INTRODUCTION TO METAL JOINING.

Metal joining : Joining may be defined formally as the process of bringing two or more surfaces into intimate contact in order to establish continuity of a field across the resulting interface.

Metal joints are basically classified as

- Permanent joints : These joints are made by welding, brazing, soldering, folding and riveting.
- Temporary joints : These joints are made by screwing, bolting, wedging, taper fitting, force and shrink fitting etc.

Welding : is a technique or process of joining two similar or dissimilar metals by application of heat with or without pressure and with or without the use of filler material.

Weldability : is the degree of ease with which two metals (similar or dissimilar) are joined with or without the application of pressure and with or without the use of filler metal

Different types of welding :

The classification of welding is carried out in two ways :

1.) Based on composition of joint : It is categorised in three ways :

(a) Autogenous welding : is a technique of joining similar metals by melting the edges together, without the addition of filler metal.

(b) Homogenous welding : is the technique of joining similar metals with the help of filler rod of same metal.

(c) Heterogenous welding: is the process of joining dissmilar metals using filler rod.

2. Based on application of Pressure: is categorised in two ways.

(a) Forge or Pressure welding:
In this technique, the workpieces are heated to plastic state and then they are joined by applying external pressure on them.

(b) Fusion or Non-pressure welding:
In this technique, the material at the joint is heated to a molten state and then allowed to solidify.

Various welding and allied process are

1. oxy-acetylene welding (Gas welding)
2. Arc welding:
   - Carbon arc welding
   - Metal arc welding
   - Submerged arc welding
3. Resistance welding:
   - Spot welding
   - Seam welding
   - Butt welding
   - Precussion welding
   - Electric resistance welding
4. Atomic hydrogen welding (Thermo-chemical welding)

Important terms used in welding:

- Base metal: the metal to be joined or cut.
- Bead or weld bead: is the metal added during welding.

★ Forge or Pressure Welding (Plastic Welding)

- Forge or Pressure Welding (Under pressure without additional filler metal)
  - Heat Created by
    - Blacksmith's fire
      - Blacksmith forge welding
    - Electric current
      - Resistance Welding
        - Spot welding
        - Seam Welding
        - Projection welding
        - Upset butt welding
        - Flash butt welding
        - Percussion welding.
    - Friction
      - Friction Welding
  - Cold pressure welding

★ Fusion or Non-pressure Welding

- Fusion or Non-Pressure Welding (With additional filler metal)
  - Heat Created by
    - Electric arc
      - Carbon arc Welding
      - Metal arc Welding
      - Submerged arc Welding
      - Inert gas arc Welding
        - Tungsten inert gas arc welding (TIG)
        - Metal Inert gas arc welding (MIG)
      - Studarc welding
    - Gas
      - Oxy Acetylene
      - Air Acetylene
      - Oxy Hydrogen
    - Chemical Reaction
      - Thermit Welding
      - Atomic Hydrogen Welding

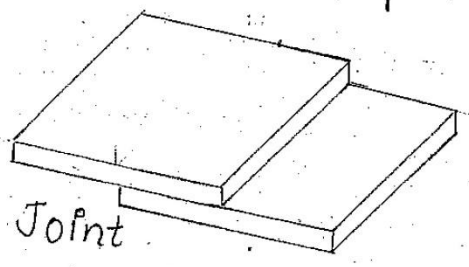
Applications of welding:

- Automobile construction.
- Railroad equipment.
- Ships.
- Aircraft construction.
- Building construction.
- Bridges construction.
- Pressure vessels.
- storage tanks
- Piping and pipe lines
- Repair of broken and damaged parts.
- Material handling equipments etc.

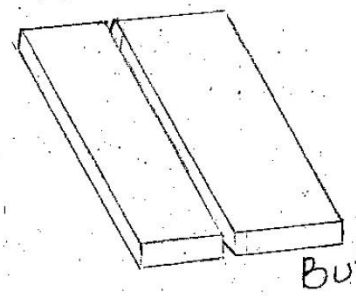
Types of welding joints:

5 basic types of joints are commonly used in fusion welding.

1. Lap joint: is obtainted by overlapping the metal and then welding the edges.



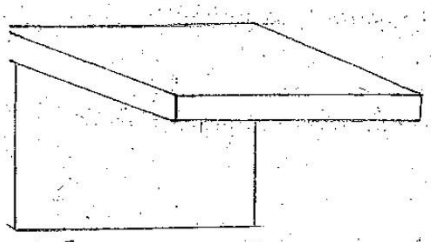
Lap Joint



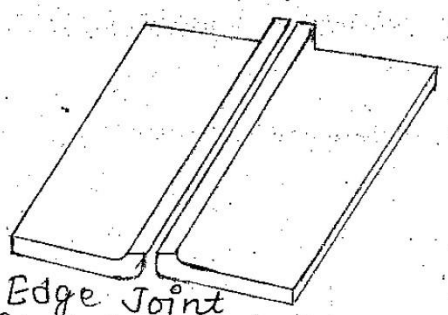
Butt Joint

2. Butt joint: is obtained by welding the ends or edges of two plates, which are approx. in same plane. Butt joint may be square, single V, double V and single U or double U butt joint.

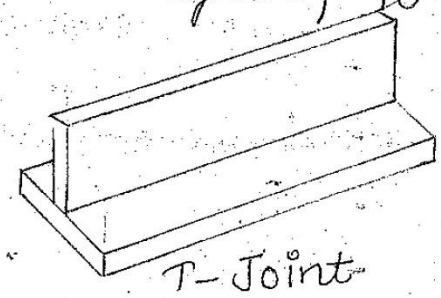
3. Corner joint: is obtained by joining edges of two plates whose edges are at an angle of 90°



Corner Joint



Edge Joint



T-Joint

4. Edge joint: is obtained by joining 2 parallel plat having thickness less than 6mm.

5. T-Joint: is obtained by joining two plates whose surfaces are at right angle to each other. Suitable in to

- Weld pass : is a single movement of the welding torch or electrode along the length of joint, which results in a bead.

- Backing : is the material support provided at the root side of a weld to aid in the control of penetration.

- Deposition rate : rate at which weld metal is deposited per unit time.

- Weld metal : is the metal that solidifies in the joint. It may be only base metal or a mixture of base metal and filler metal.

Advantages of Welding :

- A good weld is as strong as the base metal.
- A large no. of metals/alloys can be joined by welding.
- Repair by welding is very easy.
- It can be easily machanized.
- Portable welding equipments are available.
- Welding is a cost effective process of joining.
- welding structures are comparatively lighter.
- It can produced 100% efficient joint.
- welding joints distribute operating stresses evenly.

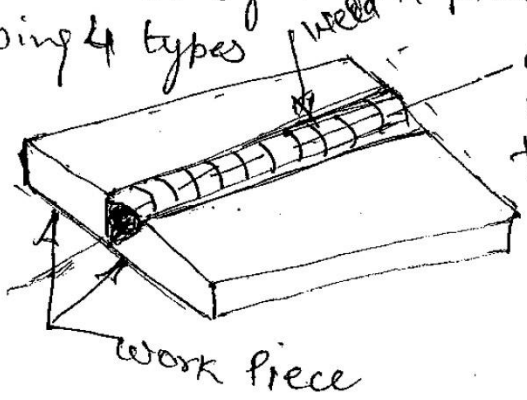
Disadvantages of welding :

- It produces the harmful radiation, fumes and spatter.
- A skilled welder is required.
- Welding heat produces metallurgical changes.
- Edge preparation is required before welding.
- More safety devices are required.
- Jigs and fixtures are required to hold the parts to be welded.

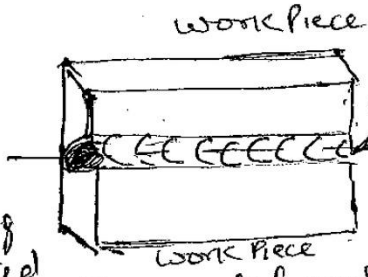
Welding positions: (1) Flat Position (2) Horizontal Position (3) vertical Position (4) overhead position

According to the location of work pieces weding positions are of the following 4 types

1) Flat Position

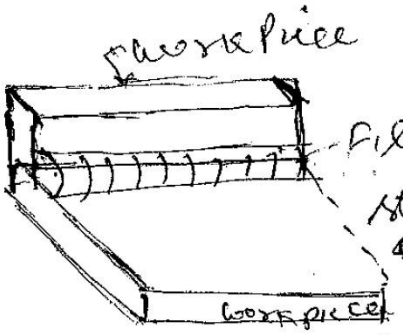


(2)



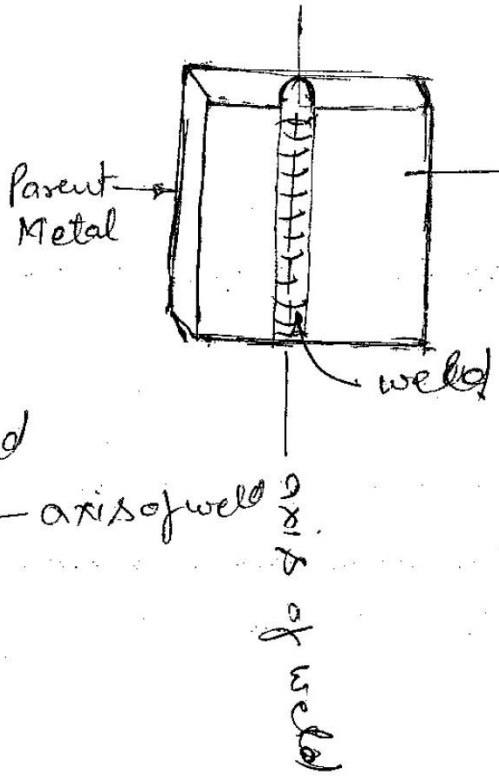
Welding is started rom right hand side & proceeds left ward

Horizontal welding Position Groove weld

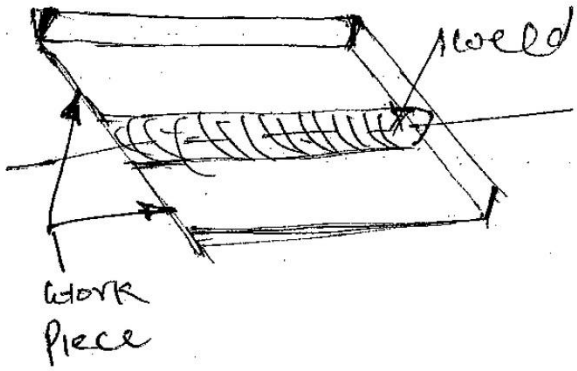


Horizontal welding Position Filled weld

(3) Vertical Position



4 overhead Position



FLUX

Flux : is any substance or mixture used to promote the fusion of metals. It is nearly inert at room temp. but becomes strongly reducing at elevated temperatures, preventing the formation of metal oxides. It may be added seperately but generally used as the coating of electrodes. Commonly used fluxes are : Borax (for brazing), olive oil and sal ammoniac (for iron), Rosin, tallow, olive oil and zinc chloride (for Al), Cryolite, Lithium chloride etc.

The materials constituting the flux are termed as its components. These components may be sub-divided into following categories:

- Gas forming : components are organic matters such as stach, wood pulp etc. which form gas layer, thus isolating the welding zone from the ambient air
- Slag Forming: components are chinaclay, felspar, Mn and titanium ores etc. which enchance slag formation This slag covering the molten metal prevents it from coming into contact with ambient air.
- Reducing : components such as ferro-silicon, ferro-titanium, ferro-manganese reduces the oxides which are likely to be formed in the liquid bath of molten metal
- Alloys : The alloying components such as ferro-silicon, ferro-chromium, chromium oxide are used for rendering the metal heat proof.
- stabilizing : components also form slag. In the presence of arc, these components ionize the zone between the electrode and parts to be welded and thus ensuring the stable buring of arc.
- Binding: components are added so that covering may have proper binding with the bare electrode.

Functions of Flux: In addition to formation of gaseous shield the different functions of flux are given below;

(i) It takes away the impurities present on the surface to be weld.

(ii) It forms the slag over the weld that reduces blow holes, porosity and chances of crack formation.

(iii) It enables the use of alternating current.

(iv) It prevents overheating of electrodes.

(v) It provides strength and flexibility to the welding.

(vi) It increases the rate of melting and therefore welding operations can be performed faster.

(vii) It increases the fluidity.

(viii) Many fluxes contain stabilising material like titanium oxide and potassium compounds that help in maintaining the arc.

(ix) It reduces under cutting.

Requirements of good flux material are:

1. A flux should have a lower melting point than the base metal.

2. It must not cause any corrosive action on the finished weld.

3. It must make the welding process easier and serve to rebore trapped gases and form slag to remove impurities like sand, scale and dirt.

4. The molten flux should easily spread over the area next to welding spot so that it may clean the surface ahead.

5. It must be capable of forming a protective glaze on the weld surround surface.
The fluxes ultimately provide a reliable joint between the parent and filler metals.

Properties of Flux:

- It should be sufficient enough to dissolve the scale (oxide) present on the surface.
- It should be lighter in comparison to molten metal so that it may float on the top of metal and after cooling may be easily chipped off.
- It should be stored in a dry place and should not be allowed to mix with other types of fluxes.
- It should not be allowed to remain on the finished weld
- Fusion rate of the flux should be high.
- The resistance to hot and cold cracking should be high.
- The Flux should have good mechanical properties.
- Penetration should be medium.

Electrodes:

An electrode is an electrical conductor referred to as either an anode or cathode.
In welding an electrode is used to conduct current through a workpiece to fuse two pieces together.
Each electrode may become either as an anode or cathode depending on the voltage applied to cell. A bipolar electrode is an electrode that functions as the anode of one cell and cathode of another.

The electrodes are generally categorized in two ways:

1. Based on the covering
   - Bare electrodes: as their name implies are bare i.e. without any covering. These are cheaper but welds are of poor quality. Therefore these are very rarely used.
   - Coated or shielded electrodes: have a coating of several chemicals such as cellulose, titanium, sodium iron power. The coverings are provided by either dipping the wire cores in a bath or during extrusion. About 20 to 25 mm length at one end is left bare where the electrode is held in the electrode holder.

2. Based on the use:
   - Consumable electrodes: are used up during welding. These are used in case of gas metal arc welding or shielded metal arc welding.
   - Non-consumable electrodes: are not used up. These are used in gas tungsten arc welding. Seperate filler rods if necessary can be used to fill the gap along joints. These are made up of carbon graphite or tungsten.

Size of Electrodes : The electrodes are manufacture in standard lengths of 250 mm, 300 mm, 350 mm and 450 mm.

The standard size (diameter) of electrodes are 1.6 mm, 2 mm, 2.5 mm, 3.2 mm, 4 mm, 6 mm, 7 mm, 8 mm & 9 mm.

Electrodes Classification and coding

As per ISI coding system an electrode is specified by six digits with a prefix Letter M which indicate the suitability for metal arc welding. These six digits stand for the following:

(1) 1st digit : numbered from 1 to 8 each no. stands for a particular type of covering provide on the electrode.

(2) 2nd digit : numbered from 1 to 6 and each no. stands for a particular position of welding in which the electrode can be used.

(3) 3rd digit : Numbered from 0 to 7 each no. stands for a particular current condition suitable for that particular electrode.

(4) 4th digit : numbered from 1 to 8 and each no. stands for a particular tensile strength in kg/cm²

(5) 5th digit : Numbered from 1 to 5 and each no. stands for percentage elongation of deposited weld metal in tensile testing.

(6) 6th digit : Numbered from 1 to 5 and each No. stands for minium impact value of the weld metal.

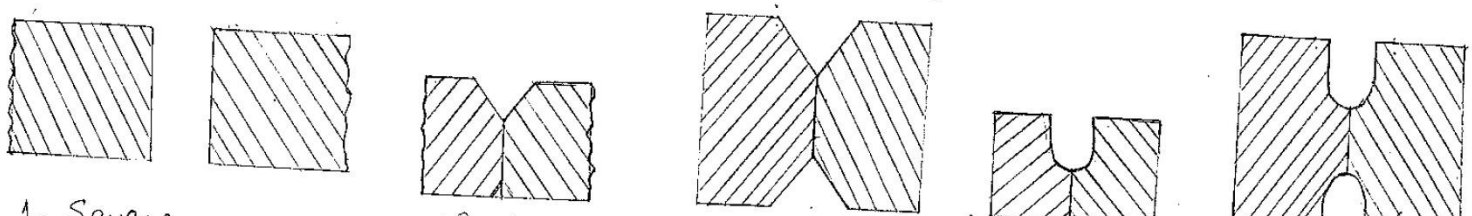
Electrodes may be constructed of metals such as copper silver, lead or zinc. However it may also be made up of a non-metal such as carbon.

The factors which influence the selection of a particular electrode are:

- Availability of current - A.C. or D.C.
- Composition of base metal.
- Thickness of base metal.
- Welding position - flat, horizontal, vertical or overhead
- Fit-up of components to be welded.
- Expected physical properties of welded joints i.e. strength, ductility, soundness, appearance etc.
- Amount of penetration required in welding.
- Skill of welders in using particular types of electrodes under specific conditions.
- Economic considerations - welding costs are largely affected by deposition rate and also by electrode costs.

Edge Prepration:

In order to obtain sound welds, good edge prepration is very essential. It consists of suitably bevelling the edges, and carefully cleaning the faces to be welded from dust, sand, grit, oil and grease.



1. Square 2. Single V 3. Double V. 4. Single U 5. Double U

Different edge preparation is particularly used in fusion welding process for welding butt joints: (1) square (2) single V (3) double V (4) Single U and (5) Double U

The prepartion of edges depends upon the thickness of metal being welded.

1. Square butt welds : are used for thickness of 3 to 5 mm. Before welding edges are spaced about 3mm apart.

2. Single V butt welds : are frequently used for metals over 8 mm and upto about 16 mm thick. The edges forming the joint are bevelled to form an included angle of 70° to 90° depending upon the welding technique to be used.

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

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

Gas Welding.

Gas welding also called an oxy-fuel gas welding is done by burning a combustible gas with air or oxygen in a concentrated flame of high temp.

The process is fusion welding process wherein joint is completely melted to obtain the fusion.

Oxy - Acetylene welding:

Here the fuel gas used is acetylene. This process is particularly suitable for joining metal sheets and plates of thickness 2 to 50 mm. With material thicker than 15 mm, additional metal called filler metal is added.

Principle of operation:

When acetylene is mixed with oxygen in correct proportions in the welding torch and ignited the flame is produced which is sufficiently hot to melt and join the parent metal.

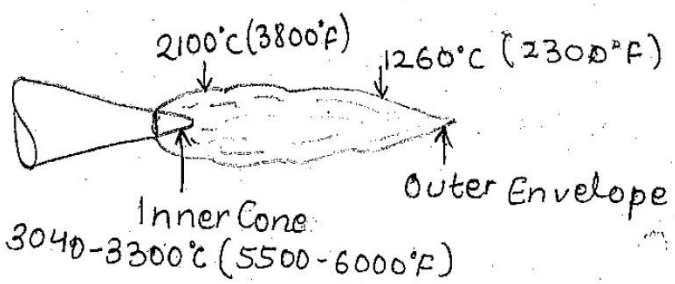
Types of flames:

Fig — Principle of Gas Welding

1. Neutral flame: is produced when oxygen to acetylene ratio is 1.1 : 1.

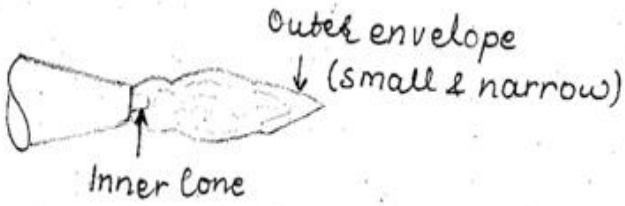
   Temperature is of the order of about 5900°F (3200°

   The flame has nicely defined inner cone which is light blue in color and develops heat. It is surrounded by outer envelope which is dark blue in color and protects the molten metal from oxidation.



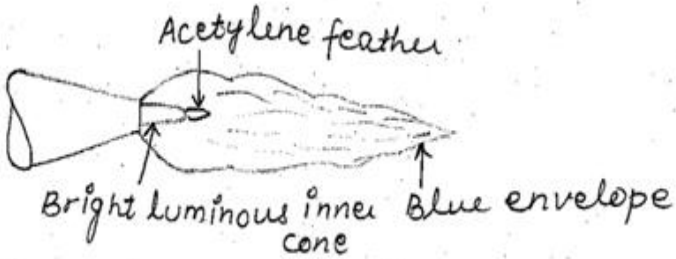
It is widely used for steel, stainless steel, copper and aluminium.

2. Oxidizing flame: has excess of oxygen. Its inner cone is more pointed, outer flame envelope is much shorter.
It burns with a loud roar and temp. is about 6300°F because of excess O_2 complete combustion takes place.



Oxidising flame is necessary for welding brass & bronze metals

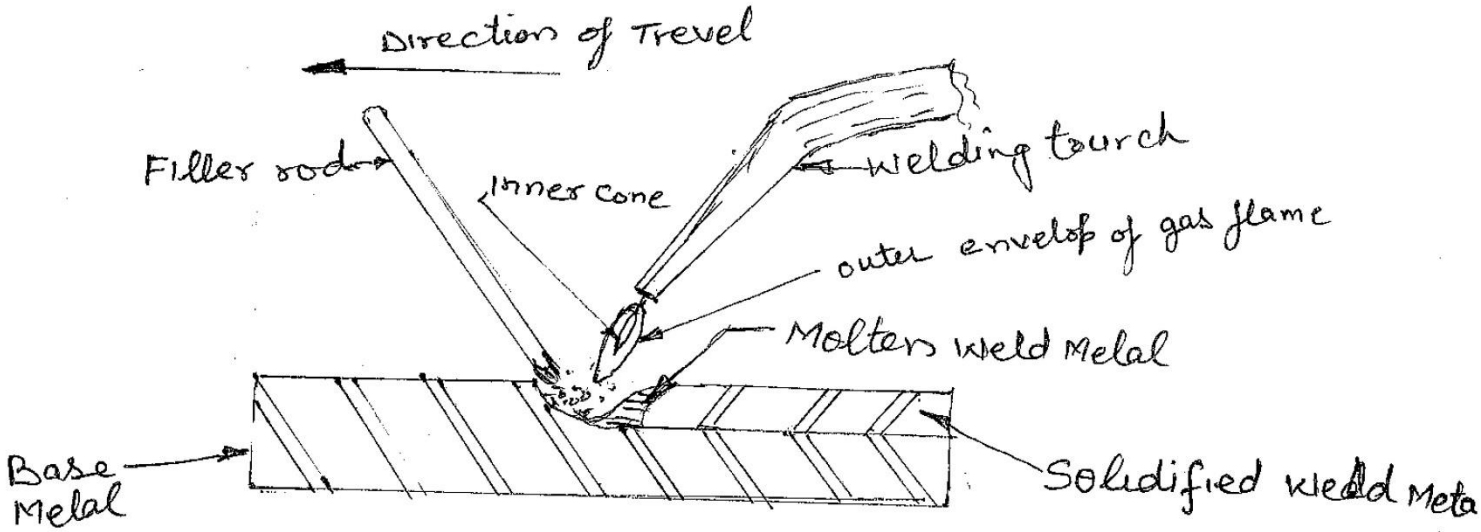
3. Reducing flame: also called carburizing flame is one in which there is excess of acetylene. It has three cones. The sharply defined inner cone, an intermediate cone of whitish color and bluish outer cone. Temperature is the order of 5500°F.



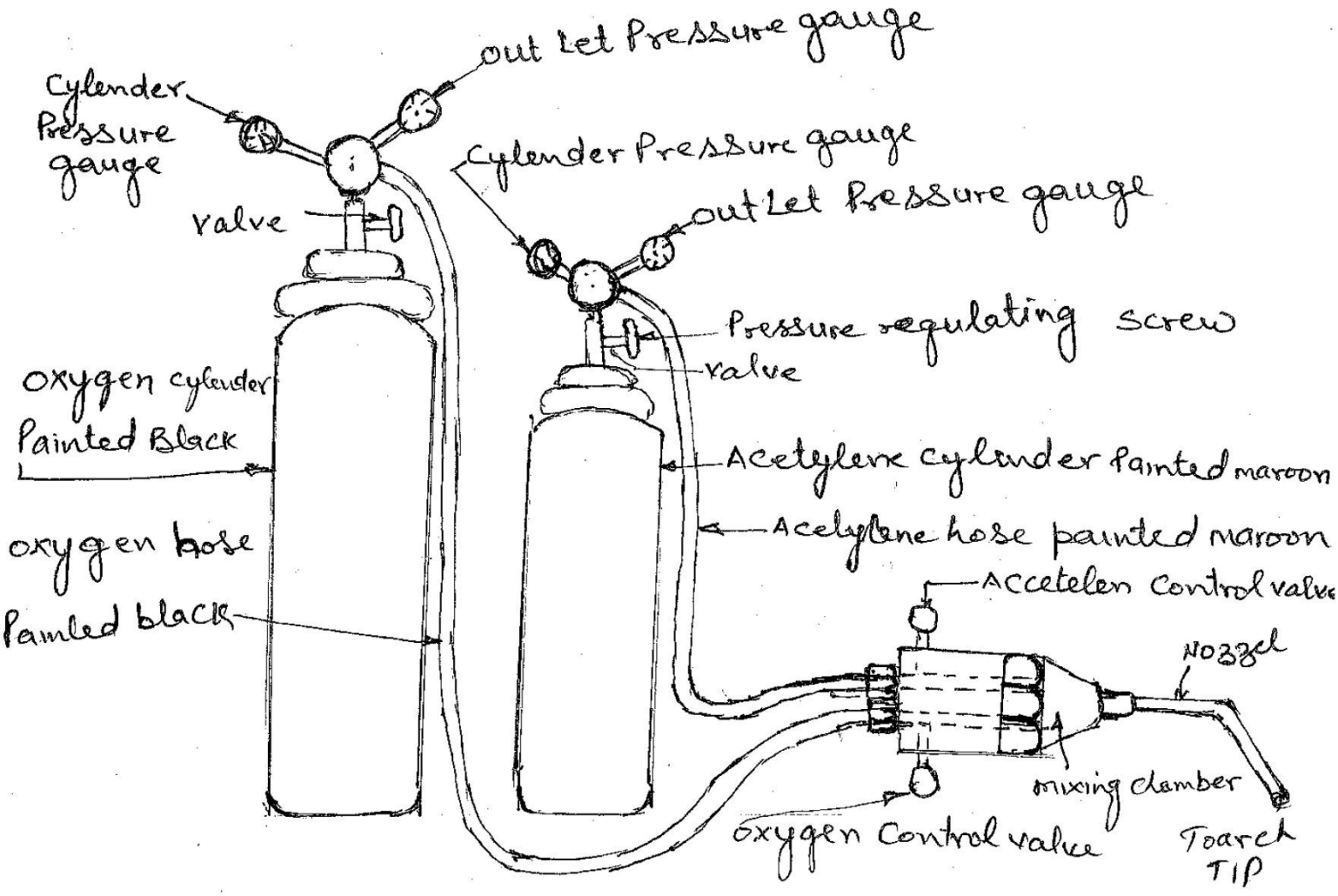
It is used for the welding of lead and for carburizing (surface hardening) purposes.
It is used with low alloy steel rod for welding high carbon steel.

Chemistry of oxy-acetylene flame:
combustion of gas mixture takes place in two main stages:

Stage 1: oxgen and acetylene in equal proportions by volume burn in the inner cone and form carbon monoxid



oxy-Acetylene gas welding



High Pressure oxy-Acetylen gas welding equipment Arrangment.

while the hydrogen is liberated.

$$2C_2H_2 + 2O_2 \longrightarrow 4CO + 2H_2 \quad -(i)$$

Stag 2 : CO produced in stage 1 uses the oxygen from the air and results in carbon dioxide and water vapours.

$$4CO + 2H_2 + 3O_2 \longrightarrow 4CO_2 + 2H_2O \quad -(ii)$$

combining (i) and (ii)

$$2C_2H_2 + 5O_2 \longrightarrow 4CO_2 + 2H_2O$$

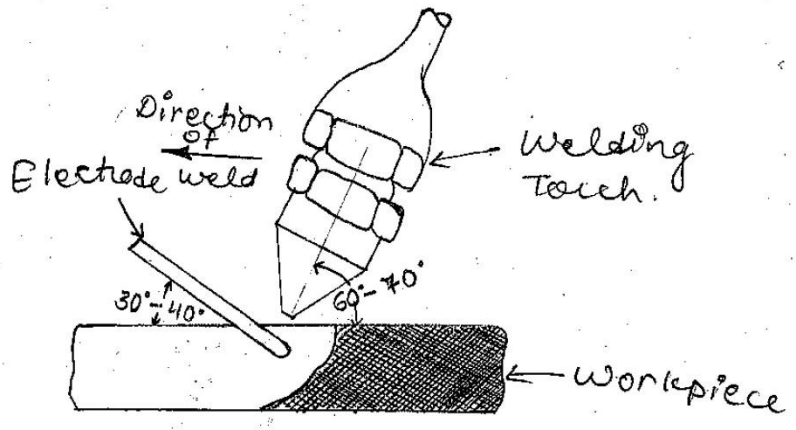
We see that two fifth of O_2 necessary for complete combustion of acetylene is received from cylinders and rest from surrounding air atmosphere.

Welding Technique:

Depending on the ways in which welding rod and the welding torch can be used, there are 2 techniques:

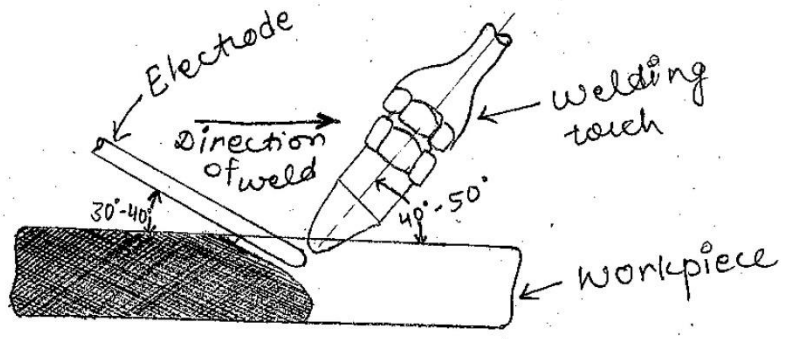
1. Leftward technique or fore-hand welding:

In this the weld is made working from right to left. welding flame is directed away from the finished weld. welding torch is given small sideways movements, while filler rod is moved steadily across the joint.



The leftward method is most advantageous on plates upto about 3mm.

2. Rightward Technique or back-hand welding: is carried out from left to right. The torch flame is directed towards the completed weld. It has no lateral movement.



This method is very suitable for steel work over 12 mm thick.

Welding Equipments:

- Oxygen gas cylinders: are painted black and valve outlets are screwed right handed.
- Acetylene gas cylinders: are painted maroon and valves are screwed left handed. These are chamfered or grooved.
- Pressure regulator: are used to reduce the high pressure of gas in the cylinder to a suitable working pressure and to produce a steady flow of gas under varying cylinder pressures.
- Welding torch: is used for mixing oxygen and acetylene in correct proportion and burning the mixture at the end of tip.
- Filler rods and fluxes.
- Gas lighter
- Goggles and gloves etc.

Fig. Gas welding Equipments

Advantages:

- It can be applied to a wide variety of manufacturing and maintenance situations.
- Rate of heating and cooling of weld deposit and job is slow.
- No electric current is required.
- Equipment cost is less.
- Maintenance is easy.
- Operator is having better control as sources of heat and filler metals are seperate.

Disadvantages:

- Refractory metals (tungsten, molybdenum, tantalum) and reactive metals (titanium and zirconium) can not be welded.
- gas flame takes a long time to heat up the metal
- Heat affected zone is wider.
- Acetylene oxygen gases are expensive.
- For storage of gases more safety is needed.
- Skilled operators are needed.

Applications:

- Used for welding mild steel, stainless steel, copper, cast iron, high carbon steels etc.
- For joining thin materials.
- In automotive and aircraft industries.
- In sheet metal fabricating plants.

ARC WELDING

Arc welding is the most extensively employed method of joining metal parts. In this method, source of heat is an electric arc produced between two conductors. One is made +ve terminal, and other one is -ve terminal. Arc welding is a group of fusion welding processes without the application of pressure or with or without the use of filler metal depending upon the thickness of base plates

Arc Welding Principle:

In this method, arc is generated between the +ve pole of DC (direct current) called anode and -ve pole of DC called cathode. When these two poles are brought together, and seperated for a small distance (1.5-3 mm) such that current continues to flow through a path of ionized particles, called plasma an electric arc is formed.

Since, the resistance of this ionized gas column is high, so more ions will flow from anode to the cathode. Heat is generated as the ions strike the cathode.

Arc Welding Equipments: most commonly used are:

- AC or DC power supply source
- Electrode holder
- Electrode
- Cable, Cable Connectors
- Chipping hammer
- Earthing clamps
- Wire brush
- Helmet
- Safety goggles
- Hand gloves
- Aprons, sleeves etc.

The main types of arc welding are:

- Carbon Arc Welding (CAW)
- Metal Arc Welding (MAW)
- Submerged arc welding (SAW)
- Tungsten Inert Gas welding or Gas Tungsten Arc Welding (TIG) (GTAW)
- Metal Inert Gas Welding (MIG) or Gas Metal Arc Welding (GMAW).

According to shielding these may also be classified as unshielded arc welding and shielded arc welding.

Unshielded Arc Welding: when a bare electrode as filler rod is used for welding it is said to be unshielded arc welding. In this case the deposited welding metal while in molten state absorbs oxygen from the atmosphere due to which the resulting joint is of poor quality and low strength.

Shielded Arc Welding: when coated electrodes are used for welding then it is called shielded Arc welding. The weld made from coated electrodes are free from blow holes and produce better quality and much stronger welded joints.

Polarity in Arc Welding.

Polarity is defined as the type of potential given to the workpiece or electrode. In case of direct curren power source, positive and negative terminals are fixed whereas in case of alternating current (A.C.), power source, positive and negative terminals are not fixed i.e. the terminal which is +ve during one half of cycle becomes negative in another half. So polarity principle is applicable only in case of direct current power source.

Polarity are of following two types;

1. Straight polarity: In this, electrode is having -ve terminal while workpiece is connected to the +ve terminal of the direct current power source. It is also known as direct current straight polarity (DCSP)
2. Reverse Polarity; Here, electrode is connected to +ve terminal whereas workpiece is connected to -ve terminal of direct current power source. It is also know as direct current reverse polarity (DCRP).

Application: About 2/3 (67%) of total heat produced during welding is generated at +ve terminal while rest of total heat is generated at -ve terminal. So, if our job is thick, means we want more heat on workpie so we connect workpiece to the positive terminal hence we adopt straight polarity.

Similarly, if job is thin, means we want less heat on ~~electrode (generally)~~ job so we connect workpiece to the -ve terminal and hence we adopt reverse polarity.

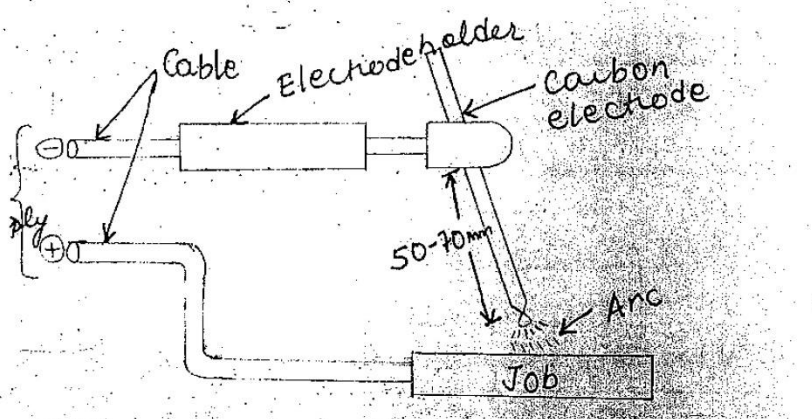
If our electrode is non-consumable, means we want less heat on electrode (generally) so connect electrode to the -ve terminal i.e. use straight polarity for doing welding.

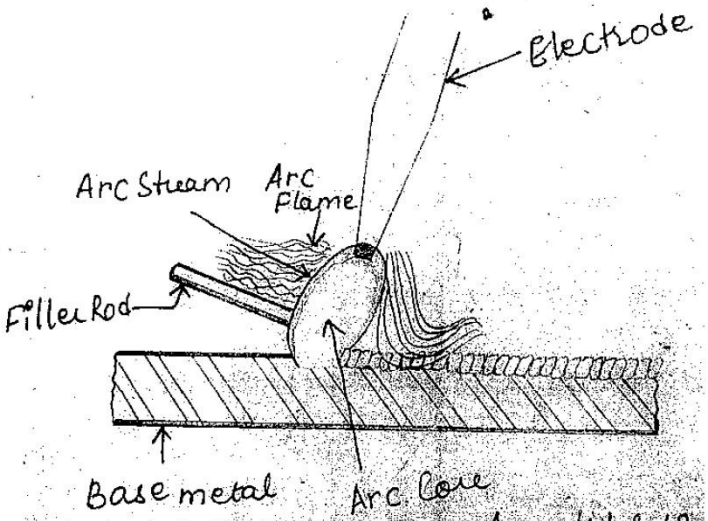
DCSP and DCRP are also called as Direct Current Electrode Negative (DCEN) and Direct current electrode positive (DCEP) respectively.

Carbon Arc Welding:

It is a fusion arc welding process in which welding heat is obtained from an electric arc produced between a carbon electrode (-ve terminal) and workpiece (+ve terminal). Welding may be carried out in air or inert atmosphere. Filler metal may or may not be used.

In this process, the electrode used is non-consumab so less heat is required at the electrode. That is wh it is made -ve terminal and workpiece the +ve terminal. About 67% of heat is generated on +ve termin and 33% on -ve terminal. Because the polarity is fixed so DC is usually used for welding. Because Carbon electrodes are cheaper than graphite electrod and also having long life more current carrying capacity and lesser electrical resistance, they are more preferred.





Principle of Carbon Arc Weldin

Advantages:

- Process is simple so less time is required to have good skill.
- It can be easily mechanized.
- Welding heat source and filler metal source are seperate. So better control is there.
- Total welding cost is less.

Disadvantages:

- Since DC is used so there are more chances of arc blow which give poor weld with blow holes and porosity.
- If by chance carbon is transferred from electrode, it causes a harder weld deposite in case of ferrous materials.

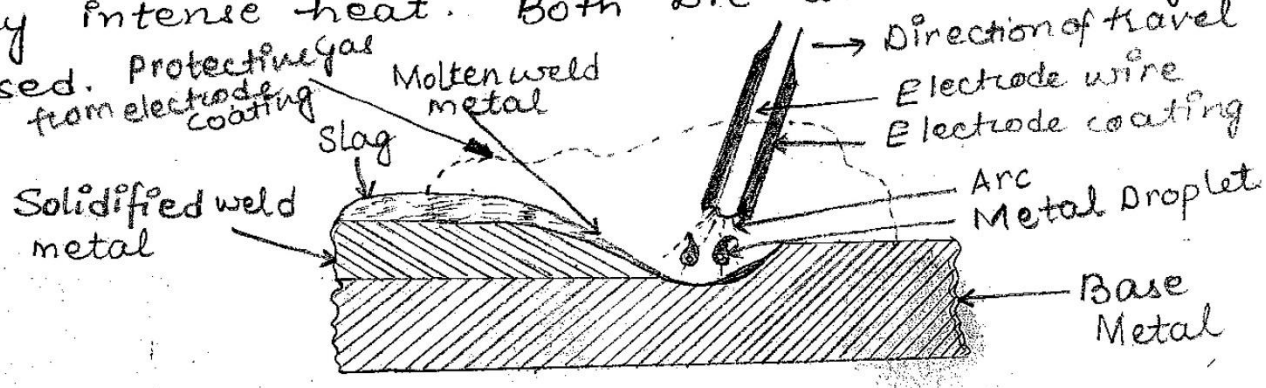
Applications:

- Used for welding cast iron, steel, copper, bronze galvenized iron, aluminium and for rough cutting of metal.
- Employed for brazing, preheating and postheating of welded joints.

Shielded Metal Arc Welding:

Here, the welding heat is produced from an electric arc set up between a flux coated electrode and the workpiece. The electrode is consumable so supplies the necessary filler metal. The covering on the electrode serves the purpose of flux.

During the welding process, the metal electrode is melted by the heat of arc and fuses with the workpiece. The temperature produced by the heat is about 2400°c to 2700°c. The arc temperature and thus the arc heat can be increased or decreased by employing higher or lower arc currents. A high current arc with a smaller arc length produces a very intense heat. Both D.C. and A.C. may be used.



Advantages:

- The welding equipment is simple, less costly, and portable.
- Welding can be carried out in any position with highest weld qualities.
- Wide varities of electrodes are available.
- Total welding cost is less.

Disadvantages:

- The length of each electrode is limited and when new electrode is used, proper cleaning has to be done which decreases the welding speed.
- Welding control is difficult as compared to MIG welding.
- If the covering absorbs moisture, the moisture causes the porosity defect.
- Because of flux coating, chances of slag slag entrapment are more.

Applications:

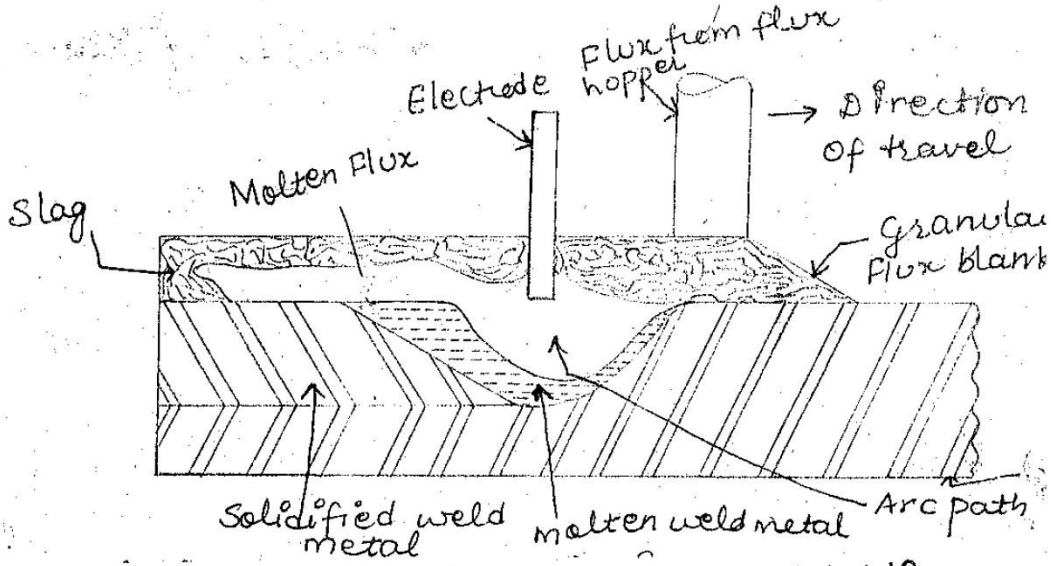
- It is used both as a fabrication process and for maintenance and repair jobs.
- It is also used in shipbuilding, pipelines, buildings and bridges construction, tanks, boilers, automotive and aircraft industries etc.

Submerged Arc Welding :

In this welding process a consumable bare electrode wire is fed continuously and automatically from a roll of wire (maintained on a wheel). In the welding zone electric arc is produced between the electrode and workpiece.

This is also known as hidden arc or subarc welding. The arc, end of the electrode and molten pool remain completely hidden and are invisible because these are submerged under a granular material (flux). The continuously fed bare metal electrode melts and acts as filler rod. As the weld proceeds, the fused flux solidify to form a protective covering slag which cracks off on cooling and can be easily removed while the unused flux is collected by vaccum system and reused.

Normally DC is employed using 600 to 1000 A current for welding alloy and stainless steel, although AC is preferrable for low-carbon steel. The current for AC is usually 2000 A.



Principle of Submerged Arc Welding.

Advantages :

- Partly because it is automated, it is much faster than regular arc welding.
- Operator is not exposed to usual spatter and can work without helmet and other safety equipments.
- Fewer passes are required due to deep penetration and more disposition rates.

- No edge preparation is required.
- Less distortion
- Very neat appearance and smooth weld shapes can be obtained.

Disadvantages:

- Since the arc, end of the electrodes remains completely hidden, so jigs, fixtures, accessories and pointers are required to ensure proper welding at the joint.
- Flux needs preplacing which is not always possib
- It is not economical for smaller welds and for thin pieces.
- Welding equipment is costly.
- Flux consumption is very much.
- It is limited to welding in flat position only
- Cast iron, Al alloys, Mg alloys cannot be welded by this process.

Applications

- Welding of bridge girders, railroads, structural shapes, pressure vessels, pipes and structure of railways coaches and Locomotives.
- shipbuildings, automotive industries, nuclear power industries etc.
- Welding metals like mild steel, low alloy steel etc.

Use of A.C. and D.C. in arc welding.

Based on the suitability, any of the A.C. or D.C can be used in arc welding process.

In A.C., there is no fixed polarity at the terminal and they interchange in every cycle. Also the alternating current acquires zero value twice in each cycle. At these particular moments, the potential difference between the terminals is also zero and hence a higher voltage is required to maintain the arc at this moment.

Unlike A.C., in D.C. welding the electrode acts as one terminal and the job the other terminal. The potential difference can be so adjusted that the heat developed at the positive terminal is higher, nearly $\frac{2}{3}$rd and that on the negative terminal lower, nearly $1/3$rd of the total heat evolved.

Polarity is a very significant factor in all D.C. welding works. This polarity can be of two types:

1. Straight polarity : In this, the electrode forms the negative terminal and the workpiece +ve. This is also known as Direct current electrode negative (DCEN).

2. Reverse polarity: In this, the electrode forms the positive terminal and the workpiece negative. This is called as Direct current electrode positive (DCEP).

Tungesten Inert Gas (TIG) or Gas Tungsten Arc Welding (GTAW)

It is basically an arc welding process in which the arc is struck between a non-consumable tungsten electrode and the base metal.

The electrode is held in a special type of electrode holder which is so designed that apart from holding the electrode, it also carries a passage around the electrode for flow of inert gas to provide the protective shield around the arc.

Argon is normally used as it requires a lower arc voltage, easier arc starting and provides a smooth arc action. Helium is used where higher heat input is required.

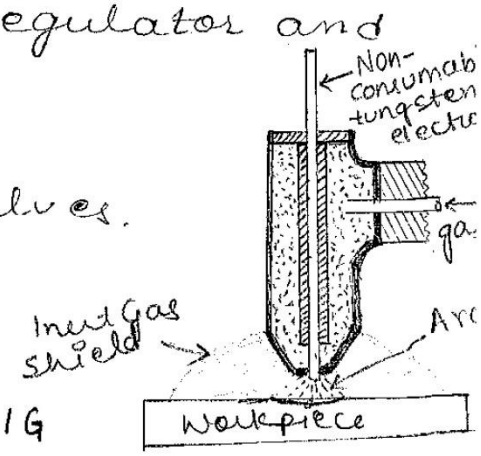
Welding operation is done by striking an arc between the workpiece and tungsten electrode in an atmosphere of inert gas. After striking the arc, it is allowed to impinge on the job and a molten weld pool is created.

Filler metal, if required should be added by dipping the filler rod in weld pool.

Both AC and DC power sources can be used.

Equipments

- Welding torch, tungsten electrode and filler metal.
- Welding power source, high frequency unit, DC suppressor unit and cable.
- Inert gas cylinder, pressure regulator and flow meter.
- cooling water supply
- Water and gas solenoid valves.



TIG

Advantages

- No flux is used so no danger of flux entrapment
- Clear visibility of the arc, so better control.
- It can weld in all positions.
- High quality of weld for thin materials (as thin as 0.12,5 mm)
- Heat affected zone is very less.
- Unlike metals can be welded to each other like mild steel to stainless steel, brass to copper etc.

Disadvantages

- Tungsten, if transfers can contaminate the weld pool.
- Filler rod end if by chance comes out of the inert gas shield can cause weld metal contamination.
- Equipments costs are higher than flux shielded metal arc welding.
- Electrode is non-consumable, so seperate filler rod is needed, so there is decrease in welding speed.

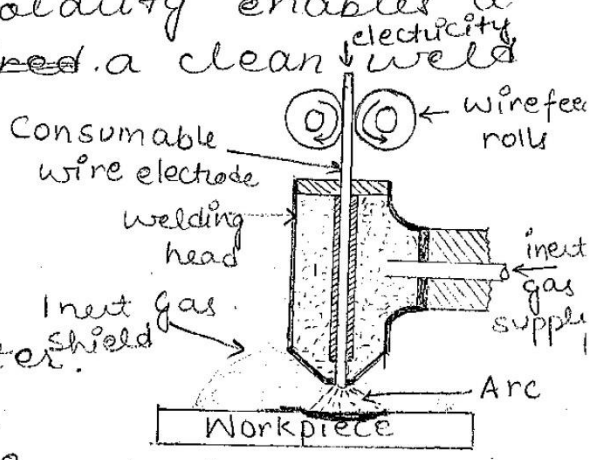
Applications

- Welding of carbon steel, stainless steel, nickel, aluminium, magnesium, brass, copper bronze, titanium etc.
- Welding of sheet metal and thinner section
- Used in aircrafts, rocket motor chambers, transistor cases, and instrument industries.

Metal Inert Gas (MIG) or Gas Metal Arc Welding (GMAW)

MIG involves welding of metals using a consumable metal electrode in an inert gas atmosphere. The electrode is in the form of a continuous wire which is fed into arc, by an adjustable speed electric motor, at the same speed at which it is melted and deposited in the weld.

Usually, D.C. with reverse polarity is used in MIG welding. AC is not used in this method. Even D.C. with straight polarity is not often used. Use of D.C. reverse polarity enables a deeper penetration and ~~required~~ a clean weld surface.



MIG

Equipments:

- An inert gas cylinder
- Gas regulator and flowmeter.
- Gas hoses and connections.
- A power source and welding leads.
- MIG welding gun.
- A spool of electrode wire.
- Electrode wire feeder.
- Water supply with water hoses.

Advantages

- GMAW doesnot require the high degree of operator skill.
- Continuous welding at higher speeds and in all positions with deeper penetration is possible
- Thick and thin, both types of workpieces can be welded effectively.
- The process can be easily mechanized.
- Since flux is used so more visibility, neatness cleanliness, spatter free weld.

Disadvantages :

- Welding equipment is more complex and more cost
- The metallurgical and mechanical properties of th joint may be affected due to high cooling rate
- It is difficult to weld in small corner.
- Process variables are more.
- It is less suitable for outdoor work because stro wind may blow away gas shield.

Applications

- It is suitable for welding variety of ferrous and non-ferrous metals.
- Metal fabrication industries, shipbuildings, automobiles, pressure vessel industries etc.
- Welding tool steels and dies.

Comparison between TIG and MIG

Common points of TIG and MIG are :

- Both use same gases for shielding depending on the metals to be welded.
- Both can be used for welding metals like stainless steel, non-ferrous alloys and aluminium.
- Gas flow and its controls are same in both.
- cleaning the weld is important in both cases
- No flux is required for both.

Differences between TIG and MIG.

TIG	MIG
1. TIG welding uses a permanent, non-consumable tungsten electrode.	MIG uses consumable continuous coil electrode of same chemical composition as the material being welded.
2. TIG welding electrode serves the purpose of producing the arc only. Filler rod is added seperately.	MIG welding electrodes serves both the purpose of producing the arc as well as of filler metal.
3. TIG is not as fast as MIG because in this, seperate filler rod is used.	MIG is fast as compared to TIG because electrode and filler metal is same, which is in the form of wire.
4. TIG welding requires a skilled operator.	No so much skill is required for an operator.
5. If filler metal is added, operator's both hands are engaged. So work must be held in position with clamps or fixtures.	In MIG welding, the wire electrode and gases come from the same run and thus can be made easily automatic.
6. It uses DCSP but in case of welding thin sheets DCRP is used.	MIG uses both types of polar Generally DCRP is used.
7. TIG welding torch is water cooled.	Generally no water cooling is necessary.
8. Penetration is not so much deeper as with MIG	Deeper penetration can be obtained as compared to TIG.
9. TIG is not used oftenfor welding plates thicker than 6 mm.	It is best suited for thick (more than 6 mm) jobs.

Resistance Welding.

Resistance welding is a group of welding processes in which welding heat is obtained from the resistance of the work to the flow of electric current and by the application of pressure. No filler metal or flux is added.

Principle of Resistance welding:

In this, a low voltage (typically 1 volt) and very high current (typically 15000A) is passed through the joint for a very short time (typically .25s). This high amperage heats the joint because heat generated in resistance welding can be expressed as:

$$H = I^2RT$$

where H = Total heat generated in the work

I = Electric current, Amp.

T = Time for which current is passing through the joint, sec.

R = Resistance at the joint.

Resistance of the joint is composed of:

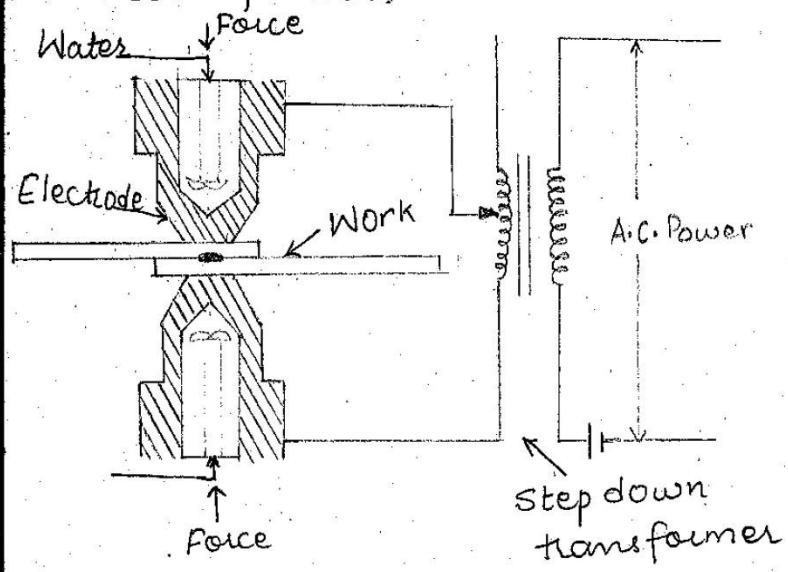
- Resistance of the electrode. (R_1)
- The contact resistance between the electrode and the workpiece (R_2)
- The contact resistance between two pieces (R_3)
- The resistance of the work piece plates (R_4)

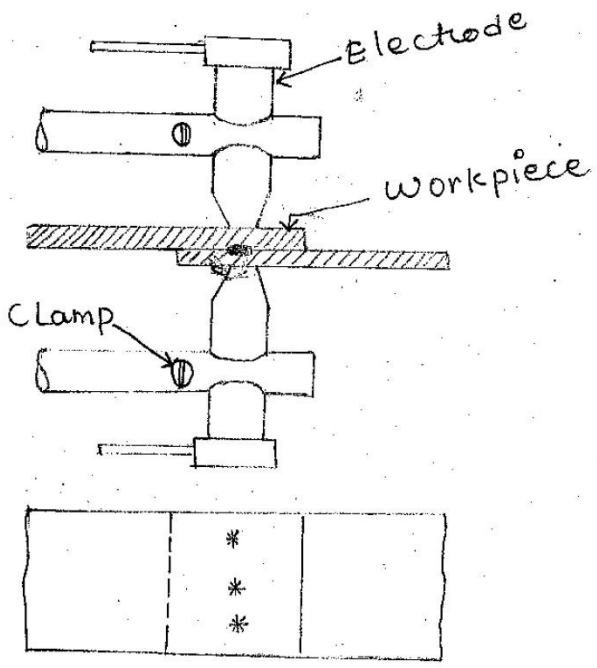
In order to obtain a sound weld and to avoid overheating of welding electrodes; R_1, R_2 and R_4 should be kept as low as possible compared to R_3.

Types of Resistance welding:

- Spot welding
- Seam welding
- butt welding
- Percussion welding

Spot Welding: is a resistance welding process in which overlapping sheets are joined by local fusion at one or more spots by the heat and pressure is applied by the electrodes one above and other below the workpieces.





Advantages:

- Low cost.
- Less skilled worker can perform this welding.
- Higher productivity.
- operation may be made automatic or semiautomatic
- No edge preparation is needed.

Applications:

- Welding of low carbon steels, high speed steels, stainless steels, Al, Cu, nickel etc.
- In automobile and aircraft industries
- steel household furnitures.
- Containers.

Advantages of Resistance Welding:

- Very little skill is required to operate the resistance welding machine.
- High production rate so well suited for mass production
- Heating of workpiece is confined to a very small part, which results in less distortion.
- No filler rod and flux is needed.
- It is possible to weld dissimilar metals as well as metal plates of different thickness.
- Semi-automatic equipments are available.
- There are no consumables used in this process except for the electrical power and relatively small electrode wear. As a result it is very economical process.

Disadvantages of Resistance Welding

- The initial cost of equipment is high.
- Certain resistance welding operations are limited only to lap joints.
- Skilled persons are needed for maintenance
- Bigger job thickness can not be welded.

Applications:

- Joining sheets, bars and tubes.
- Making fuel tanks of cars, tractors etc.
- Making metal furniture.
- Making containers.
- Welding aircraft and automobile parts.

Projection Welding

Projection welding is one of the advancement of spot welding, where one of the sheet to be joined has a number of projections to help localise the current at a predetermined spot. Thus, the surfaces of the workpieces are in contact with each other only at the projections.

As the current is switched on, it will pass through these projections. Because of heat produced due to resistance to the flow of electric current, these projections are melted and are pressed together to complete the weld, by pressing the upper electrode downward. The melted projections form the weld. Welding can be done at several points simultaneously. The projections are generally very small of the order of 0.8mm and are obtained by means of embossing.

Advantages:

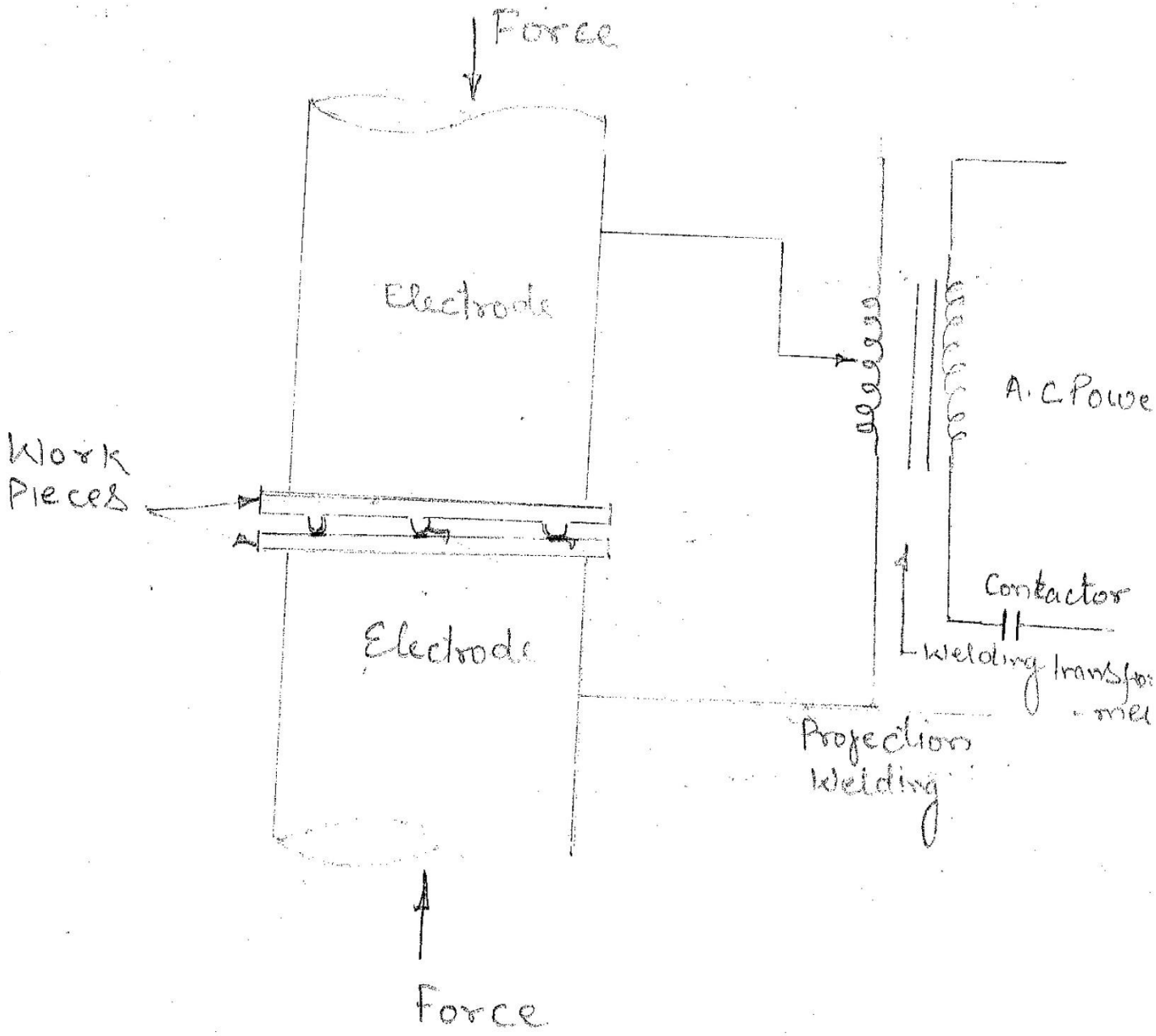
- More than one spot can be welded simultaneously.
- The welds may be placed closer than spot welding.
- Proper heat balance can be easily obtained. Projections are to be made in thicker plate or in the plate which is having higher electrical conductivity.
- Life of electrode is much longer than the life of electrode in spot welding.
- The uniformity and appearance of the weld is better as compared to spot welding.

Disadvantages:

- Making of projections is an extra operation.
- All projections should be of same height.
- Metals, which cannot support projections, cannot be welded satisfactorily.

Application:

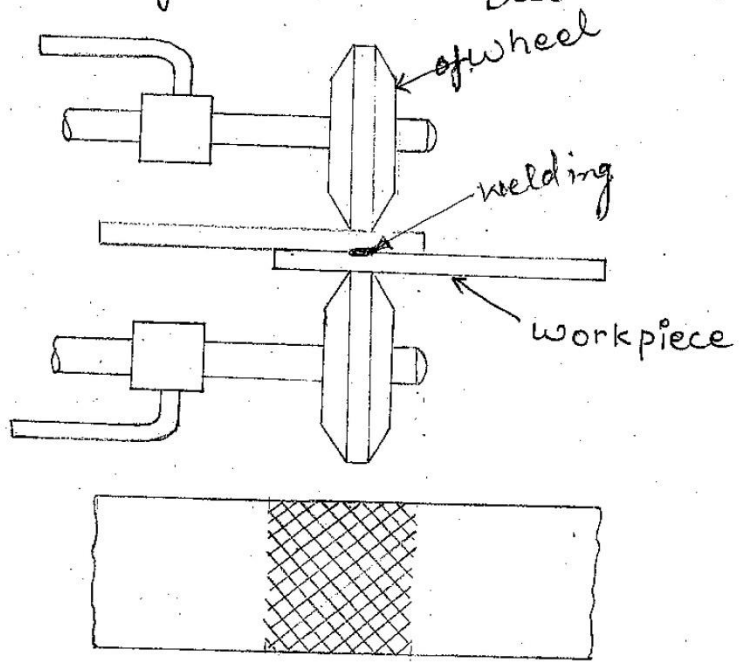
- Small fasteners, nuts etc. can be welded to larger components.
- It is used for welding of refrigerator condensers, joining of wires etc.
- Welding of stainless steel parts, titanium alloys, monel alloys etc.



Principle of projection welding

Seam Welding :

In this overlapping sheets are joined by local fusion progressively along a joint by rotating the circular electrodes. Fusion takes place because of heat which is generated, from the resistance to electric current flow through the work parts which are held together under pressure by electrodes.



Advantages of Seam Welding :

- It can produce gas tight or liquid tight joints.
- Overlap can be less than spot or projections weld.
- Several parallel seams may be produced.

Disadvantages of Seam Welding :

- Cost of equipment is high as compared to spot welding set.
- Welding can be done only along a straight or uniformly curved line.
- It is difficult to weld thickness greater than 3mm.

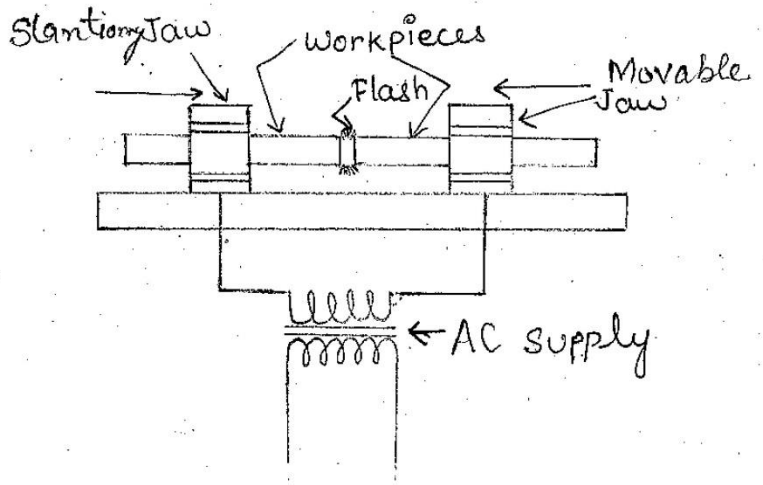
Applications :

- Used for welding of stainless steels, aluminium and its alloys, nickel and its alloys and magnesium alloys etc.

Butt welding: is of two types:

1. Flash butt welding: Here the heat required for melting is obtained by means of an arc rather than simple resistance heating.

The edges to be welded are brought in light contact. A high voltage starts a flashing action between the two surfaces and continues as the parts advance slowly and the forging temperature is reached. The upsetting action forces out the impurities caused by flashing. This forced-out metal is called the flash



Advantages:

- It consumes less welding current than upset butt weld process.
- Flash welding offers strength factor upto 100%
- Preparation of weld surface is not required.
- The process is cheap.
- It is faster process.

Disadvantages:

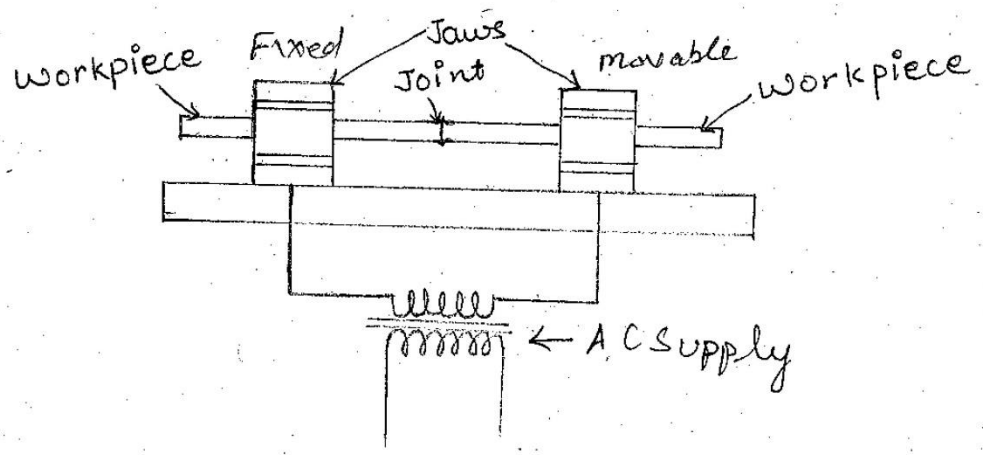
- Concentricity and straightness of workpieces during welding is difficult to maintain.
- The shape of workpieces should be similar which is not always possible.
- chances of fire hazards are there.
- Flashes may cause eye trouble.

Applications:

- used for welding of bar, rods and tubes.
- Used for welding of saw blades into continuous loops, taps and reamers to alloy steel shanks.

2. Upset butt welding :

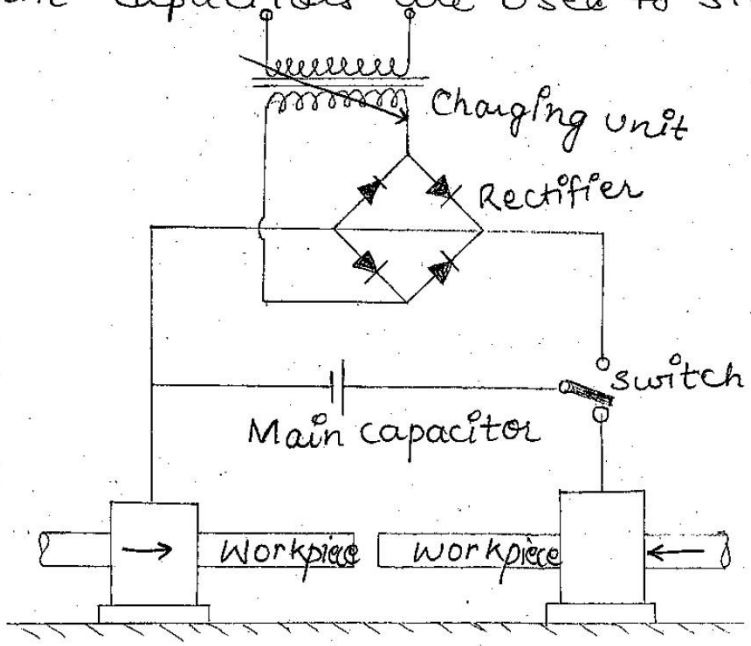
In this, the two pieces to be joined are held tightly together and current is applied, so that the heat is generated over the entire area of abutting surfaces. Pressure is applied throughout the heating period. This pressure is later on increased when the welding temperature has been reached.



Applications :

- In wire drawing industries.
- For producing butt joints in tubes, pipes, rods etc.

Percussion Welding : In this, welding heat is obtained from an arc produced by a rapid discharge of stored electrical energy. Pressure is applied percussively (rapidly) during and immediately following the electric discharge. The electrostatic capacitors are used to store the electrical energy.



Advantages:

- Arc temperature is more as compared to flash butt welding.
- Strong joints are produced.
- There is no or very less upsetting.

Disadvantages;

- This process is limited to butt welds only.
- Equipment used for this purpose is quite expensiv
- The equipment must be extremely rugged and provided with accurate holding fixtures and sensitive timing devices etc.

Applications:

- Used for welding stellite tips to tools, silver contact tips to copper, copper to aluminium etc.
- It is used in telephone industries.
- Also used for welding fine wire leads to filaments in lamps etc.

Atomic Hydrogen Welding

Atomic hydrogen welding is a thermo-chemical weldi process in which exothermic reaction takes place whic produces the necessary heat for welding.

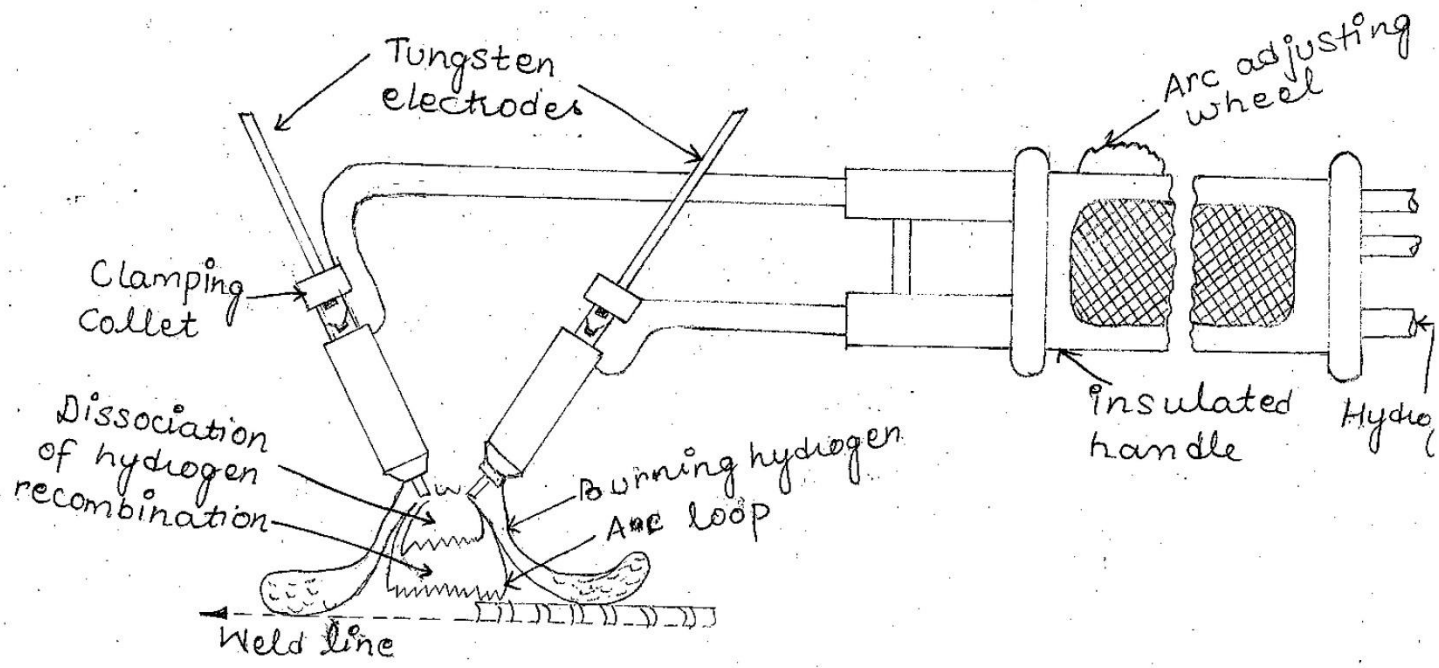
The heat is obtained from an electric arc maintaine between two tungusten electrodes in an atmosphere of hydrogen, which also acts as a shielding gas.

Filler rod and pressure may or may not be applied depending upon the requirement.

Principle:

This process combines gas welding with electric arc welding. The electrode holder consists of two electrodes arranged in inclined position and the hydrogen nozzle is in between the tips of these electrodes to eject the hydrogen. The electric arc between the electrodes breaks down the molecular hydrogen into atomic hydrogen.

The atomic hydrogen, when touches the relatively cold metal, recombines into molecular hydrogen, thus liberating considerable heat, which melts the metal to be welded.



Equipment:

- Welding torch with tungsten electrode.
- Hydrogen gas supply (cylinder, pressure regulator, hoses etc)
- A.C. power supply.

Advantages:

- High heat concentration is available.
- H_2 gas itself acts as a shielding gas
- The job is seperate from the electric circuit.
- smooth, uniform, strong and ductile welds can be obtained.
- H_2 gas also cools the electrodes.

Disadvantages

- welding speed is less
- Operation cost is high.

Applications:

- used in die repairs, welding of stainless steel, aluminium etc.
- Also used to apply carbides and many hard facing alloys on soft metals.

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Difference between AC and DC Welding (Arc) :

A.C. arc welding	D.C arc welding
Transformer is power source.	1. Motor generator or AC, DC rectifier set
AC across the arc.	2. DC across the arc.
Uniform heat distribution across the arc.	3. Heat distribution 2/3 at positive pole and $\frac{1}{3}$ at negative pole.
4. The arc is unstable.	4. Arc is quite stable.
5. Output depends on voltage supplied.	5. Not affected by normal neutron in power supply.
6. Cheap in cost.	6. Costly.
7. No moving parts in transformer.	7. Number of moving parts are needed to convert AC to DC.
8. Not suitable for light coated electrodes and for light sheet gauge work.	8. Suitable for all types of work and uses all types of electrodes.
9. Only ferrous metals can be welded as polarity does not exist.	9. By changing the polarity both ferrous and non-ferrous metals can be welded.

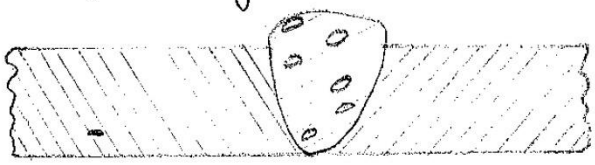
Gas welding	Arc welding
1. The heat of welding is obtained by the combustion of fuel gas.	The welding heat is obtained from an electric arc between electrode and work.
2. The highest flame temperature that can be reached is 3200°C.	The temperature produced by an electric arc is about 5500°C.
3. Gas welding is classified into three types : oxy-acetylene, oxy-hydrogen and air-acetylene welding.	Arc welding is of six types : carbon, metal, submerged, inert gas arc welding, atomic hydrogen welding and stud welding.
4. Heat transfer is slow, hence the welding speed is low.	Welding speed is better than that of gas welding.
5. There is a possibility of explosion if the equipments are not properly handled.	Arc welding is safer than the gas welding.

WELDING DEFECTS

During welding process various defects can creep in the joint which include porosity and blow holes, slag inclusion and incomplete fusion etc. These defects along with their causes and remedies are explained below.

1. Porosity and Blow Holes

The trapping of gases in the weld bead leads to a formation of a group of small voids which is known as porosity. These gases may get produced due to electrode coating, ingredients, oil, rust, dust etc.



When the voids formed in the weld bead are comparatively larger, these are known as blow holes.

Causes:

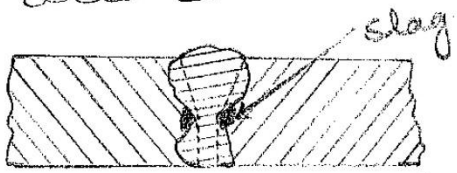
- High welding speed
- Dirty base metal
- Electrode with damp and damaged coating.
- Improper arc length, welding current, welding Technique.
- Excessive hydrogen, nitrogen or oxygen in welding atmosphere.

Remedies:

- Reduced welding speed to allow time for gases to escape.
- Clean the base metal properly.
- Proper electrode should be used.
- Use proper arc length, welding current and welding technique.
- Use filler metal having high content of deoxidizers.

2. Slag Inclusion

Flux used in welding reacts with impurities and forms a slag. The mixing of this slag with weld bead is called slag inclusion. Slag inclusion are compounds such as oxides, fluxes and electrode coating materials that are trapped in the weld zone.



Causes:

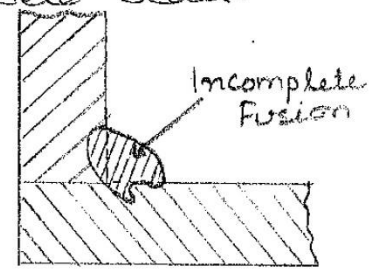
- Slag removal is not proper.
- Longer arc length.
- Less electrode angle, slow speed and too large electrode.
- Oxide inclusions.
- Improper joint design.
- Entrapped pieces of electrode covering.

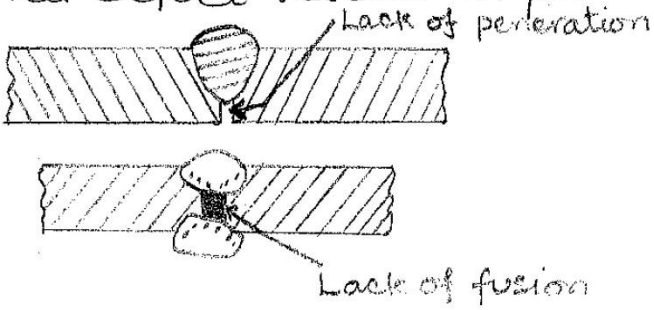
Remedies:

- Clean surface and previous weld bead properly.
- Use proper arc length.
- Use more electrode angle, more speed and small electrode.
- Providing proper gas shielding.
- Use fresh and proper electrode.

3. Incomplete Fusion and Penetration

If the molten metal does not mix (fuse) properly with the base metal that defect is called incomplete fusion or lack of fusion. This defect results in poor weld beads.





Incomplete penetration occurs due to insufficient depth of the welded joint.

Causes:

- Less arc current
- Faster arc travel speed
- Longer arc length
- Electrode diameter too large.
- Improper electrode position
- Improper joint design.

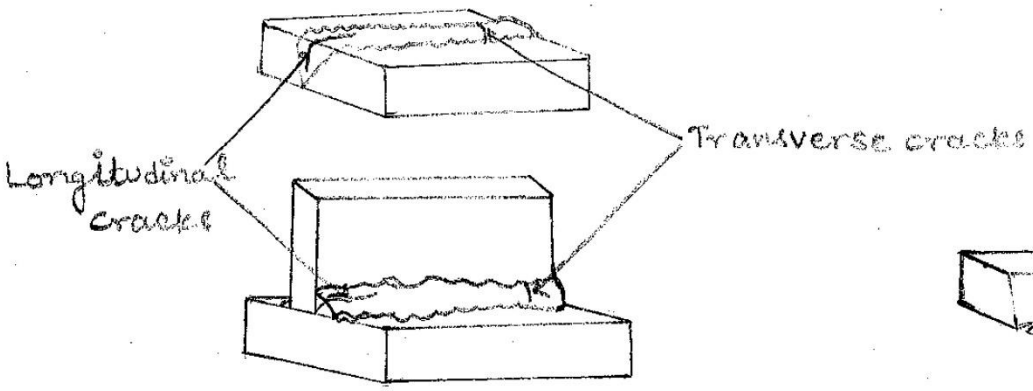
Remedies:

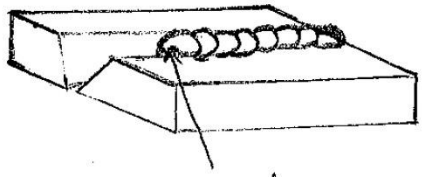
- Use proper arc current
- Use less arc travel speed
- Use shorter arc length.

- Use small electrodes.
- Maintain proper electrode position.
- change or redesign the joint.

4. Cracks

Cracks may occur in various locations and directions in the weld area. Cracks may appear in the crater, under bead, base metal or in the root. Cracks are classified as hot or cold. Hot cracks occur while the joint is still at elevated temperatures. Cold cracks develop after the weld metal has solidified.





Causes:

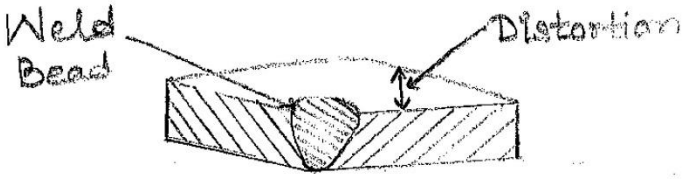
- High cooling rate
- Hydrogen content produced because of damp coating or rusty and wet workpiece.
- Small weld bead
- Residual stresses
- Low ductility.

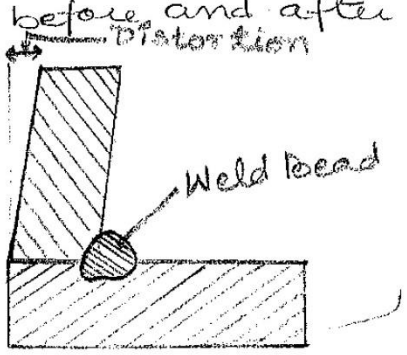
Remedies:

- Cooling rate should be reduced.
- Use fresh electrodes or baked electrodes.
- Increase electrode size, raise welding current, reduce travel speed.
- Reduce the residual stresses by preheat or mechanica or apply intermediate stresses relief heat treatmen
- Use pre-heat, anneal the base metal.

5. Distortion

The change in shape and difference between the positions of the two plates before and after welding is known as distortion.





Causes :

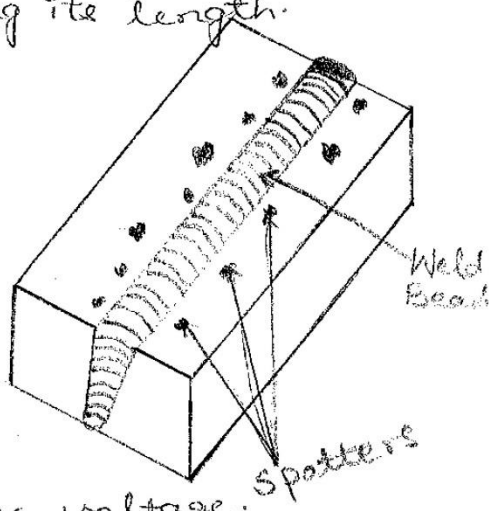
- High cooling rate
- Small diameter electrode
- Residual stress
- Poor clamping and fixtures
- slow arc travel speed.

Remedies :

- cooling rate should be reduced.
- Use proper diameter electrode
- Reduce the residual stresses
- Use proper clamps, jigs and fixtures
- Maintain proper arc travel speed.

6. Spatter

spatter refers to small particles of metals, which are scattered around the weld along its length.



Causes :

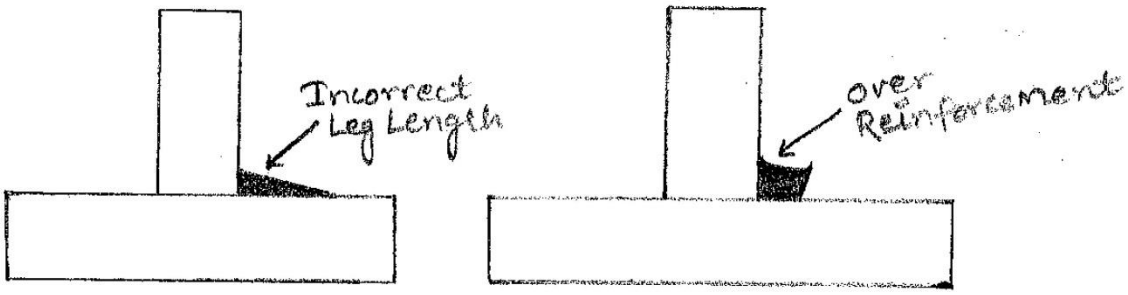
- Use of excessive current
- Use of too long arc length
- Damp electrodes
- Arc blow
- Use of too high arc voltage.

Remedies :

- Use proper welding current
- Use proper arc length and lower arc voltage.
- Use fresh or baked electrodes.
- Reduce arc blow (use A.C. if possible)

7. Poor Weld Bead Appearance

If the weld bead deposited is not straight, width of bead is not constant, ripples are not consistent, then the weld bead is called poor.



Causes :

- Arc length being not constant
- Improper welding technique
- Damaged electrode coating
- Poor earth and electrode holder connections.

Remedies:

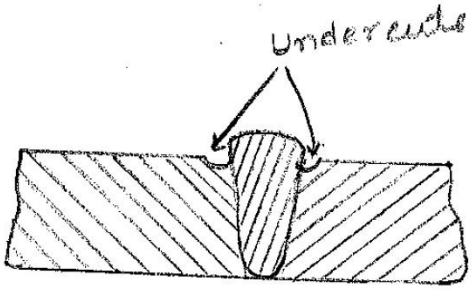
- Maintain constant arc length throughout the weldi
- Use proper welding technique.
- Use fresh electrodes.
- Proper earth and electrode holder connections.

8. Undercutting.

The formation of groove in the parent metal along the sides of the weld bead is called undercutting. This defect weakens the weld.

Causes:

- Higher current
- Too large electrode diameter.
- Excessive weaving.
- Faster arc travel speed.



Remedies:

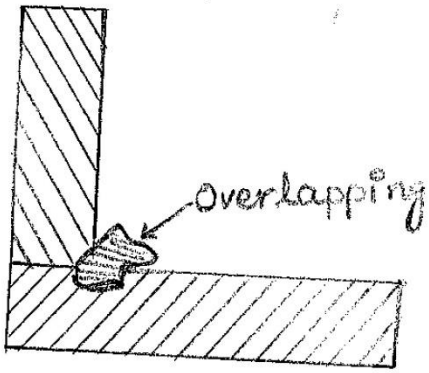
- Use proper current
- Use proper electrode
- Weaving should be proper and as per requirement.
- Maintain proper arc travel speed.

9. Overlapping

If the molten metal from the electrode flows over the parent metal surface and remains there without getting properly fused, that defect is called overlapping.

Causes:

- Lower arc current
- Slower arc travel speed.
- Improper joint geometry
- Longer arc.



Remedies:

- Maintain and use proper arc current
- Maintain proper arc travel speed
- Use proper joint geometry
- Use proper arcs.

Brazing and Soldering.

Brazing: is a process of joining two pieces of a metal in which a non-ferrous alloy is introduced in a liquid state between the workpieces to be joined and allowed to solidify.

The melting point of the filler metal is above 450°C but lower than the melting temperature of parent metal and this filler material is known as spelter.

Fluxes are also added into the brazed joint to remove any of the oxide present or prevent the formation of oxides.

The fluxes generally used are combinations of borax, boric acid, chlorides, fluorides and other wetting agents.

Brazing Equipments:

- blow pipe
- brazing heath.

Types of Brazing:

Based on the way actual heating is done, brazing is of four types:

1. Torch Brazing: is very common and heating is done by a blow torch.
2. Furnace brazing: is carried out in controlled atmosphere.
3. Resistance brazing: is done on some small parts in production.
4. Immersion Brazing: is used in large scale productio

Filler metals used are:

- Aluminium silicon
- copper phosphorus
- copper zinc
- silver
- magnesium
- Nickel etc.

Brazing Procedure:

- Clean and prepare the surface to be brazed. cleaning may be done by solvents, acids pickling and by mechanical means.
- Flux both the base metal and filler metal surface by spraying, brushing or by mechanical means.
- Align the base metal parts to be joined.
- Heat the joint. Heat sources used are a molten bath of brazing filler metal, oxy-acetylene torch, electrical resistance heating or induction heating.
- Apply filler metal to the joint.
- Allow cooling of the brazed joint.
- Remove flux residue from the completed joint.

Advantages

- Distortion is less in brazed joints because of lower temperature used.
- The joint can be quickly finished without much skill.
- Brazing can join cast metals to wrought metals.
- Sheet metal assemblies can be joined.
- It has the ability to preserve metal coating.

Disadvantages:

- It requires tightly mating parts.
- It requires proper cleaning.
- Size of the jobs are limited.
- Joints are not successful at elevated temperatures.
- Colour of filler metal may not match with base metal.

Applications:

- Brazing is used for fastening of pipe fittings, tanks carbide tips on tools, radiators, heat exchangers and electrical parts etc.
- Used to join Band saws, parts of bicycle such as frame and rims.
- It is used to join dissimilar metals and also porous metal components.

Soldering: is a process of joining two pieces of metals in which a fusible alloy or metal having melting point below 450°C is introduced in a liquid state between the workpieces to be joined and allowed to solidify.

It is similar to brazing the difference being the use of a softer filler material known as solder. It gives a less stronger joint than brazing.

Composition of some of solders is:

Soft solder: Lead 37% and tin 63%

Medium solder: Lead and tin each 50%

Electrician solder: Lead 58% and tin 42%

Plumber's solder: Lead 70% and tin 30%

Fluxes are added to remove the oxides from the joints. These are:

- Inorganic fluxes (corrosive flux): consists of Zn and NH_4Cl.
- Organic fluxes (Mild fluxes): consists of lactic acid stearic acid, benzoic acid, glutamic acid etc.
- Rosin (Non-corrosive flux): consists of gum extruded from pine trees.

Types of soldering:

soldering is divided into two classifications:

1. Soft soldering: is used extensively in sheet-metal work for joining parts that are not exposed to the action of high temperatures and are not subject to excessive loads and forces.
   It is employed for joining wires and small parts.

2. Hard soldering: employs solders which melt at higher temperatures and are stronger than those in soft soldering. The temperature of various hard solders vary from 600°C to 900°C.
   In this, a blow torch constitutes the equipment.

Soldering Procedure:

1. Select the right solder, flux, joint design and clearance.
2. Clean and prepare the surfaces to be joined.
3. Align the components.
4. Coat the surfaces with flux.
5. Take a blob of solder on the bit of the hot soldering iron and allow it to run down till filling the recess of joints for light work.

   For heavy work the hot iron should be held against the soldering stick and molten solder be allowed to fill the longer length of the joint.
6. Wipe off excess of solder with a piece of felt or cotton waste.
7. Wash the joint thoroughly with warm water to remove the traces of acid flux.

Applications of Soldering:

In practice, it is done for the following work;

- Connections in wireless sets (radio), TV sets etc.
- Wiring joints in electrical connections, battery and other terminals.
- Radiator brass tubes for motor car.
- Copper tubing carrying liquid fuel, gas or air used on engines.
- Brass halved bearings are joined with solder when relined with white metal and bored on lathe.
- It is sometimes used to repair utensils.

SOLDERING

Soldering is defined as the joining process in which joint is made by using filler metal having melting point not more than 400°C. The filler metal used is called solder. It also requires an appropiate flux which is applied at the surfaces to be joined and on the solder iron. The purpose of applying flux is to prevent the oxidation of metal to be soldered.

Flux may be organic or inorganic substance. the common examples of flux are zinc chloride, Ammonium chloride and muriatic acid. Flux should have some characteristics such as it should melt at soldering temperature and it should be light in weight so that it can be displaced by molten solder material easily.

Solder i.e filler metal is the alloy of metal having low melting point. The most popular solder metals are alloy of tin and lead, silver and antimony, lead and silver and tin and silver. Solder is called <u>soft solder</u> if its melting point is comparatively much lower than the metal to be soldered and the process is then called <u>hard soldering</u>.

<u>Procedure of soldering</u>:- The procedure of soldering is as follows:-

1) The parts to be joined are throughly cleaned by filing, scraping, etc cleaning is necessary to get a good strong soldered joint.

(2) The pieces of the metal to be joined are heated to the required temperature.

3) Applying the flux, usually zinc chloride or other commercial flux in the form of Paste.

4) The pieces are then bevelled with the end of the solder stick or wire kept in contact with the fluxed surface.

(13)

5) Heating the soldering iron bit either electrically or by means of stove.

6) picking up the required quantity of solder and spreading over the surface and gap to be soldered.

7) Applying the flux over the electrically heated soldering iron the joints are thoroughly cleaned and soldering is carried out with the soldering iron.

ADVANTAGES :-

(1) soldering is widely used in Electronic applications because a suitable soldering provides electrically conductive strong joint.

2) soldering can be used to join various metals and of varying thickness.

3) Automated Equipments used in soldering give high rate of production.

4) Both similar and dissimilar material can be joined.

Disadvantages :-

(1) Mechanical strength of soldered joint is very low so it cannot be used to carry load.

2) It can not withstand heat due to low melting point of solder.

3) Not suitable for joining parts which require much strength or the parts that are subjected to vibration or heat.

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Soldering methods/ Types

The following are the important soldering methods based on different modes of heating:

- Iron soldering
- Torch soldering
- Dip soldering
- Wave soldering
- Induction soldering
- Resistance soldering
- Ultrasonic soldering
- Furnace soldering

(14)

1 Iron Soldering

The iron soldering method uses a soldering iron and is the most commonly used method of manual welding. The copper tip of the soldering iron can be heated electrically or by oil, coke or gas burners. But external heating consumes more time and hence it is heated by electrical resistance of the solder tip. The solder is melted by touching it to the tip of the soldering iron and is applied where the joint is requried to be made. Generally the tip of the soldering iron is coated with iron to increase its life.

.2 Torch Soldering

Torch soldering uses oxyacetylene or air-acetylene torch for heating and is used widely for soldering copper tubing to copper fittings.

.3 Dip Soldering

Dip soldering uses a solder-bath maintained at a desired temperature and is used when soldering needs to be performed in one go since the parts to be joined are dipped in the solder-bath. It finds extensive application in joining wire ends in electronic industry, soldering automobile radiators, and tinning.

.4 Wave Soldering

Wave soldering uses the wave pattern of the molten solder (solder-bath) for joining the parts and is used mostly in electronic industry for the production of electronic circuit boards.

.5 Induction Soldering

Induction soldering uses the heat produced by induced current and is used when large numbers of identical parts are required to be soldered.

.6 Resistance Soldering

Resistance soldering uses the resistance of the workpiece to get the desired heat.

.7 Ultrasonic Soldering

Ultrasonic soldering uses high frequency vibrations as heating source and is used to solder the return bends to sockets of aluminium air-conditioner coils.

.8 Furnace/Oven Soldering

Gas or electric furnaces are used in soldering only when a number of joints are required to be produced to increase the production rate and the assembly is complex making other methods of heating the joints impractical.

4) Aluminium and stainless steels are difficult to solder because of the strong, thin-oxide (or) film (after cleaning).

5) Butt joint cannot be made because of small facing surface.

Applications :—

1) Electrical components in television, Radio, transistor and tape recorder.

2) Electronic components like printed circuit boards.

3) Automobiles parts like radiators and coating and joining the metal etc.

4) Used for joining wires and small parts.

5) Sheet metal work for joining parts that are not subjected to heavy loads and high temperatures.

BRAZING

Brazing is also a process of joining of metal by using filler metal and filling it to the joint like soldering. It is different from soldering in the sense that the filler metal is harder and has high melting point than solder. the melting point of the filler metal used in brazing is higher than that of solder but lower than that of the metal to be joined. It is called spelter. As the brazed joint is formed by solidification of molten filler metal in the very narrow clearence between the parts to be joined, due to metallurgical bonding and geometric conditions of joint it becomes stronger than the filler metal.

PROCEDURE :— Brazing is done like soldering :—

First of all, surfaces of the parts are made throughly clean and free from oxides, oil and dust. In brazing the bond is formed by wetting the metal surface, with molten filler metal, by capilliary action which can happen only when the surfaces are perfectly clean. The gap between the parts is adjusted to a narrow limit and flux is applied to them. Metal pieces to be brazed are heated to a temperature above the melting point of spelter and molten spelter is filled into the gap to be joined and allowed to solidify slowly.

The clearence between the metal pieces to be brazed or width of joint plays important role in making a strong joint and so a good quality joint. A clearence of 0.02 mm. to 0.2 mm gives good result.

Selection of spelter depends on the base metal combination to be brazed. A spelter metal must have characteristics like melting point lower than base metal, lower than base metal. low surface tension in molten state, high fluidity, non-oxidizing tendency at high temperature and chemical inactivity to base metal. Common examples of spelter are alloy of Aluminium and silicon, Copper and zinc, Nickel and silver etc. (15)

Common examples of flux used in brazing process are borax, borate, chlorides and Flourides. Main function of flux are improving wetting action of spelter, Protecting formation of metal oxide, low melting point and viscosity so that it can be easily displaced by the spelter from the joints. Flux comes at the top of the joint after solidification of molten spelter and can be wiped off easily.

ADVANTAGES:— ① Brazing can be used to join pieces of any metal and also dissimilar metals.
② Both type of joints, lap joint and butt joint can be made.

Limitations:— Brazing produces weaker joint than welding.
(ii) the joint can not be used in heat effected zone.
(iii) Colour of joint may be different from the colour of base metal.

Applications :—
It is used to join tubes, pipes, wires, cables, tool bits of cutting tool, jewellery and in maintenance of low load bearing structures.

On the basis of filler material used, brazing can be classified as:
(i) Silver brazing (ii) Copper brazing (iii) Aluminium Brazing
On the basis of method of heating brazing can be classified as:

(a) *Torch Brazing* : Torch brazing is the most versatile method. It is similar to oxy-acetylene welding. In this process, reducing flame is used to heat the joint area. A flux is applied and as soon as it melts, the filler metal is hand fed to the joint area. When the filler metal melts, it flows into the clearance between the base metal components by capillary action. This method finds applications in fabrication industry and repair work.

(b) *Furnace Brazing* : In this method the atmosphere of the furnace is controlled to prevent oxidation by hydorgen, dissociated ammonia, nitrogen or any gas, thus allowing the molten brazing metal to flow smoothly and uniformly around the joint.

(c) *Induction Brazing* : In this metals, the metals to be welded are surrounded by metallic coils through which high frequency current is passed. This induces eddy current which produces localized heating. The parts to be brazed are pre-fluxed and the brazing is placed in the joint before switching on the current.

(d) *Dip Brazing* : In dip brazing, the parts to be brazed are dipped into a bath of molten filler metal covered by a layer of molten flux. Surface not required to be coated with the brazing alloy must be protected by molasses or by lamp black. This process is used for small parts.

(e) *Salt Bath Brazing* : The source of heating in salt bath brazing is a molten bath of fluoride and chloride salts. This salt bath removes thin oxide films from the metals to be joined. The filler metal replaced in the joint area and is also sometimes cladded before dipped in the salt bath.

(f) *Resistance Brazing* : It is similer to spot welding. Electrical resistance is used for joining parts. The parts to be joined are placed between the electrodes of the welding machine with the filler metal and fulx preloaded at the joint area. Current is then applied until the filler metal melts and flows around the joint.

This method is used in the manufacture of copper transformer leads.

Advantages of Brazing :

- Due to the higher melting point of the brazing filler metal, the joint is more stronger than produced by soldering.
- Similar and dissimilar metals can be joined. Difficult-to-weld metals are easily brazed.
- Any thinner sections or complex assemblies can be easily joined.
- Due to low temperature applications as compared to other welding processes heat-affected zones, warping or distortion are minimum.
- The process is quick and economical, and can be easily automated.
- When made properly the strength of the joint may exceed even the strength of the base metal.

Comparision of Welding, Soldering and Brazing process

Welding	Soldering	Brazing
1. It is a type of fusion welding used to join metal. It may also be non fusion type.	1. It is a type of fusion welding used to join metals.	1. It is a type of fusion welding used to join metals.
2. It produce stronger joint than soldering and brazing.	2. The joint made is weaker than made by brazing and welding.	2. The joint made is weaker than the welding but stronger than soldering.
3. Filler metal used has a very high melting point.	3. Filler metal used in called solder and have lowest melting point.	3. Filler metal used is called spelter and have melting point more than solder but less than filler metal used in welding.
4. Joint is formed by filling the gap with melton filler metal and then by solidifying it. Some of bare metal also melt and mixed with filler metal.	4. The joint is formed by applying melton solder at the interface of pieces to be joined and allow it solidifies.	4. The joint is made by welding the surfaces to be joined with spelter. Wetting takes place due to capillary action of melton spelter.
5. It is widely used in making steel structure and also have numerous applications.	5. It has limited applications mainly used in making electrical contacts of wires.	5. It has more applications than soldering.