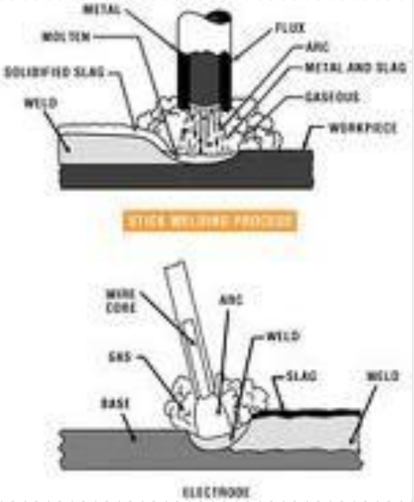
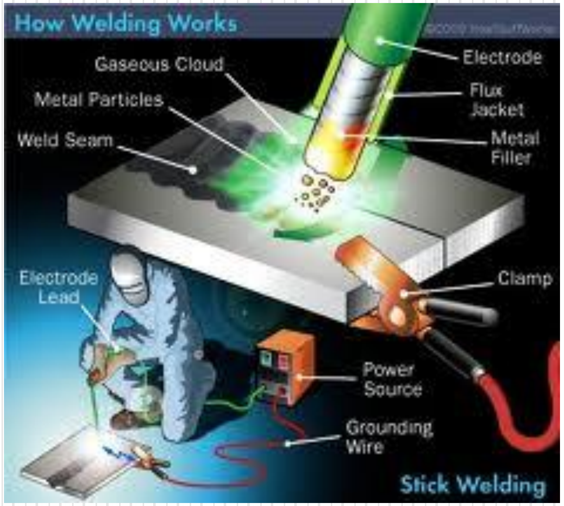
Mechanical Joining Processes





By prof.A.chandrashekhar

Introduction

➢The Products which are not possible to manufacture as single piece are fabricated by joining different parts.
Examples of such products are steel furniture, computers and wooden chairs, bridges, transmission or electric towers.

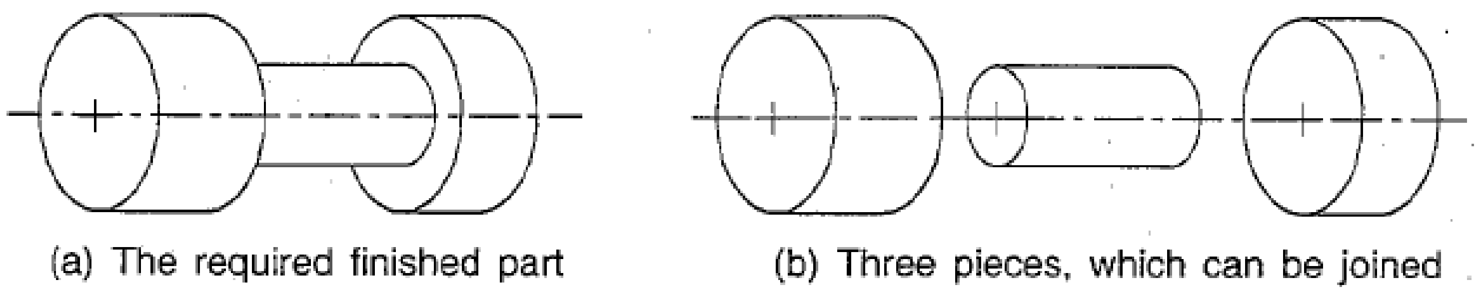


Figure 15.1 Typical component that can be manufactured by joining.

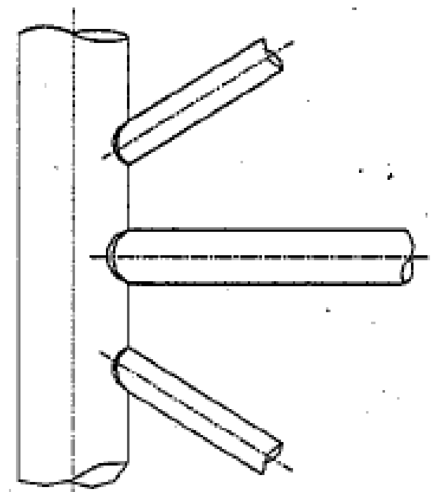


Figure 15.2 A complex tubular part.

Classification of Joining Processes

- All joining processes can be categorized based on the type of joint produced under two categories:

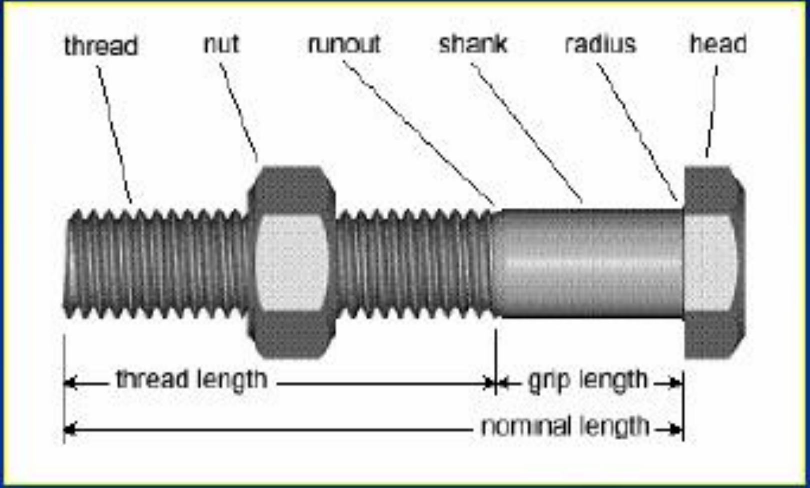
1. Permanent Joint
2. Temporary joint

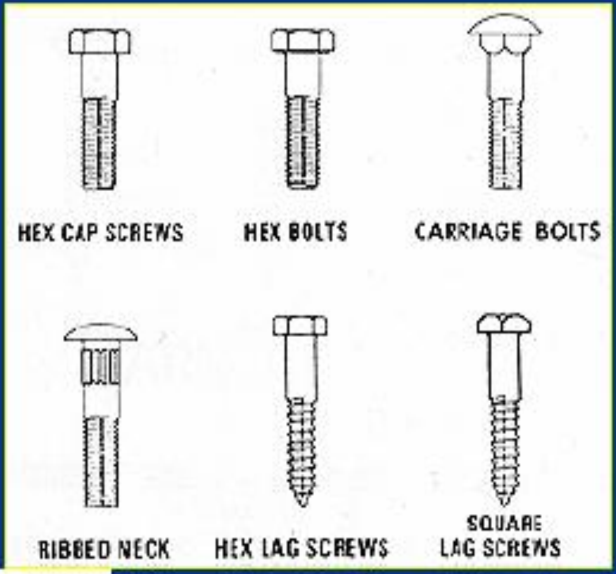
- Permanent Joint: the joint is made such that it has the properties similar to the base metal of the two parts.
- Permanently joined parts cannot be separated in to their original shape, size and surface finish.
- A temporary joint can be easily dismantled separating the original parts without any damage to them.

Conventional joining techniques

- **Bolting**

A fastening method using a **threaded pin** or rod with a head at one end (bolt), designed to be inserted through holes in assembled parts and secured by a ***mated nut***, that is tightened by applying ***torque***.





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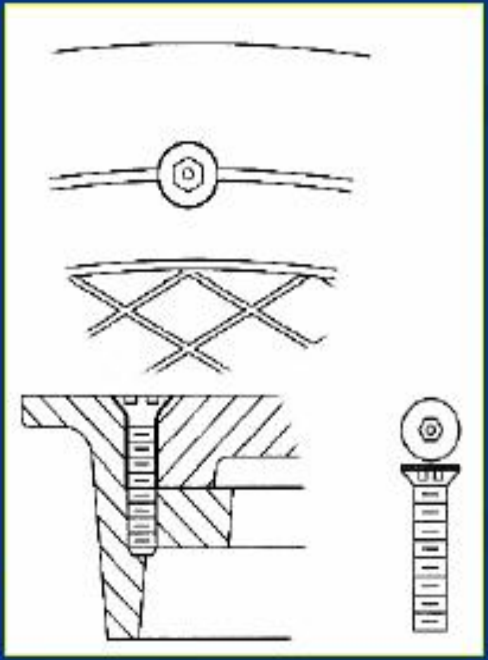
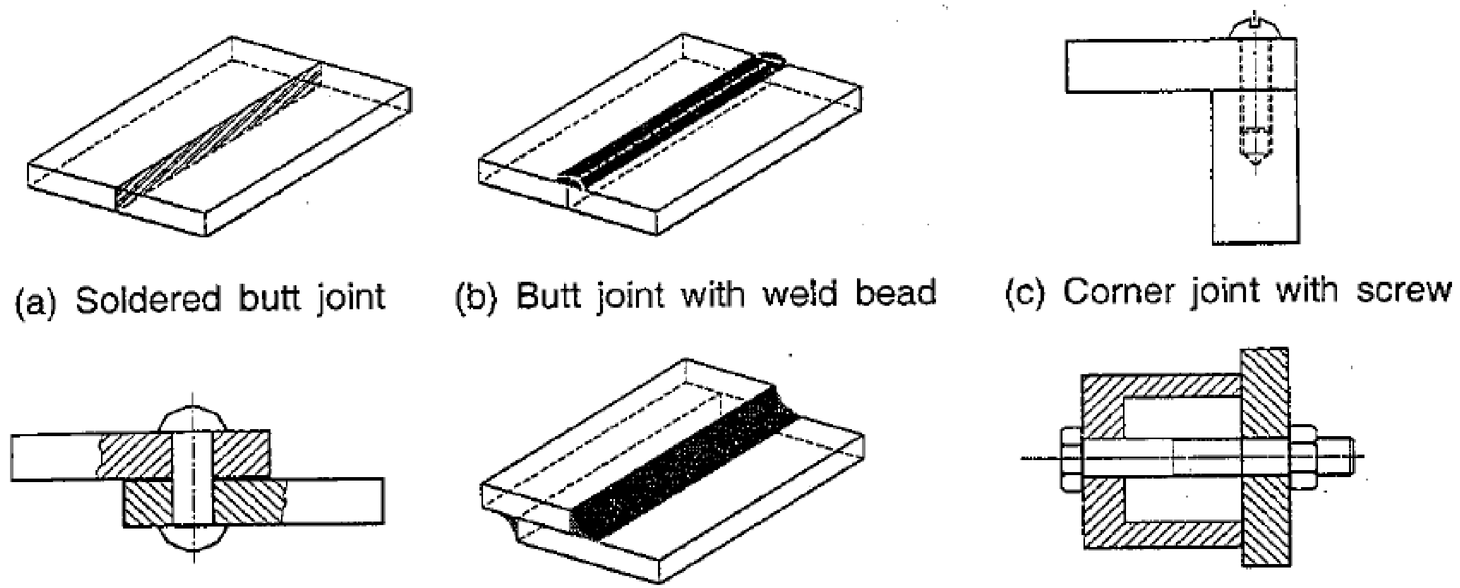


- All the joining processes can also be categorized under five headings, based on the process used for making the joint,

1. Welding
2. Brazing
3. Soldering
4. Mechanical fasteners (rivets, bolts and nuts , screws, etc.,)
5. Adhesive bonding



(a) Soldered butt joint (b) Butt joint with weld bead (c) Corner joint with screw

(d) Lap joint with rivet (e) Lap joint with fillet weld (f) An assembly with bolt and nut

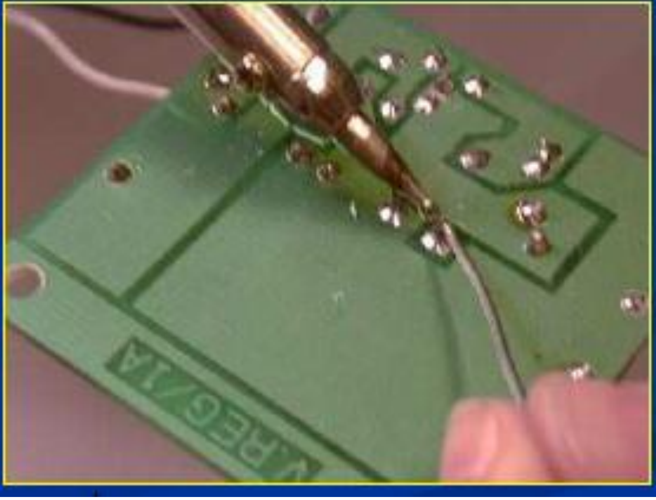
Figure 15.3 Examples of joints that can be made by different joining processes.

Mechanical Fastening

- Any shape and material almost
- Disassemblable (except Rivets, etc.)
- Least expensive for low volume (standardized)
- Problems: strength, seal, insertion, loosening

Conventional joining techniques

- Soldering
  - A joining method using a low melting point ***lead-tin alloy*** (solder) to fill in a small gap between sheets.
  - The ***solder*** wets the metal and produce an intermetallic bond.
  - T ~ 183–275 ^{o}C depending on compositions.



- Mechanical fasteners are most widely used for temporary joints with the exception of rivets, which need to be broken or destroyed for dismantling.
- Welding and adhesive bonding are used to make permanent or semi-permanent joint.
- Brazing and soldering are considered to form permanent joints, but for repair or replacement, we can dismantle them by heating.
- The choice of particular joining process depends upon several factors such as application, nature of loads or stresses, joint design, material involved, and size and shape of the component.

Welding Process

- Welding process can be defined as the process of metallurgically joining two pieces of metals by fusing to produce essentially a single piece of the metal.
- The welding process joins two pieces of metal by applying intense heat or pressure or both to melt the edges of the metal so that they fuse permanently.
- In welding filler material may also be used.
- The heat required for the process of welding can be obtained by using an electric arc, electric current, gas flame or chemical reaction.

Terminologies used in welding process:

- **Base Metal:**

  The work pieces to be joined are known as base metal.
- Weld bead: it is the material, which is deposited by the process of welding. It appears as a separate material from the base metal in the form of bead. This is also referred to as bead.
- Puddle: it is the portion of the base metals at the joint, which is melted by the heat during welding.
- Weld pass: it is the movement of the welding torch from one end of the joint to the other end, which results in a joint.
- Tack weld: a temporary small weld done at the ends of the work pieces to hold the work pieces together during welding.

Types of welding processes:

- Depending upon the source of heat employed for welding process, welding processes are classified in to two main categories:

1. ARC Welding
2. GAS Welding

ARC welding:

- In this process, the heat required for fusing the material is obtained from an electric arc.

GAS welding:

In this process, the heat required for fusing the material is obtained in the form of a flame obtained by burning a mixture of oxygen and some other combustible gas such as acetylene.

Pre-welding requirements:

- For obtaining high quality welds, it is essential that the base metals to be welded should be clean, free from dirt, grease, oil, moisture. Presence of these foreign materials prevents proper fusion of materials.
- The joint edges must be prepared before welding so that proper joint can be made.

Types of welding Joints:

The basic types of joints are:

- Butt joint, lap joint, Corner joint, and T- joint.

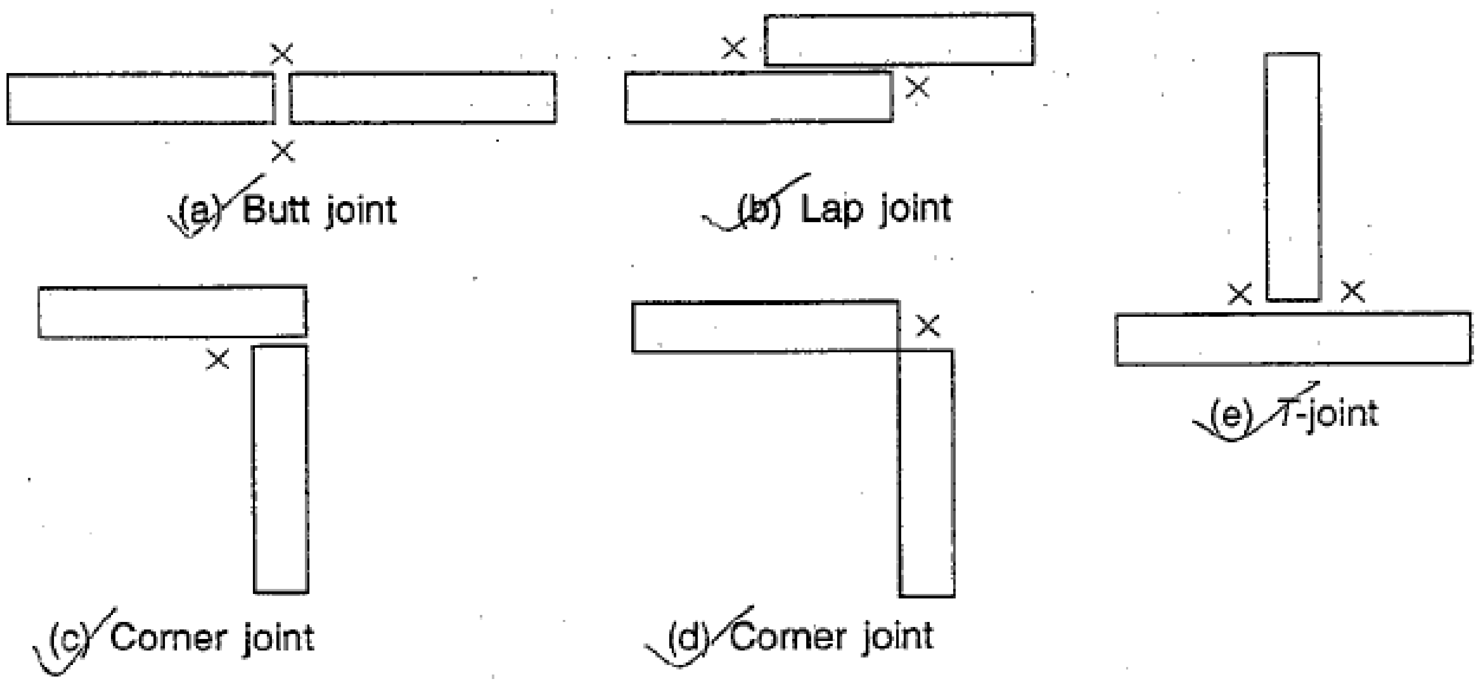
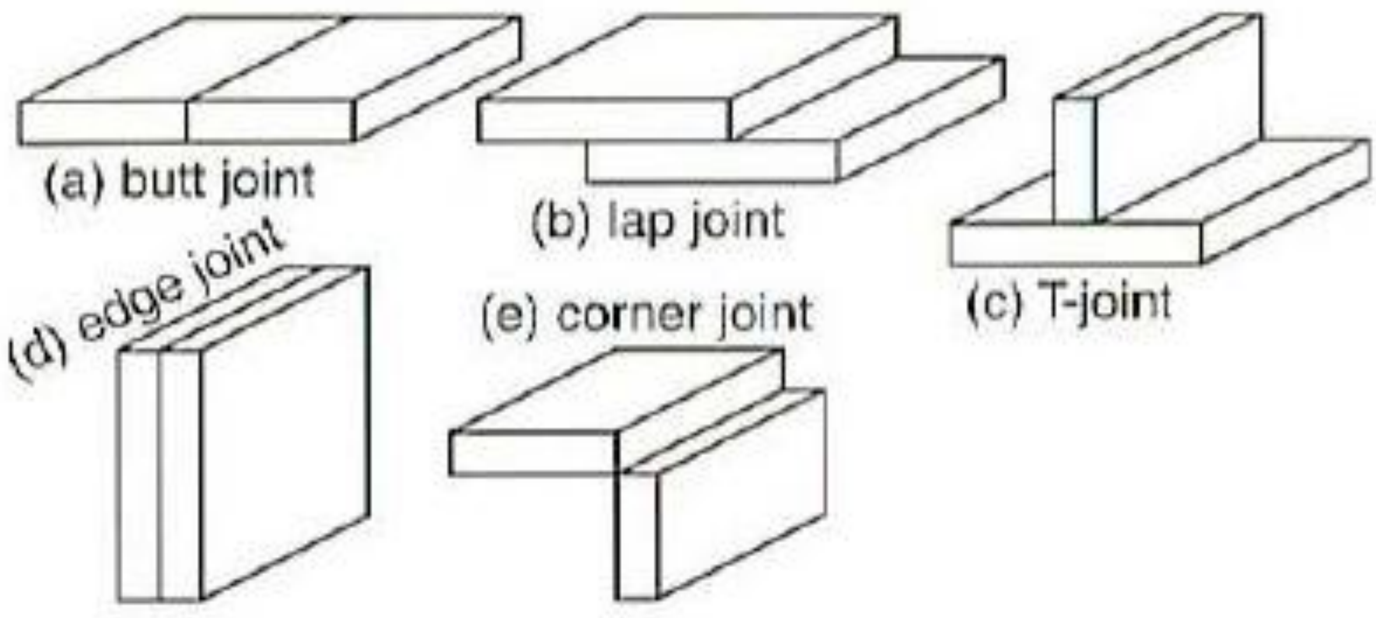
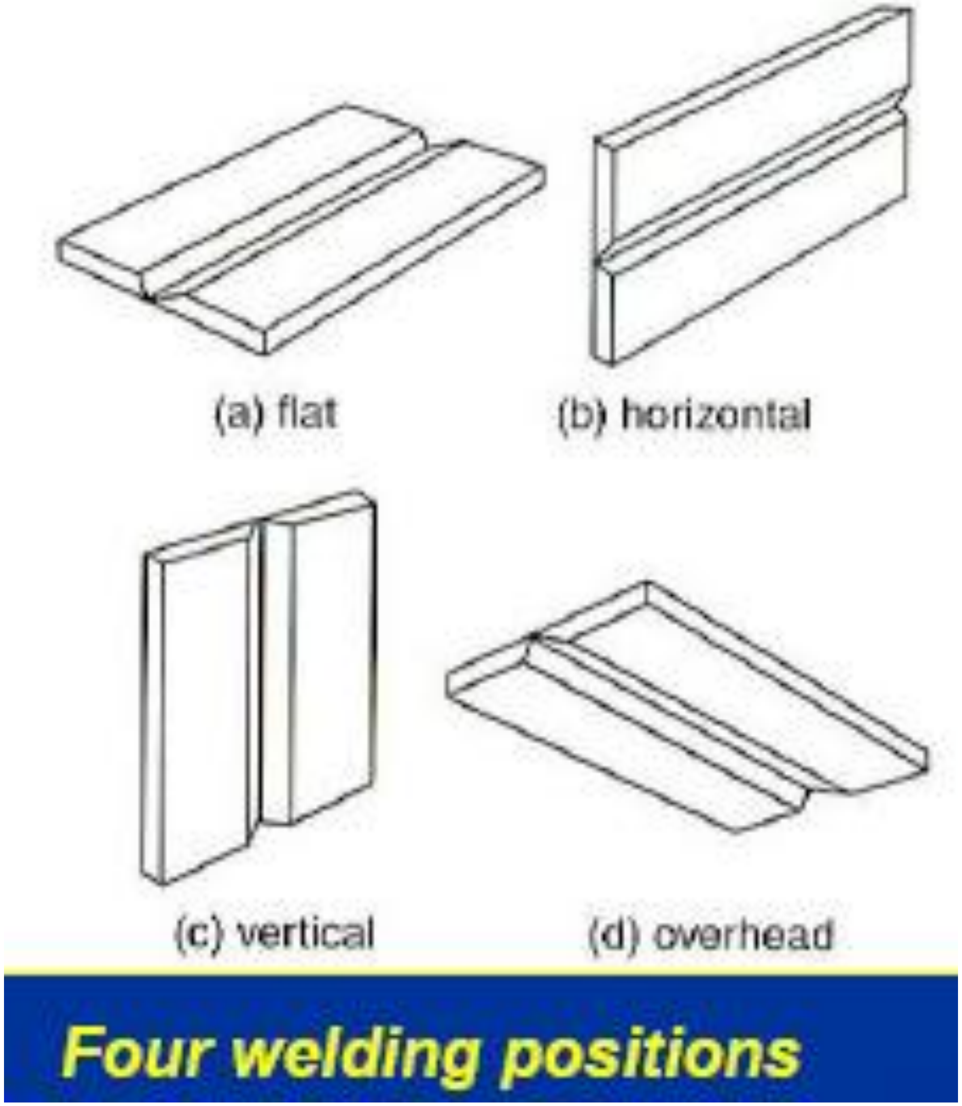


Figure 15.4 Different types of joints.



Five basic types of weld joint designs.


(a) flat
(b) horizontal
(c) vertical
(d) overhead
Four welding positions

Edge preparations for welding

- To obtain sound welds, it is desirable that weld should completely penetrate the metal thickness.
- The heat will not be able to melt the joint edge to their thick ness if thick plates are to be welded. Hence ,to obtain complete penetration and sound welds, edge penetration is required.
- The maximum thickness for which weld penetration is possible with square faces is called root.
- If the thickness of the material is too large, either double-V or double-U groove should be used.

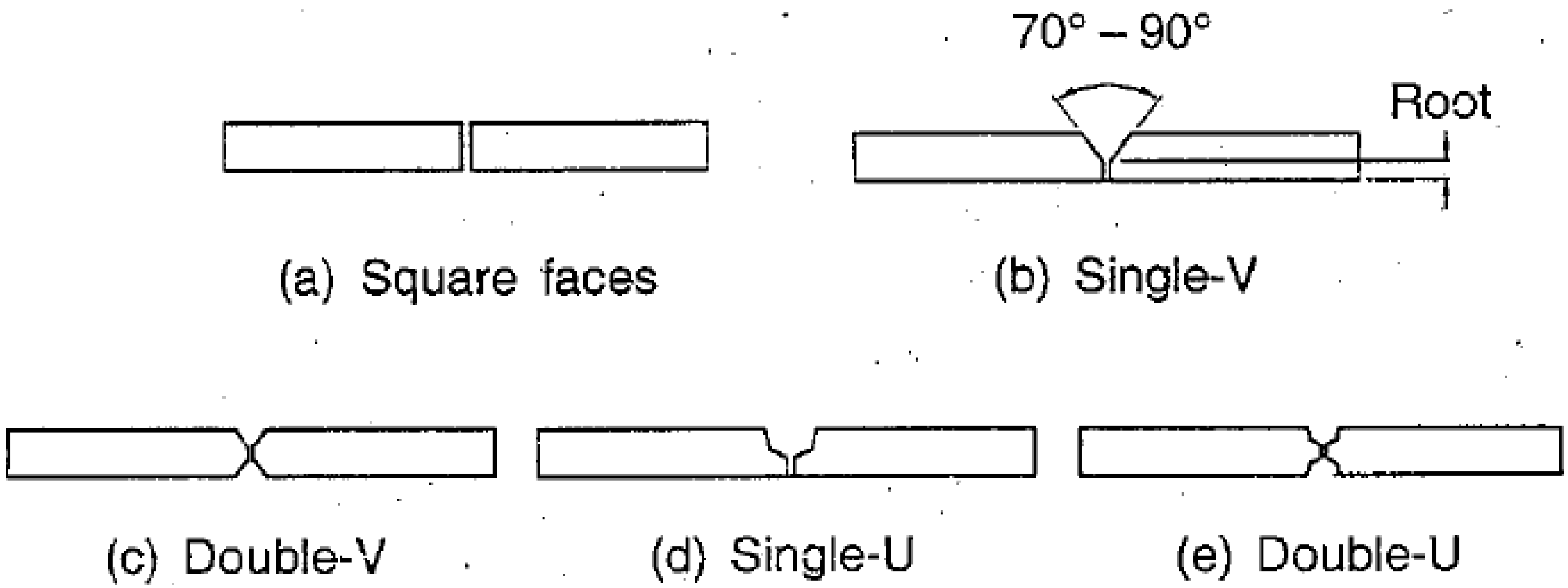


Figure 15.5 Edge preparations for butt joints.

Welding technique

- The term ***welding technique*** implies the direction in which the heat is concentrated during welding.
- The heat may be concentrated either in the weld bead or ahead of the weld bead during the process of welding.

Depending upon whether the heat is concentrated on the weld bead or ahead of the weld bead, the welding technique is classified as:

1. Forehand welding
2. Backhand welding.

Forehand welding

- In the ***forehand welding***, the torch points in the same direction in which the welding is being done so that heat is not flowing in to the metal as much as it could.
- The fore hand welding is used for relatively thin parts.

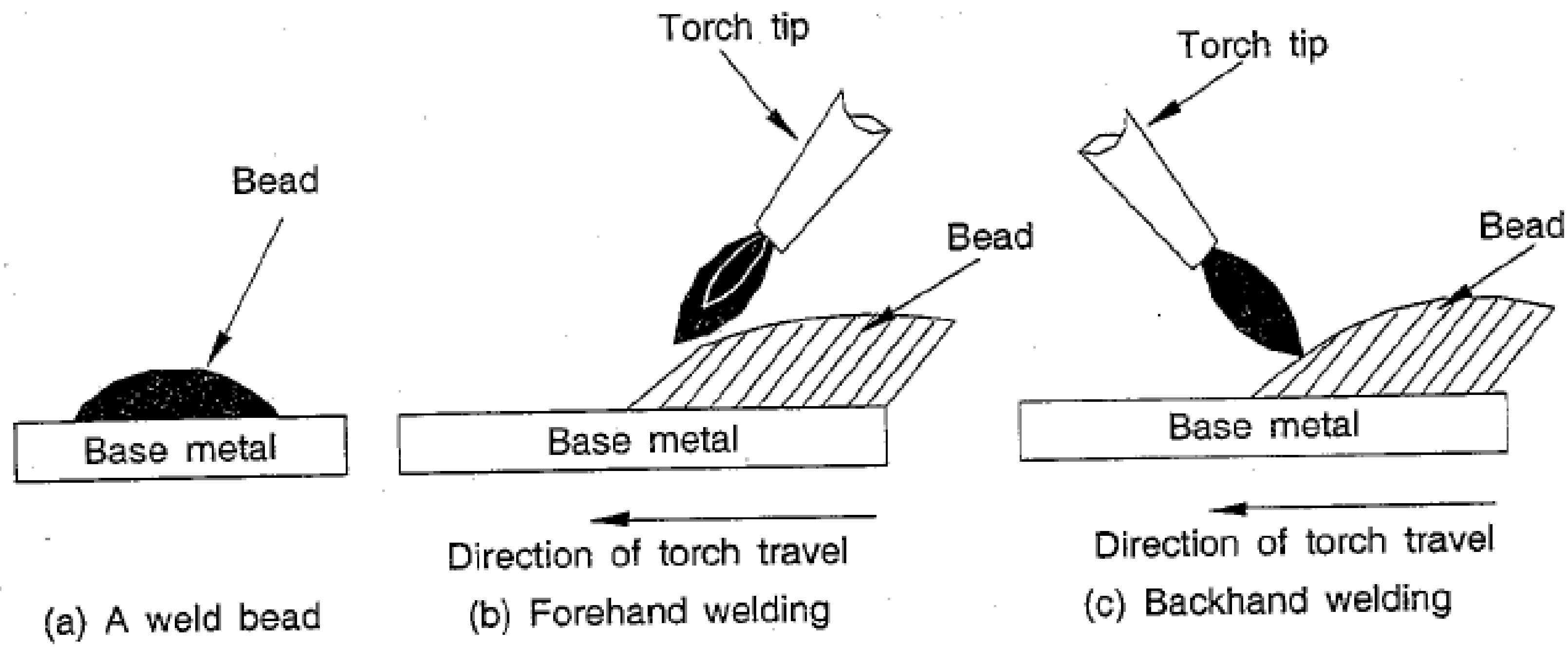


Figure 15.6 Welding techniques.

Backhand welding

- In the ***backhand welding*** the torch is pointing in the direction opposite to that in which the welding is being done.
- In this technique, the heat is concentrated into the metal, so that thicker parts can be welded successfully.

Arc Welding

- the process of arc welding requires a suitable *electrode, low* voltage-high current producing electrical equipment, cables, and a workpiece.
- The workpiece is attached to one of the cables and the electrode, to the other cable.
- An *electric arc* is then struck between workpiece and the electrode as a large current jumps between the electrode and the workpiece, producing immense heat. Next, the electrode is moved along the seams of the metal to be welded, allowing sufficient time for the arc heat to melt and fuse the metal.

Electron theory of arc column

- When an electric arc is struck between two electrodes, flow of electrons takes place from *cathode* (electrode) to *anode* (workpiece).
- Since, the mass of the electrons is very small, they travel with very high velocities, and when they strike the surface of the workpiece, kinetic energy acquired by these electrons is converted into heat energy. At the same time the positively charged ions traveling from anode to cathode provide protecting shield to the flowing electrons
- Approximately 50% of the electrical energy put into the arc system comes out in the form of heat energy.

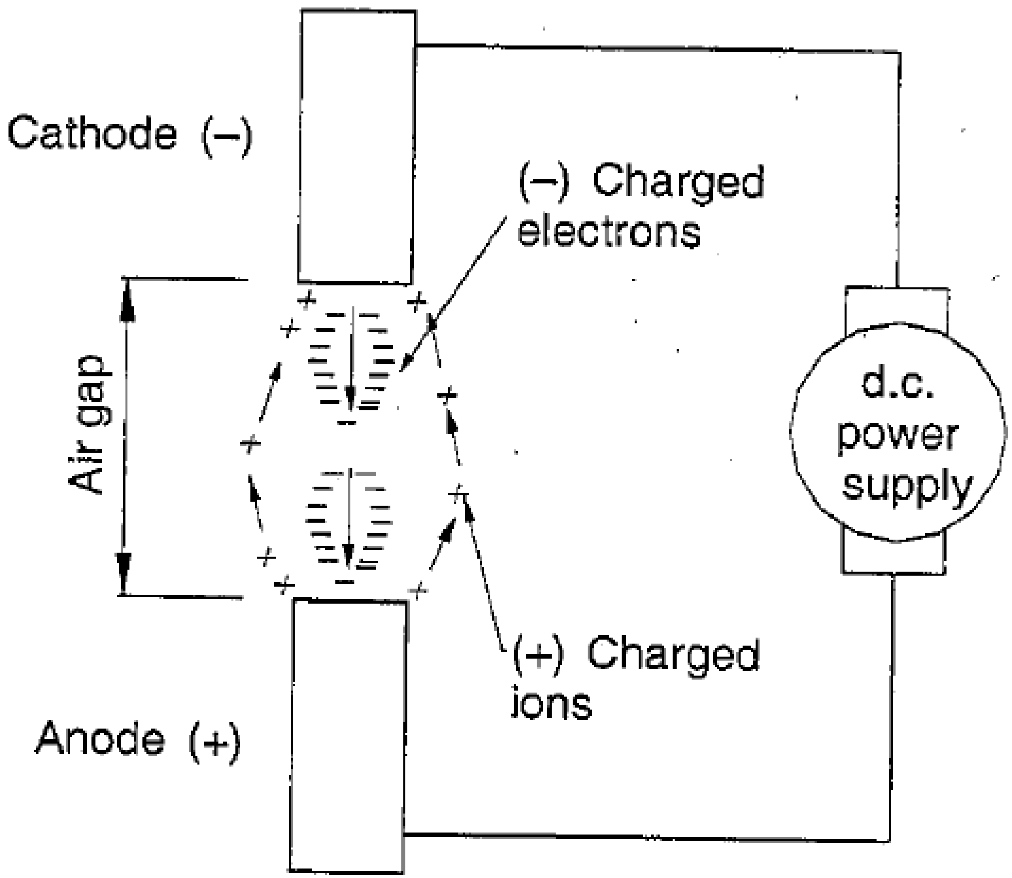
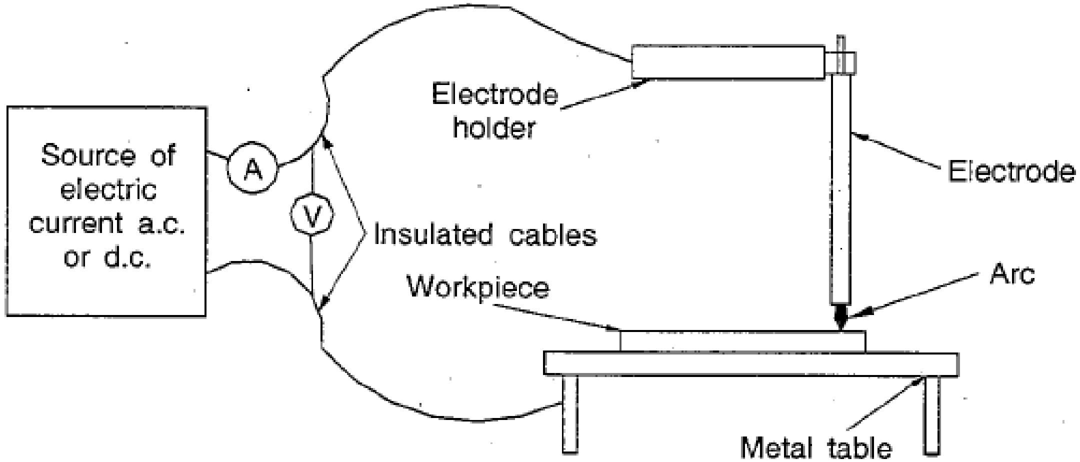


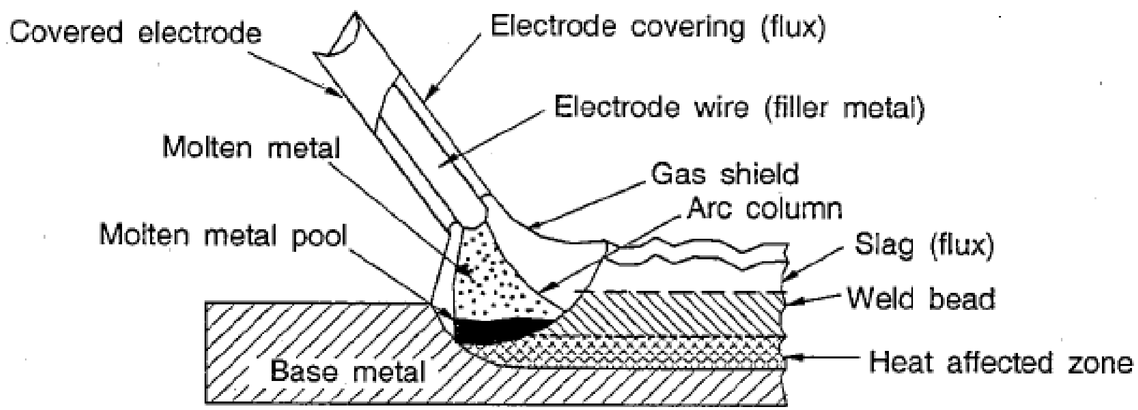
Figure 15.7 Electron theory of arc column.

Arc welding process

- In the arc welding process, the heat required for welding is obtained through electrical energy.
- Electrodes carry out the process, which are thin long rods of metal or' graphite.
- The electric arc is initiated by striking the tip of an electrode against the workpiece and then withdrawing it quickly to a distance to maintain the arc.
- The arc can produce the temperature of the order of 30,000°C. This heat is sufficient enough to melt the base metal and a portion of the tip of the electrode.
- Electrodes used for arc welding process are usually coated. The function 'of the coating, which acts as flux, is to form a gaseous shield around the weld to protect the molten metal from the atmosphere.



(a) Arc welding set-up



(b) Electrode metal deposition process.

Figure 15.8 The arc welding set-up and arc welding process.

Gas Welding

- Gas welding is also *a fusion* welding process in which the heat required for fusing the material is obtained by the combustion of oxygen with other fuel gas such as acetylene, propane, butane or natural gas.
- The type of fuel gas to be used is determined by the desired flame temperature.
- The most commonly used gas in welding is acetylene, and hence, the process of gas welding is known as *oxy-acetylene welding*
- The oxy-acetylene flame produces the highest flame temperature of approximately 3300 °C while *oxy-hydrogen* flame gives a maximum temperature of about 2200 °C.
- Gas welding is very commonly used for repairing the broken or damaged parts.

Gas welding process

- The gas welding system consists of two cylinders, one containing oxygen and other containing acetylene; hoses for transporting the gases and a torch.
- The complete combustion of acetylene in an atmosphere of oxygen is represented by the following summary reaction:
- $2C_2H_2 + 50_2 \leftarrow> 4CO_2 + 2H_20$ (vapour) + Heat (300 kcal/mole)
- The temperature generated during the process of oxy-acetylene welding is of the order 3300 °C.

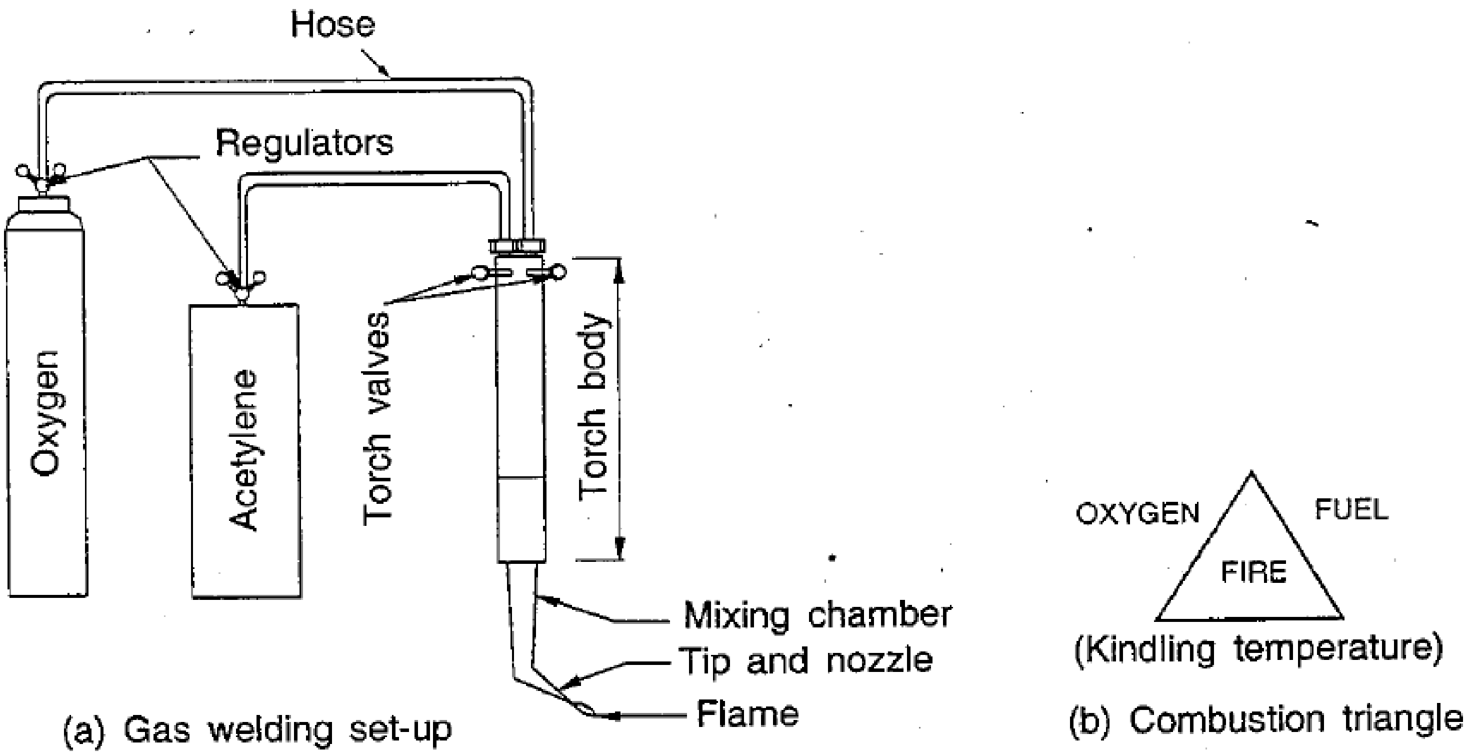


Figure 15.10 Gas welding equipment and combustion triangle.

Types of flames

- Based on the compositions of oxygen and acetylene, it is possible to obtain three different types of flames in the gas welding, viz.

1. Carbonizing flame (or reducing flame)
2. Oxidizing flame
3. Neutral flame (or balanced flame).

Carbonizing flame

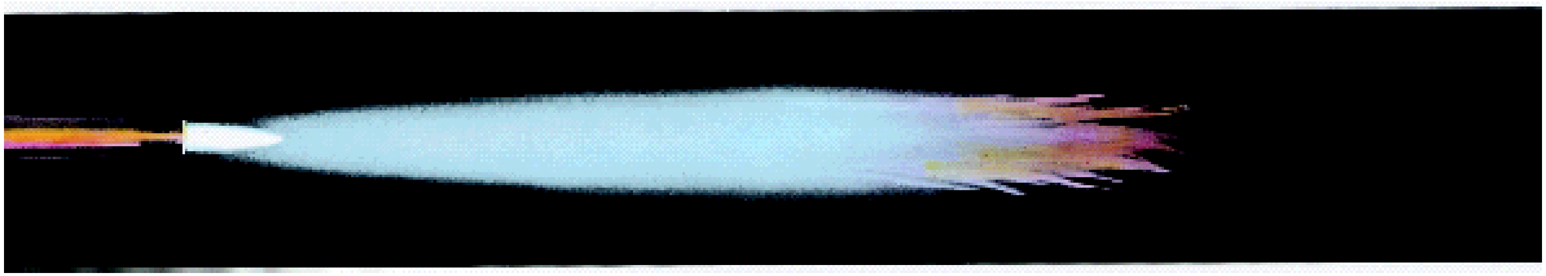
- It is obtained when acetylene is in excess. Since it contains excess of acetylene, its flame temperature is low, and the available carbon is not burnt completely because of less oxygen; and the leftover carbon is forced into the molten metal. This excess of carbon gets absorbed in ferrous metals, making the weld bead hard and brittle.

Oxidizing flame

- consists of excess of oxygen. Oxidizing flame produces the hottest flame that can be produced by any oxygen-fuel source. Since the flame contains excess of oxygen, it causes the metal to burn or oxidize quickly.

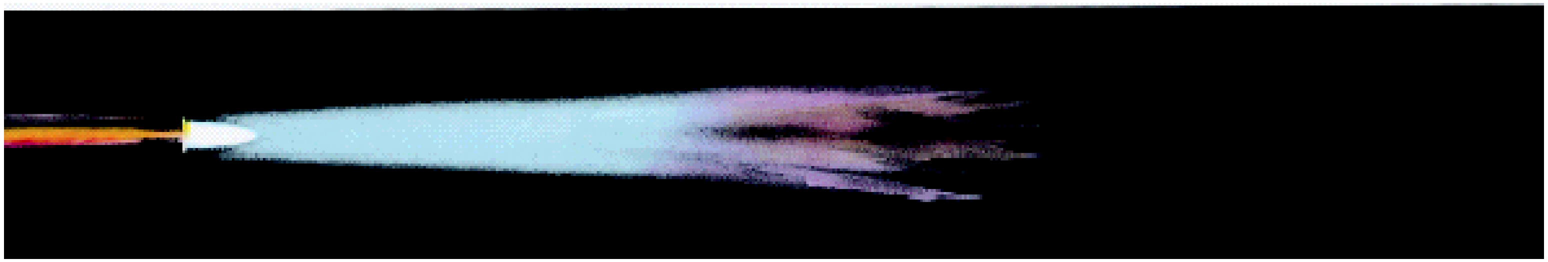
Neutral flame

- contains equal proportions of oxygen and acetylene. Unlike carbonizing or oxidizing flame, neutral flame has little effect on the base metal and it produces sound weld beads when compared to carbonizing and oxidizing flames.



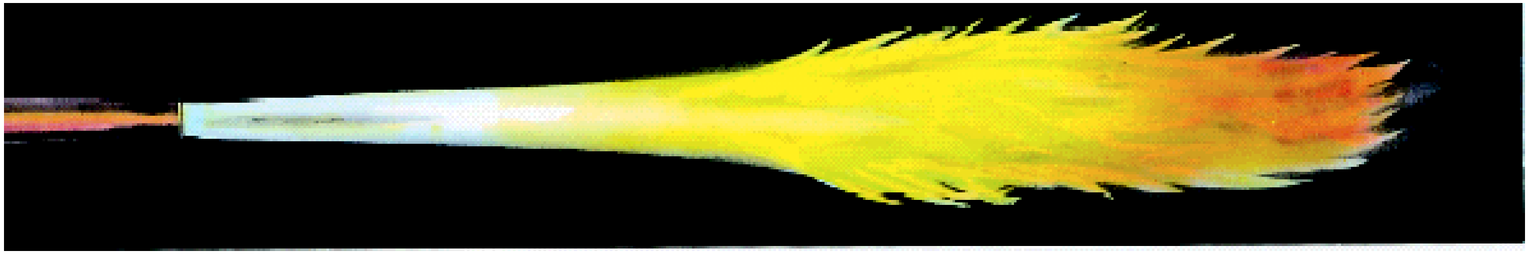
Neutral Flame

(Acetylene and oxygen.) Temperature 5589˚F (3087˚C). For fusion welding of steel and cast iron.

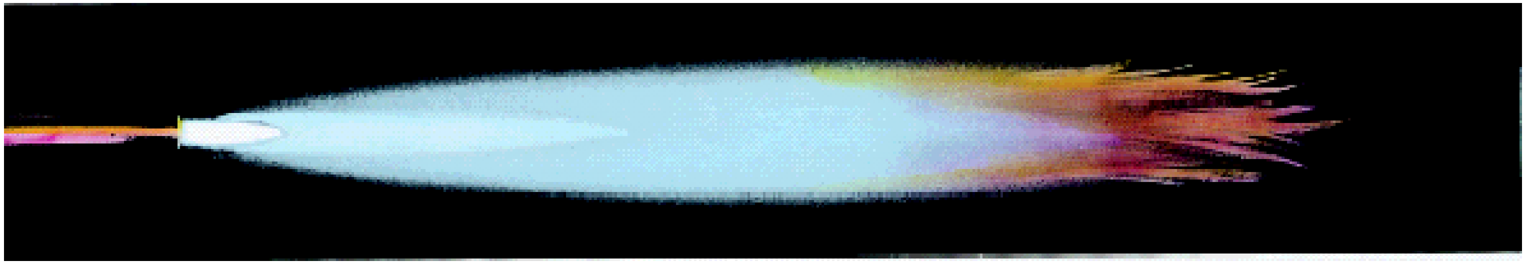


Oxidizing Flame

(Acetylene and excess oxygen.) For braze welding with bronze rod.



Acetylene Burning in Atmosphere
Open fuel gas valve until smoke clears from flame.



Carburizing Flame
(Excess acetylene with oxygen.) Used for hard-facing and welding white metal.

- Flux added to the welded metal, removes oxides from the surfaces of the parent metals and helps oxides to float up in the molten metal pool.
- The common fluxes used in the gas welding are made of sodium, potassium, lithium and borax.
- Flux can be applied as paste, powder, liquid, solid coating or gas during gas welding.

Filler material

- Filler material is generally added in the gas welding.
- The filler is melted by the flame and is added to the molten metal that fills the space between the pieces being joined.
- The filler material must be of the same composition as the base metal.
- *Autogenous: some metals can be welded without the addition of extra filler material*

Resistance Welding

- In *resistance welding,* the heat required for welding is produced by means of the electrical resistance between the two members to be joined. This process is also known as *electric welding.*

The heat generated in resistance welding is given by

$$H = I^2 R t k$$

where

- H = heat generated, in joules (watt sec)
- I = current in amperes
- R = resistance in ohms
- t = time of current flow in seconds
- k = constant to account for losses due to radiation and conduction. The value of k *is* normally less than one.

Spot welding

- *Spot welding is* the simplest and most commonly used resistance welding process, mostly used to weld sheets.

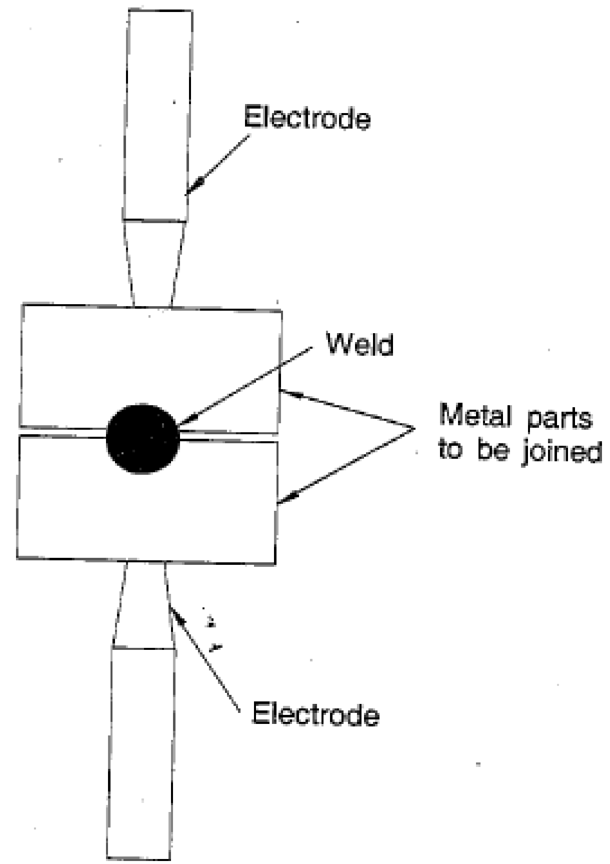
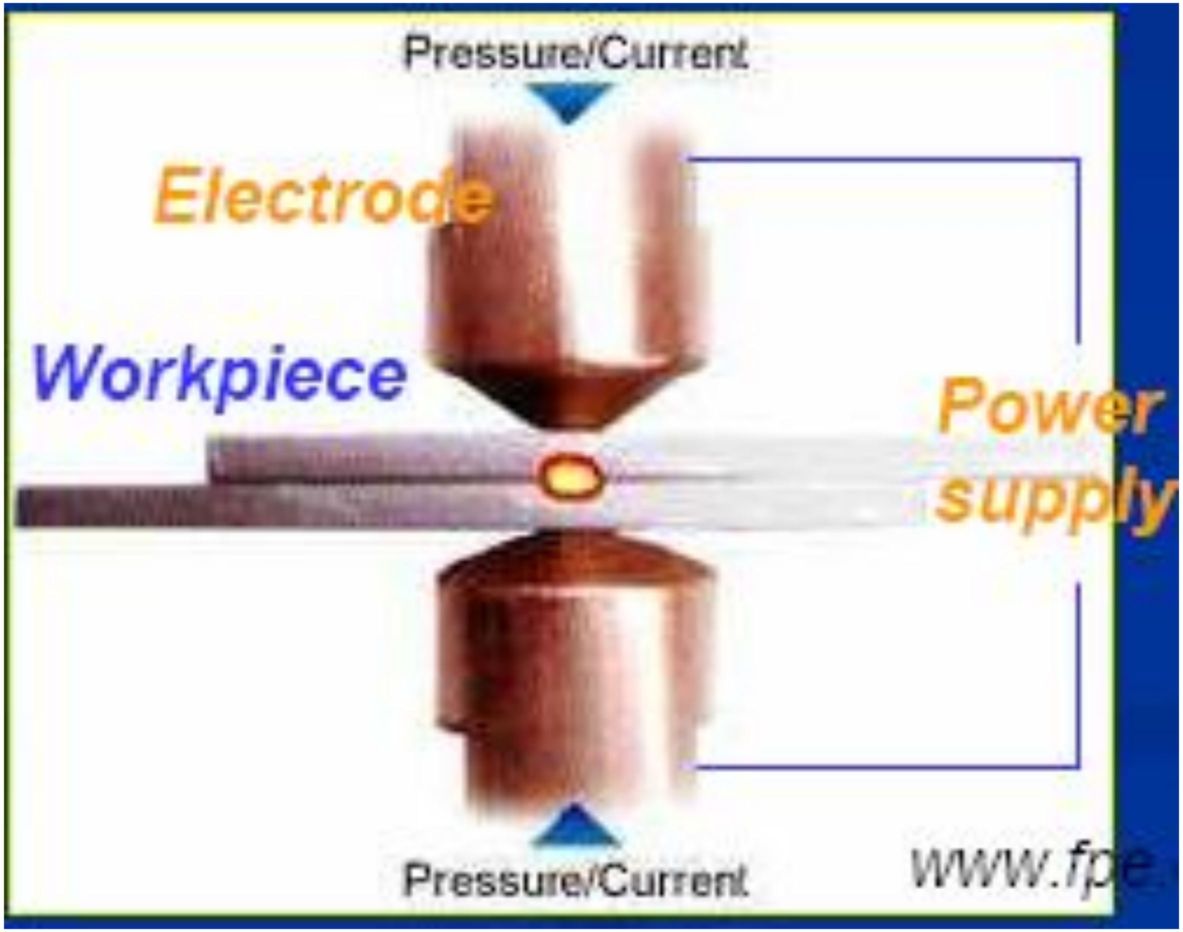


Figure 15.11 Spot welding process.


Pressure/Current
Electrode
Workpiece
Power
supply
Pressure/Current

Seam welding

- In *seam welding*, the cylindrical electrodes of spot welding are replaced by electrode wheels.
- With a continuous a.c. power supply, the electrically conducting electrode wheels produce continuous weld in two parts whenever the current reaches sufficiently high level in the a.c. cycle, resulting spot welds at regular intervals.

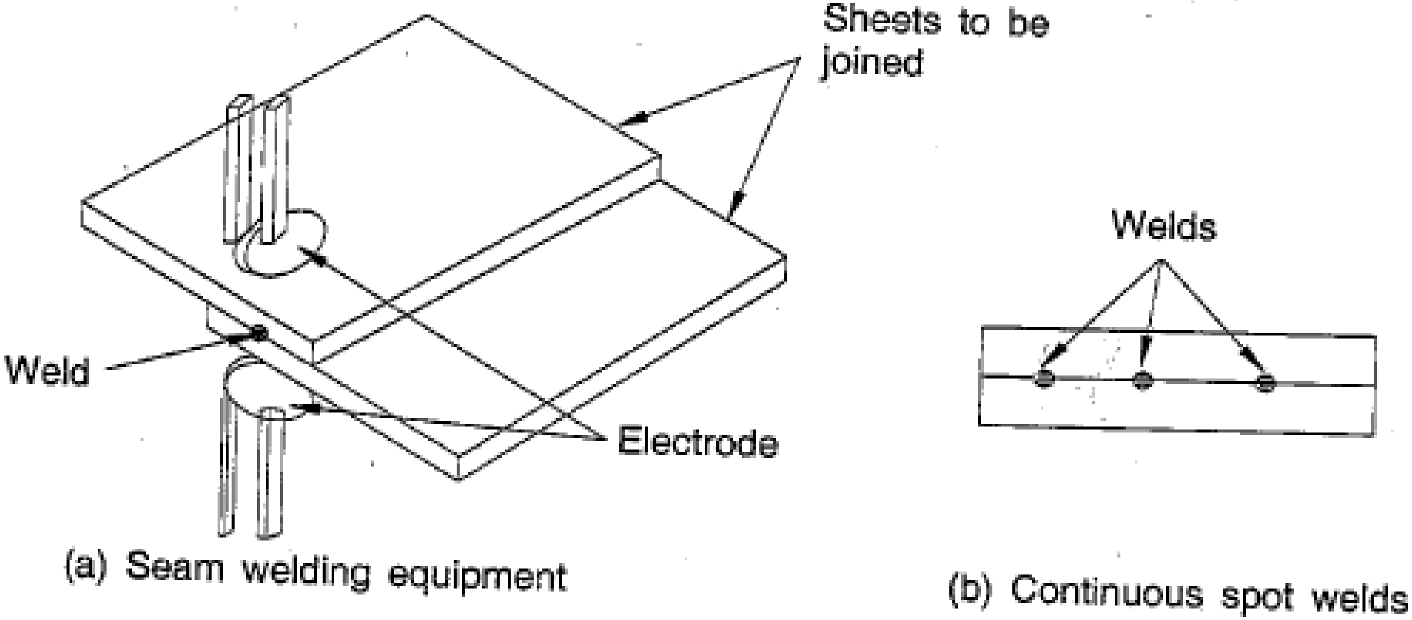


Figure 15.12 Seam welding process.

Tungsten inert gas (TIG) welding

- The tungsten inert gas welding process is essentially an arc welding process in which non-consumable tungsten electrode is used in an externally applied protective inert gas atmosphere.
- This welding process is also known as *Gas tungsten arc welding* (GTAW).
- This process can also be used to weld dissimilar metals. Unlike other processes of welding, TIG welding does not produce deep penetration and hence it requires more passes to weld thick metals. As a result, TIG welding is slow and results in an expensive product.

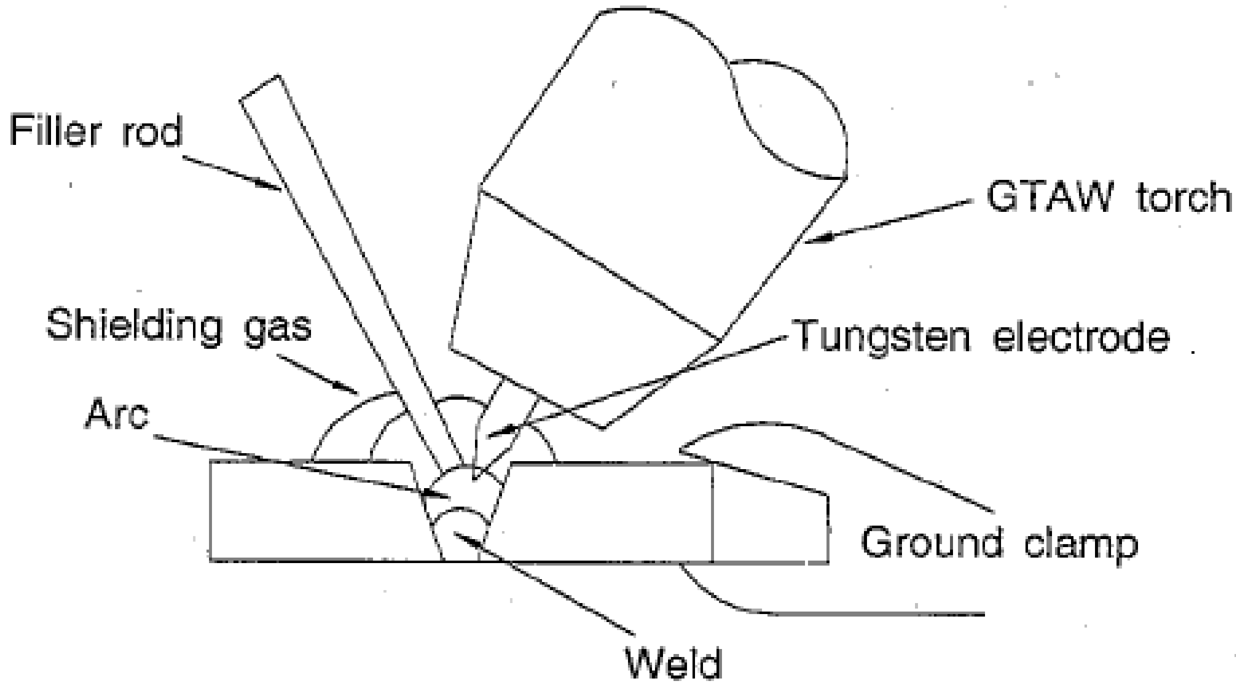


Figure 15.13 TIG welding.

Soldering and Brazing

- In *soldering* and *brazing* processes, the metal parts being joined are heated but not melted and a molten filler metal is made to flow between the two closely placed adjacent surfaces by the capillary action. A strong joint between the parts is formed on cooling to room temperature by the bond formed at the high temperature between the parent metal atoms and the filler metal atoms.
- These processes are suitable for joining the dissimilar metals also.
- Brazing is distinguished from soldering by the melting temperatures of the filler material. If the filler material melts below 450°C, it is soldering; but if the filler material melts above this temperature, the process is brazing.

Soldering

- soldering is used for making low mechanical strength joints.
- The filler metal used has a *low* melting point *and* is called *solder*.
- ***Basic operations in soldering.***

1. *Shaping and fitting of metal parts together.*
2. *Cleaning of surfaces.*
3. *Flux application*
4. *Application of heat and solder*

Solder

- *Most* solders are alloys of lead and tin.
- Solder may also contain certain other elements like cadmium, and antimony in small quantities.
- The percentage composition of tin and lead determines the physical and mechanical properties of the solder and the joint made.
- Solder is available in many forms-bar, stick, fill, wire, strip, and so on.

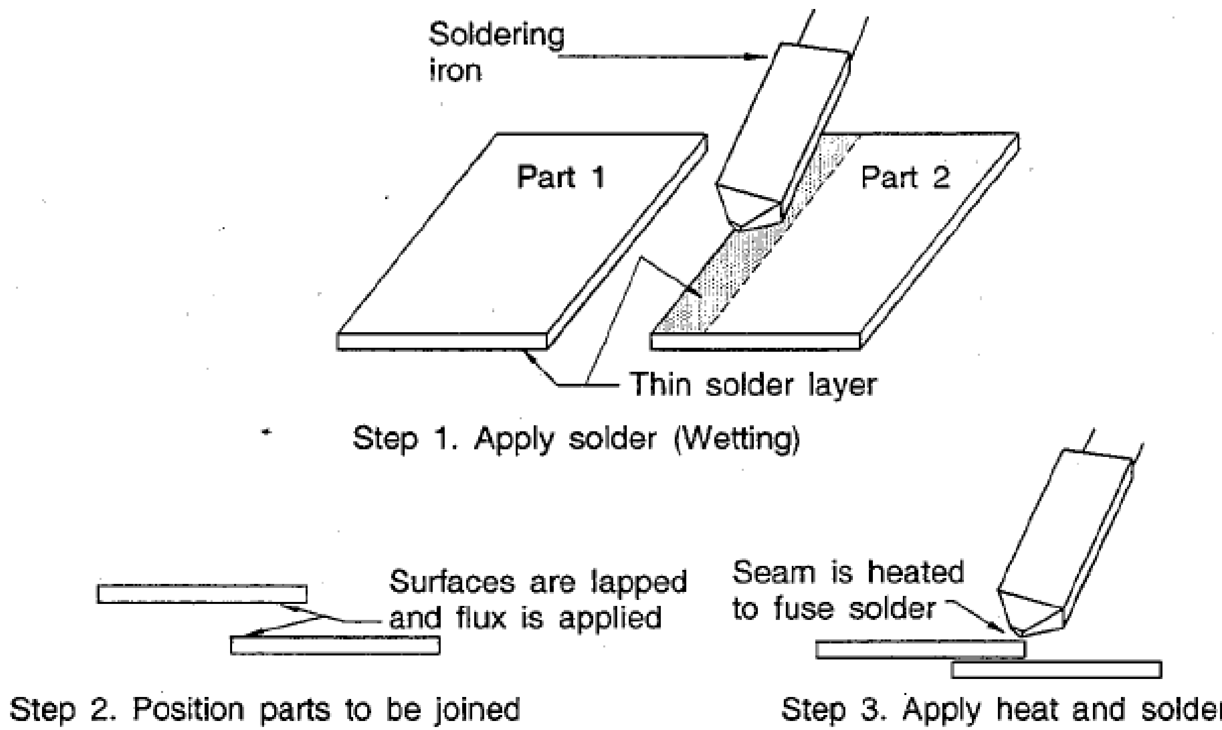


Figure 15.14 Soldering of a simple lap joint.

Fluxes

- The function of the flux is to remove the non-metallic oxide film from the metal surface during the heating and soldering operation so that the clean, metals may make mutual metallic contact.
- The flux does not constitute a part of the soldered joint.
- Zinc chloride, ammonium chloride, and hydrochloric acid are the examples of fluxes commonly used in soldering.

Brazing

- **American Welding Society** defines brazing "as a process of making joints "wherein coalescence is produced by heating to suitable temperatures above 500°C and by using a non-ferrous filler metal having a melting point (up to 900°C) below that of the base metal, the filler metal being distributed between the closely fitted surfaces of the joint by capillary action".

- Since brazing is a high temperature operation, it is useful for joining thick metal parts or for making relatively stronger joints.
- Both similar and dissimilar parts can be joined
- Borax is the most widely used flux during the process of brazing. It will dissolve the oxides of most of the common metals.

Methods of brazing

- Based upon the method of heating used, different brazing methods have evolved.

1. *Torch brazing.*

   Torch brazing is the most widely used brazing method.

   Heat is produced, generally, by burning a mixture of oxy-acetylene gas, as in the gas welding.

   A carbonizing flame is suitable *for* brazing purpose as it produces sufficiently high temperature needed for brazing.

Torch Brazing

2. Furnace brazing.

Furnace brazing is suitable for brazing large number of small or medium parts.

Usually brazing filler metal in the granular or powder form or as strips, is placed at the joint,. and then the assembly is placed in the furnace and heated.

Large number of small parts can be accommodated in a furnace and Simultaneously brazed.

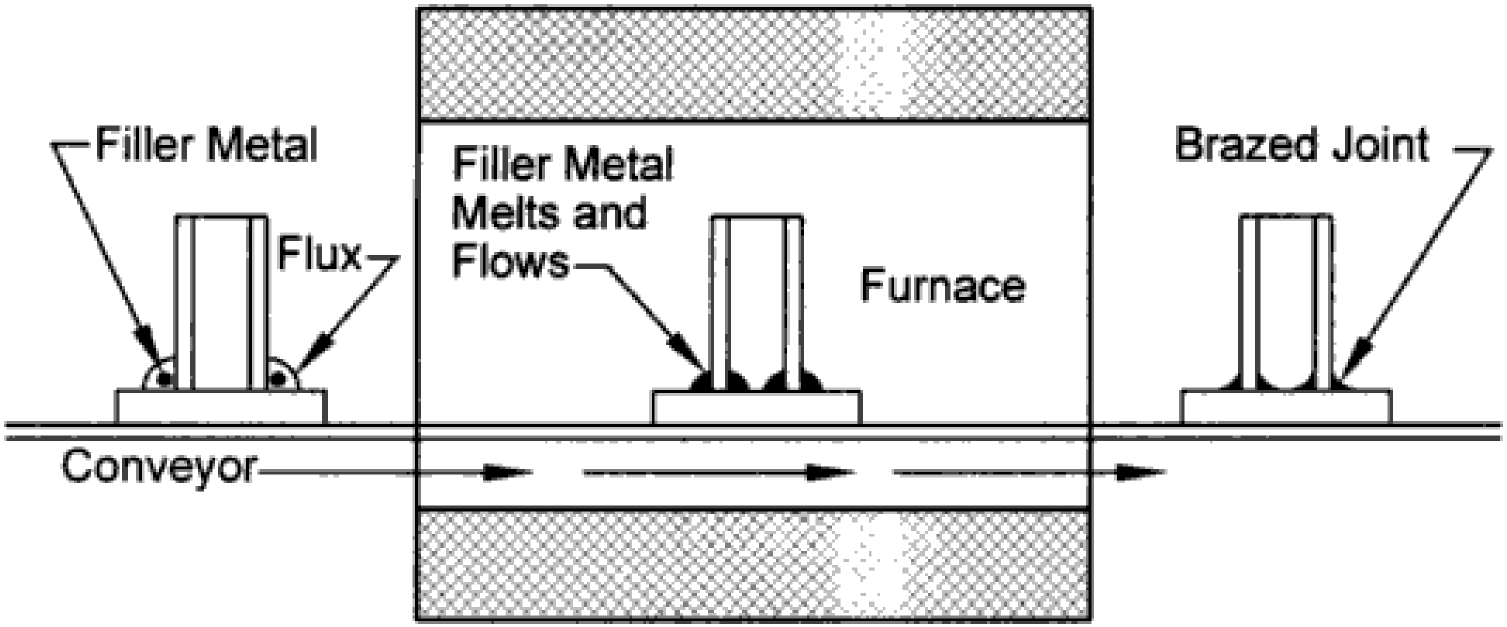


Figure 3–4. Furnace brazing.