

# Welding



## Learning Objectives

- Students understand the process of welding and its uses, types of welding used in industries.
- To know about various field of using welding nowadays.



Nirai neera neeravar kaenmai piraimadhi  
Pinneera paedhaiyaar natpu. – Kural 782.

The friendship of the wise waxes like the new moon; (but) that  
of fools wanes like the full moon.

## CONTENTS

- |  |   |
|--|---|
| 7.1 Introduction   | 7.11 Gas welding                                    |
| 7.2 Types of welding   | 7.12 Types of welding                               |
| 7.3 Classification of welding process                                      | 7.13 Filler rods used in gas welding                |
| 7.4 Arc. Welding   | 7.14 Advantages of Gas welding                      |
| 7.5 Arc welding equipments   | 7.15 Disadvantages of Gas welding                   |
| 7.6 Difference between D.C. welding generator, and AC welding Transformer. | 7.16 Difference between Arc welding and Gas welding |
| 7.7 Specification of Electrodes.   | 7.17 Resistance welding                             |
| 7.8 Types of Electrodes.   | 7.18 Welding Related processes.                     |
| 7.9 Selection of electrodes.   | 7.19 Types of welding joint                         |
| 7.10 Carbon Arc welding  | 7.20 Safety precautions for welding.                |



The Inventor of Arc welding is Sir Humbry David, by using two carbon electrodes and he find the flame between the rods.

Gas welding was invented by Nicole Benar Dass, Russian scientist by using oxygen Acetylene gas and found high flame which is used to connect two metals.

## 7.1 Introduction

Welding can be defined as the process of joining two metal parts by applying heat. In industry, welding process is primarily used for fabricating works.



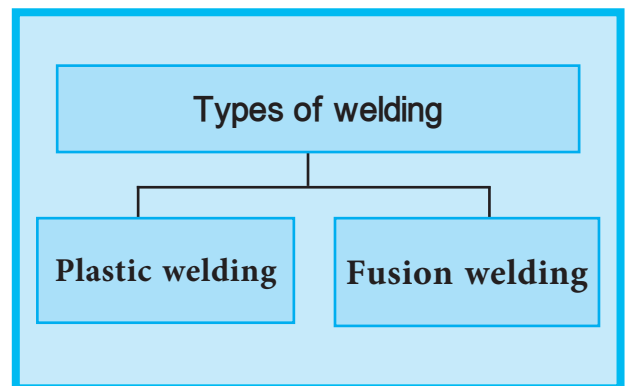
Welding is useful in making permanent joints. It can be performed by applying or not applying pressure. The contours of the metal parts are molten to make the joint in some methods. In some types of welding processes, filler metal is used. In some other methods, filler metal is not used.

The process of welding finds application in manufacturing automobiles, aeroplanes, rail coaches, machine components, metal structures, boilers and ships. Generally, welding process is applied wherever metal works are performed.

## 7.2 Types of Welding

There are two types by which welding is performed

1. Plastic welding
2. Fusion welding



### Plastic Welding

In this type, the metal parts are heated to plastic state, In this stage. Pressure is applied to make a perfect joint. It is also known as pressure welding.

### Fusion Welding

The metal parts are heated upto the point of melting in this type. The joint is made at this stage and the parts are allowed to cool. On cooling, the molten metal forms a solid joint. No pressure is applied in this method. Hence, it is also known as pressure less welding or Fusion welding Arc welding and gas welding fall in this category.

## 7.3 Classification of Welding processes

1. Arc welding
  - a. Carbon arc welding
  - b. Metal Arc welding
  - c. Metal inert gas welding
  - d. Tungsten inert gas welding
  - e. Atomic hydrogen welding
  - f. Plasma arc welding
  - g. Submerged welding
  - h. Electro slag welding
2. Gas Welding
  - a. Oxy – acetylene welding
  - b. Air – acetylene welding
  - c. Oxy hydrogen welding
3. Welding related processes
  - a. Oxy – acetylene cutting
  - b. Arc cutting
  - c. Hard facing
  - d. Brazing
  - e. Soldering

## 7.4 Arc welding

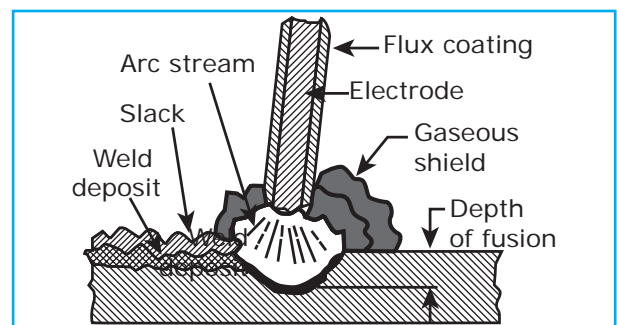
In arc welding, the edges of two metal parts are melted by an electric arc and the joint is made. An electrode made of a suitable metal is utilised for this purpose. The electrode is taken closer to the parts to be joined and electric current is supplied to both the parts and the electrode. An electric arc is made between the electrode and the metal parts. This arc generates high temperature and melts the metal parts. The parts are joined at this molten state. The filler metal in the form of electrode is deposited along the joint. The metal parts are joined without the application of any



pressure. Electrical energy is converted into heat energy in arc welding.



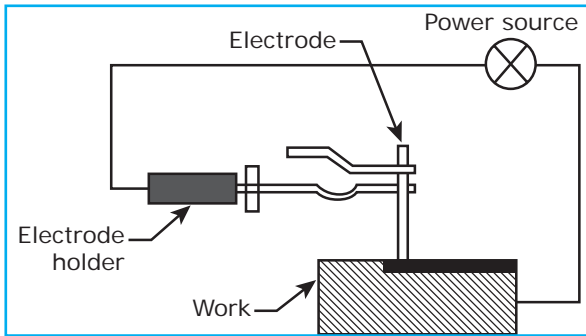
The distance between the metal parts and the electrode should be around 3mm. The heat generated during arc welding ranges from 5000°C to 6000°C. A generator or a transformer supplies the required current to both the electrode and the metal parts. The electrodes are flux coated to prevent the molten metal from reacting with the atmosphere.



Arc welding

## 7.5 Arc welding equipments

The following equipments are used for the process of arc welding



Arc welding equipments

1. D.C welding generator (or) AC transformer
2. Cables
3. Electrode cable
4. Work cable
5. Electrode holder
6. Electrode
7. Gloves
8. Protective shield (or) Goggles
9. Apron for the operator
10. Wire brush
11. Chipping hammer

## 7.6 Differences between DC generator and AC transformer

DC generator	AC transformer
Low efficiency	High efficiency
High power cost	Low power cost
High machine cost	Low machine cost
Runs on low voltage	Runs on high voltage
Safe equipment	The chances of accidents is high
Uncoated electrodes may be used	Only flux coated electrodes are used
Joints are made with ferrous and non-ferrous metal parts.	Non-ferrous metal parts cannot be joined

Work is connected to the positive terminal (+) and the electrode is connected to the negative terminal (-)	No restriction in the direction of power supply connection
Noisy functioning	No noise during operation
Easy maintenance of equipments	Requires proper maintenance
The cost of the process is low	High process cost
Thin metal parts can easily be welded	Difficult to weld thin parts

## 7.7 Specification of electrodes

### Electrodes - figure

Generally, the size of the electrodes is specified by the length and its diameter. They are available to a maximum of 12 mm diameter and 45mm length. The size of the electrode increases with the current used. In manual welding, the size of the electrode changes according to the thickness of the metal parts. Spring like electrodes are used in automatic welding.



## 7.8 Types of electrode

The electrodes used in arc welding are two types

1. Consumable electrode
2. Non – consumable electrode



There are three types of consumable electrodes. They are

- 1. Bare electrodes
- 2. Lightly coated electrodes
- 3. Heavily coated electrodes

Non – consumable electrodes are used in the processes of atomic hydrogen welding and TIG welding.

7.9 Selection of electrodes

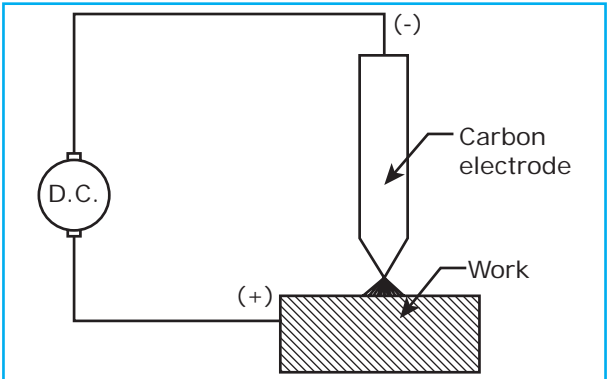
The material used for manufacturing electrodes depends upon the material to be welded. Given is the list indicating suitable materials for manufacturing electrodes for welding different metals.

S. No	Material to be welded	Electrode material
1	Wrought iron	Low Carbon Steel Rod
2	Mild Steel	Mild Steel, Copper coated Rod
3	Alloy Steel	Nickel Steel Rod
4	Cast Iron	Cast Iron Rod
5	Aluminium	Cast Aluminium Alloy Rod
6	Carbon Steel	Steel wire (0.15% Carbon & 0.025%) Phosperous & Sulphur
7	Copper	Copper Rod
8	Brass	Brass Rod

7.10 Carbon arc welding

In carbon arc welding, the process of welding is carried out by an electric arc. The arc formed between the electrode and the work piece generates high amount of heat. In D.C electric supply, the carbon electrode is connected to the negative terminal and the positive

terminal is connected to the work piece. During the formation of the electric arc, the temperature of the positive terminal is 4000°C and the negative terminal will be around 3000°C. Carbon, the electrode material will not fuse with the work piece materials. This prevents the joint from becoming weak. A lengthy arc produces carbon – monoxide at the location of welding and prevents the molten metal from reacting with the atmospheric air.



Carbon arc welding

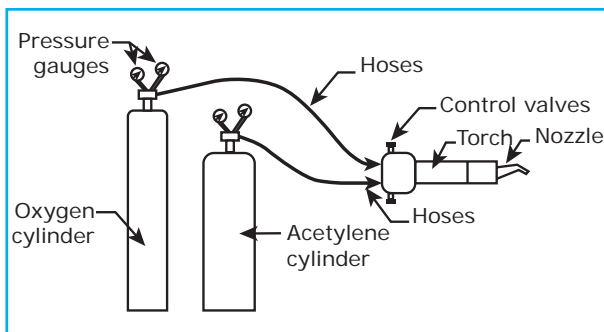
Both ferrous and non- ferrous metals can be welded by this method. Steel sheets, copper and its alloys, brass and aluminium parts are welded using carbon arc welding. This method of welding can also be done automatically. Starting of the electric arc is easy and the temperature is controlled easily. The disadvantage of this method is the presence of blow holes in the joint.

7.11 Gas welding

Gas welding is the process of melting and joining metal parts by means of a gas flame. Generally pressure is not applied during the process of gas welding. Oxygen and acetylene gases are made to pass through the welding torch. These gases are mixed at the required ratio



at the torch and the tip of the welding torch is ignited to produce the flame. Because of the heat generated by the flame, the edges of the metal parts are melted. Filler rod provides the additional metal required for making the joint. The flux coated on the electrodes prevents oxidation and removes impurities. This method is suitable in welding metal parts of thickness varying from 2mm to 50mm. The temperature of the flame is around 3200°C.



Gas Welding

### Gas Welding equipments

The following equipments are necessary for gas welding

1. Gas cylinders
2. Regulators
3. Pressure gauges
4. Rubber hoses
5. Welding torch
6. Safety goggles
7. Gloves
8. Spark lighter
9. Wire brush

### Gas cylinders

Oxygen and acetylene gases are stored in separate cylinders and used for gas welding. The colour of oxygen cylinder is black and the acetylene gas is stored in maroon cylinders. Oxygen is stored at a pressure of 125kg/cm<sup>2</sup>. Acetylene gas is stored at a pressure of 16Kg/cm<sup>2</sup>. In the cylinder.



Gas Cylinder

## Regulators

Separate regulators are fitted on both the cylinders. A regulator is used to control the working pressure of the gases. The working pressures of oxygen is  $1\text{Kg}/\text{cm}^2$  and acetylene is  $0.15\text{Kg}/\text{cm}^2$ . Working pressure of these gases are altered according to the thickness of the metal parts of the joint.



Regulators

Two pressure gauges are fitted each on the oxygen cylinder and on the acetylene cylinder. One of the pressure gauges indicates the pressure of the cylinder and the other gauge indicates the working pressure of the specific gas.

## Hoses

Separate hoses are used to connect the two cylinders with the welding torch through regulators. The colour of the hose from the

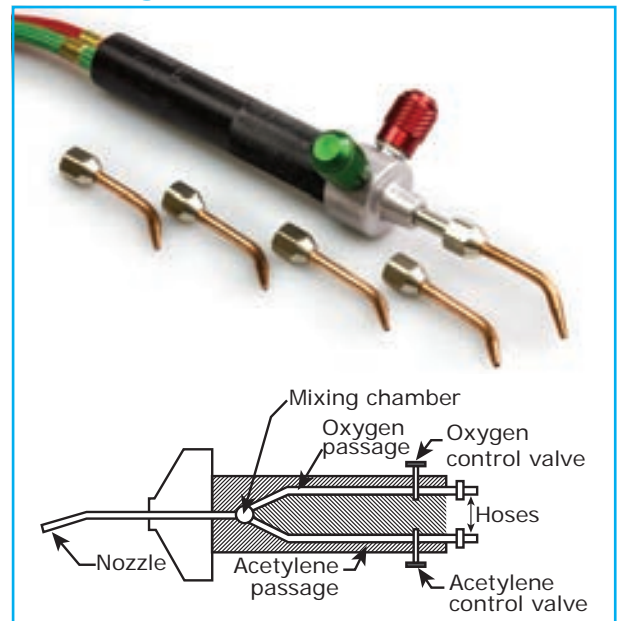
oxygen cylinder is black and the one from the acetylene cylinder is red. These hoses carry the gases to the welding torch.



oxygen hose

acetylene hose

## Welding torch



Welding Torch

Oxygen and acetylene reach the welding torch through the passages of hoses from the respective cylinders. These gases

are mixed in the mixing chamber of the welding torch. Flame is produced at the tip of the torch when the gases are ignited. There are two control valves present in the torch to control the quantity of oxygen and acetylene. By this control, the grade of the flame can be altered. The size of the flame is altered to suit the thickness of the metal parts.

### Goggles

Oxy acetylene flame emits ultraviolet and infrared rays. These rays are highly harmful to bare eyes. In order to protect the eyes of the welder, goggles should be used by him.



Goggles

### Welding gloves

Protective hand gloves are used by the operator to prevent possible damages that may be caused by high temperatures and metal splashes during welding.



Gloves

### Spark lighter

Spark lighter is used to ignite the oxy-acetylene gas at the tip of the welding torch.




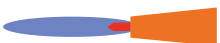
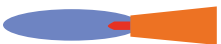
Spark Lighter

### Wire brush

Wire brushes are useful for cleaning the weld before and after the welding process.

## 7.12 Types of gas flame

The size of the flame can be altered by varying the ratio of oxygen and acetylene. By doing so, the following three types of flames are obtained.

1. Neutral flame 
2. Carburising flame 
3. Oxidising flame 

### Neutral flame

The supply of equal quantities of oxygen and acetylene produces neutral flame. There are two zones in this flame-1. Sharp and bright inner cone and 2. Bluish outer cone. The temperature of the inner cone will be around  $3200^{\circ}\text{C}$ . This neutral flame is generally used as it will not cause any chemical reaction upon the heated metal.



## Carburising flame

This flame is also known as reducing flame. The supply of acetylene will be more than oxygen to produce this flame. Carburising flame consists of three zones namely,

1. Sharp inner cone
2. White intermediate cone
3. Bluish outer cone

Carburising flame is useful in welding low carbon steel and alloy steels. It is also used to harden the outer surface of metal parts.

## Oxidising flame

Oxidising flame is obtained by supplying more oxygen than acetylene. It consists of two zones namely bright inner cone and outer cone. This flame is useful in welding brass and bronze.

### 7.13 Filler rods used in gas welding

Filler rods used in gas welding supply the additional metal in making joints. These rods are melted by the gas flame and deposited over the parts of the joint. Generally the filler rods are made of the same metal as that of the parts of the joint.

The diameter of the filler rod depends upon the thickness of the parts to be welded. The strength of the welding joint is increased by adding Nickel or Chromium in filler rods. A thin coat of copper is provided on the filler rods to prevent the molten metal from reacting with atmospheric oxygen. Flux may be applied either in powdered form or liquid form.

### 7.14 Advantages of gas welding

1. Applied for different classes of work
2. Welding temperature is controlled easily
3. The quantity of filler metal added in the joint can easily be controlled
4. The cost of the welding unit is less
5. The cost of maintenance is less
6. Both welding and cutting can be done

### 7.15 Disadvantages of gas welding

1. Intended for welding thin work pieces only
2. The process of welding is slow
3. The time taken by the gas flame to heat the metal is more when compared with electric arc.
4. The strength of the joint is less
5. Great care should be taken in handling and storing gas cylinders.

### 7.16 Differences between arc welding and gas welding

Arc welding	Gas welding
The heat is generated by the electric arc	The required heat is provided by the gas flame.
The working temperature is about 4000°C	The temperature of the gas flame is about 3200°C
The filler rod is used as electrode.	Filler rod is used separately
Care should be taken against the dangers that may be caused because of electricity	The danger of the process is because of the gases at high pressure

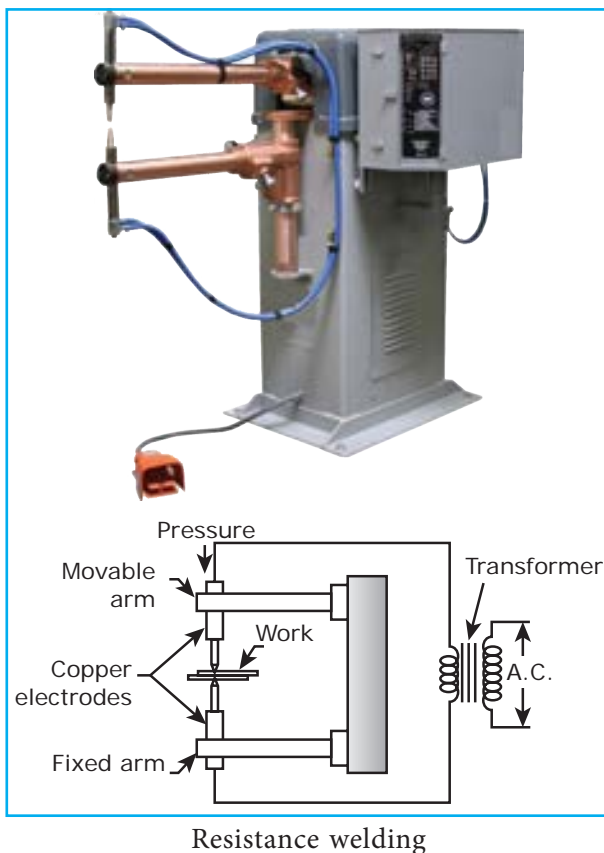
The strength of the joint is more	The joint is not as strong as that of arc welding
Brazing and soldering cannot be performed by the electric arc.	The processes of brazing and soldering can be done with the gas flame.
The filler rod metal should be selected as the same metal as that of the parts of the joint.	The filler rod metal can be different from that of the parts of the joint.

### 7.17 Resistance welding

The process of resistance welding involves

Developing electrical resistance in the parts of the joint to bring them into a plastic state and

Applying pressure on the parts to make the joint.



Two copper electrodes are connected to an electric circuit of low resistance. The parts to be welded are placed between the electrodes. When current is allowed to pass through the electrodes, high electrical resistance is developed at the joint. Because of the resistance, heat is generated at the joint. The metal parts reach plastic state at this high temperature.

At this point, pressure is applied by means of either mechanical or hydraulic or pneumatic power source to make the joint. Current is provided by a suitable A.C. transformer. Resistance welding is useful in welding sheet metal, bars and pipes.

### 7.18 Welding related processes

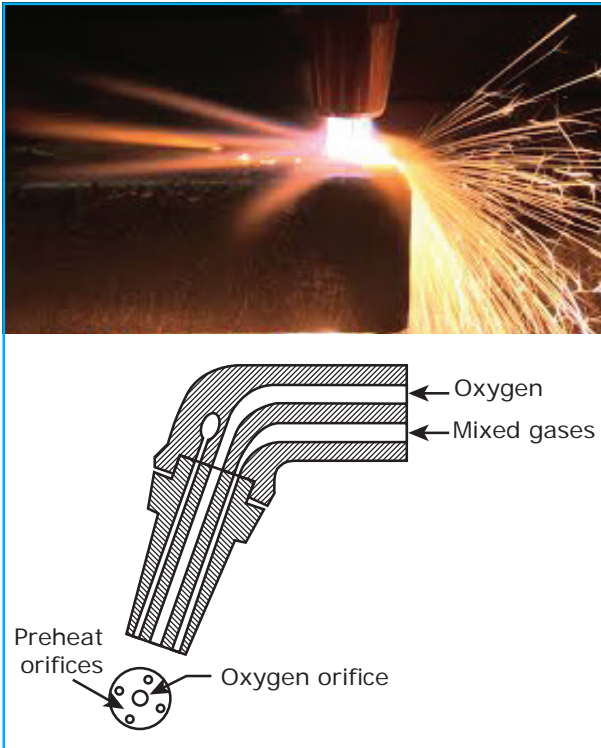
Following are some important welding related processes used in industries.



1. Oxy - acetylene cutting
2. Arc cutting
3. Hard facing
4. Soldering
5. Brazing

#### Oxy-acetylene cutting

Plates made of iron and steel are cut by oxygen, acetylene cutting torch. Oxygen and acetylene are mixed in the cutting torch and a gas flame is generated. The flame heats the sheets to bring them to red hot condition. High pressure oxygen is supplied on the red hot metal through a separate central hole of the cutting torch. Iron and steel sheets are thus cut by the jet of oxygen.



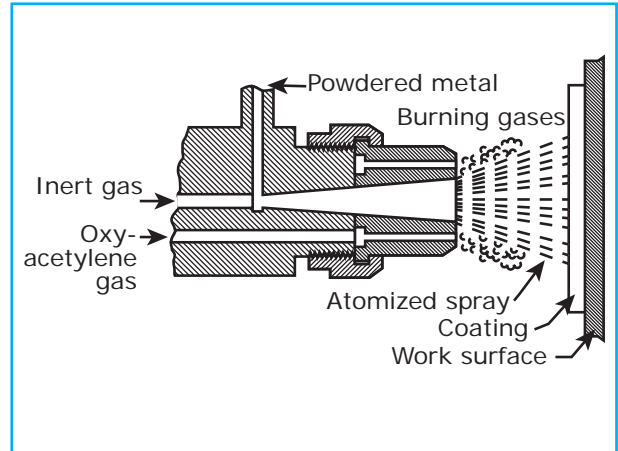
Oxy – Acetylene Cutting

### Arc cutting

In this process, the metal parts are heated by means of carbon or metal electrodes. High pressure air is supplied on the molten metal to remove it and cut the metal parts. Oxygen jet is supplied along with the electrode instead of air nowadays. Arc cutting is not suitable for accurate work.

### Hard facing

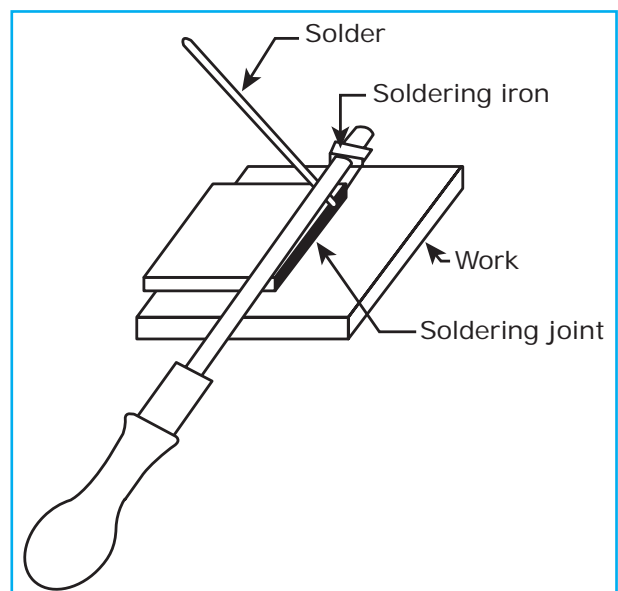
Hard facing is a process of coating a hard material on soft metal parts. Powdered coating metal is filled in the welding gun. The metal powder is melted by the oxy-acetylene gas flame. The supply of inert gas at pressure makes the powdered metal to split into small particles. These particles are sprayed on the surfaces of the soft metal. Coatings of Tungsten carbide, Chromium carbide and Aluminium oxide can be made on the surfaces of different cutting tools and cutters.



Hard facing

### Soldering

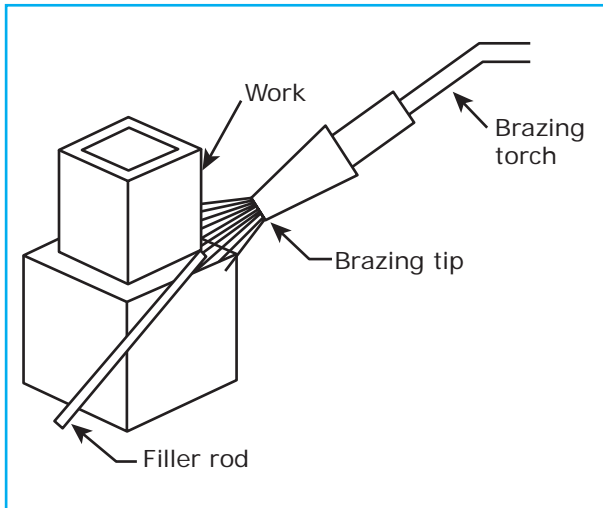
Two parts made of similar or dissimilar metals are joined by a solder made of a fusible alloy. Solder is an alloy made of Tin and Lead. The melting temperature of the solder is in the range of 150°C to 350°C. The surfaces of the two metal parts are cleaned and held in correct positions. Flux paste made of zinc chloride is applied on the parts by soldering iron. Application of flux prevents oxidation. The solder is melted by the heat provided by the soldering iron and filled between the metal parts. The solder solidifies and joints the metal parts.



Soldering

## Brazing

In brazing, filler metal in molten state is filled between the metal parts of the joint. The filler rod is heated up to  $450^{\circ}\text{C}$ . The parts to be joined are cleaned and the molten filler metal is applied between the parts to make the joint. In this method, the metal parts are not melted.



Brazing

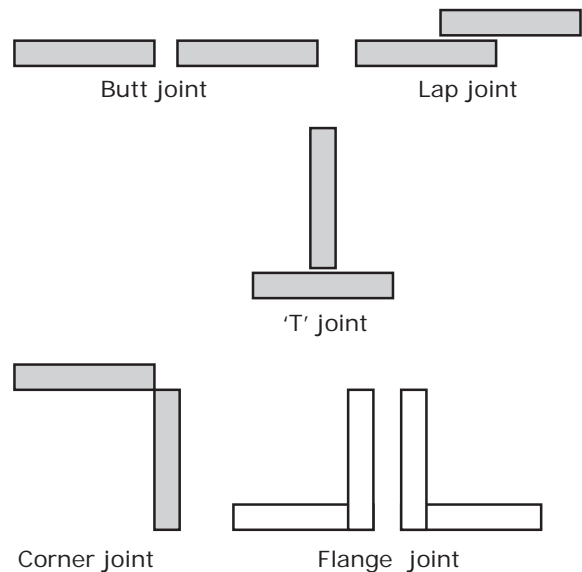
### 7.19 Types of welding joints

Following are the various types of welded joints

1. Butt joint
2. Lap joint
3. T-joint
4. Corner joint
5. Flange joint

#### Butt joint

Butt joint is a joint in which the corners or the edges of two metal parts are joined. The process is done by keeping the metal parts on a same plane. The edges of metal parts of thickness upto 5mm may be kept open square. If the thickness of the metal parts exceeds 5mm, edges of the parts need to be prepared in proper shape before welding.



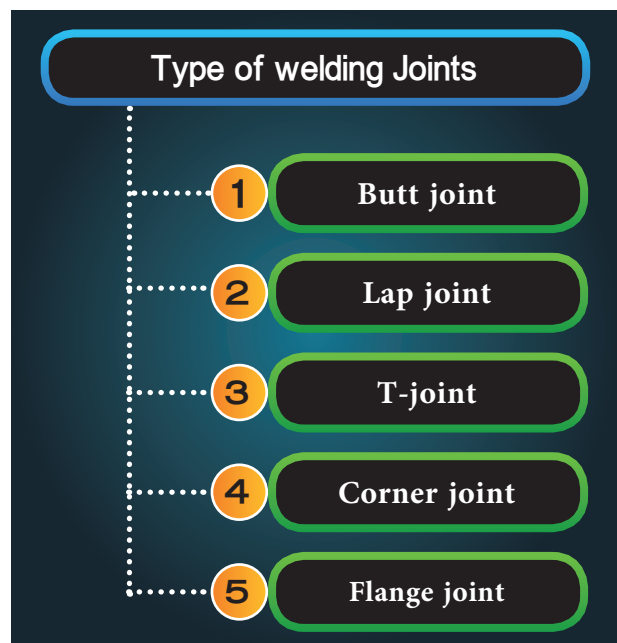
Type of welding Joints

#### Lap Joint

It is a joint in which the metal plates are placed over lapping before welding. The edge of one part is welded with the surface of the other plate. There are two types of lap joint namely (i) single lap joint and (ii) double lap joint.

#### T-Joint

This joint is made by keeping the metal plates at perpendicular ( $90^{\circ}$ ) to each other. Sheets with thickeners over 3mm only are welded by this type of joints.





## Corner joint

Two metal sheets kept at  $90^\circ$  to each other are welded by this joint. This method is adopted when making boxes and tanks. Corner joints are adopted for thin and thick sheets.

## Flange joint

The plates of the joint may be kept parallel or at  $90^\circ$  to each other. The edges of the plates are bent to form the shape of a flange.

### 7.20 Safety precautions for welding

We make use of electrical devices and inflammable gases like oxygen and acetylene in welding. If proper care is not shown in handling them, there is always a possibility of accidents taking place. So, welding process should be carried out with due safety and caution.

#### Safety precautions for gas welding

1. Gas cylinders should be kept in ventilated locations.
2. Cylinders should not be kept near hot locations. They should be kept away from electrical terminals.

3. Pressure regulators should be closed after the welding work is completed.
4. Regulators should be handled properly.
5. Old and worn out regulators should be replaced immediately.
6. The operator should wear goggles, gloves, apron and proper footwear.
7. Fire extinguishers and first – aid box should be kept ready always.

#### Safety precautions for arc welding

1. The welder should always wear goggles. Gloves, apron and proper footwear during welding
2. Welding shop should be located properly so that it does not cause any discomfort to others.
3. The welder should act carefully against electric shocks.
4. A high quality electrode holder should be put into use.
5. Power supply should be provided at required voltage and uniform current
6. Fire extinguishers and First – aid box should always be kept ready in a welding shop.

#### ACTIVITY

1. Students to visit the welding workshop to study different types of welding joints and give practice any two types of welding joints.

## Questions

### Part I.

#### Choose the correct option 1 Mark

1. Carbon Arc welding is related to .....
  - a) Gas welding
  - b) Resistance welding

- c) Arc welding
- d) Solid state welding

2. The heat generated during arc welding is
  - a)  $100^\circ\text{C} - 150^\circ\text{C}$
  - b)  $50^\circ\text{C} - 100^\circ\text{C}$
  - c)  $5000^\circ\text{C} - 6000^\circ\text{C}$
  - d)  $15^\circ - 200^\circ\text{C}$

3. The pressure of acetylene in the cylinder of gas welding equipments is
  - a)  $16\text{kg/cm}^2$
  - b)  $125\text{kg/cm}^2$
  - c)  $100\text{kg/cm}^2$
  - d)  $14\text{ kg/cm}^2$
4. The pressure of oxygen in the cylinder of gas welding equipment is
  - a)  $16\text{kg/cm}^2$
  - b)  $125\text{kg/cm}^2$
  - c)  $100\text{kg/cm}^2$
  - d)  $14\text{ kg/cm}^2$
5. Plastic welding is
  - a) Pressure welding
  - b) Resistance welding
  - c) Fusion welding
  - d) Arc welding
6. Fusion welding is
  - a) Pressure welding
  - b) Non-pressure welding
  - c) Resistance welding
  - d) Thermit welding



## Part II.

**Answer the following questions in one or two sentences**      **3 Marks**

7. Mention any three types of arc-welding.
8. State any three types of gas welding.
9. State any three types of welding related process.
10. How is the welding electrodes specified?
11. What are the types of electrodes?

12. Name the three types of flames generated in gas welding.
13. What are the types of welded joints?

## Part III.

**Answer the following questions in about a page**      **5 Marks**

14. Explain any two types of equipments used in gas welding.
15. Explain any one type flame obtained in gas welding with a diagram.
16. What are the advantages of gas welding?
17. Explain the oxy-acetylene cutting with diagram.
18. Explain Hard-facing with diagram.
19. Explain Soldering with diagram.

## Part IV.

**Answer the following Questions in detail.**      **10 Marks**

20. Explain arc welding with a diagram.
21. List out the arc welding equipments with a diagram.
22. What are differences between AC arc welding transformer and DC arc welding generator?
23. Explain carbon arc welding with a diagram.
24. Explain gas welding with a neat sketch.
25. List out the differences between arc and gas welding.
26. Sketch and explain resistance welding.
27. What are the safety precautions during the process of gas and arc welding?