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.

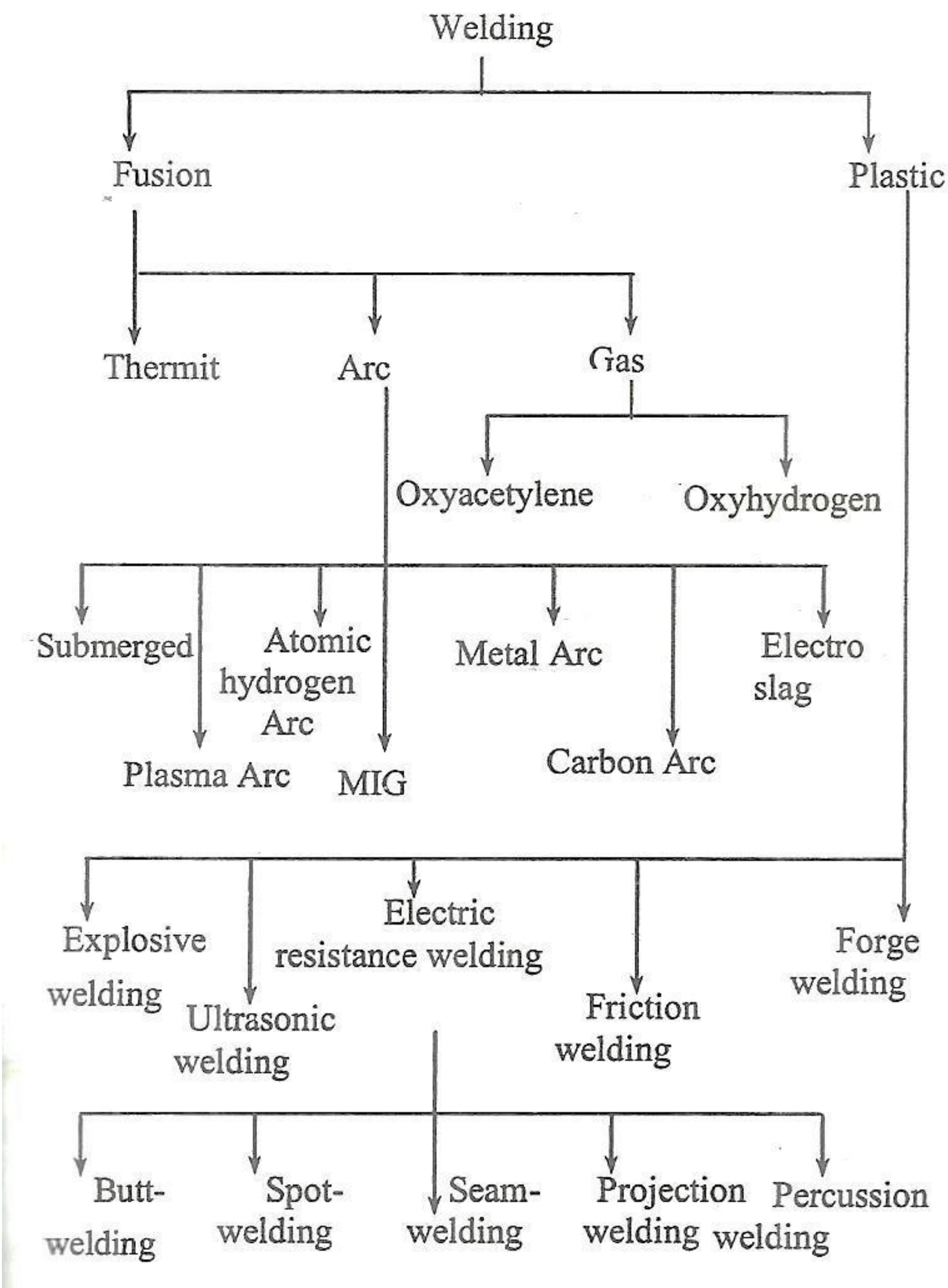
2.2.2 Plastic Welding

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.

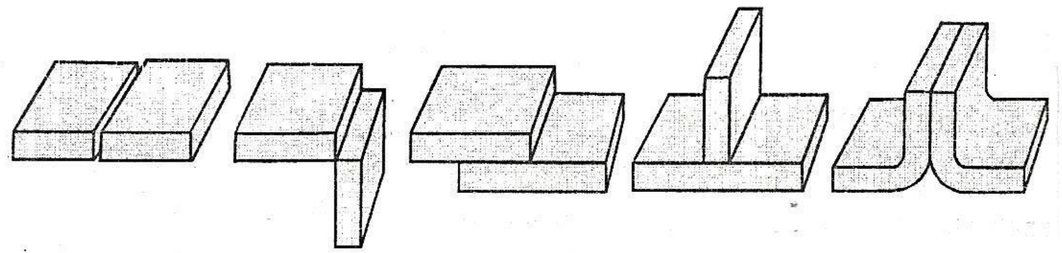


Figure 2.1 Types of weld joint

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.

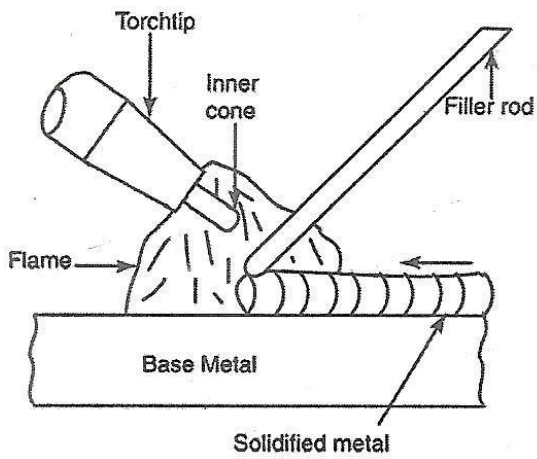


Figure 2.2 Oxy-Acetylene welding

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.

$$CaC_2 + 2H_20\ \ Ca(OH)_2 + C_2H_2 + 127.3\ KJ/mol.$$

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.

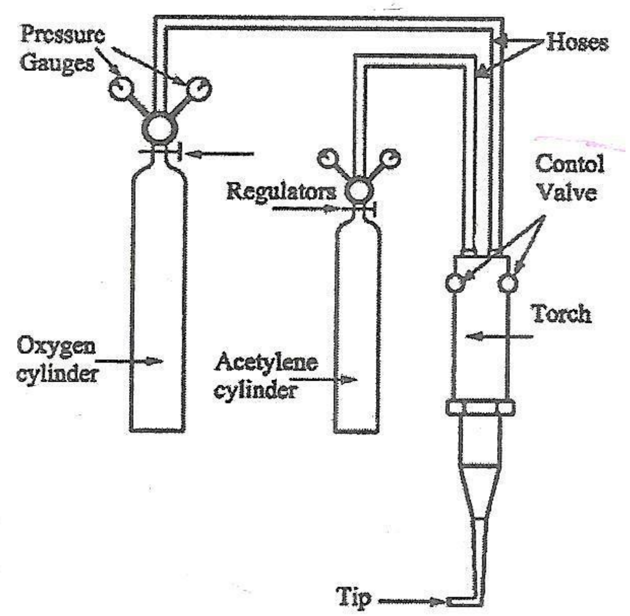


Figure 2.3 Gas Welding Equipment

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.

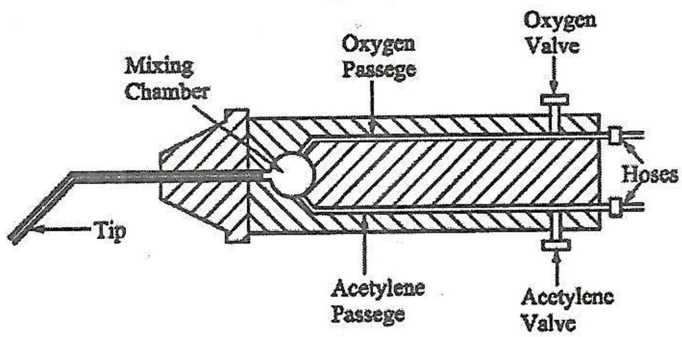


Figure 2.4 Welding Torch

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.

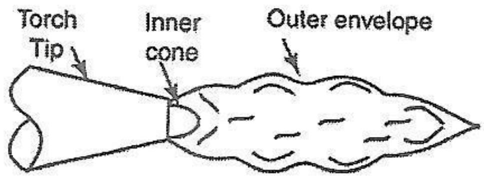


Figure 2.5 Neutral Flame

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.

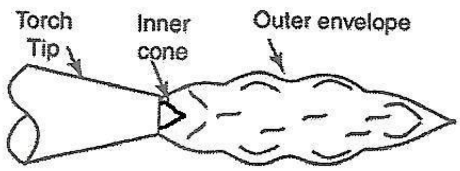


Figure 2.6 Oxidising flame

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.

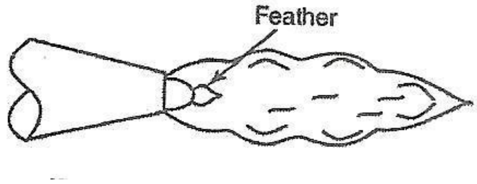


Figure 2.7 carburizing flame

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.

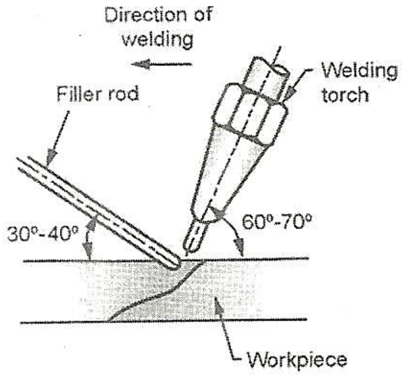


Figure 2.8 Leftward Technique

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.

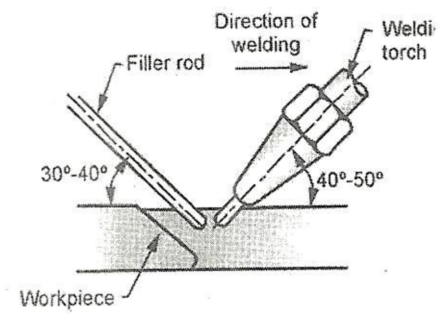


Figure 2.9 Rightward Technique

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.

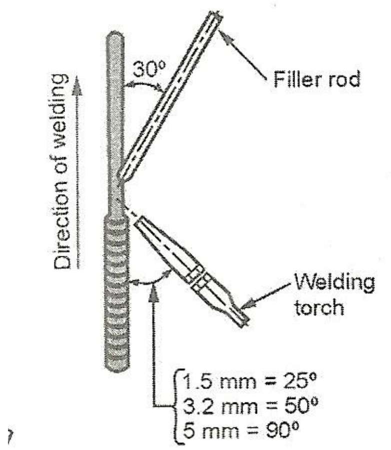


Figure 2.10 Vertical welding

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.

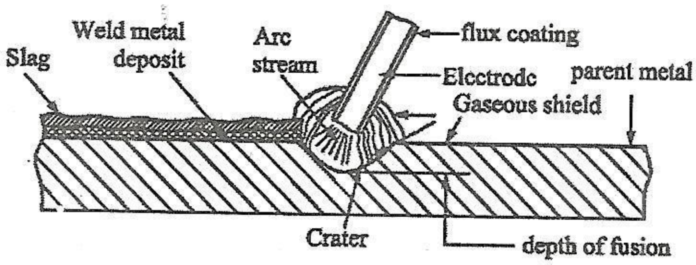


Figure 2.11 Manual metal arc welding process

The molten metal is forced out of the pool by the electric arc. Hence, a small depression is formed in the parent metal where the molten metal is piled up. This is known as “arc carter”. The distance between the tip of the electrode and the bottom of the arc crater is called “arc length”.

2.8.1 Manual metal Arc welding equipment

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

1. Welding generator (DC) or transformer (A.C)
2. Electrode
3. Electrode holder
4. Two cables one for work and other for electrode
5. Gloves
6. Protective shield
7. Apron
8. Wire brush
9. Chipping hammer
10. Safety goggles.

In the electric arc welding, both D.C. and A.C are used for producing arc. D.C. machines and D.C. generators are driven by an electric motor of an I.C. engine. A.C. welding machines are transformers which are used for stepping down the main supply voltage because the available supply voltage is at 220/440V. But normal welding requires 20 to 90 volts.

The specification s of D.C generator and transformer for welding are given below.

Specification for generator

Generator	- Separately or self excited 3 phase 50 cycles per second
Current range	- 125A to 500A-D.C machine
Circuit voltage	- 30V to 80V
Arc Voltage	- 20v to 40 v
Power factor	- 0.7
Efficiency	- 60%
Electric Consumption	- 6 to 10 kWh/kg of metal deposit

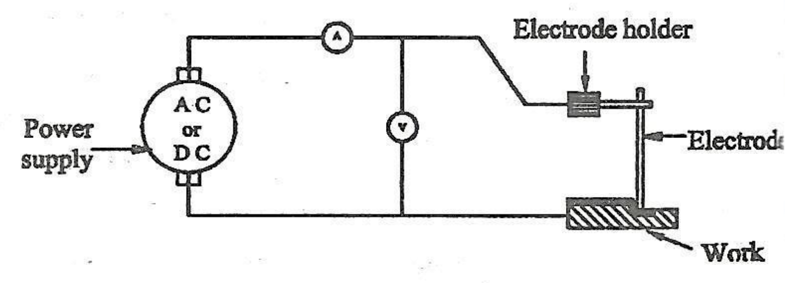


Figure 2.12 Electric arc welding machine components

Specification transformer

Transformer	- Oil cooled, double wound, step down Transformer 3-phase 50 cycles per second
Current	- 50A to 40A-A.C machine
Circuit	- 80V
Arc Voltage	- 40 v
Power factor	- 0.4
Efficiency	- 85%
Electric Consumption	- 4 kwh/kg of metal deposit

2.8.2 Comparison of A.C and D.C welding machines

S. No	A.C. machine (Transformer)	D.C. machine (Generator)
1.	Efficiency is more. (80 to 85%)	Efficiency is less. (30 to 60%)
2.	Power consumption is less.	Power consumption is more.
3.	Cost of equipment is less.	Cost of equipment is more.
4.	Any terminal can be connected to work or electrode.	Positive terminal is connected to work and negative terminal is connected to electrode.
5.	It is noiseless operation.	It is very noisy operation.
6.	**Disadvantages** Voltage is higher. Hence, it is not safe.	**Advantages** Voltage is low. Hence, it provides operation.
7.	It is not suitable for welding nonferrous metals.	It is very much suitable for both ferrous and nonferrous metals.
8.	Only coated electrode can be used.	Bare electrodes can be used.
9.	It is not preferred for welding thin sections.	It is preferred for welding thin sections.

10.	Maintenance of equipment is costly and difficult.	Maintenance of equipment is cheaper and simple.
11.	Power factor is low.	Power factor is low.

2.8.3 Comparison of manual metal Arc welding and Gas welding

Arc welding	Gas welding
1. Heat is produced by electric arc.	Heat is produced by the gas flame.
2. The arc temperature is about 4000°C.	The fame temperature is about 3200°C.
3. Filler rod is used as electrode.	Filler rod is introduced separately.
4. It is suitable for welding medium and thick work.	It is suitable for welding thin work.
5. Arc welded joints have very high strength.	Gas welded joints do not have much strength.
6. Filler metal should be same as or an alloy of parent metal	Filler metal need not be same as the parent metal.
7. Brazing and soldering cannot be done using electric arc.	Brazing and soldering are done using gas.

2.8.4 Electrode Types

Commonly there are two types of electrodes used in arc welding process. They are

Consumable electrode, and

Non-Consumable electrode

1. Consumable electrode

The consumable electrode is not only used to produce arc between work and electrode but also provides filler material during welding. These may be made of various metals depending upon their purposes and the chemical composition of the metals to be welded. Since, it is melting during the welding process, the electrode should move towards the work to maintain constant the arc length.

The consumables electrodes may be classified into following types:

1. Bare Electrodes
2. Lightly Coated Electrode
3. Heavily Coated Electrode

Bare Electrodes do not have any coating of flux on their surface. They are rarely used to weld wrought iron and mild steel. They must be used only with straight polarity. When bare electrodes are used, the molten metal reacts with the atmosphere. This causes defects in the weld. Therefore, it is used in the submerged arc welding and inert gas welding. In these processes, atmosphere reaction is prevented by separately supplying flux or insert gas.

Lightly Coated electrodes have a coating layer of several tenths of a millimeter and is 1 to 5% of the electrode weight. The main purpose of light coating is to increase arc stability called as ionizing coating. It does not prevent oxidation of molten metal. The welds due to lack of protection of oxidation reaction have poor mechanical properties and hence, it is used for welding non-essential jobs.

Heavily coated electrodes are covered with high quality covering of 1 to 3 mm thick. This coating is composed of ionizing, deoxidizing, gas generating, slag-forming alloying and binding materials. The weight of such a coating is from 15 to 30% of the electrode rod. The greatest amount of welding is done with heavy coated electrode.

The flux coating is meant for following purposes:

1. To give stability to the arc.
2. To produce a gas shield around the arc and the molten metal. It prevents atmospheric reaction.
3. To provide the formation of slag so as to protect the welding seam from rapid cooling.
4. To introduce different alloying elements to the weld metals. These alloying elements increase the strength of the weld.
5. Increase deposition efficiency.

2. Non – Consumable electrode

Non-consumable electrodes are made of carbon, graphite or tungsten, which do not consume during the welding only. Tungsten electrodes are used for D.C as well as A.C welding. Non-consumable electrodes are used in atomic hydrogen welding and TIG welding. Here, arc length remains constant and hence, it is stable.

2.8.5 Specification and Choice of Electrodes

Bare and coated electrodes are specified by the diameter and length. Electrodes are available up to 12 mm diameters and 450 mm long. For hand welding, the diameter of the electrode will increase with the increase in the thickness of the work piece. For heavy currents, thicker electrodes are used. In semi automatics and automatic welding, electrode wire wound in coil is used.

The metal of the electrode will depend upon the kind of parent metal. The following table represents the electrodes used for welding different metals.

Work piece	Electrode
1. Wrought iron	Low carbon steel rod.
2. Cast Iron	Cast iron rods.

3. Mild steel	Mild steel copper coated rod.
4. Alloy steel	Low-alloy steel rod containing 0.25% carbon.
5. Aluminum	Cost aluminum alloy rod.
6. Carbon steel	Soft steel wire containing 0.1 to 0.18% carbon and 0.0025 to 0.04% phosphorus and sulphur.
7. Copper casting	Copper rod
8. Brass	Drawn brass rod.

2.8.6 Selection of electrodes

The choice of an electrode depends on the following factors

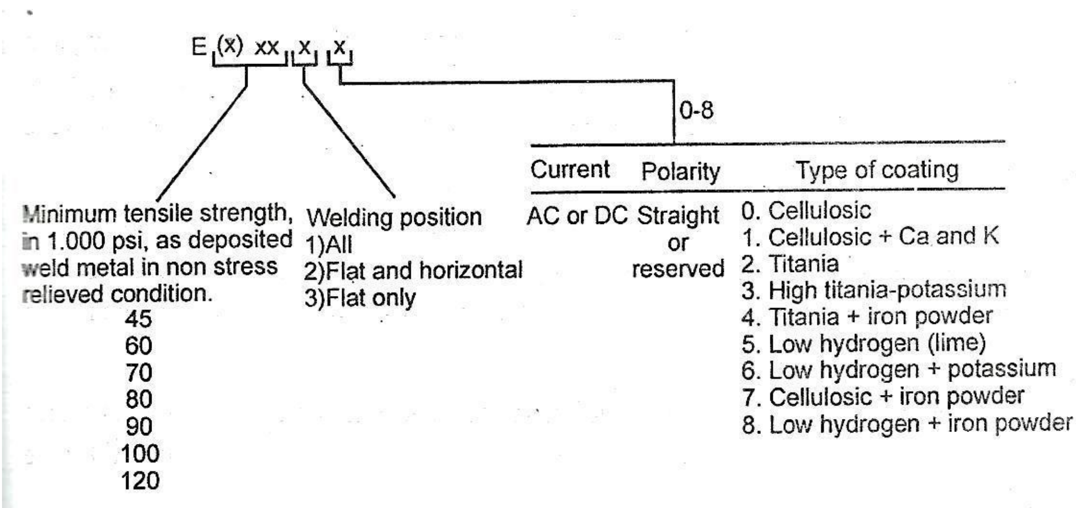
a. Chemical composition of the base metal.
b. Thickness of work piece.
c. Nature of electrode coating (cellulose, rutile, low hydrogen etc)., arc behaviour and metal losses due to volatilization and spatter.

Electrode coatings

A variety of electrode coatings have been developed. The celluslose and titania (rutile) coatings contain SiO_2; TiO_2; small amount of FeO, MagO, and Na_2O; and volatile matter.

Upon decomposition, the volatile matter may release hydrogen, which can dissolve in the weld metal and lead to embrittlement of cracking in the joint. Low-hydrogen electrodes are available with compositions designed to provide shielding without the emission of hydrogen. Since many of the electrode coatings can absorb moisture, and this is another source of undesirable hydrogen, the coated electrodes are often baked just prior to use.

Iron powder can be added to the electrode coating to significantly increase the amount of weld metal that can be deposited with a given size electrode wire and current. Alloy elements can also be incorporated into the coating to adjust the chemistry of the weld.



2.8.7 Filler and Flux material using in Arc welding process

The electrode rod is made of a material that is compatible with the base material being welded and is covered with a flux that protects the weld area from oxidation and contamination by producing CO_2gas during the welding process. The electrode core itself acts as a filler material making separate filler unnecessary. The process is very versatile, requiring little operator training and inexpensive equipment. However, weld times are rather slow, since the consumable electrodes must be frequently replaced and because slag and the residue from the flux must be clipped away after welding. Furthermore, the process is generally limited to welding ferrous materials, though specialty electrodes have made possible the welding of cast iron, nickel, aluminum, copper and other metals. The versatility of the method makes it popular in a number of application including repair work and construction.

2.9 Gas Tungsten Arc Welding (GTAW)

Gas tungsten arc welding is also called TIG welding. In GTAW welding, the electric arc is produced between a non-consumable tungsten electrode and the work piece. There is an electrode holder in which the non-consumable tungsten electrode is fixed when the arc is produced.

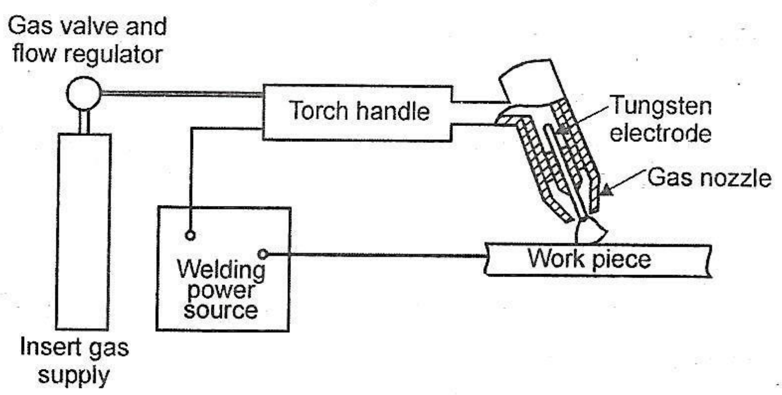


Figure 2.13 Gas Tungsten Arc Welding Equipment

By supplying the electric power between the electrode and the work piece, the insert gas from the cylinder passes through the nozzle of the welding head around the electrode. The insert gas surrounds the arc and protects the weld from atmospheric effects and hence, defect free joints are made.

Filler metal may or may not be used. When a filler metal is used, it is usually fed manually into the weld pool. An electrode used in this process is tungsten. It has high melting point (330°C), therefore, it will not be melted during welding. This process is used for welding steel, aluminum, Cast iron, Magnesium, Stainless steel, Nickel based alloys, copper based alloys and low alloy steel. It is also used for combining the dissimilar metals in hard facing and in surfacing of metals. This process is used for the metals having thickness less than 6.5mm

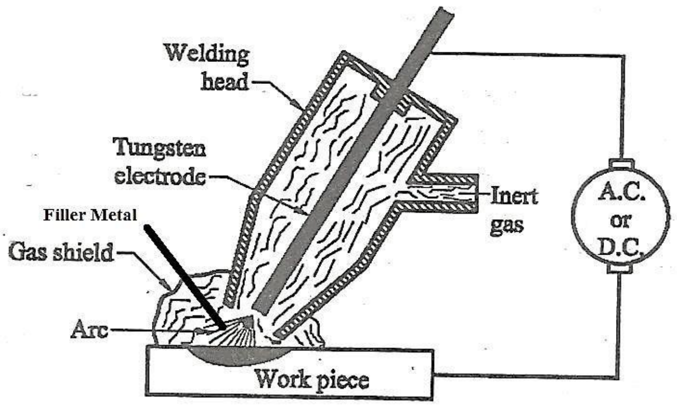


Figure 2.14 Gas Tungsten Arc Welding Process

Advantages

1. No flux is required.
2. The welding speed is high.
3. It can be used for both ferrous and non ferrous metals.
4. It produces high quality weld.
5. No weld cleaning is necessary.
6. The arc and weld pool are clearly visible during welding.

2.10 Gas metal arc welding (GMAW)

The process is also called as metal inert gas welding (MIG). In this arc welding, the electric arc is produced between a consumable metal electrode and the work piece.

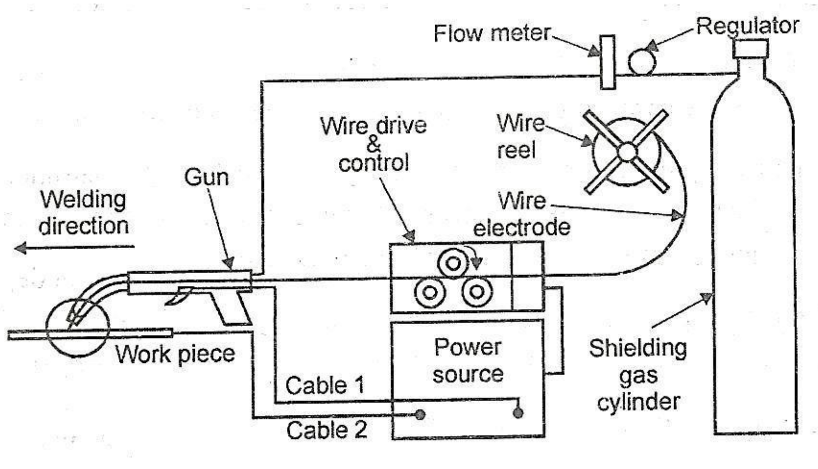


Figure 2.15 Gas metal arc welding Equipment

During welding, the arc and welding zone are surrounded by an inert gas, as show in figure. Argon or Helium is used as the inert gas. The surrounded air protects the weld from atmosphere. The electrode is fed continuously through welding head because during welding the electrode is melted by arc and deposited over the work piece. The welding can be done manually or automatically. Either D.C generator or A.C transformer is used for MIG welding. The current ranges from 100 to 400 A depending upon the diameter of the wire. The welding head may be either air or water-cooled depending upon the current being used.

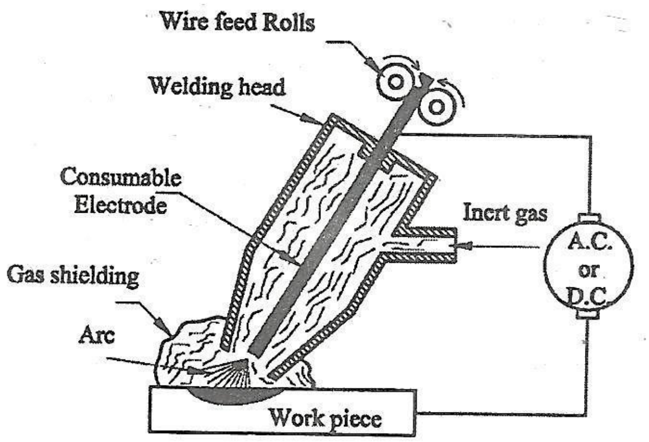


Figure 2.16 Gas metal arc welding Process

This process is used for welding thick plates. It is used for welding aluminum; stainless steel, nickel, and magnesium without weld defects.

Advantages:

1. No flux is required.
2. High welding speed is obtained.
3. It is possible to weld ferrous and non-ferrous metals.
4. It provides greater efficiency
5. It produces high quality weld
6. The process is cheaper

2.11 Submerged arc welding (SAW)

2.11.1 Flux Core

When the flux is required continuously or where the larger quantity of flux has to be supplied, on that time the flux is used in the form of wire wound on a rotating drum or reel called as flux core. It is separately supplied instead of using welding rod along with flux material. Flux is mainly used to avoid oxidation reaction with oxygen present in the atmosphere. If the flux is used along with filler material in the form of coated electrodes, the oxidation reaction may not be completely prevented. In order to avoid oxidation reaction completely, enough quantity of flux should be supplied with a separate control independently with filler material.

E.g. the complete welding setup is dipped in the flux powder named as submerged arc welding.

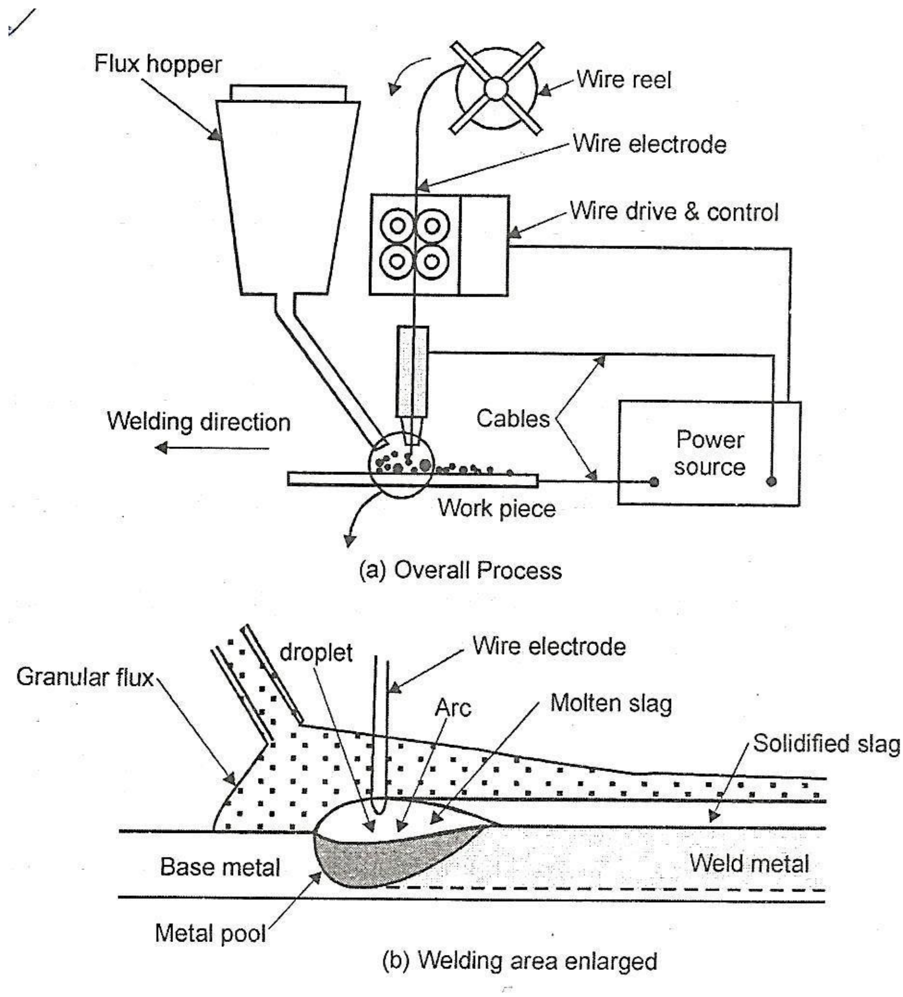


Figure 2.17 Submerged arc welding

Submerged arc welding is also called as sub arc welding or hidden arc welding. In this welding, an electric arc is produced between consumable bare electrode and the work piece. But the arc is completely submerged i.e., hidden under the flux powder. The arc is not visible outside. The metal electrode is continuously fed from the reel by a moving head. The flux powder is fed in front of the moving head. It is supplied from a hopper. When the arc is produced in the welding zone at the end of the electrode and the arc is completely covered by flux powder. So, there will not be any defect in the weld due to atmosphere effects.

The flux powder used here is made up of silica, metal oxides and other compounds fused together and then crushed to the proper size. Another group of fluxes is made of similar material bonded and formed into granules. The flux not only protects the weld surface from atmosphere and also acts as a deoxidiser and scavenger. It may also contain powder metal alloying elements. The flux covers the arc and molten metal. Some of the flux melts and forms the slag on the weld. The unused flux is sucked by a pipe. Voltage used here is 25 to 40V. current used depends on work piece thickness. Normally, D.D. is employed using 600A to 1000A and A.C. is usually 200A.

Since, the flux must cover the joint to be welded. This method is restricted to make straight welds in the flat position. Thus, it is suitable for cylinders, steel pipes etc.

Submerged are welding is used specially for welding carbon steels and alloy steels. It can be used to weld chromium steels and austenitic chromium-nickel steels. Plates of 12 to 50mm can be welded with one pass.

Advantages

1. Very high quality welds are produced.
2. It is a very fast method.
3. Deep penetration can be obtained.
4. Shielding accessory for the eyes is not needed.
5. Long joints can be easily welded.

Disadvantages

1. It is not suitable for welding works which is inclined and vertical.
2. The welding zone is not seen. So, it is difficult to guide the electrode movement.

2.12 Electro Slag Welding (ESW)

Principle

Electro slag is a welding process in which the coalescence is formed by molten slag and molten metal pool remains shielded by the molten slag.

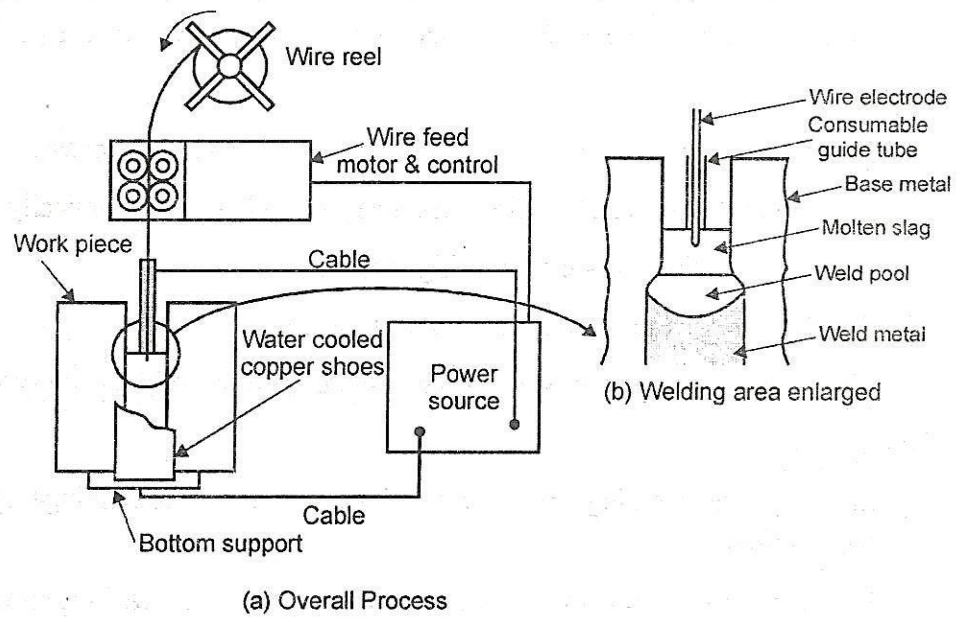


Figure 2.18 Electro Slag Welding Equipment

Working

In this welding process, the electric are is struck between the electrode and work jointed by the use of steel wood. Welding flux is added and melted by the use of heat flux added and further melted by the use of heat from the arc. This action is stopped until the molten slag is formed and molten slag remains between the electrode and the work. The temperature of this slag remains between 1600 to 1900° C inside surface. So, this high amount of heat energy is enough for melting the work piece and the electrode. Thus, the weld is formed.

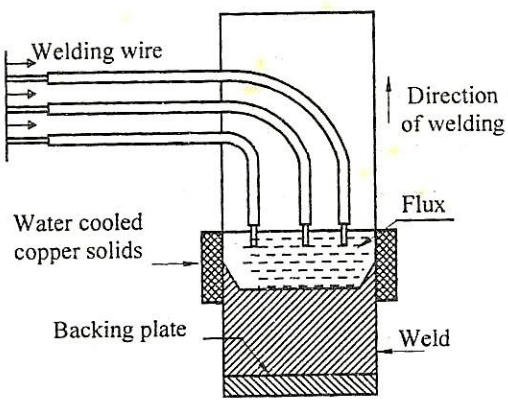


Figure 2.19 Electro Slag Welding process

The electric current passes from the electrode to the work piece through the slag pool. The welding flux used in electro slag welding should be cleared from impurities and oxidation.

Applications

1. It is used for welding carbon steels alloys steels and nickel alloys.
2. Forgings and castings are welded.
3. Heavy plates can be welded.

Advantages

1. Heavy thickness metals can be welded economically.
2. Low stress formation.
3. Preparation of joints is easier.
4. High deposition during the weld.
5. Low distortion.

Disadvantages

1. It is difficult to weld cylindrical objects.
2. Hot cracking may occur.
3. Grain size becomes larger.
4. The cost is high.

2.13 RESISTANCE WELDING

In resistance welding, the parts to be joined are heated to plastic state by their resistance to the flow of electric current and mechanical pressure is applied to complete the weld. In this process, there are two copper electrodes in a circuit of low resistance. The metal parts to be welded are placed between the electrodes. When the current is passed through the electrodes, the electrical resistance at the metal joints becomes very high. So, the metals are brought to red-hot plastic condition. Now, the mechanical pressure is applied to complete the weld. Therefore, the heat developed by the current is proportional to the electric resistance of the weld.

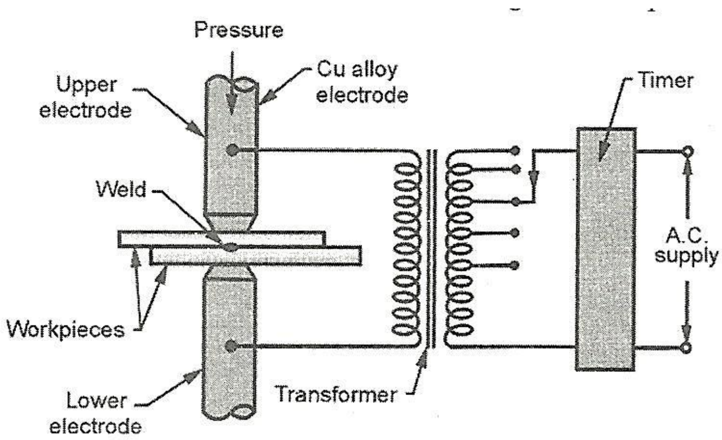


Figure 2.20 Resistance Welding

The heat generated in the weld may be expressed by

Q = RT

Where, Q

I Current in amps

R

T

A.C. with a suitable transformer is used for the power supply. Usually, 4 to 12 volt is used dependent on the composition, area and thickness of the metal to be welded. The power supply ranges from 6 top 18kW per area used.

Resistance welding is used in mass production for welding sheet metal, wire and tubes. It is also used in welding bars, boxes, cans, rods pipes and frames metals of medium and high resistance such as steel, stainless steel, monel metal and silicon bronze which are easy to weld.

The various types of resistance welding are:

1. Spot-welding
2. Seam welding
3. Butt-welding
4. Projection welding
5. Percussion Butt-welding

2.13.1 Spot welding

It is one type of electrical resistance welding process. Spot welding is used for making lap joints. By using this method, the metal sheets from 0.025 mm to 1.25 mm thickness can be easily welded. The metal pieces are assembled and placed between two copper electrodes and then current is passed. The parts are heated at their area of contact by electrical resistance. Then the electrodes are pressed against the metal pieces by mechanical or hydraulic pressure.

The electrodes must possess high electrical and thermal conductivity and retain the strength at high temperature. So, they are made of pure copper for a limited amount of service and of alloys of copper or tungsten. The electrode pressure can be in the range of up to 2kN. They are made of cold rolled electrolytic copper – transfer or molybdenum alloys. Electrodes are cooled with water during the operation to prevent overheating.

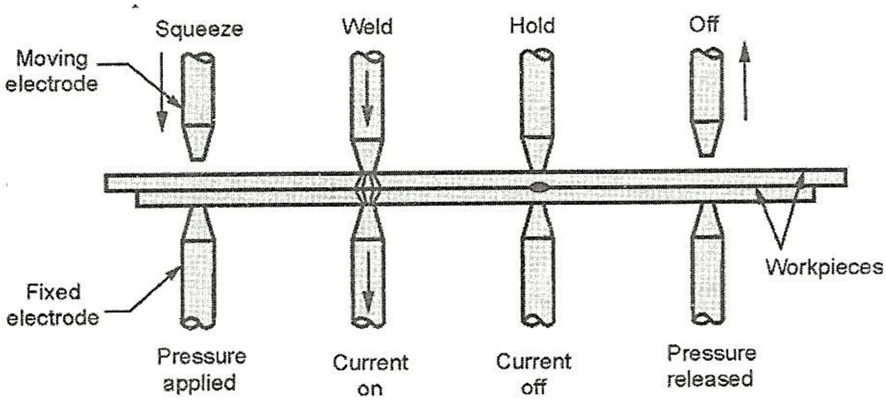


Fig. 2.21 : Stages in making a spot welding

Spot welding can be done on metal strips up to 12mm thick. All combination of ductile metals and alloys can be spot-welded. It is used for fabricating all types of sheet metal structure where the mechanical strength rather than water or air tightness is required.

2.13.2 Butt Welding

This is one kind of resistance welding. There are two types of butt-welding, namely

1. Upset butt welding
2. Flash butt welding.

1. Upset butt-welding

For making upset welding, the edges of the work piece should be cleaned perfectly and flatten the parts to be welded are clamped in copper jaws, as shown in figure. The jaws act as electrodes. Both the work pieces of edges are prepared and butted together.

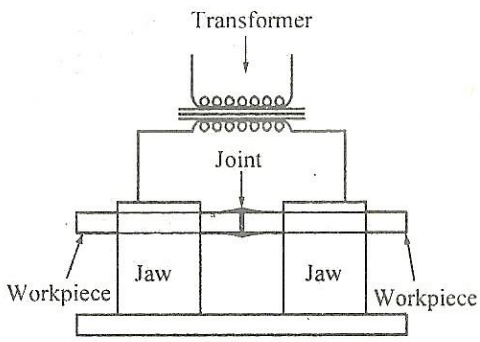


Figure 2.22 Upset butt-welding

There may be some gap between the parts, but it should be such that no arcing takes place. Then the jaws are brought together in a solid contact when the current flaws through the point of contact of jaws to form a locality of high electric resistance. At this point, the applied pressure upsets or forges the parts together. This process is mainly used for welding nonferrous materials of smaller cross section such as bars, rods, wire, tube etc.,

2. Flash butt welding

In this process, the parts to be welded are clamped in copper jaws of the welding machine. They act as electrodes. The jaws are water-cooled. They are connected to the heavy current electric power supply. The work pieces are brought together in a slight contact when the current flows through the work pieces, an electric arc or flash is produced. The ends reach fusing temperature and power is switched off. Now, the ends are forced together by applying mechanical force to complete the weld. In this welding, a small projection is produced around the weld. That projection is finished by grinding. This process is used for the part having larger cross section. This process is suitable for welding steel and ferrous alloy other than cast iron.

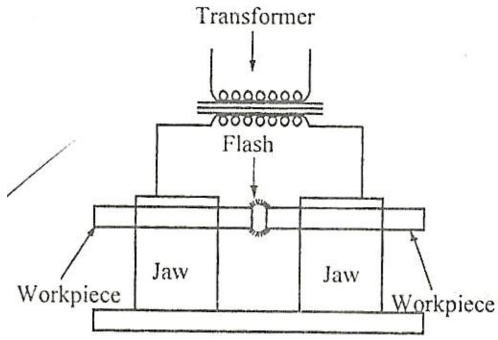


Figure 2.23 Flash butt welding

A major advantage of flash butt welding is that many dissimilar metals with different melting temperature can be flash welded. Butt welding is used in automobile construction of the body, axles. Wheels frames etc., The non ferrous alloys such as lead, tin, zinc, antimony, bismuth and their alloys cannot be welded by this method.

2.13.3 Seam Welding

In previous, spot welding is not continuous one where as seam welding is used to produce continuous joint between two overlapping pieces of sheet metal. The work pieces are placed between two rotating wheel electrodes when electric current is passed through the electrodes. High heat is produced on the work pieces between wheels. At the same time, the pressure is applied to complete the weld. The work piece is continuously moved in between the wheels. Thus, the leak proof continuous seam is achieved by supplying coolant to the electrodes. Finally, it speeds up the welding process.

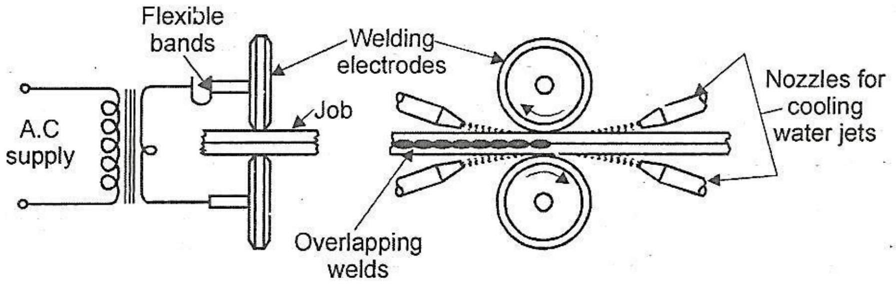


Figure 2.24 Seam Welding

Applications

Seam welding is used to make leak proof tanks, drums, radiators, household utensils, automobile bodies etc. It is also used for welding thin sheets.

2.13.4 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 work pieces. 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, causing an intense are 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. The method is also used to weld pins, studs, bolts and so on. This method is limited to small areas of about 150 to 300 mm^2.

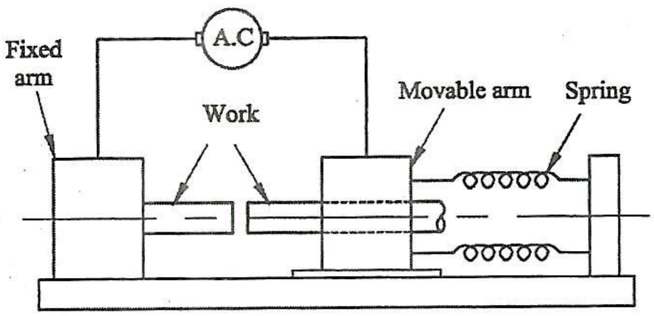


Figure 2.25 Percussion Welding

2.13.5 Projection welding

Projection welding is one kind of resistance welding which is developed from spot welding. In this, a series of spots are welded at a time. The metal pieces to be welded are placed between two metal arms which act as electrodes. One of the work pieces has projections on its surface. The work pieces are clamped between the arms. When A.C. is supplied, the welding current will be passed through these projections.

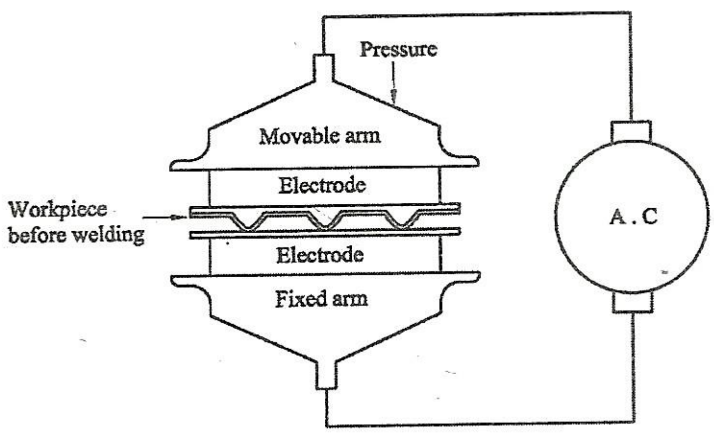


Figure 2.26 Projection welding

The heat is produced at the contact point of the base metal because of electrical resistance. Now, the work pieces are pressed together by bringing down the upper electrode. The projections are made into flat under pressure and the two pieces are joined together by a strong weld at all points of contact. The surface at the projection must be cleaned. There should not by any scale on the surface. An un-cleaned surface will reduce the resistance to the current flow. So the joint will be weaker.

Projection welding is used for joining thin sheet metals of thickness upto to 3 mm. It is used in automobile industries. A wire or rod may be easily welded on its length of a flat surface. This welding process is used in mass production.

2.14 Plasma Arc Welding

Conventional methods are not suitable for machining metals such as cast alloy, wasp alloy, carbides having promising applications in various industries also machining these materials in conventional methods causing increased machining cost. So, these types of materials in special welding methods are preferred. It will increase the productivity, number of rejected components are reduced and achieving the close tolerance.

Principle

Plasma is high temperature ionized gas. It is a mixture of neutral atoms, positively charged atoms and free elements. When this high temperature plasma is passed through the orifice, the proportion of the ionized gas increases and plasma arc welding is formed.

Working

When the high heat content plasma gas is forced through the torch, orifice is surrounded by negative tungsten electrode in the form of jet. The plasma cutting force imposes a swirl on the orifice gas flow. The arc is initiated in the beginning by supplying electrical energy between nozzle and tungsten electrode. This will release high energy and heat. This heat is normally in between 10000°C to 30000°C. This high amount of heat energy is used to weld the metal they are two types plasma are welding used practically, They are

1. Transfer type, and
2. Non-transferred type

Transferred type

In transferred type, the tungsten electrode is connected to the negative terminal and the work piece is connected to the positive terminal. An electric are in maintained between the electrode and the work piece heats a so-axial flowing gas and maintains it in a plasma state. It is difficult to initiate the arc first between the work piece and the electrode. For that, the pilot are is struck between the nozzle and the electrode.

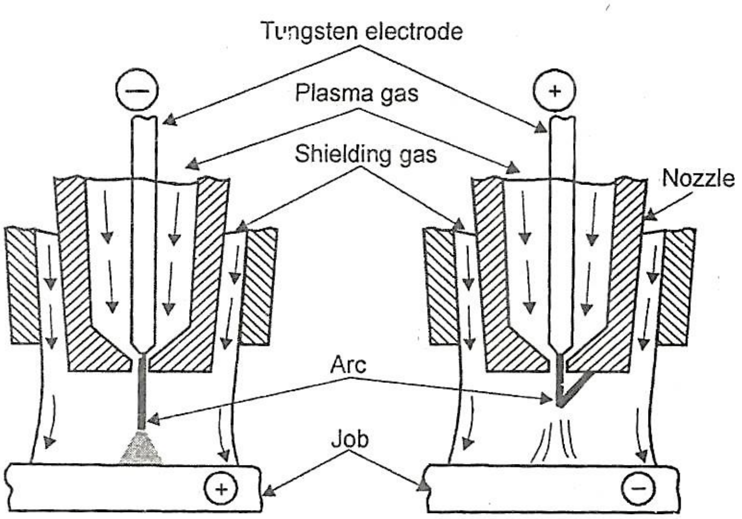


Figure 2.27 Plasma Arc Welding

Non-transferred type

In this type, power is directly connected with the electrode and the torch of nozzle. The electrode carries the same current. Thus, the ionizing is at high velocity gas that is strewing towards the work piece. The main advantage of this type is that the spot moves inside the wall and heat the incoming gas and outer layer remains cool. This type plasma has low thermal efficiency.

The base metals welded by plasma arc welding are:

1. Stainless steels
2. Titanium alloys
3. Carbon and low alloy steels
4. Copper alloys
5. Aluminum alloys

The types of joint which are made by plasma arc welding are:

1. Filler welds
2. T-welds
3. Grooves (Single groove (or) „V" groove)
4. Square groove

Applications

1. It is used in aerospace applications.
2. It is used for melting high melting point metals.
3. It is used for welding titanium plates.
4. It is used in welding nickel alloys.
5. It is used for tube mill applications.

Advantages

1. Penetration is uniform
2. Arc stability is good
3. Fully penetrated keyholes can be obtained
4. High accuracy weld can be produced
5. High speed weld can be obtained

Disadvantages

1. Huge noise occurs during welding.
2. Chances of electric hazards may occur during welding.
3. It is limited to high thickness applications.
4. Ultraviolet radiations can affect human body.
5. Gas consumption is high.

2.15 Thermit welding

Thermit welding comprises a group of welding processes wherein coalescence is produced by heating with superheated liquid metal and slag resulting from chemical reaction between and metal oxide and aluminum, with or without the application of pressure. The liquid metal acts as filler metal too.

Procedure of thermit welding

The various steps involved in the non-pressure fusion thermit welding of metal parts are given below. The mold is non-repetitive in nature and is used for repair welds.

Clean the joint

An oxyacetylene torch may be used to clean the metal surfaces by heating. During cleaning, all dirt, grease, loose oxides, scale, etc., must be removed.

Allow for contraction

After cleaning, the part to be welded are to be linked up with a space of about 1.5 to 6mm between the ends, depending upon the size of the parts to be joined.

This space makes up for

1. The contraction of the thermit steel in cooling
2. The shrinkage of the base metal which has been heated during the welding Operation.

Construct the mold

After the parts have been cleaned and spaced properly, the next stage is the making of the wax pattern from which the mould will be formed and which must in shape constitude a replica of the eventual weld.

The molding material should be about 100mm thick between the wax pattern and the molding box at all points.

The mold should provided with the necessary number of pouring gates, heating gates and risers depending on the size of the weld.

Preheating the mold

The mold prepared as above is then preheated in order to:

1. Melt away and remove the wax thereby leaving a mold cavity in the exact shape of the Weld.
2. Dry the mold thoroughly otherwise the superheated molten metal will form steam within the mold and cause porous weld.

Crucible and its charging

Thermit mixture is charged in the container knows as crucible or reaction vessel. The vessel is of conical shape and is lined with management tar-lining.

The outside shell of this vessel is made up of sheet steel. Located at the bottom of the vessel is a magnesia stone and magnesia thimble through which the tapping pin is suspended.

The thimble is plugged by suspending the tapping pin through the thimble and placing a metal disc above the pin. This disc is then covered with refractory sand.

After drying the crucible, small quantity of the thermit power is first introduced, the object being to avoid damage to the refractory sand layer and to cushion off the plugging material in the bottom of the crucible from the impact of the full weight of the thermit charge.

Igniting the thermit mixture

A low ignition point thermit in the form of a powder is placed on the top of the thermit in the crucible.To ignition the reaction, the low ignition-temperature thermit is contacted with a hot rod. This ignition immediately starts the reaction in the main thermit charge.

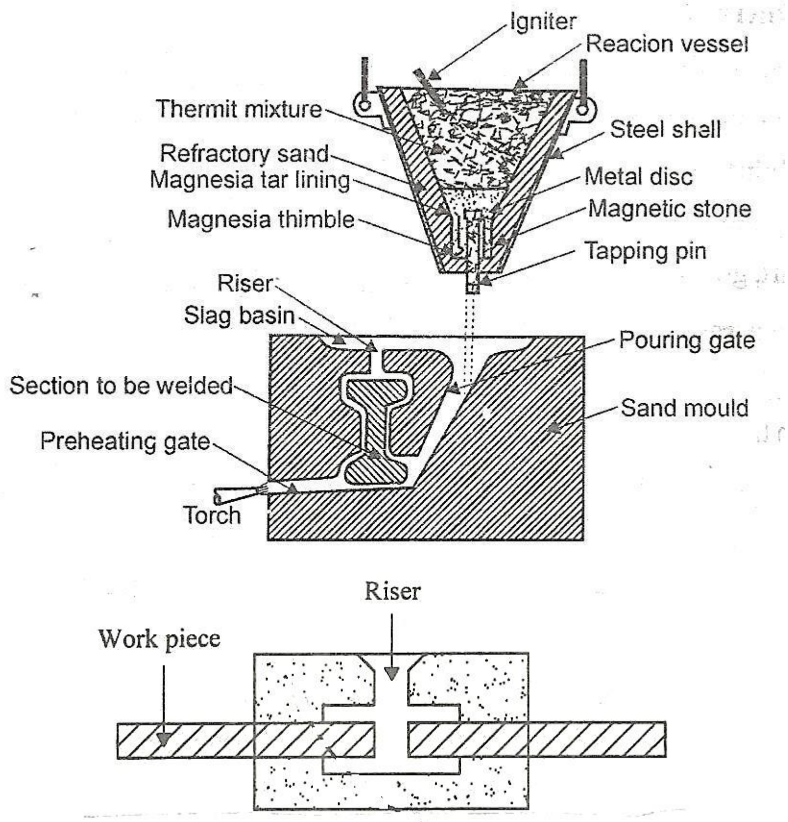


Figure 2.28 Thermit welding

Opening the mold

The actual period for which the mold is left unopened depends upon the dimensions of the weld, being shorter (two or three hours) for small sections and longer (about four hours) for heavy sections. The longer the mould can be left unopened, the better it is.

Finishing the weld

After removing the mold, the risers and gates are cut away with a cutting torch. In case of shafts or parts requiring specific finished contour the same can be given by either machine or grinding.

Advantage

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

Limitations

Thermit welding is applicable only to ferrous metal parts of heavy sections, i.e., mill housing and heavy rail sections.

The process is uneconomical if used to weld cheap metal of light parts.

2.16 Electron Beam Welding (EBM)

Principle

Beam of electron is used for producing high temperatures and melting the work piece to be welded.

Working

When tungsten filament is electrically heated in vacuum, it will emit the electrons. This electrons carrying the negative charge which is passed through the anode hole. The electron beam is focused by the focusing lens. When the focused electron beam strikes the work piece, the kinetic energy of this electron beam is converted into heat energy. This heat energy is used to weld the metals. The operation is carried out in vacuum. So, it is possible to weld holes. The beam are focused about 0.25 to 1mm diameter and the power density of 10kW/mm2. Aluminium material has focusing length of about 40mm and steel about 30mm.

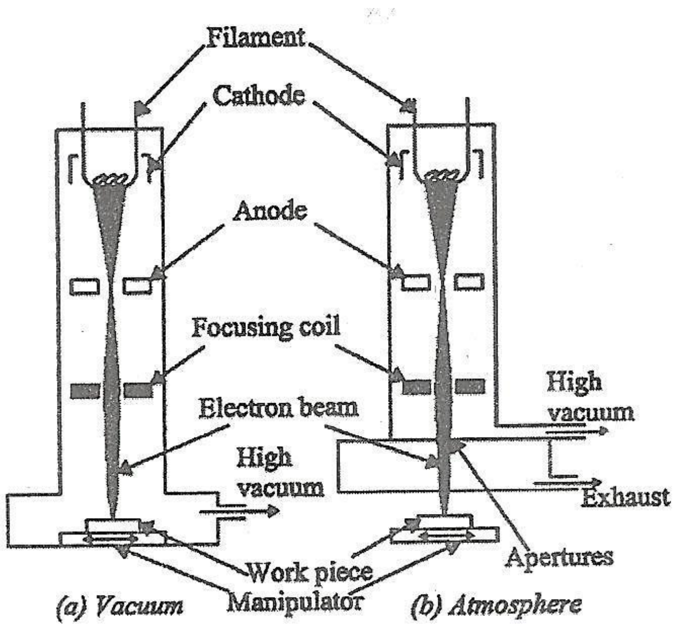


Figure 2.29 Electron Beam Welding

The variables which are controlled in the electron beam welding are:

1. Voltage
2. Speed
3. Distance between beam gun to work piece.

Advantages

1. High quality weld is produced.
2. Deep welding is possible.
3. Clean and bright weld can be obtained.
4. High speed operation can be achieved.
5. Dimensional accuracy is good.
6. Energy loss is very less.

7. Very small part can be welded.
8. There is no need of using electrodes.

Disadvantages

1. The cost is high.
2. Skilled persons are required.
3. It is limited to small size welding.
4. Welding should be carried out in vacuum seal only.
5. It is a time consuming process.

Applications

1. Dissimilar metals can be welded.
2. Refractory and reaching metals can be welded.
3. It is used in aircrafts.
4. It is suitable for large scale.
5. It is used in cams.

2.17 Friction welding

Principle

It is a solid state welding process wherein coalescence is formed by the heat which is obtained from mechanically induced sliding motion between rubbing surfaces.

Working

Initially, the components to be welded are held under pressure. One part is rotated at high speed and other part is held stationary. In this welding, the movable clamp is moved and contacted with the rotating component. The heat is produced between contact surfaces. This heat is used to weld the components under pressure. The pressure during welding may be about to few Mpa.

During this period, the metal is slowly extruded from the weld region to form on upset. For stopping the relative motion, the brake system is applied.

The parameters which are considered in friction welds are:

1. Friction Pressure
2. Speed
3. Burn off.

The materials that can be welded are listed below.

1. Brass of Bronze
2. Nickel
3. Titanium alloys
4. Stainless steel
5. Aluminium and aluminium alloys

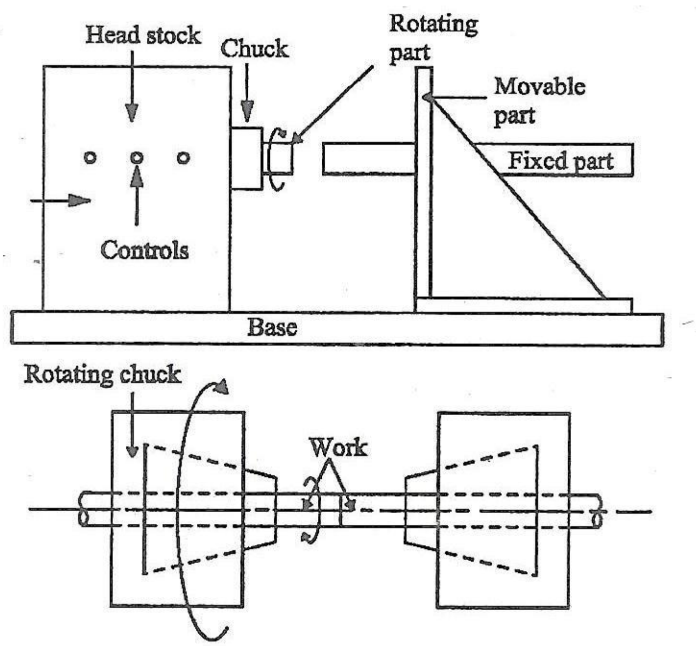


Figure 2.30 Friction welding

The basic joints are made by friction welding as follows:

1. Bar-belt Joint
2. Bar-Ball Joint
3. Tee-Butt Joint.

Applications

1. It is used in super alloys.
2. It is used in produce axle shafts, valves and gears.
3. It is used in production cutting tools such as tapers reamers drills.
4. It is used in refrigeration.
5. It is used for making simple forgings.
6. It is used for manufacturing of all steel alloys.

Advantages

1. Power consumption is low.
2. The operation is easy.
3. Parameters are easily determined.
4. It is smooth and clean process.
5. Heat is quickly dissipated.
6. It is an automation process.
7. There is no filler metal flux

Disadvantages

1. Heavy components are not used for weld.
2. There is a possibility of heavy flash out.
3. Heavy rigid machines are required.
4. It is not suitable for flat and angular welds.

Difference between friction welding and Inertia welding:

Friction Welding	Inertia Welding
1. Power from electric motor.	1. Power from flywheel.
2. Size of the motor limits the power.	2. Power is independent of the size of the motor.
3. Heat is produced by sliding motion	3. Heat is produced by intermolecular bonding.
4. Friction speed is very important.	4. Speed of the flywheel is very important.

2.18 Friction stir welding

Friction stair welding (FSW) is a solid state welding process in which a rotating tool is fed along the joint line between two work pieces. During welding, heat is generated due to friction and the metal is mechanically stirring to form the weld seam. FSW differs from normal friction welding in such a way by generating friction heat by a separate wear-resistant tool instead of the parts between them.

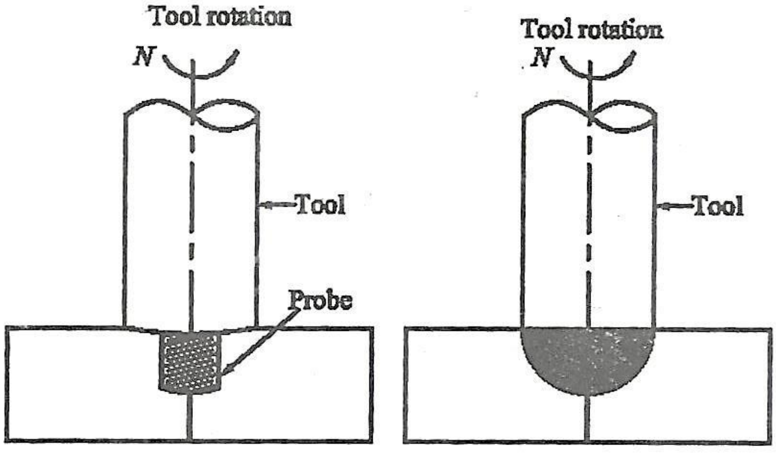


Figure 2.31 Friction stir welding

In friction stir welding process, the rotating tool consists of a cylindrical shoulder rubs against the top surfaces of the two parts thereby developing friction heat and the probe simultaneously generates additional heat by mechanical mixing of the metal along the butt surfaces. At the same time, the probe has been designed in order to perform the mixing perfectly. The heat is produced by the combination of friction and mixing but the metal will not melt but it softens. The softening of metal takes place up to a highly plastic condition. When the tool moves forward along the joint, the leading surface of the rotating probe is forcing the metal around it. Then the developed force forges the metal into a weld flowing around the probe.

FSW process is used in: aerospace, automotive, railway, and shipbuilding industries. The main applications are butt joints on large aluminium parts. Sometimes, steel, copper, and titanium, as well as polymers and composites are also jointed by using FSW.

Advantages

1. It ensures the good mechanical properties of the weld joint.
2. It avoids toxic fumes, warping, shielding issues, and other problems associated with are welding.
3. It permits less distortion or shrinkage on joints.
4. It provides good weld appearance.

Disadvantages

1. An exit hole remains the same after the tool is withdrawn from the work.
2. Heavy-duty clamping of the parts is required.

2.19 Soldering, Brazing and Braze Welding

2.19.1 Soldering

Soldering is a common process for joining steel, copper and other materials at low temperature.

It is defined as a group of joining processes where coalescence is produced by heating to a suitable temperature and by using a filler metal having a liquidus not exceeding 427°C and below the solidus of base metals.

The filler metal (solder) is generally distributed between the properly fitted surfaces of the joint by capillary action.

Soldering is divided into two types i.e.

- Soft solder
- Hard Solder

Soft soldering is used in sheet metal work for joining parts that are not exposed to the high temperature action and not subjected to excessive loads and forces.

Soft soldering is also used for joining wires and small parts.

A suitable flux is always used in soft soldering.

Zinc chloride is a common flux used in this process.

The function of flux is to prevent oxidation of the surfaces to be soldered or to dissolve oxides that settle on the metal surfaces while heating process.

A blow torch or soldering iron constitutes the equipment for heating the base metals and melting the solder and the flux.

Hard soldering uses solders which melt at higher temperatures and are stronger than those used in soft soldering.

Silver soldering is a hard soldering method and in that silver alloyed with tin is used as solder.

The temperature of hard solders vary from 600 to 900°C.

The fluxes are generally in the form of paste and applied to the joint before heating by using brush.

In hard soldering, blow torch constitutes the equipment.

Figure 2.32 shows the commonly used soldering iron.

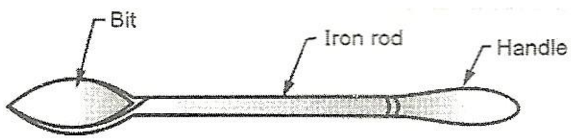


Figure 2.32. Soldering Iron

It consists of a copper bit tapered to form an edge at its end which is fastened to an iron rod in a wooden handle.

Any source of heat is satisfactory for heating the bit.

Generally, the bit is heated in gas or coke fire, cleaned, dipped in flux and then rubbed against the solder.

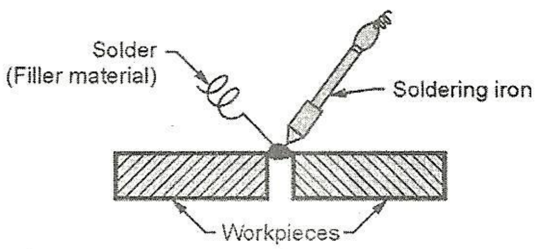


Figure 2.33. Soldering Processes

All soldering techniques requires almost same procedure as discussed below Refer figure 2.33.

1. Clean the metal parts to be joined.
2. Fit the joints and heat the parts.
3. Apply the flux and filler materials.
4. Remove the heat and hold the assembly until the filler metal has completely solidified.
5. Clean the of cooled parts, if required.

Soldering filler materials

The various soldering filler materials (solders) are as follows:

1. **Tin – lead solders:** They possess good corrosion resistance and used to join most of the metals.
2. **Tin – antimony solders:** They are having poor flow characteristics and generally used for soldering of copper and its alloys.
3. **Cadmium – silver solders:** They are used for joining aluminum to itself or to other metals. Because of cadmium sometimes it is hazards to health.
4. **Zinc-aluminum solders:** They are used for joining aluminum. They develop joints with high strength and good corrosion resistance.

Soldering fluxes

The purpose of soldering flux is to remove and exclude small amounts of oxides and other surface compounds from the surfaces being soldered and prevent reoxidation of the surfaces while soldering. The commonly used soldering fluxes are as follows:

1. Corrosive fluxes (consist of zinc and aluminum chloride)
2. Non – corrosive fluxes (consist of gum exuded from pine trees)
3. Mild fluxes (consist of lactic acid, stearic acid, benzoic acid and glutamic acid)

Advantages

By soldering process variety of dissimilar metals can be joined.

It is a simple and low cost method.

Workpieces of different thickness can also be joined.

The joint formed in the process, do not require any machining.

Soldering is a low temperature process, hence there is no change in the properties of metals.

Disadvantages

Soldered joints do not have much strength, so the process should not be used for high load carrying members.

Since soldering temperatures are low, a soldered joint has limited service at elevated temperature.

Corrosion resistance of soldered joint is less.

Commonly used solder alloys are mixtures of tin and lead but, the used lead is toxic in nature.

Applications

Soldering process is commonly used for joining following components:

Most frequent application of soldering is assembly of electronic components (chips, IC‟s, etc.) to printed circuit boards.

Joints in sheet metal objects like food cans, roof flashing, iron, etc.

Joints in the wires.

Now - a- days jewellery components are also assembled and repaired by soldering process.

2.19.2 Brazing

It is defined as a group of joining processes where coalescence is produced by heating to a suitable temperature and by using a filler metal having a liquidus above 470°C and below the solidus of the base metal.

In brazing, metallic parts are joined by a non-ferrous filler metal or alloy.

The filler metal is distributed between the closely fitted surfaces of the joint by capillary actin.

The filler metals used in the process are divided in two types:

- Copper base alloys
- Silver base alloys

Similar to soldering, the parts to be joined by brazing are carefully cleaned, the flux applied and the parts clamped in position for joining.

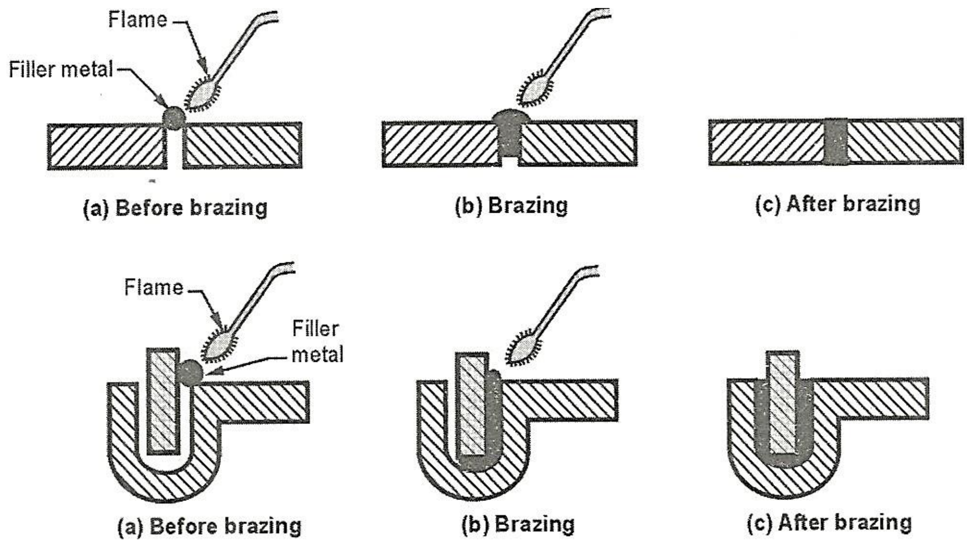


Figure 2.34 Brazing of different components

Borax is commonly used flux in brazing process.

They are then heated to a temperature above the melting point of the spelter (harder filler material) which is then allowed to flow by capillary action into the space between the parts and to slowly cool.

There are various brazing methods such as:

- Torch brazing
- Resistance brazing
- Immersion brazing
- Furnace brazing

Advantages

By brazing process dissimilar metals and non-metals can be brazed.

Due to uniform heating of parts, it produces less thermal distortion than the welding process.

Complicated components can also be brazed at low cost.

It is suitable for mass production.

Machining of the brazed joint is not required.

Brazing does not melt the base metal which allows much tighter control over the tolerances.

Brazing produces a clean joint.

Disadvantages

Strength of the brazed joints is less as compared to welded joints.

Brazed joints can be damaged under high service temperatures.

Brazed joints requires a high degree of base metal cleanliness.

The joint colour is different than that of base metal which creates an asthetic disadvantage.

Filler metals used in the process are costly.

Applications

Brazing is applicable to cast and wrought iron, steel, Cu, A1, Mg and their alloys. Brazing can join:

- Cast metal to wrought metals
- Non-metals to metals
- Dissimilar metals
- Porous metal components

It is used in place of welding where special metallurgical characteristics of metals are required after joining.

Brazing filler metals

A brazing filler metal must possess following properties:

Ability to we the base metals on which it is used.

Proper melting temperature and flow properties.

Desirable mechanical and physical properties in the joint.

Composition of sufficient homogeneity and stability to minimize separation by liquation during brazing.

The filler metals used in brazing are as follows:

1. **Aluminium – Silicon (A1-Si):** It is a general purpose brazing filler metal used where controlled flow is required.
2. **Magnesium (Mg):** It is used for brazing of magnesium alloys.
3. Copper and copper-Zinc (Cu and Cu-Zn): It is used in all brazing process on steel, nickel base alloys giving a better colour match.
4. **Gold:** It is used for joining parts in electron tube assemblies where volatile components are undesirable.
5. **Silver brazing alloys:** They are used for joining most ferrous and non-ferrous metals except aluminium and magnesium using all methods of heating.

Brazing fluxes

The main function of flux in brazing is to prevent oxidation of the base metal and filler metal. It must posses following properties:

It must melt and cover the braze are at a temperature below that of the solidus of the filler metal used.

Low melting point.

Sufficient surface tension.

Low viscosity.

It is easy to remove after brazing. The

commonly used fluxes are listed below.

Fused Borax (for high temperature)

Boric acid (act as a cleaning agent).

Chlorides, Sodium and potassium hydroxides.

Fluoborates (Compounds of fluorine, boron and active metals)

2.19.3 Braze Welding

Braze welding is also called as bronze welding.

Bronze welding does not mean the welding of bronze, but it is a welding using bronze filler rod.

It is a method of welding where a groove, fillet, plug or slot is made by using a non-ferrous filler metal having a melting point below that of the parent metal but above 427°C.

The filler metal is not distributed in the joint by capillary action.

In bronze welding, the edges or surfaces of the material to be joined are heated to a temperature which corresponds to the melting point of the bronze-filling rod used.

Filler rod consists of 60% Cu and 40% Zn, which given high tensile strength and ductility.

The process consists of cleaning the surfaces to be joined, heating them to braze welding temperature which depends on the filler rod composition and applying the flux for removing the oxide.

Generally, the heat source is oxy-acetylene flame.

The main advantage of the process is that, during the operation temperature is low.

Applications

It is used for welding of dissimilar metals.

Metals having high melting point such as steel, cast iron, copper, brass can be bronze welded.

It is also used for fabrication of metal furniture, bicycles, automobiles, refrigerators and domestic appliances.

2.19.4 Comparison between soldering, Brazing and Braze Welding

Sl. No	Parameter	Soldering	Brazing	Braze Welding
1	Principle	The filler metal is usually distributed between the properly fitted surfaces of the joint by capillary action.	The filler alloy is fed To one or more points in the assembly and it is drawn into the rest of the joint by capillary action.	The filler alloy is deposited directly at the point where it is desired.
2	Temperature	Filler metal has melting point below 427°C.	Filler metal has melting point below 427°C.	Filler metal has meting point above 427°C.
3	Strength of Joint	Weak	Strong	Moderate
4	Application	Used for carbon,low alloy steels, cast iron, stainless steel, Cu and alloys, etc	Used for cat iron, steels, Cu and alloys, Mg and alloys, etc.	Used for cast iron, steels, malleable iron Cu, Ni and alloys, etc.

5	Corrosion resistance	Less	More	Moderate
6	Joint Profile	Small gap between the joints.	Smooth joint.	Joint show the ripples.

2.20 Defects in Welding

The improper welding parameters, the base metal and the selection of method introduce defects in the weld metal. So, the defective weld causes failure in service conditions and damages to the properties the defects in weld depending on thickness, load, environment and size of weld. The major defects which are causing in the weld are:

1. Incomplete fusion
2. Cracks
3. Porosity
4. Undercut
5. Distortion
6. Slag Inclusion
7. Lamellar Tearing
8. Overlapping

1. Incomplete Fusion

This is due to improper penetration of the joint. The parameter mainly affects the welding current. If the current is very low, it is not sufficient to heat the metal all over the place. The wrong design of the also weld causes defects.

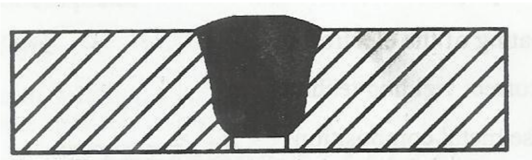


Figure 2.35 Incomplete Fusion

2. Cracks

The cracks are mainly classified into two types

1. Hot Cracking
2. Cold Cracking

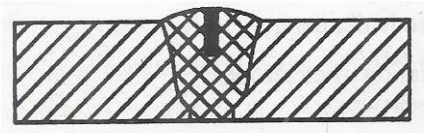


Figure2.36 Cracks

Hot cracking occurs at high temperature and cold cracking occurs at room temperature. The main causes of crack formation are:

1. Arc speed
2. Ductility
3. Solidification rate
4. Temperature

3. Porosity

It is due to the presence of gases in the solidifying metal which are producing porosity. The gases are oxygen, nitrogen and hydrogen. The parameters which are causing porosity are:

1. Arc Speed
2. Coating of the electrode
3. Incorrect welding technique
4. Base metal composition.

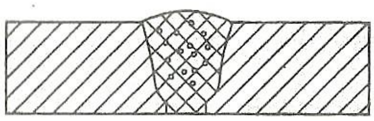


Figure 2.37 Porosity

The sources of hydrogen on the weld pool are electrode coatings. Then the oxygen becomes as oxide form in the pool. Nitrogen enters in the form of atmospheric nitrogen.

4. Undercut:

A groove gets formed in the parent metal along the sides of the weld. The main causes of the undercut are:

1. High current
2. Arc length
3. Electrode diameter
4. Inclination of electrode

5. Distortion

It is defined as the change in shape and difference between positions of two plates during the welding. The base metal under the arc melts and already welded base metal starts cooling. This will create a temperature difference in the weld and will cause distortion.

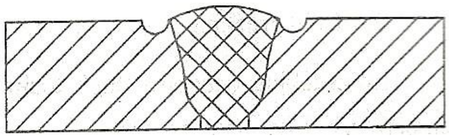


Figure 2.38 Distortion

The factors which are causing distortion are:

1. Arc speed
2. Number of passes

3. Stresses in plates
4. Joint type
5. Order of welding

6. Slag Inclusions:

During the solidification of weld, any foreign materials present in the molten metal will not float. It will be entrapped inside the metal. So, this will lower the strength of the joint.

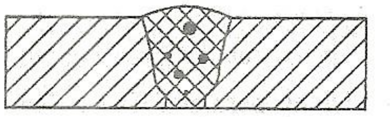


Figure 2.39 Slag Inclusions

7. Lamellar Tearing

This is due to the presence of non-metallic inclusions. It is formed during the non-metallic inclusions running parallel to the plate. It is seen in large structures. T type and corner joints are getting in this type of cracks.

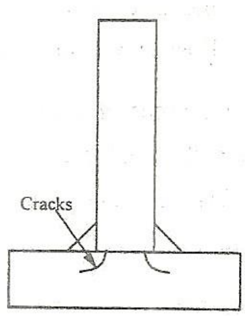


Figure 2.40 Lamellar Tearing

8. Over Lapping

It occurs when the molten metal flows over the parent metal and remains without fusing. The parameters which are causing overlap are:

1. Arc length
2. Arc speed
3. Joint type
4. Current

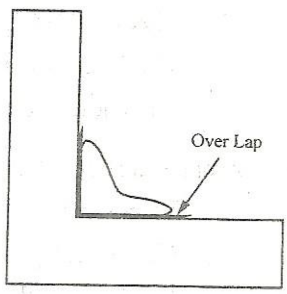


Figure 2.41 Over Lapping