MODULE -4

WELDING PROCESS

JOINING PROCESSES

Operating principle, basic equipment, merits and applications of: Fusion welding processes: Gas welding - Types – Flame characteristics; Manual metal arc welding – Gas Tungsten arc welding - Gas metal arc welding – Submerged arc welding

DEFINITION

Welding is a process of joining two metals (like or unlike) by the application of heat or heat and pressure using a filler material.

Welding is carried out by heating the edges of the work pieces to a suitable temperature and then fused together with or without the application of pressure. Since a slight gap usually exists between the edges of the work pieces, a filler metal is used to supply additional material to fill the gap. But, welding can also be carried out without the use of filler metal. The filler metal is melted in the gap, combines with the molten metal of the work piece, and upon solidification forms an integral part of the weld.

PRINCIPLE OF WELDING

An ideal joint between two pieces of metal or plastic can be made by heating the work pieces to a suitable temperature. In other words, on heating, the materials soften sufficiently so that the surfaces fuse together. The bonding force holds the atoms, ions or molecules together in a solid.

This bonding on contact is achieved only when:

• The contaminated surface layers on the work piece are removed,

• Recontamination is avoided, and

• The two surfaces are made smooth, flat and fit each other exactly.

In highly deformable materials, the above factors can be achieved by rapidly forcing the two surfaces of the work piece to come closer together so that plastic deformation makes their shape conform to each another; at the same time, the surface layers are broken up, allowing the intimate contact needed to fuse the materials. This was the principle of the first way known to weld metals; by hammering the pieces together while they are in hot condition.

Deformation of the surfaces can be done by rubbing the two surfaces against each other or by heating the metals and pressing them (by applying force) against a suitable material to fuse, But in most of the applications, the size, shape, location, or properties of the material restricts it to be plastically deformed.

In such cases, the edges of the parts to be joined are brought together, melted and fused to each other. Coalescence takes place wherein molten metal from one work piece merge with molten metal of another work piece. When the coalesced liquid solidifies, the two work pieces join together to form a single component.

CLASSIFICATION OF WELDING PROCESSES

There are various welding processes; each suitable for a particular work piece metal, environment, application etc. These processes can be classified based on various factors like source of heat (arc, flame, etc.), temperature (work piece heated to plastic state or molten state) etc.

In general, welding processes are classified in the following manner:

(i) Gas Welding

(a) Oxy-acetylene welding (b) Oxy-hydrogen welding

(ii) Arc Welding

(a) Manual metal arc or Flux shielded metal arc welding
(b) Tungsten inert gas welding (c) Metal inert gas welding
(d) Submerged arc welding (e) Electro slag welding
(f) Plasma arc welding (g) Stud arc welding

(iii) Resistance Welding

(a) Spot welding (b) Seam welding
(c) Flash butt welding (d) Projection welding
(e) Percussion welding

(iv) Solid state welding

(a) Friction welding (b) Explosive welding
(c) Diffusion welding (d) Forge welding
(e) Ultrasonic welding (f) Roll welding
(g) Cold welding

(v) Thermo-chemical welding

(a) Atomic hydrogen welding
(b) Thermit welding

(vi) Radiant energy welding

(a) Laser welding
(b) Electron beam welding

APPLICATIONS OF WELDING

Welding finds application in ship building, automobiles, aircraft, power plants, building and bridge constructions, storage tanks, pressure vessels, machine tools, and almost in all sectors, where parts are fabricated as per the needs. Apart from fabrication work, welding is also used in repair and maintenance work; for example joining broken parts and rebuilding worn out components.

ADVANTAGES & LIMITATIONS OF WELDING

Like all other manufacturing processes, welding too has its own advantages and limitations that make the designer to choose the process only for a certain application.

Advantages

a) The strength of the joint obtained in welding is much stronger than the workpiece metal.
b) Metals with different chemical compositions can be welded easily.
c) Welding equipments are portable. Hence, the parts can be fabricated at the relevant location instead of transporting the entire assembly to its destination.
d) Complex shapes that are difficult to cast or machine can be easily assembled in parts by welding process.
e) Parts can be fabricated at reasonable costs.

Limitations

a) The process gives out harmful radiations, fumes and spatter. Hence, care should be taken during welding.
b) Skilled operator is required to produce a good joint.
c) The high heat involved in the process causes changes in the structure of metal thereby lowering its properties.

GAS WELDING

Oxy-Acetylene welding

In gas welding, a gas flame is used to melt the edges of metals to be joined. The flame is produced at the tip of welding torch. Oxygen and Acetylene are the gases used to produce the welding flame. The flame will only melt the metal. A flux is used during welting to prevent oxidations and to remove impurities. Metals 2mm to 50mm thick are welded by gas welding. The temperature of oxyacetylene flame is about 3200°c. Figure shows Gas welding equipments.

Gas Welding Equipment

1. Gas Cylinders

   Pressure

   Oxygen – 125 kg/cm^2

   Acetylene – 16 kg/cm^2

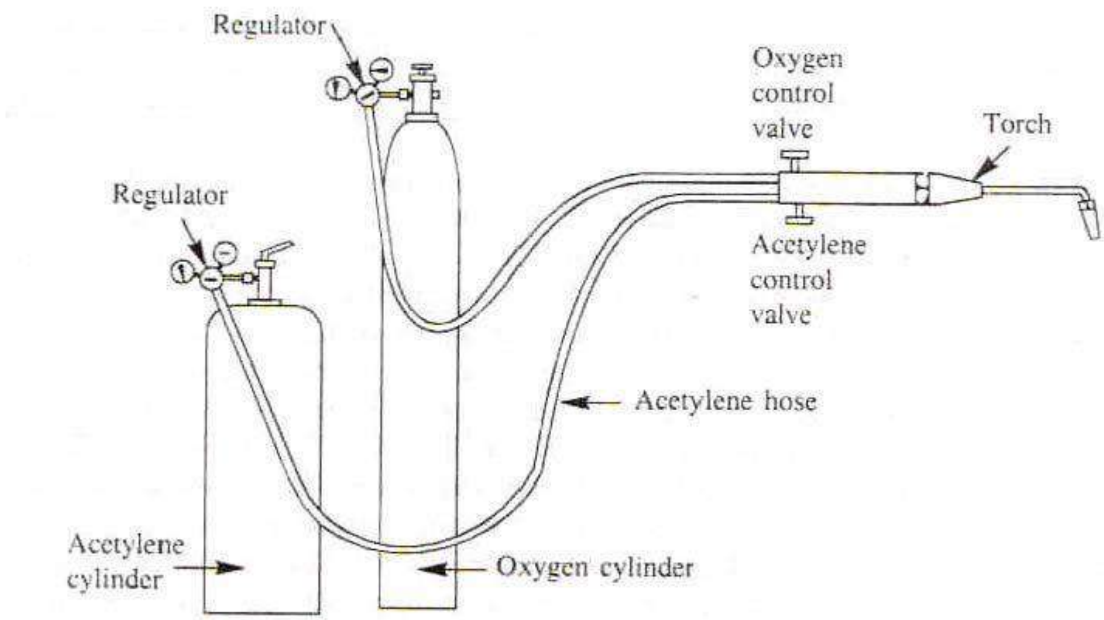
2. Regulators

   Working pressure of oxygen 1 kg/cm^2

   Working pressure of acetylene 0.15 kg/cm^2

Working pressure varies depends upon the thickness of the work pieces welded.

3. Pressure Gauges
4. Hoses
5. Welding torch
6. Check valve
7. Non return valve

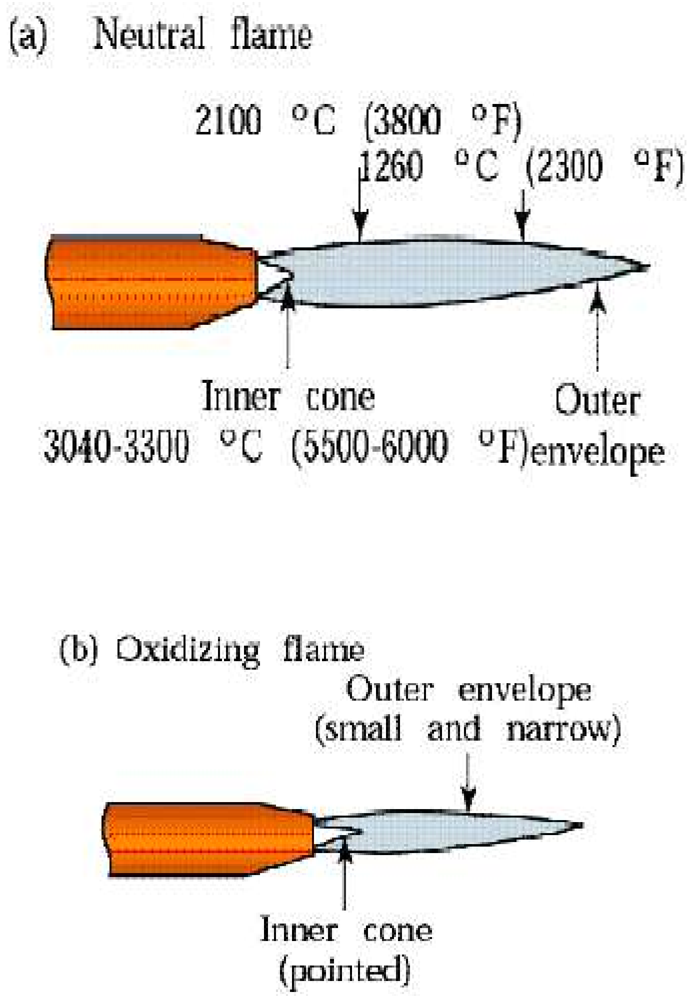


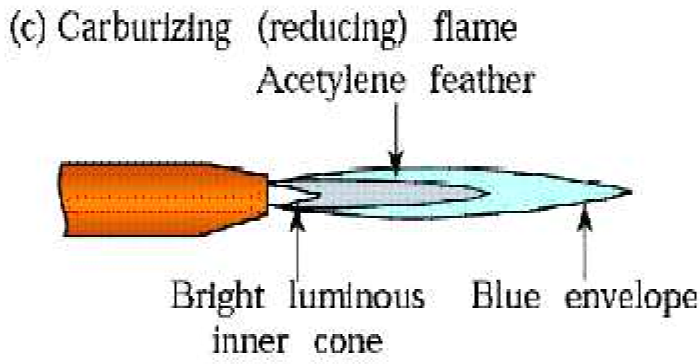
TYPES OF FLAMES

- When acetylene is burned in air, it produces a yellow sooty flame, which is not enough for welding applications
- Oxygen is turned on, flame immediately changes into a long white inner area (Feather) surrounded by a transparent blue envelope is called **Carburizing flame** (30000c)
- This flames are used for hardening the surfaces
- Addition of little more oxygen give a bright whitish cone surrounded by the transparent blue envelope is called **Neutral flame** (It has a balance of fuel gas and oxygen)

- Most commonly used flame because it has temperature about 32000c
- Used for welding steels, aluminium, copper and cast iron
- If more oxygen is added, the cone becomes darker and more pointed, while the envelope becomes shorter and more fierce is called **Oxidizing flame**
- Has the highest temperature about 34000c
- Used for welding brass and brazing operation

Fig 4 shows the types of flames.





Advantages

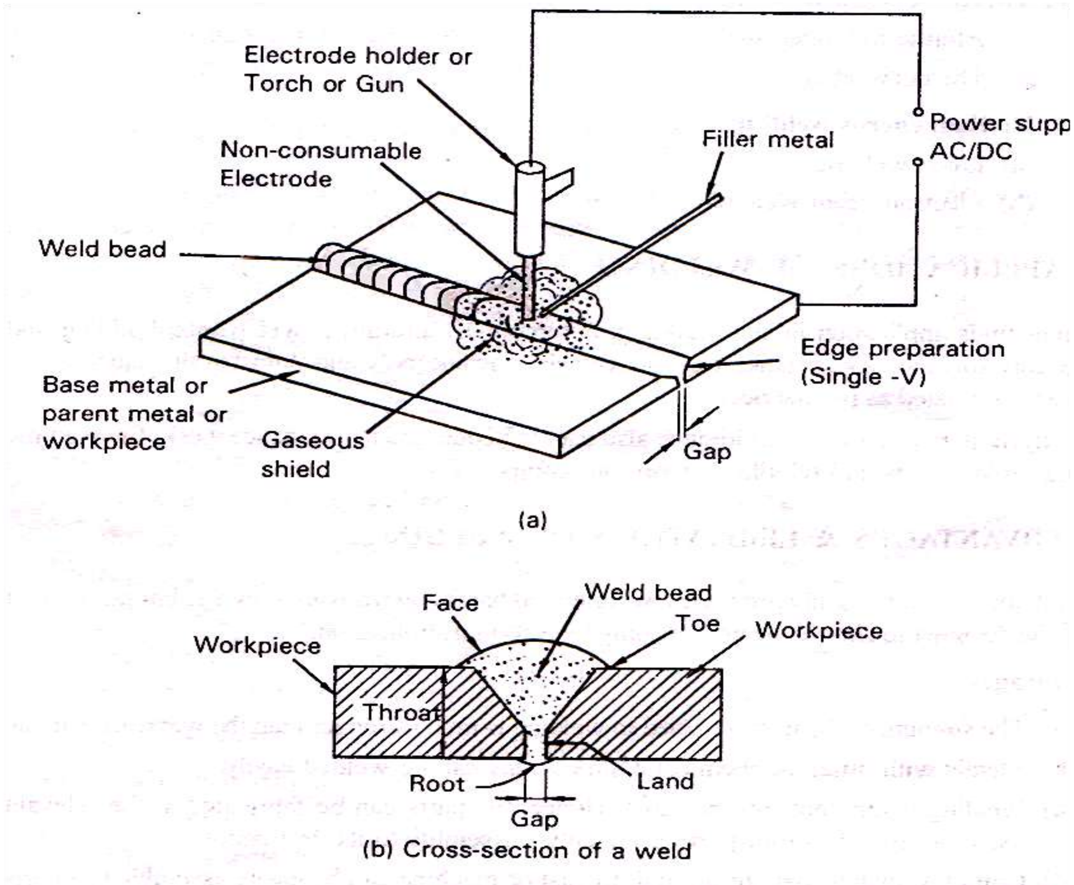
1. Equipment has versatile
2. Same equipment can be used for oxy acetylene cutting and brazing by varying the torch size
3. Heat can controlled easily

Disadvantages

1. Slower process
2. Risk is involved in handling gas cylinders

WELDING TERMINOLOGY

Figure shows a typical welding process which helps the reader to understand the various terms involved in welding.



Typical welding process

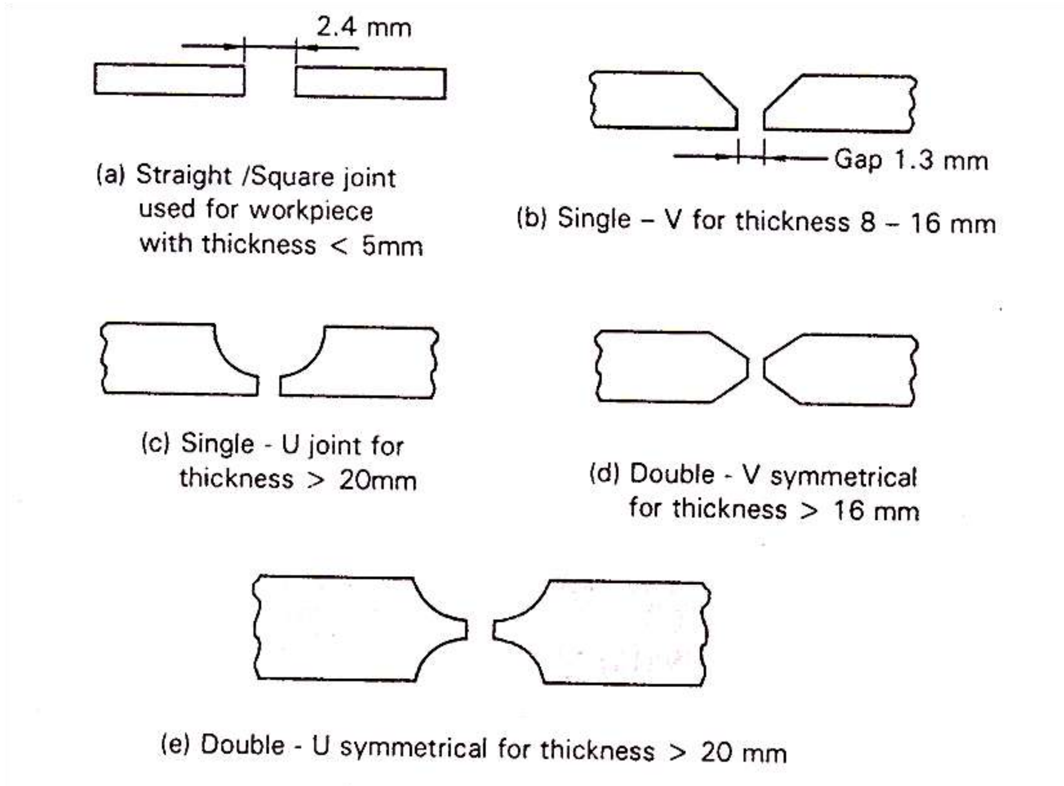
EDGE PREPARATION

Before starting the welding process, the edges of the two work pieces to be welded should be prepared well to obtain a sound weld. This process is called edge preparation and involves two operations:

(a) Preparation of joint and (b) Cleaning of joint.

(a) Joint preparation

Joint preparation involves cutting or beveling the edges of the two work pieces to suitable shapes so that heat would be able to penetrate to the entire depth of the work piece. Figure shows the different shapes that can be prepared based on the application.



Edge preparation

Figure (a) shows a square or straight joint suitable for work pieces with thickness less than 5 mm. Some work pieces are beveled only on one side, as in single- V or single- U joints, but for very thick plates, beveling is required on both sides as shown in figure (d) and (e).

(b) Cleaning of joint

Work piece surfaces are often chemically contaminated by dirt, grease, oxides etc. Most metals are very reactive, and in air, they become coated, with an oxide layer or with adsorbed gas. This layer prevents intimate contact from being made between the two metal surfaces. Hence, the edges of the work pieces and the area adjoining them should be cleaned thoroughly to remove the contaminants. Cleaning is done either chemically by using acetone or carbon tetrachloride solution or mechanically by using wire brush, hand files or grinding process.

ARC WELDING PROCESS

Arc welding process is a fusion method of welding that utilizes the high intensity of the arc generated by the flow of current to melt the work pieces. A solid continuous joint is formed upon cooling.

Principle

The source of heat for arc welding process is an electric arc generated between two electrically conducting materials: the work piece and the electrode. The work piece is connected to one pole of the electric circuit, while the electrode to the other pole of the circuit.

When the tip of the electrode is brought in contact with the work piece material, and momentarily separated by small distance of 2-4 mm, an arc can be generated. The electrical energy is thus converted to heat energy. The temperature at the tip of the arc may reach up to about 6000°C. The high heat of the arc melts the edges of the work pieces. Coalescence takes place, wherein the molten metal from one work piece combines with the molten metal of another work piece. When the coalesced liquid solidifies, the two work pieces join together to form a single component.

The electrode material can be either a non-consumable material or a consumable material. The non-consumable electrode made of tungsten, graphite etc., serve only to strike the arc, and is not consumed during the welding process. Whereas, the consumable electrode which is made of the same material as that of the work piece metal helps to strike the arc, and at the same time melts (gets consumed) and combines with the molten metal of the work piece to form a weld.

METAL ARC WELDING (MAW) OR FLUX SHIELDED METALARC WELDING (FSMAW)

Flux shielded metal arc welding, also known as manual metal arc welding is a group of arc welding process in which the work pieces are joined by the heat obtained from an electric arc struck between a flux coated consumable electrode and the work piece. The flux coated on the electrode serves as a shielding gas to prevent atmospheric contamination of molten metal. Figure shows the flux shielded metal arc welding process.

Description and Operation:

a) An electrode holder, which holds the electrode firmly forms one pole of the electric circuit, while the work piece to be welded forms the other pole. Either AC (alternating current) or DC (direct current) can be used to supply the required current for welding.

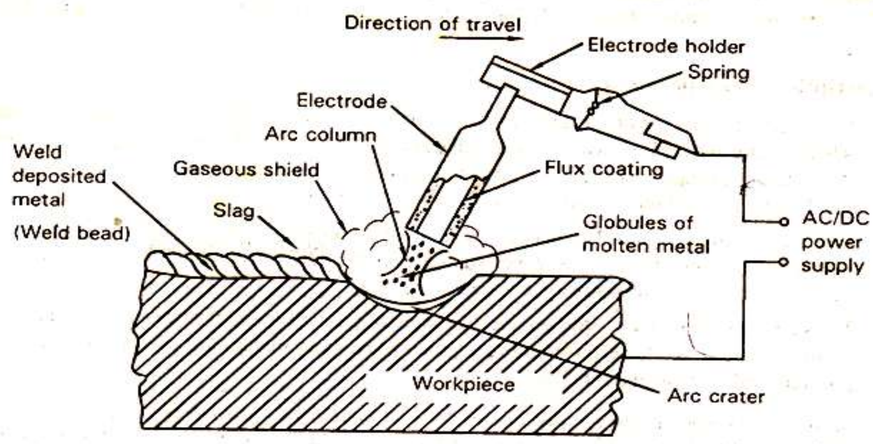
b) The electrode used in this process is a metallic wire, which is made of the same material or nearly the same chemical composition as that of the work piece material. The metallic wire is coated with a suitable flux material like rutile (titania), calcium fluoride, cellulose, iron oxide, etc., which gives off gases as it decomposes. The various benefits of flex coating include:

- Prevents oxidation of the molten metal
- Stabilizes the arc
- Formation of slag. The flux chemically reacts with the oxides to form a slag. The slag floats and covers the top portion of the molten metal thereby preventing it from rapid cooling.

c) In operation, an arc is struck by touching the tip of the electrode on the work piece (similar to striking a match stick), and instantaneously the electrode is separated by a small distance of 2 - 4 mm such that the arc still remains between the electrode and the work piece.

d) The high heat at the tip of the arc melts the work piece metal forming a small molten metal pool. At the same time, the tip of the electrode also melts. The molten metal of the electrode is transferred into the molten metal of the work piece in the form of globules of molten metal.

e) The deposited metal fills the joint and bonds the joint to form a single piece of metal. The electrode is moved along the surface to be welded to complete the joint. The arc is extinguished by increasing the arc length, i.e., by widening the gap between the work piece and the electrode.



METAL ARC WELDING

Advantages

• The process is simple and inexpensive. Hence, suitable for shop jobs and field work.
• Eliminates skilled labor.
• The process dominates other welding processes in maintenance and repair industry.
• Used to weld ferrous and a few non-ferrous metals like aluminum, nickel, copper alloys etc.

Disadvantages

• Weld times are rather slow, since the consumable electrode must be frequently replaced.
• Weld spatter, poor fusion, shallow penetration, and cracking are a few major problems associated with the process. However, by proper welding practice, they can be minimized.

Applications

The process finds applications in building and bridge construction, ship building, boiler and pressure vessel fabrication, joining of large pipes and penstock, and in almost all repair and maintenance work.

INERT GAS WELDING

These are of two types

1) Tungsten inert gas welding (TIG)
2) Metal inert gas welding (MIG)

TUNGSTEN INERT GAS WELDING (TIG)

Tungsten inert gas welding or gas tungsten arc welding (GTAW) is a group of welding process in which the work pieces are joined by the heat obtained from an electric arc, struck between a non-consumable tungsten electrode and the work piece, in the presence of an inert gas atmosphere. A filler metal may be added if required, during the welding process. Figure shows the TIG process.

Description and Operation

a) TIG equipment consists of a welding torch in which a non-consumable tungsten alloy electrode is held rigidly in the collet. Various alloys like zirconium, thorium, lanthanum etc., are alloyed with tungsten to improve arc stability, better current carrying capacity, resistance to contamination etc. The diameter of the electrode varies from 0.5 - 6.4 mm.

b) TIG welding makes use of a inert gas (shielding gas) like argon or helium to protect the welding area from atmospheric gases such as oxygen and nitrogen, otherwise which may cause fusion defects and porosity in the weld metal. The shielding gas flow from the cylinder, through the passage in the electrode holder, and then impinges on the work piece. Pressure regulator and flow meters are used to regulate the pressure and flow of gas from the cylinder.

c) Either AC or DC can be used to supply the required current. AC is preferred for welding magnesium, aluminum and their alloys, while DC is used for welding stainless steel, nickel, copper and its alloys.

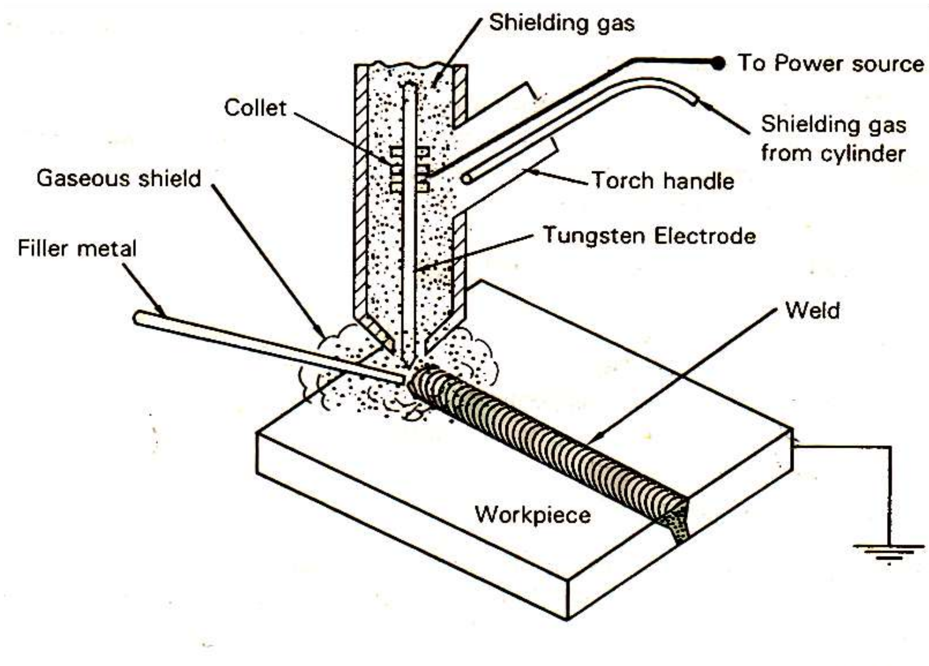
d) In operation, the work pieces to be joined are cleaned to remove dirt, grease and other oxides chemically or mechanically to obtain a sound weld.

e) The welding current and inert gas supply are turned ON. An arc is struck by touching the tip of the tungsten electrode with the work piece, and instantaneously the electrode is separated from the work piece by a small distance of 1.5 - 3 mm such that the arc still remains between the electrode and the work piece.

f) The high intensity of the arc melts the work piece metal forming a small molten metal pool. Filler metal in the form of a rod is added manually to the front end of the weld pool.

g) The deposited filler metal fills and bonds the joint to form a single piece of metal.

h) The arc is extinguished by widening the gap between the work piece and the electrode. The shielding gas is allowed to impinge on the solidifying weld pool for a few seconds even after the arc is extinguished. This will avoid atmospheric contamination of the solidifying metal thereby increasing the strength of the joint.



TUNGSTEN INERT GAS WELDING

Advantages

• Suitable for thin metals.

• Clear visibility of the arc provides the operator to have a greater control over the weld.

• Strong and high quality joints are obtained (due to the pressure of inert gas).

• No flux is used. Hence, no slag formation. This results in clean weld joints.

Disadvantages

• TIG is the most difficult process compared to all the other welding processes. The welder must maintain short arc length, avoid contact between electrode and the work piece and manually feed the filler metal with one hand while manipulating the torch with the other hand.

• Tungsten material when gets transferred into the molten metal contaminates the same leading to a hard and brittle joint.

• Skilled operator is required.

• Process is slower. .

• Not suitable for thick metals.

Applications

TIG welding is most commonly used to weld stainless steel and non-ferrous materials such as aluminum and magnesium. Aerospace industry is one of the primary users of TIG welding process. Refrigerators, air conditioners and chemical plants are the other users.

METAL INERT GAS (MIG) WELDING

Metal inert gas welding or gas metal arc welding (GMAW) is a group of arc welding process in which the work pieces are joined by the heat obtained from an electric arc struck between a bare (uncoated) consumable electrode and the work piece in the presence of an inert gas atmosphere. The consumable electrode acts as a filler metal to fill the gap between the two work pieces. Figure shows the MIG welding process. .

Description and Operation

a) The equipment consists of a welding torch in which a bare (uncoated) consumable electrode in the form of a wire is held and guided by a guide tube. The electrode material used in MIG welding is of the same material or nearly the same chemical composition as that of the base metal. Its diameter varies from 0.7-2.4 mm. The electrode is fed continuously at a constant rate through feed rollers driven by an electric motor.

b) MIG makes use of shielding gas to prevent atmospheric contamination of the molten weld pool. Mixture of argon and carbon dioxide in a 75% to 25% or 80% to 20% mixture is commonly used. The shielding gas flow from the cylinder, through the passage in the electrode holder, and then impinges on the work piece.

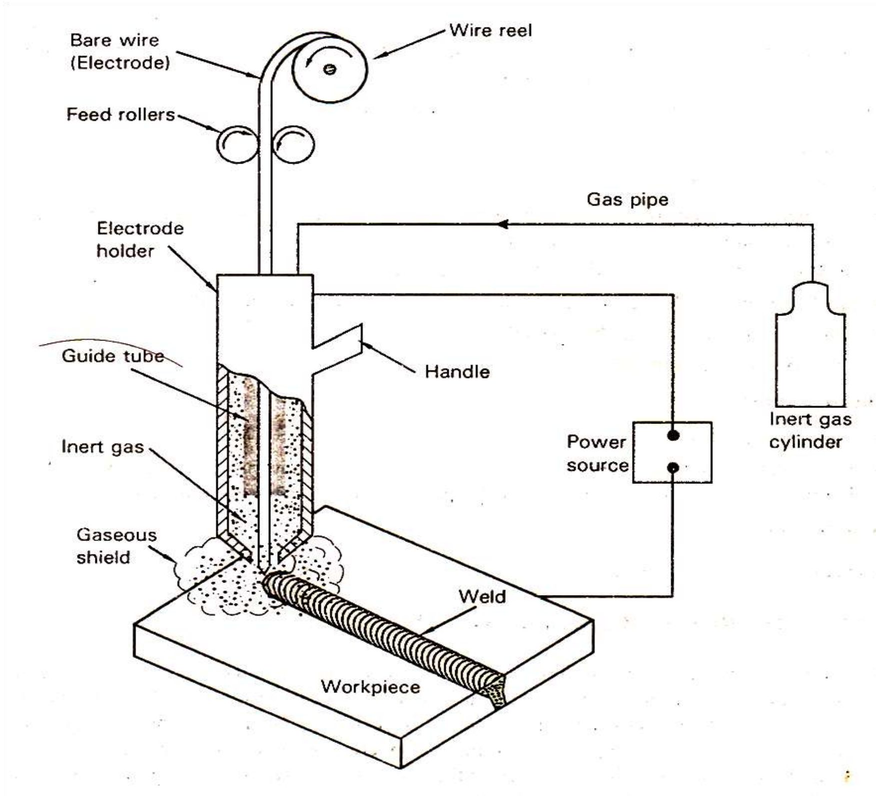
c) AC is rarely used with MIG welding; instead DC is employed, and the electrode is positively charged. This results in faster melting of the electrode, which increases weld penetration and welding speed.

d) In operation, the work pieces to be joined are cleaned to remove dust, grease and other oxides, chemically or mechanically to obtain a sound weld. The tip of the electrode is also cleaned with a wire brush.

e) The control switch provided in the welding torch is switched ON to initiate the electric power, shielding gas and the wire (electrode) feed.

f) An arc is struck by touching the tip of the electrode with the work piece, and instantaneously the electrode is separated from the work piece by a small distance of 1.5 - 3 mm such that the arc still remains between the electrode and the work piece.

g) The high intensity of the arc melts the work piece metal forming a small molten pool. At the same time, the tip of the electrode also melts and combines with the molten metal of the work pieces thereby filling the gap between the two work pieces. The deposited metal upon solidification bonds the joint to form a single piece of metal.



METAL INERT GAS WELDING

Advantages

• MIG welding is fast and economical.

• The electrode and inert gas are automatically fed. This reduces the burden on the operator, and also helps him to concentrate on the arc.

• Weld deposition rate is high due to the continuous wire feed.

• No flux is used. Hence, no slag formation. This results in clean welds. .

• Thin and thick metals can be welded.

• Process can be automated.

Disadvantages

• Equipment is costlier.

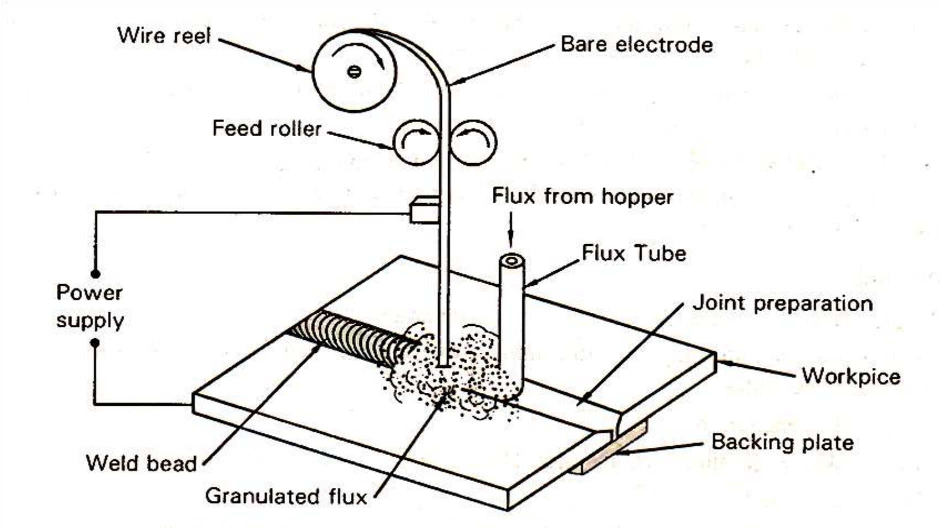
• Dross and porosity (gas entrapment in weld pool) are the most prevalent quality problems in this process. However, extensive edge preparation can eliminate this defect.

Applications

Used extensively in sheet metal industry, and automobile industries.

SUBMERGED ARC WELDING (SAW)

Submerged arc welding is a group of arc welding process in which the work pieces are joined by the heat obtained from an electric arc struck between a bare consumable electrode and the work piece. The arc is struck beneath a covering layer of granulated flux. Thus, the arc zone and the molten weld pool are protected from atmospheric contamination by being submerged under a blanket of granular flux. This gives the name submerged arc welding to the process. Figure shows the submerged arc welding process.



SUBMERGED ARC WELDING

Description and Operation

a) The equipment consists of a welding head carrying a bare consumable electrode and a flux tube. The flux tube remains ahead of the electrode, stores the granulated or powdered flux, and drops the same on the joint to be welded. The flux may contain oxides of calcium, silicon, magnesium, aluminum or manganese along with alloying elements depending on the requirements. The flux shields and protects the molten weld metal from atmospheric contamination.

b) The electrode which is bare (uncoated), and in the form of wire is fed continuously through feed rollers. It is usually copper plated to prevent rusting and to increase its electrical conductivity (since it is submerged under flux). The diameter of the electrode ranges from 1.6 - 8 mm and the electrode material depends on the type of the work piece metal being welded.

c) The process makes use of either AC or DC for supplying the required current.

d) In operation, edge preparation is carried out to obtain a sound weld. Flux is deposited at the joint to be welded.

e) Welding current is switched ON. An arc is struck between the electrode and the work piece under the layer of flux. The flux covers the arc thereby increasing the heat near the weld zone. This heat melts the filler metal and the work piece metal forming a molten weld pool. At the same time, a portion of the flux melts and reacts with the molten weld pool to form a slag. The slag floats on the surface providing thermal insulation to the molten metal thereby allowing it to cool slowly.

f) The welding head is moved along the surface to be welded, and the continuously fed electrode completes the weld.

g) The un-melted flux is collected by a suction pipe and reused. The layer of slag on the surface of the weld portion is chipped out, and the weld is finished.

h) Since the weld pool is covered by flux, solidification of molten metal is slow. Hence, a backing plate made from copper or steel is used at the bottom of the joint to support the molten metal until solidification is complete.

Advantages

- High productivity process, due to high heat concentration.
- Weld deposition rate is high due to continuous wire feed. Hence, single pass welds can be made in thick plates.
- Deep weld penetration.
- Less smoke, as the flux hides the arc. Hence, improved working conditions.
- Can be automated.
- Process is best suitable for outdoor works, and in areas with relatively high winds.
- There is no chance of spatter of molten metal, as the arc is beneath the flux.

Disadvantages

- The invisible arc and the weld zone make the operator difficult to judge the progress of welding.
- Use of powdered flux restricts the process to be carried only in flat positions.
- Slow cooling rates may lead to hot cracking defects.
- Need for extensive flux handling.

Applications

Used especially for large products, and in the fabrication of pressure vessels, penstocks, boilers etc.

QUESTIONS

1) Define welding. Explain the principle of Welding Process.**(Jun 2015)**
2) Classify different types of welding and mention advantages and disadvantages.**(Dec 2015)**
3) Sketch and explain Metal Arc welding process. **(Jun 2016)**
4) Sketch and explain Atomic hydrogen welding process. **(Jun 2015)**
5) Sketch and explain TIG welding process. Mention its advantages, disadvantages and limitations.**(Dec 2015)**
6) Explain with a neat sketch Submerged Arc Welding (SAW) process**(Jun 2015)**
7) With a neat sketch explain LASER beam welding and mention its advantages, disadvantages and limitations.**(Jun 2014)**
8) Sketch and explain MIG welding process. Mention its advantages, disadvantages and limitations **(Jun 2014)**
9) With a neat sketch explain friction welding and mention its advantages, disadvantages and limitations. **(Jun 2016)**
10) With a neat sketch explain Electron beam welding and mention its advantages, disadvantages and limitations. **(Jun 2014)**
11) With a neat sketch explain Explosive welding and mention its advantages, disadvantages and limitations. **(May 2013)**
12) Sketch and explain Thermit welding process and mention its advantages, disadvantages and limitations. **(Jun 2015)**