2.1 Introduction

The process of joining similar metals by the application of heat is called „welding". Welding can be obtained with or without application of pressure and with or without addition of filler metal, which is known as "electrode". During welding, the edges of these metal pieces are either melted or brought to the plastic condition. The welding process is used for making permanent joints which is obtained by homogenous mixture of two materials. The heat may be developed in several ways for welding operation. A good welded join is as strong as the parent metal.

Now a days, welding finds wide spread application in almost all branches of engineering industry. Welding is extensively employed in the fabrication and erection of steel structure in industry and construction e.g. Structural joints of bridges and buildings, pipelines etc. It is also used in various industries such as aircraft frame works, railway wagons, furniture, automobile bodies, ship building etc., depending upon their application.

2.2 Classification of welding process

There are two main types of welding process which are classified according to the source of energy employed for heating the metals and the state of metal at the place being welded.

1. Fusion welding
2. Plastic welding

2.2.1 Fusion welding

In fusion welding, the metal at the joint is heated to a molten state and then it is allowed to solidify. Pressure is not applied during the welding process and hence, it is also called an non-pressure welding. Filler material may be required during this type of welding.

E.g: Gas welding, Arc welding, Thermit welding.

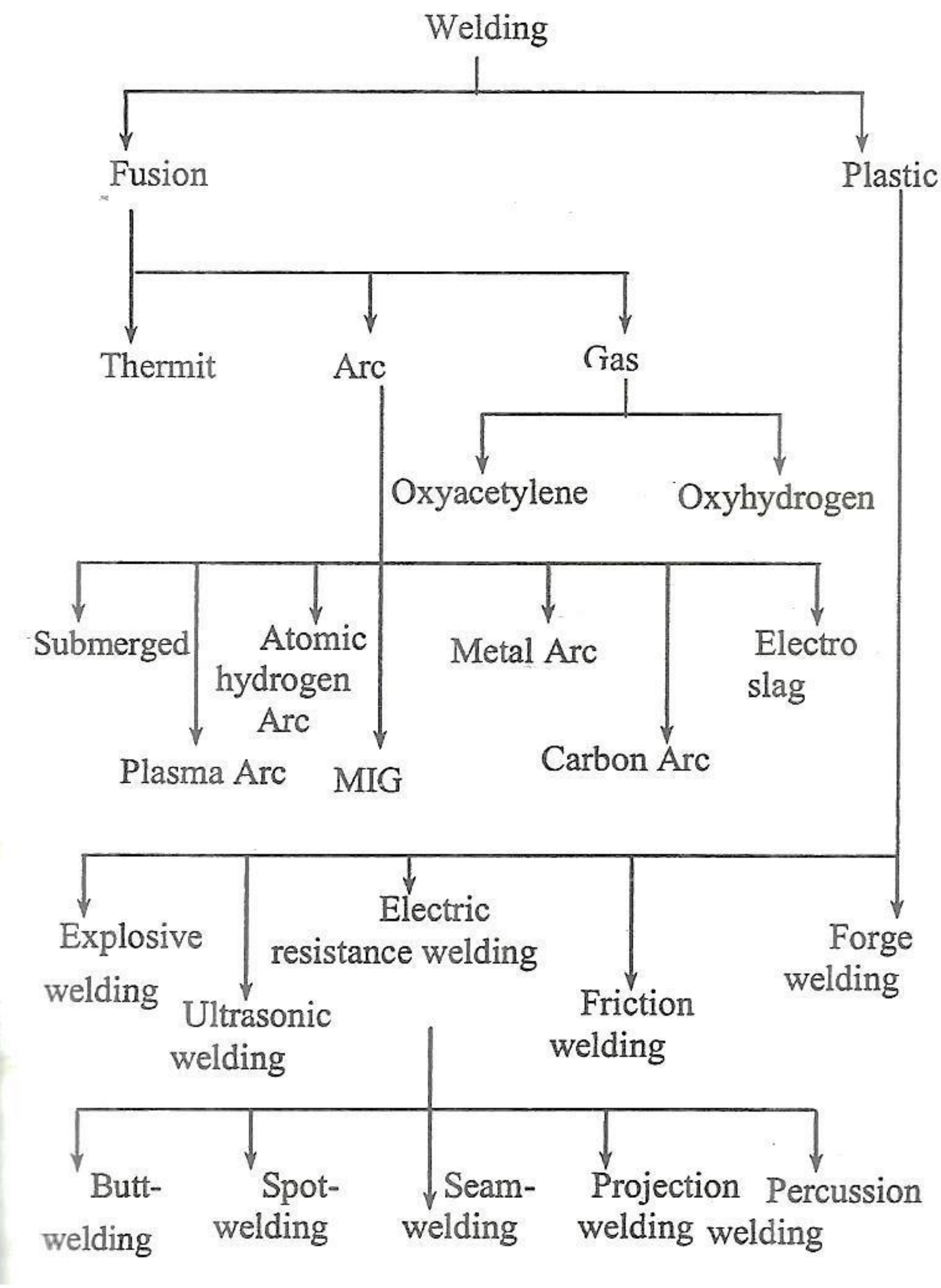
2.2.2 Plastic Welding

In plastic welding, the metal parts are heated to a plastic state and are pressed together to make the joint. Hence, it is also known as pressure welding. Here, there is no filler materials required.

E.g.: Electric resistance welding, Forge welding

2.3 TYPES OF WELDING

The tree given below lists the various types of welding.



2.4 Classification of welding processes

The welding process can also be classified.

a) Autogeneous:

The process is one in which no filler metal is added to the joint interface.

E.g. Electric resistance welding.

b) Homogeneous:

The process is one which the filler metal is added and is of the same type as parent metal.

c) Heterogeneous:

The process is one which the filler metal is used but it is of different type from the parent metal.

E.g. Brazing, Soldering.

2.5 Types of weld joints

Welding produces a solid connection between two pieces, called a weld joint. A weld joint is the junction of the edges or surfaces of parts that have been joined by welding.

a) **But joint:** In the joint type, the parts lie in the same plane and are joined at their edges.
b) **Corner joint:** The parts in a corner joint form a right angle and are joined at the corner of the angle.
c) **Lab joint:** This joint type consists of two overlapping parts.
d) **T-joint:** In the T-joint, one part is perpendicular to the other in the approximate shape of the letter T.
e) **Edge joint:** The parts is an edge joint are parallel with at least one of their edges in common, and the joint is made at the common edges.

Five basic types of joints a) butt, b) corner, c) lap, d) tee, and e) edge.

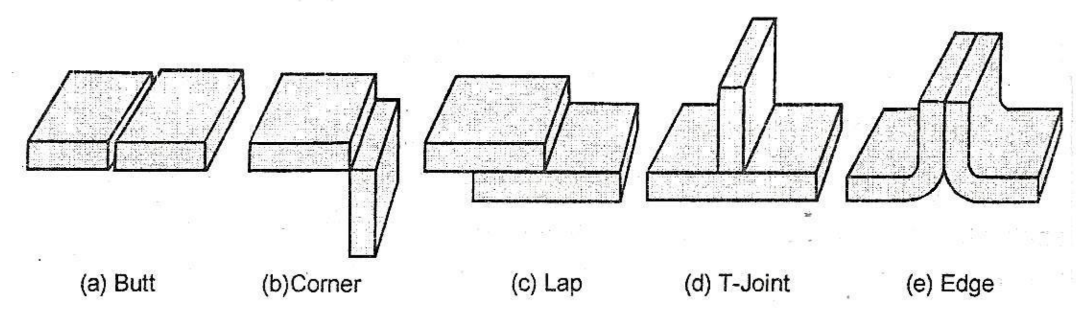


Figure 2.1 Types of weld joint

2.6 Fusion Welding

Gas welding, manual metal arc welding, gas tungsten arc welding, gas metal arc welding, submerged are welding, electro slag welding are under the category of fusion welding.

2.7 Gas Welding

There are three types of gas welding process used in industries such as

1. Oxy – acetylene welding,
2. Oxy – hydrogen welding, and
3. Air – hydrogen welding.

2.7.1 Oxy-Acetylene Welding

Gas welding is one type of welding process in which the edges of the metals to be welded are melted by using gas flame. No pressure is applied during welding except pressure gas welding.

The flame is produced at the tip of a welding torch. The welding heat is obtained by burning a mixture of oxygen and combustible gas. The gases are mixed in the required proportion in a welding torch which provides a control for the welding flame.

The gases commonly employed for gas welding are acetylene, hydrogen, propane and butane. The most common form of gas welding is oxy-acetylene welding.

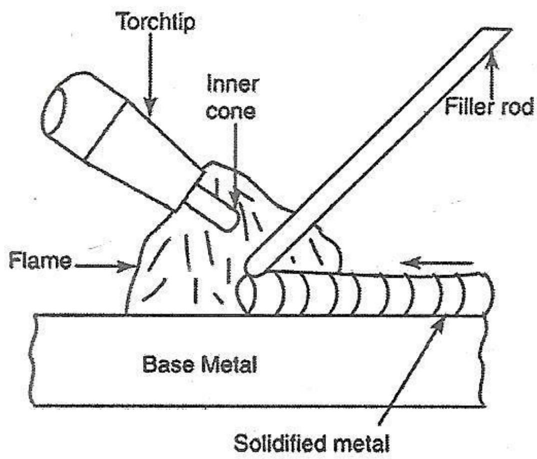


Figure 2.2 Oxy-Acetylene welding

The flame only will melt the metal. So, the additional metal to the weld is supplied by the filler rod. A flux is used during welding to prevent oxidation and to remove impurities. Metal 2mm to 50 mm thick are welded by gas welding. The temperature of oxy- acetylene flame in its hottest region is about 3200°C. The cost of acetylene is low. The gases O_2 and C_2H_2 can be stored at high pressure in separate steel cylinders. But the acetylene is very harmful, if it is not handled carefully.

There are two types of oxy-acetylene system employed depending upon the manner in which acetylene is supplied for welding. These are two types of system.

1. High-pressure system, and
2. Low-pressure system

In high – pressure system, both oxygen and acetylene are supplied from high-pressure cylinders. Oxygen is compressed to 120 atm gauge pressure. But the acetylene can not be compressed more than 1.5atm such as in the form of "dissolved acetylene". The acetylene is dissolved in acetone under a pressure of 16-22atm gauges. At normal pressure, one liter of acetone is dissolved about 25 liters of acetylene. The maximum recommended pressure of acetylene in the cylinder through a rubber hose is 1 bar. In high pressure (H.P) systems, the pressure of acetylene at the welding torch is from 0.66 to 1 bar.

In a low-pressure system, the acetylene is produced at the place of welding by interaction of calcium carbide and water in acetylene generator, the chemical reaction.

$$\mathbf{C_aC_2 + 2H_20 \;\; Ca(OH)_2 + C_2H_2 + 127.3\ KJ/mol.}$$

From the above equation, it is obvious that heat generated in this reaction is very high. The pressure of acetylene of the torch is upto 0.06 bar. For oxygen, the desired pressure in welding torch is

1. H.P. System 0.1 to 3.5 bar
2. L.P. System 0.5 to 3.5 bar

2.7.2 Oxy – hydrogen welding

Oxy-hydrogen flame is used to weld and braze metals only with low melting points, e.g., aluminum, magnesium, lead etc. The temperature of the hottest part of an oxy-hydrogen flame suitable for welding is only about 2500°C against 3200°C of an oxy-acetylene flame. In oxy-hydrogen welding, if a higher temperature is obtained by increasing the oxygen supply, the flame becomes quite unsuitable for welding. Oxy – hydrogen welding is therefore not used for welding steel. Hydrogen is available in compressed gas cylinders.

Complete combustion of hydrogen requires an oxygen-to-hydrogen ratio of 1 to 2,

$$2H_2 + O_2 \;\; 2H_2O$$

This gas mixture produces a strongly oxidizing flame. Since there is no carbon, the oxy-hydrogen flame is only reducing (and never carburizing). The oxy-hydrogen welding is similar to oxy-acetylene welding with the difference that a special regulator is used for metering the hydrogen gas

2.7.3 Air-acetylene welding

Air – acetylene welding is a gas welding process wherein coalescence s produced by heating with a gas flame obtained from the combusting of acetylene with air, without the application of pressure and with or without the use of filler metal.

It operates on the Bunsen burner principal, i.e., the acetylene flowing under pressure through a Bunsen jet aspirates the appropriate amount of air for combustion purposes.

Acetylene is obtained from a cylinder through a pressure regulator and hose. As the acetylene flows through the torch it draws air from the atmosphere into it in order to obtain the oxygen necessary for combustion.

2.7.4 Gas Welding Equipment

The following are the most commonly used equipment for gas welding.

1. Gas cylinders

For gas welding, a head of oxygen and acetylene are used. These two gases are stored in separate cylinders. The standard colour for oxygen cylinder is black. The oxygen is stored in the cylinder at a pressure of 125 to 140 kg/cm^2. Its capacity is 6.23m^3. The standard colour for acetylene cylinder is maroon. It is stored at a pressure of 16 kg/cm^2. Its capacity is 7.6m^3. Acetylene cylinder is fitted with a fusible plug to avoid explosion.

2. Pressure regulators

Each cylinder is fitted with a pressure regulator. These regulators are used to reduce and control the working pressure of the gases. The working pressure of oxygen is between 0.7 and 2.8 kg/cm^2. The working pressure of acetylene is between 0.07 and 1.03 kg/cm^2 depending upon the thickness of the work pieces to be welded.

3. **Pressure gauges**

There are four pressure gauges provided in which two are placed on the oxygen cylinder regulators and two on acetylene cylinder regulators. Among two, one pressure gauge is for showing the cylinder pressure. The other one is for showing the working pressure for welding.

4. Hoses

The regulator of each cylinder is connected to the torch through two long hoses. It should be flexible, strong, desirable, non-process and light. Oxygen cylinder is connected with black colour hose whereas acetylene cylinder is connected with red colour.

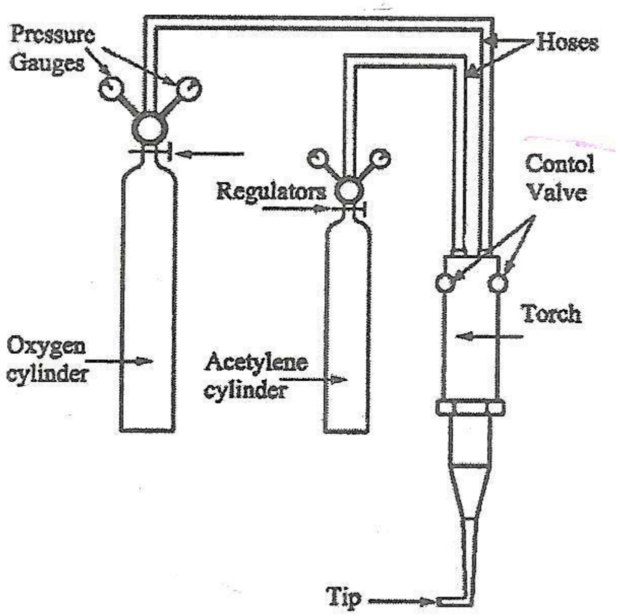


Figure 2.3 Gas Welding Equipment

5. Welding torch

Oxygen and acetylene enter the torch through the hose in separate passages. Both the gases are mixed in the mixing chamber of the torch. When it is ignited, a flame will be produced at the tip of the torch called a nozzle. There are two control valves on the welding torch. They are used to control the quantity of oxygen and acetylene to adjust the flame. The nozzles or tips are made of copper or copper alloy. Tips are in different sizes depending upon the type of metal to be welded and its thickness.

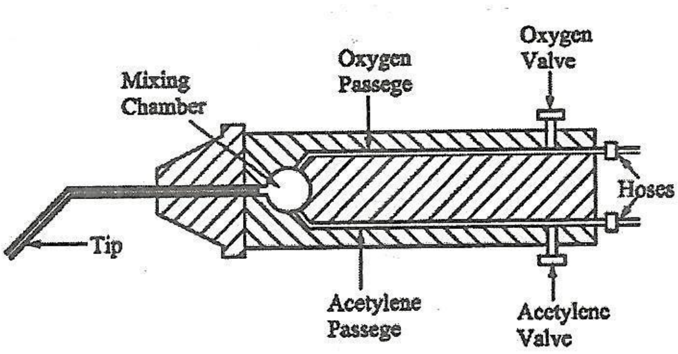


Figure 2.4 Welding Torch

There are two types of torches such as

1. Equal pressure type, and
2. Injector type

6. Goggles

The welding goggles are used to protect eyes from the flame heat, and ultraviolet and infrared rays.

7. Welding gloves

Gloves are used to protect hand from the injury causing by heat and metal splashes.

8. Spark lighter

It is an igniter to start the burning of the oxy acetylene gases.

9. Wire brush

It is used to clean the weld joint before and after welding.

2.7.5 Flame Characteristics

It is very important to adjust the flame to suit the welding conditions. It is done by regulating the supply of oxygen and acetylene. By varying the ratio of oxygen and acetylene, the following three types of flames can be obtained.

1. Neutral flame
2. Carburizing flame, and
3. Oxidising flame

1. Neutral flame:

It is produced when equal volume of oxygen and acetylene are mixed in the welding torch and burnt at the tip of the torch. The temperature of the neutral flame is about 3260°C. The flame has a nicely defined inner cone which is light blue in colour and surrounded by an outer flame envelope. This flame is called as neutral flame because it does not cause any chemical change in the molten metal and hence will not oxidise or carburize the metal.

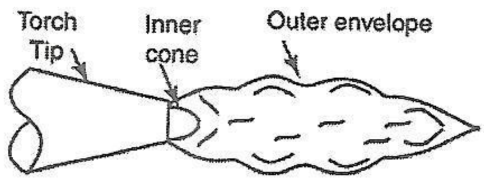


Figure 2.5 Neutral Flame

A neutral flame is mostly used for the welding of:

- Mild steel
- Cast iron
- Aluminium
- Stainless steel
- Copper

2. Oxidising flame

If, after the neutral flame has been established, the oxygen supply is further increased then oxidising flame will be developed. It is recognised by the small white cone which is shorter, much bluer in colour and more pointed than neutral flame. This flame is hotter than neutral flame because of excess oxygen which causes the temperature to rise up to 3480°C.

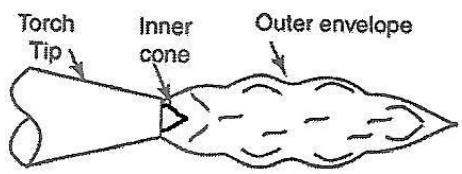


Figure 2.6 Oxidising flame

This excess oxygen causes the weld bead and surrounding area to have a dirty appearance hence, this flame has limited use in welding and not used in the welding of steel.

- An oxidising flame is used for:
- Copper-base metals
- Zinc-base metals
- Ferrous metals such as manganese steel, cast iron, etc.

3. Reducing flame (carburizing flame)

If the amount of oxygen supplied to the neutral flame is reduced, then the generated flame will be a carburising flame or reducing flame i.e. more content of acetylene. It is recognised by acetylene feather which exists between the inner cone and the outer envelope. This outer flame envelope is longer than neutral flame and is usually much brighter in colour. A reducing flame has an approximate temperature of 2740°C.

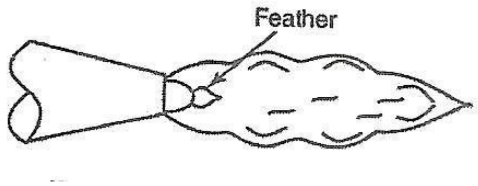


Figure 2.7 carburizing flame

This flame is generally used for: Welding of low alloy steel rods

- Non-ferrous metals
- High carbon steel

2.7.6 Gas Welding Techniques

In gas welding, the direction of travel, tilt of the torch and the welding rod has appreciable effects on the speed and quality of welding. There are three typical procedures that may be used, which are as follows:

a) Leftward or fore-hand welding method

b) Rightward or back-hand welding method

c) Vertical welding method

1. Leftward (forward) welding method

In this technique, the welder holds welding torch in his right hand and filler rod in the left hand. The welding flame is directed from right to left as shown in Figure 2.8. The welding torch should be given a small sideways movement and the filler rod should be moved steadily without sideways movement. The heat of the welding torch is held at an angle between 60°-70° to the weld plane and the filler rod at 30°-40°. This technique is generally used on thin metals i.e. having thickness less than 5 mm.

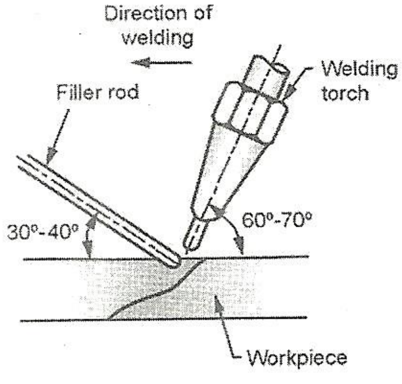


Figure 2.8 Leftward Technique

2. Rightward (backward) welding method

In this technique, the welding torch is held in the right hand of the welder and the filler rod in the left hand. But, welding flame is directed from left to right as shown in figure 2.9. In this, the welding torch has no lateral movement. The welding torch should make an angle of 40°-50° with the weld plane and the filler rod should be at an angle of 30°-40°. Under the above conditions, in the rightward technique the welding speed is 20-25% higher and fuel consumption 15-25% lower than the leftward technique.

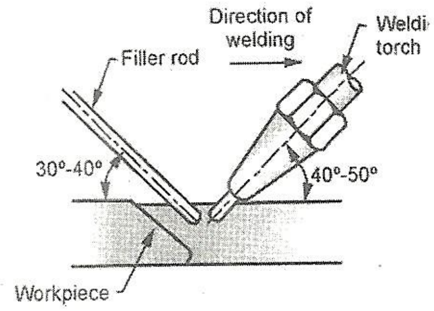


Figure 2.9 Rightward Technique

3. Vertical welding method

This method is more advantageous for plate thickness of 6 mm and above. In this, the welder starts at the bottom of the welder joint and gives an oscillating movement to the welding torch which points slightly upwards. It can be done by one or two operators. In case of single operator technique, the angle between the welding torch and plate increases as the thickness of the plate increases. Refer figure 2.10.

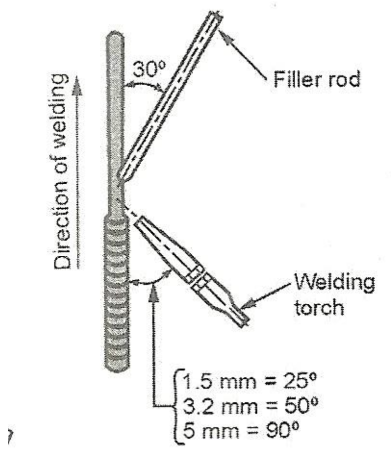


Figure 2.10 Vertical welding

2.7.7 Filler Rods for Gas Welding

Filler rod or welding rod used in gas welding is to supply additional metal to make the joint. It is a metal rod which is made of the same material as a parent metal. Diameter of the filler rod is depending on the thickness of the metal to be weld. The filler rod diameter *'d'* can be approximately determined by the following relationship.

$d=t/2+1$

Where,

t- thickness of the metal to be welded in mm

Different alloying elements such as chromium and nickel can be added to the filler rod. This will increase the strength of the joint. Filler rods are coated with copper to prevent oxidation of the molten metal.

2.7.8 Advantages and Limitations of Gas Welding

Advantages of gas welding

1. Temperature of flame can be easily controlled.
2. The amount of filler metal deposits can be controlled easily.
3. The flame can be used for welding and cutting.
4. All types of metal can be welded.
5. The cost of equipment is less.
6. It can be used in the factory or in the field.
7. Maintenance cost of gas welding equipment is less

Limitations of gas welding

1. It is not suitable for joining thick plates.
2. It is a slow process.
3. Strength of weld is not so good as arc welding.
4. Handling and storing of gas cylinders need more care.
5. Gas flame takes up a longer time to heat up the metal than an electric arc.

2.8 Manual metal arc welding

In arc welding process, the heat is developed by an electric arc. The arc is produced between an electrode and the work. Arc welding is the process of joining two metal pieces by melting their edges by an electric arc. In arc welding, the electrical energy is converted in to heat energy. The electrode and work piece are brought near to each other with a small air gap of 3mm approximately. Then, the current is passed through the work piece and the electrode to produce an electric arc.

The work piece is melted by the arc. The electrode is also melted and hence, both the workpieces become a single piece without applying any external pressure. The temperature of arc is about 5000°C to 6000°C. The electrode supplies additional filler metal into the joints and is deposited along the joint. A transformer or generator is used for supplying the current. The depth to which the metal is melted and deposited is called depth of fusion. To obtain better depth of fusion, the electrode is kept at 70° inclination to the vertical.

Electrodes used in arc welding are generally coated with a flux. The flux is used to prevent the reaction of the molten metal with atmospheric air. It also removes the impurities from the molten metal and forms a slag. This slag gets deposited over the weld metal. This slag protects the weld seam from rapid cooling.