



Manufacturing Technology

Joining Processes

YOU MAY GET STUDY MATERIAL FROM
AMIESTUDYCIRCLE.COM

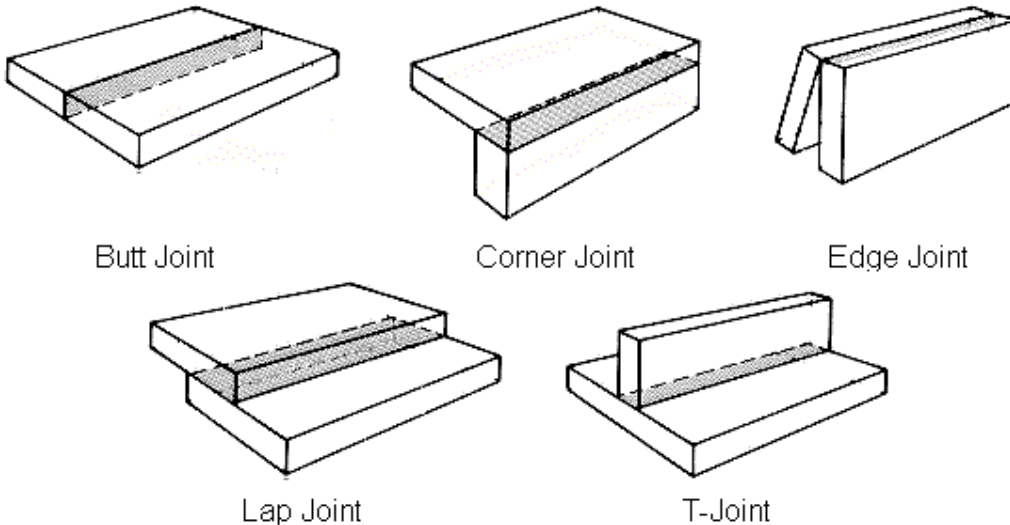
INFO@AMIESTUDYCIRCLE.COM

WHATSAPP/CALL: 9412903929

Joining Processes

Welding is defined as the joining of metals by heat with or without pressure, and with or without the addition of other (filler) materials, to obtain a homogeneous and interlocking or fused joint. The strength of the joint is often equal to that of the base materials. Many processes are classified under the definition of welding. Soldering is not included because the strength of joints depends upon adhesion rather than fusion. Cold welding may be properly called 'welding' when the molecules actually interlock to form a homogeneous joints.

WELDING JOINTS



USE OF HEAT IN WELDING PROCESSES

There are two general ways of applying heat. The first method applies “concentrated heat” to a limited and localized area near the joint, and thus restricts the expansion and contraction of the material. This is done in most electrical processes, such as metallic arc welding, electron beam welding and the resistance welding methods.

The second method applies a general heat to the material near the joint, which raises the temperature to that required to join the parts. Thus when the material cools, there are no localized stresses that will tend to pull the joint apart. Furnace brazing, dip brazing, forge welding and preheating for arc and gas welding are used in the second method.

WELDABILITY

Weldability denotes the relative ease of producing a weld which is free from defects such as cracks, hard spots, porosity or non-metallic inclusions. Weldability depends on one or more of following major factors:

1. **Melting Point:** when welding low M.P. alloys such as aluminium in thin sections, care must be taken to avoid melting too much base metal.

2. **Thermal Conductivity:** Alloys with higher thermal conductivity, such as aluminium, are difficult to bring to the fusion point. Welds in certain alloys, may cool quickly and crack. A high intensity heat source is very important. For example, for a given size weld, aluminium alloy requires upto three times as much heat per unit volume as does steel.
3. **Thermal expansion:** Rapid cooling for alloys with high thermal coefficients of expansion results in large residual stresses and excessive distortion.
4. **Surface Condition:** Surface coated with oils, oxides, dirt or paint hinder fusion and result in excessive porosity.
5. **Change in Microstructure:** Not only are steels above 0.4% C subject to grain growth in the HAZ (Heat affected zone) but martensite is also formed wherever the temperature exceeds 13300F for a sufficient time.

RESIDUAL (THERMAL) STRESSES IN WELDING

Residual stresses result from the restrained expansion and contraction that occur during the localized heating and cooling in the region of the weld deposit. The magnitude of such stresses depends upon the design of the weldment, the support, and the clamping of the components, their material and the welding process used. It is conceded generally that residual stresses can be detrimental under certain severe engineering applications. For example, deflections of members usually cannot be as great on designs with large residual stresses as those members that have had their residual stresses relieved. There is, however, no conclusive proof that residual stresses lower the strength of structural parts that are subjected to tension.

The residual stresses whether they are tensile or compressive type predominantly affect the soundness, dimensional stability and mechanical performance of the weld joints.

In fusion welding, the molten pool solidifies as a casting poured into a metal mould. It is restrained from contracting by an amount which varies with the welding process. The cooling rate has a great influence on the amount and nature of the residual stress. In general there are residual tensile stresses in the weld deposit which counterbalance compressive stresses in the base metal. They are proportional in the intensity to the weld size, and the maximum stress occurs in the direction of welding with the transverse stress the next highest in intensity. The stress in the thickness direction is least because there is the least hindrance to contraction in that direction.

Controlling the residual (thermal) stresses

The critical applications frequently demands relieving residual stresses of weld joints by thermal or mechanical methods. Relieving of residual stresses is primarily based on releasing the locked-in strain by developing conditions to facilitate plastic flow so as to relieve stresses.

- **Thermal method** is based on the fact that the yield strength and hardness of the metals decrease with increase of temperature which in turn facilitates the release of

locked in strain thus relieves residual stresses. Reduction in residual stresses depends on “how far reduction in yield strength and hardness take place with increase of temperature”. Greater is the softening more will be the relieving of residual stresses. Therefore, in general, higher is the temperature of thermal treatment of the weld joint greater will be reduction in residual stresses.

- **Mechanical method** is based on the principle of relieving residual stresses by applying external load beyond yield strength level to cause plastic deformation so as to release locked-in strain. External load is applied in an area which is expected to have peak residual stresses.
- **Mechanical Vibration** The vibrations of a frequency close to natural frequency of welded joint is applied on the component to be stress relieved. The vibratory stress can be applied in whole of the components or in localized manner using pulsators. The development of resonance state of mechanical vibrations on the welded joints helps to release the locked in strains so to reduce residual stresses.

GAS WELDING

Gas welding usually refers to oxyacetylene welding or, as the name implies, the burning of acetylene, the fuel gas, with the addition of oxygen to create a high temperature flame. The flame temperature normally obtained with 2 parts oxygen to 1 parts of acetylene is about 3232 °C. The gases are fed through the torch on a 1:1 ratio with the remaining 1 parts of oxygen coming from the surrounding air.

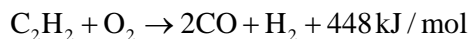
Gas cylinders

The oxygen cylinder is of a seamless drawn steel with a capacity of 220 ft at a pressure of 16.8 MPa at a temperature of 21 °C.

Acetylene can be compressed into a steel cylinder under a pressure of 17 kg/cm . The acetylene is dissolved in acetone, which in turn is absorbed by the porous materials in the cylinder, such as charcoal, Portland cement etc. This is necessary because acetylene when stored in a free state under pressure greater than 2.2 kg/cm can dissociate by heat or shock and possibly explode. Acetylene cylinders should not be used in a horizontal position since some of acetone would be drawn off.

Reactions

Following reactions will take place for oxy-acetylene welding.

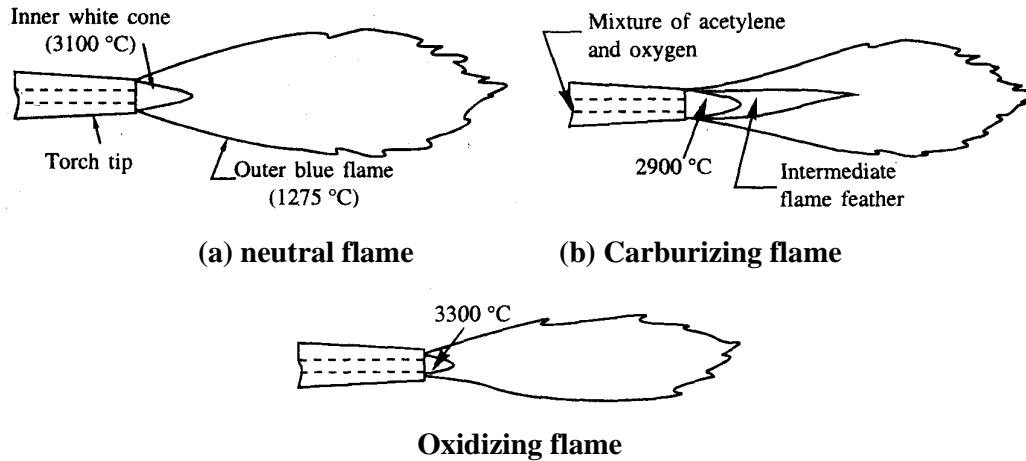


The carbon monoxide (CO) and hydrogen produced in the first stage further combine with the atmospheric oxygen and give rise to the outer bluish flame, with the following reaction.



Oxyacetylene Flame

Three distinct flame variations are produced with an oxyacetylene gas mixture, reducing or carburizing, neutral, and oxidizing. All three flames are shown in given figure.

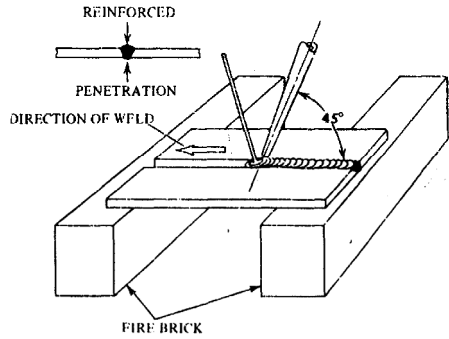


Each of the three flames may be used as follows:

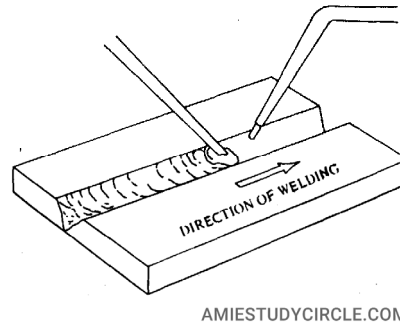
- When less oxygen is supplied, a part of combustible material is left, which causes a reduced flame or carburizing flame. Carburizing flame may be used to advantage in welding high-carbon steels. If a carburizing flame is used in welding steels, the excess carbon will enter the metal, causing porosity in solidified metal.
- In neutral flame, all the acetylene is burned and all the heat in acetylene is released. Neutral flame is used for most welding operations.
- When oxygen is in excess, it is called oxidizing flame. Oxidizing flame is used for fusion welding of brass and bronze; however, the flame is only slightly oxidizing. An oxidizing flame used on steel will cause the metal to foam and spark. Oxidizing flame has the maximum temperature of 3482 °C.

Gas Welding Procedure

There are several methods of oxyacetylene welding that produce good results. Both forehand and backhand welding are used. In forehand welding, the welding rod precedes the tip of the torch in the direction the weld is being made. (Fig. a). This position, with the torch at about 45 degrees to the plate, permits uniform preheating of the plate edges immediately ahead of the molten puddle. In backhand welding, the torch is pointed back at the molten puddle with the torch held at about 60 degrees to the plate (Fig. b).



(a) Forehand welding



(b) Backhand welding

Advantages: Following are advantages of gas welding.

- The gas flame is generally more easily controlled and is not as piercing as shielded arc welding. Therefore, it is used extensively for sheet metal fabrication and repairs.
- The oxyacetylene or oxy-MAPP flame is versatile. It may be used for brazing, preheating, post-heating, heating for forming, heat treatment, flame cutting and more.
- The gas welding outfit is very portable.

Limitations: Following are limitations

- The process is much slower than arc welding.
- Harmful thermal effects (such as more distortion, increased grain growth and in some cases, a loss of corrosion resistance) are aggravated by prolonged heat.
- There are safety problems in handling gases.
- Flux applications and their shielding provided by the secondary envelope of the flame are not nearly as positive as that supplied by the gases used for GTA and GMA welding.

METALLIC ARC WELDING

The term 'arc welding' is used by the trade when the arc is formed between the metal at the joint and the metal electrode which melts and fills the joint. The molten metal is protected from contamination by three general methods:

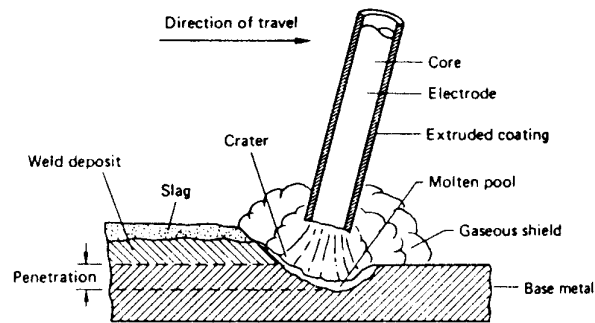
1. The electrode is coated with a flux which melts and forms a gaseous envelope around the arc and a liquid covering over the molten metal
2. An inert gas envelope (or shield) is blown around the electrode as it melts. The inert gas is argon, helium or carbon dioxide. The electrode as argon is especially satisfactory in the welding of aluminium, magnesium and stainless steels.
3. The end of the electrode is submerged in a powdered flux (as in submerged metal arc welding). This surrounds the arc and protects it and the molten metal.

Shielding not only provides protection from the atmosphere for the molten metal (thus preventing the formation of oxides and nitrides), but it also affects the stability and metal transfer characteristics of the arc. The coating on the electrode supplies ingredients that react with deleterious substances, such as oxides and salts, and ties up these substances chemically into a slag. The slag is lighter than the weld pool, and it therefore rises to the top and crusts over the newly solidified metal. Even after solidification, the slag continues to protect the weld metal until it cools to the point where reaction with the air is negligible.

Arc Welding Processes

Arc welding processes most widely used are shielded metal arc welding (SMAW), flux cored welding (FCW), gas metal arc welding (GMAW) or MIG, gas tungsten arc welding (GTAW) or TIG, plasma arc welding (PAW), submerged-arc welding (SAW), electro slag welding (ESW), and stud arc welding (SW).

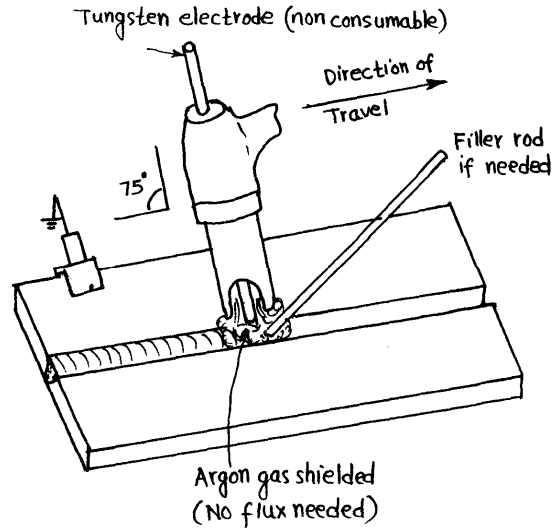
Shielded Metal Arc Welding: SMAW, commonly called stick welding, is the oldest of the modern arc welding processes. It is also most widely used. Basically is a manual process in which the heat is generated by an arc that is established between the flux covered consumable electrode and the work as shown in figure.



SMAW is widely used because the equipment is relatively simple, very portable and less expensive than any other arc welding equipment. Welding can be done in virtually any position. The process is well adapted to making repairs even in out of position locations (other than flat).

Metal deposition rate is not as high as in certain other arc welding processes. Welding must be interrupted each time an electrode is consumed, causing downtime and a wasted stub. Slag must be chipped and wire brushed from the weld surface; Softer metals such as zinc, lead and tin, which have low melting point and boiling temperatures, do not lend themselves to SMAW.

Gas tungsten Arc Welding (GTAW) or TIG (Tungsten Inert Gas): TIG Welding consists of a non consumable, torch held tungsten electrode and a workpiece as shown in figure. If filler metal is required, a welding rod is fed into the weld zone and melted with the base metal.



Argon provides the most stable arc and most efficient cleaning action. Helium is hotter than argon and so provides deeper penetration at higher welding speeds. Argon and hydrogen mixtures help prevent weld bead discoloration.

GTAW or TIG welding can be used to make top quality welds in almost all metals and alloys, including high temperature alloys, many hard facing alloys, titanium, zirconium, gold and silver. Almost no cleanup is required since no flux is required. There is very little, if any weld spatter. Welding thin materials where a high quality finish is required.

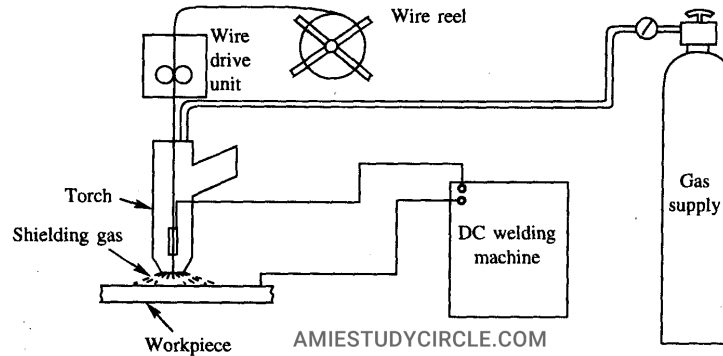
The main disadvantage of GTAW is that it is relatively slow and for that reason is not well suited to welding heavier metals.

Gas Metal Arc Welding (GMAW) or MIG Welding: GMAW is also popularly known as MIG Welding, short for Metal Inert Gas Welding. However, since CO₂ gas, which is not inert, is often used for shielding the arc, the term is not all inclusive. GMAW is the answer to a long sought method of being able to weld continuously without the interruption of changing electrodes. This necessitated automatic wire feeding.

MIG welding employs the following three basic processes.

- Bare-wire electrode process
- Magnetic flux process
- Flux-cored electrode process.

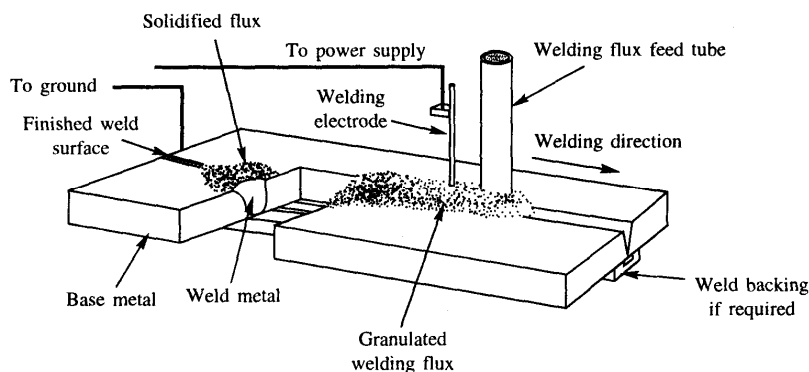
Originally only inert gases, argon and helium were used for shielding. Now, CO₂ is used extensively, and CO₂ and oxygen are often mixed with inert gases. Generally, argon, helium, or mixtures of these gases are used when welding non ferrous metals, CO₂ for steels, and CO₂ with argon and sometimes helium for steel and stainless steels and also argon and small amounts of oxygen for steels and stainless steels.



Most GMAW is done with dcrp (direct current reverse polarity) because it produces deeper penetration than straight polarity. Also, straight polarity tends to produce an unstable arc with considerable spatter.

The main advantage of GMAW welding is that it can produce high quality welds at high speeds and there is no flux to remove. It is a very versatile process that is used on both light and heavy gage structural plates. It is used easily on carbon steels, low alloy steels, stainless steels, aluminium, magnesium, copper, nickel and titanium.

Submerged Arc Welding (SAW): Submerged-arc welding derives its name from the fact that the arc is hidden under a heavy coating of granular mineral material or flux. A bare wire is used, and the fusible flux blanket provides protection for the molten metal from the atmosphere. The dry granular flux is fed continuously from a hopper through a tube placed slightly ahead of the arc zone. The arc is struck in the submerged area and the weld is completed without the usual sparks, spatter and smoke. The process generally is fully automatic.



The current used for SAW can be either ac or dc. By using dcrp, deeper penetration can be obtained ; however with dcsp (direct current straight polarity) a higher deposition rate with a broader weld bead can be achieved.

Submerged arc welding has several distinct advantages. Very high currents can be used ranging from 200 to 2000A. It may be noted that in conventional welding, where the arc is exposed, currents above 300A must be used with great care due to the intensity of high infrared and ultraviolet rays. The ability to use high current in SAW welding brings with it

MANUFACTURING TECHNOLOGY**JOINING PROCESSES****A FOCUSED APPROACH**

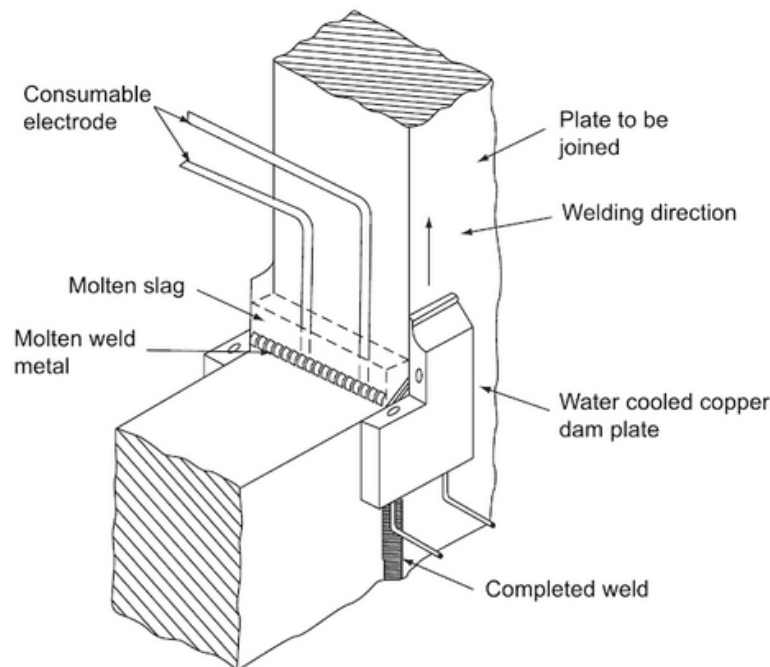
high deposition rates and good penetration. The process is thermally efficient as much of the heat is kept under a blanket of slag. Because of high deposition rates and smooth bead, SAW is a preferred process used in rebuilding and hard surfacing crushing rolls, and in manufacturing a wide variety of equipment.

One disadvantage inherent in the process is that since the weld cannot be seen, it is more difficult to guide it. Another disadvantage is that it is largely limited to flat position welding. Overhead welding is impractical due to the high fluidity of the weld pool and the granular flux.

The SAW process is usually not suitable for metal less than about 3/16 in (7.92mm) thick because burn through is likely.

Electro Slag Welding (ESW) The electroslag welding (ESW) process is developed essentially to weld very large plates without any edge preparation. This is essentially a single-pass process using a consumable electrode for filling the gap between the two heavy plates. The heat required for melting the plates and the electrode is obtained initially by means of an arc so that flux will form the molten slag. Once the molten slag is formed, the arc is extinguished and the heat of welding is obtained by the resistance heating of the slag itself.

The typical electro slag welding set-up is shown in following figure.



For effective welding, it is necessary to maintain a continuous slag pool and therefore the best way to maintain it, is to weld vertically. The slag pool is contained in the groove with the help of two water-cooled copper dam plates which move along with the weld, as shown. The size and type of electrodes chosen for a given operation depends on the width of the joint. In this figure, two electrodes for feeding through the feed rollers (not shown) into the weld /one, are shown.

The flux required to maintain a satisfactory amount of slag is fairly small, of the order of 0.2 to 0.3 kg per metre of weld length, irrespective of the plate thickness. Thus, the heat utilised for melting the slag is much less. Most of the heat supplied in electro slag welding thus, melts the joint. By this process, a plate of 200 mm thickness can easily be welded in a single pass. Because of the vertical welding, any gas present easily bubbles out through the slag and therefore, better welds can be had. The heating and cooling of the edge is more gradual. The slag floating at the top would be preheating the joint before the actual melting by the heat liberated from the electrode. Whatever be the thickness of the plate, no edge preparation is required.

electroslag welding is useful for welding very thick plates. The workpieces whose thicknesses are less than 50 mm may not be economical for welding by this process, unlike submerged arc welding.

Some typical applications of this welding process are in the fabrication of high-pressure vessels, frames of heavy mechanical and hydraulic presses, rolling mill frames, ship hulls, locomotive frames, etc.

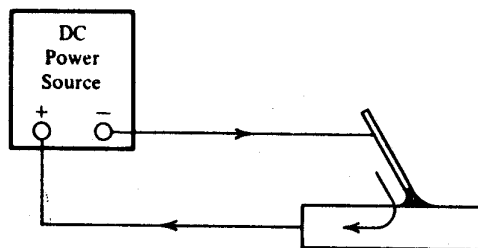
Systems for Power Supply in Arc Welding

Arc welding may be performed by using two types of power supplies Direct Current (DC) or Alternating Current (AC) power supplies.

D.C. Power Supply

D.C. power supply may be obtained by either (i) motor generator system (ii) Rectifier system or (iii) Converter systems.

Polarity: In conventional d.c. welding where the workpiece is the positive pole and the electrode is negative the hookup is referred to as being straight polarity (dcsp) (See figure). When the arrangement is reversed, it is referred to as reverse polarity (dcrp).



Polarity can be used to control the location of the liberated heat. Usually it is preferable to have more of the heat at the workpiece because that is the larger area. Thus, if large deposits are to be made on heavy workpiece, straight polarity would be the most effective hookup. On the other hand, in overhead welding where the weld pool should be kept relatively small and a fast freeze helps hold the metal in place, reverse polarity would be best. Where it is necessary to keep the workpiece as cool as possible, as in arc welding cast iron, reverse polarity is the best choice.

In general, the use of dcsp will result in a higher deposition rate (more metal deposited per unit time) but less penetration. The converse is also true.

A.C Arc Welding

A.C. Welding machines are generally of two types:(i) motor generator type and (ii) Transformer type.

The distinct advantage that a.c. arc welding has over d.c. welding is that there is virtually no magnetic blow. The reversal of current flow each 1/100 the of a second keeps the effect of magnetic field to a minimum. The reversal of the field at such a frequency results in much more stable arc stream. Because arc blow is minimized, quality welds are always produced with a.c.

A.C. arc produces good penetration. It is an easy arc to control and to maintain once the arc is obtained. However, because of the a.c. flow, flow of very high frequency current at the time the arc is struck.

A.C. arc welding is usually faster, because larger electrodes and therefore more current can be used due to minimum magnetic blow conditions. Some of the basic features of AC arc welding are:

- good forceful arc
- Arc blow is absent
- Weld arc is easy to hold once obtained.
- A good way to weld aluminium.
- The most popular application is production welding on heavy gauge steel.

A.C. arc welding can use larger electrodes and therefore more current than when DC welding. A longer arc can be drawn when using AC equipment than with DC.

One particular advantage of AC welding is its ability to produce excellent deep penetration fillet welds.

Arc Welding Defects

Improper welding procedure and lack of skill on the part of welder may result in many welding defects.

The major welding defects are described below:

1. **Incomplete fusion and lack of penetration:** Incomplete fusion can be avoided by proper weld joint preparation, using adequate current and travel speed of electrode should not be too high.
2. **Porosity:** Molten metal has a tendency to absorb gases. The entrapped gases cause porosity or blow holes in the weld bead. Remedy lies in cleaning the work piece surface of all oil, grease and paint etc. before welding and ensuring that electrode

coating is free from dampness. If necessary, electrodes can be dried in an oven before use.

3. **Slag inclusion:** It refers to slag or other non-metallic inclusions getting entrapped in the weld bead. The most common reason for slag inclusion is that between two electrode runs, the slag, has not been completely removed by chipping and wire brushing.
4. **Undercut:** Undercutting is often caused due to high amperage used. It denotes the melting away of the base metal at the line where the final layer of weld bead merges into the surface of the base metal. The undercut portion must be rectified by depositing weld metal on it.
5. **Cracking:** Cracks can take place either in the weld bead itself (called hot cracks) or in the heat affected zone (cold cracks). Hot cracks may take place due to narrow deep welds and are caused due to shrinkage of weld metal, particularly if impurities like sulphur are present in the weld metal. Excessive joint restraint can also cause such cracks. Cold cracks occur due to inadequate ductility or presence of hydrogen in hardenable steels. Preheating and post heating of base material will help in avoiding cold cracks.

Heat Affected Zone

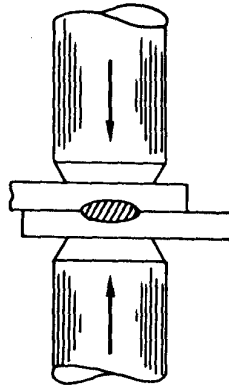
In the arc welding process, a great amount of heat output takes place resulting in formation of a molten pool in the arc area. The heat is also conducted into the vicinity of the joint on either side. The temperature of the material on both sides of the weld bead may not be as high as the melting point of the metal, but, is very close to it. As we move away from the joint or weld bead, the metal may be heated to lesser and lesser temperature. As the electrode travels over the joint and moves away, the heated metal cools as quickly as it was heated. Thus, we can conclude, that the metal adjacent to the weld bead has been subjected to a heat treatment. If steel is being welded, this heating and quick cooling may result in formation of martensitic and other structures which may be prone to cracking and hardness. The area so affected by welding is called “heat affected zone”.

RESISTANCE WELDING

Resistance welding is based on the well known principle that, as a metal impedes the flow of electric current, heat is generated. The interface between the two surface of the workpiece offers the greatest resistance to current flow in comparison to the balance of the circuit and is therefore the area of greatest heat. The heat generation is directly proportional to the square of the current times the resistance.

Types of Resistance Welds: Types of resistance welds includes spot welding butt welding, seam welding, upset welding, projection welding, flash welding and high frequency welding.

Spot welding differs from most other welding processes in two major ways: external pressure is applied, and the weld is not exposed to the atmosphere.

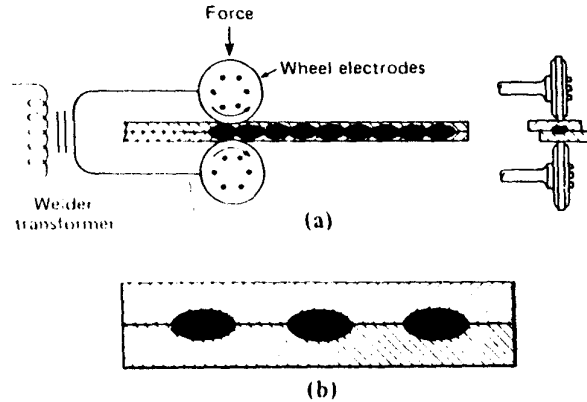


Because no material is added to the weld, the basic metallurgical composition remains unchanged. However, the applied pressure has the effect of refining the grain structure of the weld metal. Coalescence takes place while the material is in a plastic state, and the resultant metallurgical structure is finer and more uniform than that of a cast joint as in normal fusion welding. Also, protection from the atmosphere allows the metal to remain pure.

Four step resistance welding cycle are given below:

- The steps which are used in spot welding for producing the joints starts with the firm contact between the electrode and the work piece, and the firm contact between the work piece interface. So, under the pressure, the electrode surface is a the pressure is applied through the electrode on the surface of the work piece to have the firm contact between the electrode and work piece, and the firm contact between the work piece surfaces So, weld cycle starts with the upper electrode moving and contacting the work piece, resting on the lower electrode which is stationary and work pieces are held under pressure and then flow of current is started for preset time.
- And when flow of current starts, it generates heat at the interface and the maximum heat is generated at the interface and which leads to the partial melting of the work pieces of surfaces at the interface. And under pressure, the molten metal is squeezed and consolidated to form nugget.
- And when the nugget is formed, weld nugget is formed, it is allowed to cool under pressure and then pressure is released gracefully. These are the four steps in producing the joint by spot welding, and the entire, all these four steps are termed as **resistance spot welding cycle**.

Seam welding is a continuous type of spot welding. Instead of using regular rod-type pointed electrodes.

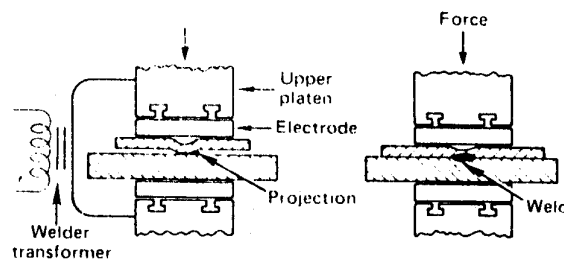


(a) Seam spot welding (b) Intermittent welding

The work is passed between copper wheels or rollers that act as electrodes. The appearance of the completed weld is that of a series of overlapping spot welds that resemble stitches. Seam welding can be used to produce highly efficient water and gas tight joints. A variation of seam welding used to produce a series of intermittent spots is called roll welding.

Projection Welding

Projection welding is another variation of spot welding. Small projections are raised on one side of the sheet with a punch and die. The projections act to localize the heat of the welding circuit. During the welding process, the projections collapse; owing to heat and pressure and the parts to be joined are brought in close contact.

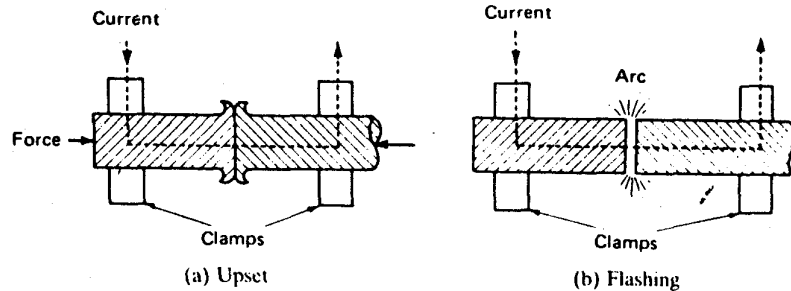


One of the most common applications of projection welding is for attaching small fasteners, nuts, special bolts, studs and similar parts to larger components. A wide variety of these parts are made with preformed projections.

Resistance Butt Welds

Upset Welding: The material to be welded, usually bar stock, is clamped so that the ends are in contact with each other. High density current, usually from 2000 to 5000A/in, is used to make the weld. The high resistance of the joint causes fusion to take place at the interface.

Just enough pressure is applied to keep the joint from arcing. As the metal becomes plastic, the force is enough to make a large, symmetrical upset that eliminates oxidized metal from the joint (see figure a). The metal is not melted and no spatter results. For most applications, the upset must be machined off before use.



Flash Butt Welding : In flash butt welding, the ends of the stock are clamped with a slight separation before welding. As the current is turned on, it jumps the gap and creates a great deal of heat. Some of the metal burns away. The two pieces are moved toward each other in an accelerated motion, and as they reach the proper temperature, they are forced together under high pressure and the current is cut off (figure b).

Advantages and limitations of Resistance Welding

Spot welding can be used for fast, economical joining of steels upto 1/8 in (317 mm) thick and occasionally upto 1/4 in (6.35 mm) thick. The process is well suited to high speed, mass production setups. The use of automatic current control, timing, and electrode force makes spot welding a reliable process. Spot welding equipment is relatively expensive.

Seam welders can be used to make gas tight and liquid tight joints. Seam welding also requires less overlap than spot welds and can in fact be made with less overlap than the diameter of the spot weld.

Flash welding can be used to produce assemblies that otherwise would require forgings or castings. Flash welding is used in producing such widely varying products as aircraft landing gear, band saw blades, pipelines, and welding tap and reamer bodies to low carbon steel and alloy steel shanks.

Projection welding is particularly useful in mounting metal stampings in material from 0.53 to 3.43 mm thick. Projection welds also reduced the amount of current required because of the greater current density where needed.

The major limitation in the resistance welding is the heavy current level requirements, which impose a high KVA demand on the plant.

SOLID STATE WELDING

Solid state welding is a group of welding processes which produces coalescence at temperatures essentially below the melting point of the base materials being joined, without the addition of brazing filler metal. Pressure may or may not be used. These processes are

sometimes erroneously called solid state bonding processes: this group of welding processes includes cold welding, diffusion welding, explosion welding, forge welding, friction welding, hot pressure welding, roll welding, and ultrasonic welding.

In all of these processes time, temperature, and pressure individually or in combination produce coalescence of the base metal without significant melting of the base metals.

Cold Welding (CW)

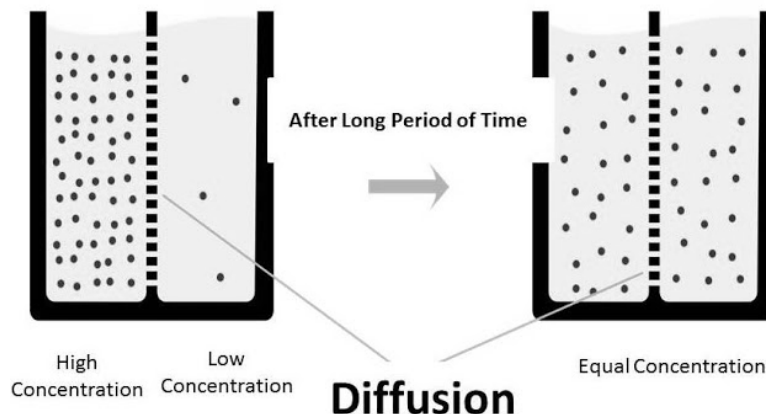
Cold welding is a solid state welding process which uses pressure at room temperature to produce coalescence (clutter) of metals with substantial deformation at the weld.

Welding is accomplished by using extremely high pressures on extremely clean interfacing materials. Sufficiently high pressure can be obtained with simple hand tools when extremely thin materials are being joined. When cold welding heavier sections a press is usually required to exert sufficient pressure to make a successful weld.

Indentations are usually made in the parts being cold welded. The process is readily adaptable to joining ductile metals. Aluminum and copper are readily cold welded. Aluminum and copper can be joined together by cold welding.

Diffusion Welding (DFW)

This process works on basic principle of diffusion. Diffusion means movement of molecules or atoms from high concentration region to low concentration region. This is fundamental principle of diffusion welding. In this welding process both the welding plates are placed one over other in high pressure and temperature for a long period of time. This high pressure force starts diffusion between interface surfaces. This diffusion can be accelerated by the application of high temperature. This temperature does not melt the welding plates. The temperature range is about 50-60% of melting temperature. This whole process takes place in vacuum or in inert environment which protects the welding plates form oxidation.



The process is used for joining refractory metals at temperatures that do not affect their metallurgical properties. Heating is usually accomplished by induction, resistance, or furnace.

Atmosphere and vacuum furnaces are used and for most refractory metals a protective inert atmosphere is desirable.

Explosion Welding (EXW)

Explosion welding is a solid state welding process in which coalescence is effected by high-velocity movement together of the parts to be joined produced by a controlled detonation. Even though heat is not applied in making an explosion weld it appears that the metal at the interface is molten during welding.

This heat comes from several sources, from the shock wave associated with impact and from the energy expended in collision. Heat is also released by plastic deformation associated with jetting and ripple formation at the interface between the parts being welded. It is found necessary to allow the metal to flow plastically in order to provide a quality weld.

Explosion welding creates a strong weld between almost all metals. It has been used to weld dissimilar metals that were not weldable by the arc processes. The weld apparently does not disturb the effects of cold work or other forms of mechanical or thermal treatment. The process is self-contained, it is portable, and welding can be achieved quickly over large areas. The strength of the weld joint is equal to or greater than the strength of the weaker of the two metals joined.

Explosion welding has not become too widely used except in a few limited fields. One of the most widely used applications of explosion welding has been in the cladding of base metals with thinner alloys. Another application for explosion welding is in the joining of tube-to-tube sheets for the manufacture of heat exchangers. The process is also used as a repair tool for repairing leaking tube-to-tube sheet joints. Another and new application has been the joining of pipes in a socket joint. This application will be of increasing importance in the future.

Forge Welding (FOW)

Forge welding is a solid state welding process which produces coalescence of metals by heating them in a forge and by applying pressure or blows sufficient to cause permanent deformation at the interface.

This is one of the older welding processes and at one time was called hammer welding. Forge welds made by blacksmiths were made by heating the parts to be joined to a red heat considerably below the molten temperature. Normal practice was to apply flux to the interface. The blacksmith by skillful use of a hammer and an anvil was able to create pressure at the faying surfaces sufficient to cause coalescence. This process is of minor industrial significance today.

Friction Welding (FRW)

Friction welding is a solid state welding process which produces coalescence of materials by the heat obtained from mechanically-induced sliding motion between rubbing surfaces. The work parts are held together under pressure. This process usually involves the rotating of one

part against another to generate frictional heat at the junction. When a suitable high temperature has been reached, rotational motion ceases and additional pressure is applied and coalescence occurs.

There are two variations of the friction welding process. In the original process one part is held stationary and the other part is rotated by a motor which maintains an essentially constant rotational speed. The two parts are brought in contact under pressure for a specified period of time with a specific pressure. Rotating power is disengaged from the rotating piece and the pressure is increased. When the rotating piece stops the weld is completed. This process can be accurately controlled when speed, pressure, and time are closely regulated.

The other variation is called inertia welding. Here a flywheel is revolved by a motor until a preset speed is reached. It, in turn, rotates one of the pieces to be welded. The motor is disengaged from the flywheel and the other part to be welded is brought in contact under pressure with the rotating piece. During the predetermined time during which the rotational speed of the part is reduced the flywheel is brought to an immediate stop and additional pressure is provided to complete the weld.

Both methods utilize frictional heat and produce welds of similar quality. Slightly better control is claimed with the original process.

Among the advantages of friction welding is the ability to produce high quality welds in a short cycle time. No filler metal is required and flux is not used. The process is capable of welding most of the common metals. It can also be used to join many combinations of dissimilar metals.

Hot Pressure Welding (HPW)

Hot pressure welding is a solid state welding process which produces coalescence of materials with heat and the application of pressure sufficient to produce macro-deformation of the base metal.

In this process coalescence occurs at the interface between the parts because of pressure and heat which is accompanied by noticeable deformation. The deformation of the surface cracks the surface oxide film and increases the areas of clean metal. Welding this metal to the clean metal of the abutting part is accomplished by diffusion across the interface so that coalescence of the faying surface occurs. This type of operation is normally carried on in closed chambers where vacuum or a shielding medium may be used. It is used primarily in the production of weldments for the aerospace industry. A variation is the hot isostatic pressure welding method. In this case, the pressure is applied by means of a hot inert gas in a pressure vessel.

Roll Welding (ROW)

Roll welding is a solid state welding process which produces coalescence of metals by heating and by applying pressure with rolls sufficient to cause deformation at the faying surfaces. This process is similar to forge welding except that pressure is applied by means of

rolls rather than by means of hammer blows. Coalescence occurs at the interface between the two parts by means of diffusion at the faying surfaces.

One of the major uses of this process is the cladding of mild or low-alloy steel with a high-alloy material such as stainless steel. It is also used for making bimetallic materials for the instrument industry.

Ultrasonic Welding (USW)

Ultrasonic welding is a solid state welding process which produces coalescence by the local application of high-frequency vibratory energy as the work parts are held together under pressure. Welding occurs when the ultrasonic tip or electrode, the energy coupling device, is clamped against the work pieces and is made to oscillate in a plane parallel to the weld interface.

The combined clamping pressure and oscillating forces introduce dynamic stresses in the base metal. This produces minute deformations which create a moderate temperature rise in the base metal at the weld zone. This coupled with the clamping pressure provides for coalescence across the interface to produce the weld. Ultrasonic energy will aid in cleaning the weld area by breaking up oxide films and causing them to be carried away.

The vibratory energy that produces the minute deformation comes from a transducer which converts high-frequency alternating electrical energy into mechanical energy. The transducer is coupled to the work by various types of tooling which can range from tips similar to resistance welding tips to resistance roll welding electrode wheels. The normal weld is the lap joint weld.

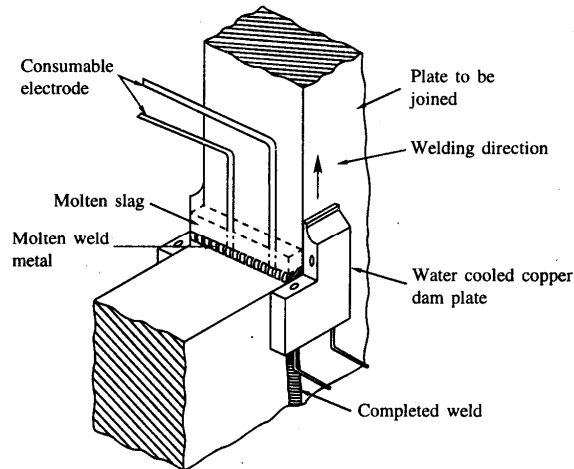
The temperature at the weld is not raised to the melting point and therefore there is no nugget similar to resistance welding. Weld strength is equal to the strength of the base metal. Most ductile metals can be welded together and there are many combinations of dissimilar metals that can be welded. The process is restricted to relatively thin materials normally in the foil or extremely thin gauge thicknesses.

This process is used extensively in the electronics, aerospace, and instrument industries. It is also used for producing packages and containers and for sealing them.

MISCELLANEOUS WELDING PROCESSES

Electro slag Welding

The electro slag welding process is unique in that it joins plates by casting the filler metal between the butted edges of the parent metal. The joint is made in one pass. The filler metal may be alloyed as desired through the introduction of alloy granules on top of the molten flux or through the cored consumable electrode.

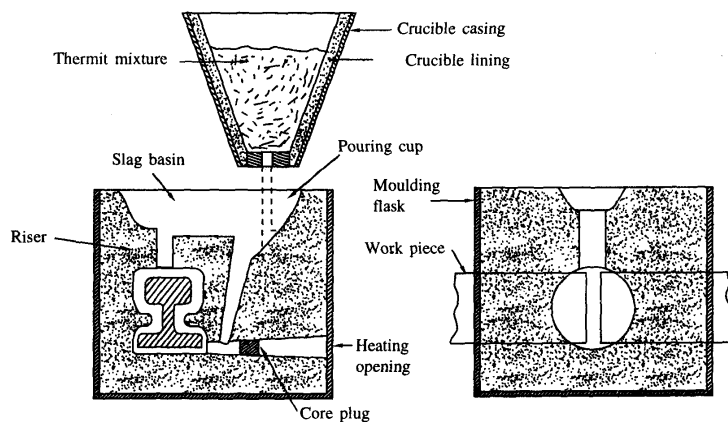


The process is applied to vertical joints. Copper bottom and side plates are needed to start the process. Special fixtures and procedures can produce circumferential welds to join thick walled pipe of large diameter.

Thermit Welding

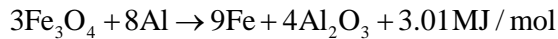
In this welding technique, heat generated by the exothermic chemical reaction between ferric oxide and aluminium powder is used to melt the filler metal, and then this molten filler metal is poured between the broken parts (to be welded) to complete the welding.

A clay mould is built around the broken part (such as iron girder, channels, rails, flywheel rims, etc.) A crucible with a plug is fitted in it. Thermit mixture (a mixture of ferric oxide, aluminium and magnesium powders) is filled in it. On the top is placed a mixture of barium peroxide(oxidising agent) and magnesium powder. It is ignited by a magnesium ribbon inserted in the ignition mixture. The heat so produced makes the iron near to its boiling point. The plug in the bottom is removed. Molten iron falls on the broken part and melts it. In this way fusion of base metal and filler takes place and the welding is completed. It should be noted that no pressure is applied in thermit welding technique.



Setup for thermit welding

Following reaction will take place



The temperature reached is of the order of 3000°C.

Electron Beam Welding

Electron beam welding (EBW) is a welding process which produces clattering of metals with the heat obtained from a concentrated beam composed primarily of high-velocity electrons impinging upon the surfaces to be joined. Heat is generated in the workpiece as it is bombarded by a dense stream of high-velocity electrons. Virtually all of the kinetic energy—the energy of motion—of the electrons is transformed into heat upon impact.

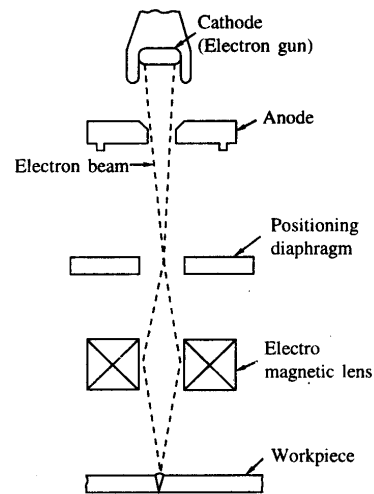
In this welding process, the electron gun and the work piece are housed in a vacuum chamber. There are three basic components in an electron beam-welding machine. These are (1) the electron beam gun, (2) the power supply with controls, and (3) a vacuum work chamber with work-handling equipment. The electron beam gun emits electrons, accelerates the beam of electrons, and focuses it on the work piece.

One of the major advantages of electron beam welding is its tremendous penetration. This occurs when the highly accelerated electron hits the base metal. It will penetrate slightly below the surface and at that point release the bulk of its kinetic energy which turns to heat energy. The addition of the heat brings about a substantial temperature increase at the point of impact. The succession of electrons striking the same place causes melting and then evaporation of the base metal. This creates metal vapors but the electron beam travels through the vapor much easier than solid metal. This causes the beam to penetrate deeper into the base metal.

Since the electron beam has tremendous penetrating characteristics, with the lower heat input, the heat-affected zone is much smaller than that of any arc welding process. In addition, because of the almost parallel sides of the weld nugget, distortion is greatly minimized. The cooling rate is much higher and for many metals this is advantageous; however, for high-carbon steel this is a disadvantage and cracking may occur.

Filler metal is *not* used in electron beam welding; however, when welding mild steel highly deoxidized filler metal is sometimes used. This helps deoxidize the molten metal and produce dense welds.

Almost all metals can be welded with the electron beam welding process. The metals that are most often welded are the super alloys, the refractory metals, the reactive metals, and the stainless steels. Many combinations of dissimilar metals can also be welded.



One of the disadvantages of the electron beam process is its high capital cost. The price of the equipment is very high and it is expensive to operate due to the need for vacuum pumps. In addition, fit up must be precise and locating the parts with respect to the beam must be perfect.

Laser Beam Welding (Solid State Welding)

The laser (light amplification by stimulated emission of radiation) is a concentrated beam of coherent monochromatic radiation. It is possible to use a monochromatic source as laser provided all the waves are of single phase (coherent). This is achieved by means of the stimulation. Because of the coherency, it is possible to concentrate the laser beam by means of an optical lens to a spot of any desired size without appreciably losing any of its intensity. Thus, the laser beam is a high energy source of heat to melt (even evaporate) the joint for fusion welding in laser beam welding (LBW).

In laser beam welding two types of lasers are generally used. They are solid state lasers and gas lasers.

In the *solid state lasers*, the light is emitted from a glass or a single crystal (such as ruby) that is doped with transition elements (such as chromium for ruby). When normal white light impinges on the crystal, the outer shell electrons of the dope elements go to a higher energy metastable state. They return to the normal state after emitting the extra energy in the form of a photon. All the photons are stimulated to emit at a given instant so that they will form a coherent radiation which can be concentrated by optical lenses. Thus the output would be normally in pulses. The power ratings of such units may be up to 2 kW.

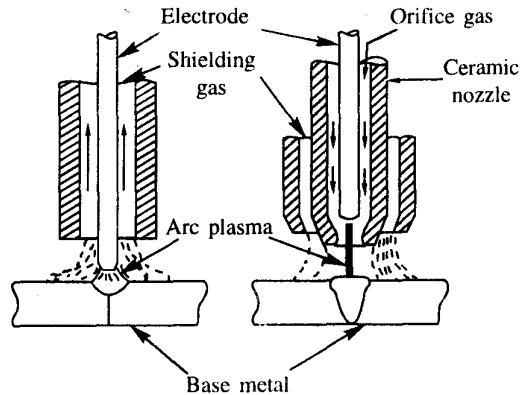
In *gas lasers*, the gas (such as carbon dioxide) molecules are excited to the higher vibrational energy level by means of an electric discharge. The transition from this high energy level to the normal level generates the radiation which is coherent and gets focused by means of the usual optical lenses. Continuous wave gas lasers using carbon dioxide gas with powers up to 20 kW are used for laser beam welding.

Plasma Arc Welding

A plasma is a gas which is heated to an extremely high temperature and ionized so that it becomes electrically conductive. Similar to GTAW (TIG), the plasma arc welding process uses this plasma to transfer an electric arc to a work piece. The metal to be welded is melted by the intense heat of the arc and fuses together.

In the plasma welding torch a Tungsten electrode is located within a copper nozzle having a small opening at the tip. A pilot arc is initiated between the torch electrode and nozzle tip. This arc is then transferred to the metal to be welded.

By forcing the plasma gas and arc through a constricted orifice, the torch delivers a high concentration of heat to a small area. With high performance welding equipment, the plasma process produces exceptionally high quality welds.



Plasma gases are normally argon. The torch also uses a secondary gas, argon, argon/hydrogen or helium which assists in shielding the molten weld puddle thus minimizing oxidation of the weld.

The plasma process is generally more precise than conventional TIG.

TESTING OF WELDS

Welded joints may be tested either destructively or nondestructively. Each technique has certain capabilities and limitations, as well as sensitivity, reliability, and requirements for special equipment and operator skill.

Destructive Testing Techniques:

- **Tension test:** Generally, it is carried out using a round specimen. When determining the strength of a welded joint, also standardised flat specimens are used. A specimen is ruptured by a test machine while the actual force and the elongation of the specimen is measured. With these measurement values, tension σ and strain ϵ are calculated. Stress-strain curves are then obtained. These curves indicate the yield strength, Y , ultimate tensile strength, UTS, and ductility of the Welded joint (elongation and reduction of area) in different locations and directions.
- **Tension-shear test:** The specimens in the tension-shear test are prepared to simulate conditions to which actual Welded joints are subjected. These specimens are subjected to tension so that the shear strength of the weld metal and the location of fracture can be determined.
- **Bend test:** Several bend tests have been developed to determine the ductility and strength of welded joints. In one common test, the welded specimen is bent around a fixture (wraparound bend test). In another test, the specimens are tested in three-point transverse bending. These tests help to determine the relative ductility and strength of welded joints.
- **Fracture toughness test:** Fracture toughness tests commonly utilize the impact testing techniques. Charpy V-notch specimens are first prepared and then tested for toughness. Another toughness test is the drop weight test, in which the energy is supplied by a falling weight.

- **Corrosion and creep tests:** In addition to undergoing mechanical tests, welded joints also may be tested for their resistance to corrosion and creep. Because of the difference in the composition and microstructure of the materials in the weld zone, preferential corrosion may take place in the zone. Creep tests are important in determining the behaviour of welded joints and structures subjected to elevated temperatures.

Non-destructive Testing Techniques.

Welded structures often have to be tested non-destructively, particularly for critical applications in which weld failure can be catastrophic, such as in pressure vessels, load-bearing structural members, and power plants. Non-destructive testing techniques for welded joints generally consist of the following methods (these tests are described in Section 36.10):

- Visual
- Radiographic (X-rays)
- Magnetic-particle
- Liquid-penetrant
- Ultrasonic.

Testing for hardness distribution in the weld zone also may be a useful indicator of weld strength and micro structural changes.

DESIGN CONSIDERATIONS

The general design guidelines for welding may be summarized as follows:

- Product design should minimize the number of welds because, unless automated, welding can be costly.
- Weld location should be selected so as to avoid excessive stresses or stress concentrations in the welded structure and for appearance.
- Weld location should be selected so as not to interfere with any subsequent processing of the joined components or with their intended use. Components should fit properly prior to Welding. The method used to prepare edges, such as sawing, machining, or shearing, also can affect weld quality.
- The need for edge preparation should be avoided or minimized.
- Weld-bead size should be as small as possible, While maintaining the strength of the joint, to conserve Weld metal and for better appearance.

WELDING PROCESS SELECTION

In addition to taking into account the process characteristics, capabilities, and material considerations described thus far in this chapter, the selection of a weld joint and an appropriate welding process involve the following considerations:

MANUFACTURING TECHNOLOGY**JOINING PROCESSES****A FOCUSED APPROACH**

- Configuration of the parts or structure to be joined, joint design, thickness and size of the components, and number of joints required.
- The methods used in manufacturing the components to be joined.
- Types of materials involved, which may be metallic or non-metallic.
- Location, accessibility, and ease of joining.
- Application and service requirements, such a type of loading, any stresses generated, and the environment.
- Effects of distortion, warping, discoloration of appearance, and service.

WELDING DISTORTION

Distortion in a weld results from the expansion and contraction of the weld metal and adjacent base metal during the heating and cooling cycle of the welding process. Doing all welding on one side of a part will cause much more distortion than if the welds are alternated from one side to the other. During this heating and cooling cycle, many factors affect shrinkage of the metal and lead to distortion, such as physical and mechanical properties that change as heat is applied.

To prevent or minimize weld distortion, methods must be used both in design and during welding to overcome the effects of the heating and cooling cycle. Shrinkage cannot be prevented, but it can be controlled. Several ways can be used to minimize distortion caused by shrinkage:

- **Do not over weld** The more metal placed in a joint, the greater the shrinkage forces. Correctly sizing a weld for the requirements of the joint not only minimizes distortion, but also saves weld metal and time. The amount of weld metal in a fillet weld can be minimized by the use of a flat or slightly convex bead, and in a butt joint by proper edge preparation.
- **Use intermittent welding** Another way to minimize weld metal is to use intermittent rather than continuous welds where possible.
- **Use as few weld passes as possible** Fewer passes with large electrodes are preferable to a greater number of passes with small electrodes when transverse distortion could be a problem. Shrinkage caused by each pass tends to be cumulative, thereby increasing total shrinkage when many passes are used.
- **Use back step welding** In the back step technique, the general progression of welding may be, say, from left to right, but each bead segment is deposited from right to left.

BRAZING

Brazing is a process of joining metals with a non-ferrous filler metal that has a melting point below that the metal being joined. By AWS (American Welding Society) definition, the melting point of the filler metal will be above 427 °C. Below this temperature are the

solders. The filler metal must wet the surfaces to be jointed; that is, there must be a molecular attraction between the molten filler material and the materials being joined. The brazing alloy, when heated to the proper temperature, flows into the small joint clearances by capillary action. A limited amount of alloying occurs between the filler metal and the base metal at elevated temperatures. As a result, the strength of the joint when properly made may exceed that of the base material. The heat for brazing may be provided in many different ways, the most common of which are by torch, induction, furnace, and hot dipping.

Brazing Types

Torch brazing: Torch brazing is especially good for repair work in the field and for small-lot jobs in the shop. A slightly reducing flame (excess acetylene) may be used to avoid oxidation of the metal. The filler material is touched to the joint when the flux becomes a clear liquid. It is the parent metal not the flame, that transfers the heat to the brazing alloy.

Induction Brazing: The heat for induction brazing is furnished by an a.c. coil placed in closed proximity to the joint. The high frequency current is provided by a solid state oscillator. This high frequency alternating current develop heat in the work by electrical resistance. This method has the advantages of providing (i) good heat distribution (ii) accurate heat control (iii) uniformity of results and (iv) speed. It is especially good for certain types of repetitive work that require close control.

Furnace Brazing: Parts that are to be furnace brazed have the flux and brazing material pre-placed in the joint. Automatic controls regulate both time and temperature and, where applicable, atmosphere.

Dip Brazing: Dip brazing gets its name from the fact that parts are jigged and are placed in a chemical or molten-metal both maintained at the correct brazing temperature. The number and size of the parts to be brazed are limited only by the capacity of the both and the handling facilities.

Brazing Fluxes

The primary purpose of brazing fluxes is to dissolve and absorb oxides that heating tends to form. When the metal is heated to the brazing temperature, the flux becomes a clear liquid that wets the surface and aids in the flow of the filler metal. Some of the most common ingredients of fluxes are sodium, potassium and lithium. They are used in making up chemical compounds such as borates, fluorides chlorides, boric acids, alkalies and wetting agents.

Brazing Filler Metals

Brazing filler metals are divided into seven classification. In order of popularity, these are silver, copper, copper-zinc, copper-phosphorous, aluminium-silicon, copper-gold and magnesium. Copper-zinc alloys are known as hard solders having high melting temperatures.

Advantages of Brazing

Brazing is well suited to mass production techniques for joining both ferrous and non-ferrous metals. Some of the principal advantages are.

- Dissimilar metals can be joined easily.
- Assemblies can be joined in a virtually stress free condition.
- Complex assemblies can be joined in several steps by using filler metals with progressively lower melting temperatures.
- Materials of different thicknesses can be joined easily.
- Brazed joints require little or no finishing other than flux removal.

Limitations of Brazing

- Joint design is somewhat limited if strength is a factor.
- Jointing is generally limited to sheet metal thicknesses and relatively small assemblies.
- Cost of joint preparation can be high.

Braze Welding

Braze welding is similar to brazing in that the base metal is not melted but joined by an alloy of lower melting point. The main difference is that in braze welding the alloy is not drawn into the joint by capillary action. A braze welded joint is prepared very much like a joint is prepared for welding except that an effort should be made to avoid sharp corners, because they are easily overheated and may also be points of stress concentration.

Braze welding is used extensively for repair work, as well as some fabrication on such metals as cast iron, malleable iron, wrought iron and steel. It is used, but to a lesser extent, on copper, nickel and high melting point brasses.

SOLDERING

Soldering is a way of joining two or more pieces of metal by means of a fusible alloy of metal, called solder, applied in the molten state. Soldering can be distinguished from brazing in that it is done at a lower temperature (below 427 °C) and there is less alloying of the filler metal with the base metal.

Solder Alloys

The four metals used as the principal alloying elements of all non proprietary solder formulations are tin, lead, cadmium, and zinc.

The low melting point solders (190 to 313 °C) are the most widely used and are of the tin-lead or tin-antimony type. The tin-lead alloys provide good strength at low temperatures. All solders containing lead and tin as alloying constituents are referred to as 'soft solders'. A combination of 62% lead and 38% tin produces the lowest melting point (183 °C).

The tin-lead-antimony solders are generally used for the same types of applications as the tin-lead alloys except that they are not recommended for use on aluminium, zinc or galvanized steel.

The tin-zinc group of alloys is used mainly for soldering aluminum, primarily where a low soldering temperature than that of a zinc-aluminium solder is required. Zinc-aluminum solders are designed specifically for soldering aluminium.

Aluminium Soldering

Aluminium is often thought of as being very difficult to solder. One reason is that an oxide film forms quickly over the surface after cleaning. Now, however, there are several methods of removing the oxide as the soldering is being done. These methods are flux soldering, friction soldering and ultrasonic soldering.

ADHESIVE BONDING

Numerous parts and components can be joined and assembled by adhesives rather than by one or more of the joining methods described thus far. A common example of adhesive bonding is plywood, where several layers of wood are bonded with wood glue.

As an example and in order to show various applications of structural adhesives, the following are several examples where adhesives that are used as bonding materials for the construction and manufacture of ground, air and sea vehicles:

- adhesive applications on vehicles
- glue Adhesive for bonding structures or racks.
- glue Adhesive for bonding the front, side and rear window glass.
- Adhesive for bonding body roof structure.
- glue Adhesive for bonding side panels of the structure.
- glue Adhesive for bonding the floor.
- glue Adhesive for bonding the cabins of the vehicles.
- glue Adhesives for bonding different elements of the equipment.

To meet the requirements of a particular application, an adhesive may require one or more of the following properties:

- Strength: shear and peel
- Toughness
- Resistance to various fluids and chemicals
- Resistance to environmental degradation, including heat and moisture
- Capability to wet the surfaces to be bonded.

Types of Adhesives and Adhesive Systems

Several types of adhesives are available, and more continue to be developed that provide adequate joint strength-including fatigue strength (Table 32.4). The three basic types of adhesives are the following:

- **Natural adhesives** such as starch, dextrin (a gummy substance obtained from starch), soya flour, and animal products.
- **Inorganic adhesives** such as sodium silicate and magnesium oxychloride.
- **Synthetic organic adhesives** which may be thermoplastics (used for nonstructural and some structural bonding) or thermosetting polymers (used primarily for structural bonding).

Many of these adhesives can be combined to optimize their properties, such as the combinations of epoxy-silicon, nitrile-phenolic, and epoxy-phenolic. The least expensive adhesives are epoxies and phenolics, which are followed in affordability by polyurethanes, acrylics, silicones, and cyanoacrylates. Adhesives for high-temperature applications in a range up to about 260°C (such as polyimides and polybenzimidazoles) are generally the most expensive. Most adhesives have an optimum temperature (ranging from about room temperature to about 200°C) for maximum shear strength.

Major industries that use adhesive bonding extensively are the aerospace, automotive, appliances, and building products industries. Applications include automotive brake-lining assemblies, laminated windshield glass, appliances, helicopter blades, honeycomb structures, and aircraft bodies and control surfaces.

Advantages of Adhesive Bonding

The interfacial bond has sufficient strength for structural applications, but is also used for non-structural purposes, such as sealing, insulation, the prevention of electrochemical corrosion between dissimilar metals, and the reduction of vibration and of noise (by means of internal damping at the joints).

- Adhesive bonding distributes the load at an interface and thereby eliminates localized stresses that usually result from joining the components with mechanical fasteners, such as bolts and screws. Moreover, structural integrity of the
- sections is maintained (because no holes are required).
- The external appearance of the bonded components is unaffected.
- Very thin and fragile components can be bonded without significant increase in their weight.
- Porous materials and materials of very different properties and sizes can be joined.
- Because adhesive bonding usually is carried out at a temperature between room temperature and about 200°C, there is no significant distortion of the components or

change in their original properties. Avoiding distortion is important, particularly for materials that are heat sensitive.

Limitations of Adhesive Bonding

- There is a limited range of service temperatures.
- Bonding time can be long.
- There is a need for great care in surface preparation.
- Bonded joints are difficult to test non-destructively, particularly for large structures.
- The limited reliability of adhesively bonded structures during their service life and under hostile environmental conditions (such as degradation by temperature, oxidation, stress corrosion, radiation, or dissolution) may be a significant concern.

ASSIGNMENT

- Q.1. (AMIE W16, 4 marks):** Describe the term "weldability". Explain the effect of alloying elements in weldability.
- Q.2. (AMIE W05, 8 marks):** Describe the working principle of "arc welding". Explain the shielded arc welding and how does it save the weldment from oxidation and absorption of nitrogen. What precautions need to be observed in arc welding.
- Q.3. (AMIE S10, 5 marks):** Why are shielded metal-arc welding electrodes coated?
- Q.4. (AMIE S06, 7 marks):** Briefly describe the process of metal inert gas welding.
- Q.5. (AMIE W12, 5 marks):** Enlist the advantages of submerged arc welding.
- Q.6. (AMIE S10, 5 marks):** Explain the basic principle of electric arc welding.
- Q.7. (AMIE W12, 4 marks):** Explain the mechanism of metal transfer in MIG/ MAG welding.
- Q.8. (AMIE S15, W17, 8 marks):** Explain electroslag welding process with diagram and with its applications.
- Q.9. (AMIE S11, 10 marks):** Explain TIG and MIG system of arc welding. Write their applications and limitations.
- Q.10. (AMIE S13, 6 marks):** Between MIG and SAW processes, which one can have higher deposition rate? Why?
- Q.11. (AMIE S17, 8 marks):** What type of metals can be welded by the MIG process? What are the basic carbon dioxide MIG welding processes? How do they differ?
- Q.12. (AMIE S15, 16, 18, 8 marks):** Name solid state welding processes and explain any one of them with a neat sketch. How it is different from other welding processes?
- Q.13. (AMIE W16, 5 marks):** Discuss the principle and the process of diffusion bonding process.
- Q.14. (AMIE W13, 6 marks):** Explain the following:
- (i) Role of welding processes in the present age
 - (ii) Use of coated rod in the a.c. welding
 - (iii) Appearance and properties of neutral, reducing and oxidizing flame.
- Q.15. (AMIE W12, 5 marks):** Discuss process selection parameters for welded joints.
- Q.16. (AMIE W10, S15, 4 marks):** Describe the applications of mechanical fastening processes.
- Q.17. (AMIE W12, 7 marks):** How do you select a welding process for a given application?
- Q.18. (AMIE W12, S16, 4 marks):** Classify the fusion welding processes.
- Q.19. (AMIE S06, 7 marks):** Describe the principle of operation of electron beam welding.
- Q.20. (AMIE S13, W17, 8 marks):** What is friction welding? Explain it with diagram. How are rotation and pressure related in this process?
- Q.21. (AMIE W12, 17, S17, 5 marks):** Discuss basic design considerations in welding.
- Q.22. (AMIE S11, 10 marks):** Describe the effect of various welding parameters that control the metallurgical structure of the heat-affected zone in C 50 steel.
- Q.23. (AMIE W16, 5 marks):** What is resistance welding? Explain the four period resistance welding cycle.
- Q.24. (AMIE S12, W16, 17, 5 marks):** What is heat-affected zone in a welded joint? Explain with reference to medium carbon steel.
- Q.25. (AMIE W16, 5 marks):** When and why parts are preheated before welding?

Answer: Preheating the steel to be welded slows the cooling rate in the weld area. This may be necessary to avoid cracking of the weld metal or heat affected zone. The need for preheat increases with steel thickness, weld restraint, the carbon/alloy content of the steel, and the diffusible hydrogen of the weld metal. Preheat is commonly applied with fuel gas torches or electrical resistance heaters.

MANUFACTURING TECHNOLOGY**JOINING PROCESSES**

- Q.26. (AMIE S12, 5 marks):** What is the difference between the tools used in spot resistance and seam resistance welding?
- Q.27. (AMIE S12, 5 marks):** Which process would be selected for aluminium welding? Why?
- Q.28. (AMIE W13, 14 marks):** Discuss the causes and cures for (i) porosity, (ii) penetration, (iii) wrap-age, (iv) distortion, (v) poor fusion, (vi) cracking, and (vii) undercutting.
- Q.29. (AMIE W12, 7 marks):** Name destructive and non-destructive testing methods of welded joints and explain one destructive and one non-destructive testing method.
- Q.30. (AMIE W12, 17, S15, 16, 4 marks):** Explain the testing of welding joints.
- Q.31. (AMIE S18, 8 marks):** Make a note on stresses and distortion in welding.
- Q.32. (AMIE W15, 7 marks):** What is distortion? Name and explain four ways to control distortion in base metal in welding?
- Q.33. (AMIE S17, 4 marks):** What is the effect of restraining a joint and how it could be utilised in minimising the weld distortion?
- Q.34. (AMIE W16, 8 marks):** Give the reasons for development of thermal stresses in welds. How these stresses can be measured and explain the methods of minimising them?
- Q.35. (AMIE W10, 12, S12, 5 marks):** Differentiate between welding, brazing and soldering.
- Q.36. (AMIE S13, 18, 6 marks):** How is brazing different from soldering? Explain the principle of liquid filler metal flow into the joint.
- Q.37. (AMIE S10, 10 marks):** Differentiate between welding, brazing, soldering and adhesive bonding. Identify any one unique application of each one of them.
- Q.38. (AMIE W15, 6 marks):** What are the four most common braze weld designs?
- Q.39. (AMIE S16, 5 marks):** Differentiate between brazing and braze welding.
- Q.40. (AMIE W12, S15, 4 marks):** Compare the relative merits and demerits of welding over adhesive bonding.
- Q.41. (AMIE S16, 5 marks):** What are the applications of adhesive bonding?

(For online support such as eBooks, video lectures, audio lectures, unsolved papers, online objective questions, test series and course updates, visit www.amiestudycircle.com)