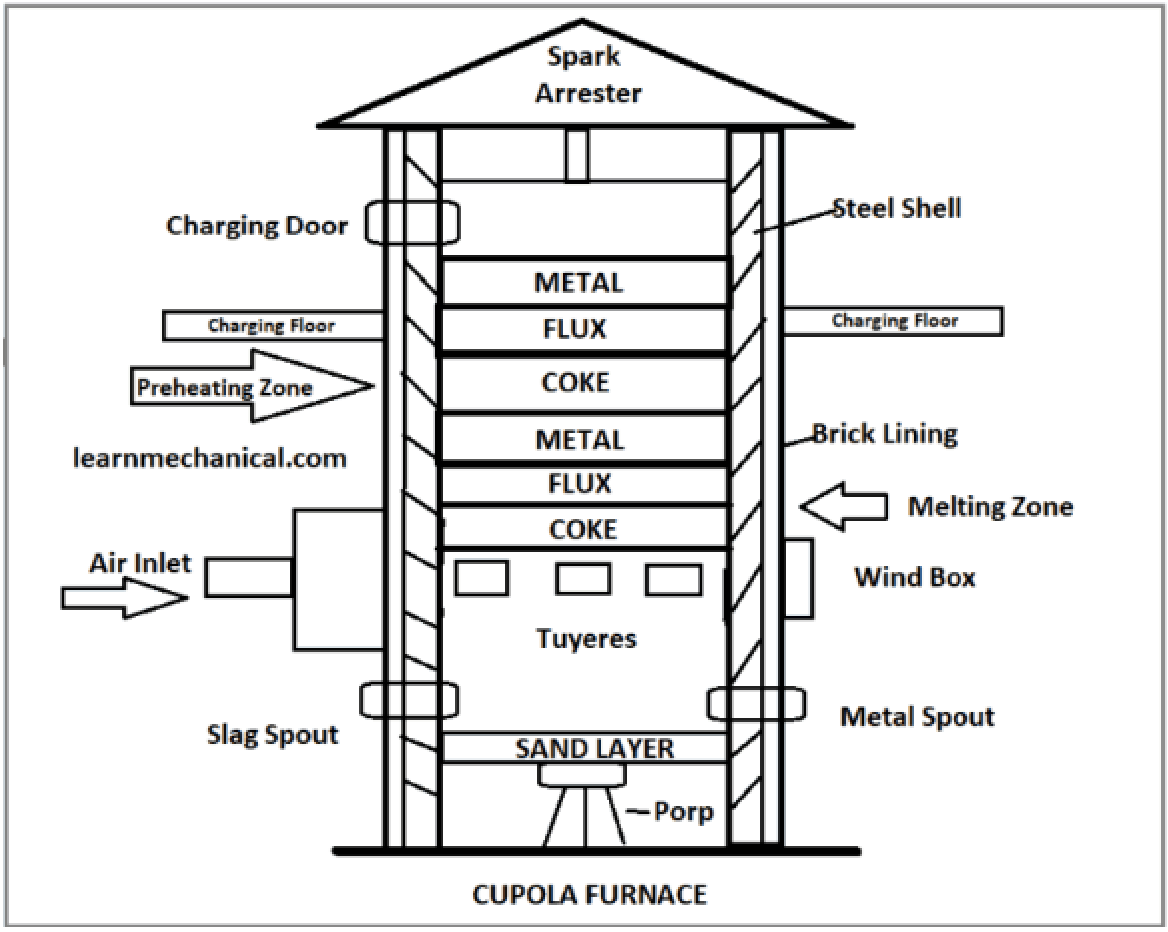
The working of Cupola furnace is, over the sand Bottom, Coke in charged extending up to a predetermined height. This serves as the coke bed within which the combustion takes place. Cupola operation is started by igniting the coke bed at its bottom. After the Coke bed is properly Ignited, alternate charges of limestone, pig iron, and coke are charged until the level of the charging door.

Then the air blast is turned on and combustion occurs rapidly within the coke bed. Within 5 to 10 minutes after the blast is turned on the first molten cast iron appears at the tap hole.

Usually, the first iron which comes out will be too cold to pour into sand molds. During the cupola operation, molten metal may be tracked every 10 minutes depending on the melting rate and the capacity. All the oxygen in the air blast is consumed by the combustion, within the combustion zone. The chemical reaction takes place which is,

$$C + O_2 \text{ (from the air)} \rightarrow CO_2 + \text{Heat}$$

This is an exothermic reaction. The temperature in this zone varies from 1550 to 1850 degree Celsius.



Then hot gases consisting of nitrogen and carbon dioxide moved upward from the combustion zone, where the temperature is 1650 degree Celsius. The portion of the coke bed is reducing zone. It is a protective zone to prevent the oxidation of the metal charge above and while dropping through it. As the hot carbon dioxide gas moves upward through the hot coke, some of it is reduced by the following reaction. This is an endothermic reaction.

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

The first layer of iron above the reducing zone is the melting zone where the solid iron is converted into the molten state. A significant portion of the carbon is picked up by the metal also takes place in this zone. The hot gas is passed upward from the reducing and melting zones into the preheating zone which includes all layers of charge above the melting zone up to the charging door.

Since the layer of the charge is preheated by the outgoing gases which exist at the top of the cylindrical shell. This temperature is this zone is around 1090 degrees Celsius.

Advantages of cupola furnace

1. It is a simple and economical device.
2. A wide range of materials can be melt.
3. This device used for removing the slag present in the Iron.
4. Comparison of electric furnace it is very less harmful.
5. This is having high melting heat i.e. 100 tones/hr.
6. The floor space required is less and to perform the operation skilled operator not required.

Disadvantages of cupola furnace

The main disadvantage is that sometimes unable to maintain the close temperature.

Applications of cupola furnace

The main application of cupola furnace is different types of cast iron is produced from this device like malleable, grey cast iron, and the copper base alloy is also manufactured by this device.

2.5.3 OIL-FIRED TILTING FURNACE

An oil-fired tilting furnace consists of an outer shell having a refractory lining inside. The hollow portion around the crucible forms a chamber through which burning fuel circulates. It is used for melting non-ferrous metals in small quantity and is fired by oil. It is mounted on two pedestals above the floor level. For pouring the molten metal, the furnace is rotated by the geared hand wheel.

Oil and air are admitted with pressure through a nozzle. The crucible is placed in the heating chamber and is heated by the flame. The furnace can be stopped whenever needed & temperature can be controlled easily. They give lesser pollution as shown in fig. 41.

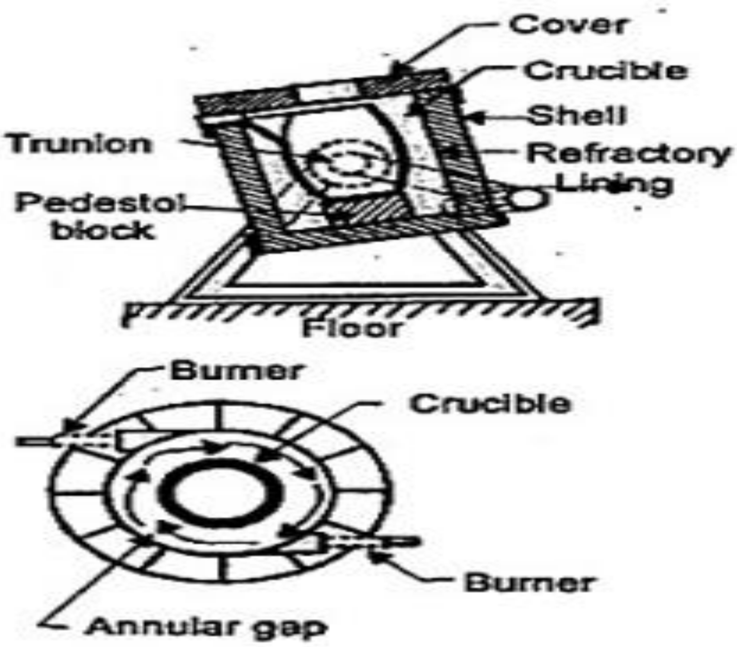


Fig. 41: Oil-fired tilting furnace

2.5.4 ELECTRIC INDUCTION FURNACE

The principle of induction melting is that a high voltage electrical source from a primary coil induces a low voltage, high current in the metal or secondary coil. Induction heating is simply a method of transferring heat energy. Induction furnaces are ideal for melting and alloying a wide variety of metals with minimum melt losses, however, little refining of the metal is possible.

The heart of the induction furnace is the coil, which consists of a hollow section of heavy duty, high conductivity copper tubing which is wound into a helical coil. Coil shape is contained within a steel shell and magnetic shielding is used to prevent heating of the supporting shell. To protect it from overheating, the coil is water-cooled, the water being re-circulated and cooled in a cooling tower.

The shell is supported on trunnions on which the furnace tilts to facilitate pouring.

The crucible is formed by ramming a granular refractory between the coil and a hollow internal former which is melted away with the first heat leaving a sintered lining as shown in fig.42.

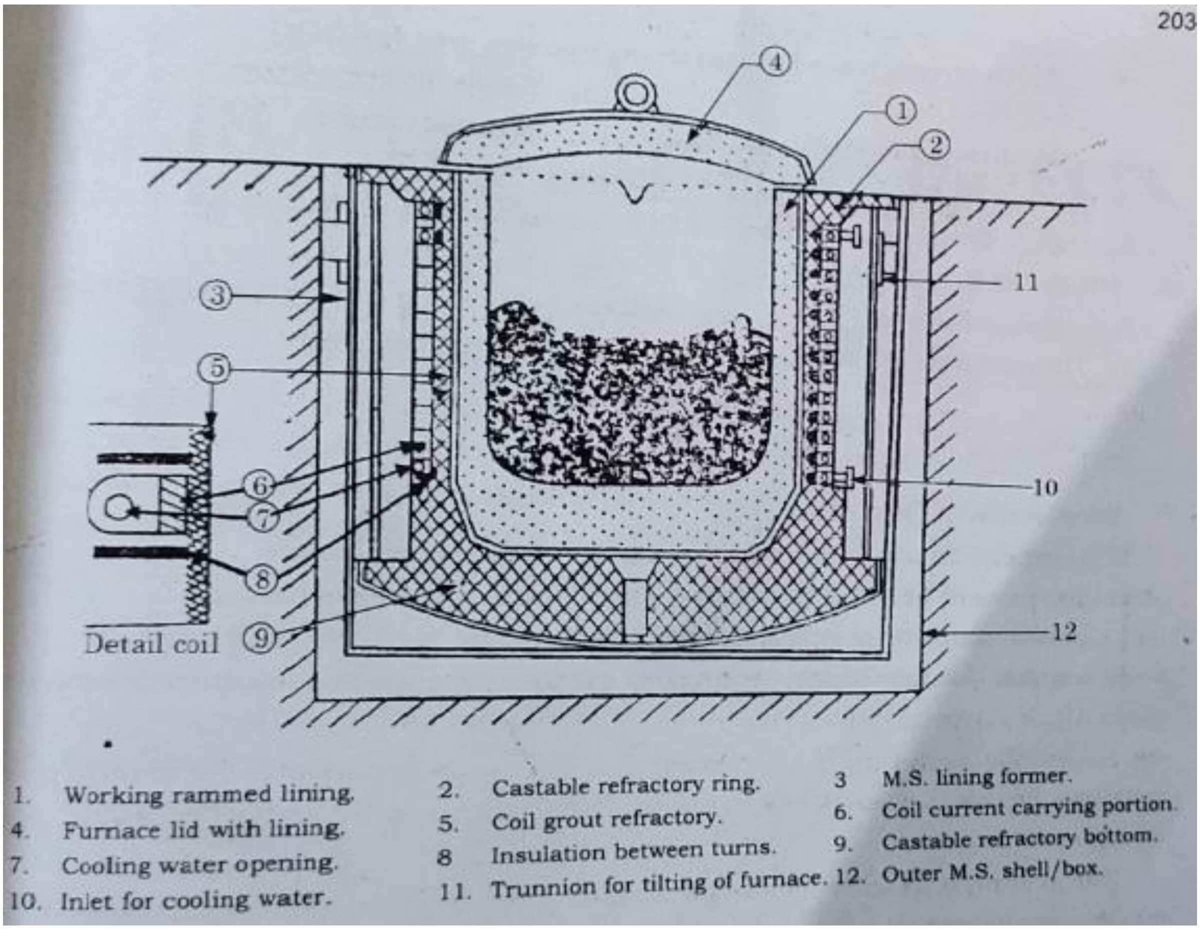


Fig. 42: electric induction furnace

The power crucible converts the voltage and frequency of main supply, to that required for electrical melting. Frequencies used in induction melting vary from 50 cycles per second (mains frequency) to 10,000 cycles per second (high frequency). The higher the operating frequency, the greater the maximum amount of power that can be applied to a furnace of given capacity and the lower the amount of turbulence induced.

When the charge material is molten, the interaction of the magnetic field and the electrical currents flowing in the induction coil produce a stirring action within the molten metal. This stirring action forces the molten metal to rise upwards in the center causing the characteristic meniscus on the surface of the metal. The degree of stirring action is influenced by the power and frequency applied as well as the size and shape of the coil and the density and viscosity of the molten metal. The stirring action within the bath is important as it helps with mixing of alloys and melting of turnings as well as homogenizing of temperature throughout the furnace. Excessive stirring can increase gas pick up, lining wear and oxidation of alloys. The induction furnace has largely replaced the crucible furnace, especially for melting of high melting point alloys. The coreless induction furnace is commonly used to melt all grades of steels and irons as well as many non-ferrous alloys. The furnace is ideal for re-melting and alloying because of the high degree of control over temperature and chemistry while the induction current provides good circulation of the melt.