CHAPTER 7

WELDING, BRAZING AND SOLDERING

7.1 Introduction

Metal fabrication involves joining of two metals together. Various processes are used to join the metals together depending the material and thickness of the parts to be joined and degree of permanency required etc. Here some of the important features and methods of joining by welding, soldering and brazing are discussed.

7.2 Welding

Welding may be defined as the metallurgical joining of two metal pieces together to produce essentially a single piece of metal. Welding is extensively used in the fabrication work in which metal plates, rolled steel sections, castings of ferrous materials are joined together. It is also used for repairing broken, worn-out, or defective metal parts.

1. *Principle of Welding*

A *welding* is a metallurgical process in which the junction of the two parts to be joined are heated and then fused together with or without the application of pressure to produce a continuity of the homogenous material of the same composition and the characteristics of the parts which are being joined .

2. *Types of Welding*

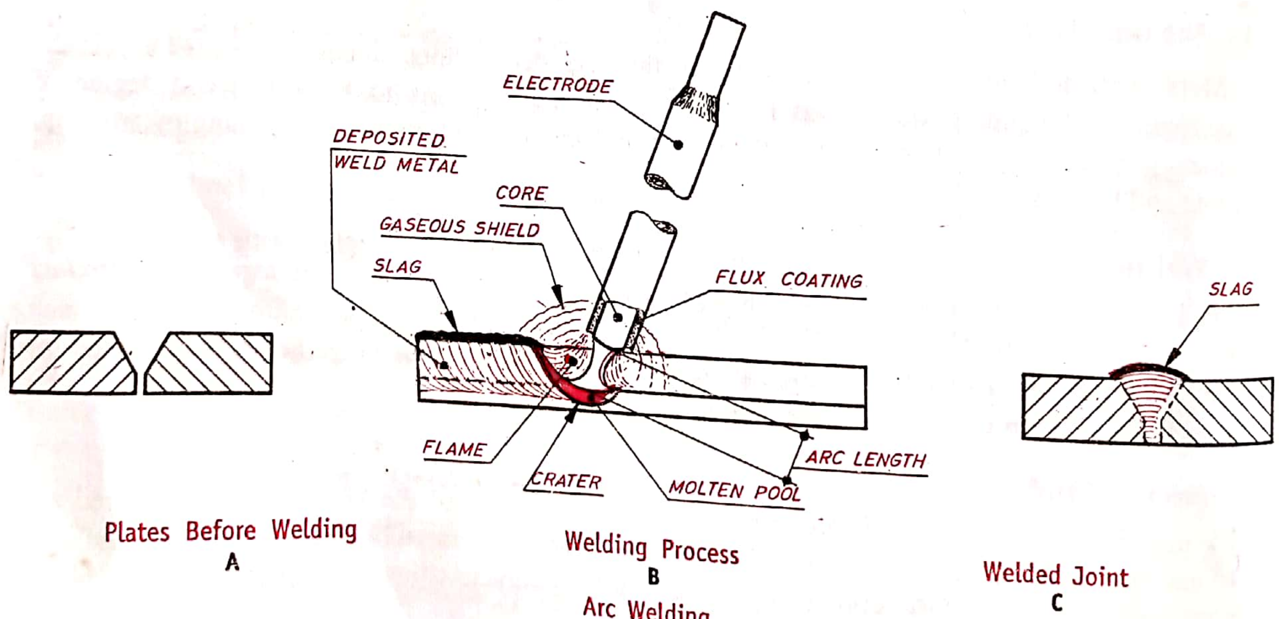
Welding processes may be classified based on the basic principles employed as ; *(i) pressure welding* and *(ii) fusion welding.*

In *pressure welding,* the parts to be joined are heated only up to the *plastic state* and then fused together by applying the external pressure. The different types of pressure welding are : *forge welding* and *resistance welding.*

In *fusion welding* which is also known as *non-pressure welding,* the joint of the two parts is heated to the molten state and allowed to solidify. The different types of fusion welding are : *arc welding* and *gas welding.*

7.3 Arc Welding

The principle of arc welding is as follows. When two conductors of an electric circuit are touched together momentarily and then instantaneously separated slightly, assuming that there is sufficient voltage in the circuit to maintain the flow of current, an electric arc is formed. Concentrated heat is produced throughout the length of the arc at a temperature of about 5000 to 6000°C. In arc welding, usually the parts to be welded are wired as one pole of the circuit, and the electrode held by the operator forms the other pole. When the arc is produced, the intense heat quickly melts the workpiece metal which is directly under the arc, forming a small molten metal pool. At the same time the tip of the electrode at the arc also melts, and this molten metal of the electrode is carried over by the arc to the molten metal pool of the workpiece. The molten metal in the pool is agitated by the action of the arc, thoroughly mixing the base and the filler metal. A solid joint will be formed when the molten metal cools and solidifies. The flux coating over the electrode produces an inert gaseous shield surrounding the arc and protects the molten metal from oxidizing by coming in contact with the atmosphere. *Fig. 7.1* illustrates the arc welding process.



Arc Welding
Fig. 7.1

1. Arc Welding Machine

Both alternating current (A.C) and direct current (D.C) are used for arc welding. Whenever A.C. supply is not available, *D.C generators* are used for D.C arc welding. For A.C arc welding a *step down transformer* is used. The transformer receives the A.C. supply between 200 and 440 volts and transforms it to the required low voltage in the range of 80 to 100 volts. A high current of 100A to 400 A will be suitable for general arc welding work.

In D.C welding, the workpiece is connected to the *positive pole* of a D.C generator and the electrode to the *negative pole* in order to melt greater mass of metal in the base material. This kind of setup is said to have " *straight polarity*". When the less heat is required at the base material, the polarity is reversed. Because of this option of selection of polarity depending upon the type of the job, in D.C. welding it is possible to melt many metals which require more heat to melt.

In A.C. arc welding, there is no choice of polarity since they change in every cycle. As the A.C. current acquires zero values twice in every cycle, at these moments the potential difference is also zero and hence higher voltage is required to maintain the arc.

2. Arc Welding Electrodes

The two types of electrodes used in arc welding are *(i) consumable electrodes* and *(ii) non-consumable electrodes.*

Consumable electrodes also melt along with the workpieces and fill the joint. They are made of various metals depending upon their purpose and the chemical composition of the workpieces. The consumable electrodes either will be *bare or coated.* When the bare electrodes are used, the globules of the molten metal while passing from the electrodes absorb oxygen and nitrogen from the atmospheric air to form non-metallic constituents which gets trapped in the solidifying weld metal and thereby, decreasing the strength of the joint. The coated electrodes facilitate ; (i) the protection of molten metal form oxygen and nitrogen of the air by providing a gas shield around the arc and the molten pool of metal; (ii) to establish and maintain the arc throughout welding ; (iii) the formation of slag over the joint thus protects from rapid cooling ; and (iv) the addition of alloying element. The electrodes are made of either soft steel wire or alloy steel. The coating is usually composed of chalk, ferro manganese, starch, kaolin, alloying and binding materials.

When *non-consumable electrodes* are used, an additional filler material is also required. The advantages of using this type of electrode is that the amount of the metal deposited by the filler rod can be controlled which is not possible in the other types of electrodes.

3. Electric Arc Cutting

In electric arc cutting, a very high current is passed so as to melt the workpiece. The insulating cover of the coated electrodes permits the introduction of the electrode into the cut without causing a short circuit. The electrode is also used up during cutting. All metals which can be readily melted can be cut. Generally arc cutting is employed to cut cast iron, alloy steels, non-ferrous metals and scrap metal.

7.4 Resistance Welding

This type of welding employs the principles of both the pressure and fusion welding methods. It consists of heating of the parts to be welded to the plastic state and joined together by applying the mechanical pressure. The heating is accomplished by the passage of a heavy localized electric current discharged at a low voltage across the contact area of the metal parts to be joined. The current flowing from one part to the other at the joint encounters a very high resistance and the temperature at the joint increases. When the temperature attained is slightly greater than the melting temperature of the parts external mechanical pressure is applied at the joint which will result in a forge weld fastening the parts together. The parts to be welded by resistance welding are relatively thin in comparison with the parts which are normally gas or arc welded. Generally the resistance welding is employed for fastening thin metal sheets and wires.

General Welding Procedure

A Step-by-step general procedure for welding is as described below:

Step 1: ***Cleaning*** **:** The surfaces of the parts to be welded need to be thoroughly cleaned for removal of dirt, oil, grease, etc.

Step 2: ***Edge Preparation*** **:** The process of preparing a contour at the edges of the pieces to be joined is called as *edge preparation*. This involves beveling or grooving. The idea of doing this is to get fusion or penetration through the entire thickness of the member.

Step 3: ***Clamping*** **:** Next, the parts to be welded are clamped suitably through jigs and fixtures so that there are no undesirable movements during welding.

Step 4: ***Check for safety devices*** **:** Safety devices like goggles and shields to protect the eyes, protective clothing to prevent the sparks and flying globules of molten metal, safety shoes, gloves, aprons and other safety devices must be ensured.

Step 5: ***The Initial weld*** **:** Initial tack welds are done at the opposite corners of the joint to secure the pieces together. Any cracks at this stage must be chipped off as the presence of these cracks causes residual stresses. The length and spacing of the tack weld varies with the thickness of the metal and the length of the joint.

Step 6: ***Intermediate and final welding*** **:** The weld joint is formed through various *weaving movements* (of varying shapes called *weld beads*). During the process, filler metal and a suitable flux are used. After the intermediate run of welding, the final run is taken.

Step 7: ***Excess material removal*** **:** Extra material on the weld surface can be removed using tongs and chipper. The final weld is now allowed to cool and finally cleaned.

7.5 Gas Welding

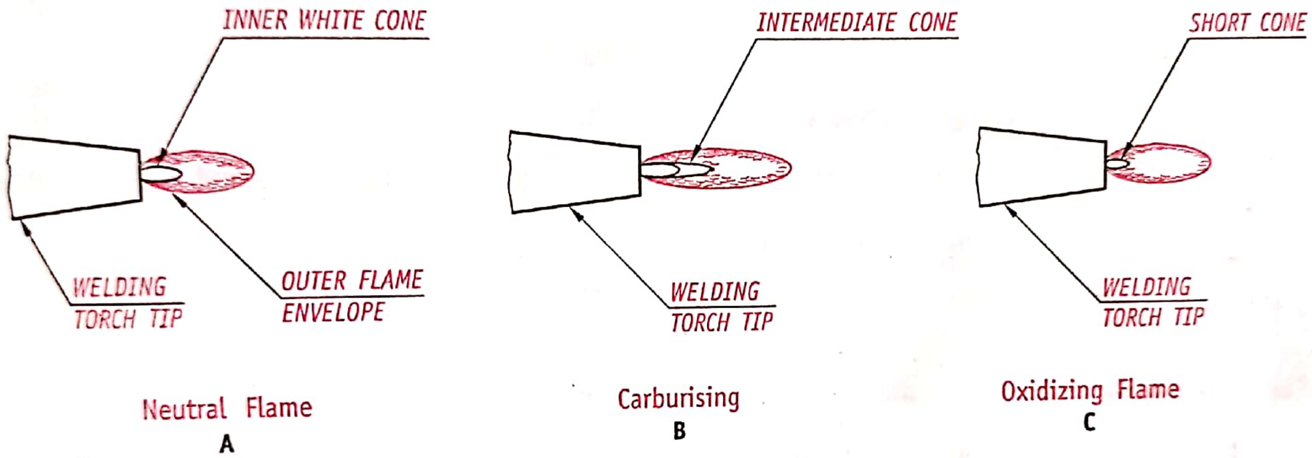
Gas welding is a *fusion method* of welding, in which a strong gas flame is used to raise the temperature of the workpieces so as to melt them. As in arc welding, a filler metal is used to fill the joint. The gases that can be used for heating are ; (i) oxygen and acetylene mixture and (ii) oxygen and hydrogen mixture. The oxy-acetylene gas mixture is most commonly used in gas welding.

Oxy-Acetylene Welding

When right proportions of oxygen and acetylene are mixed in the welding torch and then ignited, the flame produced at the nozzle tip is called as the *oxy-acetylene flame*. This flame when used in welding becomes *oxy-acetylene welding*. The temperature attained by the oxy-acetylene flame is around 3200°C and therefore has the ability to melt all commercial metals. Thus, there is a complete bonding of the joining metals that can be achieved during welding.

Types of Oxy-Acetylene Flames

For the complete combustion of the acetylene, 2.5 volumes of oxygen are required for 1 volume of acetylene. In practice, however, ratio of the parts of oxygen to the parts of the acetylene, referred as *gas ratio* varies from 0.95 to 1.5. Depending on the gas ratio, *neutral, oxidizing and carburising or reducing flames* as shown in *Fig. 7.2* can be obtained.



Oxy-Acetylene Flames
Fig. 7.2

A *neutral flame* shown in *Fig. 7.2A* is obtained by supplying equal volumes of oxygen and acetylene. The neutral flame consists of an inner small *whitish cone* surrounded by a sharply defined *blue flame*. Most of the oxy-acetylene welding is done with the use of the neutral flame.

A *carburising* or a *reducing flame* shown in *Fig. 7.2B* is obtained by supplying excess acetylene in the gas ratio between 0.95 to 1. It has *three cones* ; an *inner white cone*, surrounded by an *intermediate whitish cone* known as "*intermediate flame feather*" and a *bluish envelope flame*. This flame is generally used due to its reducing nature, for welding alloy steels, cast iron and aluminium to protect from the oxidizable elements.

The *oxidizing flame* shown in *Fig. 7.2C* is obtained when there is excess oxygen. having gas ratio in the high range from 1.15 to 1.5. In appearance it resembles a neutral flame with the exception that the inner white cone flame is some what shorter. This is used for oxy-acetylene cutting and is not suitable for welding, since the weld metal will be oxidized.

Oxy-Acetylene Welding Equipment

The oxy-acetylene gas equipment consists of *two large steel cylinders* ; one containing oxygen at high pressure, and the other dissolved acetylene also at high pressure, *rubber tubes, pressure regulators* and *blow torch*. The oxygen and the acetylene are supplied to the blow torch separately, where both of them get mixed and come out through the nozzle of the blow torch.

Advantages of Oxy-Acetylene Welding

1. Most versatile process of welding with wide use in various manufacturing activities.
2. Low cost of the equipment and low cost of maintenance of the equipment.
3. Here, the heat source and the filler metal are separated, and hence control can be exercised on the rate at which the filler metal deposits.
4. The rate of heating and cooling is slow. This helps in retaining the structural homogeneity.
5. The equipment is portable and multi-functional because, apart from gas welding, it can also be used in torch brazing, braze welding, preheating and post-heating.

Disadvantages of Oxy-Acetylene Welding

1. Difficult to attain low-cost target while joining heavy sections.
2. Handling and storage of gases not an easy job.
3. It takes a long time for the flame to heat up the metal piece than compared to arc welding.
4. Possible hazards due to explosion of gases.

7.6 Welding Defects

The following are some of the defects which reduce the efficiency of a welded joint.

1. *Cracking* – It occurs due to incorrect electrodes or wrong working procedures. Cracked welds must be cut out and re–welded.
2. *Incorrect edge preparation* – Too narrow an angle of the edges of the workpieces result in poor fusion, slag inclusion and weak weld. Too wide an angle between the inclined edges results in heavy welding, resulting in overheating and locked up stresses.
3. *Craters* – These are concave depressions in the external surface of the welded joints which reduces the volume of the weld and thus the strength of the joint.
4. *Under-cutting* – It is the excess melting of the parent metal which reduces its strength.
5. *Unequal legs* – In fillet welding, the unequal length of the legs of the weld reduces the strength of the joint.
6. *Porous weld* – Insufficient gap between the electrode and the workpiece results in poor penetration which may cause slag inclusion and porous welds.
7. *Over welding* – When welding is carried over an already welded layer, it may overheat the earlier layer of weld and there may not be proper fusion between the two layers.

2. Cylinders, Boilers and Vessels Manufacturing: Here, welding is used to join rolled cylindrical sheet along the height of the cylinder and join the dish-end plates to the cylindrical part.
3. Welding process is used extensively in the construction of various types of structures like bridges, buildings, and ships.
4. Used in machine tool industry in building various mechanical, food-processing, farming, earth-moving and textile machineries.
5. Used in building of bus, truck and car bodies and parts.
6. Used in the manufacturing of furnaces and tanks.
7. Used in the manufacturing of Steel furniture.
8. Used in the manufacturing of cranes and hoists.
9. Used in the manufacturing of Railway equipment.

7.9 Soldering

Soldering is a method of uniting two thin metal pieces using a dissimilar metal or an alloy by the application of heat. The alloy of lead and tin, called *soft solder,* is used in varying proportions for sheet metal work, plumbing work and electrical junctions. The melting temperature of the soft solder will be between 150 to 350°C. To clean the joint surfaces and to prevent the oxidation, a suitable flux is used while soldering. Zinc chloride is the flux that is commonly used in soft soldering. A soldering iron is used to apply the heat produced from the electrical source.

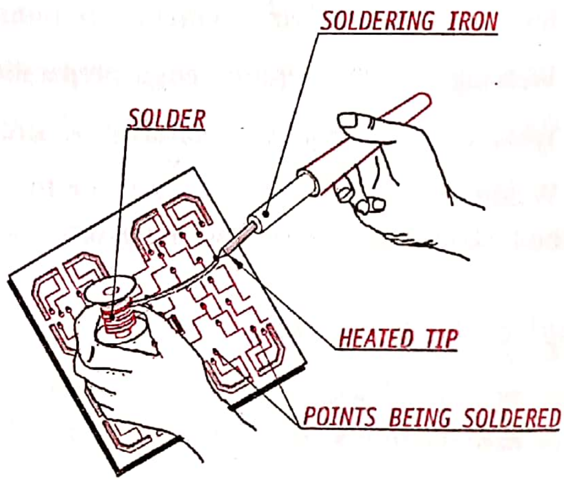
An alloy of copper, tin and silver known as *hard solder* is used for stronger joints. The soldering temperatures of hard solders ranges from 600 to 900°C.

7.10 Method of Soldering

The method of soldering is illustrated as a step-by-step procedure below:

1. Cleaning of joining surfaces : Firstly, the joining surfaces are cleaned mechanically to make them free from dust, oil, scales, etc and ensure that the molten filler metal wets the surfaces.

2. Application of flux : Then, the joining surfaces are coated with a flux, usually rosin or borax. This cleans the surfaces chemically and helps the solder in making a bond.



Soldering Technique
Fig. 7.3

3. Tinning of the surfaces to be soldered : Before carrying out the soldering operation, the soldering iron must be "tinned". This is to remove a thin film of oxide that forms on the copper bit, which in turn does not allow the job to be heated and thus it becomes difficult to solder. In tinning, the copper bit is heated and then rubbed with a file to clean it properly and then rotating with solder using resin. This causes the formation of a thin film of solder over the copper bit. This whole process is called "tinning".

4. Heating : The soldering iron is then heated and the flowing molten filler metal fills the joint interface. Allow the soldered area to cool and then solidify thus making the joint.

5. Final Clean-up : After completing the soldering, and the joints are formed, clean it with steel wool or solvent to remove left-over flux. After this clean the soldering iron using a damp sponge.

Fig. 7.3 shows the Soldering Technique.

7.11 Advantages of Soldering

1. Low cost and easy to use.
2. Soldered joints are easy to repair or do rework.
3. The soldered joint can last for many many years.
4. Low energy is required to solder.
5. An experienced person can exercise a high degree of control over the soldering process.

7.12 Brazing

Brazing is a method of joining two similar or dissimilar metals using a special fusible alloy. It produces joints stronger than soldering. During brazing, the base metal of the two pieces to be joined is not melted. The filler metal must have the ability to wet the surfaces of the base metal to which it is applied. Some diffusion or alloying of the filler metal with the base metal takes place even though the base metal does not reach its melting temperature. The materials used in brazing are *copper base* and *silver base alloys.* These two can be classified under the name "Spelters".

7.13 Method of Brazing

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

7.14 Advantages of Brazing

1. It is easy to learn.
2. It is possible to join virtually any dissimilar metals.
3. The bond line is very neat aesthetically.
4. Joint strength is strong enough for most non-heavy-duty type of applications.

7.15 Differences between Soldering and Brazing

Sl.No.	Soldering	Brazing
1.	In case of Soldering, the metals are joined with the help of a filler metal with a low melting point, below 450° C, and below the melting point of the metals to be joined.	In case of Brazing, the filler metal has a melting temperature of more than 450°C and up to 1000° C
2.	Weaker joints compared to Brazing.	Stronger joints compared to Soldering.
3.	The typical Solder filler metals are alloys of tin.	The typical filler metals for Brazing are Aluminium, Silver, Copper, Nickel and Gold.
4.	The flux used is usually Rosin.	The flux used is usually Borax.
5.	Economical Process	Not as economical as Soldering
6.	Usually suitable process to join metals with small thicknesses.	Suitable Process even for joining metals of larger thicknesses.

7.16 Differences between Brazing and Welding

Sl.No.	Brazing	Welding
1.	In case of Brazing, the metals to be joined are not melted and the joint is produced through the solidification and adhesion of a thin layer of molten filler metal.	In case of Welding, the surfaces to be joined are melted.
2.	There is no penetration into the base metal.	There is penetration into the base metal.
3.	The molten Brazing filler alloy spreads along the joint.	The molten Brazing filler alloy does not spread along the joint and soldifies where it melts.
4.	Relatively weaker joints.	Relatively stronger joints are produced.
5.	Average operator skill level is required.	High Operator Skill and Experience.
6.	Not as economical as Welding	Economical compared to Brazing.