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.

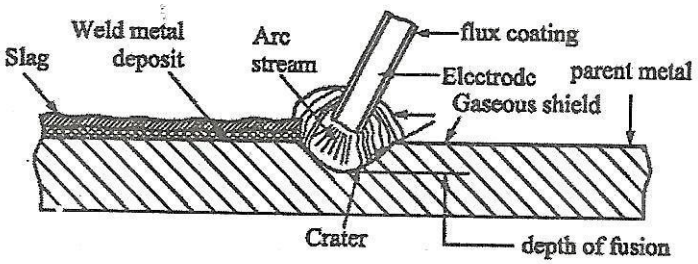


Figure 2.11 Manual metal arc welding process

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

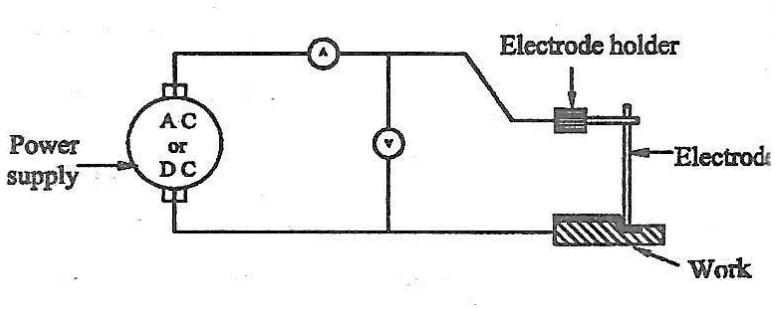


Figure 2.12 Electric arc welding machine components

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

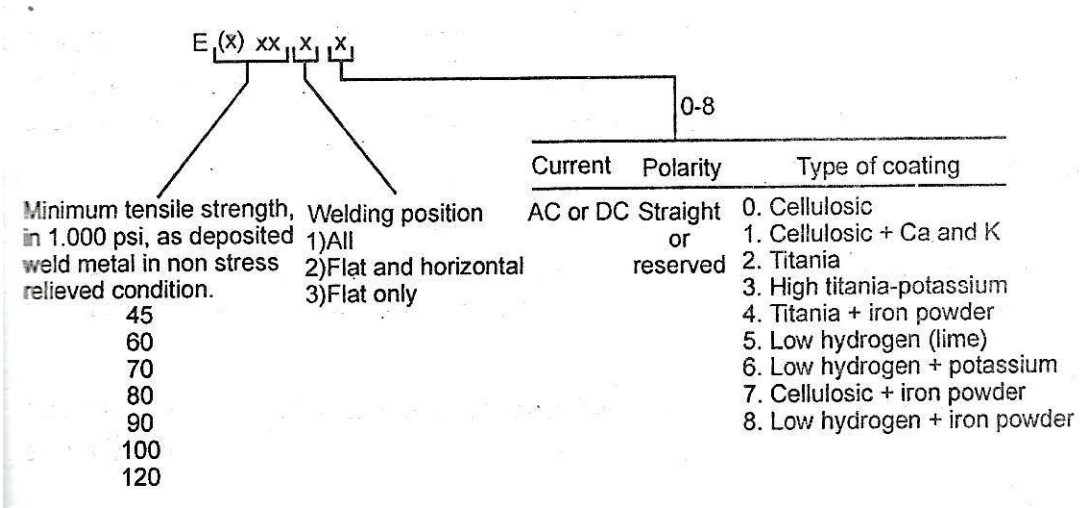
a. Chemical composition of the base metal.
b. Thickness of work piece.
c. Nature of electrode coating (cellulose, rutile, low hydrogen etc)., arc behaviour and metal losses due to volatilization and spatter.

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.

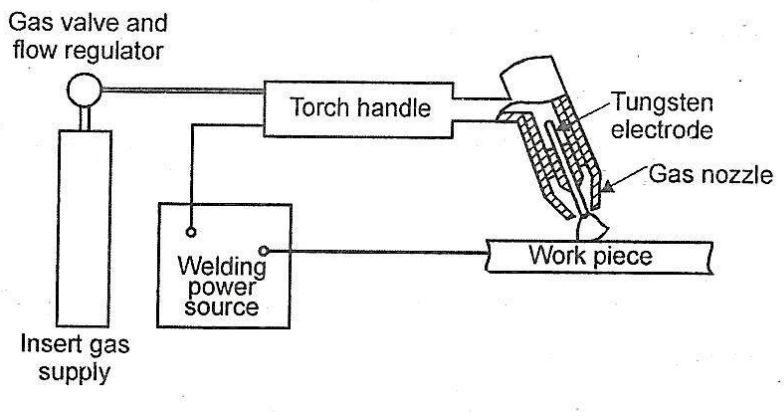


Figure 2.13 Gas Tungsten Arc Welding Equipment

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