

## Importance and Basic Concept of Welding

**Welding** is a fabrication process that joins materials, usually metals or thermoplastics, by causing coalescence. This is often done by melting the work pieces and adding a filler material to form a pool of molten material (the *weld pool*) that cools to become a strong joint, with pressure sometimes used in conjunction with heat, or by itself, to produce the weld.

Welding is used in every industry large or small, as a principle means of fabrication and repairing metal product. The process is efficient, economical and dependable. This is the only process which has been tried in the space and finds applications for fabricating products in air, underwater and in space

## Classification of welding process

There are many ways in which the welding processes can be classified. A simple and logical way is to satisfy the welding processes according to the sources of energy used for achieving coalescence. The welding processes can thus be broadly classified as;

- (a) Fusion welding
- (b) Pressure welding
- (c) Thermo chemical welding

### (a) Fusion welding

#### 1. Gas flame welding

- Oxy-acetylene welding
- Oxy-hydrogen welding

#### 2. Electric arc welding

- Carbon arc welding
- Shielded metal arc welding
- Submerged arc welding
- Tungsten arc welding
- Metal inert gas (MIG) welding
- Plasma arc welding
- Atomic hydrogen welding

#### 3. Radiant energy welding

- Electron beam welding
- Laser beam welding

#### 4. Electric resistance welding

- Spot welding

Prepared by;

Mahmood Alam  
Deptt. Of Mechanical Engg.  
Integral University  
Lucknow

- Seam welding
- Projection welding
- Resistance butt welding
- Flash welding
- Percussion welding
- Electroslag welding

The following processes fall under solid state (cold) welding

**(a) Pressure welding**

- Friction welding
- Ultrasonic welding
- Explosive welding
- Forge and diffusive welding

**(c) Thermo chemical welding**

- Thermit welding
- Atomic hydrogen welding

Out of the above welding processes carbon arc and atomic hydrogen welding are not commonly used in industries these days.

## **Fusion welding;**

Fusion welding is a group of processes that bond metals together by heating a portion of each piece above the melting point and causing them to flow and fuse together. Usually filler materials are used to insure the joint is filled. All fusion welding processes have four requirements for obtaining satisfactory welds.

1. A source of energy to create union (e.g. gas flame, electric arc, electric resistance etc.)
2. Removing surface contaminants (e.g. organic and oxide films etc.)
3. Protecting metal from atmospheric contamination ( shielding gas atmosphere like argon, helium, carbon dioxide, smoke of burning flux coating)
4. Control of weld metallurgy (e.g. preheat, post welding heat treatment)

## **Gas Welding**

It is fusion welding process that joins the metal by using heat of combustion of a strong gas flame. The intense heat raises the temperature of ends, melts and fuses together the edges of the plate to be welded. Filler metal may be added the plate to flowing molten to fill the cavity between the plates. Different oxy-acetylene combinations are used to produce different types heating flames i.e.  $O_2$  and  $C_2H_2$ ,  $O_2$  and  $H_2$  with coal gas etc. Oxy –acetylene welding is the most

Prepared by;

Mahmood Alam  
Deptt. Of Mechanical Engg.  
Integral University  
Lucknow

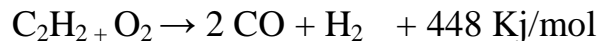
commonly used gas welding process. This process is explained in detail in the following paragraphs.

### **Oxy-Acetylene Welding (O<sub>2</sub>, C<sub>2</sub>H<sub>2</sub>)-**

Oxyacetylene welding is a gas welding process. In this process coalescence (or bond) is produced by heating with the gas flame obtained from the combustion of acetylene with oxygen. A welding torch is used to mix the gases in the proper proportions and to direct the flame against the parts to be welded. The molten edges of the parts then literally fuse together and after cooling form a strong joint. Usually, it is necessary to add extra material to the joint. The correct material in the rod form of a rod is dipped in a flux powder and is fused with the puddle of and fuses with the puddle of molten metal obtained from the parent metal parts. Acetylene is widely used as the combustible gas because of its high flame temperature when mixed with oxygen. The temperature, which ranges from approximately 2100<sup>0</sup>- 3500<sup>0</sup>, is far above the melting point of all commercial metals thus it provides a means for the rapid, localized melting essential in welding. The oxyacetylene flame is also used in cutting ferrous metals. The oxyacetylene welding and cutting methods are widely used by all types of maintenance activities because the flame is easy to regulate, the gases may be produced inexpensively, and the equipment can be transported easily and safely.

### **Combustion of gas and heat liberated**

#### **First stage-**



#### **Second stage**



Total heat liberated by combustion= 448+812= 1260 Kj/mol of acetylene

### **Gas welding equipments**

1. Oxygen gas cylinder
2. Acetylene gas cylinder
3. Welding torch
4. Pressure regulator
5. Hose pipe
6. Stop valve
7. Pressure gauge

Prepared by;

Mahmood Alam  
Deptt. Of Mechanical Engg.  
Integral University  
Lucknow

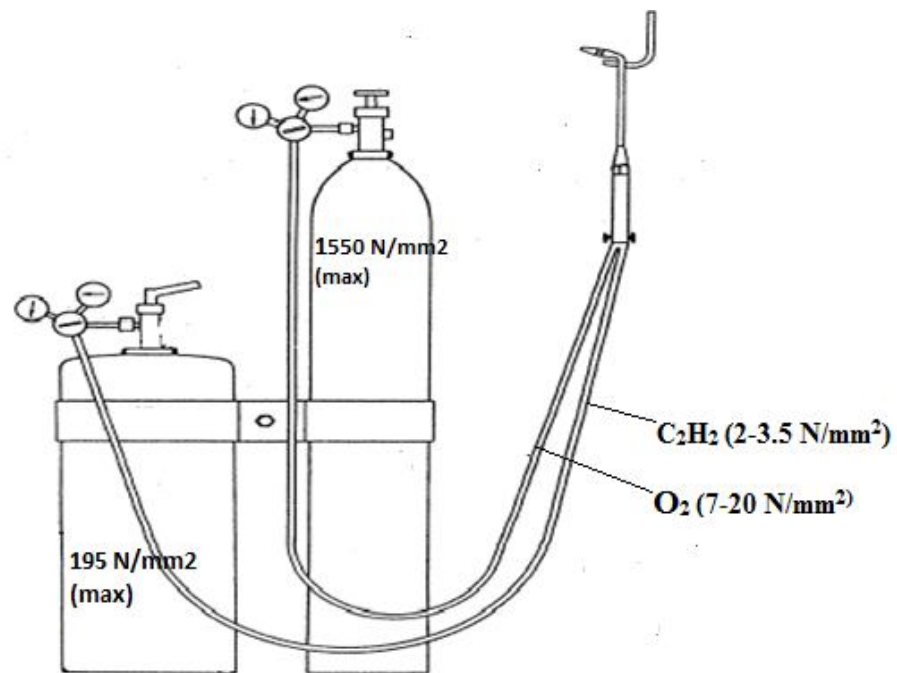


Figure -Oxy acetylene equipments

## Types of flame

To achieve successful and efficient welding, proper mixing of gas in appropriate proportion is necessary. According to the volume of O<sub>2</sub> and C<sub>2</sub>H<sub>2</sub> flame can be classified as

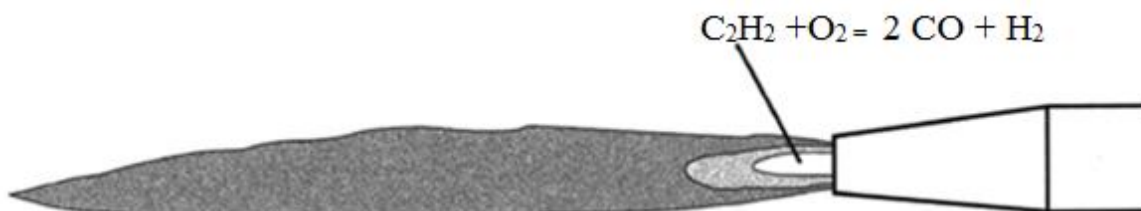


Figure - Gas welding flame

1. **Neutral flame-** Neutral Flame is produced when equal volume of O<sub>2</sub> and C<sub>2</sub>H<sub>2</sub> are mixed. It has well defined inner cone, which has light blue color. Neutral Flame doesn't create any change in the molten metal and doesn't oxidize or carburize the metal. This flame is used for welding of mild steel, cast iron, aluminum and stainless steel. Temperature of neutral flame is 3232<sup>0</sup> C.

Prepared by;

Mahmood Alam  
Deptt. Of Mechanical Engg.  
Integral University  
Lucknow

2. **Oxidizing flame**- oxidizing flame is obtained by increasing the supply of oxygen in mixture. It has small white cone which is shorter and more pointed than that of neutral flame. It creates high temperature of  $3482^{\circ}\text{C}$ . It is normally not used except in the case of brass.

3. **Reducing flame**- it is produced when supply of  $\text{C}_2\text{H}_2$  is higher than supply of oxygen and can create an approximate temperature of  $3150^{\circ}\text{C}$  its outer envelope is longer than that of neutral flame. It is used for the welding of lead.

In these flames the temperature is maximum at the tip of the inner cone. Feather or brush exists next to the cone and occurs in carburizing flame only.

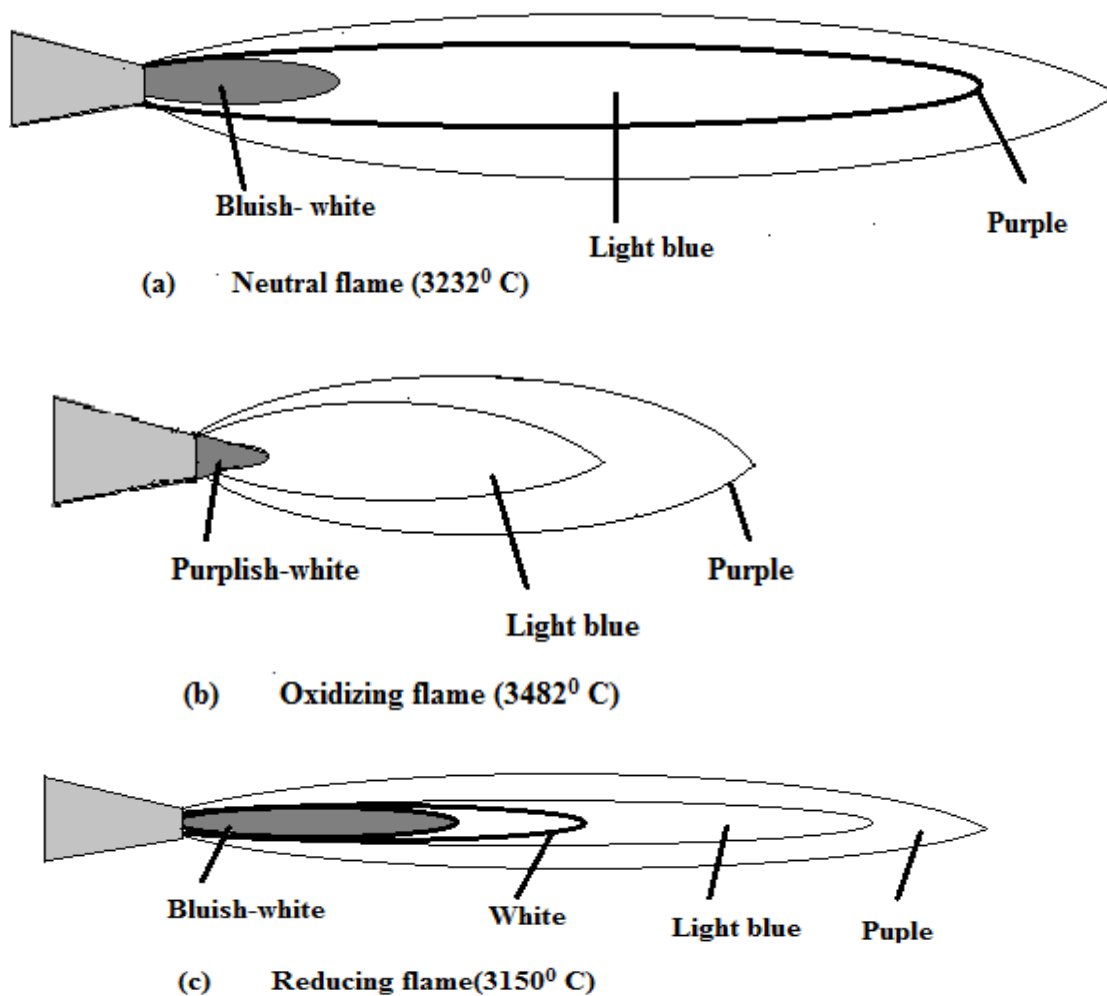


Figure -Types of gas welding flame

Prepared by;

Mahmood Alam  
Deptt. Of Mechanical Engg.  
Integral University  
Lucknow

## Electric arc Welding

1. In electric arc welding metal pieces to be joined are heated to melting point by creating an electric arc between them to form a pool of molten metal and then allowing it solidify to form welded joint. Sometimes additional material is added to form the weld by melting the wire known as filler metal. Electric arc welding is classified as
  1. Carbon arc welding (Obsolete)
  2. Metal arc welding

### Metal arc welding-

In metal arc welding arc is maintained between electrode and work piece and work piece which form the two terminals. In this welding electrode used may be bare or coated. Bare electrode has same composition as that of parent metal whereas coated electrode have some material or flux that prevents the oxidation of surface.

To obtain the required heat arc is struck by making light contact of electrode with work piece and then electrode is withdrawn to a proper distance. This current arc produces large amount of heat and melts the electrode end and the work piece. Due to melting of electrode material droplets are transferred to the work piece through the arc and deposited along the joint.

Metal electrode is coated with a flux which burns and produces a gas shield around the arc to protect it from atmospheric contamination of molten weld metal

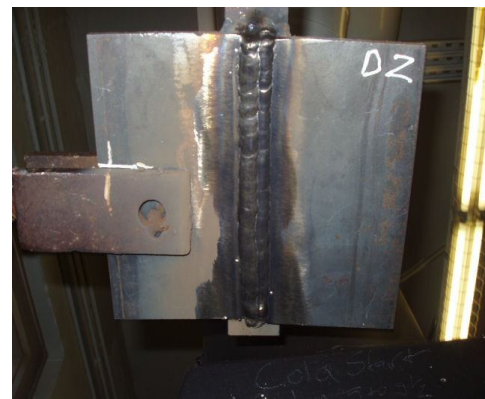
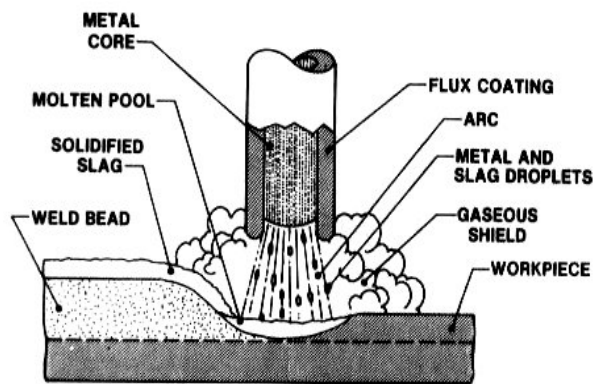


Figure-Electric arc welding

Prepared by;

Mahmood Alam  
Deptt. Of Mechanical Engg.  
Integral University  
Lucknow

**Arc welding Power source-** In arc welding both A.C and D.C. power sources could be used. In D.C. welding

**Polarity in arc welding-** When A.C is used polarity is not fixed at any terminal and it interchanges in every cycle thus the heat generated at each pole is same. But in D.C welding polarity is fixed. Job acts as one terminal and electrode acts as another terminal. Heat developed at +ve terminal is  $\frac{2}{3}$  rd and at -ve terminal is  $\frac{1}{3}$  rd of the total heat. In D.C welding polarity is of two types.

### **Straight polarity-**

In straight polarity electrode forms the -ve terminal and work piece forms the +ve terminal. This polarity is used in welding of thick materials due to large requirement of heat on the plate

### **Reverse polarity-**

In Reverse polarity electrode forms the +ve terminal and work piece form the -ve terminal. This polarity is used in welding of thin materials due to less requirement of heat in welding zone.

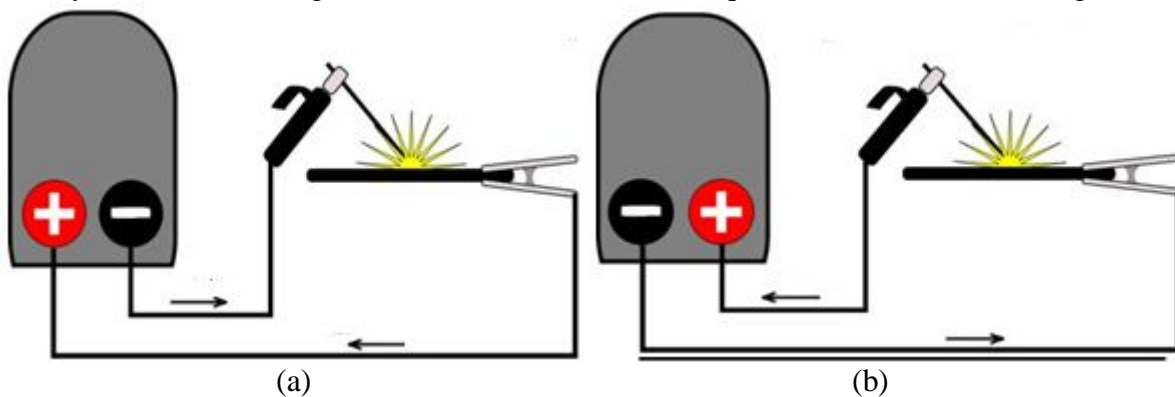


Figure (a) D C Straight polarity (b) D C Reverse polarity

### **Types of electrodes**

1. Consumable electrodes
  - a. Bare Electrodes
  - b. Coated Electrodes
2. Non- consumable electrodes

### **Resistance Welding**

It is the process of joining two metal pieces by application of mechanical pressure and heat. The heat is generated due the resistance offered by the two pieces to the flow of current. In resistance welding two metal pieces to be joined are held together and high electric current is passed

Prepared by;

Mahmood Alam  
Deptt. Of Mechanical Engg.  
Integral University  
Lucknow

through it. Due to flow of current across the resistance the temperature at the junction reaches the fusion point. At this time slight mechanical pressure is applied to complete the weld.

The magnitude of current in resistance welding varies from 3000 to 100,000 ampere for a fraction of a second with voltage of 1 to 25 volts.

Heat generated in resistance welding is given by

$$H=I^2 RT$$

Where H= Heat generated in Joules

I= Current in ampere

T= Time of current flow in second

Resistance welding can be further classified as

- ✓ Spot welding
- ✓ Seam welding
- ✓ Projection welding
- ✓ Butt welding
- ✓ Flash welding
- ✓ Percussion welding

### **Resistance spot welding-**

Spot welding is a resistance welding process in which overlapping metal plates are held between two copper electrodes, which concentrate welding current to melt the interface over a spot and apply pressure to complete the weld.

In this welding

- ✓ Current is order of 3000- 10000 ampere
- ✓ Temperature of weld zone is 815<sup>0</sup> C-930<sup>0</sup> C
- ✓ Electrode- Copper base alloy
- ✓ Weld nugget- 6-10 mm in diameter

### **Advantage;-**

- High welding rates;
- Low fumes;
- Cost effectiveness;
- Easy automation;
- No filler materials are required;
- Low distortions.

Prepared by;

Mahmood Alam  
Deptt. Of Mechanical Engg.  
Integral University  
Lucknow

**Disadvantages**

- High equipment cost;
- Low strength of discontinuous welds;
- Thickness of welded sheets is limited - up to 1/4" (6 mm);

**Resistance Seam welding-** Seam welding is similar to spot welding except that continuous circular rotating electrodes are used in place of tip electrode. The weld produced is continuous air tight seam. It can also be defined as continuous series of spot welds.

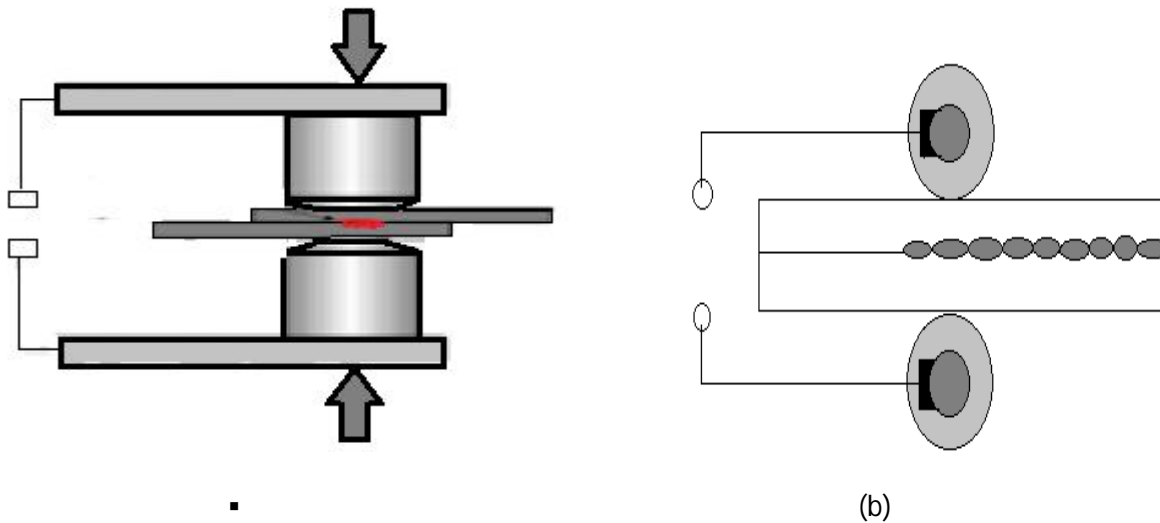
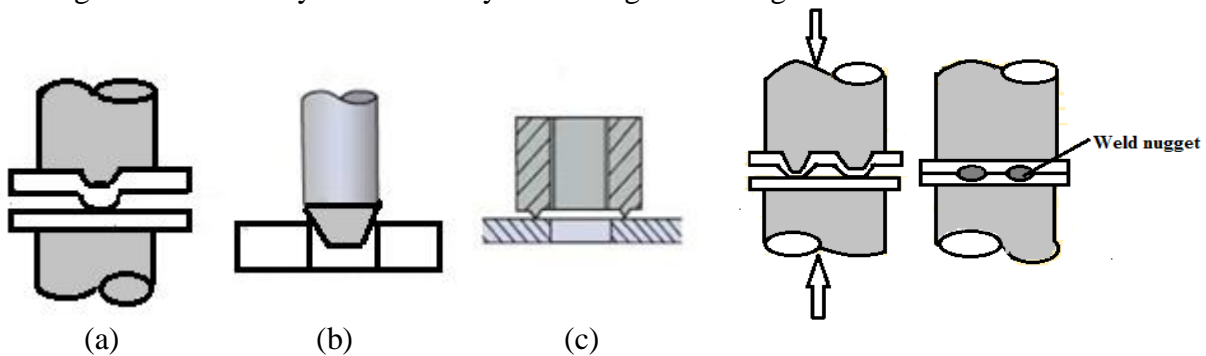


Figure (a) Spot welding and (b) Seam welding

**Resistance projection welding-** Projection welding is a development of resistance spot welding. In spot welding, the size and position of the welds are determined by the size of the electrode tip and the contact point on the work pieces, whereas in projection welding the size and position of the weld or welds are determined by the design of the component to be welded. The force and current are concentrated in a small contact area which occurs naturally, as in cross wire welding or is deliberately introduced by machining or forming



Prepared by;

Mahmood Alam  
 Deptt. Of Mechanical Engg.  
 Integral University  
 Lucknow

Figure 5.7 Example of projection welding configurations: a) embossed projection; b) stud to plate; c) annular projection

### Advantage

The advantages of projection welding include its versatility, the speed and ability to automate, the ability to make a number of welds simultaneously and minimization of marking on one side of joints in sheet materials. Capacitor discharge supplies used with machined annular projections can compete with power beam welding, as the weld is completed in a single shot within milliseconds.

### Disadvantage

There are some limitations on material weldability but attention to correct setting up and good process control can solve most production problems. The main safety factors are trapping hazards and splash metal. Little fume is produced but may need attention when welding coated steels or when oils or organic materials are present.

### Flash Welding (FW)

Flash Welding is a Resistance Welding (RW) process, in which ends of rods (tubes, sheets) are heated and fused by an arc struck between them and then forged (brought into a contact under a pressure) producing a weld.

The welded parts are held in electrode clamps, one of which is stationary and the second is movable. Flash Welding method permits fast (about 1 min.) joining of large and complex parts. Welded parts are often annealed for improvement of Toughness of the weld. Steels, Aluminum alloys, Copper alloys, Magnesium alloys, Copper alloys and Nickel alloys may be welded by Flash. Thick pipes, ends of band saws, frames, and aircraft landing gears are produced by Flash Welding.

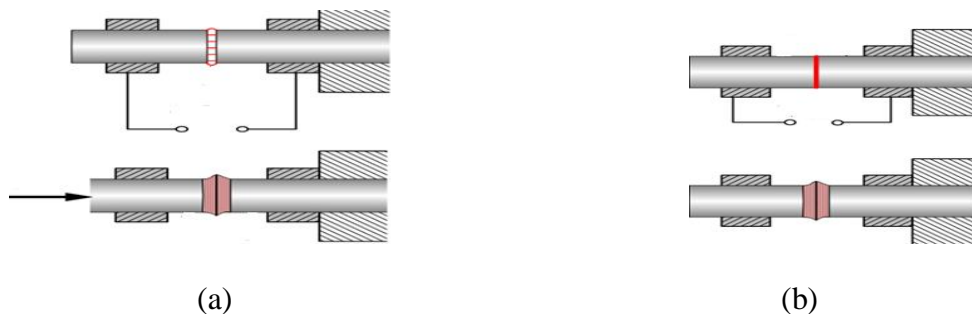


Figure (a) Flash Welding and (b) Butt welding

### Resistance Butt Welding

Resistance Butt Welding is a Resistance Welding (RW) process, in which ends of wires or rods are held under a pressure and heated by an electric current passing through the contact area and producing a weld.

Butt welding is used for welding small parts. The process is highly productive and clean. In

Prepared by;

Mahmood Alam  
 Deptt. Of Mechanical Engg.  
 Integral University  
 Lucknow

contrast to Flash Welding, Butt Welding provides joining with no loss of the welded materials.

**Percussion Welding** - It is a resistance welding process wherein coalescence is produced simultaneously over the entire area of abutting surfaces by heat obtained from an arc produced by a rapid discharge of electrical energy, with pressure percussively (rapidly) applied during or immediately following the electrical discharge.

## Soldering and Brazing

### Soldering

Soldering involves the heating a joint to a suitable temperature and using filler metal (solder) which melts below  $450^{\circ}$  C. solder gets distributed between the properly fitted surfaces of the joint by capillary attraction. Heat is required to melt the solder, promotes fluxing action on metal surface which permits the molten solder to wet and flow into the joint. Successful soldering requires:

2. Proper fit-up (close together)
3. Cleaning the surfaces to be joined
4. Applying flux, assembling parts, and applying heat and solder.
5. Remove flux residues after joint is cooled

### Soldering Methods

1. Dip soldering
2. Iron soldering
3. Resistance soldering
4. Torch soldering
5. Induction soldering
6. Furnace soldering
7. Infrared soldering
8. Ultrasonic soldering

Solders can be classified as:

6. **Soft Solder**- is an alloy of lead and tin with the following composition
  - a) Tin 50%, Lead 50%
  - b) Tin 67%, Lead 33%
  - c) Tin 33%, Lead 67%

Soft solder melts at temperature below  $350^{\circ}$  C and operation is known as soft soldering.

7. **Hard Solder**- is an alloy of Copper and Zinc that melts above  $600^{\circ}$  C the operation is performed with hand solder is called hand soldering.

To prevent the oxidation of joint surfaces, fluxes are used. Flux should be light in weight so it could be displaced by molten metal

Example of flux- Zinc chloride, rosin and rosin plus alcohol based flux, mixture of zinc chloride and ammonium chloride

Prepared by;

Mahmood Alam  
Deptt. Of Mechanical Engg.  
Integral University  
Lucknow

Skill is needed for manual soldering operation especially for critical electronic equipment/components. Automated soldering requires less operator skill as the process variables are set before the soldering operation, machine setting, process control and inspection determine joint quality. Lap joint is most commonly used while special types of joints are used to solder electronic components.



(a)



(b)

Figure (a) Soldering operation (b) 30 watt Solder iron

### Application

1. Process is used to join a wide range of metal thickness from thin film to quite heavy components like bus bars and piping.
2. Expensive automated equipment produces many high quality joints at a time, thus reducing the cost per joint.
3. Manual soldering is although slow, but still economical when production needs are low or joint design is complex.

### Brazing

Brazing is a group of welding processes in which the parts are heated to suitable temperature and the filler metal used has a melting temperature above  $450^{\circ}\text{C}$  and below the solidus of the base metal. The filler metal flows between the closely fitted joints by capillary attraction.

In Braze welding, the filler metal is deposited in a groove exactly at the point where it is to be used capillary action is not a factor. Brazing differs from soldering by the filler metal melting temperature being below  $450^{\circ}\text{C}$ .

The basic elements to be considered for brazing are:

1. Joint design
2. Filler metal
3. Uniform heat
4. Protective (or reactive) cover

Prepared by;

Mahmood Alam  
Deptt. Of Mechanical Engg.  
Integral University  
Lucknow

Processes used for brazing are classified on the basis of methods of heating.

1. Torch brazing (oxy-fuel gas torch: for welding thin section 0.25 mm to 6 mm) making lap joint
2. Furnace brazing (flux and braze filler is preplaced.
3. Induction brazing (3 mm normal up 25 mm)
4. Resistance brazing (0.1-12.00 mm sheets)
5. Dip brazing (molten salt or molten metal bath)
6. Infrared brazing
7. Diffusion brazing

Prepared by;

Mahmood Alam  
Deptt. Of Mechanical Engg.  
Integral University  
Lucknow