METAL JOINING PROCESSES

Lecture 1

FUNDAMENTALS OF METAL JOINING AND CLASSIFICATION

Joining is concerned primarily with the assembly of the components into subassemblies or final products. The joining processes can be divided into three major categories: fasteners, welding, and adhesives. These categories are extremely broad and contain a vast amount of information. Joining focuses primarily on assembly of components or parts into subassemblies or final products.

The three major categories of joining processes follow.

1) **Fasteners**: These are mechanical devices that join materials via clamping forces, pressure, or friction, which do not involve molecular bonding between the surfaces as the primary bonding force. Some examples would be a threaded fastener, pins, and riveting.
2) **Cohesion** (**welding**): This involves the joining of two or more pieces of material by means of heat, pressure, or both, with or without a filler metal, to produce a localized union through fusion or recrystallization creating a chemical bond. Welding process is classified by their energy source. The different energy sources used in welding are: electrical, mechanical, chemical, and optical (beam, ray). Some examples of welding processes are: arc welding, resistance spot welding, friction welding, oxyacetylene welding, and electron beam welding.
3) **Adhesion** (**gluing**): This is the joining of two or more material components through the forces of attraction between the adhesive and the materials being joined (adherends). Gluing processes depend primarily upon adhesive bonding. Some of the other adhesive processes are brazing, soldering, and epoxy bonding.

Brazing and soldering are two methods of adhesive bonding that are often incorrectly classified as welding processes, since they involve metallic bonding. According to the American Welding Society (3), the definitions of these two processes are:

- **Brazing:** The filler metal has a liquidus above 450°C (840°F) and below the solidus of the base metal; and the filler metal is distributed by capillary attraction. The filler metals for brazing contain metals such as copper, silver, and gold,
- **Soldering:** The filler metal has a liquidus below 450°C (840°F) and below the solidus of the base metal; and the filler metal is distributed by capillary attraction. the filler metals for soldering contain metals such as lead, tin, and cadmium

❖ WELDING:

- Welding is a process for joining two similar or dissimilar metals by fusion.
- It joins different metals/alloys, with or without the application of pressure and with or without the use of filler metal.
- The fusion of metal takes place by means of heat. The heat may be generated either from combustion of gases, electric arc, electric resistance or by chemical reaction.
- During some type of welding processes, pressure may also be employed, but this is not an essential requirement for all welding processes.
- Welding provides a permanent joint but it normally affects the metallurgy of the components.
- It is usually accompanied by post weld heat treatment for most of the critical components.
- The welding is widely used as a fabrication and repairing process in industries.
- Some of the typical applications of welding include the fabrication of ships, pressure vessels, automobile bodies, off-shore platform, bridges, welded pipes, sealing of nuclear fuel and explosives, etc.
- The weldability may be defined as property of a metal which indicates the ease with which it can be welded with other similar or dissimilar metals.
- Weldability of a material depends upon various factors like the metallurgical changes that occur due to welding, changes in hardness in and around the weld, gas evolution and absorption, extent of oxidation, and the effect on cracking tendency of the joint.
- Plain low carbon steel (C-0.12%) has the best weldability amongst metals. Generally it is seen that the materials with high castability usually have low weldability

❖ ADVANTAGES AND DISADVANTAGES OF WELDING

Advantages

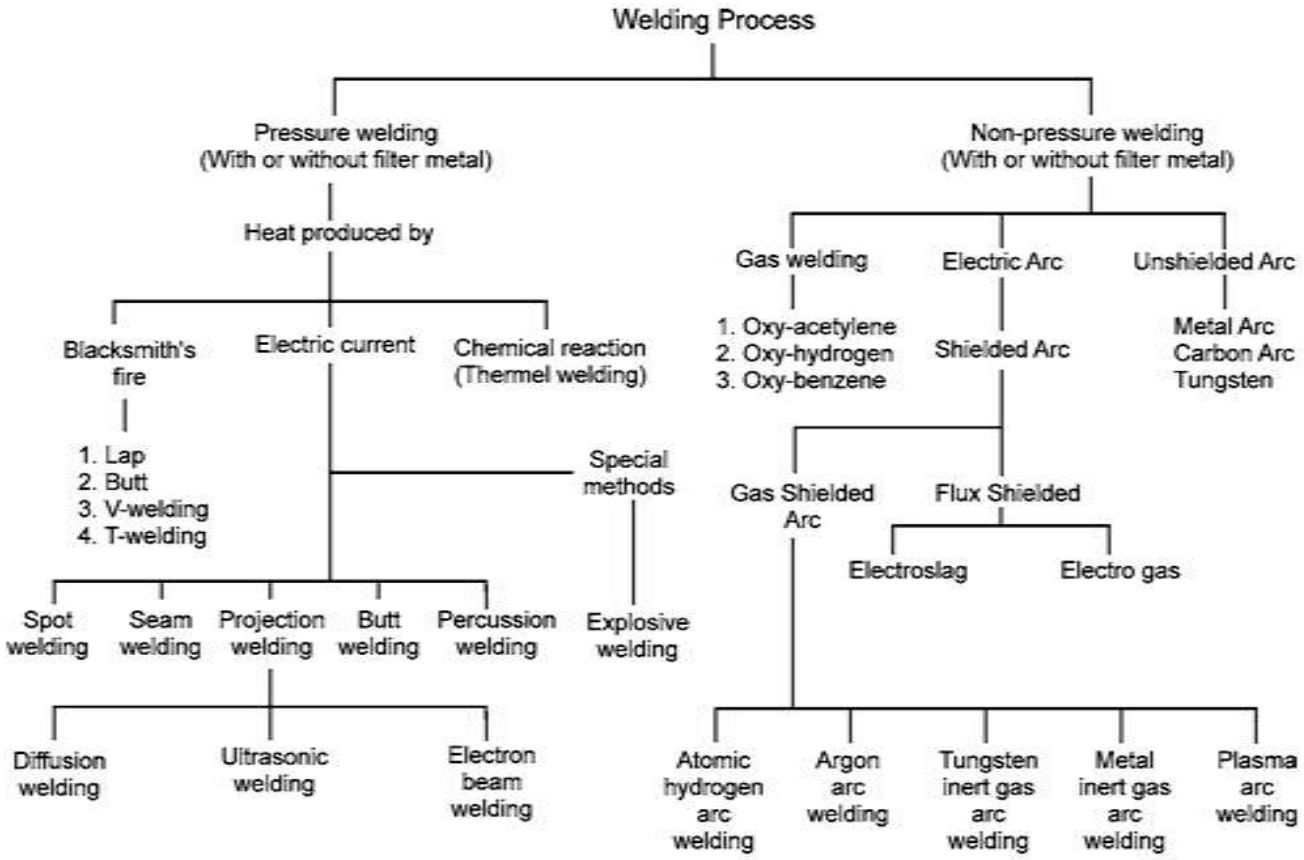
1) Welding is more economical and is much faster process as compared to other processes (riveting, bolting, casting etc.)
2) Welding, if properly controlled results permanent joints having strength equal or sometimes more than base metal.
3) Large number of metals and alloys both similar and dissimilar can be joined by welding.
4) General welding equipment is not very costly.
5) Portable welding equipments can be easily made available.
6) Welding permits considerable freedom in design.
7) Welding can join welding jobs through spots, as continuous pressure tight seams, end-to-end and in a number of other configurations.
8) Welding can also be mechanized.

Disadvantages

1) It results in residual stresses and distortion of the workpiece.
2) Welded joint needs stress relieving and heat treatment.
3) Welding gives out harmful radiations (light), fumes and spatter.
4) Jigs, and fixtures may also be needed to hold and position the parts to be welded
5) Edges preparation of the welding jobs are required before welding
6) Skilled welder is required for production of good welding
7) Heat during welding produces metallurgical changes as the structure of the welded joint is not same as that of the parent metal.

❖ CLASSIFICATION OF WELDING AND ALLIED PROCESSES

Oxy-Fuel Gas Welding Processes	**Resistance Welding**
a) Air-acetylene welding	a) Spot Welding
b) Oxy-acetylene welding	b) Seam Welding
c) Oxy-hydrogen welding	c) Projection Welding
d) Pressure gas welding	d) Resistance Butt Welding
	e) Flash Butt Welding
Arc Welding Processes	f) Percussion Welding
a) Carbon Arc Welding	g) High Frequency Resistance Welding
b) Shielded Metal Arc Welding	h) High Frequency Induction Welding
c) Submerged Arc Welding	
d) Gas Tungsten Arc Welding	**Solid-State Welding Processes**
e) Gas Metal Arc Welding	a) Forge Welding
f) Plasma Arc Welding	b) Cold Pressure Welding
g) Atomic Hydrogen Welding	c) Friction Welding
h) Electro-slag Welding	d) Explosive Welding
i) Stud Arc Welding	e) Diffusion Welding
j) Electro-gas Welding	f) Cold Pressure Welding
	g) Thermo-compression Welding
Thermit Welding Processes	
a) Thermit Welding	**Radiant Energy Welding Processes**
b) Pressure Thermit Welding	a) Laser Welding
	b) Electron Beam Welding


Welding Process
Pressure welding
(With or without filter metal)
Non-pressure welding
(With or without filter metal)
Heat produced by
Gas welding
Electric Arc
Unshielded Arc
Blacksmith's fire
Electric current
Chemical reaction (Thermel welding)
1. Oxy-acetylene
2. Oxy-hydrogen
3. Oxy-benzene
Shielded Arc
Metal Arc
Carbon Arc
Tungsten
1. Lap
2. Butt
3. V-welding
4. T-welding
Special methods
Gas Shielded Arc
Flux Shielded
Electroslag
Electro gas
Spot welding
Seam welding
Projection welding
Butt welding
Percussion welding
Explosive welding
Diffusion welding
Ultrasonic welding
Electron beam welding
Atomic hydrogen arc welding
Argon arc welding
Tungsten inert gas arc welding
Metal inert gas arc welding
Plasma arc welding

Lecture 2

WORKING PRINCIPLE OF GAS WELDING

❖ GAS WELDING WORKING PRINCIPLE:

- A fusion welding process which joins metals, using the heat of combustion of an oxygen /air and fuel gas (i.e. acetylene, hydrogen propane or butane) mixture is usually referred as 'gas welding'.
- The intense heat (flame) thus produced melts and fuses together the edges of the parts to be welded, generally with the addition of a filler metal.
- Operation of gas welding is shown in Fig. below. The fuel gas generally employed is acetylene; however gases other than acetylene can also be used though with lower flame temperature.
- Oxy-acetylene flame is the most versatile and hottest of all the flames produced by the combination of oxygen and other fuel gases.
- Other gases such as Hydrogen, Propane, Butane, Natural gas etc., may be used for some welding and brazing applications.

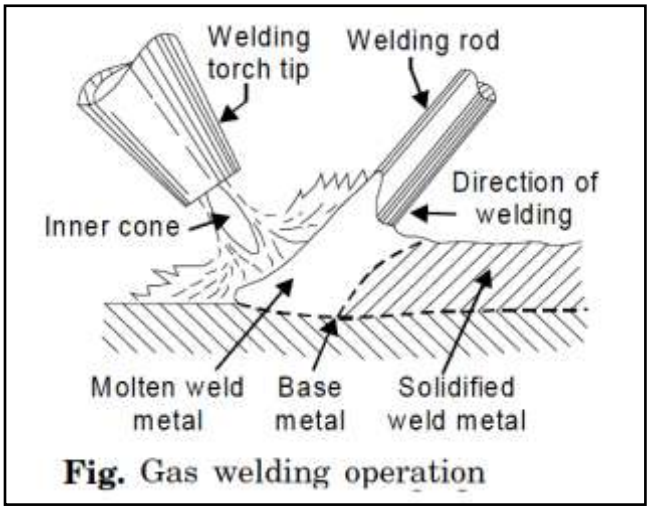


Fig. Gas welding operation

❖ OXY-ACETYLENT WELDING

In this process, acetylene is mixed with oxygen in correct proportions in the welding torch and ignited. The flame resulting at the tip of the torch is sufficiently hot to melt and join the parent metal. The oxy-acetylene flame reaches a temperature of about 3300°C and thus can melt most of the ferrous and non-ferrous metals in common use. A filler metal rod or welding rod is generally added to the molten metal pool to build up the seam slightly for greater strength.

❖ OXY-ACETYLENT WELDING PROCESS

- To start welding, the acetylene control valve is turned first.
- When acetylene comes out of the nozzle, it should be ignited with spark lighter.
- It will give a yellow-colored smoke flame. After it, oxygen cylinder valve is opened and supply is increased until a most suitable flame is obtained.
- Then the flame is focused on the edges to be welded. Flux and filler metal are also added with the heat of flame.
- The edges and filler metal melt and a joint are formed after cooling of the molten metal.
- The joint may be formed with or without using filler metal.

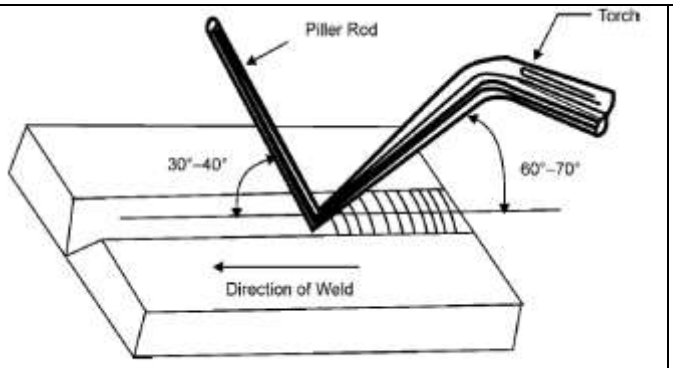


Fig. : Leftward Welding

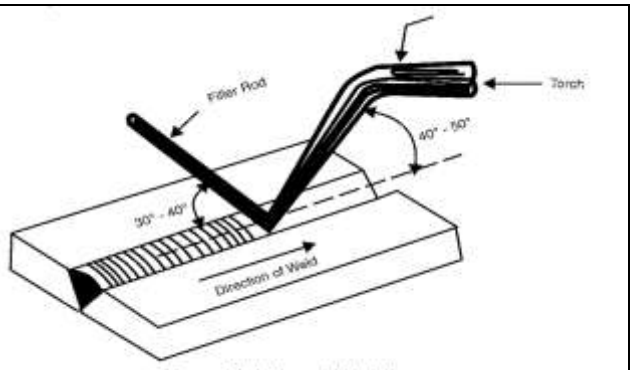


Fig. : Rightward Welding

❖ TYPES OF WELDING FLAMES

1. Neutral welding flame (Acetylene and oxygen in equal proportions).
2. Carburizing welding flame or reducing (excess of acetylene).
3. Oxidizing welding flame (excess of oxygen).

❖ Neutral Welding Flame

- A neutral flame results when approximately equal volumes of oxygen and acetylene are mixed in the welding torch and burnt at the torch tip.
- The temperature of the neutral flame is of the order of about 5900°F (3260°C). It has a clear, well defined inner cone, indicating that the combustion is complete.
- The inner cone is light blue in color.
- It is surrounded by an outer flame envelope, produced by the combination of oxygen in the air and superheated carbon monoxide and hydrogen gases from the inner cone.
- This envelope is usually a much darker blue than the inner cone.
- A neutral flame is named so because it affects no chemical change on the molten metal and, therefore will not oxidize or carburize the metal.
- The neutral flame is commonly used for the welding of mild steel, stainless steel, cast Iron, copper, and alluminium.

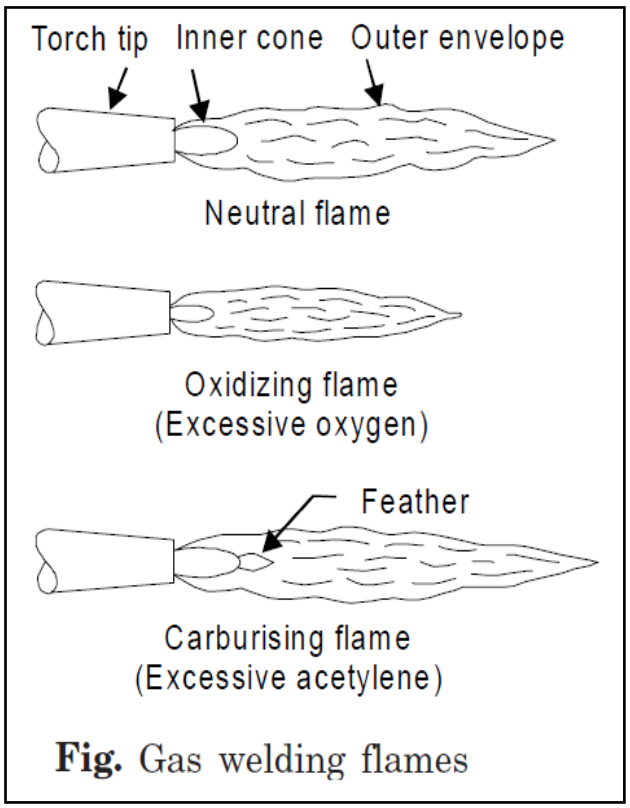


Fig. Gas welding flames

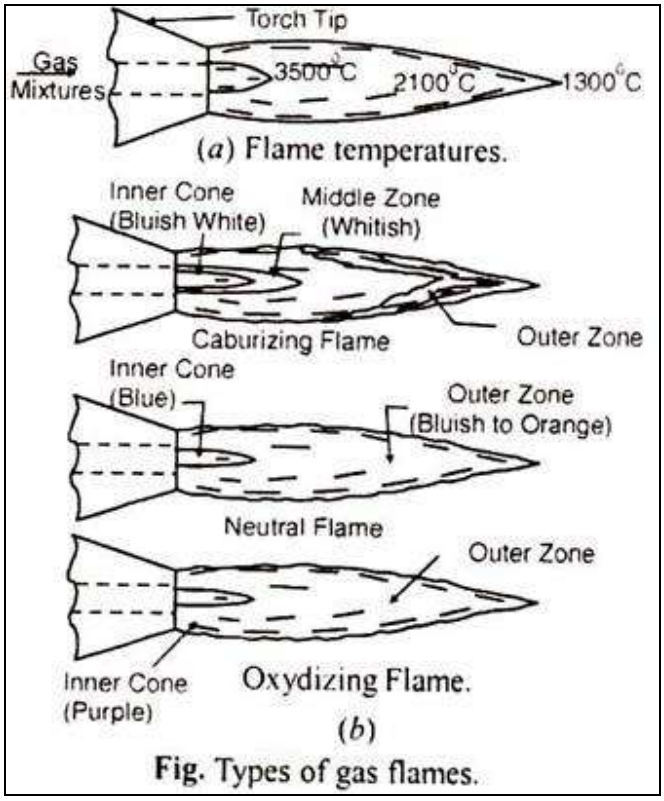


Fig. Types of gas flames.

➢ Carburizing or Reducing Welding Flame

- The carburizing or reducing flame has excess of acetylene and can be recognized by acetylene feather, which exists between the inner cone and the outer envelope.
- The outer flame envelope is longer than that of the neutral flame and is usually much brighter in color.
- With iron and steel, carburizing flame produces very hard, brittle substance known as iron carbide.
- A reducing flame may be distinguished from carburizing flame by the fact that a carburizing flame contains more acetylene than a reducing flame.
- A reducing flame has an approximate temperature of 3038°C.
- A carburizing-flame is used in the welding of lead and for carburizing (surface hardening) purpose.
- A reducing flame, on the other hand, does not carburize the metal; rather it ensures the absence of the oxidizing condition.
- It is used for welding with low alloy steel rods and for welding those metals, (e.g., non-ferrous) that do not tend to absorb carbon. This flame is very well used for welding high carbon steel.

❖ **Oxidizing Welding flame**

- The oxidizing flame has an excess of oxygen over the acetylene.
- An oxidizing flame can be recognized by the small cone, which is shorter, much bluer in color and more pointed than that of the neutral flame.
- The outer flame envelope is much shorter and tends to fan out at the end. Such a flame makes a loud roaring sound.
- It is the hottest flame (temperature as high as 6300°F) produced by any oxy-fuel gas source.
- The excess oxygen especially at high temperatures tends to combine with many metals to form hard, brittle, low strength oxides.
- An excess of oxygen causes the weld bead and the surrounding area to have a scummy or dirty appearance.
- It is not used in the welding of steel.
- A slightly oxidizing flame is helpful when welding (i) Copper-base metals (ii) Zinc-base metals and (iii) A few types of ferrous metals such as manganese steel and cast iron.
- The oxidizing atmosphere in these cases, create a base metal oxide that protects the base metal.

Lecture 3

EQUIPMENTS, APPLICATION, ADVANTAGES AND LIMITATION OF GAS WELDING

❖ **Gas Welding Equipments**

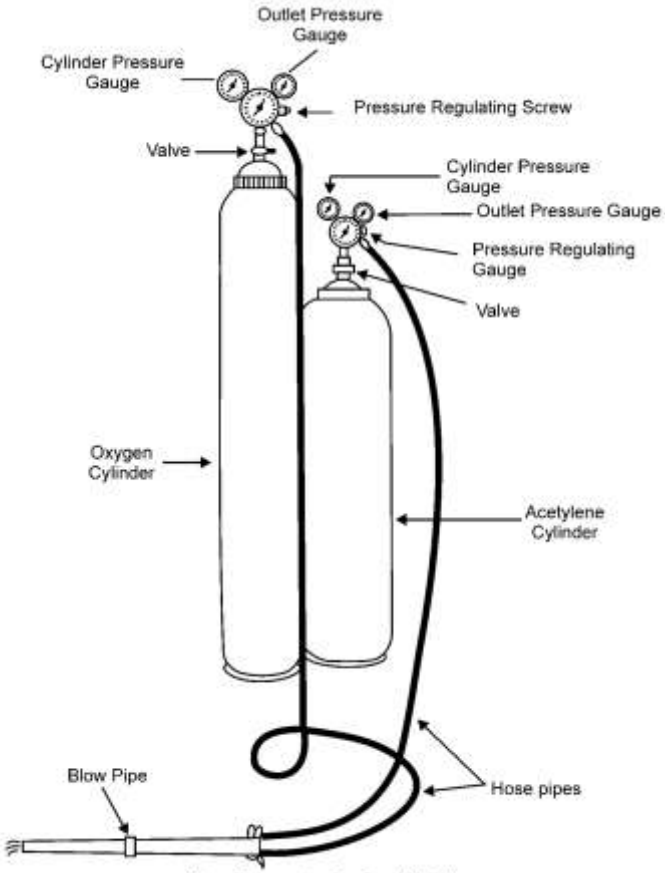


Fig.: Apparatus for Gas Welding

❖ **Oxygen Cylinder:** The cylinder is made up of steel in capacity range 2.25 to 6.3 m^3. The cylinders are filled with oxygen at about 150 kg/cm^2 at 21°C. A safety valve is also provided on it. The cylinder can be opened or closed by a wheel which operates a valve. A protector cap is provided on the top of a cylinder to safeguard the valve.

❖ **Acetylene Cylinder:** Acetylene cylinders are also made up of steel. Gas is filled at a pressure of 18-20 kg/cm^2. The capacity of the cylinder is about $10m^3$. Regulator valve and safety valve are mounted on cylinder. Safety plugs are also provided on the bottom of the cylinder. When filled into the cylinder, the acetylene is dissolved in acetone.

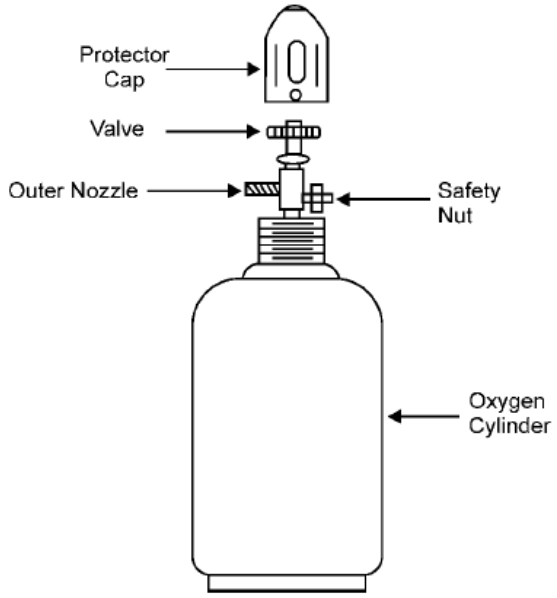


Fig. : Oxygen Cylinder

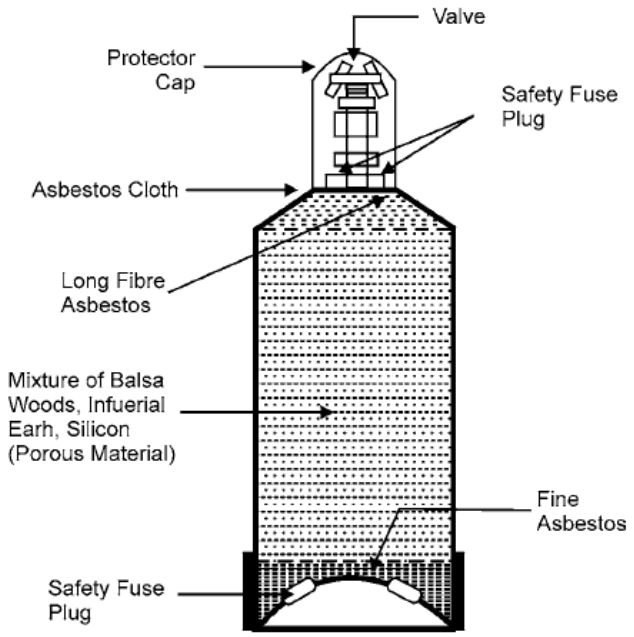


Fig.: Acetylene Cylinder

❖ **Welding Torch:**

It is a tool for mixing oxygen and acetylene in correct proportion and burning the mixture at the end of a tip. Gas flow to the torch is controlled with the help of two needle valves in the handle of the torch.

There are two basic types of gas welding torches:

(1) Positive pressure (also known as medium or equal pressure), and

(2) Low pressure or injector type

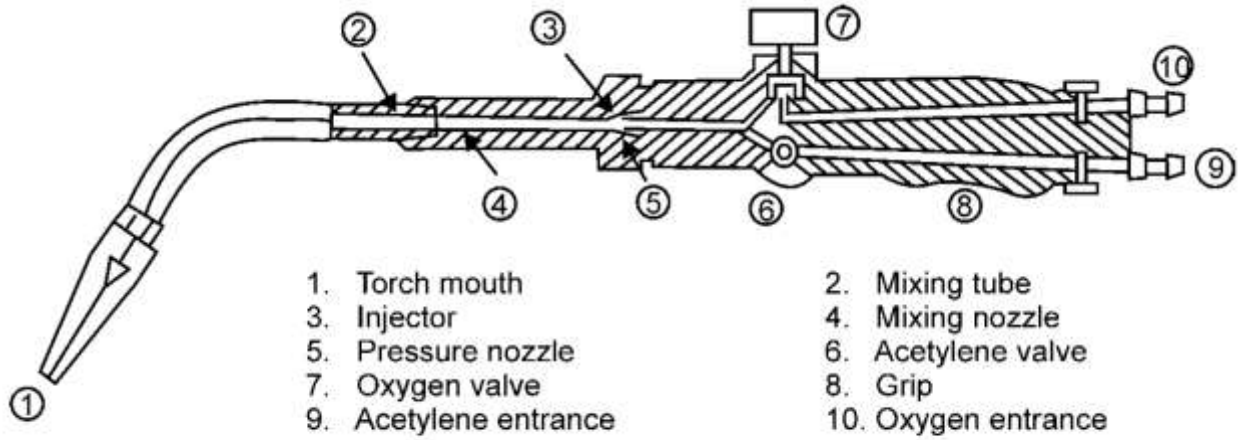


Fig. : Welding Torch

❖ Advantages of Gas Welding

- Weld ferrous and non-ferrous metals: One of the great strengths of gas welding is that it can weld non-ferrous and ferrous metals together.
- No requirement for electricity: When we compare gas welding to the other popular weld methods like arc welding, gas welding does not require any electricity to operate. Hence, you can use gas welding in places that do not have access to electricity.
- Cheap Equipment costs: The initial capital for gas welding is very low as it doesn't require specialized machinery.
- Doesn't require specialized labor: Gas welding doesn't require highly specialized labor. This makes it easier to find gas welders, as well as keeps the labor charge low.
- Portable equipment: The whole setup for Gas Welding is easily portable.
- Equipment is cheap as compared to other welding process.
- It can be used for welding of all types of metals.
- Maintenance of equipment is very less.
- It is a portable process.
- It can be used for cutting of metals of small thickness.
- It is specially used for sheet metal work.

❖ Disadvantages of Gas Welding

- Not suitable for thick sections
- Cannot be used for high strength steel
- The slow rate of heating
- Cannot reach the temperatures of arc welding
- Doesn't have a dedicated flux shielding system
- It takes long time for heating the job as compared to the arc welding.
- The heat affected area is more.
- This is prone to corrosion and brittleness.
- Gases are expensive and difficult to store.

❖ Application of gas welding

- Repair works: One of the most common applications of gas welding is for repair works.
- Fabrication of sheet metal: Thin to medium sheet metals are easily weld using gas welding.
- Aircraft industry: Oxy-Acetylene welding is used in joining various aircraft parts.
- Automotive industry: Used to weld parts of the frame and the chassis.
- Joining High carbon Steel: Gas welding is very effective in melting high carbon steel.

❖ Safety Recommendations for Gas Welding:

1. Always handle the gas cylinders with care.
2. The adjusting screw on the regulator must be fully released before opening a cylinder valve.
3. Never use matchsticks for lighting a torch.
4. Never lubricate the regulator valve with oil or grease, it may cause explosion.
5. Always use goggles while working.
6. Proper ventilation must be provided in the shop.
7. Acetylene cylinders should be stored in upright position.
8. Do not open acetylene cylinders near sparks or fire.
9. Never remove torch tips with pliers.
10. The cylinder should be leak proof.
11. Always use protective caps over the valves.
12. Keep in mind the location of the fire extinguishers.

Lecture 4

WORKING PRINCIPLE, TYPES, AND EQUIPMENTS OF ELECTRIC WELDING

❖ ARC WELDING PROCESSES

Arc welding is a type of welding process using an electric arc to create heat to melt and join metals. A power supply creates an electric arc between a consumable or non-consumable electrode and the base material using either direct (DC) or alternating (AC) currents.

Power supply is given to electrode and the work. A suitable gap is kept between the work and electrode. A high current is passed through the circuit. An arc is produced around the area to be welded. The electric energy is converted into heat energy, producing a temperature of 3000°C to 4000°C. This heat melts the edges to be welded and molten pool is formed. On solidification the welding joint is obtained.

The arc can be either manually or mechanically guided along the line of the join, while the electrode either simply carries the current or conducts the current and melts into the weld pool at the same time to supply filler metal to the join.

Because the metals react chemically to oxygen and nitrogen in the air when heated to high temperatures by the arc, a protective shielding gas or slag is used to minimize the contact of the molten metal with the air. Once cooled, the molten metal solidifies to form a metallurgical bond.

The various arc welding processes are:

1) Carbon Arc Welding
2) Shielded Metal Arc Welding
3) Flux Cored Arc Welding
4) Gas Tungsten Arc Welding
5) Gas Metal Arc Welding
6) Plasma Arc Welding
7) Atomic Hydrogen Welding
8) Electro slag Welding
9) Stud Arc Welding
10) Electro gas Welding

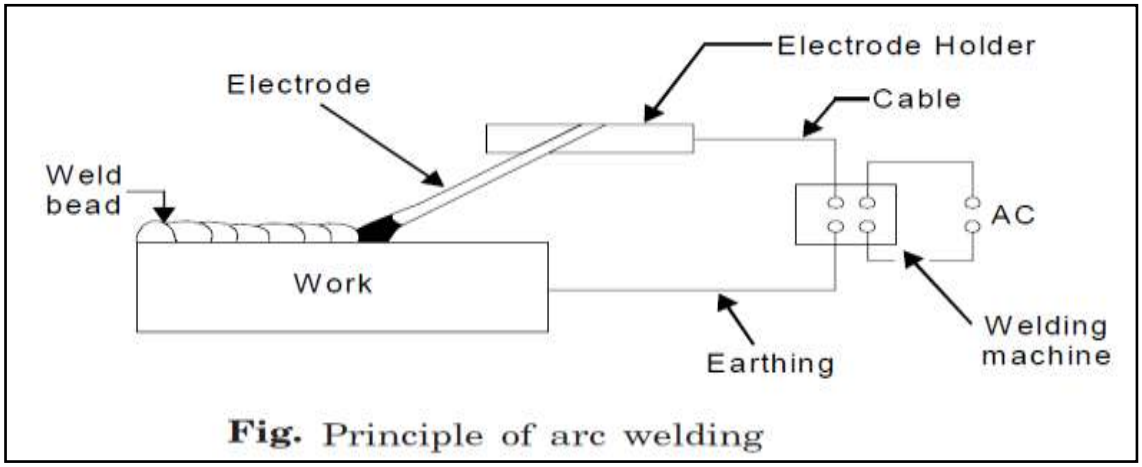
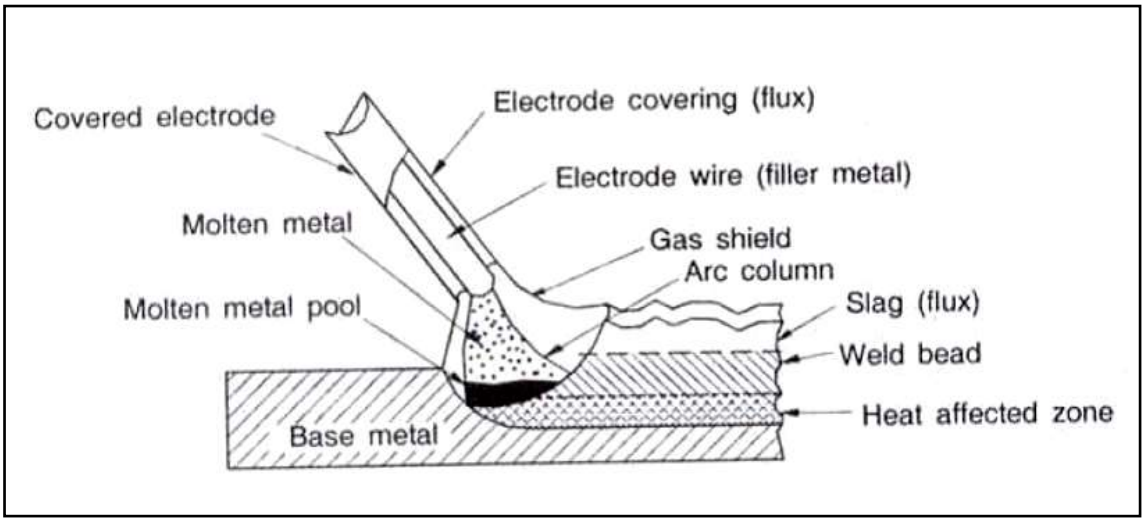


Fig. Principle of arc welding



❖ Electric Power for Welding

AC current or DC current can be used for arc welding. For most purposes, DC current is preferred. In D.C. welding, a D.C. generator or a solid state rectifier is used. D.C. machines are made up to the capacity range of 600 amperes. The voltage in open circuit is kept around 45 to 95 volts and in closed circuit it is kept 17 to 25 volts. D.C. current can be given in two ways:

(a) Straight polarity welding.

(b) Reverse polarity welding

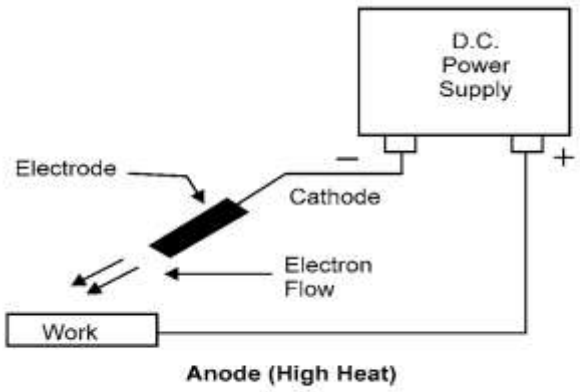


Fig.: Straight Polarity Welding

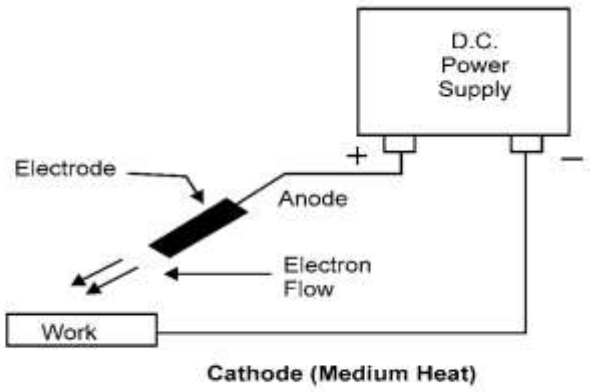


Fig.: Reverse Polarity Welding

- In straight polarity welding work piece is made anode and the electrode is made cathode. Electrons flow from cathode to anode, thus, heat is produced at the materials to be welded.
- In reverse polarity system the work is made cathode and the electrode is made anode. This welding is done specially for thin section.
- AC welding has the advantage of being cheap. Equipment used is simpler than DC welding. A transformer is used to increase the current output at the electrode. The current varies from 150 to 1000 amperes depending upon the type of work.

❖ Effect of Arc Length

Arc length is the distance from the tip of the electrode to the bottom of the arc. It should vary from 3 to 4 mm. In short arc length, the time of contact will be shorter and will make a wide and shallow bead. The penetration is low as compared to long arc lengths.

❖ TYPES OF WELDING JOINTS

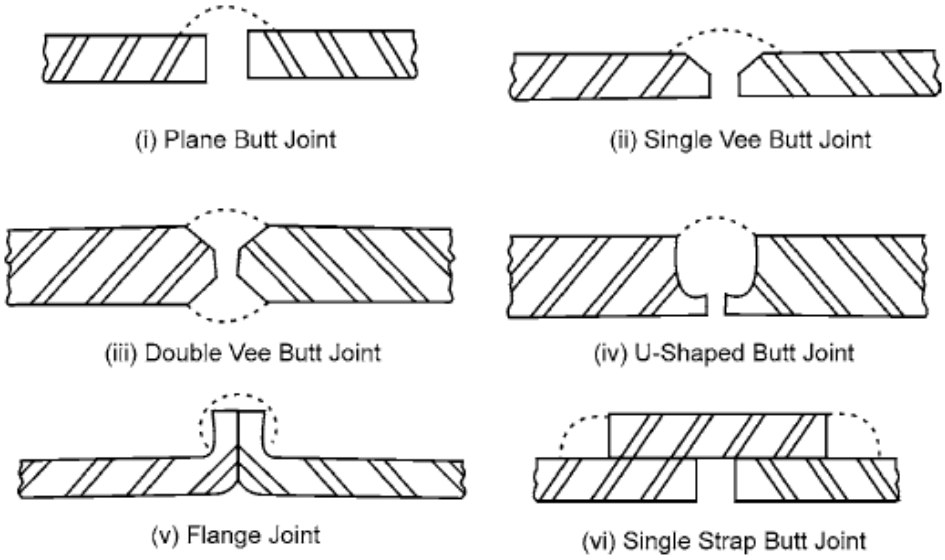


Fig. : Different Types of Butt Joints

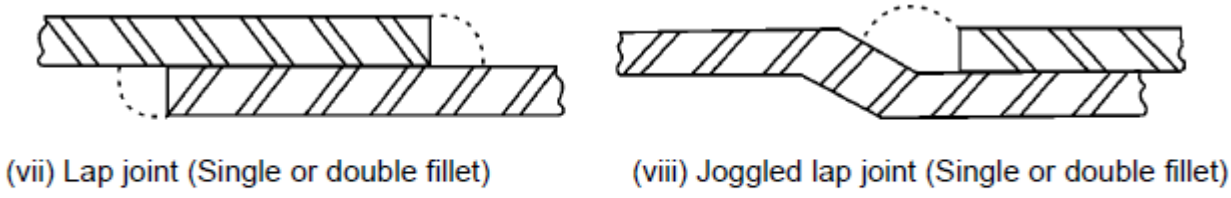


Fig. : Different Types of Lap Joints

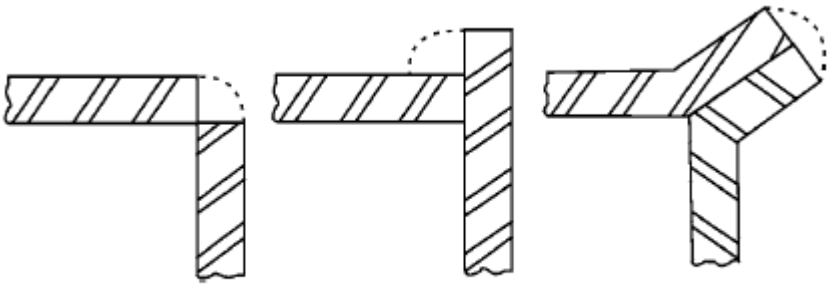


Fig. : Corner Joint

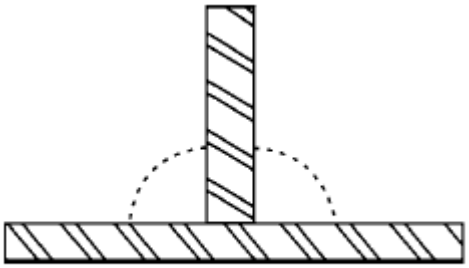


Fig. : T-joint

Lecture 5

WORKING PRINCIPLE, APPLICATION, ADVANTAGES AND DISADVANTAGES OF SMAW

❖ SHIELDED METAL ARC WELDING (SMAW)

Shielded metal arc welding (SMAW) is a commonly used arc welding process manually carried by welder. It is an arc welding process in which heat for welding is produced through an electric arc set up between a flux coated electrode and the workpiece.

The flux coating of electrode decomposes due to arc heat and serves many functions, like weld metal protection, arc stability etc. Inner core of the electrode supply the filler material for making a weld. If the parent metal is thick it may be necessary to make two or three passes for completing the weld.

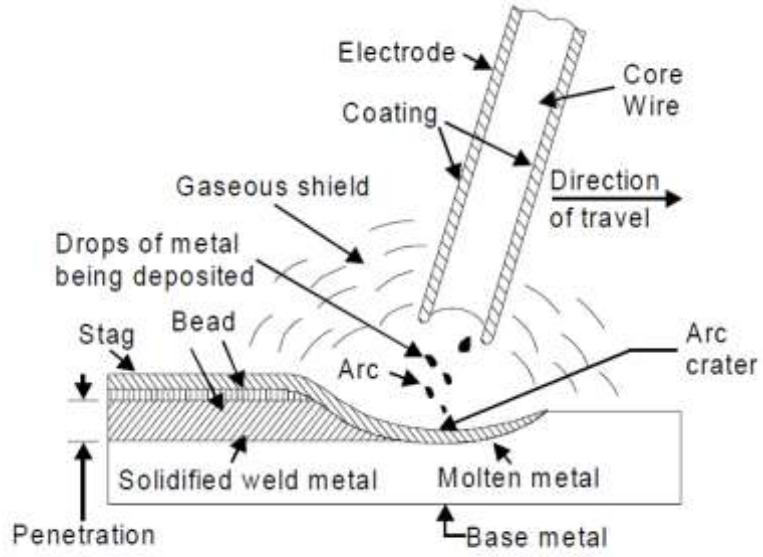


Fig. Arc welding operation

❖ Advantages of SMAW:

1) Shielded Metal Arc Welding (SMAW) can be carried out in any position with highest weld quality.
2) SMAW is the simplest of all the arc welding processes.
3) This welding process finds innumerable applications, because of the availability of a wide variety of electrodes.
4) Big range of metals and their alloys can be welded easily.
5) The process can be very well employed for hard facing and metal resistance etc.
6) Joints (e.g., between nozzles and shell in a pressure vessel) which because of their position are difficult to be welded by automatic welding machines can be easily accomplished by flux shielded metal arc welding.
7) The SMAW welding equipment is portable and the cost is fairly low.

❖ Limitations of SMAW

1) Due to flux coated electrodes, the chances of slag entrapment and other related defects are more as compared to MIG and TIG welding.
2) Duo to fumes and particles of slag, the arc and metal transfer is not very clear and thus welding control in this process is a bit difficult as compared to MIG welding.
3) Due to limited length of each electrode and brittle flux coating on it, mechanization is difficult.
4) In welding long joints (e.g., in pressure vessels), as one electrode finishes, the weld is to be progressed with the next electrode. Unless properly cared, a defect (like slag inclusion or insufficient penetration) may occur at the place where welding is restarted with the new electrode
5) The process uses stick electrodes and thus it is slower as compared to MIG welding.

❖ Applications of SMAW

1) All the commonly employed metals and their alloys can be welded by this process.
2) The process finds applications in
   (a) Building and Bridge construction
   (b) Automotive and aircraft industry, etc.
   (c) Air receiver, tank, boiler and pressure vessel fabrication
   (d) Ship building
   (e) Pipes and
   (f) Penstock joining

❖ Electrode Classification and Coding

According to ISI coding system, an electrode is specified by six digits with profile letter M.

For example IS: 815-1956

These six digits & M indicate the following matter:

- **M**: It indicates that it is suitable for metal arc welding.
- **First Digit**: First digit may be from 1 to 8, which indicate the type of coating on the electrode.
- **Second Digit**: It denotes the welding position for which electrode is manufactured. It varies from 1 to 6.
- **Third Digit**: It denotes the current to be used for an electrode. It is taken from 0 to 7.
- **Fourth Digit**: Fourth digit is from 1 to 8. Each digit represents the tensile strength of welded joint.
- **Fifth Digit**: It carries any number from 1 to 5. This digit denotes a specific elongation in percentage of the metal deposited.
- **Sixth Digit**: It carries any number from 1 to 5 and denotes impact strength of the joint.

❖ Functions of Electrode Coating Ingredients

1) Welding electrodes are used to join various similar and dissimilar metals as plain carbon steels, cast iron, copper, alluminium, magnesium and their alloys, stainless steels and other alloy steels.
2) Slag forming ingredients, like silicates of magnesium, alluminium, sodium, potassium, iron oxide, china clay, mica etc., produce a slag which because of its light weight forms a layer on the molten metal and protects the same from atmospheric contamination.
3) Arc stabilizing constituents like calcium carbonate, potassium silicate, titanates, magnesium silicates, etc.; add to arc stability and ease of striking the same.
4) Gas shielding ingredients, like cellulose, wood, wood flour, starch, calcium carbonate etc. form a protective gas shield around the electrode end, arc and weld pool
5) Deoxidizing elements like Ferro-manganese, and Ferro-silicon, refine the molten metal.
6) It limits spatter, produces a quiet arc and easily removable slag.
7) Alloying elements like Ferro alloys of manganese, molybdenum etc., may be added to impart suitable properties and strength to the weld metal and to make good the loss of some of the elements, which vaporize while welding.
8) Iron powder in the coating improves arc behavior, bead appearance helps increase metal deposition rate and arc travel speed.
9) The covering improves penetration and surface finish.
10) Core wire melts faster than the covering, thus forming a sleeve of the coating which constricts and produces an arc with high concentrated heat.
11) Coating saves the welder from the radiations otherwise emitted from a bare electrode while the current flows through it during welding.
12) Proper coating ingredients produce weld metals resistant to hot and cold cracking. Suitable coating will improve metal deposition rates.

Lecture 6

WORKING PRINCIPLE, APPLICATION, ADVANTAGES AND LIMITATION OF RESISTANCE WELDING

❖ RESISTANCE WELDING

- In resistance welding the metal parts to be joined are heated by their resistance to the flow of an electrical current.
- Usually this is the only source of heat, but a few of the welding operations combine resistance heating with arc heating, and possibly with combustion of metal in the arc.
- The process applies to practically all metals and most combinations of pure metals and those alloys, which have only a limited plastic range, are welded by heating the parts to fusion (melting).
- Some alloys, however, may welded without fusion; instead, the parts are heated to a plastic state at which the applied pressure causes their crystalline structures to grow together.
- The welding of dissimilar metals may be accomplished by melting both metals frequently only the metal with the lower melting point is melted, and an alloy bond is formed at the surface of the unmelted metal.

In resistance welding processes no fluxes are employed, the filler metal is rarely used and the joints are usually of the lap type. The amount of heat generated in the workpiece depends on the following factors:

(1) Magnitude of the current,

(2) Resistance of the current conducting path,

Mathematically, $H = I \times V \times t = I \times (IR) \times t = I^2Rt$

H = heat generated in joules

I = current in Amp.

R = resistance in ohms

t = time of current flow in seconds.

❖ Types of Resistance welding

The major types of resistance welding are given as under:

(1) Spot Welding	(5) Flash Butt Welding
(2) Seam Welding	(6) Percussion Welding
(3) Projection Welding	(7) High Frequency Resistance Welding
(4) Resistance Butt Welding	(8) High Frequency Induction Welding

❖ SPOT WELDING

- Spot welding is used to lap weld joints in thin metallic plates (up to 12.7 mm thick) for mechanical strength and not for tightness.
- The metallic plates are overlapped and held between two copper electrodes. A high current, depending upon plate thickness, at a very low volt-age (4-12 volts), is passed between the electrodes.
- The contact resistance of the plates causes to heat rapidly to a plastic state.
- Mechanical pressure is applied.
- Supply is cut-off for the metal to regain strength. The pressure is released.
- The process is repeated at another portion of the plates. Thus, spot joints at regular interval depending upon the strength required are obtained.
- The electrodes are water cooled to avoid overheating and softening of the tips.
- Spot welding is mainly used in the manufacture of automobile parts refrigerators, metallic toys, racks, frames, boxes, radio chassis, etc..

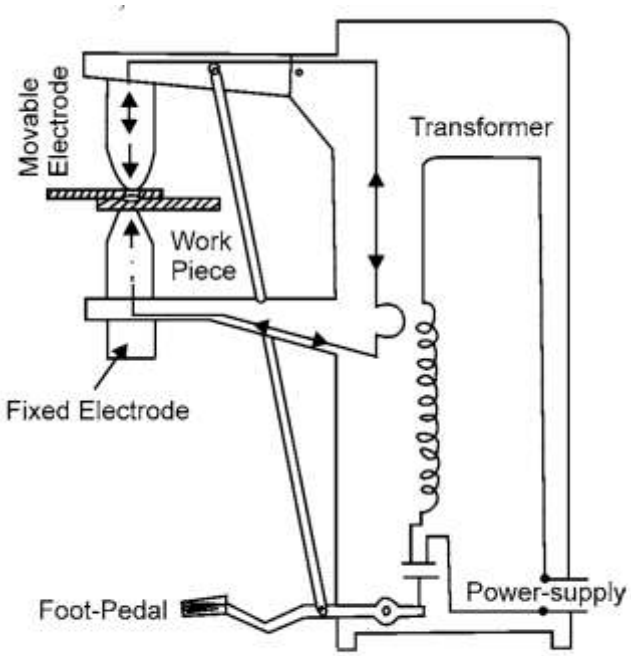


Fig.: Spot Welding

❖ Before spot welding one must make sure that

1) The job is clean, i.e., free from grease, dirt, paint, scale, oxide etc.
2) Electrode tip surface is clean, since it has to conduct the current into the work with as little loss as possible. Very fine emery cloth may be used for routine cleaning.
3) Water is running through the electrodes in order to
   (a) Avoid them from getting overheated and thus damaged,
   (b) Cool the weld.
4) Proper welding current has been set on the current selector switch.
5) Proper time has been set on the weld-timer.

❖ Spot Welding Electrodes

Spot welding electrodes are made of materials which have

(1) Higher electrical and thermal resistivity,

(2) Sufficient strength to withstand high pressure at elevated temperatures.

Copper base alloys such as copper beryllium and copper tungsten are commonly used materials for spot welding electrodes. For achieving the desired current density, it is important to have proper electrode shape for which three main types of spot welding electrodes are used which are pointed, domed and flat electrodes.

❖ Applications of Spot Welding

1) It has applications in automobile and aircraft industries
2) The attachment of braces, brackets, pads or clips to formed sheet-metal parts such as cases, covers or trays is another application of spot welding.
3) Spot welding of two 12.5 mm thick steel plates has been done satisfactorily as a replacement for riveting.
4) Many assemblies of two or more sheet metal stampings that do not require gas tight or liquid tight joints can be more economically joined by spot welding than by mechanical methods.
5) Containers and boxes frequently are spot welded.

❖ RESISTANCE SEAM WELDING

- It is a continuous type of spot welding wherein spot welds overlap each other to the desired extent.
- In this process fusion at the facing surfaces is produced by the heat obtained from the resistance to electric current (flow) through the work pieces held together under pressure by circular electrodes.
- The resulting weld is a series of overlapping resistance-spots welds made progressively along a joint by rotating the circular electrodes.
- The principle of seam welding and resistance seam welding process set up is shown in Fig. below.
- The seam welding is similar to spot welding, except that circular rolling electrodes are used to produce a continuous air-tight seam of overlapping welds.
- Overlapping continuous spot welds seams are produced by the rotating electrodes and a regularly interrupted current.

❖ Applications of Resistance Seam Welding

1. It is used for making leak proof joints in fuel tanks of automobiles.
2. Except for copper and high copper alloys, most other metals can be seam welded.
3. It is also used for making flange welds for use in watertight tanks.

❖ RESISTANCE PROJECTION WELDING

- This process is a resistance welding process in which two or more than two spot welds are made simultaneously by making raised portions or projections on predetermined locations on one of the workpiece.
- These projections act to localize the heat of the welding circuit.
- The pieces to be welded are held in position under pressure being maintained by electrodes.
- The projected contact spot for welding should be approximately equal to the weld metal thickness.
- The welding of a nut on the automotive chassis is an example of projection welding.

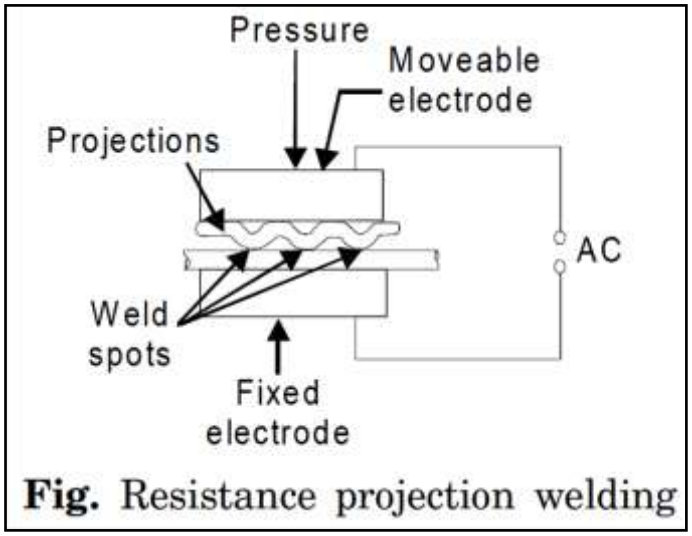


Fig. Resistance projection welding

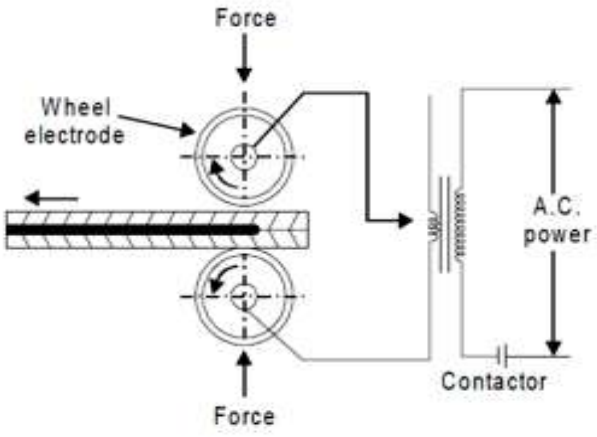


Fig. Principle of seam welding process

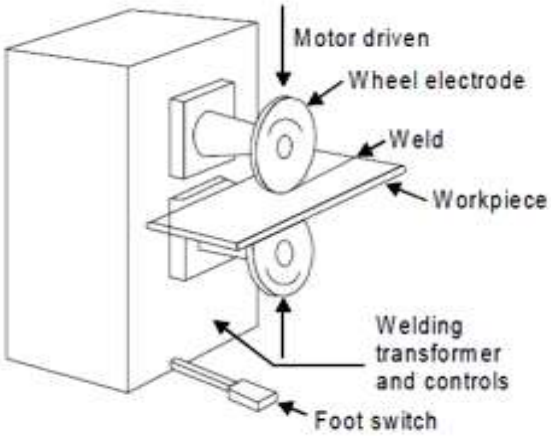


Fig. Resistance seam welding process setup

❖ Resistance Upset Butt and Flash Butt Welding

- This welding is also used for joining metal pieces end to end but it has largely replaced the butt-welding method for weld articles small cross-sections.
- It can be used for thick sections also. Initially the current is switched on and then one end the moveable part to be welded is brought gently closer to the fixed end of the other part to localize heat at the ends and thus raises the temperature of the ends quickly to the welding heat.
- On acquiring contact of fixed end and moveable end with each other, the moveable end is then pressed against one another by applying mechanical pressure.
- Thus the molten metal and slag to be squeezed out in the form of sparks enabling the pure metal to form the joint and disallowing the heat .to spread back.

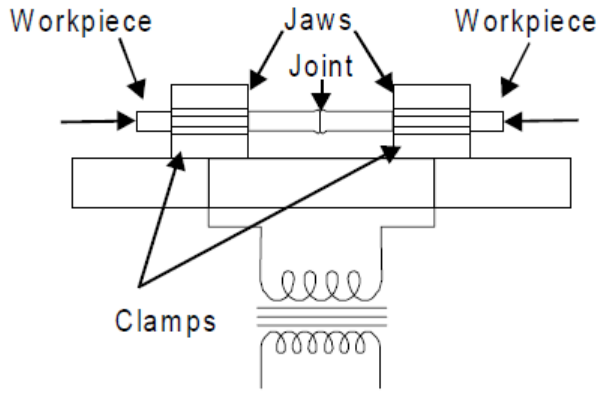


Fig. Resistance upset butt welding

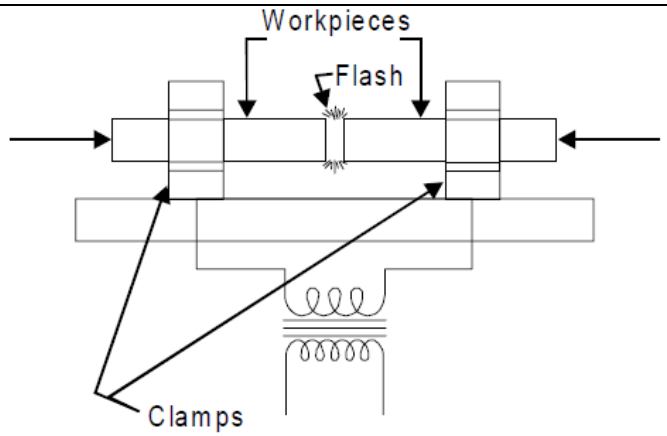


Fig. Resistance flash butt welding

❖ Merits

1) It is comparatively much faster than butt welding.
2) This method utilizes less current in comparison to butt welding as the small portion of the metal is only being heated for getting a good weld
3) Created joint by this welding is much stronger than the butt welding joint. Also the strength of the weld produced is high even more than that of the base metal. The end of the metal pieces to be welded in this welding need not be squared as it is the basic requirement in butt-welding.
4) A high degree of accuracy can be easily achieved in terms of length alignment of weld.

❖ **Demerits**

1) The periodic maintenance of machine and replacement of insulation is needed as flashing particles of molten metal are thrown out during welding which may enter into the slide ways and insulation of the set up.
2) Welder has to take enough care against possible fire hazard due to flashing during welding.
3) Additional stock has to be provided for compensating loss of metal during f1ashing and upsetting. This increases to the cost of weld.
4) Cost of removal of flash weld metal by trimming, chipping, grinding, etc. will increase to the welded product.
5) Surface of the jobs where they come in contact with the gripping surfaces, should be clean otherwise they will restrict the flow of electric current.
6) The available power, opening between the jaws of the gripping clamps and upsetting pressure of the welding set limit the size and cross sectional area of the jobs to be welded.

❖ **Applications**

- All conducting forged metals can be easily being flash welded.
- A number of dissimilar metals can also be welded by controlling the welding conditions carefully. Metals generally welded metal by the process involves lead, tin, antimony, zinc, bismuth and their alloys, low carbon steels, stainless steel, alloy steels, tool steels, copper alloys, alluminium alloys, magnesium alloys nickel alloys, molybdenum alloys, and titanium alloys.
- This process is used in automobile industry, welding of solid and tubular structural assemblies, etc. in air-craft industry, welding of band saw blades, welding of tool steel drills, reamers and taps etc. to mild steel or alloy steel shanks, welding of pipes and tubes.

Lecture 7

WELDING DEFECTS

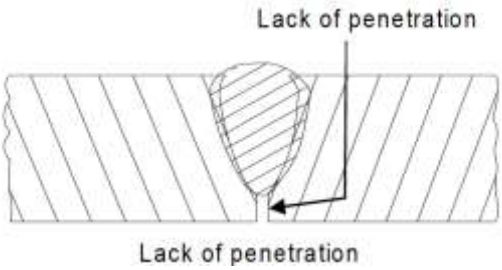
1. Lack of Penetration:

It is the failure of the filler metal to penetrate into the joint. It is due to

(a) Inadequate de-slagging

(b) Incorrect edge penetration

(c) Incorrect welding technique.



Lack of penetration

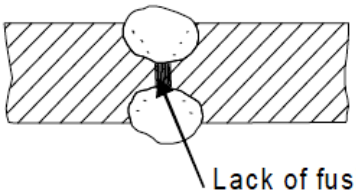
2. Lack of Fusion:

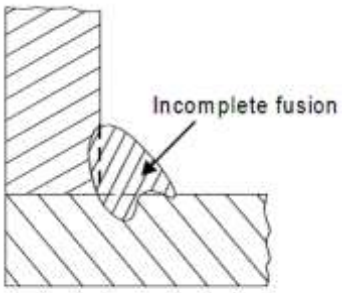
Lack of fusion is the failure of the filler metal to fuse with the parent metal. It is duo to

(a) Too fast a travel

(b) Incorrect welding technique

(c) Insufficient heat





Incomplete Fusion

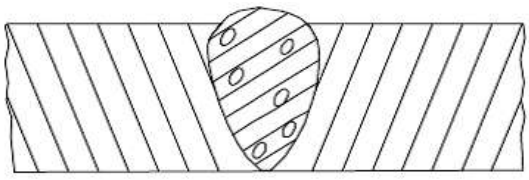
3. Porosity:

It is a group of small holes throughout the weld metal. It is caused by the trapping of gas during the welding process, due to

(a) Chemicals in the metal

(b) Dampness

(c) Too rapid cooling of the weld

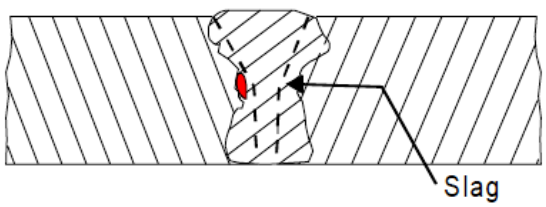

Porosity

4. Slag Inclusion:

It is the entrapment of slag or other impurities in the weld. It is caused by

(a) Slag from previous runs not being cleaned away,

(b) Insufficient cleaning and preparation of the base metal before welding commences



Slag Inclusion

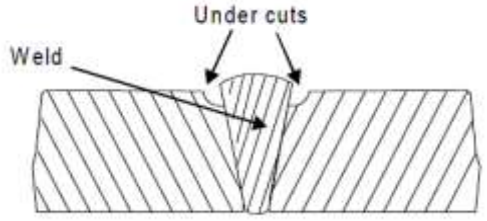
5. Undercuts:

These are grooves or slots along the edges of the weld caused by

(a) Too fast a travel

(b) Bad welding technique

(c) Too great a heat build-up

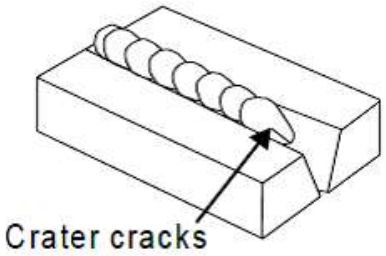


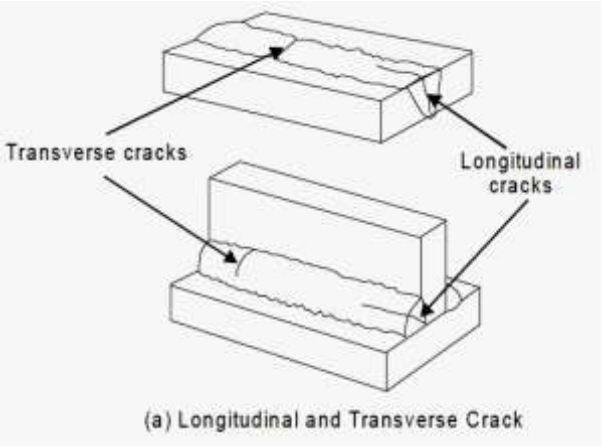
6. Cracking :

It is the formation of cracks either in the weld metal or in the parent metal. It is due to

(a) Unsuitable parent metals used in the weld

(b) Bad welding technique



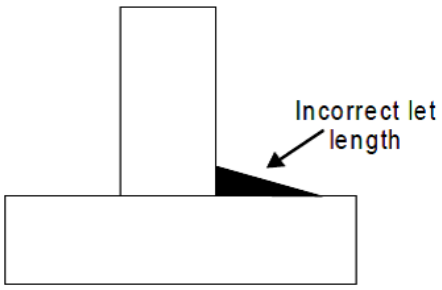


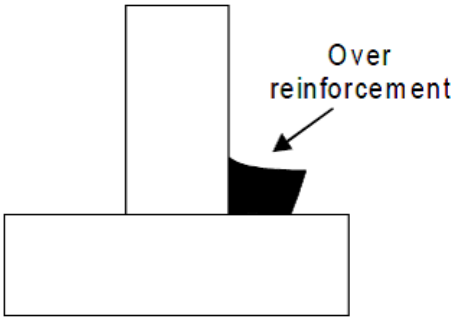
7. Poor Weld Bead Appearance:

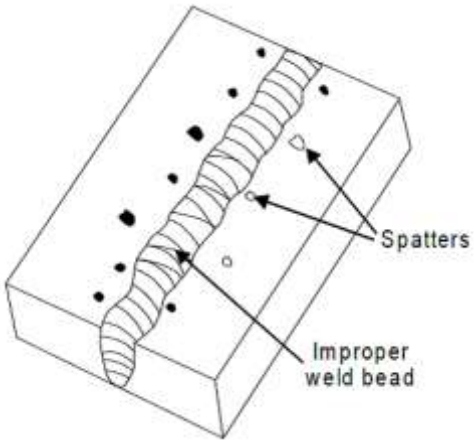
If the width of weld bead deposited is not uniform or straight, then the weld bead is termed as poor.

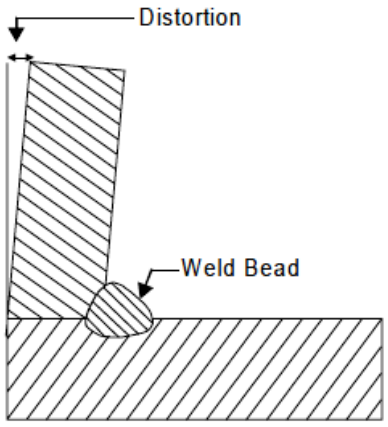
It is due to improper arc length, improper welding technique, damaged electrode coating and poor electrode and earthling connections.

It can be reduced by taking into considerations the above factors







8. Distortion: Distortion is due to high cooling rate, small diameter electrode, poor clamping and slow arc travel speed	 Distorted T Joint
9. Overlays: These consist of metal that has flowed on to the parent metal without fusing with it. The defect is due to (a) Contamination of the surface of the parent metal (b) Insufficient heat	**11. Burn Through:** It is the collapse of the weld pool due to (a) Too great a heat concentration (b) Poor edge preparation.
10. Blowholes: These are large holes in the weld caused by (a) Gas being trapped, due to moisture. (b) Contamination of either the filler or parent metals	**12. Excessive Penetration:** It is where the weld metal protrudes through the root of the weld. It is caused by (a) Incorrect edge preparation (b) Too big a heat concentration (c) Too slow a travel

Lecture 8

Working Principles and applications of Brazing and Soldering

❖ SOLDERING

Soldering is a process of joining two metals by using another low temperature metal alloy. The metal used for the joining purpose is called solder. Solders are of two types:

1. Hard solder (alloy of copper and zinc)
2. Soft solder (alloy of tin and lead)

Process:

The surfaces to be joined are cleaned and are placed on each other. A flux is employed to prevent oxidation. Zinc chloride is commonly used for this purpose. The soldering iron is heated either electrically or by some external heat. Then the hot end is dipped into the flux and solder is pressed against the surfaces to be joined. A joint is formed by melting the solder.

Applications

Soldering is widely used for sheet metal work and in radio and television work for joining wires.

Advantages

1) Joining cost is low
2) Equipment is very simple and cheap
3) Good sealing in fabrication as compared to other processes like rivet, spot weld and bolts
4) It provides a positive electrical connection
5) Due to low operating temperature the properties of base metal are not affected

Disadvantage

1. Joints formed are weak

❖ BRAZING

The process of joining two metal surfaces by heating and adding a non-ferrous alloy with melting point above 400°C is known as brazing process.

The surfaces to be joined are cleaned from all oil, dirt or oxides. Then both the surfaces are placed in joining position. Flux is sprinkled or placed on it. The heat is given to the surface and the filler metal. The molten filler metal flows to the surfaces to be joined. On cooling, brazing joint is formed. The filler metals used are copper, copper alloy, silver alloy and alluminium alloys. In brazing, the filler metal melts but the surfaces to be joined remain unmelted.

The various methods used to melt the filler metal and flux is:

(a) Gas Torch Brazing: It is a commonly used process in which oxy-acetylene torch is used.

(b) Furnace Brazing: The surfaces to be joined are placed in a furnace already hot.

(c) Dip Brazing: The surfaces to be joined are dipped in molten filler metal.

(d) Electrical Brazing: In electric brazing heat is produced by resistance or induction method.

Applications

Brazing is used for electrical items, radiators, heat exchangers, pipes & pipe fittings and tool tips.

Advantages

1) It is useful for joining dissimilar metals.
2) Thin sections can be easily joined.
3) Good finish is obtained on joint.
4) Less skill is required.
5) Cost of operation is less as compared to other welding processes.

Disadvantages

1) Low strength.
2) Not applicable for hardened steel and alluminium alloys.