

Welding

1. Introduction

- Welding is the process for joining different materials.
- Welding is used for making permanent joints.
- In order to join two or more pieces of metal together by welding process the most essential requirement is Heat. Pressure may also be employed.
- It is used in the manufacture of automobile bodies, aircraft frames, railway wagons, machine frames, structural works, tanks, furniture, boilers, general repair work and ship building

2. Welding Defined

- Welding is defined by the American welding Society (AWS) as “a materials joining process used in making welds”. A weld is defined as “a localized coalescence (the growing together of the grain structure of the materials being welded) of metals or nonmetals produced either by heating the materials to suitable temperatures, with or without application of pressure and with or without the use of filler metal”.

3. Types of Welding

- **Plastic Welding or Pressure Welding**

The piece of metal to be joined are heated to a plastic state and forced together by external pressure

Example -Resistance welding

- **Fusion Welding or Non-Pressure Welding**

The material at the joint is heated to a molten state and allowed to solidify

Example-Gas welding, Arc welding

4. Classification of Welding Processes

- There are about 35 welding processes used by industry today.
- Welding can be classified on the basis of
 - (i) Source of heat i.e. flame, arc etc.
 - (ii) Type of interaction i.e. liquid/liquid (fusion welding) or solid/solid (solid state welding)
- In general various welding processes are classified as below

1. Gas Welding

- a) Air acetylene welding
- b) Oxyacetylene welding

- c) Oxyhydrogen welding
- d) Pressure gas welding

2. Arc Welding

- a) Carbon Arc Welding
- b) Shielded Metal Arc Welding (SMAW)
- c) Submerged Arc Welding (SAW)
- d) Tungsten Inert Gas (TIG) Welding

- e) Metal Inert Gas (MIG) Welding
- f) Flux Cored Arc Welding (FCAW)
- g) Plasma Arc Welding (PAW)
- h) Electroslag Welding

3. Resistance Welding

- a) Spot Welding
- b) Projection Welding
- c) Seam Welding
- d) Resistance Butt Welding

- e) Flash Butt Welding
- f) Percussion Welding
- i) High Frequency Resistance Welding (HFRW)

4. Solid State Welding

- a) Cold Welding
- b) Diffusion Welding
- c) Explosive Welding
- d) Forge Welding

- e) Friction Welding
- f) Hot Pressure Welding
- g) Roll Welding
- h) Ultrasonic Welding

5. Thermo-Chemical Welding Processes

- a) Thermit Welding

- b) Atomic Hydrogen Welding

6. Radiant Energy Welding Processes

- a) Electron Beam Welding (EBW)

- b) Laser Beam Welding (LBW)

5. Advantages, Disadvantages and Applications of Welding

Advantages of Welding

1. A good weld is as strong as the base metal.
2. General welding equipment is not very costly.
3. Portable welding equipments are available.
4. Welding permits considerable freedom in design.
5. Welding can be mechanized.

Disadvantages of Welding

1. Welding gives harmful radiations (light), fumes and spatter.
2. Welding results in residual stresses and distortion of the workpieces.
3. Welding heat produces metallurgical changes.
4. Welding joint requires stress-relief heat treatment.

Applications of Welding

1. Aircraft Construction
2. Automobile construction
3. Bridges
4. Buildings
5. Pressure Vessels and Tanks
6. Storage Tanks
7. Pipelines.
8. Ships
9. Household and office furniture
10. Machine tool frames, cutting tools and dies.

6. Welding Positions

1. **Flat Position** - In this position, the filler metal is deposited from the upper side of the joint and the face of the weld is horizontal.
2. **Horizontal Position** - In this position, the filler metal is deposited upon a horizontal surface and the axis of the weld is horizontal.
3. **Vertical Position** - In this position, the filler metal is deposited upon a vertical surface and the axis of the weld is vertical.
4. **Overhead Position** - In this position, the filler metal is deposited from the under side of the joint and the face of the weld is horizontal.

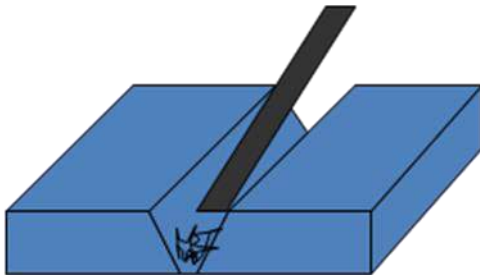


Fig. Flat Position

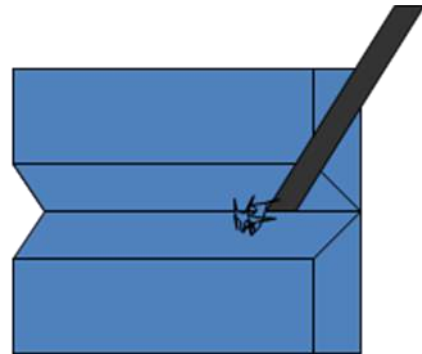


Fig. Horizontal Position

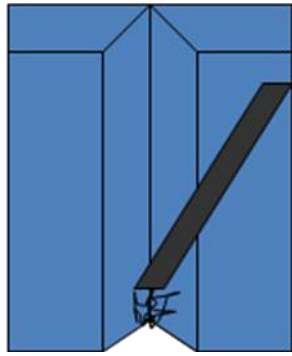


Fig. Vertical Position

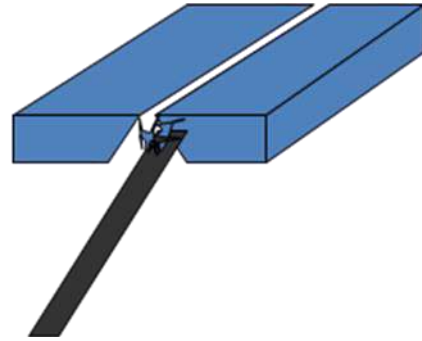


Fig. Overhead Position

7. Welding Joints

1. **Butt Joint** – Parts lying in same plane are joined at their edges.
2. **Lap Joint** – Two parts are overlapping each other.
3. **Tee Joint** – One part is perpendicular to the other to resemble letter T.
4. **Corner Joint** – Parts are joined at corner.

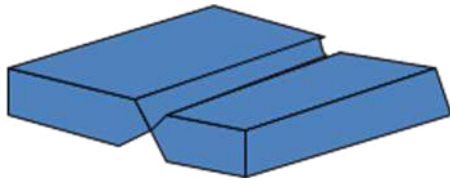


Fig. Butt Joint

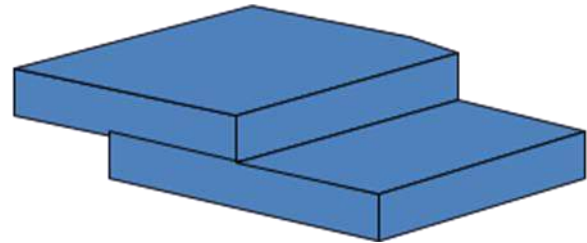


Fig. Lap Joint

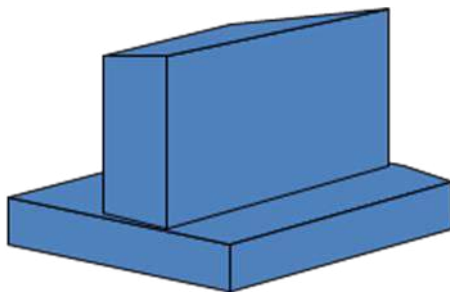


Fig. T Joint

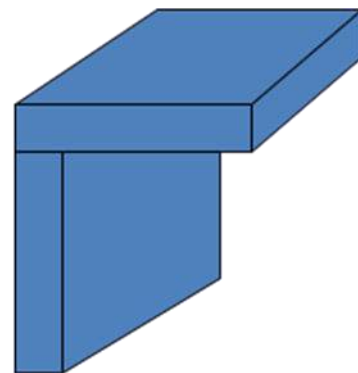


Fig. Corner Joint

8. Arc Welding

Definition-Is a welding process in which coalescence is produced by heating with an electric arc or arcs, mostly without the application of pressure and with or without the use of filler metal depending upon the base plate thickness.

1. Carbon Arc welding

- It can be classified as single carbon arc welding and twin carbon electrode arc welding.

Definition-It is an arc welding process in which coalescence is produced by heating the workpiece with an electric arc struck between a carbon electrode and the workpiece. Filler metal may or may not be used.

In twin carbon arc welding the arc is struck between two carbon electrodes produces coalescence. The workpiece do not form a part of electrical circuit.

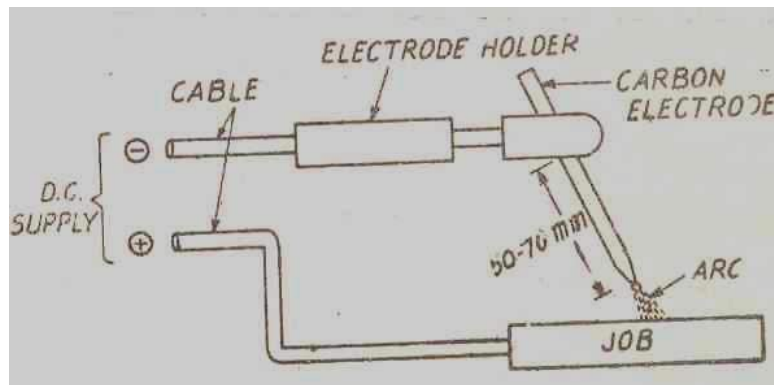


Fig. Carbon Arc Welding

Advantages

1. Equipment is simple and easily available.
2. Welding cost is low as compared to other welding processes.

Disadvantages

1. Chances of carbon being transferred from electrode to weld metal.

Applications

1. For welding of steel, aluminium, nickel, copper etc

2. Shielded Metal Arc Welding (SMAW)

Definition- In this process coalescence is produced by heating the workpiece between electric arc setup between a flux coated electrode and the workpiece. The flux covering decomposes due to heat

and performs many functions like arc stability, weld metal protection etc. the electrode itself melts and supplies the necessary filler metal.

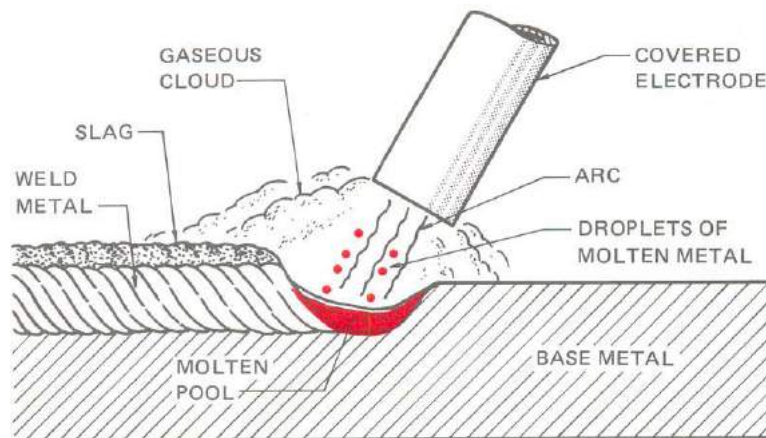


Fig. Shielded metal arc welding

The functions of the core wire include the following

1. To carry the welding current.
2. To serve as most of the filler metal in the finished wells.

The function of the flux covering include the following

1. To provide some of the alloying elements.
2. To serve as an insulator
3. To provide slag cover to protect the weld bead.
4. To provide protective gaseous shield gaseous shield during welding.

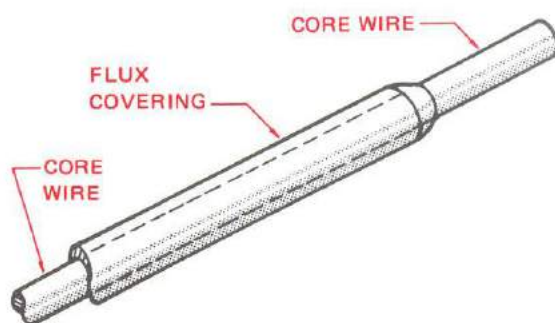


Fig. The two parts of a welding electrode

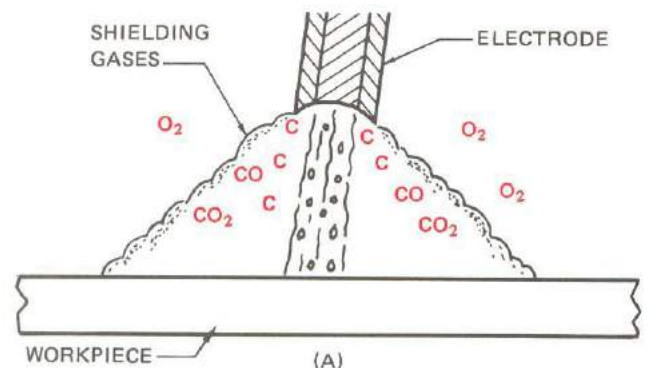


Fig. Effect of shielding gases (Oxygen in the air burned to form CO₂ and other gases that will not react with the weld)

Welding Currents

The three types of current used for welding are

1. Alternating Current (AC)
2. Direct Current Straight Polarity (DCSP)
3. Direct Current Reverse Polarity (DCRP)

1. Alternating Current (AC) –

- In AC, the electrons change direction every $1/120$ of a second so that the electrode and work alternate from anode to cathode.
- The rapid reversal of current flow causes the welding heat to be evenly distributed on both the workpiece and the electrode i.e. half on the workpiece and half on the electrode.
- The even heating gives the weld bead a balance between penetration and buildup.

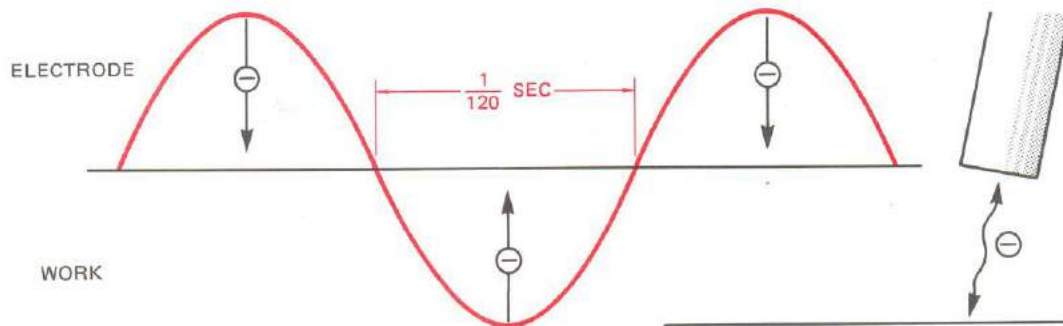


Fig. Alternating current (AC)

2. Direct Current Straight Polarity (DCSP)

- In DCSP electrode is negative and the workpiece is positive.
- DCSP has higher heat on the workpiece and lower heat on the electrode.
- The DCSP weld bead has deep penetration into base metal with little buildup.

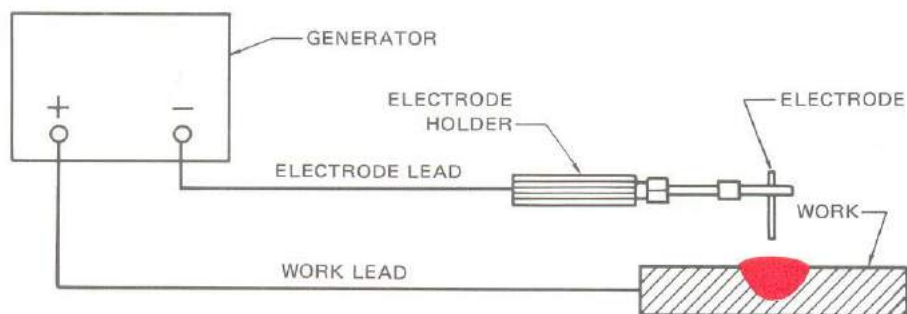


Fig. Direct Current Straight Polarity (DCSP), electrode negative (DCEN)

3. Direct Current Reverse Polarity (DCRP)

- In DCSP electrode is positive and the workpiece is negative.
- DCSP has higher heat on the electrode and lower heat on the workpiece.
- The DCSP weld bead has shallow penetration into base metal with high buildup.

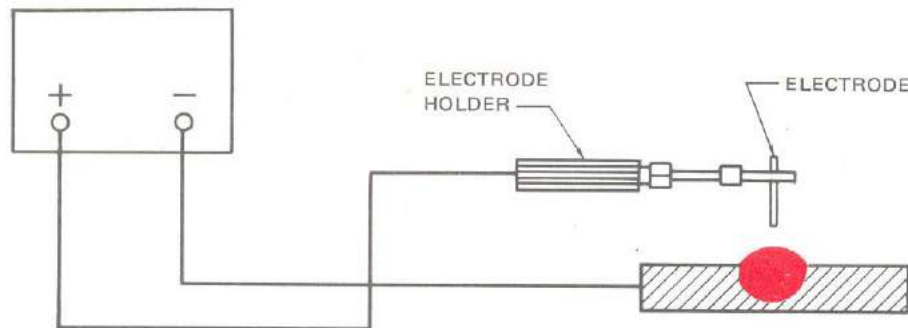


Fig. Direct Current Reverse Polarity (DCRP), electrode positive (DCEP)

Advantages

3. It is the simplest of all welding processes.
4. The equipment can be portable and the cost is low.
5. Welding can be carried out in any position with highest weld quality.

Disadvantages

2. In welding long joints as one electrode finishes, the weld is to be progressed with the next electrode.
3. Because of flux coated electrode chances of flux entrapment is more.

Applications

2. SMAW is used for fabrication, maintenance and repair work.
3. Almost all metals can be welded with this process.

3. Submerged Arc Welding

Definition-It is an arc welding process wherein coalescence is produced by heating the job with an electric arc or arcs struck between a bare metal electrode and the job. The arc, end of the electrode and molten pool remain completely hidden and are invisible being submerged under a blanket of granular flux. The continuously fed bare metal electrode melts and acts as filler rod. No pressure is applied for welding purpose.

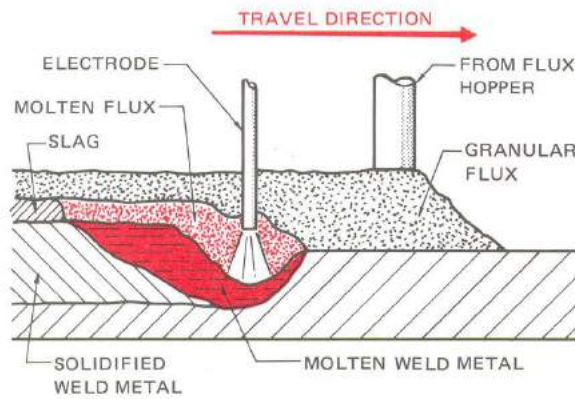


Fig. Submerged arc welding (SAW)

Advantages

1. High metal deposition rates can be achieved.
2. Very neat appearance and smooth weld shapes can be obtained.

Disadvantages

1. Since the operator cannot see the welding being carried out, he cannot judge accurately the progress of welding.
2. The process is limited to welding in flat position only.

Applications

1. For Automotive, Aviation, Ship-building, Nuclear power industry, Pressure vessel, Boilers etc.

4. Tungsten Inert Gas (TIG) Welding or Gas Tungsten Arc Welding (GTAW)

Definition-It is an arc welding process wherein coalescence is produced by heating the job with an electric arc struck between a tungsten electrode and the job. A shielding Gas, argon, helium, nitrogen etc. is used to avoid atmospheric contamination of the molten weld pool. A filler metal may be added if required.

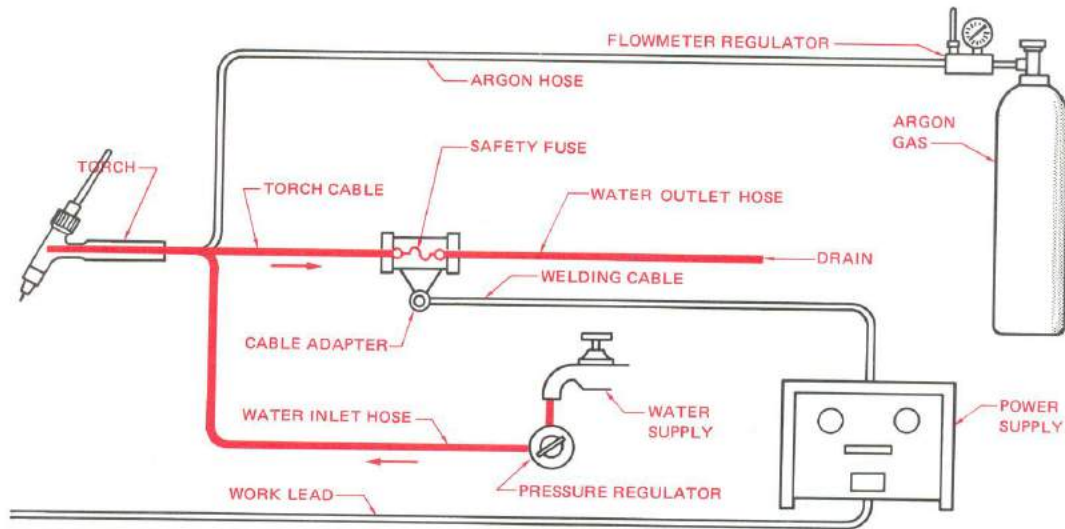


Fig. Schematic of a GTAW setup with a water-cooled torch

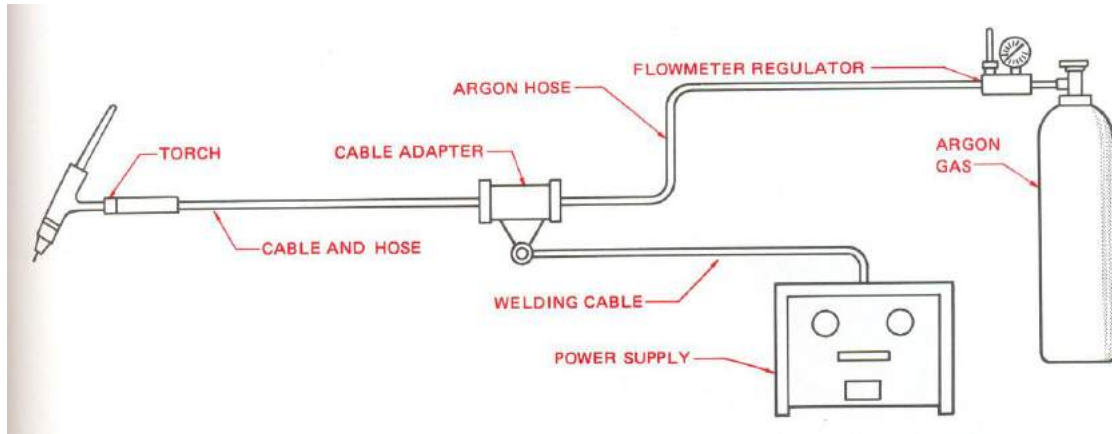


Fig. Schematic of a GTAW setup with a air-cooled torch

Tungsten Electrode-

- Pointed tungsten will have less mass near the end to absorb the heat, resulting in high surface temperatures even with low current settings.
- Rounded end will have large to absorb the heat, which results in lower surface temperature.
- Tapered electrode with a balled end will have the lowest surface temperature.

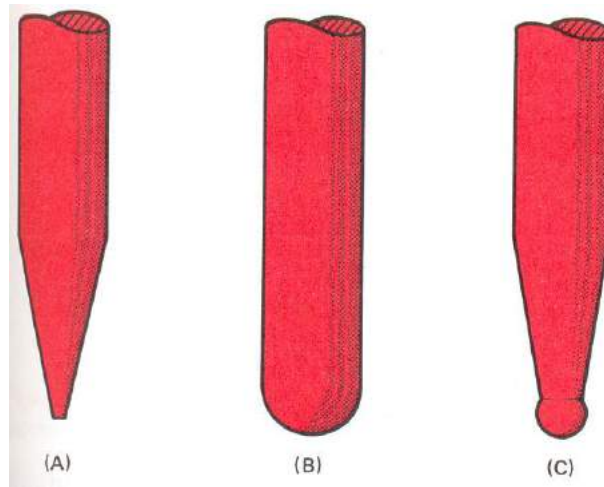


Fig. Basic tungsten electrode end shapes

A) Pointed B) Rounded C) Tapered with a balled end

Types of Tungsten's –

- Pure tungsten has a number of properties that make it an excellent non consumable electrode for the TIG welding.
- These properties can be improved by adding thorium or zirconia to the tungsten.
- Adding the thorium (thorium dioxide, ThO_2) or zirconia (zirconium dioxide, ZrO_2) in small quantities (upto 2%) will improve the electrode resistance to contamination and increases current carrying capacity.

Types of Welding currents –

- DCSP concentrates about two-third of its welding heat on the workpiece and remaining one-third of heat on the tungsten electrode.
- DCRP concentrates only one-third of its welding heat on the workpiece and remaining two-third of heat on the tungsten electrode.
- Alternating current concentrates about half of its heat on the work and the remaining half of heat on the tungsten electrode.
- Both AC and DC welding machine can be used for TIG welding.
- DC is preferred for welding of stainless steel, nickel, copper and copper alloys.
- DCRP or AC is used for welding magnesium, aluminium and their alloys.

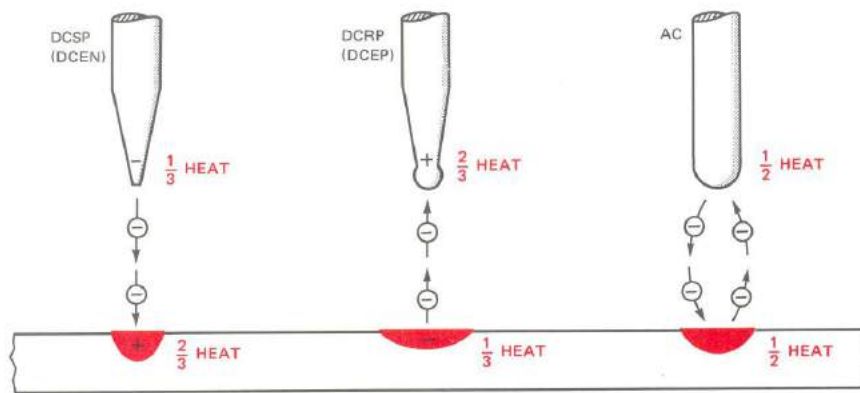


Fig. Heat distribution between the tungsten electrode and the work with each type of welding current

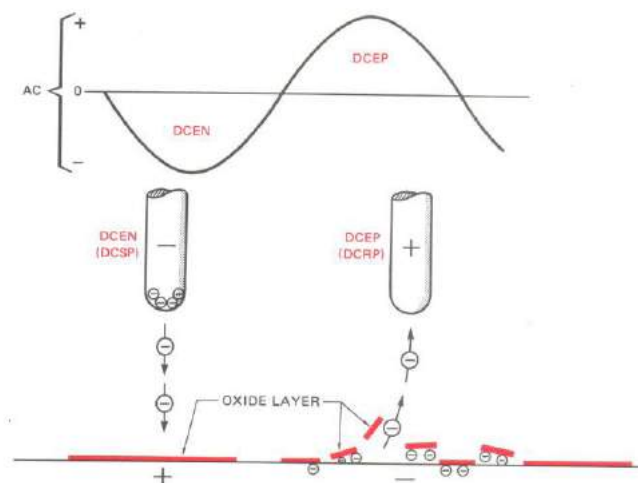


Fig. Electrons collect under the oxide layer during DCEP portion of the cycle and lifts the oxides from the surface

Advantages

1. No flux is used hence there is no danger of flux entrapment.
2. Process can weld in all positions.
3. TIG welding is very much suitable for high quality welding.

Disadvantages

1. Tungsten if it transfers to molten weld pool can contaminate the same.
2. Equipment cost is higher than SMAW welding.

Application

1. Welding of aluminium, magnesium, copper, nickel and their alloys
2. Welding of stainless steel.
3. Welding sheet metal of thinner section.

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

Definition—It is an arc welding process wherein coalescence is produced by heating the job with an electric arc struck between a continuously fed metal electrode and the job. No flux is used but the arc and molten metal are shielded by an inert gas, which may be argon, carbon dioxide etc.

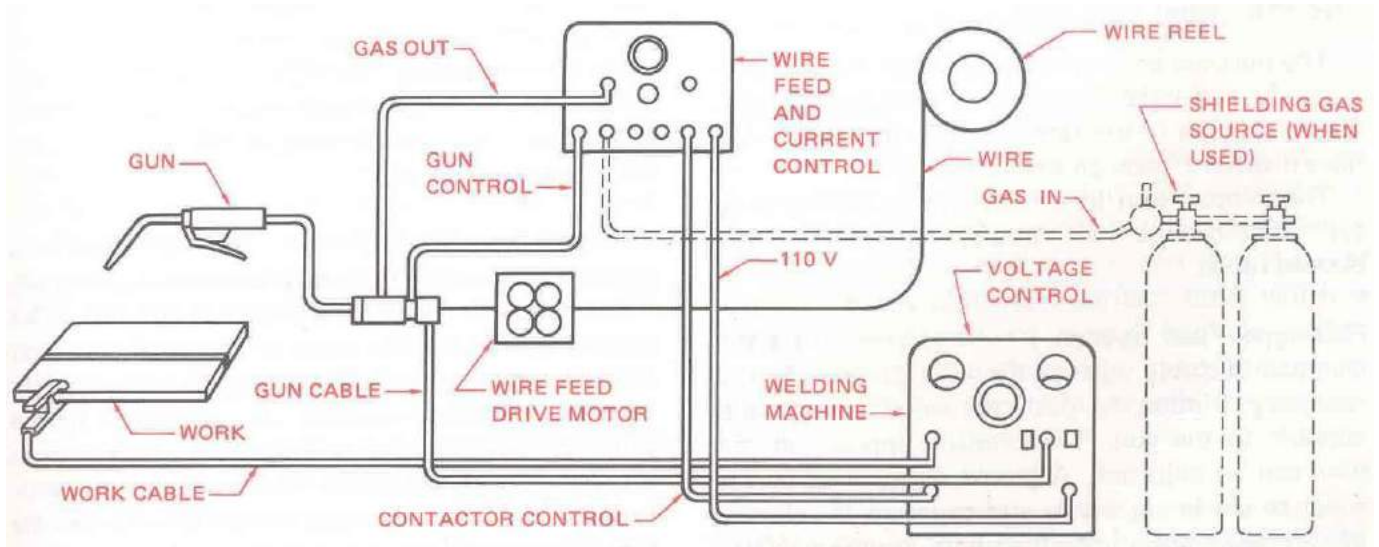


Fig. Schematic of a GMAW setup

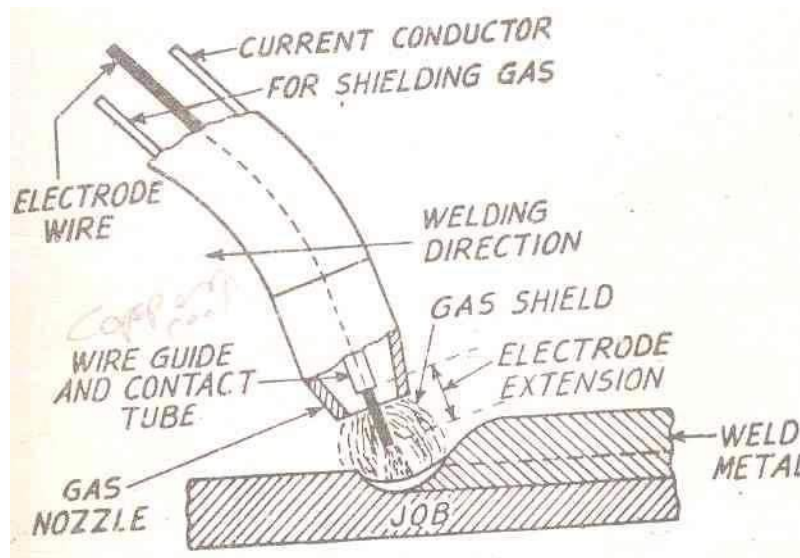


Fig. MIG welding

Advantages

1. Because of continuously fed electrode, MIG welding process is much faster as compared to TIG welding.
2. The process can be easily mechanized.

Disadvantages

1. The process is slightly more complex as compared to TIG welding.
2. Welding equipment is more complex, more costly and less portable.

Application

1. For welding of stainless steel, aluminium, magnesium nickel and their alloys.
2. For welding of tool steel and dies.
3. Used in industries like aircraft, automobile, pressure vessel, ship building etc.

6. Flux-Cored Arc Welding (FCAW)

The addition of a flux to the core of the wire has produced flux cored arc welding (FCAW). Shielding may be employed either by flux core or shielding gases may be supplied as in GMAW process.

This is used for steels and stainless steels welding.

High quality welds that are smooth and uniform are produced.

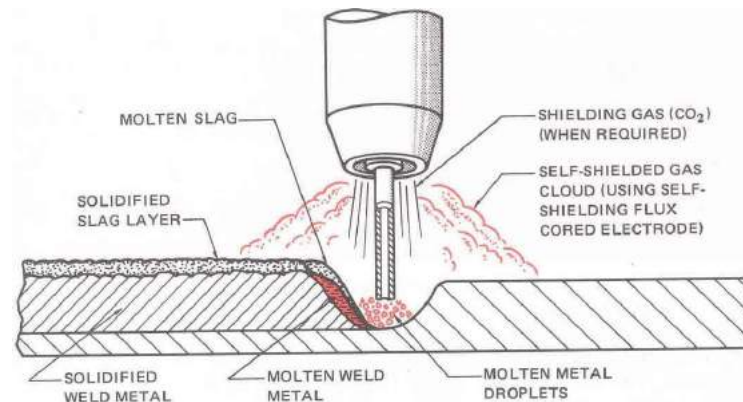


Fig. Flux Cored Arc Welding (FCAW)

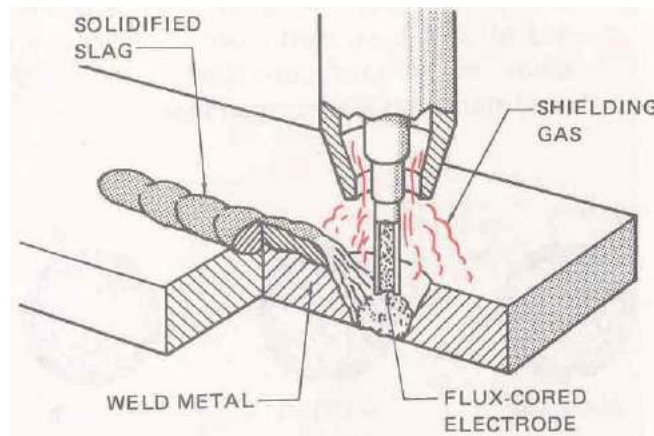


Fig. Flux Cored Arc Welding (FCAW)

7. Electroslag Welding

- Electroslag welding got originated in Russia
- Later on this process was developed in several European countries and the United States of America so that it could be used as very effective tool for welding of thick sections.

Definition- Electroslag welding is a welding process wherein coalescence is produced by molten slag which melts the filler metal and the surfaces of the work to be welded.

Electroslag welding is initiated by starting an arc between the filler metal/electrode and the work. This arc heats the flux and melts it to form the slag. The arc is then extinguished and the slag is maintained in molten condition by its resistance to the flow of electric current between the electrode and the work.

The molten pool remains shielded by the molten slag which moves along the full cross section of the joint as the welding progresses.

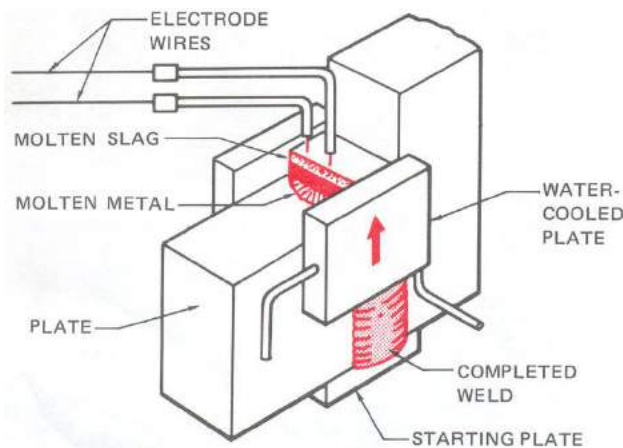


Fig. Electroslag welding process (ESW)

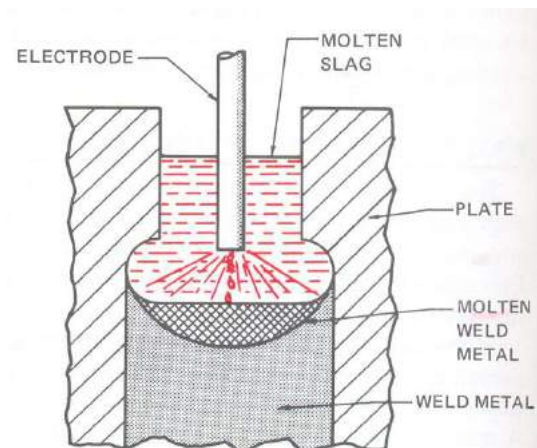


Fig. Section through workpiece and weld during the making of the weld (ESW)

Advantages

1. Thickness upto 450 mm in plain and alloy steels can be welded without difficulty.
2. Residual stresses and distortion produced are low.

Disadvantages

1. SAW is more economical than electroslag welding for joints below 60 mm thickness.
2. It is difficult to close cylindrical welds.
3. Welding is carried out in vertical position only.

Application

1. Heavy plates, forgings and castings can be butt welded.

8. Plasma Arc Welding (PAW)

- Plasma is the fourth state of matter.
- Plasma gas contains mixture of ions, electrons and highly excited atoms.

Definition- PAW is an arc welding process wherein coalescence is produced by the heat obtained from a constricted arc setup between a tungsten/alloy tungsten electrode and the water cooled nozzle (non-transferred arc) or between a tungsten/alloy tungsten electrode and the workpiece (transferred arc).

The process uses two gases, one forms the plasma arc and the second shields the arc plasma. Filler metal may or may not be added. Pressure normally is not employed.

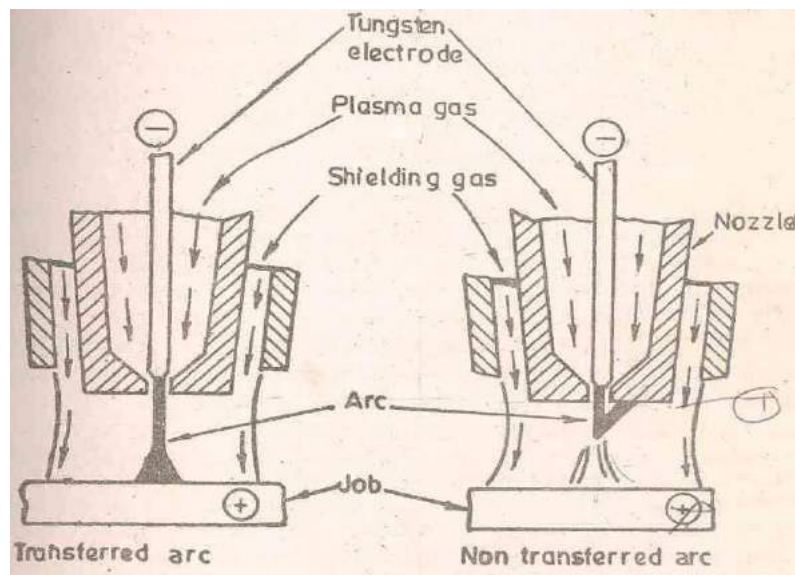


Fig. Transferred and Non Transferred Plasma Arc

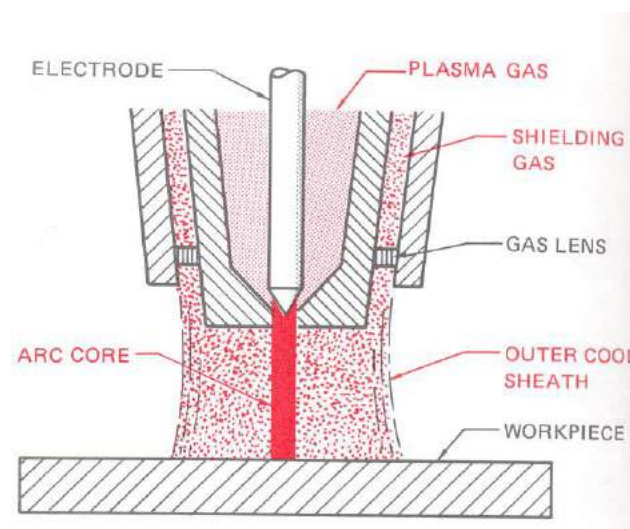


Fig. Schematic diagram of plasma welding process

Advantages

1. Excellent weld quality.
2. Uniform penetration.

Disadvantages

1. Infra red and ultra violet radiation necessitates special protection devices.
2. The process is complicated and costlier

Application

1. Welding high temperature alloys.

9. Resistance Welding

Resistance welding is defined as a process wherein coalescence is produced by the heat obtained from the resistance of the workpiece to the flow of electric current.

Pressure is always applied to ensure a continuous electrical circuit and to forge the heated parts together.

Fluxes and filler metal are not needed for this welding process.

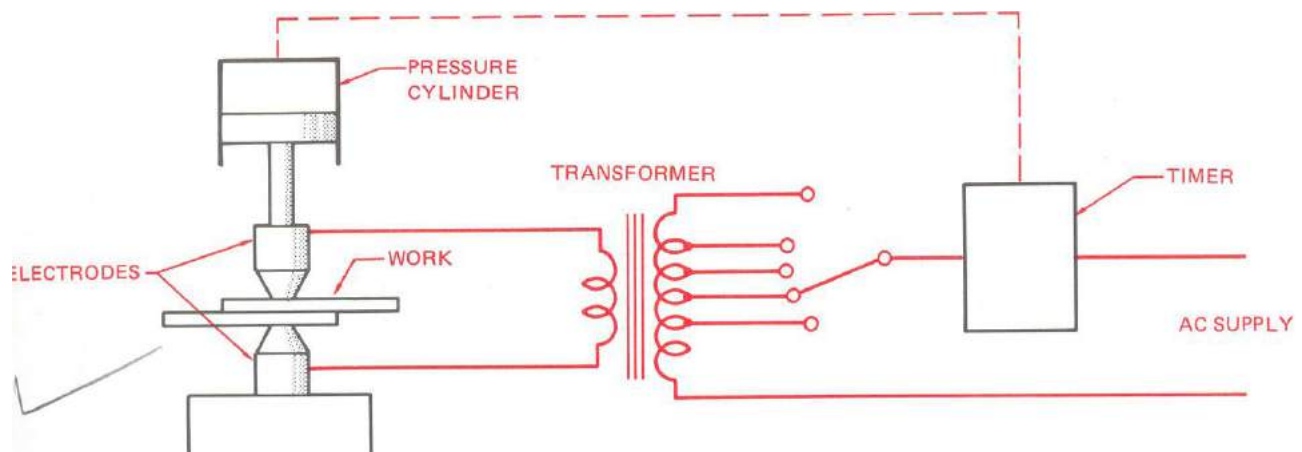


Fig.4 Fundamental resistance welding machine circuit.

Heat

The heat produced in the weld may be expressed in the following manner

$$H = I^2RT$$

Where, H = Heat

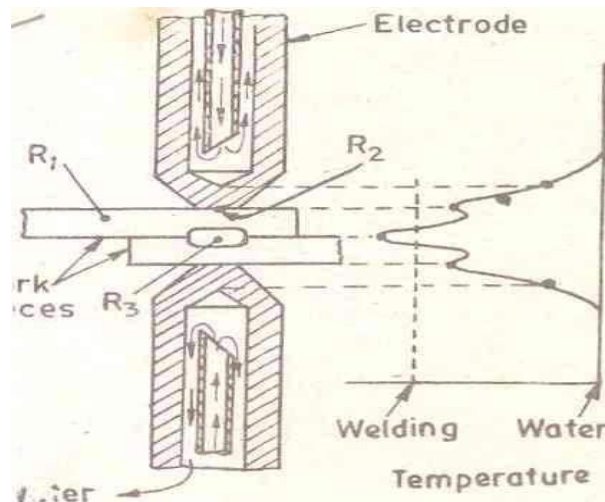
I = Current

R = Electrical resistance to the circuit

T = Duration of the current.

The capacitor stores the welding current until it is used. The required pressure or electrode force is applied to the workpiece by pneumatic, hydraulic or mechanical means.

Resistance



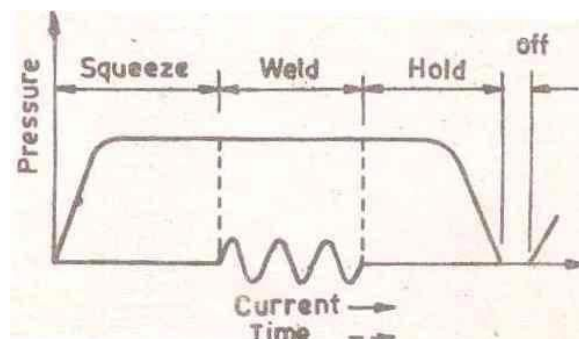
The total resistance of the system consists of

1. The resistance of the workpiece R_1 .
2. The contact resistance between the electrodes and the workpiece R_2 .
3. The resistance between the surfaces of the two metal pieces to be welded together, R_3 .

In order to obtain the sound weld and to avoid overheating of the electrodes R_1 and R_2 should be kept as low as possible with respect to R_3

- R_1 = Resistance of the workpiece depends nature of the material and its thickness. e.g. Aluminium requires high currents in order to produce the required welding temperature.
- R_2 = Resistance between electrode and the workpiece and it can be minimized by
 - a. Keeping electrode tip and the workpiece surface properly cleaned.
 - b. Using the welding electrode of highly conductive material such as Cu-Cd or Cu-Cr alloys.
 - c. Controlling the shape and size of the electrode.
- R_3 depends on quality of the surfaces. Surfaces that have not been cleaned and possess scale, dirt or other contaminants on them offer more resistance to the flow of welding current.

Time



Four periods of timings are set up on a resistance welding machine i.e.

- | | |
|-----------------|--------------|
| 1. Squeeze time | 3. Hold time |
| 2. Weld time | 4. Off time |

1. Squeeze time – It is the time between initial application of the electrode pressure on the work and the initial application of current to make the weld. During this period upper electrode comes in contact with workpiece and develops full electrode force.

2. Weld time - During this time welding current flows through the circuit i.e. it enters through one electrode, passes through the work-pieces and goes out from the second electrode.

3. Hold time – The electrode pressure is maintained until the metal has somewhat cooled.

4. Off time – It is the interval from the end of the hold time to the beginning of the squeeze time for the next welding cycle.

In automatic machines all these segments of times are controlled automatically whereas in manually operated machines only the weld time is controlled automatically.

1. Spot Welding

Spot welding is the most common of the various resistance welding processes.

Definition – Spot welding is resistance welding process in which overlapping sheets are joined by the heat obtained by resistance to flow of electric current at the interface between the workpieces that are held together under force by the two electrodes.

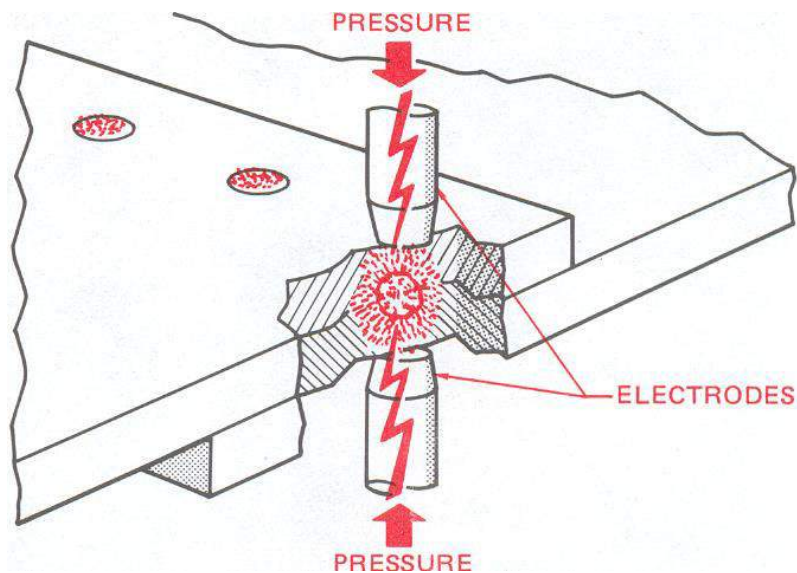


Fig. Heat resulting from resistance of the current through the metal held under pressure by the electrodes creates fusion of the two workpieces during spot welding.

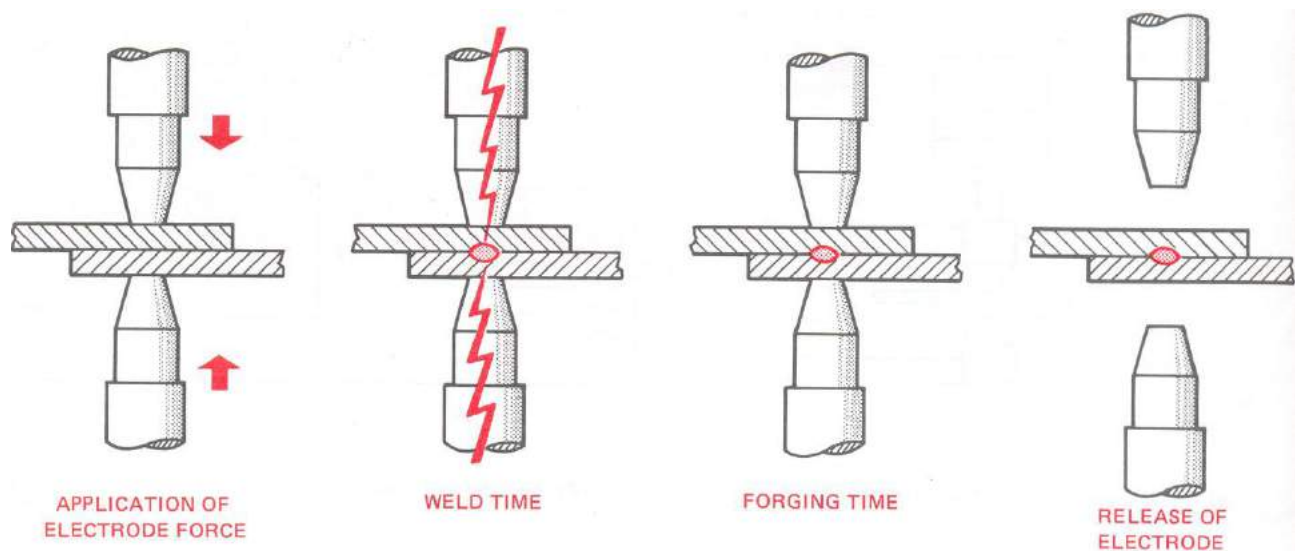


Fig. Basic periods of spot welding

Heat balance in spot welding

1. When welding two different thicknesses of the same material use a small tip area on the side of bigger thickness. This will increase current density on the side of bigger thickness.
2. When welding two dissimilar metal sheets of varying conductivity use smaller tip area on the side of the high conductivity alloy.

Advantages

1. Low cost.
2. No edge preparation is required.
3. Less skilled worker will do.

Disadvantages

1. Large thicknesses (more than 15 mm) are difficult to spot weld..

Application

1. Automobile and aircraft industry.
- 2.

2. Seam Welding

- Seam welding is similar in some ways to spot welding except that the spots are spaced so close together that they actually overlap one another to make a continuous seam weld.
- Seam welding is done by using roller type electrodes in the form of wheels that are 152 mm (6 Inch) to 229 mm (9 Inch) or more in diameter.

- These roller type electrodes are usually copper alloy discs of 10 mm (3/8 inch) to 16 mm (5/8 Inch) thick.
- Cooling is achieved by a constant stream of water directed to the electrode near the weld.
- Welding is usually done with roller electrode in motion and the rate of welding varies between 30 cm to 152 cm per minute.
- Seam welding machines generally operates on single phase AC.

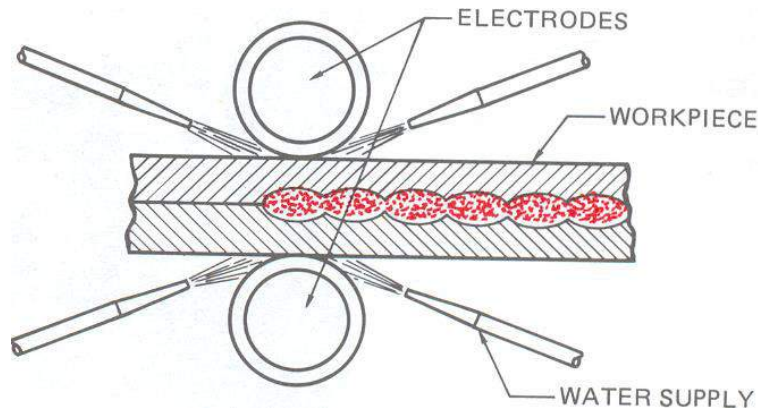


Fig. Schematic illustration of the seam welding process

Advantages

1. It can produce gas tight or liquid tight joints.
2. A single seam weld or several parallel seam weld can be produced simultaneously.

Disadvantages

1. It is difficult to weld thickness greater than 3 mm.
2. Welding can be done only along straight or uniformly curved line

Application

1. Except for copper and copper alloys most of metals of common industrial use can be seam welded.

3. Projection Welding

- Projection welding is somewhat similar to spot welding.
- Projections are formed on at least one of the workpieces at the points where welds are desired.
- The projection can be any shape such as round, oval, circular etc.
- Projection can be formed by casting, machining etc.
- When the current is turned on and pressure is applied, since all the resistance is in the projections, most of the heating occurs at the points where welds are desired.

- There are many variables in this process such as thickness of metal, number of projections and type of material.

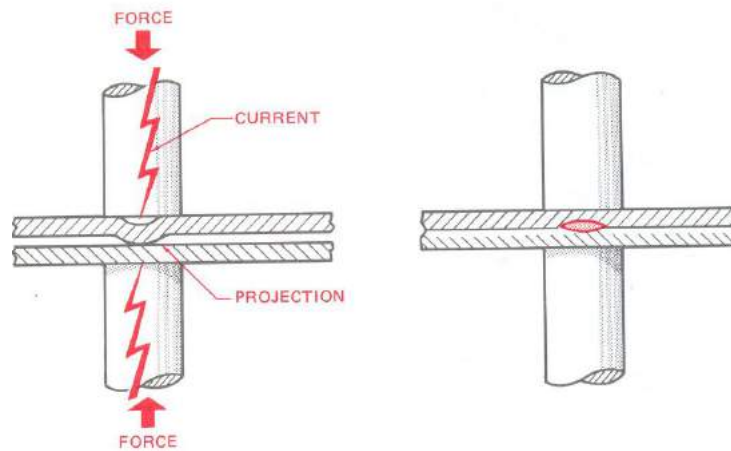


Fig. Projection welding

Advantages

1. A number of welds can be made simultaneously.
2. Projection weld can be made in metals that are too thick to be joined by spot welding.
3. Projection welding locates the weld at desired position

Disadvantages

1. Forming of projection is an extra operation.

Application

1. In automobile industry.

4. Flash Butt Welding

- Fusion is produced at the ends of workpieces by the heat produced from the resistance to the flow of electric current.
- Pressure is applied after heating is completed.
- The basic steps in flash welding are as follows
 - a. Clamp the parts together in dies.
 - b. Move one part towards the other part until an arc is established
 - c. Parts are pressed together when flashing has caused the parts to reach to plastic temperature.
 - d. Cut off the welding current when welding is complete.

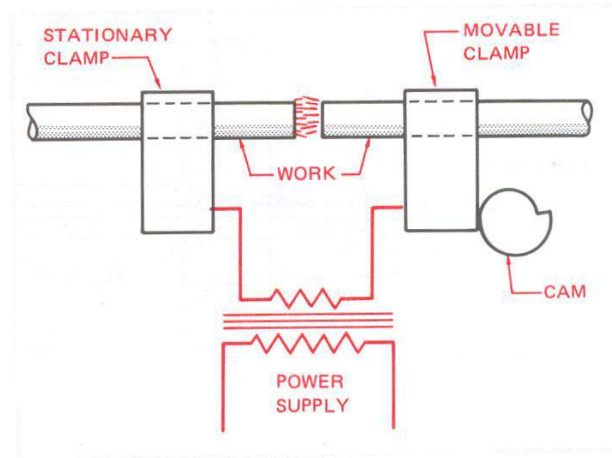


Fig. Schematic diagram of the flash welding process

Advantages

1. Many dissimilar metals with different melting temperature can be flash welded.
2. The process is cheap.

Disadvantages

1. Operator needs to be protected from flying particles.
2. Metal is lost during flashing and application of pressure.

Application

1. For welding of tubing, bars, forgings etc.
2. In automobile and aircraft products, household appliances, refrigerator etc.

5. Resistance (Upset) Butt Welding

- Two pieces of metal having the same cross section are gripped and pressed together and then current is passed from one piece to another.
- Resistance to the flow of electric current produces heat at the contact surfaces
- It is similar to flash welding except that no flashing occurs in this process.
- As compared to flash butt welding less current is needed in this process.
- This process requires more welding time than flash butt welding.
- Resistance butt welding is largely replaced by flash butt welding.

6. Percussion Welding

- It is actually a variation of flash welding.
- A short application of high-intensity energy instantly heats the workpieces to be joined.
- A rapid heating is immediately followed by a quick blow to make the weld.

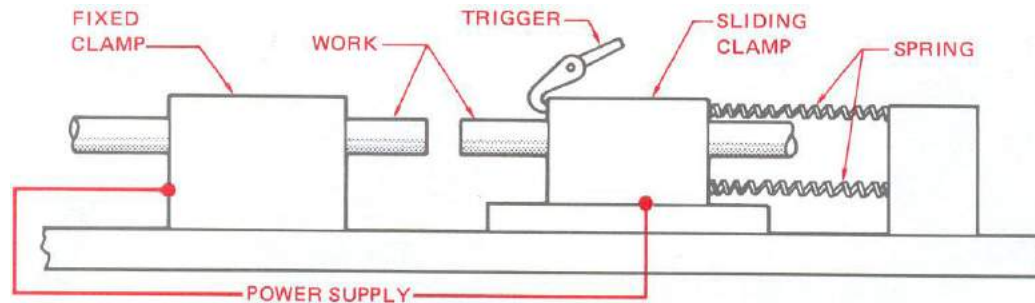


Fig. Principle of percussion welding

Advantages

1. Heat treated or cold worked parts can be welded without destroying the heat treatment.

Disadvantages

1. Process is limited to butt welding joints only.

Application

1. In telephone industries, electrical and electronic assembly.

10. Gas Welding

- Gas welding is a fusion welding process. It joins metals using the heat obtained from combustion of oxygen/air and fuel gas (acetylene, hydrogen, propane, butane etc) mixture.
- The intense heat produced melts the metal to be welded.
- The filler metal is generally added.

Oxy-Acetylene Welding

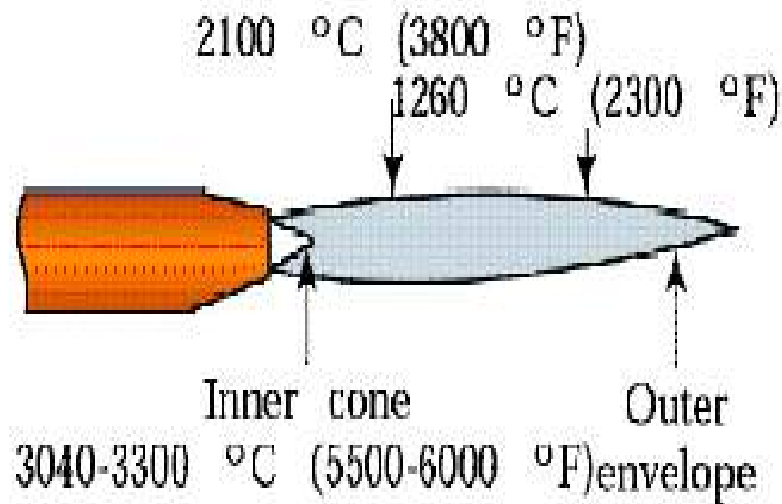
- When acetylene is mixed with oxygen in correct proportion in the welding torch and ignited, the flame resulting at the tip of the torch is sufficiently hot to melt and join the parent metal.
- The oxy-acetylene flame reaches a temperature of about 3200°C and thus can melt all commercial metal.
- A filler metal rod is generally added to the molten metal pool.
- No pressure is applied.

Types of Flames

1. Neutral Flame

- Produced when approximately equal volumes of oxygen and acetylene are mixed in the welding torch and burnt at the torch tip.
- The temperature of the neutral flame is 3260°C .
- The flame has nicely defined inner cone which is light blue in color and it is surrounded by an outer flame envelope which is much darker blue than the inner cone.
- Neutral flame is named so because it effects no chemical change on molten metal and therefore will not oxidize or carburize the metal.
- Neutral flame is commonly used for welding of
 - a. Mild Steel
 - b. Cast Iron
 - c. Aluminium
 - d. Stainless Steel
 - e. Copper

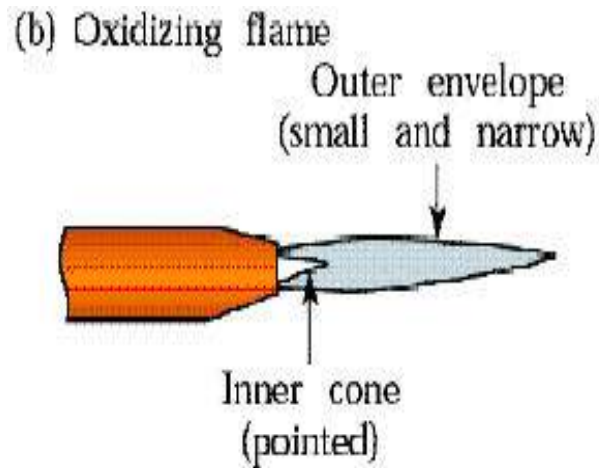
(a) Neutral flame



2. Oxidizing Flame

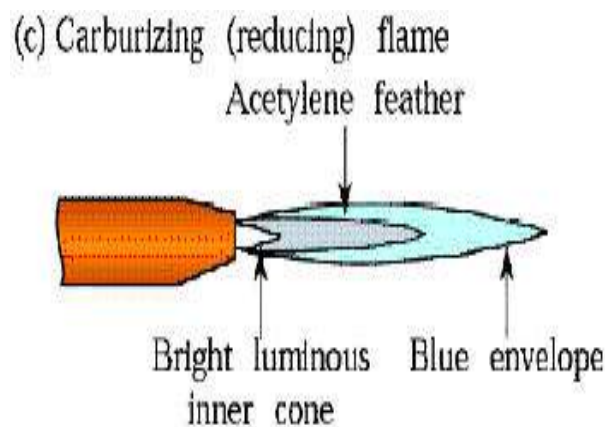
- After the establishment of neutral flame if the supply of oxygen is further increased, the result will be an oxidizing flame.
- Oxidizing flame can be recognized by the small white cone which is shorter, much bluer in color and more pointed than that of the neutral flame.
- Oxidizing flame burns with a decided loud roar.
- The temperature of the oxidizing flame is 3482°C
- Oxidizing flame has ($\text{O}_2:\text{C}_2\text{H}_2 = 1.5:1$)

- Oxidizing flame has limited use in welding as oxygen at high temperature tends to combine with many metals to form hard, brittle, low strength oxides. e. g. copper base metal and Zinc base metal.



3. Carburizing (Reducing) Flame

- If the volume of oxygen supplied to the neutral flame is reduced, the resulting flame will be a carburizing flame.
- Carburizing flame can be recognized by acetylene feather which exist between the inner cone and outer envelope.
- The outer flame envelope is longer than the neutral flame and is usually much brighter in color.
- The temperature of the carburizing flame is 3038°C
- Oxidizing flame has $(\text{O}_2:\text{C}_2\text{H}_2 = 0.9:1)$
- Carburizing flame is used in welding of lead and for surface hardening purpose.



Gas Welding Techniques

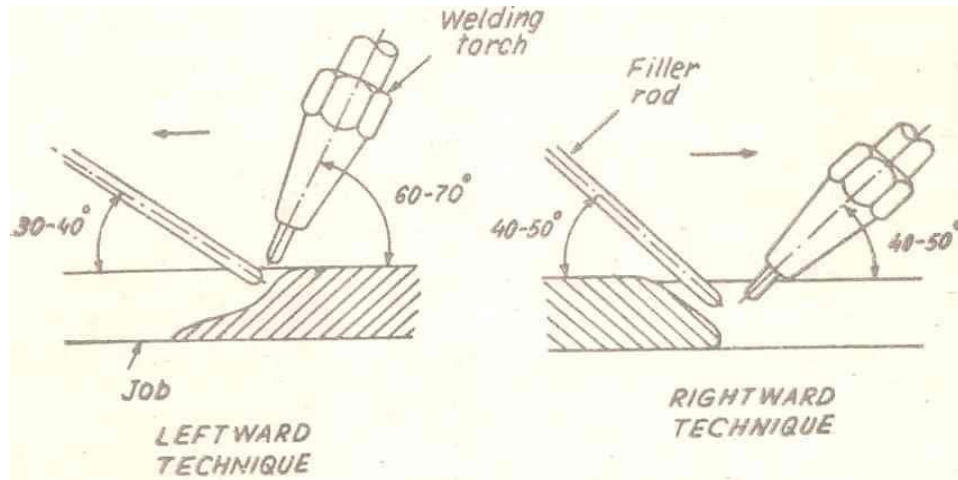
Depending upon the ways in which welding rod and the welding torch may be used; there are two usual techniques in gas welding.

1. Leftward technique or Forehand welding method.

- The welder holds the welding torch in his right hand and filler rod in the left hand.
- The welding begins at the right hand end of the joint and proceeds towards left hence the name leftward technique.
- The welding flame is directed away from the completed weld.
- The filler rod is when used is directed towards the welded part of the joint.
- Welding torch is given small sideway movement while filler rod is moved steadily across the seam.
- The filler rod is added using backward and forward movement of the rod, allowing the flame to melt bottom edges of the plate.
- Good control and neat appearance are the characteristics of gas welding.
- Leftward welding technique is usually used for welding relatively thin metals i.e. less than 5 mm thickness.

2. Rightward technique or Backhand welding method.

- The welder holds the welding torch in his right hand and filler rod in the left hand.
- The welding begins at the left hand end of the joint and proceeds towards right hence the name rightward technique.
- The welding flame is directed towards the completed weld.
- The filler rod remains between the flame and the completed weld section.
- Since the flame is constantly directed on the edges of V ahead of weld puddle no sidewise motion of the welding torch is necessary. As a result narrow V groove can be used, which provides greater control and lower welding costs.
- During welding filler rod is moved in circles (within the puddle) and semicircles (back and forth around the puddle).
- Weld puddle is less fluid and resulting in a slightly different appearance of weld surface. The ripples are heavier and spaced further apart.
- Rightward welding technique is usually used for welding thick metals i.e. above 5 mm thickness because in this technique heat is concentrated into the metal.



Welding Fluxes

- During welding, if the metal is heated / melted in air, oxygen from the air combines with the metal to form oxides which results in poor quality and low strength welds.
- A flux material is used to prevent, dissolve or facilitate removal of oxide and other undesirable substances.
- During welding flux reacts with the oxides and the slag is formed that floats and covers the top of the molten puddle and thus helps to keep out atmospheric oxygen and other gases.
- Fluxes are available in powders, pastes or liquids.
- Flux may be used by applying it directly on to the surface of base metal to be welded or by dipping the heated end of the filler rod in it.
- After welding, the slag from the welded joint can be removed by chipping, filing or grinding.
- No flux is used for gas welding of steel.
- Fluxes are used in gas welding of cast iron, stainless steel and most nonferrous metals.
- Fluxes for cast iron – borax, boric acid, soda ash and small amount of sodium chloride.
- Fluxes for stainless steel – borax, boric acid, and fluorspar.
- Fluxes for Aluminium and its alloys – lithium chloride, sodium chloride and potassium chloride.
- Fluxes for Copper and its alloys – Borax, Boric acid, magnesium silicate , lime etc
- Fluxes for Magnesium and its alloys – Sodium Chloride, Potassium fluoride, Magnesium chloride, barium chloride etc.
- Fluxes for Nickel and its alloys – Calcium fluoride, Barium fluoride etc.

Advantages

1. Cost and maintenance of welding equipment is low.
2. Welder can control the temperature of the metal in the welding zone.

Disadvantages

1. Heavy sections can not be joined economically.
2. Flame temperature is less than temperature of the arc.

Application

1. For joining thin materials.
2. For joining most ferrous and nonferrous materials.

11. Welding Symbols

- Welding symbols enabled the designer to indicate clearly to the welder the size and type of weld required to meet design requirements.
- Welding symbols are shorthand language for welder.

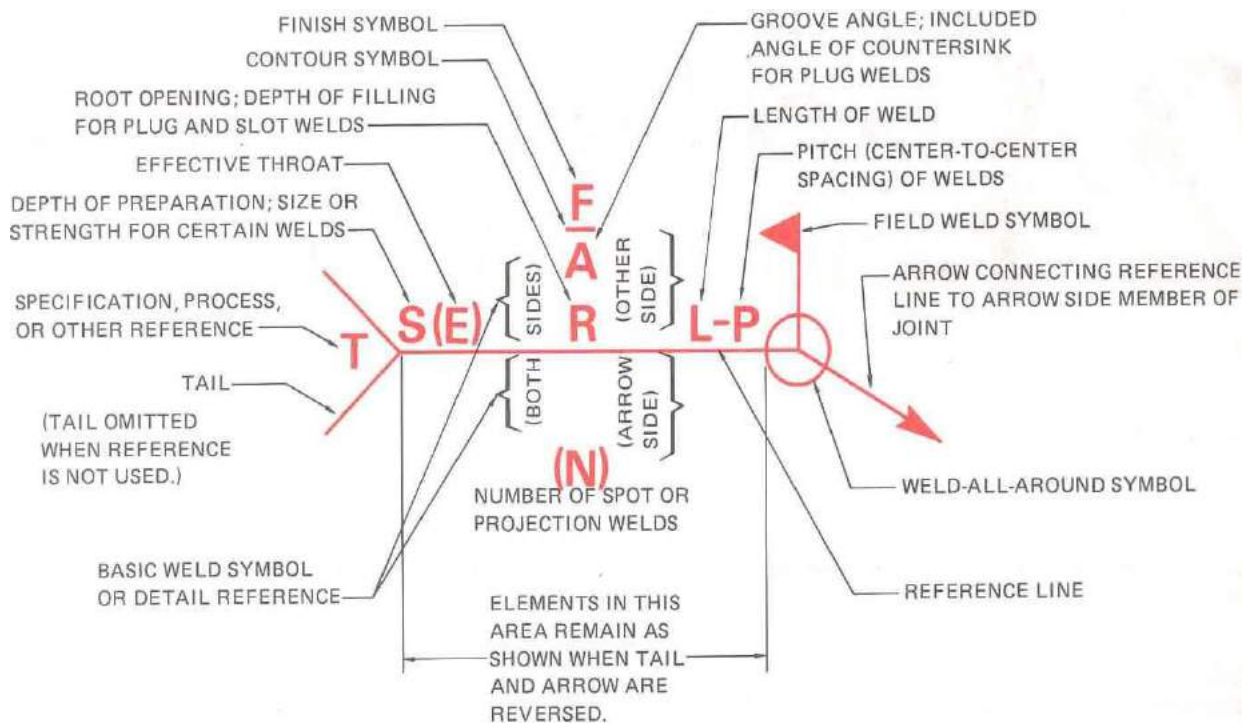
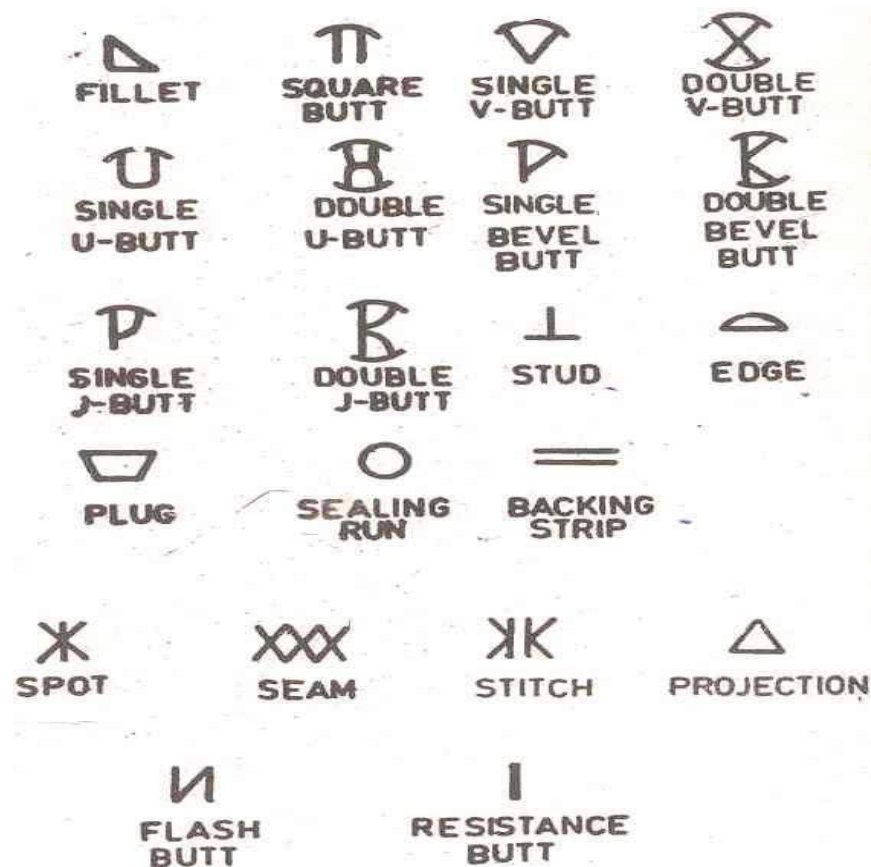


Fig. Standard Location of Elements of weld symbol

Basic weld Symbols

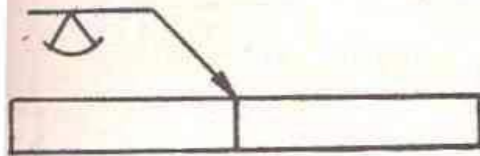


Location of the Weld

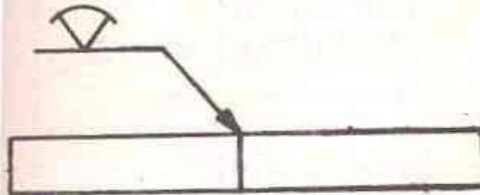
- When the weld symbol is below the reference line the weld is made on the same side of the joint as the arrow head i.e. the arrow side.
- When the weld symbol is above the reference line the weld is made on the other side of the joint apposite arrow head.
- When the weld symbol is on both sides of the reference line the weld is to be carried out on both sides of the joint.
- When resistance welds are to be indicated, the arrow shall point towards the center line along which welds are to be made.

SYMBOL

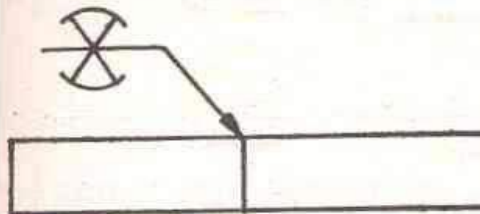
SIGNIFICANCE



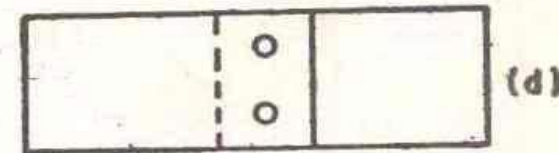
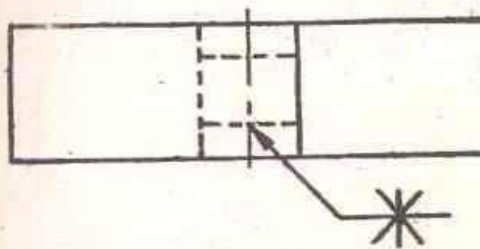
SINGLE - V



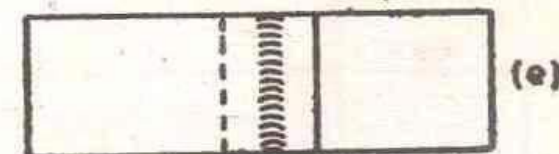
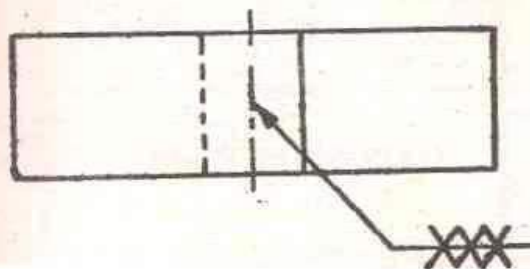
SINGLE - V



DOUBLE - V






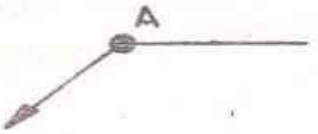

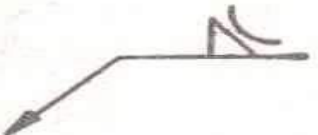

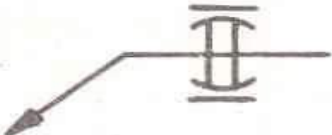





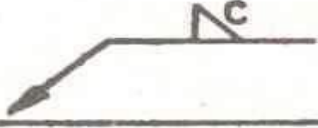

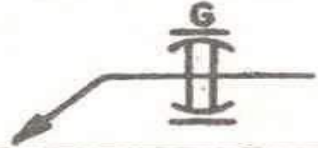


SPOT

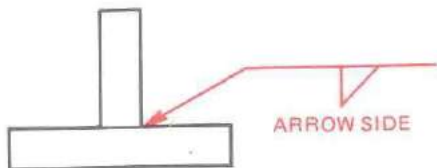
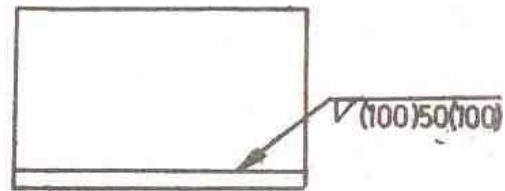
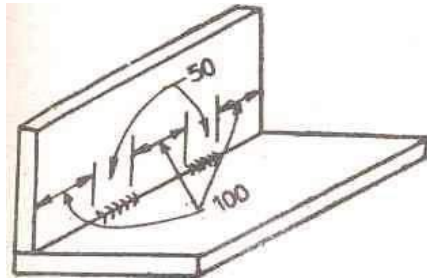
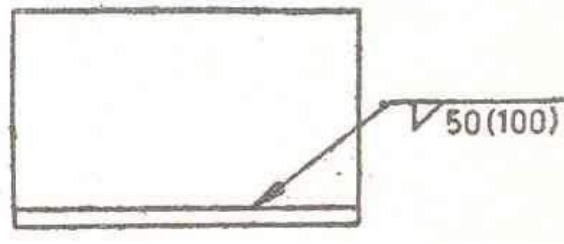
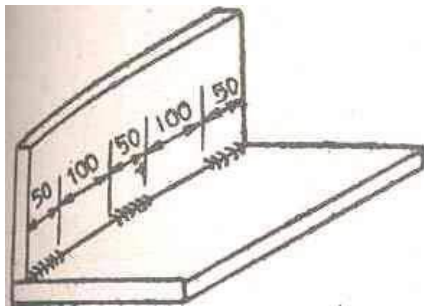


SEAM

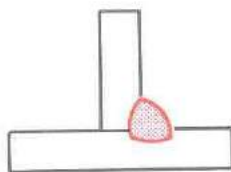
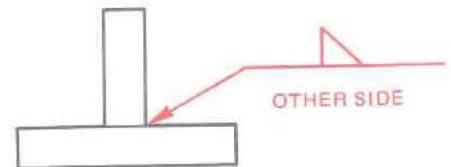
Supplementary Symbols

SYMBOL	DRAWING REPRESENTATION	
		WELD ALL-ROUND
		SITE WELD (ERECTION WELD)
		SITE WELD (ASSEMBLY WELD)
		CONCAVE CONTOUR
		FLUSH CONTOUR
		CONVEX CONTOUR
		MACHINING FINISH
		CHIPPING FINISH
		GRINDING FINISH

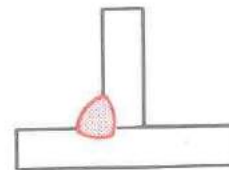
Examples of welding Symbols



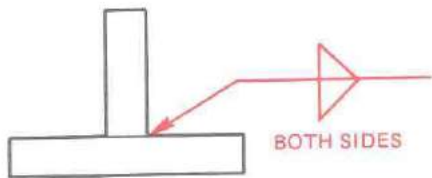
SYMBOL



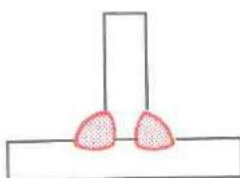
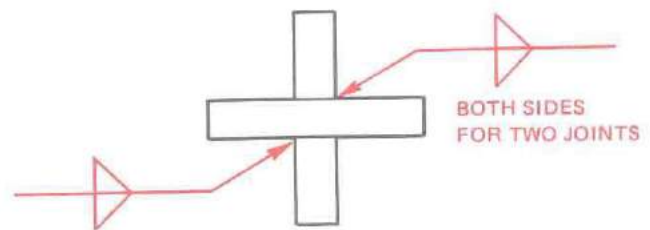
WELD



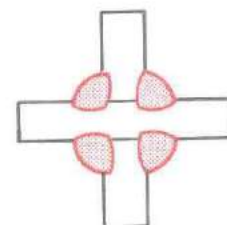
(B)



SYMBOL



WELD



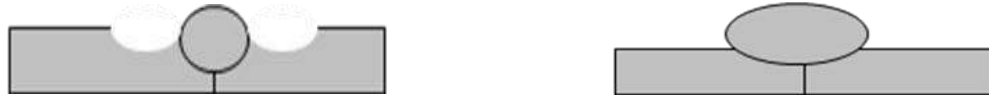
(D)

(A)

(C)

12. Welding Defects

- **Undercuts/Overlaps**



- **Grain Growth**

- A wide ΔT will exist between base metal and HAZ. Preheating and cooling methods will affect the brittleness of the metal in this region

- **Blowholes**

- Are cavities caused by gas entrapment during the solidification of the weld puddle. Prevented by proper weld technique (even temperature and speed)

- **Inclusions**

- Impurities or foreign substances which are forced into the weld puddle during the welding process. Has the same effect as a crack. Prevented by proper technique/cleanliness.

- **Segregation**

- Condition where some regions of the metal are enriched with an alloy ingredient and others aren't. Can be prevented by proper heat treatment and cooling.

- **Porosity**

- The formation of tiny pinholes generated by atmospheric contamination. Prevented by keeping a protective shield over the molten weld puddle.