WELDING PROCESSES

1. INTRODUCTION

Almost all products are assemblies of a large number of components. The process and methods used for joining depend on the type of joint, the required strength, the materials of the components being joint, the geometry of the components, and cost issues.

Why do we need joining?

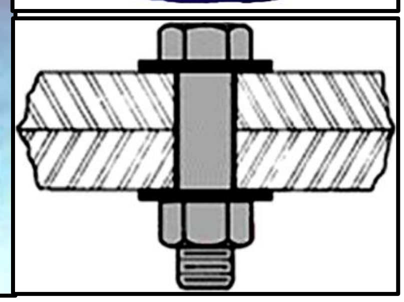
(a) To restrict some degrees of freedom of motion for components.

(b) A complex shaped component may be impossible / expensive to manufacture, but it may be possible / cheaper to make it in several parts and then join them.

(c) Some products are better made as assemblies, since they can be disassembled for maintenance.

(d) Transporting a disassembled product is sometimes easier / feasible.

Mechanical joints



Welding is a process which two materials, usually metals, are permanently joined together through localized melting.

2-Fusion Welding

In fusion welding, the joint is made by melting the metal at the interface. In many cases, extra metal is melted along the joint, to completely fill the joint region.

2.1 Oxyfuel gas welding (OFW)

Oxyfuel gas welding is a fusion welding process, the metals being joined are melted at the point where welding occurs, where no pressure is applied. Filler material usually must be added in the form of a wire or rod (called **electrode**). Composition of the electrode material should be similar (compatible) to the workpiece materials which are going to be welded.

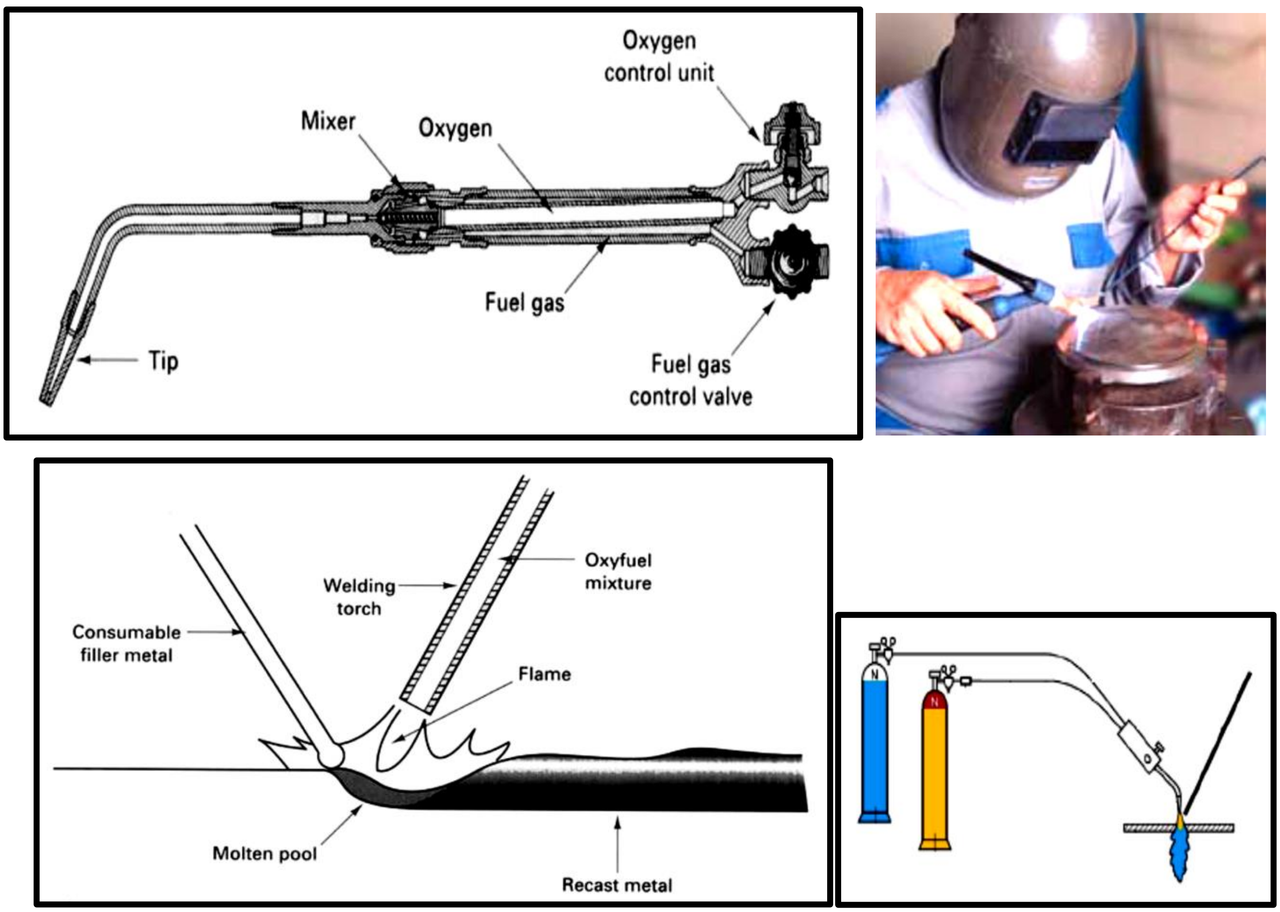


Figure (2): Oxyfuel gas welding theory and arrangments

In oxyfuel gas welding the heat source is a flame resulting from burning of a fuel gas and oxygen, mixed in welding torch with proper proportions. Acetylene is the principal fuel gas employed for this process, obtained by a reaction between Calcium Carbide and water. The combustion of oxygen and acetylene produces a temperature of about 3500°C.The filler rod is coated with **flux**.

The flux is a chemical with two uses: part of it evaporates, and the vapor surrounds the region around the molten metal, preventing oxidation. Another part of the flux melts, and dissolves impurities and metal oxides; since these are lighter than the molten metal, they float to the surface and can be removed later. Fluxes can be added as a powder, or the welding rod can be dipped in a flux paste.

2.2 Arc welding

Arc welding is a fusion welding process. Heat is obtained by an **arc** between the work and electrode. The process is useful, versatile, and widely used. But, for most applications, weld quality depends on the skill and integrity of the operator.

Here, the metal is heated by maintaining a very high voltage between the electrode and the metal. This results in dielectric breakdown of the air gap, causing a discharging arc. The temperature at the arc can reach up to 30,000°C. The filler metal used is the electrode. Either DC or AC can be used. Typically, DC welders

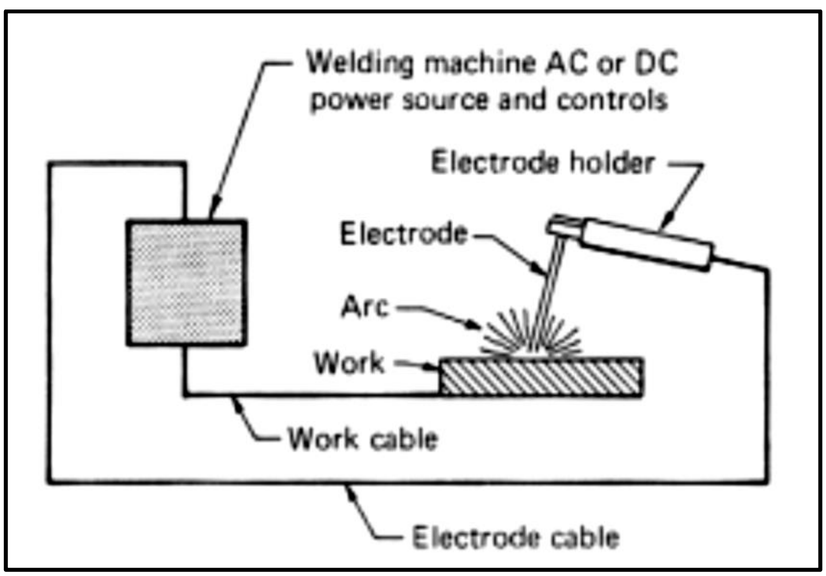
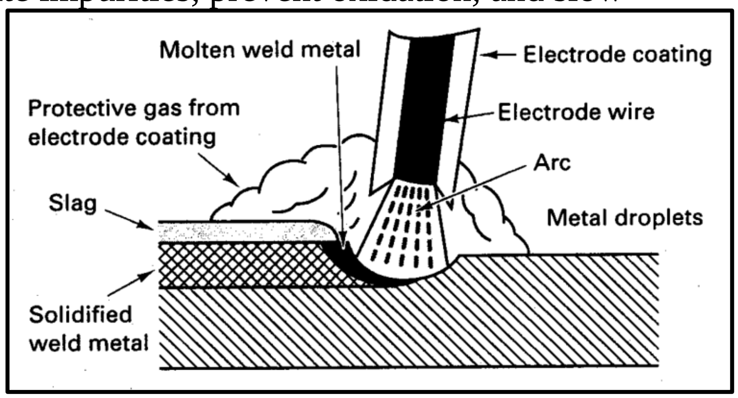


Figure (3): Schematic of Arc welding

are used for sheet metal, while high power requirements of thick members need AC supply.

Uses electrodes, which are finite-length sticks, consist of metal wire coating by a chemical components that add a desirable characteristics, including:

- Add additional filler metal and alloying elements.
- Act as a flux to remove impurities from the molten metal.
- Provide a protective atmosphere.
- Provide a protective slag to accumulate impurities, prevent oxidation, and slow down the cooling of the weld metal.
- Stabilize the arc.
- Increase the efficiency of deposition.
- Affect arc penetration.
- Influence the shape of the weld bead.



2.2.1 Gas Shielded Arc Welding

Main characteristics:

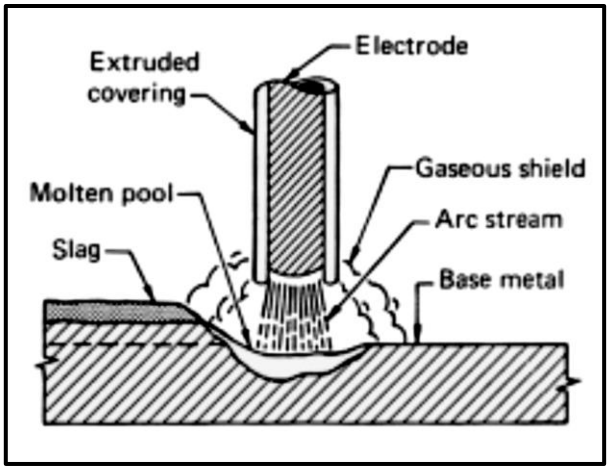
- Fast and economical.
- There is no slag formed over the weld.
- The process can be automated, can be performed by industrial robots.
- An inert gas is supplied form an inert shield around the arc from the atmosphere.
- Virtually used for any metal, primarily for welding nonferrous metals.

2.2.1.1 Metal Inert Gas Welding (MIG)

Here, an inert gas such as Argon or an Argon/Helium mixture is injected to surround the region of the weld. This ensures that the molten metals are shielded from the atmospheric oxygen.

2.2.1.2 Tungsten Inert Gas Arc welding (TIG Welding).

Here, the arc is formed between a non-consumable tungsten electrode and the metal being welded. Gas is fed through the torch to shield the electrode and molten weld pool. If filler wire is used, it is added to the weld pool separately. TIG welding can yield better quality and more precise welds. Welding Aluminum almost always requires TIG or MIG welding. TIG is also commonly used for welding Titanium, Magnesium, especially thin section welding.



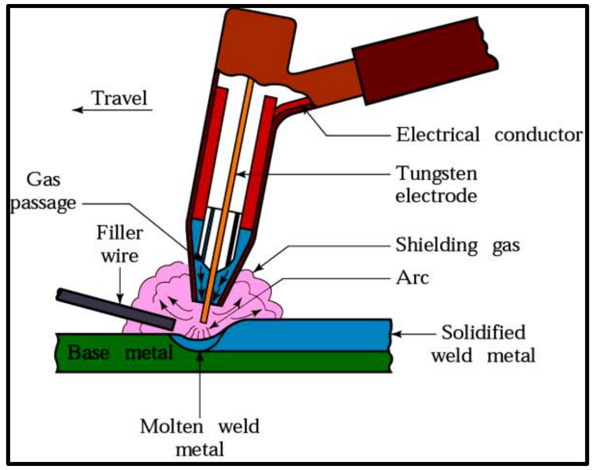


Figure 3 (a) MIG welding (b) TIG welding

2.3 Brazing and Soldering Welding

Brazing and soldering are somewhat similar processes with some common properties as given below.

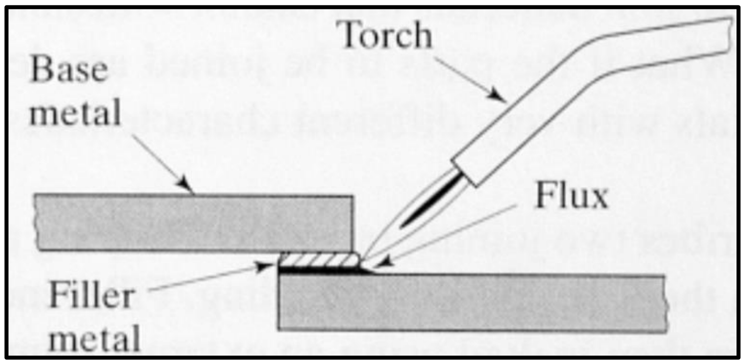
- The compositions of the brazing and soldering alloys, which are nonferrous alloys, are significantly different from the base metals.
- The melting point of these alloys are lower than that of the base metal.
- During the process the base metals are not melted.
- For both processes, the surfaces should be cleaned beforehand.
- Fluxes play a very important part by dissolving oxides prior to heating, and by preventing the formation of oxides during heating.

2.3.1 Brazing Welding

In brazing, the filler material is a metal with melting temperature lower than that of the metals being joint, and, on cooling, creates a brazed joint. In some cases, oxy-acetylene gas welding may be used for this process, with the filler made of a low melting temperature metal rod. Fluxes are used in brazing, for the same reasons as in welding. Melting temperature of braze material is above 450°C.

Braze materials are:

- Copper (for brazing of steel, HSS, and tungsten carbide),
- Copper alloys (e.g. brazing brass, manganese bronze),
- Silver (for brazing titanium),
- Silver alloys,
- Aluminum-silicon alloys.

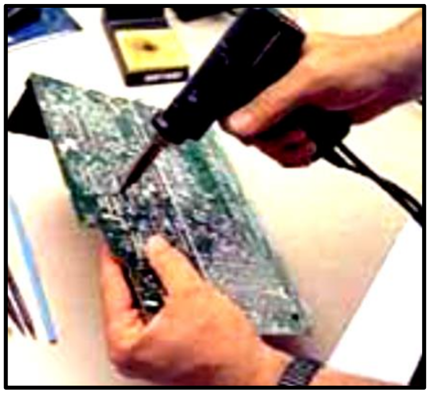
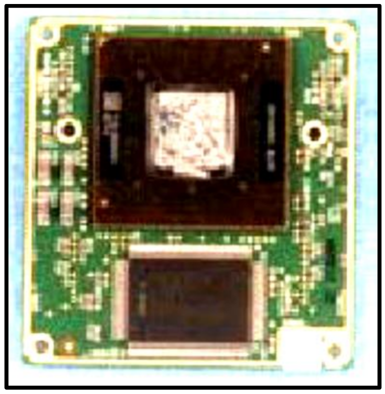
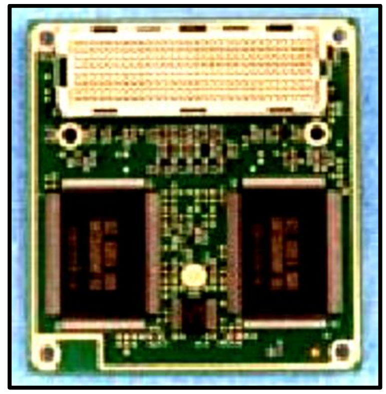


Advantages of Brazing

1. Virtually all metals can be joined.
2. Less heating is required than for welding; the process can be performed more quickly and more economically.
3. Since lower temperatures are used, fewer difficulties due to distortion are encountered, and thinner and more complex assemblies can be joined successfully.
4. Many brazing operations are adaptable to automation.

2.3.2 Soldering Welding

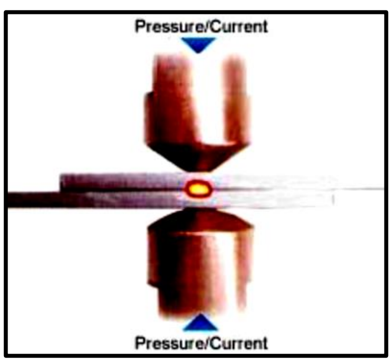
Melting temperature of solder material, called solder, is below 450°C. Solder is an alloy of lead and tin with the addition of a very small amount of antimony, melting at around 200°C. This is very useful to joints electronic circuits, which need not withstand large forces, but made with low energy& temperature processes.

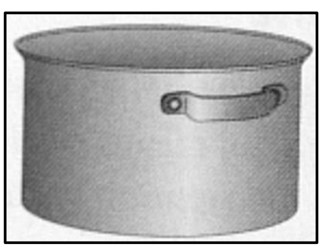




2.4 Resistance welding

Resistance welding process make use of the electrical resistance for generating heat required for melting the workpiece. It is generally used for joining thin plates and structures. It has different variants such as Spot welding, Seam welding and Projection welding.

Metal strips are welded by holding them together by a force, and raising their temperature by passing a current through the interface. Resistance welding is used in several applications; include pan-handle welding, automobile mufflers, band-saw blades, seam-joints in automobile bodies and automobile components, etc.






Spot welding Spot welding of a pan Robotic Spot welding on auto body

Figure (1): (a) Spot welding (b) and (c) Examples of resistance welding

Advantages

- Very rapid and economical process, widely used in mass production.
- The equipment can be fully automated.
- They conserve materials as no filler material, shielding gas or flux is required.
- Skilled operators are not required.
- Dissimilar metals can be easily joined.
- A high degree of reliability and reproducibility can be achieved.

Resistance Welding limitations

- There are limitations to the type of joints that can be made (mostly suitable for lap joints).
- Some materials require special surface preparations prior to welding.

2-4-1 Resistance Spot Welding

Two or more sheets of metal are held between water cooled electrodes

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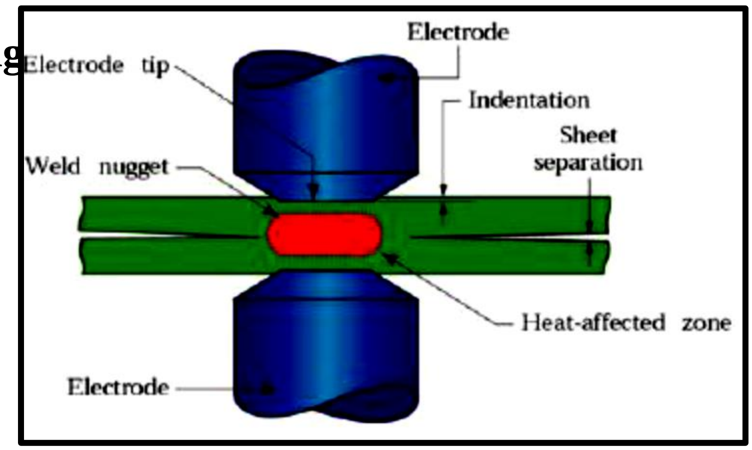
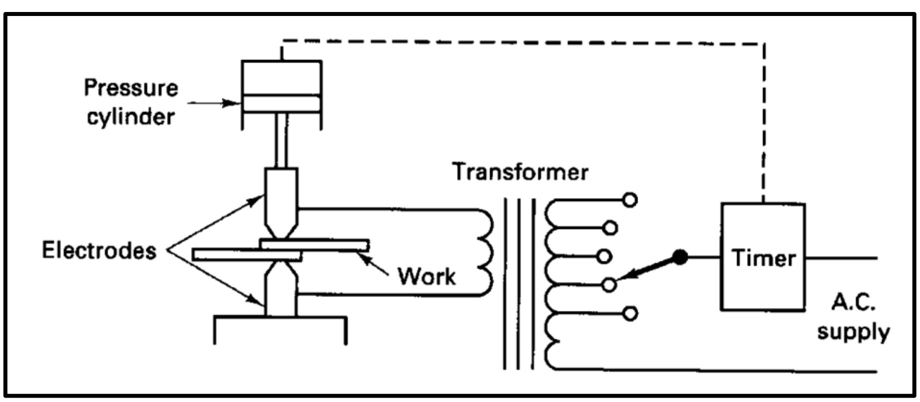
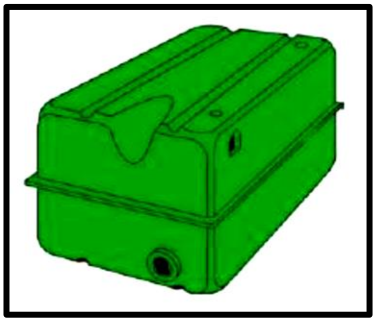
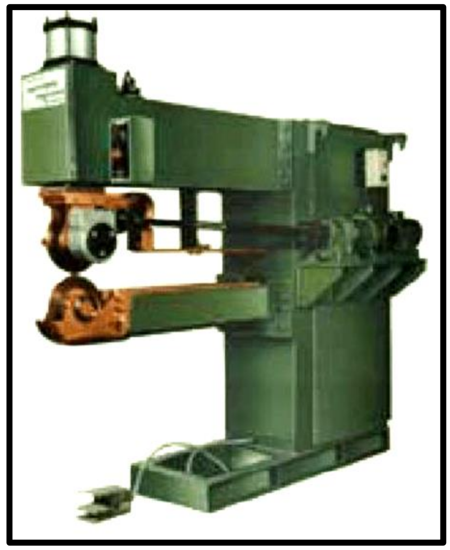


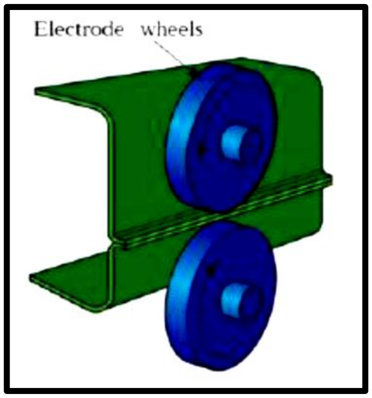


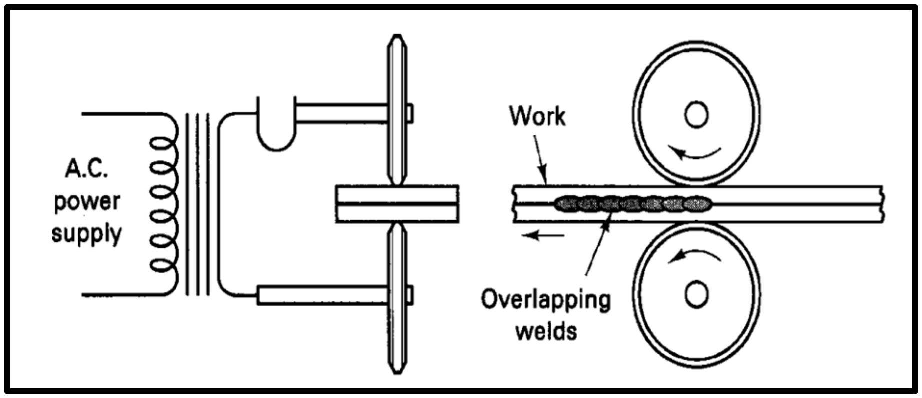
2-4-2 Resistance Seam Welding

Resistance seam welding is actually is a series of overlapping spot welds. The basic equipment is the same as for spot welds , except that two rotating disks are used as electrodes.







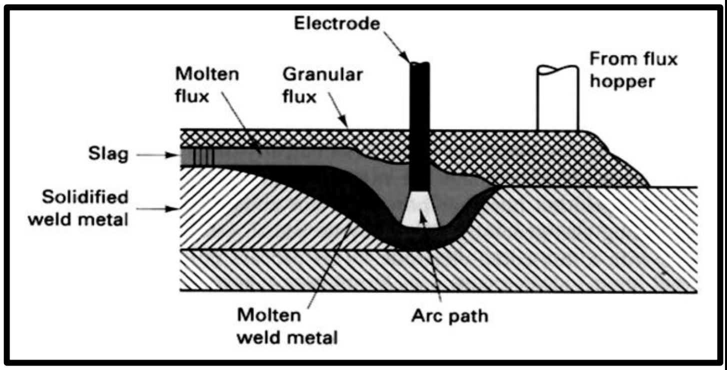


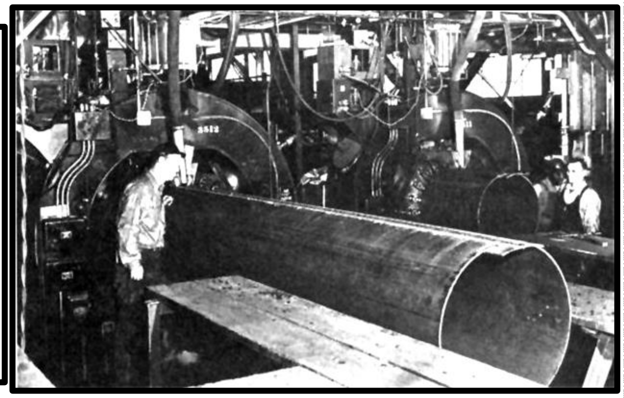
Applications:

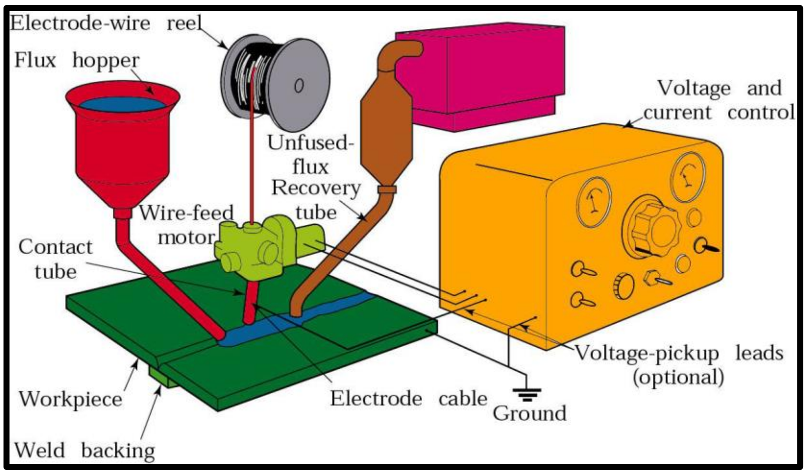
- Materials from 0.13 mm thickness to more than 19 mm thickness can be welded up to 82 meter /min.
- The combination of high frequency current and high welding speed produces a very narrow heat affected zone.
- Almost all types of materials can be welded, including dissimilar metals and high conductivity metals, such as aluminium and copper.

2.5 Submerged Arc Welding (SAW)

The Submerged Arc Welding process contributes approximately 10% of the total welding activities carried out today. In this process, the arc, is kept submerged under a blanket of granular fusible flux. The flux is deposited just ahead of the electrode, which is in the form of coiled wire. The granular flux provides excellent shielding of the molten metal and. Consequently very high quality welds are obtained.







Factors which determine the usage of SAW include:

1. The chemical composition and mechanical properties required.
2. Thickness of base metal to be welded.
3. Joint accessibility.
4. Position in which the weld is to be made.
5. Frequency and/or volume of welding to be performed.

Characteristics of SAW:

- Higher metal depositing rate,
- Higher welding speed,

- Higher process efficiency,
- Lower nitrogen and hydrogen content in the weld metal,
- Cleaner weld metal,
- Better control over the chemical composition,
- Better control over on the mechanical and metallurgical properties.

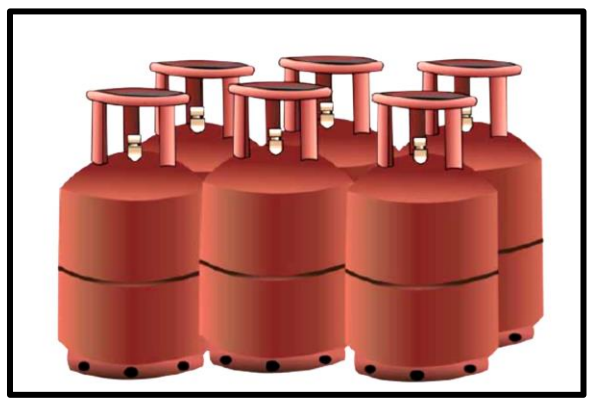
Flux material:

It is a material used to prevent, dissolve or facilitate the removal of oxides and other undesirable substances. It helps the process in the following ways:

- In protecting the weld pool and stabilizing the arc,
- Providing appropriate chemical composition as desired
- Improving the properties by alloying materials appropriately,
- Deoxidizing the weld metal,
- Improving weld bead shape parameters,
- Improving the efficiency of metal deposition.

SAW Applications:

- Used in joining the two deep drawn vessels of the liquified gas cylinder bodies
- High strength low alloy steels, Low carbon steels, Stainless steels, Aluminum Titanium and other non-ferrous alloys
- Fabrication of thick plates and thick pipes
- Pressure vessels and heat exchangers,
- Rail road tanks and ship body fabrication



3. Solid state welding

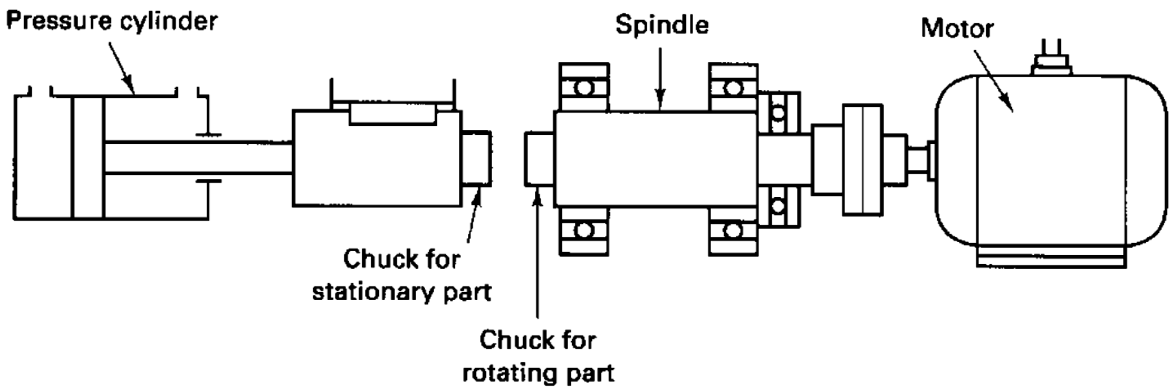
This type of weld does not melt the material, so it is called a solid state weld. Two important properties that facilitate solid state welding are (a) surfaces must be very clean, and (b) high pressure and temperature improve the diffusion process.

3.1 Friction Welding Principles:

Friction Welding is a solid state welding process which produces welds due to the compressive force contact of workpieces which are either rotating or moving relative to one another. Heat is produced due to the mechanical friction between two contacting pieces of metal that are held together while one rotates and the other is held stationary.

Main characteristics

- No material is melted.
- Simple and rapid process (cycle time usually less than 25 seconds).
- Very efficient as all of the energy used converted into heat.
- The strength of the weld is almost the same as the base metal.
- Dissimilar materials can be welded.
- Surface impurities are displaced radially into a small flash that can be removed after welding, if desired.
- Restricted to joining round bars and tubes of the same size, or to joining bars and tubes to flat surfaces.
- Before the process, the ends of the workpieces must be cut true and fairly smooth.



Advantages of Friction Welding:

- No filler material, flux or shielding gases are needed.
- It is an environment-friendly process without generation of smoke, fumes or gases.
- No material is melted so the process is in solid state with narrow heat affected zone (HAZ).
- Oxides can be removed after the welding process.
- In most cases, the weld strength is stronger than the weaker of the two materials being joined.
- The process can be easily automated for mass production.
- The process is very efficient and comparatively very rapid welds are made.
- Plant requirements are minimal and wide variety of metals and combinations can be welded.

Limitations of Friction Welding:

- The process is restricted to joining round bars or tubes of same diameter (or bars tubes to flat surfaces), i.e. capable of being rotated about the axis.
- Dry bearing and non-forgeable materials cannot be welded, i.e. one of the component must be ductile when hot, to permit deformations.

Applications of Friction Welding:

- Friction welded parts in production applications span over wide products for aerospace, agricultural, automotive, defense, marine and oil industries.
- Right from tong holds to critical aircraft engine components are friction welded in

production.

- Automotive parts that are friction welded include gears, engine valves, axle tubes, driveline components, strut rods and shock absorbers.
- Hydraulic piston rods, track rollers, gears, bushings, axles and similar parts are commonly friction welded by the manufacturers of agricultural equipment.

3.2 Ultrasonic welding

Ultrasonic welding is a solid state process in which coalescence is produced by the localized application of high frequency (10,000-20,000 Hz), low amplitude orthogonal (i.e. shearing) vibration is applied to surfaces that are held together under a rather light static normal force. Although there is some increase in temperature at the faying surfaces. The interface temperature in this process reaches maximum of 0.3~0.5T_m – in other words, there is no melting/fusion.

The ultrasonic transducer is coupled to a force-sensitive system that contains a welding tip on one end. The pieces to be welded are placed between this tip and a

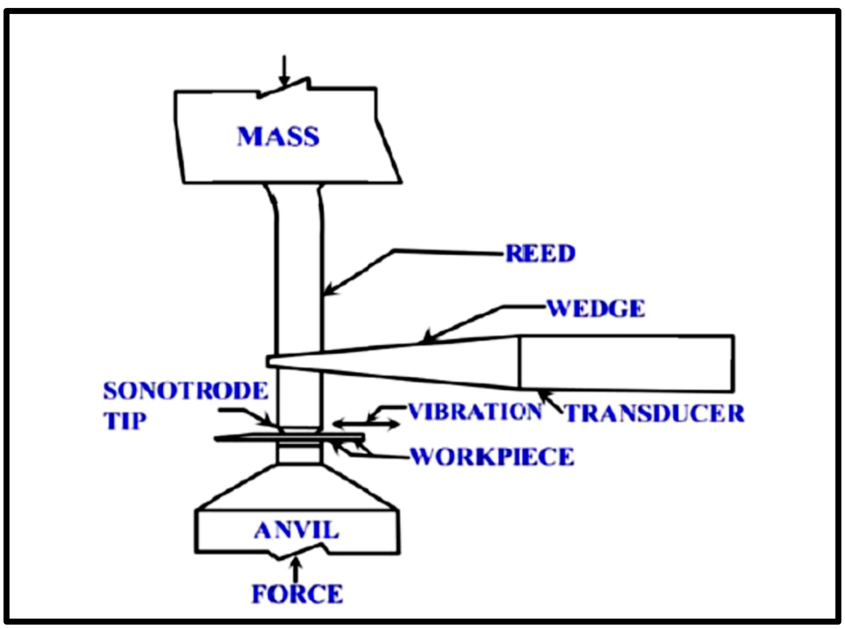


Figure (4) **Wedge-Reed Ultrasonic spot Welding system** reflecting anvil, thereby concentrating the vibratory energy. Either stationery tips (for spot welds) or rotating discs (for seam welds) can be employed.

There are four variations of the process based on the type of weld produced. These are spot, ring, line and continuous seam welding.

Advantages

- Requires a little heat application during joining without melting of the material.
- No cast or brittle inter-metallics are formed.
- The process permits welding thin to thick sections and a wide variety of dissimilar materials.
- Ultrasonic welding of aluminum, copper and other high thermal conductivity metals require substantially less energy than resistance welding.
- Since the temperatures are low and no arching or current flow is involved, the process can be applied to heat-sensitive electronic components.
- The equipment is simple and reliable and only moderate operator skills are required.
- It is possible to bond metals to non-metals, such as aluminium to ceramic or glass.

Disadvantages

- Restricted to the lap joint welding of thin materials-sheet, foil and wires and the attaching of thin sheets to heavier structural members.
- The maximum thickness of welds is about 2.5 mm for 'Al' and 1 mm for harder materials.

Applications:

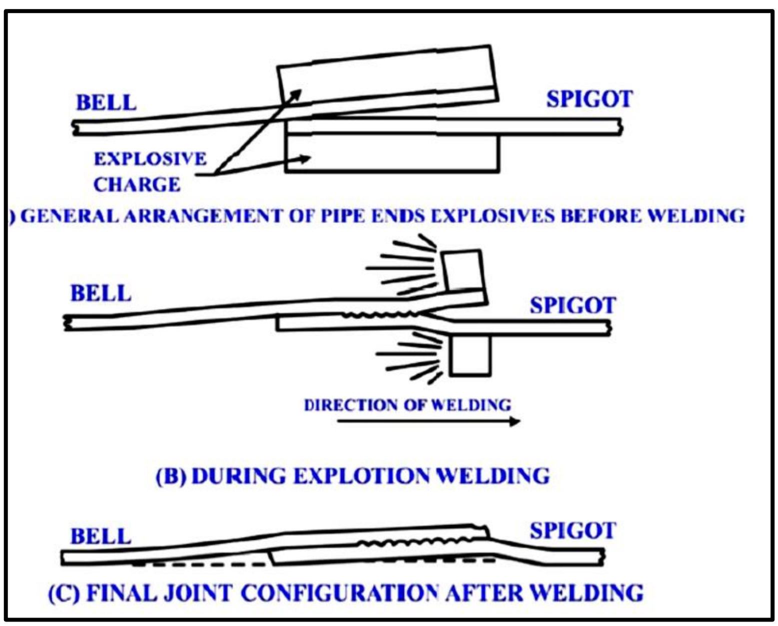
- Joining dissimilar metals in bimetallic plates,
- Microcircuit electrical contacts,

- Welding refractory or reactive metals,
- Bonding ultra-thin metals etc.

3.3 Explosive Welding (EXW)

It is a solid state welding process wherein welds are produced by the high velocity impact of the workpiece as a result of the controlled detonation. The explosion accelerates the metal to a speed at which the metallic bond gets formed between them, when they collide against each other. The weld is produced within a fraction of a second, without the addition of a filler metal.

Explosive welding is used primarily for bonding sheets of corrosion- resistant metal to heavier plates of base metal (a cladding operation), particularly when large area are involved. The bottom sheet or plate is positioned on a rigid base or anvil and the top sheet is inclined to it with a small open angle between the surfaces to be joined. An explosive material, usually in the form of a sheet, is placed on top of the two layers of metals and detonated in a progressive fashion, beginning from the mating surfaces.



Schematic of the explosive welding of girth joint in pipe