Welding Technology

UNIT-4

Arc Welding Process

4.1 Introduction

The arc welding is a fusion welding process in which the heat required to fuse the metal is obtained from an electric arc between the base metal and an electrode.

The electric arc is produced when two conductors are touches together and then separated by a small gap of 2 to 4 mm, such that the current continues to flow, through the air. The temperature produced by the electric arc is about 4000°C to 6000°C.

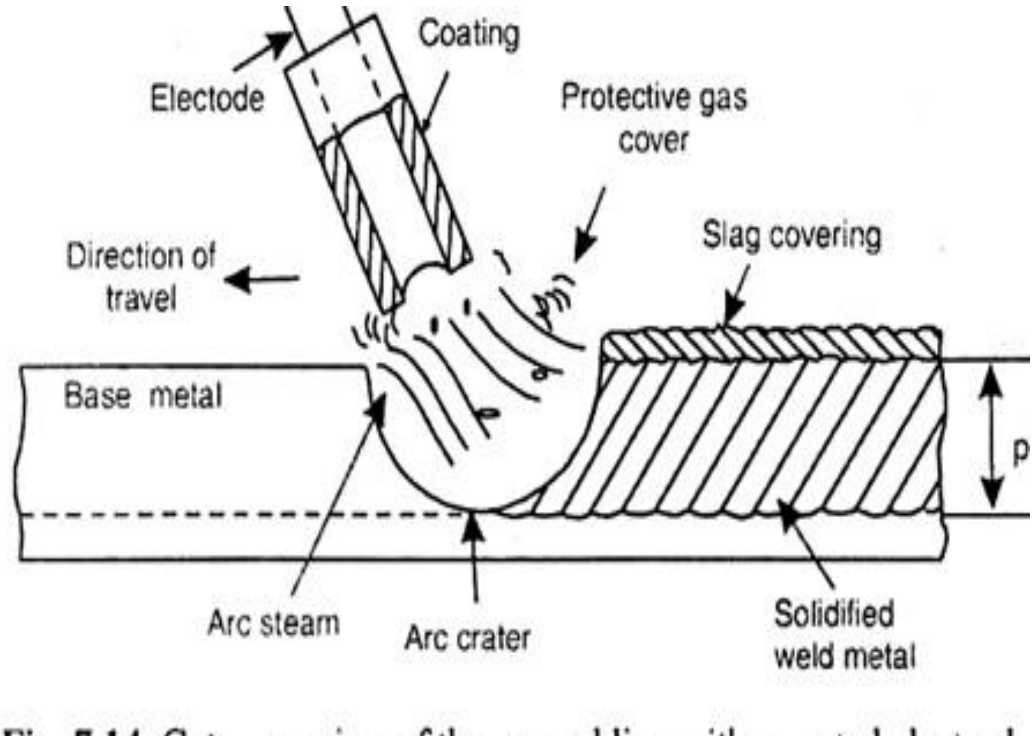


FIG 4.1 : ARC WELDING PROCESS

A metal electrode is used which supplies the filler metal. The electrode may be flux coated or bare. In case of bare electrode, extra flux material is supplied. Both direct current (D.C.) and alternating current (A.C.) are used for arc welding.

4.2 Principle

A welding arc is an electric discharge that develops primarily due to flow of current from cathode to anode. An arc is generated between two conductors of electricity, cathode and anode (considering direct current, DC), when they are touched to establish the flow of current and then separated by a small distance. When it is separated the air between the electrodes is ionised by the potential difference and that reduces electrical resistance of the air column. An arc is a sustained electric discharge through this ionised gas column called plasma between the two electrodes. In order to produce the arc, the potential difference between the two electrodes (voltage) should be sufficient to allow them to move across the air gap. The larger air gap requires higher potential differences. If the air gap becomes too large for the voltage, the arc may be extinguished.

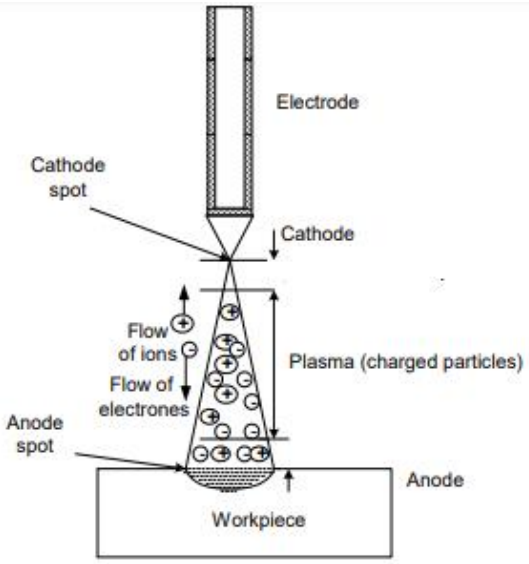


FIG 4.2 : PRINCIPLE OF ARC GENERATION

4.3 Working

- First of all, metal pieces to be weld are thoroughly cleaned to remove the dust, dirt, grease, oil, etc. Then the work piece should be firmly held in suitable fixtures. Insert a suitable electrode in the electrode holder at an angle of 60 to 80° with the work piece.

- Select the proper current and polarity. The spot are marked by the arc at the places where welding is to be done. The welding is done by making contact of the electrode with the work and then separating the electrode to a proper distance to produce an arc.
- When the arc is obtained, intense heat so produced, melts the work below the arc, and forming a molten metal pool. A small depression is formed in the work and the molten metal is deposited around the edge of this depression. It is called arc crater. The slag is brushed off easily after the joint has cooled. After welding is over, the electrode holder should be taken out quickly to break the arc and the supply of current is switched off.

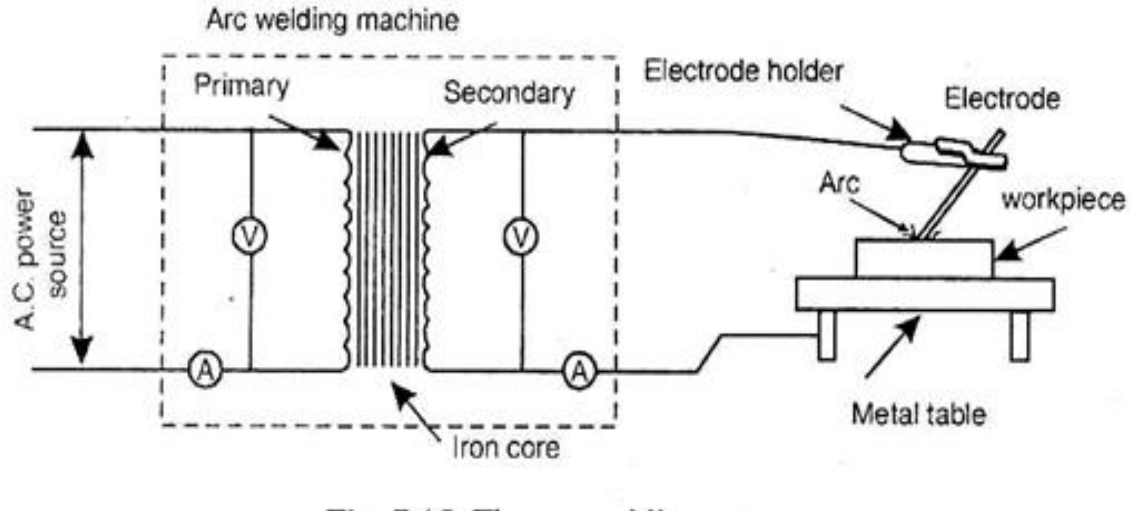


FIG. 4.3 : ARC WELDING SET UP

Electric Current for Welding:

- Both D.C. (direct current) and A.C. (alternating current) are used to produce an arc in electric arc welding. Both have their own advantages and applications.
- The D.C. welding machine obtains their power from an A.C. motor or diesel/petrol generator or from a solid state rectifier.

The capacities of D.C. machine are:

Current:

Up to 600 amperes.

Open Circuit Voltage:

- 50 to 90 volts, (to produce arc).

Closed Circuit Voltage:

- 18 to 25 volts, (to maintain arc).
- The A.C. welding machine has a step down transformer which receives current from main A.C. supply. This transformer step down the voltage from 220 V-440V to normal open circuit voltage of 80 to 100 volts. The current range available up to 400 amperes in the steps of 50 ampere.

The capacities of A.C. welding machine are:

Current Range:

- Up to 400 ampere in steps of 50 ampere.

Input Voltage:

- 220V- 440V

Actual Required Voltage:

- 80 – 100 volts.

Frequency:

- 50/60 HZ.

Significance of Polarity:

When D.C. current is used for welding, the following two types of polarity are available:

(i) Straight or positive polarity.

(ii) Reverse or negative polarity.

- When the work is made positive and electrode as negative then polarity is called straight or positive polarity, as shown in Fig. 4.4 (a).

- In straight polarity, about 67% of heat is distributed at the work (positive terminal) and 33% on the electrode (negative terminal).
- The straight polarity is used where more heat is required at the work. The ferrous metal such as mild steel, with faster speed and sound weld, uses this polarity and with non-consumable electrodes.

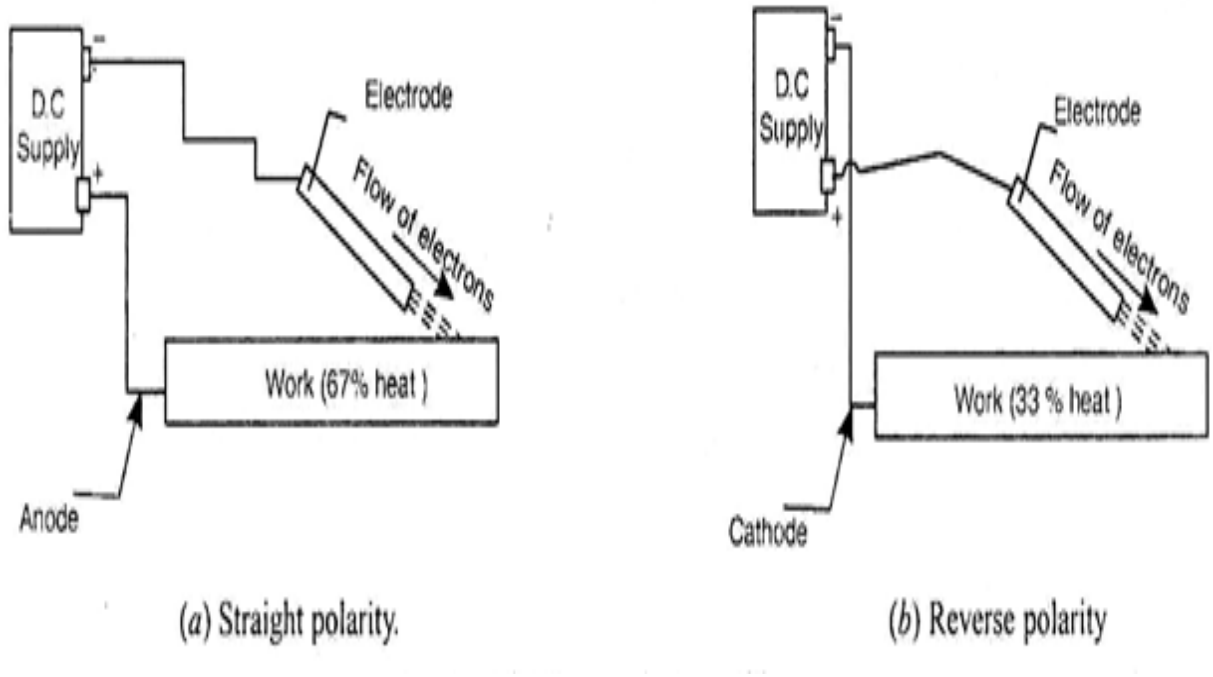


FIG 4.4: POLARITY FOR DC ARC WELDING

(b) Reverse polarity

On the other hand, when the work is made negative and electrode as positive then polarity is known as reverse or negative polarity, as shown in Fig. 4.4 (b).

- In reverse polarity, about 67% of heat is liberated at the electrode (positive terminal) and 33% on the work (negative terminal).
- The reverse polarity is used where less heat is required at the work as in case of thin sheet metal weld. The non-ferrous metals such as aluminium, brass, and bronze nickel are welded with reverse polarity.

4.4 Equipment

The various equipment required for electric arc welding are:

1. Welding Machine:

The welding machine used can be A.C. or D.C. welding machine. The A.C. welding machine has a step-down transformer to reduce the input voltage of 220- 440V to 80-100V. The D.C. welding machine consists of an A.C. motor-generator set or diesel/petrol engine-generator set or a transformer-rectifier welding set.

A.C. machine usually works with 50 hertz or 60 hertz power supply. The efficiency of A.C. welding transformer varies from 80% to 85%. The energy consumed per Kg. of deposited metal is 3 to 4 kWh for A.C. welding while 6 to 10 kWh for D.C. welding. A.C. welding machine usually work with low power factor of 0.3 to 0.4, while motor in D.C. welding has a power factor of 0.6 to 0.7. The following table 4.1 shows the voltage and current used for welding machine.

Table 4.1 : Voltage and Current for Welding Machine

Current (Amp.)	Voltage (volts)
50 to 100	15
100 to 250	20
200 to 250	25
250 to 350	30
350 to 500	35
Over 500	40

2. Electrode Holders:

The function of electrode holder is to hold the electrode at desired angle. These are available in different sizes, according to the ampere rating from 50 to 500 amperes.

3. Cables or Leads:

- The function of cables or leads is to carry the current from machine to the work. These are flexible and made of copper or aluminium. The cables are made of 900 to 2000 very fine wires twisted together so as to provide flexibility and greater strength.

- The wires are insulated by a rubber covering, a reinforced fibre covering and further with a heavy rubber coating.

4. Cable Connectors and Lugs:

- The functions of cable connectors are to make a connection between machine switches and welding electrode holder. Mechanical type connectors are used; as they can he assembled and removed very easily. Connectors are designed according to the current capacity of the cables used.

5. Chipping Hammer:

- The function of chipping hammer is to remove the slag after the weld metal has solidified. It has chisel shape and is pointed at one end.

6. Wire Brush, Power Wire Wheel:

- The function of wire brush is to remove the slag particles after chipping by chipping hammer. Sometimes, if available a power wire wheel is used in place manual wire brush.

7. Protective Clothing:

- The functions of protective clothings used are to protect the hands and clothes of the welder from the heat, spark, ultraviolet and infrared rays. Protective clothing used are leather apron, cap, leather hand gloves, leather sleeves, etc. The high ankle leather shoes must be wear by the welder.

9. Screen or Face Shield:

- The function of screen and face shield is to protect the eyes and face of the welder from the harmful ultraviolet and infrared radiations produced during welding. The shielding may be achieved from head helmet or hand helmet.

4.5 Flux Shielded Metal arc welding

The arc is struck between a flux covered stick electrode and the work pieces. The work pieces are made part of an electric circuit, known as welding circuit. It includes welding power source, welding cables, electrode holder, earth clamp and the consumable coated electrode. Figure 4.5 Shows details of welding circuit.

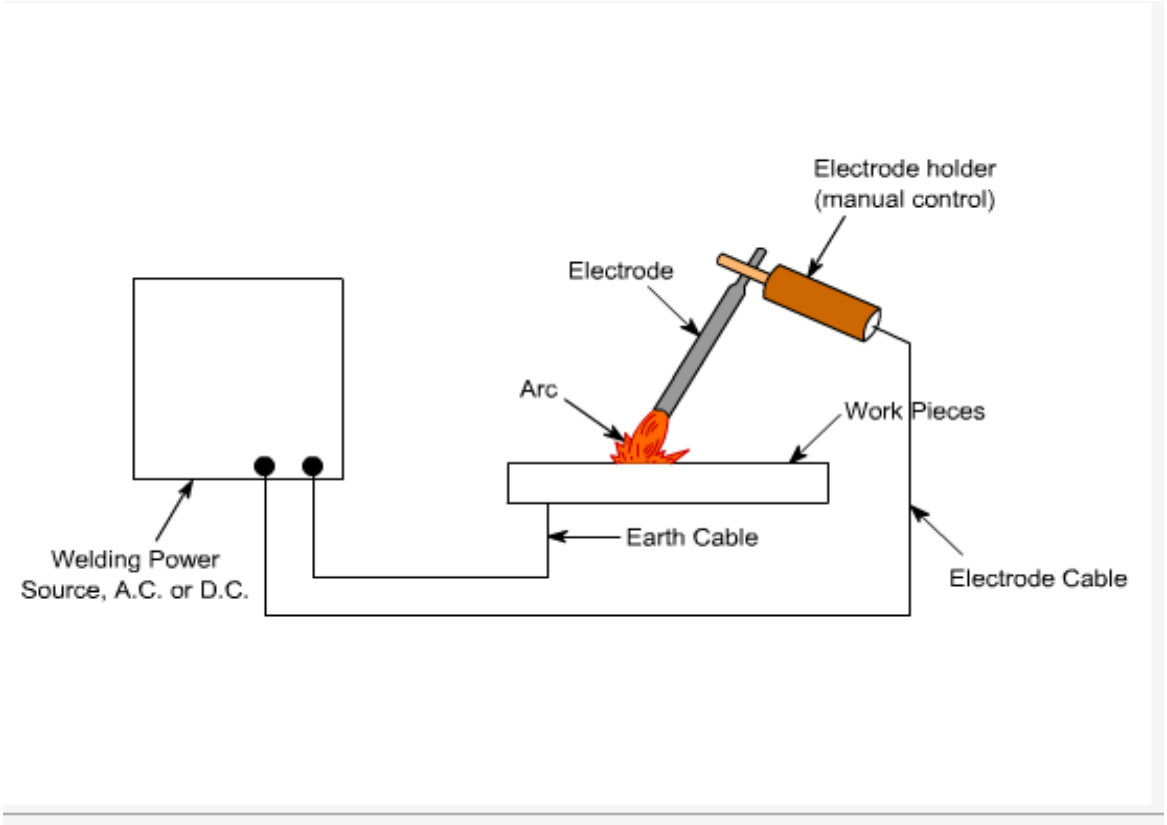
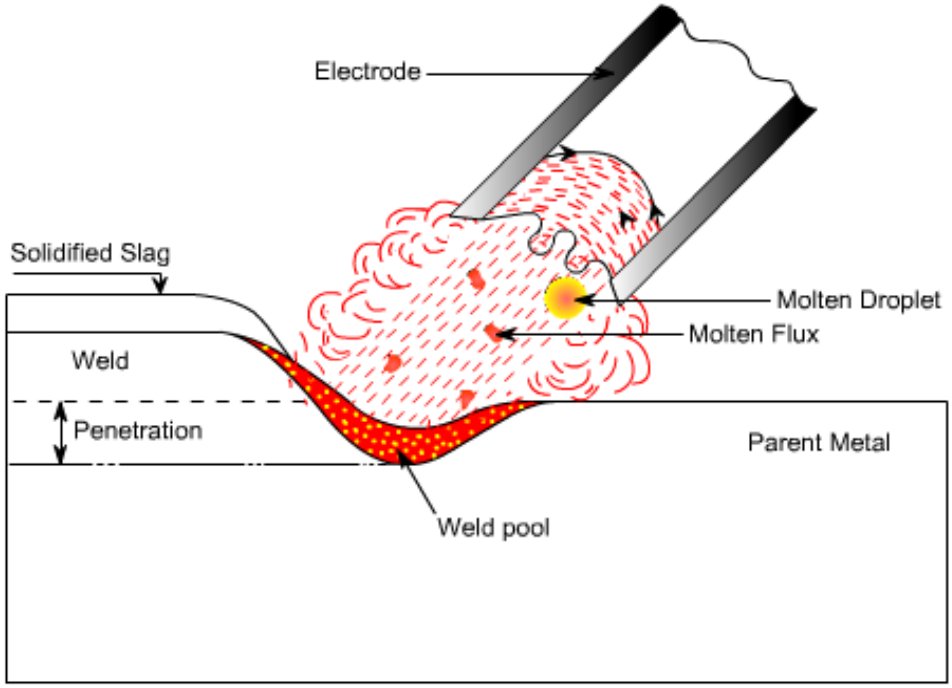


Figure 4.5 : Flux Shielded Metal arc welding circuit.

- Figure 4.6 shows the fine molten droplets of metal and molten flux coming from the tip of the coated electrode. The flux melts along with the metallic core wire and goes to weld pool where it reacts with molten metal forming slag which floats on the top of molten weld pool and solidifies after solidification of molten metal and can be removed by chipping and brushing.

- Welding power sources used may be transformer or rectifier for AC or DC supply. The requirement depends on the type of electrode coating and sometimes on the material to be welded.
- The constant-current or drooping type of power source is preferred for manual metal arc welding since it is difficult to hold a constant arc length. The changing arc length causes arc voltage to increase or decrease, which in turn produces a change in welding current. The steeper the slope of the volt-ampere curve within the welding range, the smaller the current change for a given change in arc voltage. This results into stable arc, uniform penetration and better weld seam inspite of fluctuations of arc length.
- The welding voltages range from 20 to 30 V depending upon welding current i.e. higher the current, higher the voltage. Welding current depends on the size of the electrode i.e. core diameter. The approximate average welding current for structural steel electrodes is 35.d (where d is electrode diameter in mm) with some variations with the type of coating of electrode.



: Molten Metal and Flux Transfer to Weld Pool

Figure 4.6 : Flux Shielded Metal arc welding

Applications:

lit is particularly dominant in the maintenance and repair industry, and is heavily used in the construction of steel structures and in industrial fabrication.

Advantages of Flux Shielded Metal Arc Welding):

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

Disadvantages of Flux Shielded Metal Arc Welding

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

4.6 Sub merged Arc welding

- Submerged arc welding is an arc welding process in which heat is generated by an arc which is produced between bare consumable electrode wire and the work piece.
- The arc and the weld zone are completely covered under a blanket of granular, fusible flux which melts and provides protection to the weld pool from the atmospheric gases.
- The molten flux surrounds the arc thus protecting arc from the atmospheric gases. The molten flux flows down continuously and fresh flux melts around the arc.
- The molten flux reacts with the molten metal forming slag and improves its properties and later floats on the molten/solidifying metal to protect it from atmospheric gas contamination and retards cooling rate.
- The flux may consist of fluorides of calcium and oxides of calcium, magnesium, silicon, aluminium and manganese. Alloying elements may be added as per requirements.
- Substances evolving large amount of gases during welding are never mixed with the flux. Flux with fine and coarse particle sizes are recommended for welding heavier and smaller thickness respectively.
- SAW is normally operated in the automatic or mechanized mode, however, semi-automatic (hand-held) .
- The process is normally limited to the flat or horizontal-fillet welding positions .
- Deposition rates approaching 45 kg/h (100 lb/h) have been reported.
- Although currennts ranging from 300 to 2000 A are commonly utilized, currents of up to 5000 A have also been used (multiple arcs).
- Single or multiple (2 to 5) electrode wire variations of the process exist.
- DC or AC power can be used, and combinations of DC and AC are common on multiple electrode systems.
- Constant voltage welding power supplies are most commonly used; however, constant current systems in combination with a voltage sensing wire-feeder are available.

Electrode

- SAW filler material usually is a standard wire as well as other special forms. This wire normally has a thickness of 1.6 mm to 6 mm (1/16 in. to 1/4 in.).
- Electrodes are available to weld mild steels, high carbon steels, low and special alloy steels, stainless steel and some of the nonferrous of copper and nickel.

- Electrodes are generally copper coated to prevent rusting and to increase their electrical conductivity.
- Electrodes are available in straight lengths and coils.
- Their diameters may be 1.6, 2.0, 2.4, 3, 4.0, 4.8, and 6.4 mm. The approximate value of currents to weld with 1.6, 3.2 and 6.4 mm diameter electrodes are 150–350, 250–800 and 650–1350 Amps respectively.

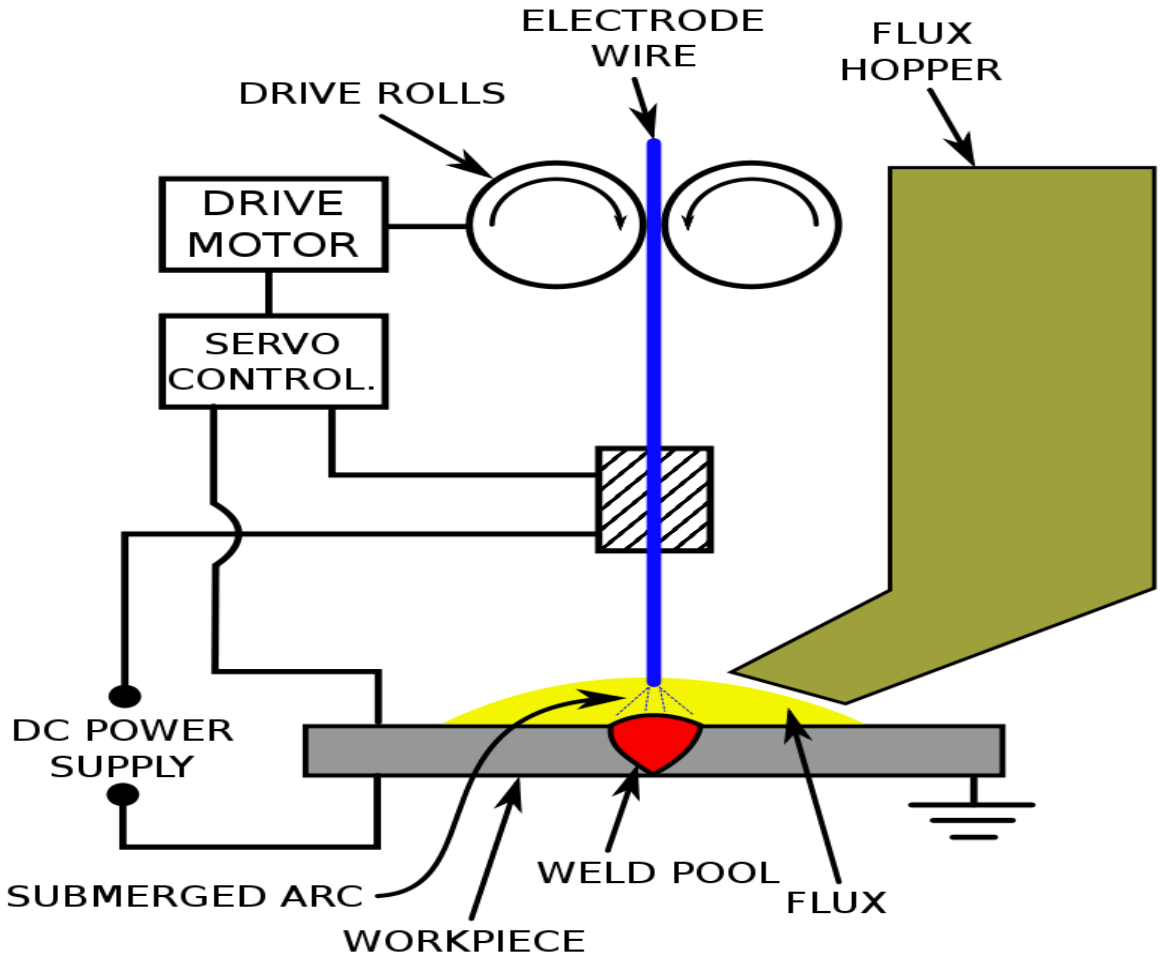


FIG 4.7 : A schematic of submerged arc welding

Material applications

- Carbon steels (structural and vessel construction)
- Low alloy steels
- Stainless steels
- Nickel-based alloys
- Surfacing applications (wear-facing, build-up, and corrosion resistant overlay of steels)

Advantages

- High deposition rates (over 45 kg/h (100 lb/h) have been reported).
- High operating factors in mechanized applications.
- Deep weld penetration.
- Sound welds are readily made (with good process design and control).
- High speed welding of thin sheet steels up to 5 m/min (16 ft/min) is possible.
- Minimal welding fume or arc light is emitted.
- Practically no edge preparation is necessary depending on joint configuration and required penetration.
- The process is suitable for both indoor and outdoor works.
- Welds produced are sound, uniform, ductile, corrosion resistant and have good impact value.
- Single pass welds can be made in thick plates with normal equipment.
- The arc is always covered under a blanket of flux, thus there is no chance of spatter of weld.
- 50% to 90% of the flux is recoverable, recycled and reused.

Limitations

- Limited to ferrous (steel or stainless steels) and some nickel-based alloys.
- Normally limited to long straight seams or rotated pipes or vessels.
- Requires relatively troublesome flux handling systems.
- Flux and slag residue can present a health and safety concern.
- Requires inter-pass and post weld slag removal.
- Requires backing strips for proper root penetration.
- Limited to high thickness materials.

4.7 TIG WELDING (TUNGSTEN INERT GAS WELDING)

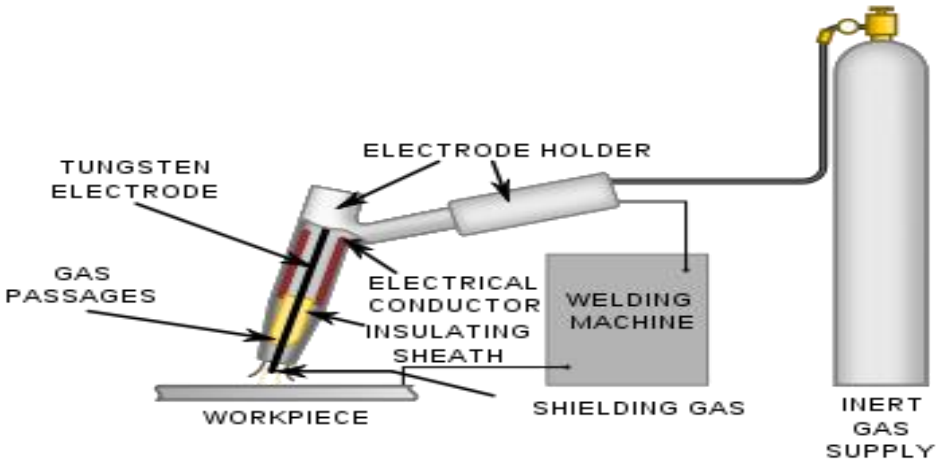


FIG 4.8 : A schematic of TIG WELDING

- Tungsten Inert Gas (TIG) or Gas Tungsten Arc (GTA) welding is the arc welding process in which arc is generated between non consumable tungsten electrode and work piece. The tungsten electrode and the weld pool are shielded by an inert gas normally argon and helium.

EQUIPMENT AND OPERATION

The basic equipment consists of the following:

Power Source:
The first unit of equipment's is power source. A high current power source needed for TIG welding. It uses both AC and DC power source. Mostly DC current is used for stainless steel, Mild Steel, Copper, Titanium, Nickel alloy, etc. and AC current is used for aluminum, aluminum alloy and magnesium. Power source consist a transformer, a rectifier and electronic controls. Mostly 10 – 35 V is required at 5-300 A current for proper arc generation.

TIG Torch:
It is a most important part of TIG welding. This torch has three main parts, tungsten electrode, collets and nozzle. This torch is either water cooled or air cooled. In this torch, collet is used to hold the tungsten electrode. These are available in varying diameter according to diameter of tungsten electrode. The nozzle allows the arc and shielded gases to flow into welding zone. The nozzle cross section is small which gives high intense arc. There are passes of shielded gases at nozzle. The nozzle of TIG needs to replace in regular interval because it wear out due to presence of intense spark.

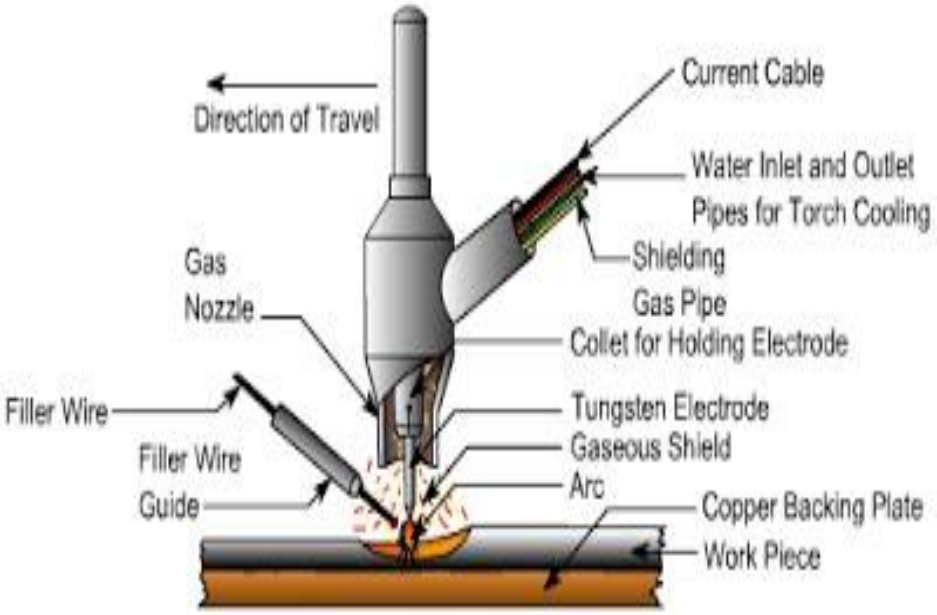
Shielding Gas Supply System:
Normally argon or other inert gases are used as shielded gas. The main purpose of shielded gas to protects the weld from oxidization. Shielded gas does not allow coming oxygen or other air into welded zone. The selection of inert gas is depends upon metal to be welded. There is a system which regulates the flow of shielded gas into welded zone.

Filler Material:
Mostly for welding thin sheets no filler material is used. But for thick weld, filler material is used. Filler material is used in form of rods which are directly feed into weld zone manually.

Working:

Working of TIG welding can be summarized as follow:

- First, a low voltage high current supply supplied by the power source to the welding electrode or tungsten electrode. Mostly, the electrode is connected to the negative terminal of power source and work piece to positive terminal.
- This current supplied form a spark between tungsten electrode and work piece. Tungsten is a non –consumable electrode, which give a highly intense arc. This arc produced heat which melts the base metals to form welding joint.



- The shielded gases like argon, helium is supplied through pressure valve and regulating valve to the welding torch. These gases form a shield which does not allow any oxygen and other reactive gases into the weld zone. These gases also create plasma which increases heat capacity of electric arc thus increases welding ability.
- For welding thin material no filler metal is required but for making thick joint some filler material used in form of rods which fed manually by the welder into welding zone.

Applications

- Gas tungsten arc welding may be used for welding almost all metals — mild steel, low alloys, stainless steel, copper and copper alloys, aluminium and aluminium alloys, nickel and nickel alloys, magnesium and magnesium alloys, titanium, and others.

- This process is most extensively used for welding aluminium and stainless steel alloys where weld integrity is of the utmost importance.

- Another use is for the root pass (initial pass) in pipe welding, which requires a weld of the highest quality.

- For high quality welds, it is usually necessary to provide an inert shielding gas inside the pipe to prevent oxidation of the inside weld bead.

Advantages of Tungsten Inert Gas Arc Welding (TIG, GTAW):

- Weld composition is close to that of the parent metal;
- High quality weld structure
- Slag removal is not required (no slag);

- Thermal distortions of work pieces are minimal due to concentration of heat in small zone.

Disadvantages of Tungsten Inert Gas Arc Welding (TIG, GTAW):

- Low welding rate;
- Relatively expensive;
- Requres high level of operators skill.

4.8 MIG Welding (Metal Inert Gas Welding)

Principle:

MIG works on same principle of TIG or **arc welding**. It works on basic principle of heat generation due to electric arc. This heat is further used to melt consumable electrode and base plate's metal which solidify together and makes a strong joint. The shielded gases are also supplied through nozzle which protects the weld zone from other reactive gases. This gives good surface finish and a stronger joint.

Power Source:

In this **type of welding** process, a DC power supply is used with reverse polarity. Reverse polarity means the electrode or in case of MIG welding electrode wire is connected positive terminal and work piece to negetive terminal. It is due to principle of electric circuit which state that 70% of heat is always on positive side. So reverse polarity ensures that the maximum amount of heat liberate at tool side which melt the filler metal in proper way. Straight polarity can cause unstable arc that result into large spatter. The power source consist a power supply, a transformer, a rectifier which change AC into DC and some electronic controls which control the current supply according to weld requirement.

Wire Feeder System:

We know that MIG welding needs continuous consumable electrode supply for welding two plates. This consumable electrode used in form of wire. These wire is continuously supplied by wire feed mechanism or system. It controls the speed of the wire and also pushes the wire form welding torch to welding area. These are available in different shapes and sizes. It consist a wire pool holder, a driving motor, a set of driving rollers and wire feed controls. The wire feed speed is directly control the current supply through power supply. If the wire feeding speed is high, it required more current in welding zone to produce proper heat for melting of it.

Welding Torch:

This torch is slightly different as used in TIG welding. In this torch there is a mechanism which hold the wire and supply it continuously with the help of wire feed. The front end of the torch is fitted with a nozzle. The nozzle is used to supply inert gases. These gases form a shielding area around the weld zone and protect it from oxidization. The welding torch is air cooled or water cooled according to the requirement. For high current supplied, the torch is water cooled and for low supply it is air cooled.

Shielding Gases:
The primary function of shielding gases is to protect weld area from other reactive gases like oxygen etc. which can affect the strength of welding joint. These shielding gases are also form plasma which helps in welding. The choice of gas is depend on the welding material. Mostly argon, helium and other inert gases are used as shielding gases.

Regulators:
As the name implies, they are used to regulate the flow of inert gases from the cylinder. The inert gases are filled into cylinder at high pressure. These gases cannot be used at this pressure so a regulator is used between the gases supply which lower down the gases pressure according to welding requirements.

Working:

Its working can be summarized as follow.

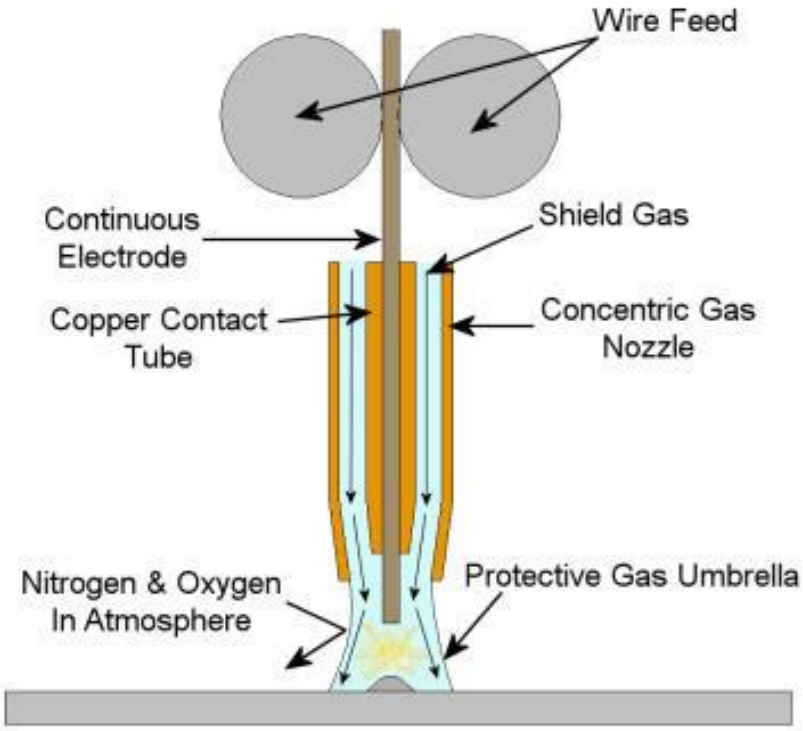


Fig 4.9 : **Metal Inert Gas Welding set up**

- First, a high voltage current is change into DC current supply with high current at low voltage. This current passes though welding electrode.
- A consumable wire is used as electrode. The electrode is connected to the negative terminal and work piece from positive terminal.
- A fine intense arc will generate between electrode and work piece due to power supply. This arc used to produce heat which melts the electrode and the base metal. Mostly electrode is made by the base metal for making uniform joint.
- This arc is well shielded by shielding gases. These gases protect the weld form other reactive gases which can damage the strength of welding joint.

- This electrode travels continuously on welding area for making proper weld joint. The angle of the direction of travel should be kept between 10-15 degree. For fillet joints the angle should be 45 degree.

Applications:

- MIG is best suited for fabrication of sheet metal.
- Generally all available metals can be weld through this process.
- It can be used for deep groove welding.

Advantages of Metal Inert Gas Welding (MIG):

- It provide higher deposition rate.
- It is faster comparing to arc welding because it supply filler material continuously.
- It produce clean weld with better quality.
- There is no slag formation.
- Minimize **weld defects**.
- This welding produces very little slag.
- It can be used to make deep groove weld.
- It can be easily automated

Disadvantages of Metal Inert Gas Welding (MIG):

- Expensive and non-portable equipment is required;
- Outdoor applications are limited because of effect of wind, dispersing the shielding gas.

Difference between MIG and TIG welding:

MIG WELDING	TIG WELDING
1. This welding is known as metal inert gas welding.	1. This is known as tungsten inert gas welding.
2. Metal rod is used as electrode and work piece used as another electrode.	2. Tungsten rod is used as electrode.
3. It is gas shielded metal arc welding.	3. It is gas shielded tungsten arc welding.
4. Continuous feed electrode wire is used which are fast feeding.	4. Welding rods are used which are slow feeding.
5. The welding area is flooded with a gas which will not combine with the metal.	5. Gas is used to protect the welded area form atmosphere.
6. MIG can weld materials such as mild steel, stainless steel and	6. TIG weld things like kitchen sinks and tool boxes. Pipe welding and other heavier tasks can also be performed, you

aluminum. A range of material thicknesses can be welded from thin gauge sheet metal right up to heavier structural plates.	just need to have a unit that is capable of putting out the amount of power that you need.
7. MIG requires consumable metallic electrode.	7. It used non consumable tungsten electrode
8. Electrode is feeded continuously from a wire reel.	8. It does not require electrode feed.
9. DC with reverse polarity is used.	9. It can use both A.C and D.C.
10. Filler metal is compulsory used.	10. Filler metal may or may not be used.
11. It can weld up to 40 mm thick metal sheet.	11. Metal thickness is limited about 5 mm.
12. MIG is comparatively faster than TIG.	12. TIG is a slow welding process.

4.9 Details of welding electrodes

Arc welding electrodes can be classified into two broad categories:

1. Non-Consumable electrodes.

2. Consumable electrodes.

1. Non-Consumable Electrodes:

These electrodes do not consumed during the welding operation, hence they named, non-consumable electrodes. They are generally made of carbon, graphite or tungsten. Carbon electrodes are softer while tungsten and graphite electrodes are hard and brittle.

Carbon and graphite electrodes can be used only for D.C. welding, while tungsten electrodes can be used for both D.C. and A.C. welding. The filler material is added separately when these types of electrodes are used. Since, the electrodes do not consumed, the arc obtained is stable.

2. Consumable Electrodes:

These electrodes get melted during welding operation, and supply the filler material. They are generally made with similar composition as the metal to be welded.

The arc length can be maintained by moving the electrode towards or away from the work.

The consumable electrodes may be of following two types:

(i) Bare Electrodes:

These are available in the form of continuous wire or rods. They must be used only with straight polarity in D.C. welding. Bare electrodes do not provide any shielding to the molten metal pool from atmospheric oxygen and nitrogen.

Hence, the welds obtained by these electrodes are of lower strength, lower ductility and lower resistance to corrosion. They find limited use in minor repair and poor quality work. They used to weld wrought iron and mild steel. In modern practice they are not used or rarely used. They are also known as plain electrodes.

(ii) Coated Electrodes:

These are sometimes also called as conventional electrodes. A coating (thin layer) of flux material is applied all-round the welding rod, and hence termed as coated electrode. The flux, during welding, provides a shielding to the molten metal zone from the atmospheric oxygen and nitrogen. This flux also prevents formation of oxides and nitrides. Flux chemically react with the oxides present in the metal and forms a low melting temperature fusible slag.

The slag is float on the top of the weld and can easily be brushed off after solidification of weld. The quality of weld produced by coated electrode is much better as compared to that of bare electrodes.

Depending on the coating factor or thickness of flux coating, coated electrodes are divided in three groups:

(a) Lightly coated electrodes.

(b) Medium coated electrodes.

(c) Heavily coated electrodes.

A comparison of three types of coated electrodes is given in the Table 7.10:

Table 7.10. Comparison of Coated electrodes.

S. No.	Basis	Light Coated	Medium Coated	Heavily Coated
1.	Flux coating	Less than 1mm	1 to 1.5mm	1.5 to 3mm
2.	Coating Factor	1.25	1.45	1.6– 2.2
3.	Weight of coating	5 to 10%	10 to 15%	15 to 30%
4.	Weld quality	Poor	improved	Best.

Advantages of Flux Coated Electrodes:

The flux coating on welding electrodes has may advantages. Some of them are following:

1. It protects the welding zone from oxidation by providing an atmosphere of inter gas around the arc.

2. It produces low melting temperature slag, which dissolves the impurities present in the metal like oxides and nitrides, and floats on the surface of the weld pool.

3. It refines the grain size of the welded metal.

4. It adds alloying elements to the welded metal.

5. It stabilizes the arc by providing certain chemicals which have this ability.

6. It reduces the spattering of weld metal.

7. It concentrates the arc stream and reduces thermal losses. This result in increased arc temperature.

8. It slows down the cooling rate of weld and accelerates hardening process.

9. It increases the rate of metal deposition and the penetration obtained.

4.10 Ingredients of coating and their functions

The electrode coating may consists two or more ingredients. Different type of coatings used for different type of metals to be welded.

The constituents of typical electrode coatings and their functions are given in table 7 11. Some of them are discussed here:

Table. 7.11. Constituents of Electrode Coatings.

Main Function	Constituent	Percentage
Gas generating	Starch Cellulose Calcium carbonate	25-40%
Slag forming	Kaolin Titanium dioxide Fledspar Asbestos	20-40%
Binding	Sodium silicate Potassium silicate	20-30%
Deoxidizing	Ferrosilicon Aluminum	5-10%
Arc stabilizing	Potassium titanate Titanium oxide	5-10%
Increasing deposition rate	Iron powder	0-4%
Improving weld strength	Different alloying elements	5-10%

1. Slag Forming Constituents:

The slag forming ingredients are silicon oxide (Sio_2), Manganese oxide (Mno_2), iron oxide (F_eO), asbestos, mica, etc. In some cases, aluminum oxide (Al_2o_3) is also used but it makes the arc less stable.

2. Constituents to Improve Arc Characteristics:

The ingredients to improve arc characteristics are sodium oxides (Na_2O), Calcium oxides (CaO), magnesium oxides (MgO), and titanium oxide (TIO_2).

3. De-Oxidising Constituents:

The deoxidising ingredients are graphite, powdered aluminum, wood flour, calcium carbonate, starch, cellulose, dolomite, etc.

4. Binding Constituents:

The binding materials used are sodium silicate, potassium silicate and asbestos.

5. Alloying Constituents:

The alloying elements used for improvement of weld strength are vanadium cobalt, molybdenum, aluminum, chromium, nickel, zirconium, tungsten, etc.

4.11 Specification of Electrodes:

The specification of electrodes are provided by Bureau of Indian standard IS : 815-1974 (second revision).

According to this, the coated electrodes are specified by:

(i) A prefix letter.

(ii) A six digit code number.

(iii) A suffix letter.

Indian system (I.S.) :	L	X	X	X	X	X	X	L
	1st	1st	2nd	3rd	4th	5th	6th	Last
	Letter			Digits				Letter
Example IS : 815 coading	:	E 314 – 411 K						
Specification	:	Ref. IS : 814 (Part–I)						

(i) Prefix Letter:

The prefix letter indicates the method of manufacturing of electrodes.

These prefix letters with method of manufacturing of electrodes are given in the Table 7.12:

Table. 7.12. Meaning of prefix letters.

Prefix letter	Method of Manufacturing
E	Solid extrusion process.
R	Extruded with reinforcement.

(ii) A Six Digit Code Number:

The six digit code number indicated the performance characteristics and mechanical properties of the weld metal deposit.

The meaning of each individual digit from one to six is given in the Table 7.13:

Table. 7.13. Meaning of individual digit in code number.

Digit	Meaning	
First digit	(*i*) Type of covering	Performance characteristics
Second digit	(*ii*) Welding position in which the electrode may be used.	
Third digit	(*iii*) Welding current condition.	Mechanical properties and weld metal deposit.
Fourth digit	(*iv*) Range of tensile strength	
Fifth digit	(*v*) Range of Yield strength	
Sixth digit	(*vi*) Percentage elongation along with the impact value of deposit metal.	

(iii) Suffix Letter:

The suffix letter indicates the special properties or characteristics of the electrode.

These are given in the Table 7.14:

Table. 7.14 Meaning of suffix letters.

Suffix letter	Special Properties/characterstics
H	Hydrogen controlled electrode.
J	Iron powder covering, giving metal recovery of 110–130% inclusive.
K	Iron powder covering, giving metal recovery of 130–150%.
P	Deep Penetration.

The first digits of the code number essentially explain the type of covering used on the electrode and this covering signifies the performance characteristics.

There are seven types of covering representing the first digit number are given in the Table 7.15:

Table. 7.15. Types of first digit numbers used.

First digit number of code	Types of Covering
1	High cellulose contents.
2	High contents of titanium along with ionizing producing a fairly viscous slag.
3	Appreciable amount of titanium with basic materials producing a fluid slag.
4	High contents of oxides or silicates, both of iron and manganese, producing an inflated slag.
5	High contents of iron oxide or silicate or both producing a solid slag.
6	High contents of calcium carbonate and fluoride.
7	Any other material, not specified above.

The second digit of the code indicates the welding position, as per Table 7.16 given below:

Table. 7.16. Types of second digit numbers used.

Second digit number of code	Welding position	Letter symbol stands for
0	F, H, V, D, O	F – Flat
1	F, H, V, O	H – Horizontal
2	F, H	V – Vertical-up
3	F	D – Vertical-down
4	F, H_f	O – Over head.
9	Any other position not clarified above.	

The third digit of the code number indicates welding current conditions recommended by the manufacturer of electrode.

These are given in the Table 7.17:

Table 7.17. Types of third digit numbers used.

Third digit number of code	Welding current conditions
0	D +
1	D +, A90
2	D –, A70
3	D –, A50
4	D +, A70
5	D ±, A90
6	D ±, A70
7	D ±, A90
9	Any other current conditions not specified above.

Notetions used : D + D.C. with electrode positive.
D – D.C. with electrode negative.
D ± D.C. with electrode positive or negative.
A 90, A 70, A 50 A.C. with open circuit voltage. not less than 90 volts, 70 volts. and 50 volts, respectivety.

The fourth, fifth and sixth digits of the code number represents tensile strength, maximum yield stress and percentage elongation with impact value.

These are given in the Table 7.18:

Table. 7.18. Types of fourth, fifth and sixth digits used.

Electrode Classfication	Tensile strength (N/mm^2)	Max-yield stress (N/mm^2)	Min-elongation in % of gauge length of $5.65\sqrt{S_o}$ value	Temperature for minium value of 47J°C
EXXX—410	410–510	330	—	—
EXXX—411	410–510	330	20	+27
EXXX—412	410–510	330	22	0
EXXX—413	410–510	330	24	–20
EXXX—414	410–510	330	24	–30
EXXX—415	410–510	330	24	–40
EXXX—510	510–610	360	—	—
EXXX—511	510–610	360	18	+27
EXXX—512	510–610	360	18	0
EXXX—513	510–610	360	20	–20
EXXX—514	510–610	360	—	–30
EXXX—515	510–610	360	—	–40

In addition to the coding given above, all electrodes must conform to the test requirements of IS: 814 (part I and II) – 1974. Each packet of electrodes must have a marking indicating coding and specification.

Example:

IS: 815 coding: E 315 – 411K

Specification: Ref: 814 (Part-1)

The significance of above example is that:

(i) The electrode is manufactured by solid extrusion and is suitable for metal arc welding of mild steel. [E].

(ii) The electrode covering has an appreciable amount of titanium with basic materials and will produce fluid slag. [3].

(iii) The electrode is suitable for welding in the flat, horizontal, vertical and overhead position. [1].

(iv) The electrode is suitable for welding with direct current, with electrode being +ve or -ve. It is also suitable of welding with an alternating current with open circuit voltage less than 90 volts. [5].

(v) The electrode has range of tensile stress of deposited metal is 410 to 510 N/mm^2. [411].

(vi) The electrode has a maximum yield stress of deposited metal is 330 N/nm^2. [411].

(vii) The electrode has a minimum percentage elongation in tensile test of deposited metal is 20 percent on a gauge length of 5.65 $\sqrt{S_o}$ and average impact test value of deposited metal is 47J at 27°C. [411].

(viii) The electrode has iron powder in the covering, giving a metal recovery of 130 to 150 percent.

(ix) The electrode conforms to IS: 814 (Part-I)-1974.