perfectly. The heat is produced by the combination of friction and mixing but the metal will not melt but it softens. The softening of metal takes place up to a highly plastic condition. When the tool moves forward along the joint, the leading surface of the rotating probe is forcing the metal around it. Then the developed force forges the metal into a weld flowing around the probe.

FSW process is used in: aerospace, automotive, railway, and shipbuilding industries. The main applications are butt joints on large aluminium parts. Sometimes, steel, copper, and titanium, as well as polymers and composites are also jointed by using FSW.

Advantages

1. It ensures the good mechanical properties of the weld joint.
2. It avoids toxic fumes, warping, shielding issues, and other problems associated with are welding.
3. It permits less distortion or shrinkage on joints.
4. It provides good weld appearance.

Disadvantages

1. An exit hole remains the same after the tool is withdrawn from the work.
2. Heavy-duty clamping of the parts is required.

2.19 Soldering, Brazing and Braze Welding

2.19.1 Soldering

Soldering is a common process for joining steel, copper and other materials at low temperature.

It is defined as a group of joining processes where coalescence is produced by heating to a suitable temperature and by using a filler metal having a liquidus not exceeding 427°C and below the solidus of base metals.

The filler metal (solder) is generally distributed between the properly fitted surfaces of the joint by capillary action.

Soldering is divided into two types i.e.

- Soft solder
- Hard Solder

Soft soldering is used in sheet metal work for joining parts that are not exposed to the high temperature action and not subjected to excessive loads and forces.

Soft soldering is also used for joining wires and small parts.

A suitable flux is always used in soft soldering.

Zinc chloride is a common flux used in this process.

The function of flux is to prevent oxidation of the surfaces to be soldered or to dissolve oxides that settle on the metal surfaces while heating process.

A blow torch or soldering iron constitutes the equipment for heating the base metals and melting the solder and the flux.

Hard soldering uses solders which melt at higher temperatures and are stronger than those used in soft soldering.

Silver soldering is a hard soldering method and in that silver alloyed with tin is used as solder.

The temperature of hard solders vary from 600 to 900°C.

The fluxes are generally in the form of paste and applied to the joint before heating by using brush.

In hard soldering, blow torch constitutes the equipment.

Figure 2.32 shows the commonly used soldering iron.

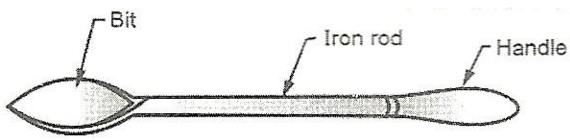

Figure 2.32. Soldering Iron

It consists of a copper bit tapered to form an edge at its end which is fastened to an iron rod in a wooden handle.

Any source of heat is satisfactory for heating the bit.

Generally, the bit is heated in gas or coke fire, cleaned, dipped in flux and then rubbed against the solder.

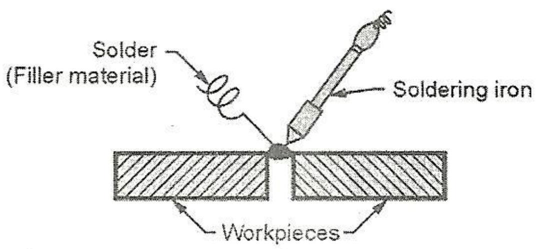

Figure 2.33. Soldering Processes

All soldering techniques requires almost same procedure as discussed below Refer figure 2.33.

1. Clean the metal parts to be joined.
2. Fit the joints and heat the parts.
3. Apply the flux and filler materials.
4. Remove the heat and hold the assembly until the filler metal has completely solidified.
5. Clean the of cooled parts, if required.

Soldering filler materials

The various soldering filler materials (solders) are as follows:

1. **Tin – lead solders:** They possess good corrosion resistance and used to join most of the metals.
2. **Tin – antimony solders:** They are having poor flow characteristics and generally used for soldering of copper and its alloys.
3. **Cadmium – silver solders:** They are used for joining aluminum to itself or to other metals. Because of cadmium sometimes it is hazards to health.
4. **Zinc-aluminum solders:** They are used for joining aluminum. They develop joints with high strength and good corrosion resistance.

Soldering fluxes

The purpose of soldering flux is to remove and exclude small amounts of oxides and other surface compounds from the surfaces being soldered and prevent reoxidation of the surfaces while soldering. The commonly used soldering fluxes are as follows:

1. Corrosive fluxes (consist of zinc and aluminum chloride)
2. Non – corrosive fluxes (consist of gum exuded from pine trees)
3. Mild fluxes (consist of lactic acid, stearic acid, benzoic acid and glutamic acid)

Advantages

By soldering process variety of dissimilar metals can be joined.

It is a simple and low cost method.

Workpieces of different thickness can also be joined.

The joint formed in the process, do not require any machining.

Soldering is a low temperature process, hence there is no change in the properties of metals.

Disadvantages

Soldered joints do not have much strength, so the process should not be used for high load carrying members.

Since soldering temperatures are low, a soldered joint has limited service at elevated temperature.

Corrosion resistance of soldered joint is less.

Commonly used solder alloys are mixtures of tin and lead but, the used lead is toxic in nature.

Applications

Soldering process is commonly used for joining following components:

Most frequent application of soldering is assembly of electronic components (chips, IC‟s, etc.) to printed circuit boards.

Joints in sheet metal objects like food cans, roof flashing, iron, etc.

Joints in the wires.

Now - a- days jewellery components are also assembled and repaired by soldering process.

2.19.2 Brazing

It is defined as a group of joining processes where coalescence is produced by heating to a suitable temperature and by using a filler metal having a liquidus above 470°C and below the solidus of the base metal.

In brazing, metallic parts are joined by a non-ferrous filler metal or alloy.

The filler metal is distributed between the closely fitted surfaces of the joint by capillary actin.

The filler metals used in the process are divided in two types:

- Copper base alloys
- Silver base alloys

Similar to soldering, the parts to be joined by brazing are carefully cleaned, the flux applied and the parts clamped in position for joining.

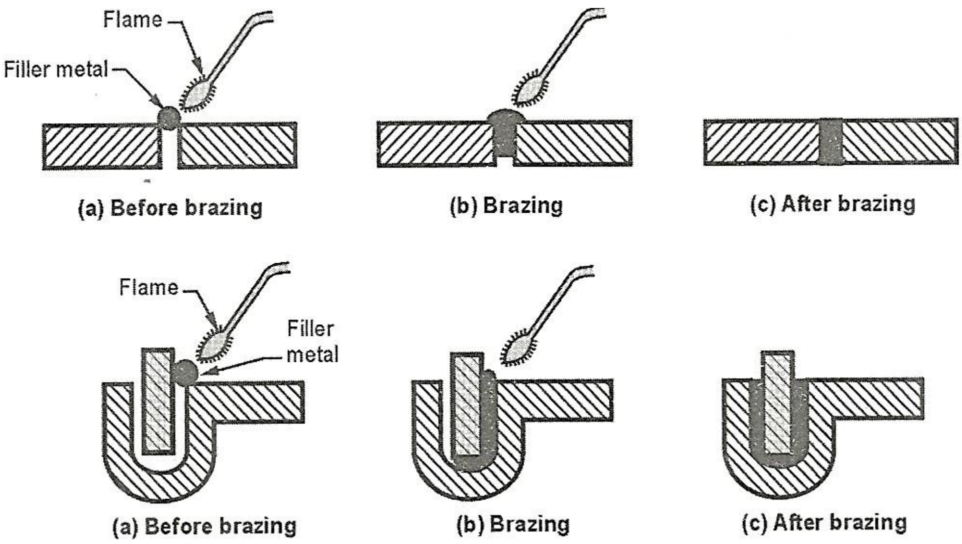

Figure 2.34 Brazing of different components

Borax is commonly used flux in brazing process.

They are then heated to a temperature above the melting point of the spelter (harder filler material) which is then allowed to flow by capillary action into the space between the parts and to slowly cool.

There are various brazing methods such as:

- Torch brazing
- Resistance brazing
- Immersion brazing
- Furnace brazing

Advantages

By brazing process dissimilar metals and non-metals can be brazed.

Due to uniform heating of parts, it produces less thermal distortion than the welding process.

Complicated components can also be brazed at low cost.

It is suitable for mass production.

Machining of the brazed joint is not required.

Brazing does not melt the base metal which allows much tighter control over the tolerances.

Brazing produces a clean joint.

Disadvantages

Strength of the brazed joints is less as compared to welded joints.

Brazed joints can be damaged under high service temperatures.

Brazed joints requires a high degree of base metal cleanliness.

The joint colour is different than that of base metal which creates an asthetic disadvantage.

Filler metals used in the process are costly.

Applications

Brazing is applicable to cast and wrought iron, steel, Cu, A1, Mg and their alloys. Brazing can join:

- Cast metal to wrought metals
- Non-metals to metals
- Dissimilar metals
- Porous metal components

It is used in place of welding where special metallurgical characteristics of metals are required after joining.

Brazing filler metals

A brazing filler metal must possess following properties:

Ability to we the base metals on which it is used.

Proper melting temperature and flow properties.

Desirable mechanical and physical properties in the joint.

Composition of sufficient homogeneity and stability to minimize separation by liquation during brazing.

The filler metals used in brazing are as follows:

1. **Aluminium – Silicon (A1-Si):** It is a general purpose brazing filler metal used where controlled flow is required.
2. **Magnesium (Mg):** It is used for brazing of magnesium alloys.
3. Copper and copper-Zinc (Cu and Cu-Zn): It is used in all brazing process on steel, nickel base alloys giving a better colour match.
4. **Gold:** It is used for joining parts in electron tube assemblies where volatile components are undesirable.
5. **Silver brazing alloys:** They are used for joining most ferrous and non-ferrous metals except aluminium and magnesium using all methods of heating.

Brazing fluxes

The main function of flux in brazing is to prevent oxidation of the base metal and filler metal. It must posses following properties:

It must melt and cover the braze are at a temperature below that of the solidus of the filler metal used.

Low melting point.

Sufficient surface tension.

Low viscosity.

It is easy to remove after brazing. The commonly used fluxes are listed below.

Fused Borax (for high temperature)

Boric acid (act as a cleaning agent).

Chlorides, Sodium and potassium hydroxides.

Fluoborates (Compounds of fluorine, boron and active metals)

2.19.3 Braze Welding

Braze welding is also called as bronze welding.

Bronze welding does not mean the welding of bronze, but it is a welding using bronze filler rod.

It is a method of welding where a groove, fillet, plug or slot is made by using a non-ferrous filler metal having a melting point below that of the parent metal but above 427°C.

The filler metal is not distributed in the joint by capillary action.

In bronze welding, the edges or surfaces of the material to be joined are heated to a temperature which corresponds to the melting point of the bronze-filling rod used.

Filler rod consists of 60% Cu and 40% Zn, which given high tensile strength and ductility.

The process consists of cleaning the surfaces to be joined, heating them to braze welding temperature which depends on the filler rod composition and applying the flux for removing the oxide.

Generally, the heat source is oxy-acetylene flame.

The main advantage of the process is that, during the operation temperature is low.

Applications

It is used for welding of dissimilar metals.

Metals having high melting point such as steel, cast iron, copper, brass can be bronze welded.

It is also used for fabrication of metal furniture, bicycles, automobiles, refrigerators and domestic appliances.

2.19.4 Comparison between soldering, Brazing and Braze Welding

Sl. No	Parameter	Soldering	Brazing	Braze Welding
1	Principle	The filler metal is usually distributed between the properly fitted surfaces of the joint by capillary action.	The filler alloy is fed To one or more points in the assembly and it is drawn into the rest of the joint by capillary action.	The filler alloy is deposited directly at the point where it is desired.
2	Temperature	Filler metal has melting point below 427°C.	Filler metal has melting point below 427°C.	Filler metal has meting point above 427°C.
3	Strength of Joint	Weak	Strong	Moderate
4	Application	Used for carbon,low alloy steels, cast iron, stainless steel, Cu and alloys, etc	Used for cat iron, steels, Cu and alloys, Mg and alloys, etc.	Used for cast iron, steels, malleable iron Cu, Ni and alloys, etc.

5	Corrosion resistance	Less	More	Moderate
6	Joint Profile	Small gap between the joints.	Smooth joint.	Joint show the ripples.

2.20 Defects in Welding

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

1. Incomplete fusion
2. Cracks
3. Porosity
4. Undercut
5. Distortion
6. Slag Inclusion
7. Lamellar Tearing
8. Overlapping

1. 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 also weld causes defects.

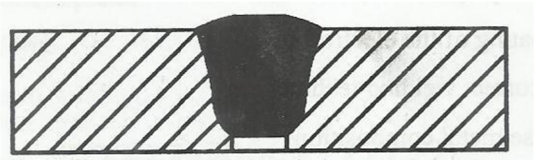

Figure 2.35 Incomplete Fusion

2. Cracks

The cracks are mainly classified into two types

1. Hot Cracking
2. Cold Cracking

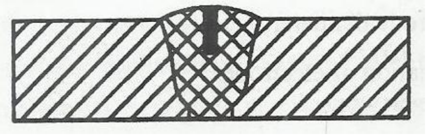

Figure2.36 Cracks

Hot cracking occurs at high temperature and cold cracking occurs at room temperature. The main causes of crack formation are:

1. Arc speed
2. Ductility
3. Solidification rate
4. Temperature

3. Porosity

It is due to the 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:

1. Arc Speed
2. Coating of the electrode
3. Incorrect welding technique
4. Base metal composition.

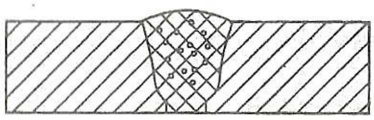

Figure 2.37 Porosity

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

4. Undercut:

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

1. High current
2. Arc length
3. Electrode diameter
4. Inclination of electrode

5. Distortion

It is defined as the change in shape and difference between 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.

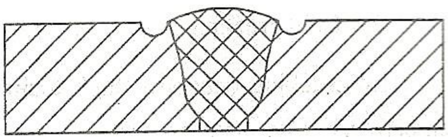

Figure 2.38 Distortion

The factors which are causing distortion are:

1. Arc speed
2. Number of passes

3. Stresses in plates
4. Joint type
5. Order of welding

6. Slag Inclusions:

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

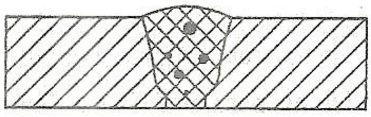

Figure 2.39 Slag Inclusions

7. Lamellar Tearing

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

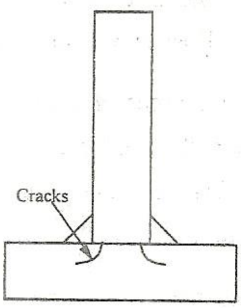

Figure 2.40 Lamellar Tearing

8. Over Lapping

It occurs when the molten metal flows over the parent metal and remains without fusing. The parameters which are causing overlap are:

1. Arc length
2. Arc speed
3. Joint type
4. Current

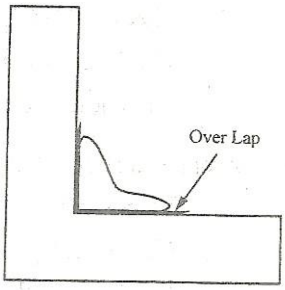

Figure 2.41 Over Lapping