SECTION *Welding*

SAFETY PRECAUTIONS

1. Protective clothing is most important in welding .
   Fire resistant gauntlet gloves should be worn for most welding operations.
2. Do not touch the electrode or fix the electrode with bare hand.
3. Do not touch the welded piece with bare hand.
4. Do not lean over the welding booth or table.
5. Do not remove the used electrode from the Electrode holder with bare hand.
6. Do not use water to extinguish an electric fire.
7. Do not stand over electric cable.
8. Do not chip the welded work piece without tongs and goggles.
9. Fumes and gases can be dangerous to health. Keep your head out of the fumes. Use enough ventilation.
10. Do not touch live electrical parts

DEFINITION

Welding is a process of joining similar metals permanently by application of heat with or without application of pressure and addition of filler material. The result is a continuity of homogeneous material, of the composition and characteristics of two parts which are being joined together.

HISTORICAL BACKGROUND

Welding can trace its historic development back to ancient times. The earliest examples come from the Bronze Age. During the Iron Age the Egyptians and people in the eastern Mediterranean area learned to weld pieces of iron together. Many tools were found which were made approximately during 1000 B.C. During the middle ages, the art of blacksmithing was developed and many items of iron were produced which were welded by hammering. In Late 1800s Gas welding and Cutting was developed. In 1900 Strohmenger introduced a coated metal electrode in Great Britain.

TYPES OF WELDING

Welding is classified under two broad headings:

(1) Plastic welding or Pressure welding.

(2) Fusion welding or Non-pressure welding.

In the plastic welding or pressure welding, the pieces of metal to be joined are heated to a plastic state and then forced together by external pressure. This procedure is used in forge welding, and resistance welding in which pressure is required.

In the fusion welding or non-pressure welding, the material at the joint is heated to a molten state and allowed to solidify. This includes gas welding, arc welding, etc.

GAS WELDING

Gas welding is done by burning a combustible gas with air or oxygen in a concentrated flame of high temperature. The purpose of flame is to heat and melt the parent metal and filler rod of a joint. It can weld most of the common materials. Equipment is inexpensive, versatile, and serves adequately in many job and general repair shops.

Gas welding is accomplished by melting the edges or surface to be joined by gas flame and allowing the molten metal to flow together, thus forming a solid continuous joint upon cooling. This process is particularly suitable for joining metal sheets and plates having thickness of 2 to 50 mm. With materials thicker than 15mm, additional metal called filler metal is added to the weld in the form of welding rod [Fig 3.1].

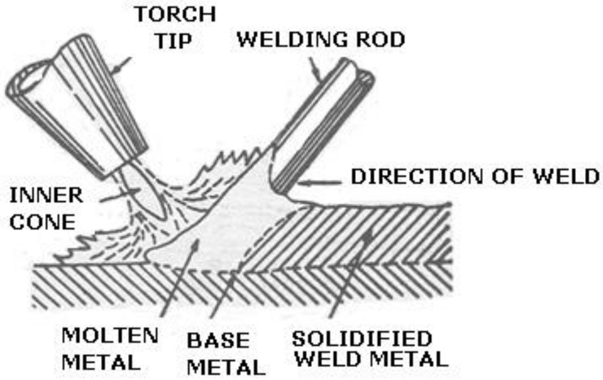

Fig.3.1. Gas Welding Process

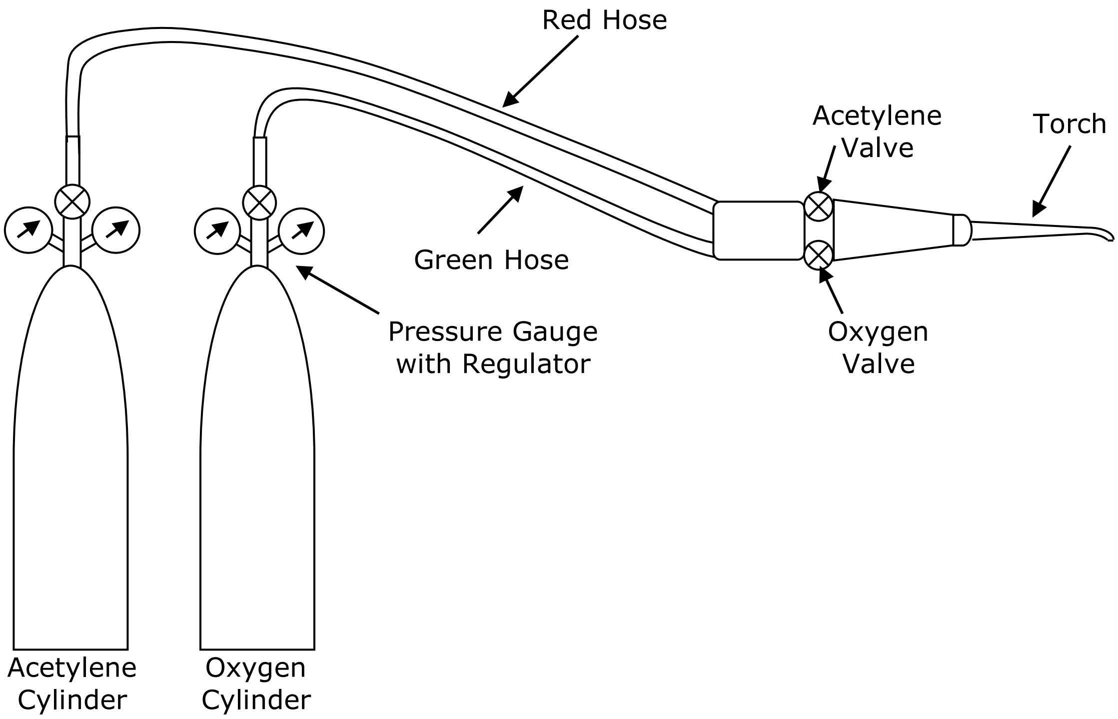

Fig.3.2 Gas welding apparatus

Various gas combinations can be used for producing a hot flame for welding metals. Common mixture of gases are oxygen and acetylene, oxygen and hydrogen, oxygen and other fuel gas, and air and acetylene. The oxygen-acetylene mixture is used to a much greater extent than the other mixtures and has a prominent place in the welding industry [Fig 3.2]. The temperature of the oxy-acetylene flame in its hottest region is about 3200^{o} C.

Flame types

The combustion of oxygen and acetylene produces an extremely hot, concentrated flame which may be adjusted to give various types of flames for different applications. Three distinctly different flame settings are given in Fig.3.3.

When acetylene is burned in air , it produces a yellow sooty flame which is not enough for welding applications. As the oxygen is turned on, the flame immediately changes in to a long white inner area (feather) surrounded by a transparent blue envelop. This is called as **Carburizing flame**. This kind of flame has low temperature (3000°C) due to an excess amount of fuel gas (acetylene). Because of less oxygen, combustion is incomplete and carbon particles may be deposited over the weld surface. More oxygen has the effect of reducing the white feather and increasing the outer, blue envelop. Carburizing flames are used for hardening the surfaces.

The addition of little more oxygen removes the feather completely, to give a bright whitish cone surrounded by the transparent blue envelop. This is called **Neutral flame**. It has a balance of fuel gas and oxygen. It is the most commonly used flame because it has temperature about 3200°C and adds nothing to the weld metal. Neutral flames are used for welding steels, aluminium, copper and cast iron.

If more oxygen is added, the cone becomes darker and more pointed, while the envelop becomes shorter and more fierce. This is called as **Oxidizing flame**. This flame has the highest temperature about 3400°C. Oxidizing flames are used for welding brass and for brazing operation.

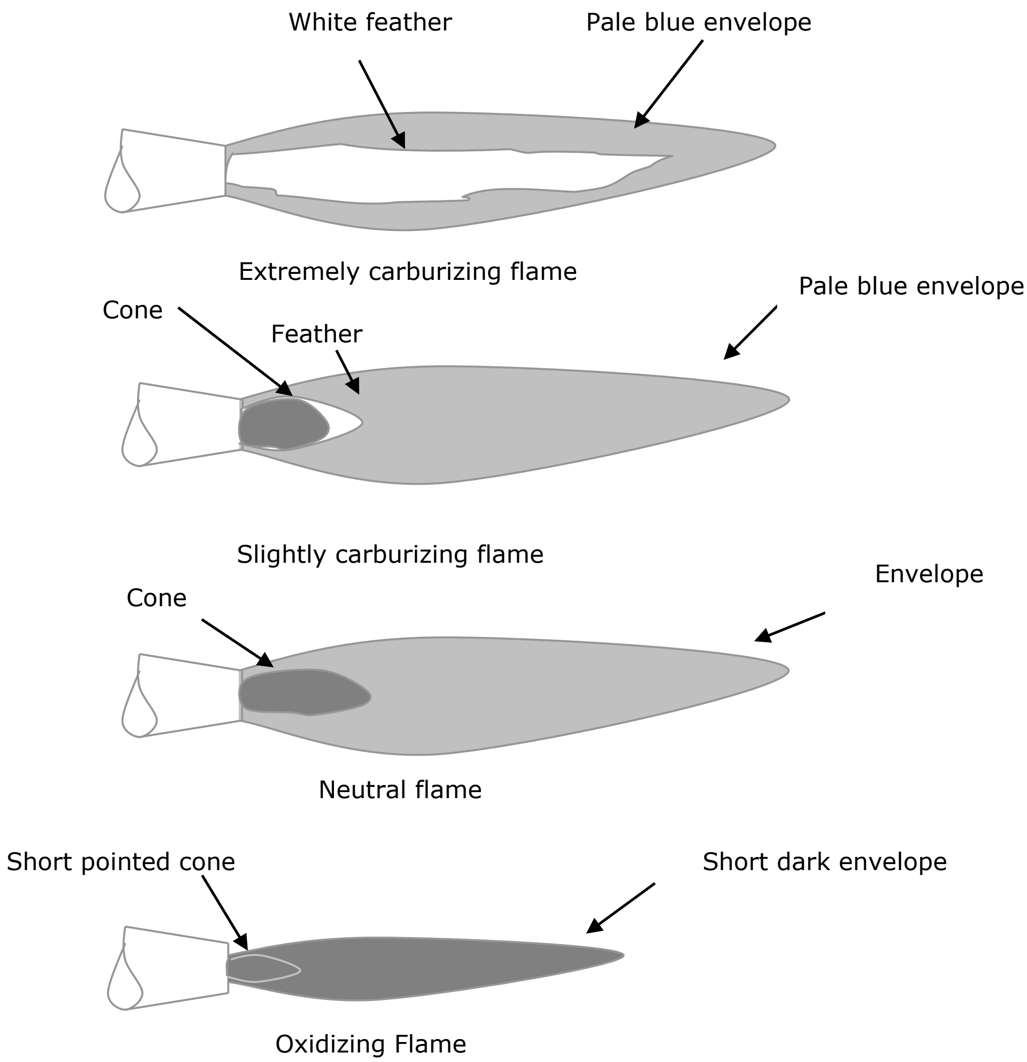

Fig.3.3. Types of flames

ARC WELDING

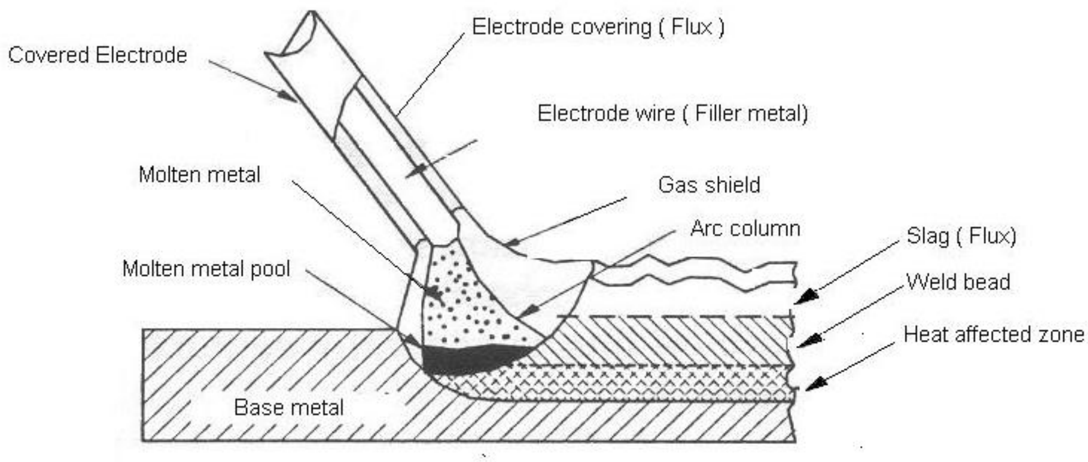

Fig 3.4 Arc Welding Process

Arc welding is the most extensively employed method of joining metal parts. Here the source of heat is an electric arc. The arc column is generated between an anode and the cathode. When these two conductors of an electric circuit are brought and separated by a small distance (2 to 4 mm) such that the current continues to flow through a path of ionized particles (gaseous medium) called plasma, an electric arc is formed. This ionized gas column acts as a high resistance conductor that enables more ions to flow from the anode to the cathode. Heat is generated as the ions strike the cathode. Hence electrical energy is converted to heat energy. Approximately 1 kWh of electricity will create 250 calories (1000J) of heat energy. The temperature at the centre of the arc being 6000^{o} to 7000^{o}C. The temperature of an electric arc, depends upon the type of electrodes between which it is struck.

The heat of the arc raises the temperature of the parent metal which is melted forming a pool of molten metal. The electrode metal (in metal arc welding) or welding rod (in carbon arc welding) is also melted and is transferred into the molten metal in the form of globules. The deposited metal serves to fill and bond the joint or to fuse and build up the parent metal surface. Two-thirds of the heat is developed near the positive pole while the remaining One-third is developed near the negative pole. As a result, an electrode that is connected to the positive pole will burn away approximately 50 percent faster than that is connected to the negative pole. This is helpful in obtaining the desired penetration of the base metal.

ARC WELDING EQUIPMENTS AND TOOLS

The most commonly used equipment for arc welding consists of the following:

1. AC Transformer/ DC Generator	2. Electrode	3. Electrode holder
4. Cables, Cable connectors	5. Ground clamps	6. Chipping Hammer
7. Wire brush	8. Safety goggles	9. Hand gloves
10. Aprons, sleeves, etc		

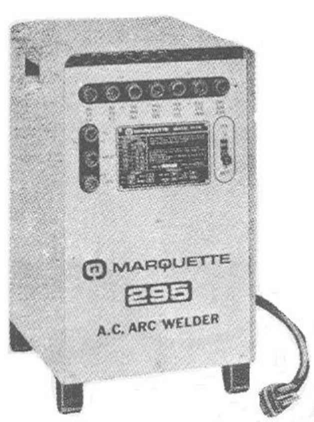

Fig 3.5 AC Transformer

AC Transformer

Both direct current and alternating current are used for electric arc welding, each having its particular applications; in some cases either is suitable. DC welding is usually obtained from generators driven by electric motor or if no electricity is available, by internal combustion engines. For AC welding supply, transformers are predominantly used for almost all arc welding where electricity supply is available. It has to step down the usual supply voltage (200 – 400 volts) to the normal open circuit welding voltage (50-90 volts).

ELECTRODES

Electrodes (Filler Rods) for arc welding are classified in to two categories:

1. Consumable electrodes

These are made of different metals. The consumable electrodes may be either bare or coated type. Bare or plain electrodes are made of various metals which do not have any coating of flux. During welding operation the bare electrode is exposed to the oxygen of the surrounding air. Hence, the molten metal is oxidized. The molten pool after solidifying contains the oxidized metal also, which ultimately decreases the strength of the joint. Hence bare electrodes have limited applications like minor repair where quality of weld is not so important.

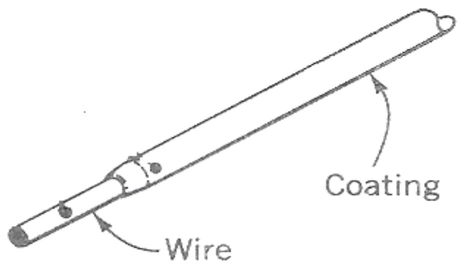

Fig 3.6 Coated Electrode

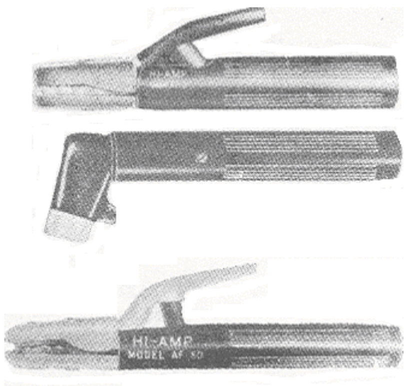

Fig 3.7 Electrode holder

Electrodes coated with flux material, such as chalk, aluminium, ferro-manganese starch, alloying and binding materials, are called flux coated electrodes (Fig 3.6). Electrodes are generally specified by diameter and length like 2.5 x 350mm

The flux coating serves the following purposes:

- (i) It facilitates the stability of the arc.
- (ii) It protects the molten metal from the atmospheric oxygen and nitrogen by producing gaseous shield around the arc and the molten pool.
- (iii) It provides the formation of slag which floats on the top of molten pool and protects the welded seam from oxidation and rapid cooling.

2. Non-consumable Electrodes

These are made of carbon, graphite or tungsten which do not get consumed during welding process. Electrodes are generally available up to 12 mm diameter and 450 mm long.

ELECTRODE HOLDER

Electrode holder is a device used to secure electrode. Most electrode holders have grooves cut in to the jaws which enable the electrode to be held at various angles for ease in manipulation [Fig.3.7.]

GROUND CLAMP

The ground clamp completes the circuit between the electrode and the welding machine. This is generally fastened to the metal being welded either with a clamp, a bolt, or some other means.

CHIPPING HAMMER AND WIRE BRUSH

The chipping hammer is chisel shaped and is pointed on one end to aid in the removal of slag.

The wire brush, which removes small particulates of slag, is generally made of stiff steel wire embedded in wood.

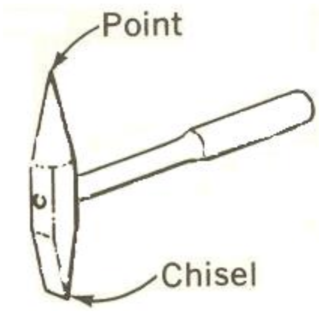

Fig 3.8 Ground clamp **Fig 3.9 (a) Chipping Hammer** **(b) Wire Brush**

SAFETY ACCESSORIES

Provisions for the safety of the operator are most important to ensure workable situations. A face protection device will stop the radiation that is prevalent in arc welding. Helmet face shield and the hand held face shield are commonly used in arc welding. Long gloves protect the hands from minor burns during the chipping operation.

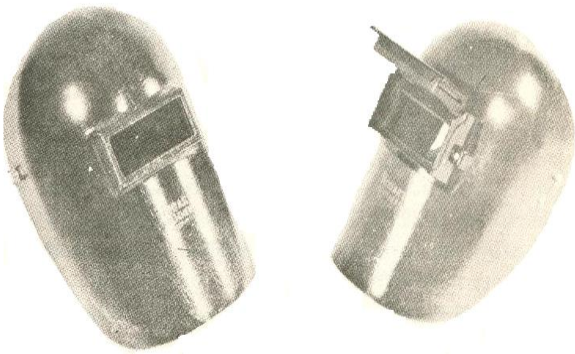

Fig 3.10 Face shield

The gloves should be worn all the time during welding. The work clothes that should be worn by the welder consist mainly of long sleeved cotton shirts and long pants. Shoes should be high topped.

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, shown in fig 3.12, the torch points in the same direction in which the welding is being done so that the heat is not flowing in to the metal as much as it could. The forehand welding is used for relatively thin parts.

Backhand Welding

In the backhand welding, shown in fig. 3.11 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.

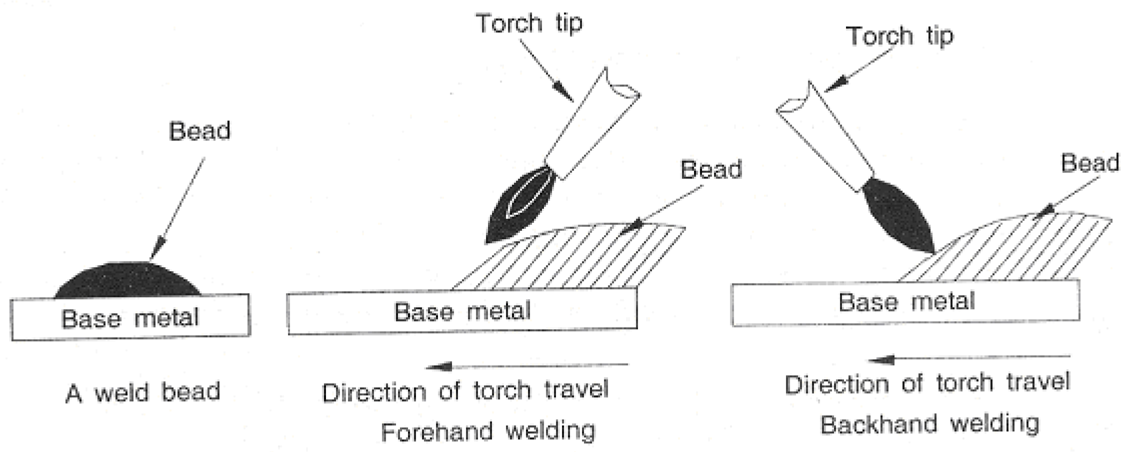

Fig 3.11 Welding Techniques

TYPES OF WELDING JOINTS

The relative positions of the two pieces being joined determine the type of joint. Five basic types of joints are used in fusion welding. These are; Butt, Lap, Tee, Corner, and Edge joints. There are also several variations of each of these joints [Fig 3.12]. The nature of the joint depends upon the kind and size of material, the process, and the strength required. A joint is selected in each case to fulfill requirements at lowest cost.

The **Butt joint** is used to join the ends or edges of two plates or surfaces located approximately in the same plane with each other. On thickness from 2 to 5 mm, the open square butt should be selected, but thickness upwards of 5mm, joints with edge preparation on one or both sides may be recommended.

The **Lap joint**, as the name implies, is used to join two over lapping plates so that the edge of each plate is welded to the surface of the other. Common lap joints are single lap and double lap. The single-welded lap does not develop full strength, but it is preferred to the butt joint for some applications. The lap joint, however, may be employed for thickness under 3mm.

The **Tee-joint** is used to weld two plates or sections whose surfaces are at approximately right angles to each other. Plates or surfaces should have good fit-up in order to ensure uniform penetration and fusion. This is suitable up to 3mm and is widely employed in thin walled structures.

The **Corner joint** is used to join the edges of two sheets or plates whose surfaces are at an angle of approximately 90^o to each other. It is common in the construction of boxes, tanks, frames, and other similar items. Welding can be done on one or both sides, depending on the position and type of corner joint used. This is suitable for both light and heavy gauges.

Lap-joints, T-joints, and corner joints are the fillet weld connections generally used. The rounding of a corner is known as filleting. Fillet welded joints are favoured by designers in the interest of fabrication cost if the load conditions permit. There are three types of fillet weld: convex, flash and concave.

The **edge joint** consists of joining two parallel plates by means of a weld. This joint is often used in sheet metal work. The two edges can be easily and quickly melted down, eliminating the need for any filler metal. In heavy plates, where beveling the edges is done to get deeper penetration, some filler rod is needed. The position of welding is marked with a cross (×) in each case.

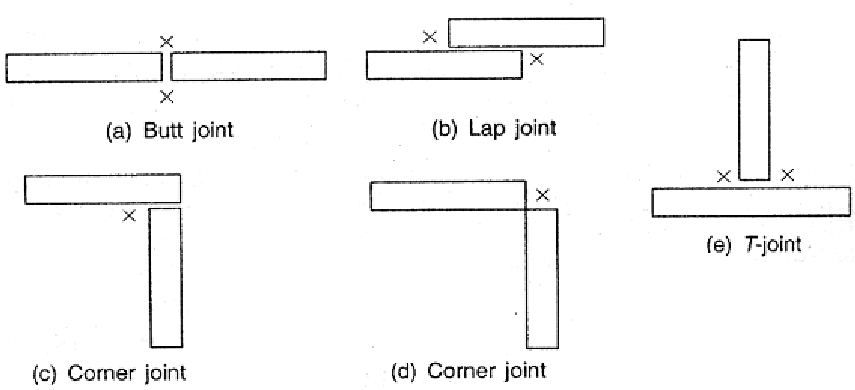

Fig 3.12 Types of welding joints

EDGE PREPARATION

To obtain sound welds, good edge preparation is particularly essential, consisting in suitably beveling the edges, and carefully cleaning the faces to be welded from dust, sand, grit, oil and grease.

Different edge preparation is particularly used in fusion welding processes for welding butt joints are: (a) square (b) single-V (c) double-V (d) single-U (e) double-U. The preparation of edges depends upon the thickness of metal being welded.

Square butt weld may be used for thickness of from 3 to 5mm. Before welding, the edges are spaced about 3mm apart.

Single-V butt welds are frequently used for metal over 8mm and up to about 16mm thick. The edges forming the joint are beveled to form an included angle of 70^o to 90^0, depending upon the welding technique to be used.

Double-V butt welds are used on metals over 16mm thick and where welding can be performed on both sides of the plate.

Single-U and double-U butt welds are used on metals over 20mm thick. They are most satisfactory and require less filler rod; but they are difficult to prepare.

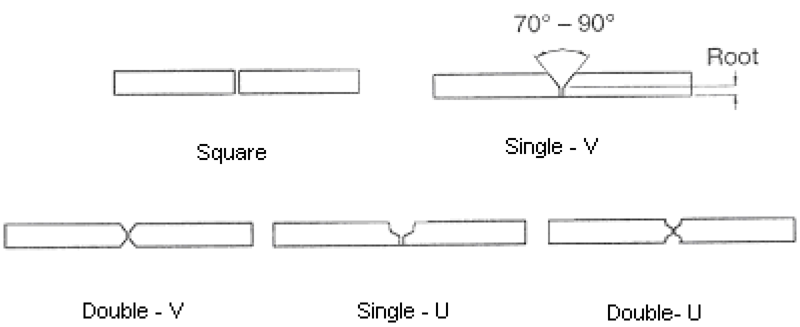

Fig 3.13 Types of Edge preparation