UNIT – 2
JOINING PROCESS

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 – Electro slag welding; Operating principle and applications of : Resistance welding - Plasma arc welding – Thermit welding – Electron beam welding – Friction welding and Friction Stir Welding; Brazing and soldering; Weld defects: types, causes and cure.

Welding

Welding is a material joining process which produces coalescence of materials by heating them to suitable temperatures with or without the application of pressure or by the application of pressure alone, and with or without the use of filler material.

Welding is used for making permanent joints. It is used in the manufacture of automobile bodies, aircraft frames, railway wagons, machine frames, structural works, tanks, furniture, boilers, general repair work and ship building.

Classification of welding processes

(i) **Arc welding**

- Carbon arc
- Metal arc
- Metal inert gas
- Tungsten inert gas
- Plasma arc
- Submerged arc
- Electro-slag

(ii) **Gas Welding**

- Oxy-acetylene
- Air-acetylene
- Oxy-hydrogen

iii) **Resistance Welding**

Butt

Spot

Seam

Projection

Percussion

(iv)Thermit Welding

(v)Solid State Welding

Friction

Ultrasonic

Diffusion

Explosive

(vi) Newer Welding

Electron-beam

Laser

(vii)Related Process

Oxy-acetylene cutting

Arc cutting

Hard facing

Brazing

Soldering

Welding practice & equipment

STEPS:

- Prepare the edges to be joined and maintain the proper position
- Open the acetylene valve and ignite the gas at tip of the torch
- Hold the torch at about 45deg to the work piece plane
- Inner flame near the work piece and filler rod at about 30 – 40 deg
- Touch filler rod at the joint and control the movement according to the flow of the material

Two Basic Types of AW Electrodes

Consumable – consumed during welding process

Source of filler metal in arc welding

Non consumable – not consumed during welding process

Filler metal must be added separately

Consumable Electrodes

Forms of consumable electrodes

- Welding rods (a.k.a. sticks) are 9 to 18 inches and 3/8 inch or less in diameter and must be changed frequently
- Weld wire can be continuously fed from spools with long lengths of wire, avoiding frequent interruptions In both rod and wire forms, electrode is consumed by arc and added to weld joint as filler metal.

Non consumable Electrodes

Made of tungsten which resists melting

Gradually depleted during welding (vaporization is principal mechanism)

Any filler metal must be supplied by a separate wire fed into weld pool

Flux

- ✓ A substance that prevents formation of oxides and other contaminants in welding, or dissolves them and facilitates removal
- ✓ Provides protective atmosphere for welding
- ✓ Stabilizes arc
- ✓ Reduces spattering

Arc welding

Uses an electric arc to coalesce metals

Arc welding is the most common method of welding metals

Electricity travels from electrode to base metal to ground

GAS WELDING PROCESS

GAS WELDING

- Sound weld is obtained by selecting proper size of flame, filler material and method of moving torch
- The temperature generated during the process is 33000c.
- When the metal is fused, oxygen from the atmosphere and the torch combines with molten metal and forms oxides, results defective weld
- Fluxes are added to the welded metal to remove oxides
- Common fluxes used are made of sodium, potassium. Lithium and borax.
- Flux can be applied as paste, powder, liquid. solid coating or gas.

GAS WELDING EQUIPMENT

1. Gas Cylinders Pressure

Oxygen – 125 kg/cm2

Acetylene – 16 kg/cm2

2. Regulators

Working pressure of oxygen 1 kg/cm2

Working pressure of acetylene 0.15 kg/cm2

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

• 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)

• 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) (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

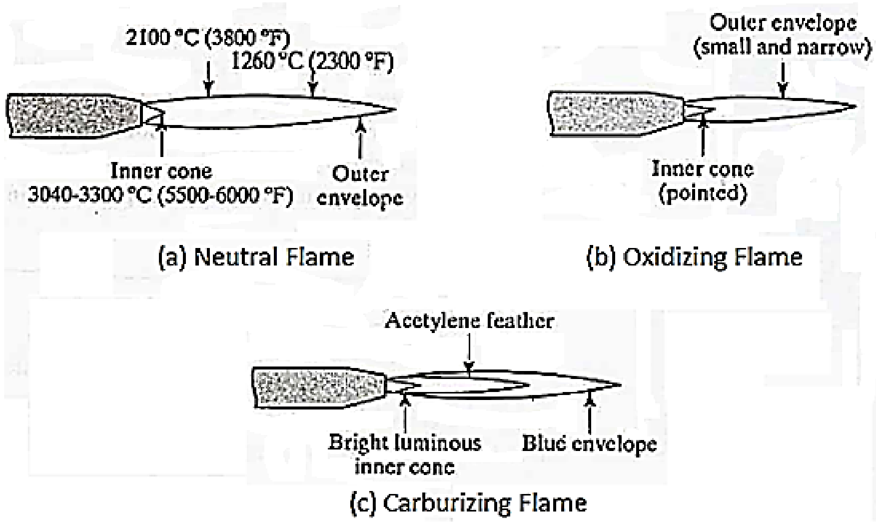


Fig.2.5 Various flame formation in Gas welding

Three basic types of oxyacetylene flames used in oxy fuel-gas welding and cutting operations:

(a) Neutral flame;
(b) oxidizing flame;
(c) carburizing, or reducing flame.

Fusion welding processes

Definition: Fusion Welding is defined as melting together and coalescing materials by means of heat

- Energy is supplied by thermal or electrical means
- Fusion welds made without filler metals are known as autogenously welds

Filler Metals:

- Additional material to weld the weld zone
- Available as rod or wire
- They can be used bare or coated with flux
- The purpose of the flux is to retard the

1. Discuss the gas welding process and the necessary equipments needed with suitable sketches. [AU-NOV/DEC-2012]

GAS WELDING PROCESS

There are three types of gas welding process used in industries such as

1. Oxy-acetylene welding
2. Oxy-hydrogen welding,
3. Air-hydrogen welding

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 control for the welding flame.

The gas commonly employed for gas welding are acetylene, hydrogen, propane and butane. The most common form of gas welding is oxy-acetylene welding.

The flame only will melt the metal. So, 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_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 systems employed depending upon the manner in which acetylene is supplied for welding. These are two types of system.

1. High pressure system
2. Low pressure system

In high pressure system, both oxygen and acetylene are supplied from high-pressure cylinders. Oxygen is compressed to 120atm gauge pressure. But the acetylene cannot be compressed more than 1.5 atm like in the form of dissolved acetylene. The acetylene is dissolved in acetone under a pressure of 16 to 22 atm gauges. At normal pressure, one litre of acetone is dissolved about 25 litres of acetylene. The maximum recommended pressure of acetylene in the cylinder through a rubber hose is 1 bar. In H.P system, the pressure of acetylene at the welding torch is from 0.66 to 1 bar.

In 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

$$CaC_2+2H_2O \rightarrow Ca\ (OH)_2+C_2H_2+127.3\ KJ/mol$$

From the above equation, it is obvious that heat generated in this reaction is very high.

The pressure of acetylene of the torch is up to 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

AIR -ACETYLENE WELDING

This process is similar to that of oxy acetylene welding process. Here air is used instead of oxygen. The air taken from the atmosphere is compressed in a compressor and mixed with acetylene to the required proportion in the torch. This type of welding has limited use, since the temperature is lower than obtained by other gas process. It is successfully used in lead welding and many low melting temperature metals and alloy.

OXY-HYDROGEN WELDING

This process is similar to Oxy-acetylene welding process .Hence oxygen and hydrogen gases are mixed with the required proportion for producing heat. In this process, special regular is used in metering the hydrogen gas. It was once used extensively to weld low temperature metals such as aluminium, lead and magnesium but it is not in use today because more versatile and faster welding process has been developed.

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

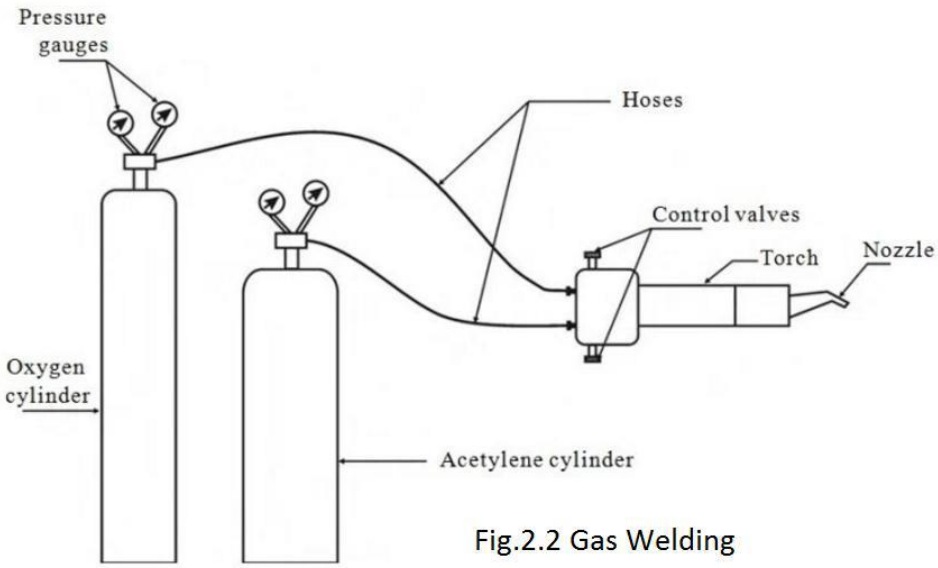


Fig.2.2 Gas Welding

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 7.6 m^3. Acetylene cylinder is fitted with 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 or placed on the oxygen cylinder regulators and two on acetylene cylinder regulators. Among two, one pressure gauges for showing cylinder pressures. 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 hose.

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 an 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 tip are made of copper or copper alloy. Tips are in different sizes depending upon the type of metal to be welded and its thickness.

There are two types of torches such as

- ✓ Equal pressure type
- ✓ Injected type

6. Goggles

The welding goggles are used to protect eyes from the flame heat, ultra violet and infra red rays

7. Welding gloves

Gloves are used to protect hand from the injury causing by heat and metal splashes.

8. Spark lighter

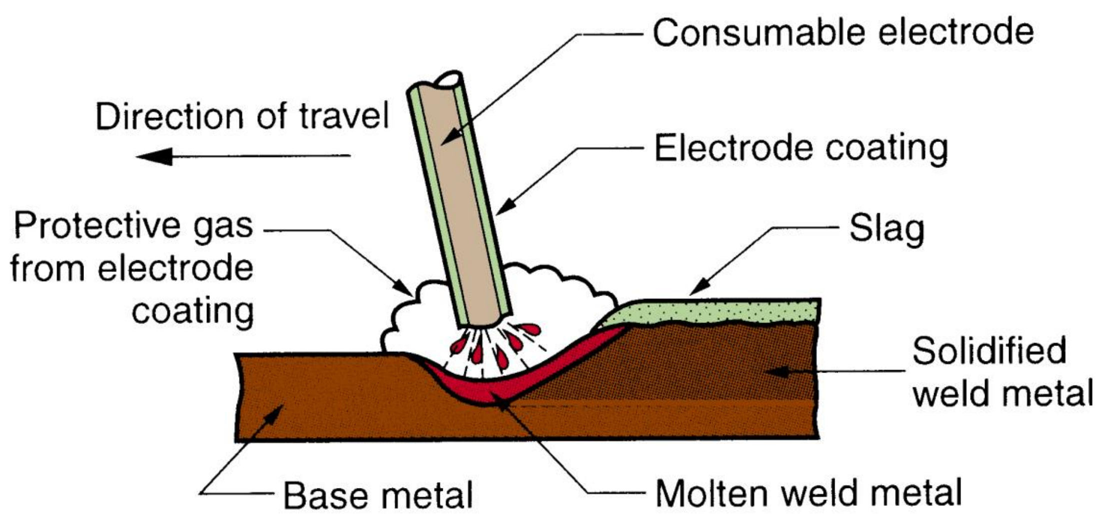
It is an igniter to start the burning of the oxy acetylene gases

9. Wire brush

It is used to clean the weld joint before and after welding

2. Explain the metal arc welding process with a sketch. [AU-NOV/DEC-2012, 2013](Nov/Dec-2018)

The process is also called as gas metal arc welding. In this arc welding, the electric arc is produced between a consumable metal electrode and the work piece. During welding, the arc and welding zone are surrounded by an inert gas as shown in fig. 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.



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

Advantages:

1. No flux is required
2. High welding speed
3. Possible to weld ferrous and non-ferrous metals
4. Greater efficiency
5. produces high quality weld
6. Cheaper process

3. Explain with a neat sketch the equipment and process of submerged arc welding. (May/ June 2013)

This is a well established and extremely versatile method of welding. Submerged-arc welding (SAW) involves the formation of an arc between a continuously fed electrode and the work piece. A blanket of powdered flux, which generates a protective gas shield and a slag (and may also be used to add alloying elements to the weld pool), protects the weld zone. A shielding gas is not required. The arc is submerged beneath the flux blanket and is not normally visible during welding.

The flux starts depositing on the joint to be welded. Since the flux when cold is non-conductor of electricity, the arc may be struck either by touching the electrode with the job or by placing steel wool between electrode and job before switching on the welding current or by using a high frequency unit. In all cases the arc is struck under a cover of flux. Flux otherwise is insulator but once it melts due to heat of the arc, it becomes highly conductive and hence the current flow is maintained between the electrode and the job through the molten flux. The upper portion of the flux, in contact with atmosphere, which is visible remains solid granular i.e., unchanged and can be reused.

The electrode at a predetermined speed is continuously fed to the joint to be welded. In semi-automatic welding sets the welding head is moved manually along the joint where as automatic welding a separate drive moves either the welding head over the stationary job or the job moves/rotates under the stationary welding head.

The arc length is kept constant by using the principle of a self adjusting arc i.e., if due to certain reasons arc length decreases, arc voltage will increase, arc current and therefore burn-off rate will increase thereby causing the arc to lengthen. The reverse occurs if the arc length increases than the normal.

Backing plate of steel or copper may be used to control penetration and to support large amounts of molten metal associated with the process.

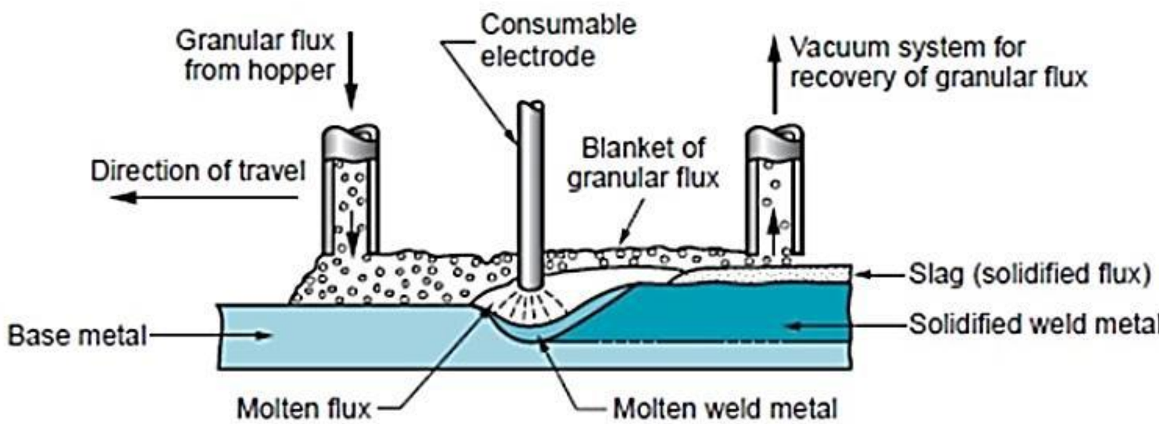


Fig.2.8 Submerged Arc Welding

Characteristics of submerged-arc welding

- ✓ The flux is fed into the weld zone from a hopper by gravity through a nozzle
- ✓ Prevents spatter and sparks;
- ✓ Suppresses the intense ultraviolet radiation and fumes characteristics of the SMAW.
- ✓ It acts as a thermal insulator by promoting deep penetration of heat into the work piece.
- ✓ The unused flux can be recovered, treated and reused.

Advantages

- ✓ High deposition rates (over 100 lb/h (45 kg/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.
- ✓ The process is suitable for both indoor and outdoor works.
- ✓ Low distortion

Limitations

- ✓ Limited to ferrous (steel or stainless steels) and some nickel-based alloys.
- ✓ Normally limited to the 1F, 1G, and 2F positions.
- ✓ 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.

4. Explain electro gas welding with its principles and application. (Nov/Dec 2013).

ELECTRO-GAS WELDING

The technique of vertical welding between water-cooled copper shoes characteristic of electro-slag welding is also used in a superficially similar process called electro-gas welding. In electro-gas welding, however, heat generation is by an electric arc which is struck from a flux-cored electrode to the molten weld pool. The flux from the flux-cored electrode forms a thin protective layer but does not give a decp-slag bath as in electro-slag welding.

Additional shielding of the weld pool is provided by a shield of carbon dioxide or argon-rich gas which is fed over the weld pool through the top of each copper shoe. Mechanically the apparatus is similar to that for the wire electrode type of electro-slag welding. Electro-gas welding can be us. on thicknesses from to 3 in., although it is chiefly used at the lower end of this range, for example in shipbuilding and the site fabrication of storage tanks.

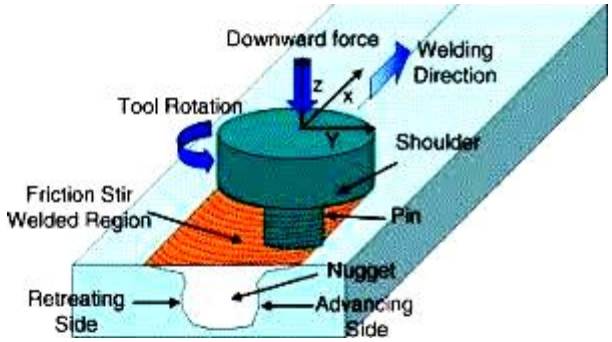
Because it is an arc-welding method and capable of speeds in excess of electro-slag welding for com-parable thicknesses, the thermal effects and therefore the metallurgy in the heat-affected zone more closely resembles a sub-merged-arc weld than an electro-slag weld. For the same reason an electro-gas weld can be started without the necessity of a starting block, and if for any reason a weld run is stopped it can be re-started with less difficulty than an electro-slag weld.

5. Explain the friction stir welding process with neat sketch.(Nov/Dec 2013).

Friction stir welding (FSW), illustrated in Figure, is a solid state welding process in which a rotating tool is fed along the joint line between two work pieces, generating friction heat and mechanically stirring the metal to form the weld seam. This process derives its name from this stirring or mixing action. FSW differs from conventional Friction welding by the fact that friction heat is generated by a separate wear-resistant tool rather than by the parts themselves.

In friction stir welding process the rotating tool is stepped, consisting of a cylindrical shoulder and a smaller probe projecting beneath it. During welding, the shoulder rubs against the top surfaces of the two parts, developing much of the friction heat, while the probe generates additional heat by mechanically mixing the metal along the butt surfaces. The probe has a geometry designed to facilitate the mixing action. The heat produced by the combination of friction and mixing does not melt the metal but softens it to a highly plastic condition.

As the tool is fed forward along the joint, the leading surface of the rotating probe forces the metal around it and into its wake, developing forces that forge the metal into a weld seam. The shoulder serves to constrain the plasticized metal flowing around the probe.



The FSW process is used in the aerospace, automotive, railway, and shipbuilding industries. Typical applications are butt joints on large aluminium parts. Other metals, including steel, copper, and titanium, as well as polymers and composites have also been joined using FSW.

Advantages:

(1) Good mechanical properties of the weld joint

(2) Avoidance of toxic fumes, warping, shielding issues, and other problems associated with arc welding

(3) Less distortion or shrinkage

(4) Good weld appearance.

Disadvantages:

(1) An exit hole is produced when the tool is withdrawn from the work

(2) Heavy-duty clamping of the parts is required.

6. Explain with neat diagram of resistance welding. (AU MAY-JUNE 2010, MAY/JUNE 2014)

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 electric in a circuit of low resistance the metal parts to he welded are placed between the electrodes when current is passed through the electrode, the electrical resistance at the metal joints becomes very high so, the metals are through to red hot plastic conduction.

Now, mechanical pressure is applied to complete the weld.

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

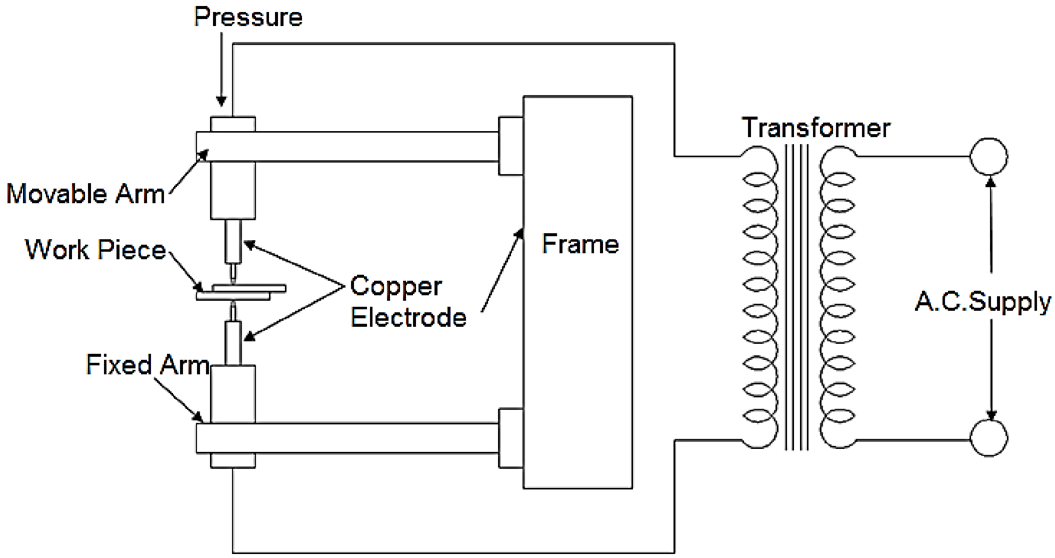


Fig. 2.10 : Resistance welding

The heat generated in the weld may be expressed by

$=I^2RT$

= heat

I= current in amps.

T= time of current flow

Therefore the heat developed by the current is proporitional to the electric resistance of the weld.

A.C with a suitable – transformer is weld for the power supply usually 4-12 rolls is used dependent on the composition, area and thickness of the metal to be welded.

7. Explain the electro slag process. (AU MAY-JUNE 10, 12, NOV/DEC 13)(Nov/Dec-2018)

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.

Working:-

In this welding process the electric are is struck between the electrode and work jointed by 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 air.

The temperature of this slag remains between 1600 to 1900°Cunside surface so this high amount of heat energy is enough for the melting the work piece and the electrode thus the weld is formed.

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 oxidation.

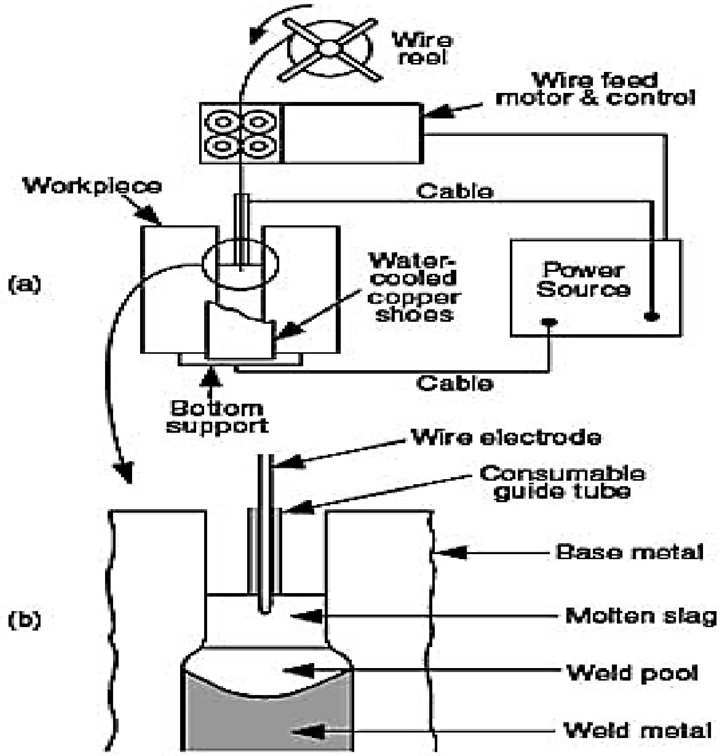


Fig.2.9 Electroslag welding

Applications:-

- ✓ It is used for welding labours steels and nickel alloys.
- ✓ Forging and casting being welded
- ✓ Heavy plastic can be welded.

Advantages:-

- ✓ Heavy thickness metals can be welded atomically
- ✓ Low stress formation preparation of joints easier
- ✓ High deposition during the weld.
- ✓ Low distortion.

Disadvantages:-

- ✓ Difficult to weld cylindrical al objects
- ✓ Hot gawking may occur
- ✓ Grain size becomes larger
- ✓ High cost.

8. Explain the process of flame cutting (AU NOV-DEC 2010)

- ✓ Introduction:-

Flame cutting is widely used in the welding and fabrication industry for making steel parts for every thing from sky scrapers and bridged to industrial equipment and farm implements

Procedure:-

Steel can catch fine and burn just like coal , wood (or) heating coil operation is to get the steel hot enough to ignite, and the pure oxygen is used to keep firing . This is a true chemical process in which the material is not simply melted away.

Operation:-

To start a cut, the user brings a flame closer to steel plate using a cutting torch. It burns a mixture of fuel gas and oxygen to create a very hot preheats flame.

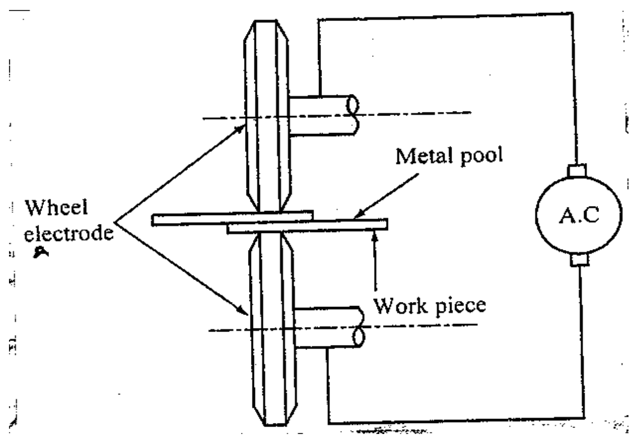
When it is hot enough an additional source of high pressure oxygen is turned on the stream will be directed at the surface of the steel at the right honest spot. The metal will start burning, at that instant, the oxygen flow it creates a hole or gauge in the metal an the way enough.

Chemical reaction:-

The chemical equation for a complete combustion of iron with oxygen is $3Fe+20_2=Fe304+267000Kcal$.

Write the process of seam welding. (AU NOV-DEC 2010, 2013)

The seam welding is used to procedure, continues joint between two over lapping pieces of sheet metal the work piece are placed between two rotating wheel electrodes when electric current is passed through the electrodes. High heat is produced on the work pieces between the wheels at the same time, pressure is applied to complete the weld the work piece is continuously mould in between the wheels thus the leak proof continuous seam is achieved by supplying coolant to be electrodes finally it spends up the welding process.



Application:-

Seam welding is used to make leak proofs, tanks, drums, radiators, house hold utensils automobiles bodies etc. it is also used for welding their sheets.

9. Explain with neat diagram of plasma arc welding. (AU MAY-JUNE 2011) [AU-NOV/DEC-2012]

Principle:-

Plasma is high temperature ionized gas. it is a mixture of a neutral atoms, positively charged atoms and free elements.

When this high temperature plasma is passes 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 surrounded by a negative tungsten electrode in the form of jet. The plasma cutting forces 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 10,000°C to 30,000°C

The high amount of heat energy is used to weld the metal there are two types of plasma arc welding.

1. Transfer type
2. Non transfer type

Transfer type:-

In transferred type, the tungsten electrode is connected to the negative terminal work piece is connected. To the positive terminal. An electric arc is maintained between the electrode and the work piece heat a co-axial flowing gas and maintain it in a plasma state.

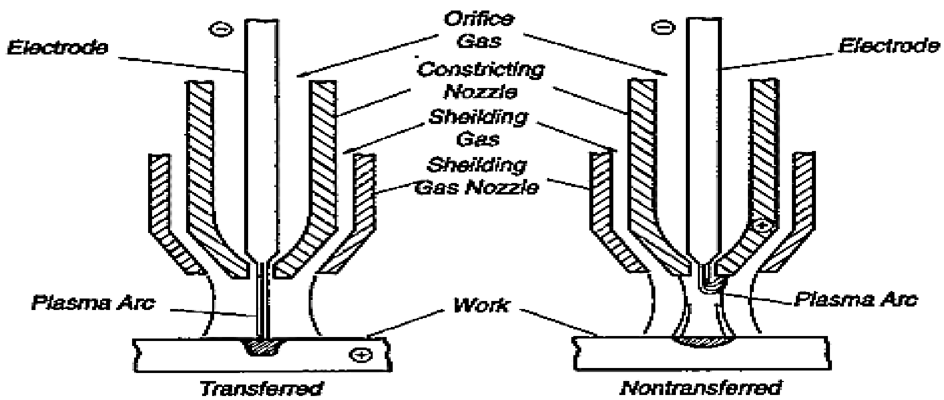


Fig. 2.17 : Plasma Arc welding

It is difficult to imitate the arc first between the work piece and the electrode for that the pilot arc is struck between the nozzle and the electrode

Non transferred type:-

In this type, power it directly connected with the electrode and the torch of nozzle. The electrode carries the same current.

Thus ionizing a high velocity gas that is strewing towards the work piece. The main advantages of this type are that the heat moves insides the wall and heat the incoming gas and outer layer remains cool.

The base metals welded by a plasma arc welding are.

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

Applications:-

1. It is used in aerospace applications
2. It is used for 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 application.

Advantages:-

1. Penetration is uniform
2. Are stability is good.
3. High accuracy weld can be produced

Disadvantages:-

1. Huge noise occurs during welding
2. Gas consumption is high
3. Ultra violet radiations can affect human body.

10. Explain with neat diagram process of laser beam welding (AU MAY-JUNE 2011)

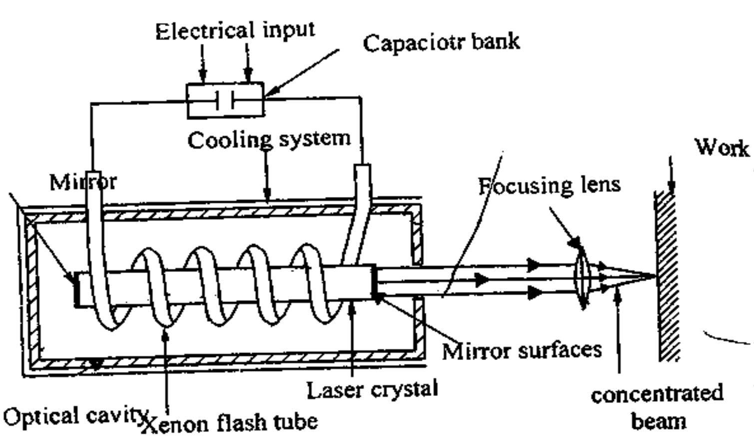
The word laser stands for light amplification by stimulated emission radiation

Principle:-

Light energy is converted into heat energy, here light is produced from the laser source like ruby by rod in the form of monochromatic light.

Working:-

Due to electrical discharge from capacitor, the flash tube converts the electrical energy into light flashers when ruby rod is exposed to the intense light flash, the chromium atoms of the crystal excited and pumped to high energy level beam this high energy level is immediately reduced to intermediate and drop to original state with the evolution of red fluorescent light.



The laser l … ut loss of intensity. The

laser light is focused by the focusing lens to the work piece in the form of coherent monochromatic light.

When this light energy is impacted to the work piece, it will convert into heat energy this heat energy is sufficient to melt the materials to be welded.

Advantages:-

1. It is used in glass and plastics
2. There is no feed of electrodes and power
3. Accuracy is greater.

Disadvantages:-

1. Welding process is low
2. Limited depth of weld can be done
3. It is not suitable for large production

Applications:-

1. Thin metals about 0.5 – 1.5 mm thick can be welded.
2. It can joint dissimilar metals.
3. It is very much useful joining metal alloys.

With the help of suitable diagram, explain the following type of welding: (May/ June 2012)

(i) TIG welding process. (May/ June 2012)

In TIG 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.

By supplying the electric power between the electrode and the work piece, the inert gas from the cylinder passes through the nozzle of the welding head around the electrode. The inert gas surrounds the arc and protects the weld from atmospheric effects and defect free joints are made. The process is also called as Gas Tungsten-arc welding (GTAN). Filler metal may or may not be used. When a filler metal is used, it is usually fed manually into the weld pool.

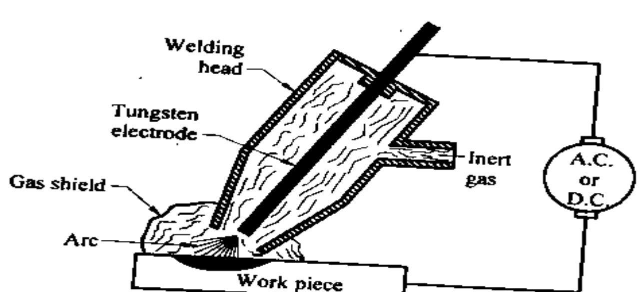


Fig 2.23 Tungsten inert gas welding

An electrode used in this process is tungsten. It has high melting point (3300C), therefore, it will not be melted during weld. This process is used for welding steel, aluminium, cast iron, Magnesium, Stainless steel, Nickel based alloy, copper based alloys and low alloy steel. It is used for combining the dissimilar metals in hard facing and surfacing of metals. This process is used for the metals having thickness less than 6.5 mm.

Advantages

1. No flux is required
2. High welding speed
3. It produces high quality weld
4. No weld cleaning is necessary

11.What is the principle of thermit welding? Explain the same with a neat sketch of the welding arrangement. (May/ June 2012)(Nov/Dec-2018)

Principle of thermit welding

Welding the parts by using liquid thermit steel around the portions to be welded is called Thermit welding. Thermit welding is a fusion of welding process. In this process, neither arc is produced to heat parts nor flames are used. For getting the high temperature, the exothermic reaction is used. Welding principle is the heat of the thermit reaction used for welding in plastic state and mechanical pressure is applied for the joint

It is depending on the chemical reaction between iron oxide and aluminium. The reaction in thermit welding is

8AL+3Fe3O4= 4Al2O3+9Fe

This reaction takes place about 30 sec only and the heat libration temperature is about 28000C. It is twice the melting temperature of steel.

Working :

Thermit is a mixture of aluminium and iron oxide in the ratio of 1:3. This is placed in a furnace and it ignited. So, the chemical reaction takes place. Due to this, liquid and slag are formed which are used for welding.

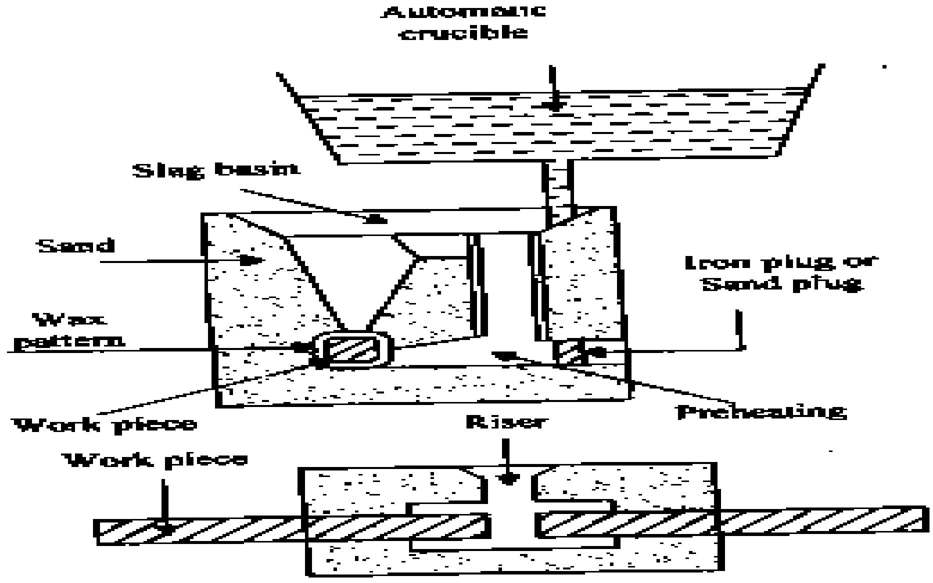


Fig 2.25 Thermit welding

The thermit welding process is classified into two types.

1. Pressure welding process
2. Non-pressure welding process

1. Pressure welding process

During the Pressure welding process, the part to be welded are butted and enclosed in a mould. The mould can be easily removed after the welding of metals.

First, the heated iron slag is poured to the mould and then the aluminium oxide is poured on the parts to be welded. This will create the heating of parts and then the pressure is applied on the work piece to join.

2. Non-pressure welding process In this process, the part to welded are lined up in parallel and a groove is taken in the parts. The wax pattern is formed in and around the welding parts. Then sand is rammed around the wax pattern and mould is completed with gate, runner and raiser around the joint is made.

Then the mould is heated and wax is melted, it will give a space between the joint. Finally, the heated iron slag and aluminium are poured into the mould after solidification of liquid metal. Thus, the joint is made.

Application

It is used in steel rolling mills.

It is used to weld non ferrous metals.

Pipes, Cables, Rails, Shafts are made in this process.

Automobile parts are welded by this process.

12. **Explain the principle of operation, advantages and limitations of electron beam welding.**

Principle: (May/ June 2012)

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. These electrons carry a 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, he 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 1 mm diameter and power density of 10kW/mm2 aluminium material having focusing length of about 40 mm and sreel about 30 mm.

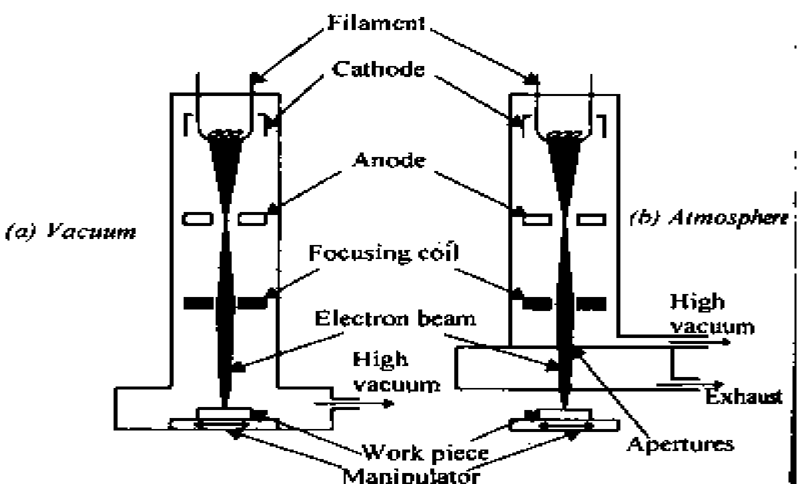


Fig 2.27 Electron beam welding

The variables which are controlled in the electro beam welding are

voltage

Speed

Distance between beam gun to work piece

Advantages

High quality weld is produced

Deep welding is possible

Clean and bright weld can be obtained

High speed operation is achieved

Dimensional accuracy is good

Energy loss is very less.

Disadvantages

Cost is high

Skilled persons are required

It is limited to small size only

It is a time consuming process

Applications

Dissimilar metals can be welded

Refractory and reaching metals can be welded

It is used in air crafts

It is suitable for large scale

It is used in cams

Thermit Welding (TW)

FW process in which heat for coalescence is produced by superheated molten metal from the chemical reaction of thermite.Thermite = mixture of Al and Fe3O4 fine powders that produce an exothermic reaction when ignited

Also used for incendiary bombs

Filler metal obtained from liquid metal

Process used for joining, but has more in common with casting than welding

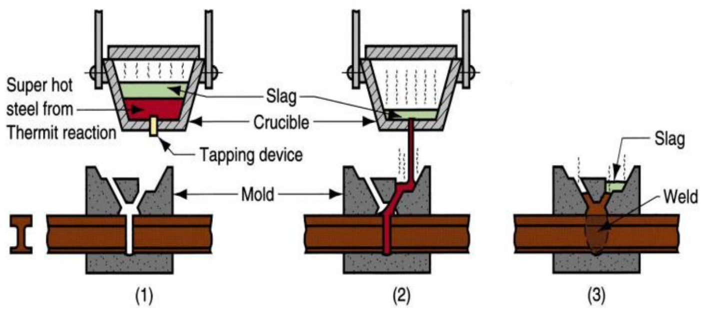


Fig: Thermit welding: (1) Thermit ignited; (2) crucible tapped, superheated metal flows into mold; (3) metal solidifies to produce weld joint.

Applications

Joining of railroad rails

Repair of cracks in large steel castings and forgings

Weld surface is often smooth enough that no finishing is required

Friction Welding (FRW)

SSW process in which coalescence is achieved by frictional heat combined with pressure

When properly carried out, no melting occurs at faying surfaces

No filler metal, flux, or shielding gases normally used

Process yields a narrow HAZ

Can be used to join dissimilar metals

Widely used commercial process, amenable to automation and mass production

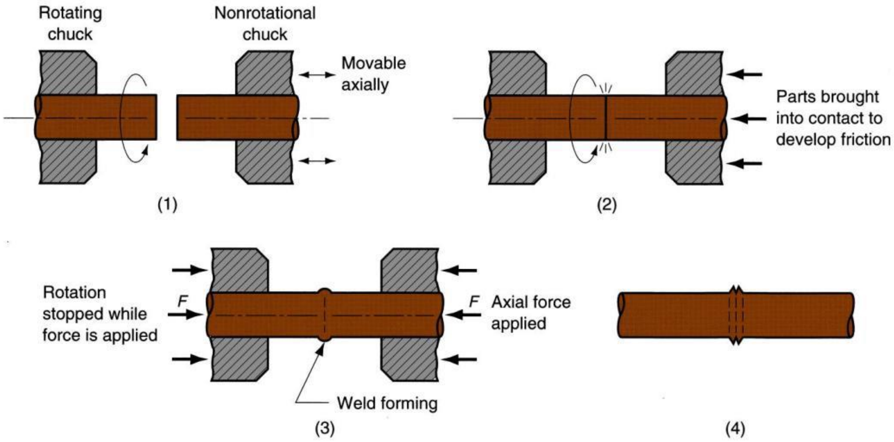


Fig: Friction welding (FRW): (1) rotating part, no contact; (2) parts brought into contact to generate friction heat; (3) rotation stopped and axial pressure applied; and (4) weld created.

Applications

Shafts and tubular parts

Industries: automotive, aircraft, farm equipment, petroleum and natural gas

Limitations

At least one of the parts must be rotational

Flash must usually be removed

Upsetting reduces the part lengths (which must be taken into consideration in product design)

Brazing

It is a low temperature joining process. It is performed at temperatures above 840º F and it generally affords strengths comparable to those of the metal which it joins. It is low temperature in that it is done below the melting point of the base metal. It is achieved by diffusion without fusion (melting) of the base

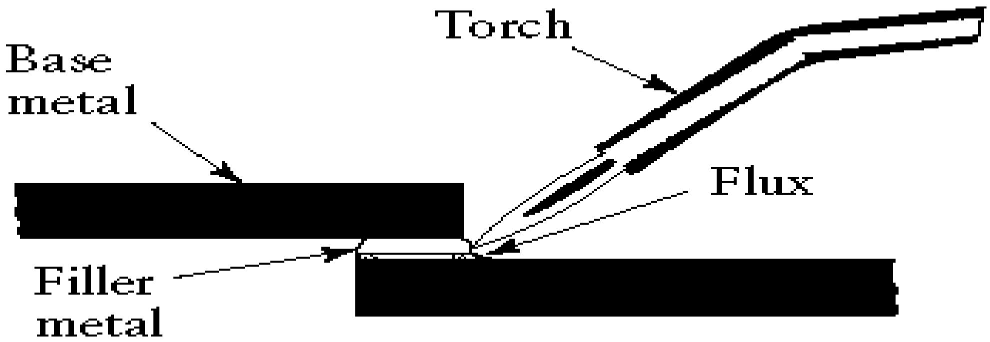
Brazing can be classified as

Torch brazing

Dip brazing

Furnace brazing

Induction brazing



Advantages

- Dissimilar metals which canot be welded can be joined by brazing
- Very thin metals can be joined
- Metals with different thickness can be joined easily
- In brazing thermal stresses are not produced in the work piece. Hence there is no distortion
- Using this process, carbides tips are brazed on the steel tool holders

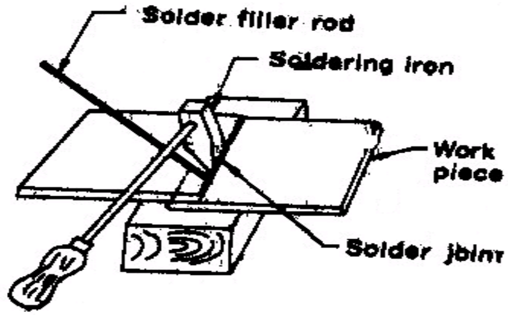
Disadvantages

- Brazed joints have lesser strength compared to welding
- Joint preparation cost is more
- Can be used for thin sheet metal sections

Soldering

- It is a low temperature joining process. It is performed at temperatures below 840ºF for joining.
- Soldering is used for,
- Sealing, as in automotive radiators or tin cans
- Electrical Connections
- Joining thermally sensitive components

• Joining dissimilar metals



Weld Defects

• Undercuts/Overlaps

• Grain Growth

A wide T will exist between base metal and HAZ. Preheating and cooling methods will affect the brittleness of the metal in this region

• Blowholes

Are cavities caused by gas entrapment during the solidification of the weld puddle. Prevented by proper weld technique (even temperature and speed)

• Inclusions

Impurities or foreign substances which are forced into the weld puddle during the welding process. Has the same effect as a crack. Prevented by proper technique/cleanliness.

• Segregation

Condition where some regions of the metal are enriched with an alloy ingredient and others aren‟t. Can be prevented by proper heat treatment and cooling.

• Porosity

The formation of tiny pinholes generated by atmospheric contamination.

Prevented by keeping a protective shield over the molten weld puddle.

13. Sketch the different types of weld defects and mention how they occur [AU-NOV/DEC-2012]

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

Incomplete fusion

Cracks

Porosity

Under cut

Distortion

Slag inclusion

Lamellar tearing

Overlapping

1. Incomplete fusion

Fig 2.29 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 weld also causes defect

2. Cracks

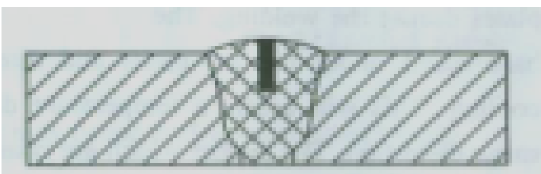


Fig 2.30 Cracks

The cracks are mainly classified into two types

Hot cracking

Cold Cracking

Hot cracking occurs at high temperature. Cold cracking occurs at room temperature.The main causes of crack formation are

Arc speed

Ductility

Solidification rate

Temperature

3. Porosity

Fig 2.31 Porosity

It is due to 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

Arc speed

Coating of the electrodes

Incorrect welding technique

Base metal composition

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

4. Undercut

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

High current

Arc length

Electro diameter

Inclination of electrode

5. Distortion

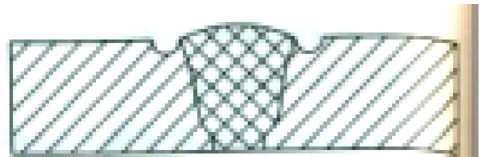


Fig 2.32 Distortion

It is defined as the change in shape and difference between the 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. The factors which are causing distortion are

Arc speed

Number of passes

Stresses in plates

Joint types

Order of welding

6. Slag inclusion

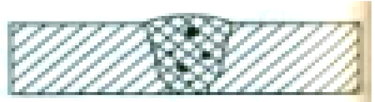


Fig 2.33 Slag inclusions

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

7. Lamellar tearing

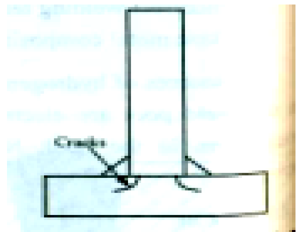


Fig 2.34 Lamellar tearing

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

8. Overlapping

It occurs when a molten metal flows over the parent metal and reminds without fusing. The parameters which are causing overlapper.

Arc length

Arc speed

Joint type

Current

Some of the welding defects may occur during we idle of metal.

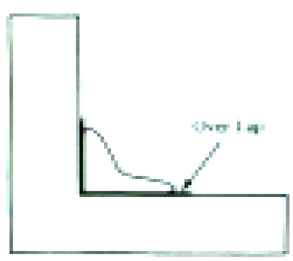


Fig 2.35 Over lapping

14. Explain any four major ways to control the output of arc welding transformer. (May/ June 2013)

Welding transformers

Figure 1.59 shows a schematic diagram of a welding transformer having thin primary windings with a large number of turns. On the other hand, the secondary has more area of cross-section and less number of turns ensuring less voltage and very high current in the secondary. One end of the secondary is connected to the welding electrode, whereas the other end is connected to the pieces to be welded.

If any high current flows, heat is produced due to the contact resistance between the electrode and the pieces to be welded. The generated heat melts a tip of the electrode and the gap between the two pieces is filled.

The winding used for the welding transformer is highly reactive. Otherwise, a separate reactor may be added in series with the secondary winding.

Figure 1.60 shows the volt-ampere characteristic of a welding transformer.

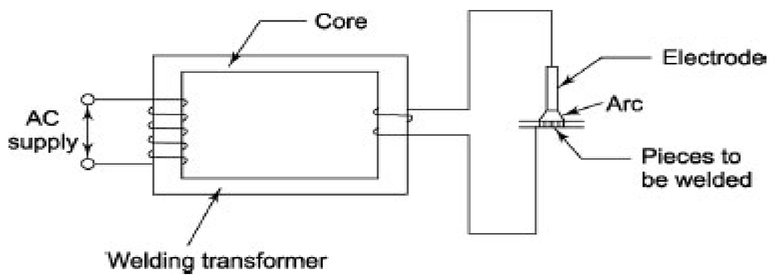


Figure 1.59 Welding Transformer

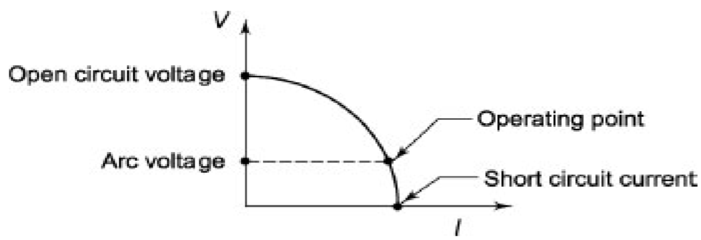


Figure 1.60 Volt-ampere Characteristic of a Welding Transformer

The winding used for the welding transformer is highly reactive. Otherwise, a separate reactor may be added in series with the secondary winding.

Figure 1.60 shows the volt-ampere characteristic of a welding transformer.

15. To control the arc, various reactors are used with welding transformers. Some methods to control the arc are given below:

1. Tapped reactor:

With the help of taps on the reactor, the output current is regulated. This has limit number of current settings shown in Figure 1.61

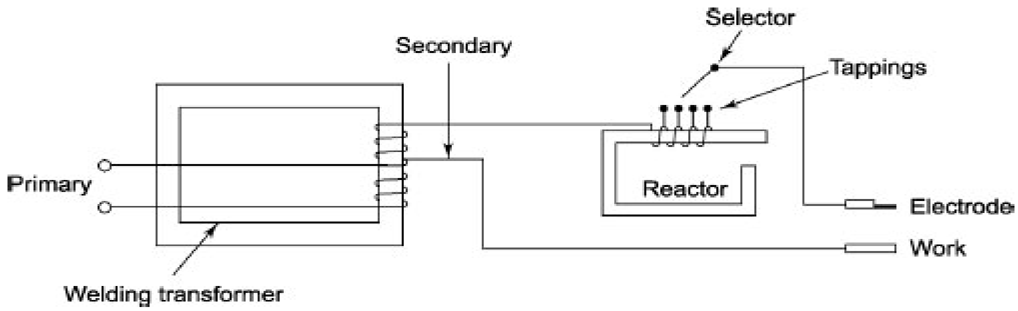


Figure 1.61 Tapped Reactor

2. Moving coil reactor:

Figure 1.62 shows a moving coil reactor in which the reactive distance between primary and secondary is adjusted. The current becomes less if the distance between the coils is large.

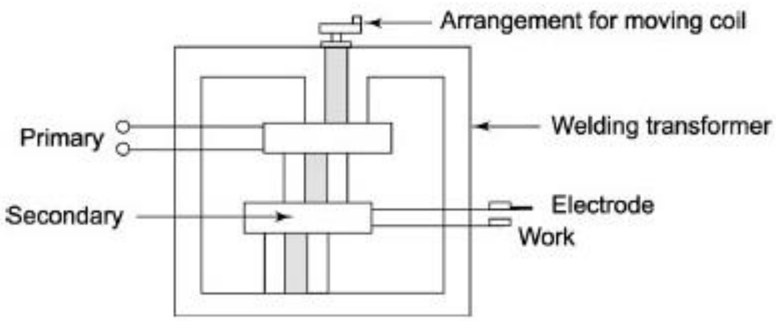


Figure 1.62 Moving Coil Reactor

3. Moving shunt reactor:

Figure 1.63 shows a moving shunt reactor in which the position of the central magnetic shunt can be adjusted. Change of the output current is obtained due to the adjustment of the shunted flux

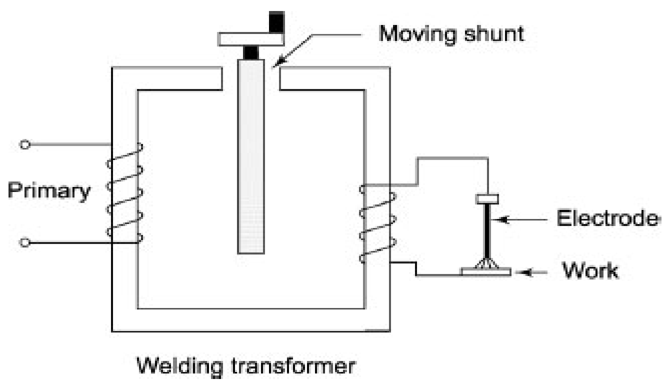


Figure 1.63 Moving Shunt Reactor

4. Continuously variable reactor:

Figure 1.64 shows a continuously variable reactor in which the height of the reactor is continuously varied. Greater reactance is obtained due to greater core insertion and hence the output current is less.

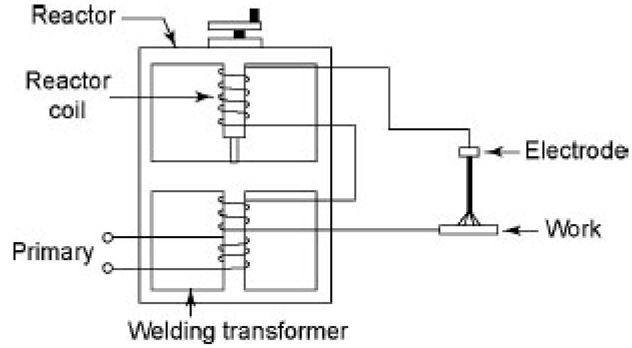


Figure 1.64 Continuously Variable Reactor

16. Explain the three variables involved in continuous drive friction welding. (May/ June 2013)

The variable parameters of the friction welding process are as follows:

1. Speed (only when DC drive is used)

2. Pressure

3. Loss of length (or time)

Let's now take a look at these parameters one at a time:

1. Speed

The function of the rotational speed is to produce a relative speed at the periphery of the components in excess of 250 Surface feet per minute (SFM) (for steels). This empirical figure is the same for solids and tubular components. Speeds below 250 Surface feet per minute (SFM) produce very high torques in the material (for a set pressure), and have a tendency to tear the metal fibers. There is no real limit as to the highest speed. Welds have been made up to 2000 SFM. However, in production welding machines, the SFM is usually arranged to be within 300-650 SFM. As an example, a machine spindle speed of 600 RPM will comfortably weld steel products of 2" dia. to 4" dia. (in fact larger than 4" dia.). The formula for calculating SFM is as follows:

Surface feet per minute (SFM) = Spindle RPM x Component dia. in feet

While high rotational speeds can be used, they do not increase the speed of welding. Very high speeds ultimately lead the machine designer to use specialized bearing arrangements, which can be a source of maintenance problems. From a weld quality standpoint, speed is generally the least important parameter.

2. Pressure

There is a wide range of pressures that might be applied (for steels) to obtain a sound weld. However, it is recommended that the heating pressure is 4 tons per. sq. in. of the component cross sectional area, and the forge pressure is 10 tons per sq. inch. These pressures can be varied if required to produce specific changes in physical properties, e.g. tensile, torsion, ductility, fatigue life, impact, etc.

(one relative to the other).

In order to calculate the machine settings for pressure, one needs to know the area of the hydraulic cylinder and the area of the component to be welded. It is then possible to calculate the PSI gauge setting for the machine. Tables for these settings for various diameters are supplied with production machines.

The formula for calculating the PSI gauge setting is as follows:

$$\text{PSI Gauge} = \frac{\text{Tons/sq. in on component x component area (sq. ins.)}}{\text{2000 x cylinder area (sq. ins.)}}$$

As previously mentioned, it is possible if required to modify the pressure input during the heating phase. This can be done to produce "back heat" or pre-heat into the components, to achieve a relatively slower quench rate. If this is required, a pressure of 1.5 tons per sq. in. of component area is applied before the heating pressure.

3. Loss of Length (or Time)

A fundamental requirement of a solid-phase weld is that at least a minimum amount of the original component surfaces are removed within a certain period of time in order to bring together clean parent materials at the forging phase. The simplest means to achieve this situation is to apply the heating phase for a pre-set time.

In practice, however, because no two surfaces of engineering parts are truly identical (grease, forging shape, forging scale, saw cut, paint, dirt, etc.), it is better, from a quality standpoint, to control the friction welding process on the length loss between the components. This method provides assurance that some of the welding cycle time has not been used in overcoming differing component surface conditions. For example, because one set of components has greater saw cut angle on their surfaces than normal, two seconds of a six second weld cycle can be used to remove this condition before getting into the heating phase proper on the full area.

17. What are the nondestructive tests used in welding inspection? Explain any one method. (May/ June 2013)

Nondestructive testing (NDT)

Non-destructive testing (NDT) is a wide group of analysis techniques used in science and industry to evaluate the properties of a material, component or system without causing damage.

The terms Nondestructive examination (NDE), Nondestructive inspection (NDI), and Nondestructive evaluation (NDE) are also commonly used to describe this technology. Because NDT does not permanently alter the article being inspected, it is a highly valuable technique that can save both money and time in product evaluation, troubleshooting, and research

Nondestructive testing is also known as nondestructive examinations or evaluation (NDE) or inspection. These techniques use the application of physical principles from the detection of flaws or discontinuities in materials without impairing their usefulness.

In the field of welding, four nondestructive tests are widely used:

Dye-penetrant testing and Fluorescent-penetrant testing

Magnetic particle testing

Ultrasonic testing

Radiographic testing

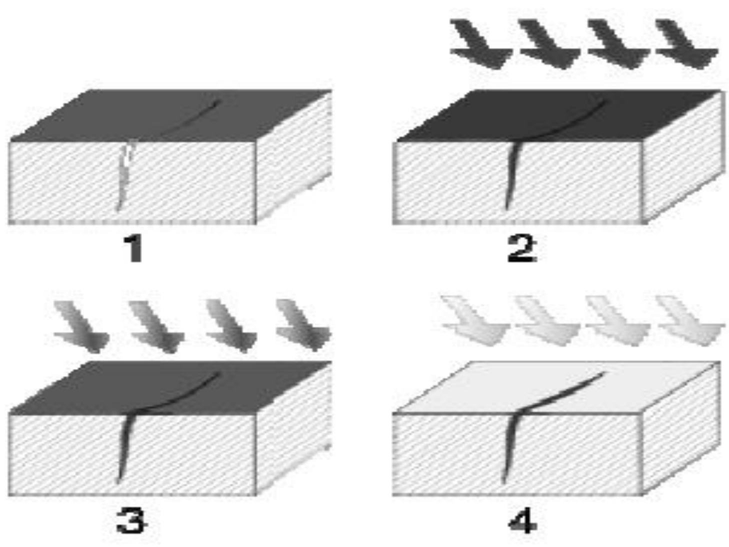
Weld Penetrant examination

Liquid-penetrant examination is a highly sensitive, nondestructive method for detecting minute discontinuities(flaws) such as cracks, pores, and porosity, which are open to the surface of the material being inspected. It may be applied to many materials, ferrous and nonferrous metals, glass and plastics.

The applied surface must be cleaned from dirt and film. So, discontinuities must be free from dirt, rust, grease, or paint to enable the penetrant to enter the surface opening.

A liquid penetrant is applied to the surface of the part to be inspected. The penetrant remains on the surface and seeps into any surface opening. The penetrant is drawn into the surface opening by capilary action. The parts may be in any position when tested. After sufficient penetration time elapsed, the surface is cleaned and excess penetrant is removed.

The penetrant is usually a red color; therefore, the indication shows up brilliantly against the white background. Even small defects may be located.



1. Section of material with a surface-breaking crack that is not visible to the naked eye.
2. Penetrant is applied to the surface.

3. Excess penetrant is removed.

4. Developer is applied, rendering the crack visible

Applications:

Liquid-penetrant examination is used to detect surface defects in aluminium, magnesium, and stainless steel weldments when the magnetic particle examination method cannot be used.

It is very usefull for locating leaks in all types of welds. Welds in pressure and storage vessels and in piping for the petroleum industry are examined for surface cracks and for porosity.

Fluorescent--Penetrant Examination:

The penetrant is fluorescent and when it is exposed to ultraviolet or black light it shows a glowing fluorescent type of read-out.

It provides a greater contrast than the visible dye penetrants.

Used for leak detection in magnetic and nonmagnetic weldments.

A fluorescent penetrant is applied to one side of the joint and a portable ultraviolet light is then used on the reverse side of the joint to examine the weld for leaks.

Inspect the root pass of highly critical pipe welds.

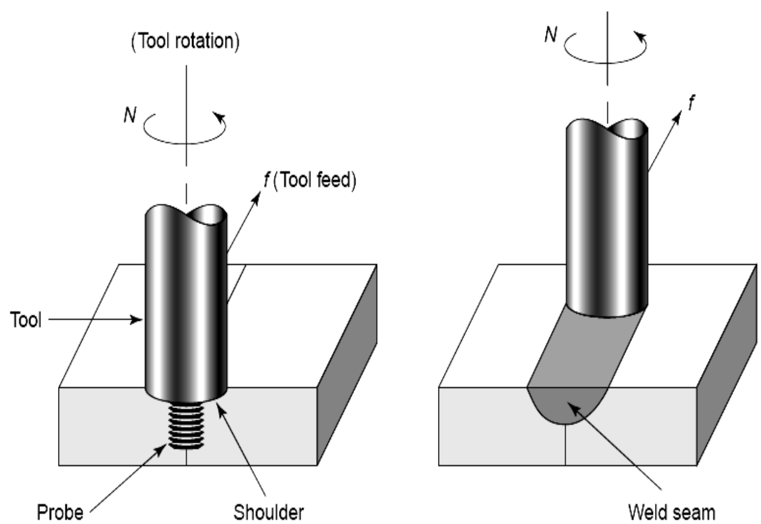


Fig: Friction stir welding

18. Explain the principle of arc welding. What are the different weld positions in arc welding? Enumerate some defects due to arc welding? (May/June 2014)

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 nearer with a small air gap of 3 mm 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 work pieces become a single piece without applying any external pressure. The temperature of arc is about 5000o to 6000oC. The electrode supplied 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 70o 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. Also it 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.

The molten metal is forced out if 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”.