UNIT III

Metal Joining Processes

- Classification of welding processes,
- Types of welding
- Welded joints and V-I characteristics,
- Arc welding,
- Weld bead geometry
- Submerged arc welding. applications, advantages and disadvantages
- Gas tungsten. applications, advantages and disadvantages
- Gas metal arc welding applications. applications, advantages and disadvantages
- Fabrication processes
- Heat affected zones in welding
- soldering
- Typesofsoldering and their applications
- brazing
- Typesof brazing and their applications
- Types and their applications
- Welding defects
- Causes and remedies

Welding:

Welding is a process of joining similar metals by application of heat with or without application of pressure and additional of filler material.

Welding joints different metals/alloys. In welding heat is supplied either electrically or by means of a gas torch.

Advantages

- Welding is more economical and is much faster process as compared to other processes (riveting, bolting, casting etc.)
- Welding, if properly controlled results permanent joints having strength equal orsometimes more than base metal.
- Large number of metals and alloys both similar and dissimilar can be joined bywelding.
- General welding equipment is not very costly.
- Portable welding equipment can be easily made available.
- Welding permits considerable freedom in design. Welding can join welding jobs through spots, as continuous pressure tight seams,endto-end and in a number of other configurations.
- Welding can also be mechanized.

Disadvantages

- It results in residual stresses and distortion of the work pieces.
- Welded joint needs stress relieving and heat treatment.
- Welding gives out harmful radiations (light), fumes and spatter.
- Jigs, and fixtures may also be needed to hold and position the parts to be welded
- Edges preparation of the welding jobs are required before welding
- Skilled welder is required for production of good welding Heat during welding produces metallurgical changes as the structure of the weldedjoint is not same as that of the parent metal.

Types of welding

There are two types of welding: -

1) Plastic welding
2) Fusion welding

1) Plastic welding (Pressure welding)

- In this type of welding the piece of metal to be joined are heated to a plastic state and then forged together by external pressure.
- This processes is used in forge welding, resistance welding

2)Fusion welding (Non-pressure)

- The fusion of metal takes place by means of heat. The heat may be generated either from combustion of gases, electric arc, electric resistance or by chemical reaction.
- In this method filler material is required during the process like arc welding, gas welding.

Classification of welding

1.Gas welding

a. Oxy-acetylene
b. Air-acetylene
c. Oxy-hydrogen

2. Arc welding

a. Carbon arc welding
b. Plasma arc welding
c. Submerged arc welding
d. Metal arc

e. Electro-slag

f. Flux-cored

g. Gas-metal arc(MIG)

h. Gas-tungsten arc (TIG)

i. Atomic-hydrogen arc

3. Resistance welding

a. Butt

b. Projection

c. Spot

d. Percussion

e. Seam

4. Thermit welding

5. Solid state welding

a. Friction

b. Explosive

c. Ultrasonic

d.Diffusion

6. Newer welding (Radiant Energy welding)

a. Electro-beam

b. Laser

Gas welding

A fusion welding process which joins metals, using the heat of combustion of an oxygen /air and fuel gas (i.e. acetylene, hydrogen) mixture is usually referred as ‘gas welding’.

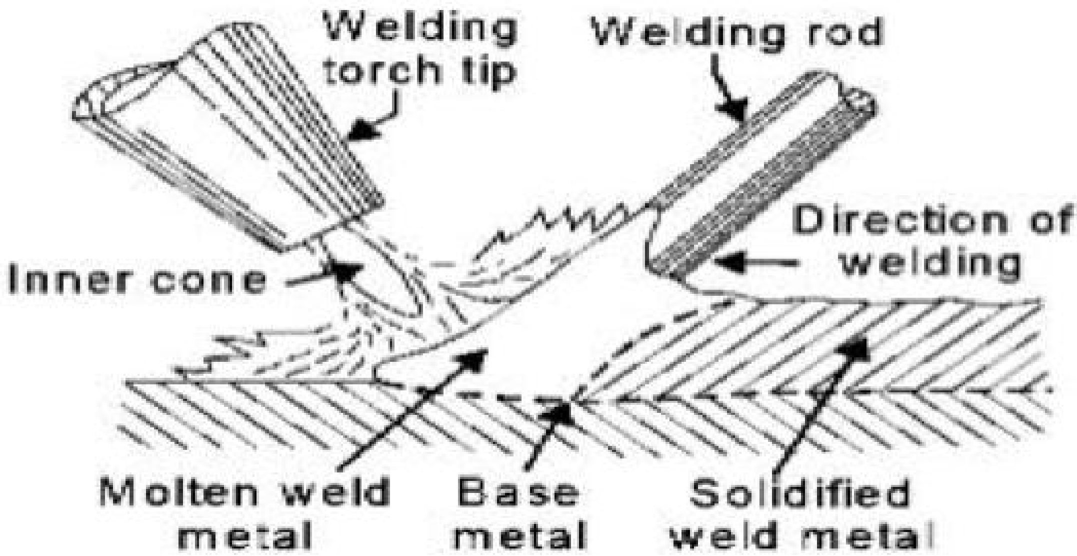


Figure 3.1 Gas welding

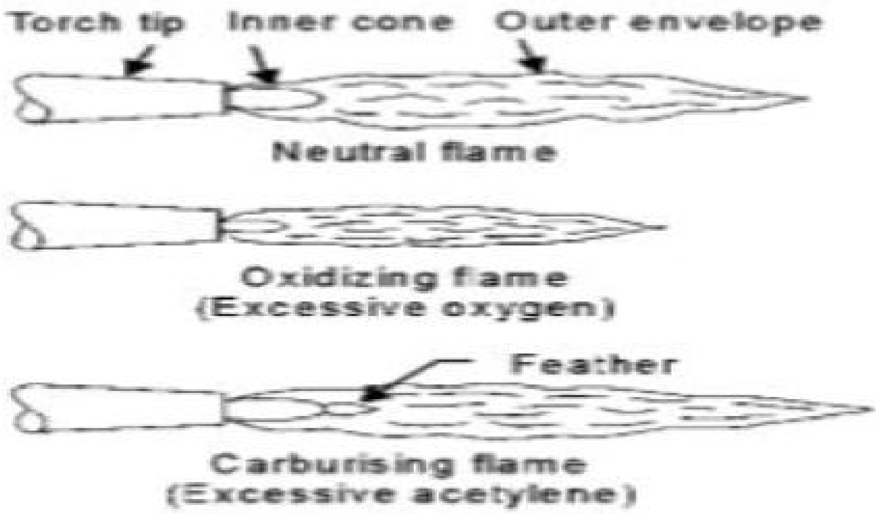
- The intense heat (flame) thus produced melts and fuses together the edges of the parts to be welded, generally with the addition of a filler metal.
- The fuel gas generally employed is acetylene; however gases other than acetylene can also be used though with lower flame temperature
- Oxy-acetylene flame is themost versatile and hottest of all the flames produced by the combination of oxygen and otherfuel gases.

Oxy-acetylene welding

- In this process, acetylene is mixed with oxygen in correct proportions 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 3300°C and thus can melt most of the ferrous and non-ferrous metals in common use.
- A filler metal rod or welding rod is generally added to the molten metal pool to build up the seam slightly for greater strength.

Types of flame

a. Neutral flame
b. Carburizing flame
c. Oxidizing flame



- *Figure 3.2 Oxy-Acetylene gas flames*

a.Neutral flame

- A neutral flame results when approximately equal volumes of oxygen and acetylene are mixedin the welding torch and burnt at the torch tip.
- The temperature of the neutral flame is ofthe order of about 5900°F (3260°C).
- It has a clear, well defined inner cone, indicating that the combustion is complete.
- The inner cone is light blue in color. It is surrounded by an outerflame envelope, produced by the combination of oxygen in the air and superheated carbon-monoxide and hydrogen gases from the inner cone.
- This envelope is usually a much darkerblue than the inner cone.
- A neutral flame is named so because it affects no chemical changeon the molten metal and, therefore will not oxidize or carburize the metal. The neutral flameis commonly used for the welding of mild steel, stainless steel, cast Iron, copper, and aluminum

b.Carburizing flame

- The carburizing or reducing flame has excess of acetylene and can be recognized byacetylene feather, which exists between the inner cone and the outer envelope.
- The outerflame envelope is longer than that of the neutral flame and is usually much brighter in color.
- With iron and steel, carburizing flame produces very hard, brittle substance known as ironcarbide.
- A reducing flame may be distinguished from carburizing flame by the fact that acarburizing flame contains more acetylene than a reducing flame.
- A reducing flame has anapproximate temperature of 3038°C.
- A carburizing-flame is used in the welding of lead and forcarburizing (surface hardening) purpose.
- A reducing flame, on the other hand, does notcarburize the metal; rather it ensures the absence of the oxidizing condition.
- It is used forwelding with low alloy steel rods and for welding those metals, (e.g., nonferrous) that donotend to absorb carbon.
- This flame is very well used for welding high carbon steel.

c.Oxidizing flame

- The oxidizing flame has an excess of oxygen over the acetylene.
- An oxidizing flame canbe recognized by the small cone, which is shorter, much bluer in color and more pointed than
- that of the neutral flame.
- The outer flame envelope is much shorter and tends to fan out atthe end. Such a flame makes a loud roaring sound.
- It is the hottest flame (temperature ashigh as 6300°F) produced by any oxy-fuel gas source.

- But the excess oxygen especially at high temperatures tends to combine with many metals to form hard, brittle, low strength oxides.
- Moreover, an excess of oxygen causes the weld bead and the surrounding area to have ascummy or dirty appearance.
- For these reasons, an oxidizing flame is of limited use in welding. It is not used in the welding of steel.
- A slightly oxidizing flame is helpful whenwelding

(i) Copper-base metals

(ii) Zinc-base metals and

(iii) A few types of ferrous metals suchas manganese steel and cast iron.

- The oxidizing atmosphere in these cases, create a base Metaloxide that protects the base metal.

Design of Welded Joint:

The details of a joint, which includes both the geometry and the required dimensions, are called the joint design.

Just what type of joint design is best suited for a particular job depends on many factors. Although welded joints are designed primarily to meet strength and safety requirements, there are other factors that must be considered.

- A few of these factorsareas follows: Whether the load will be in tension or compression and whether bending, fatigue, or impact stresses will be applied
- How a load will be applied; that is, whether the load will be steady, sudden, or variable
- The direction of the load as applied to the joint
- The cost of preparing the joint

- Another consideration that must be made is the ratio of the strength of the joint compared to the strength of the base metal.
- This ratio is called joint efficiency.
- An efficient joint is one that is just as strong as the base metal.
- Normally, the joint design is determined by a designer or engineer and is included in the project plans and specifications.
- Even so, understanding the joint design for a weld enables you to produce better welds. Earlier in this chapter,
- We discussed the five basic types of welded joints—butt, corner, tee, lap, and edge. While there are many variations, every joint you weld will be one of these basic types.
- Now, we will consider some of the variations of the welded joint designs and the efficiency of the joints.
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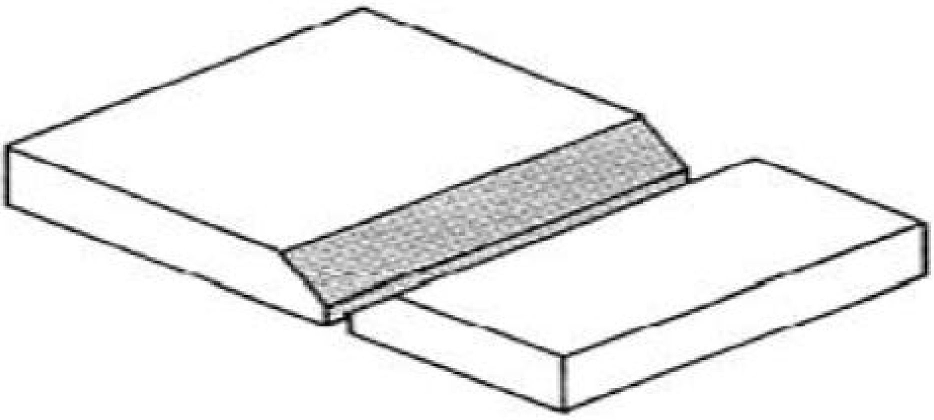
1 .BUTT JOINTS:

- The square butt joint is used primarily for metals that are 3/16 inch or less in thickness.

- The joint is reasonably strong, but its use is not recommended when the metals are subject to fatigue or impact loads.
- Preparation of the joint is simple, since it only requires matching the edges of the plates together; however, as with any other joint, it is important that it is fitted together correctly for the entire length of the joint.
- It is also important that you allow enough root opening for the joint.
- Figure shows an example of this type of joint.



- The single-V butt joint is for use on plates 1/4 inch through 3/4 inch in thickness.
- Each member should be beveled so the included angle for the joint is approximately 60 degrees for plate and 75 degrees for pipe.
- Preparation of the joint requires a special beveling machine (or cutting torch), which makes it more costly than a square butt joint.
- It also requires more filler material than the square joint; however, the joint is stronger than the square butt joint. But, as with the square joint, it is not recommended when subjected to bending at the root of the weld.

- The double-V butt joint is an excellent joint for all load conditions. Its primary use is on metals thicker than 3/4 inch but can be used on thinner plate where strength is critical.
- Compared to the single-V joint, preparation time is greater, but you use less filler metal because of the narrower included angle. Because of the heat produced by welding, you should alternate weld deposits, welding first on one side and then on the other side.
- This practice produces a more symmetrical weld and minimizes
- Remember, to produce good quality welds using the groove joint, you should ensure the fit-up is consistent for the entire length of the joint, use the correct groove angle, use the correct root opening, and use the correct root face for the joint. When you follow these principles, you produce better welds every time. Other standard grooved butt joint designs include the bevel groove, J-groove, and U-groove, as shown in figure

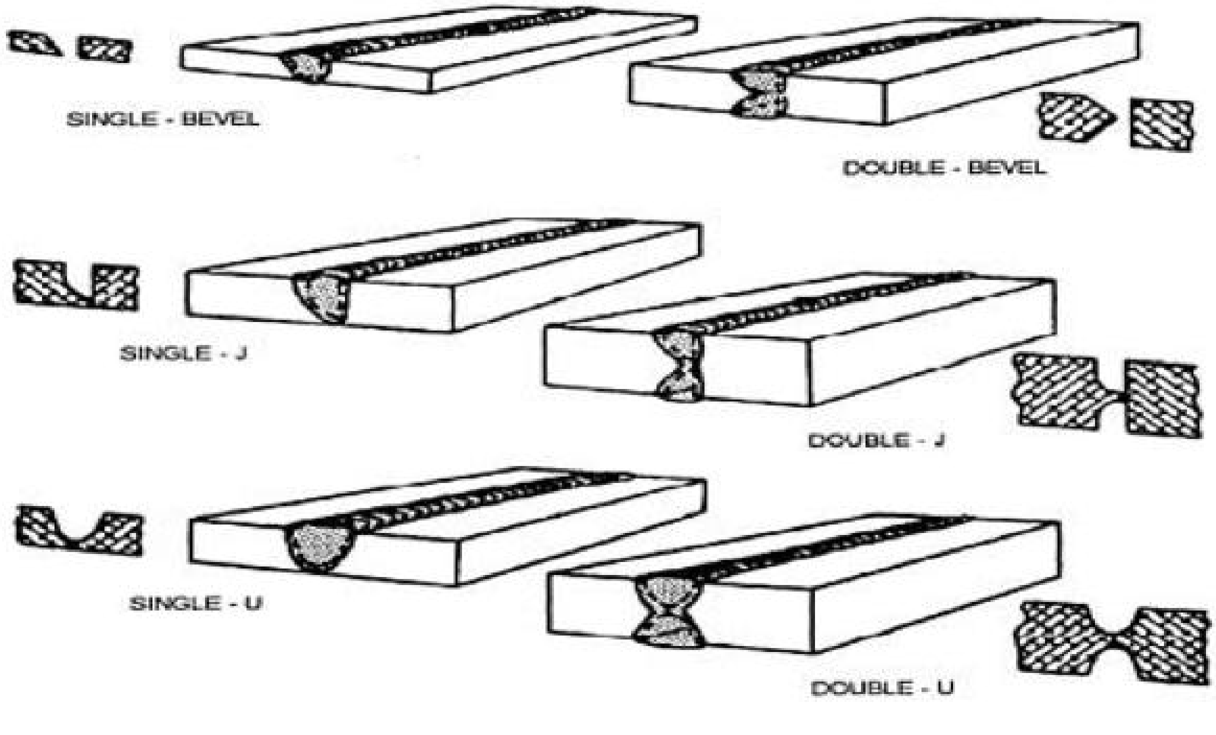


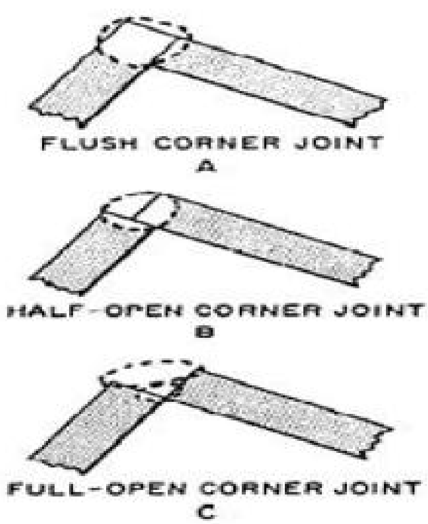
Figure —Additiona1 types of groove welds

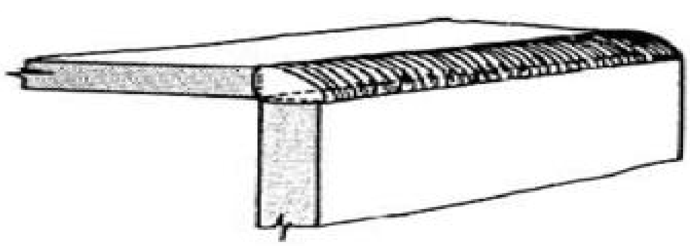
CORNER JOINTS

The flush corner joint is designed primarily for welding sheet metal that is 12 gauge or thinner. It is restricted to lighter materials, because deep penetration is sometimes difficult and the design can support only moderate loads.

The half-open corner joint is used for welding materials heavier than 12 gauge. Penetration is better than in the flush corner joint, but its use is only recommended for moderate loads.

The full-open corner joint produces a strong joint, especially when welded on both sides. It is useful for welding plates of all thicknesses.



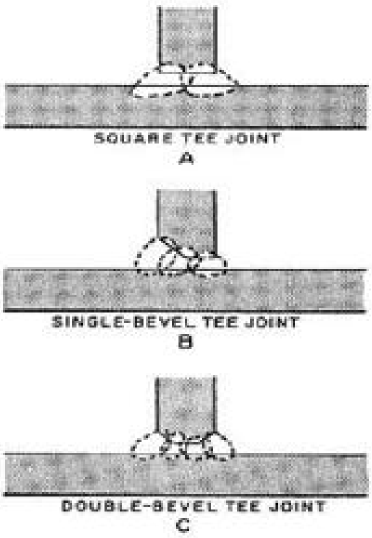


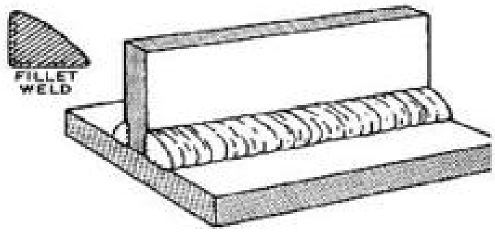
TEE JOINTS:

The square tee joint requires a fillet weld that can be made on one or both sides. It can be used for light or fairly thick materials. For maximum strength, considerable weld metal should be placed on each side of the vertical plate.

The single-bevel tee joint can withstand more severe loadings than the square tee joint, because of better distribution of stresses. It is generally used on plates of 1/2 inch or less in thickness and where welding can only be done from one side.

The double-bevel tee joint is for use where heavy loads are applied and the welding can be done on both sides of the vertical plate.





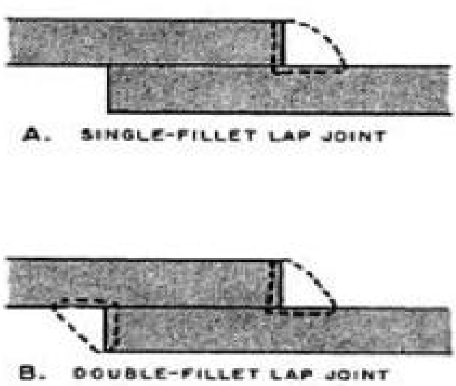
LAP JOINTS:

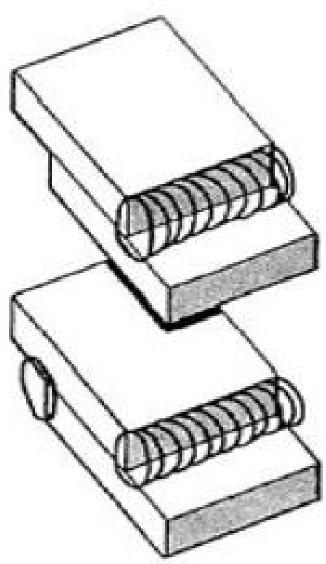
The single-fillet lap joint is easy to weld, since the filler metal is simply deposited along the seam. The strength of the weld depends on the size of the fillet.

Metal up to 1/2 inch in thickness and not subject to heavy loads can be welded using this joint.

When the joint will be subjected to heavy loads, you should use the double-fillet lap joint .

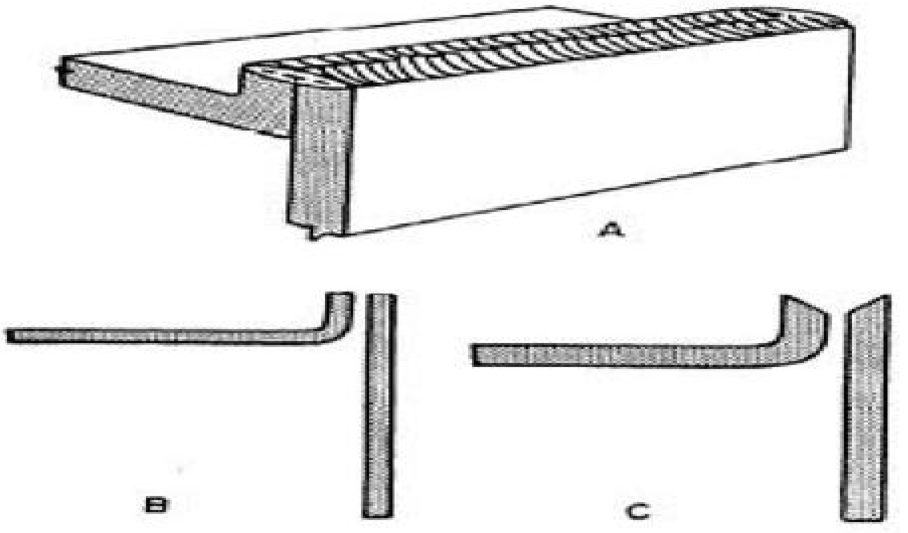
When welded properly, the strength of this joint is very close to the strength of the base metal.





5 EDGE JOINTS:

The flanged edge joint is suitable for plate 1/4 inch or less in thickness and can only sustain light loads. Edge preparation for this joint may be done, as shown in either views B or C.



Position of welding

a.Horizontal welding

b.Vertical welding

c.Overhead welding

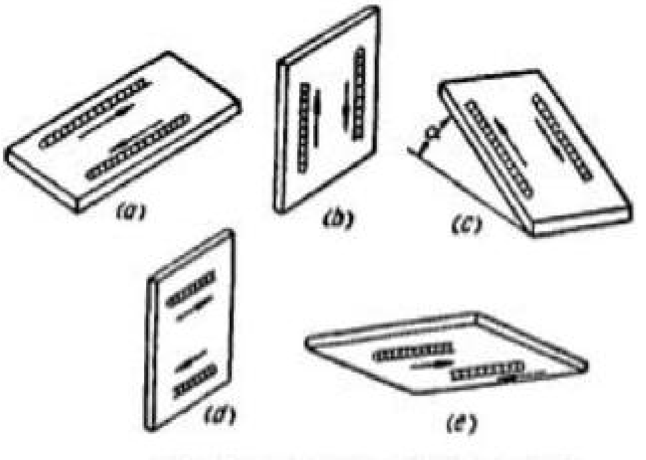


Figure 3.3 Position of welding

(a)Horizontal welding (b) Vertical welding (c) Inclined welding (d) Horizontal welding in vertical direction (e) overhead welding

a.Horizontal welding

- In horizontal position, the plane of the work piece is vertical and the deposited weld headis horizontal.
- The metal deposition rate in horizontal welding is next to that achieved in flator down hand welding position.
- This position of welding is most commonly used in weldingvessels and reservoir

b.Vertical welding

- In vertical position, the plane of the work piece is vertical and the weld is deposited upon avertical surface.
- It is difficult to produce satisfactory welds in this position due to the effectof the force of gravity on the molten metal.
- The welder must constantly control the metalso that it does not run or drop from the weld.
- Vertical welding may be of two types' viz., vertical-up and vertical-down. Vertical-up welding is preferred when strength is the majorconsideration.
- The vertical-down welding is used for a sealing operation and for welding sheetmetal.

c.Overhead welding

- The overhead position is probably even more difficult to weld than the vertical position.
- Here the pull of gravity against the molten metal is much greater.
- The force of the flameagainst the weld serves to counteract the pull of gravity. In overhead position, the plane ofthe work piece is horizontal.
- But the welding is carried out from the underside. The electrodeis held with its welding end upward.

➢ It is a good practice to use very short arc and basic coatedelectrodes for overhead welding.

Techniques of welding

a.Leftward (Forward) welding technique

b.Rightward (Backward) welding technique

c.Vertical welding

a.Leftward (Forward) welding technique

➢ In this technique, the welder holds welding torch in his right hand and filler rod in left hand.

➢ The welding flame is directed from right to left as shown in figure

➢ The welding torch should be given a small sideways movement and the filler rod should be moved steadily without sideways movement.

➢ The welding torch held at 60^0 to 70^0 to the weld plane and the filler rod at $30^o$to 40^0.

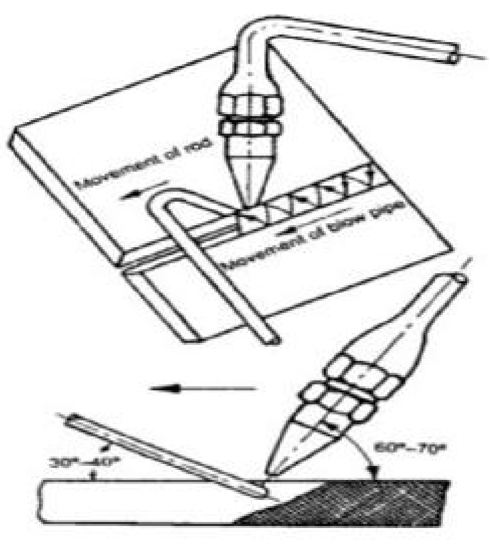


Figure 3.4 Left ward welding

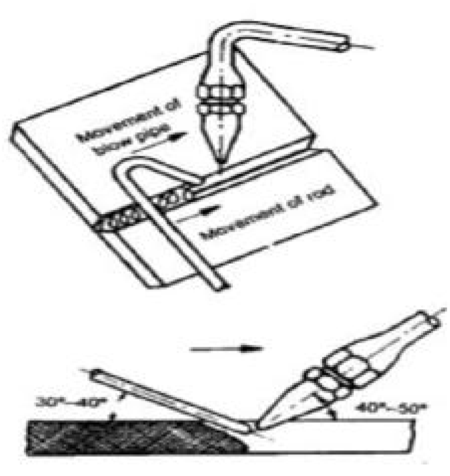


Figure 3.5 Right ward welding

➢ The method is more advantageous for plate thickness of 6 mm and above.

- In this, the welder starts at the bottom of the welded joint and gives oscillating movement to the welding torch which points slightly upwards.
- It can be done by one or two operator.
- In case of single operator technique, the angle between the welding torch and plate increases as the plate thickness increases.

Vertical welding

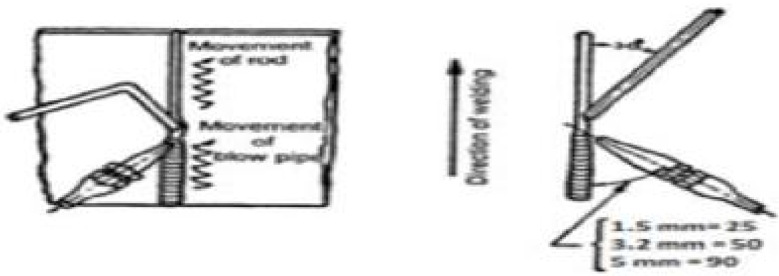


Figure 3.6 vertical welding

Welding Equipment

a.Cylinder

b.Gas pressure regulators

c.Welding torch

d.Torch tips

e.Hose pipes

f.Goggles

g.Gloves

h.Spark lighter

i.Filler rods

j.Flux

Welding Equipment

a.Cylinder

- Acetylene and oxygen gas is stored in compressed gas cylinders. These gas cylindersdiffer widely in capacity, design and color code.
- However, in most of the countries, thestandard size of these cylinders is 6 to 7 m^3 and is painted black for oxygen and maroon foracetylene.
- An acetylene cylinder is filled with some absorptive material, which is saturatedwith a chemical solvent acetone.
- Acetone has the ability to absorb a large volume of acetyleneand release it as the pressure falls. If large quantities of acetylene gas are being consumed, it is much cheaper to generate the gas at the place of use with the help of acetylene gasgenerators. Acetylene gas is generated by carbide-to-water method.
- Oxygen gas cylinders are usually equipped with about 40 liters of oxygen at a pressureof about 154 Kgf/cm^2at 21°C. To provide against dangerously excessive pressure, such ascould occur if the cylinders were exposed to fire, every valve has a safety device to releasethe oxygen before there is any danger of rupturing the cylinders.
- Fragile discs and fusibleplugs are usually provided in the cylinders valves in case it is subjected to danger

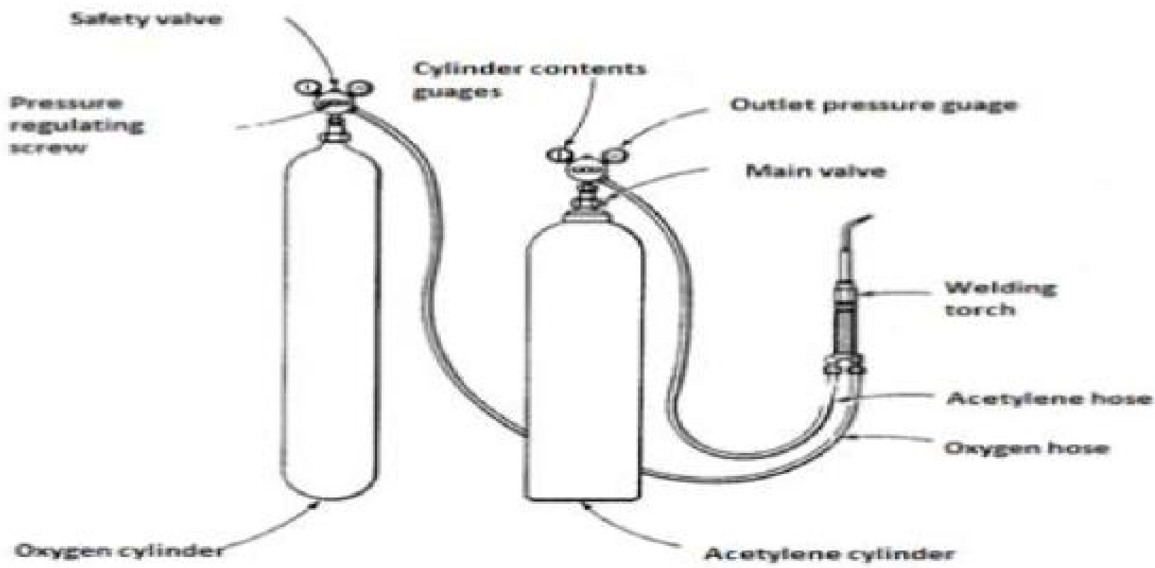


Figure 3.7 Oxy-Acetylene welding set

b.Gas pressure regulators

- Gas pressure regulators are employed for regulating the supply of acetylene and oxygengas from cylinders.
- A pressure regulator is connected between the cylinder and hose leadingto welding torch.
- The cylinder and hose connections have left-handed threads on the acetyleneregulator while these are right handed on the oxygen regulator.
- A pressure regulator is fittedwith two pressure gauges, one for indication of the gas pressure in the cylinder and the otherfor indication of the reduced pressure at which the gas is going out.

c.Welding torch

- It is a tool for mixing oxygen andacetylene in correct proportion and burning the mixture at the end of a tip.
- Gas flow to thetorch is controlled with the help of two needle valves in the handle of the torch.

There aretwo basic types of gas welding torches:

(1)Positive pressure (also known as medium or equal pressure), and

(2) Low pressure or injector type

The positive pressure type welding torch is the more common of the two types of oxyacetylenetorches.

Welding torch

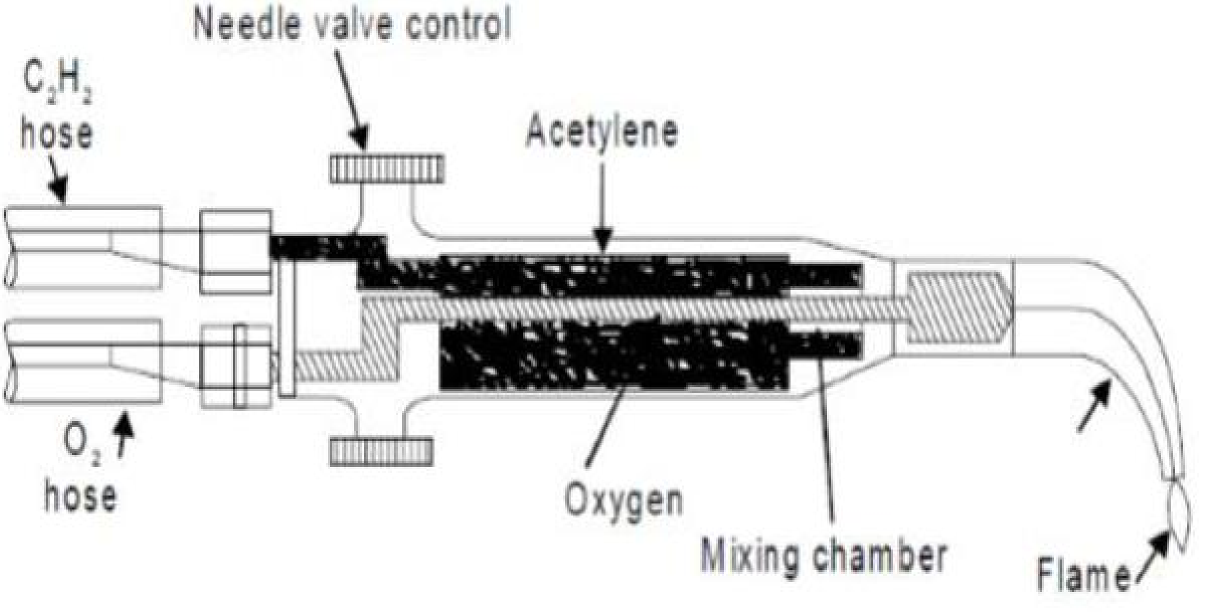


Figure 3.8 Welding torch

d.Torch tips

- It is the portion of the welding apparatus through which the gases pass just prior to theirignition and burning.
- A great variety of interchangeable welding tips differing in size, shapeand construction are available commercially. thetip sizes are identified by the diameter ofthe opening.
- The diameter of the tip opening used for welding depends upon the type of metalto be welded.

e.Hose pipes:

- The hose pipes are used for the supply of gases from the pressure regulators.
- The mostcommon method of hose pipe fitting both oxygen and acetylene gas is the reinforced rubberhose pipe.
- Green is the standard color for oxygen hose, red for acetylene, and black hose forother industrially available welding gases.

f.Goggles:

These are fitted with colored lenses and are used to protect the eyes from harmful heatand ultraviolet and infrared rays.

g.Gloves:

These are required to protect the hands from any injury due to the heat of weldingprocess.

h.Spark lighter :

It is used for frequent igniting the welding torch.

i.Filler rods:

- Gas welding can be done with or without using filler rod. When welding with the fillerrod, it should be held at approximately 900 to the welding tip.
- Filler rods have the same ornearly the same chemical composition as the base metal. Metallurgical properties of the welddeposit can be controlled by the optimum choice of filler rod.
- Most of the filler rods for gaswelding also contain deoxidizers to control the oxygen content of weld pool.

j.Flux

➢ Fluxes are used in gas welding to remove the oxide film and to maintain a clean surface.

➢ These are usually employed for gas welding of aluminum, stainless steel, cast iron, brass andsilicon bronze.

➢ They are available in the market in the form of dry powder, paste, or thicksolutions.

3.9Arc welding

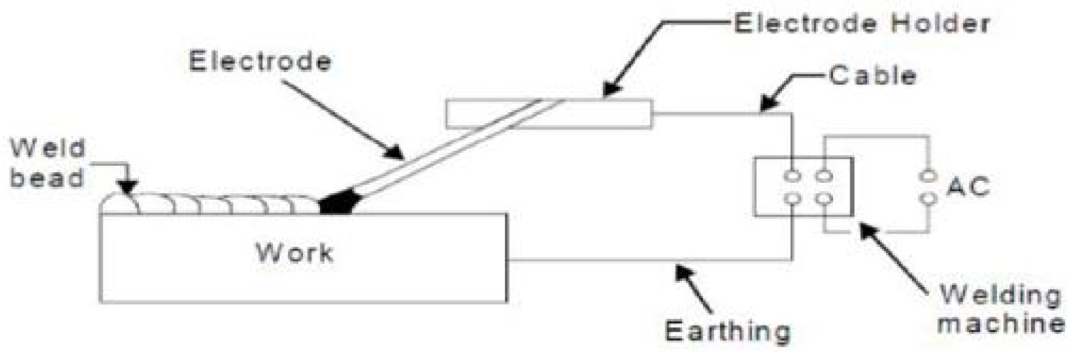


Figure 3.9 Arc Welding

9 Arc welding

➢ The process, in which an electric arc between an electrode and a workpiece or between twoelectrodes is utilized to weld base metals, is called an arc welding process.

➢ The basic elements involved in arc weldingprocess are shown in figure.

➢ Most of these processes use some shielding gas while othersemploy coatings or fluxes to prevent the weld pool from the surrounding atmosphere.

Thevarious arc welding processes are:

1. Carbon Arc Welding

2. Shielded Metal Arc Welding

3. Gas Tungsten Arc Welding

4. Gas Metal Arc Welding

5. Plasma Arc Welding

6. Atomic Hydrogen Welding

7. Electro slag Welding

Carbon arc welding

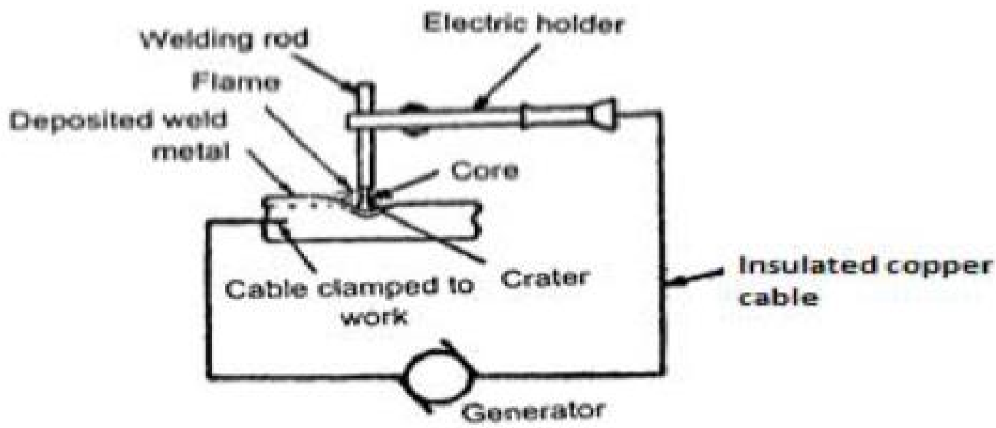


Figure 3.10 Carbon Arc Welding

Carbonarc welding

- In this process, a pure graphite or baked carbon rod is used as a non-consumable electrodeto create an electric arc between it and the work piece.
- The electric arc produces heat andweld can be made with or without the addition of filler material.

Carbon arc welding may beclassified as-

(1)Single electrode arc welding, and

(2) Twin carbon electrode arc welding

(1)Single electrode arc welding

- In single electrode arc welding, an electric arc is struck between a carbon electrode andthe work piece. Welding may be carried out in air or in an inert atmosphere.
- Direct currentstraight polarity (DCSP) is preferred to restrict electrode disintegration and the amount ofcarbon going into the weld metal.

- This process is mainly used for providing heat source forbrazing, braze welding, soldering and heat treating as well as for repairing iron and steelcastings.
- It is also used for welding of galvanized steel and copper.

(2) Twin carbon electrode arc welding

- In twin carbon arc welding the arc struck between two carbon electrodes produces heatand welds the joint.
- The arc produced between these two electrodes heats the metal to themelting temperature and welds the joint after solidification.
- The power source used is AC(Alternating Current) to keep the electrodes at the same temperature.
- Twin-electrode carbonarc welding can be used for welding in any position. This process is mainly used for joiningcopper alloys to each other or to ferrous metal.
- It can also be used for welding aluminium,nickel, zinc and lead alloys.

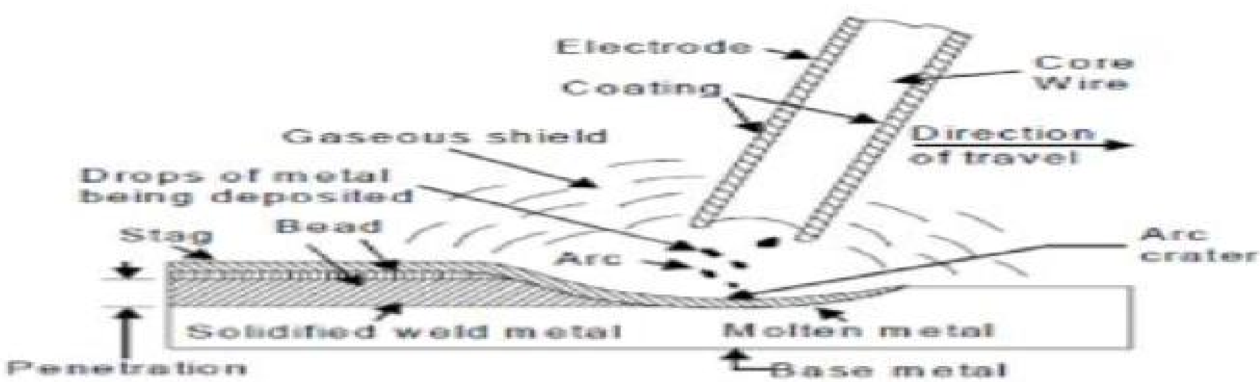


Figure 3.11 Shilded metal arc Welding

Shielded metal arc welding (SMAW)

- Shielded metal arc welding (SMAW) Shielded metal arc welding (SMAW) is a commonly used arc welding process manually carriedby welder.

- It is an arc welding process in which heat for welding is produced through anelectric arc set up between a flux coated electrode and the workpiece.

Advantagesof Shielded Metal Arc Welding (SMAW)

- Shielded Metal Arc Welding (SMAW) can be carried out in any position with highest
- weld quality.
- MMAW is the simplest of all the arc welding. This welding process finds innumerable applications, because of the availability ofa wide variety of electrodes.
- Big range of metals and their alloys can be welded easily.
- The process can be very well employed for hard facing and metal resistance etc
- Joints (e.g., between nozzles and shell in a pressure vessel) which because of theirposition are difficult to be welded by automatic welding machines can be easilyaccomplished by flux shielded metal arc welding.
- The MMAW welding equipment is portable and the cost is fairly low.

Disadvantagesof Shielded Metal Arc Welding (SMAW)

- Due to flux coated electrodes, the chances of slag entrapment and other relateddefects are more as compared to MIG and TIG welding.
- Due to fumes and particles of slag, the arc and metal transfer is not very clear andthus welding control in this process is a bit difficult as compared to MIG welding.
- Due to limited length of each electrode and brittle flux coating on it, mechanization is difficult.

- In welding long joints (e.g., in pressure vessels), as one electrode finishes, the weldis to be progressed with the next electrode. Unless properly cared, a defect (like slaginclusion or insufficient penetration) may occur at the place where welding is restartedwith the new electrode
- The process uses stick electrodes and thus it is slower as compared to MIG welding

Applicationsof Shielded Metal Arc Welding (SMAW)

- Today, almost all the commonly employed metals and their alloys can be welded bythis process.
- Shielded metal arc welding is used both as a fabrication process and for maintenanceand repair jobs.

Submerged Arc Welding

- Schematic submerged arc welding process is shown in figure. In this welding process, aconsumable bare electrode is used in combination with a flux feeder tube.
- The arc, end of thebare electrode and molten pool remain completely submerged under blanket of granular flux.
- The feed of electrode and tube is automatic and the welding is homogenous in structure. Nopressure is applied for welding purposes.
- This process is used for welding low carbon steel,bronze, nickel and other non-ferrous materials.

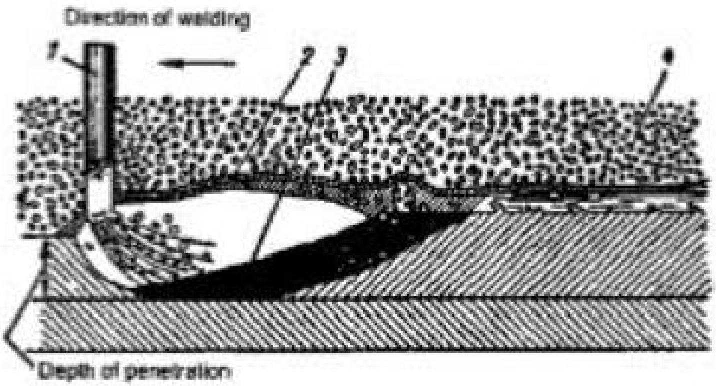


Figure 3.12 Submeged arc Welding
1 Electrode 2 envelope of flux 3 molten metal 4 flux

Gas Tungsten Arc Welding

- In this process a non-consumable tungsten electrode is used with an envelope of inert shieldinggas around it.
- The shielding gas protects the tungsten electrode and the molten metal weldpool from the atmospheric contamination.

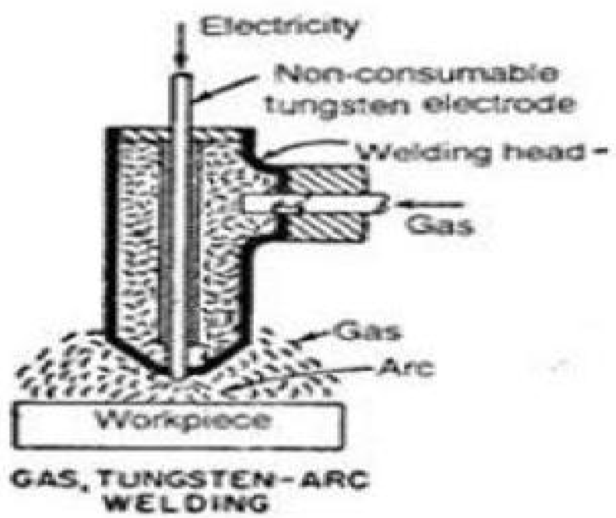


Figure 3.13 Tungusten inert gas arc welding

- The shielding gases generally used are argon, helium or their mixtures. Typical tungsten inert gas welding setup is shown in figure.
- The electrode material may be tungsten, or tungsten alloy (thoriated tungsten orzirconiated tungsten).

- Alloy-tungsten electrodes possess higher current carrying capacity, produce a steadier arc as compared to pure tungsten electrodes and high resistance tocontamination.Electric power source
- Both AC and DC power source can be used for TIG welding. DC is preferred for welding of copper, copper alloys, nickel and stainless steel whereas DC reverse polarity (DCRP) or ACis used for welding aluminum, magnesium or their alloys. DCRP removes oxide film on magnesium and aluminiumInert gases

The following inert gases are generally used in TIG welding: 1. Argon

2. Helium

3. Argon-helium mixtures

4. Argon-hydrogen mixtures

Gas Metal Arc Welding

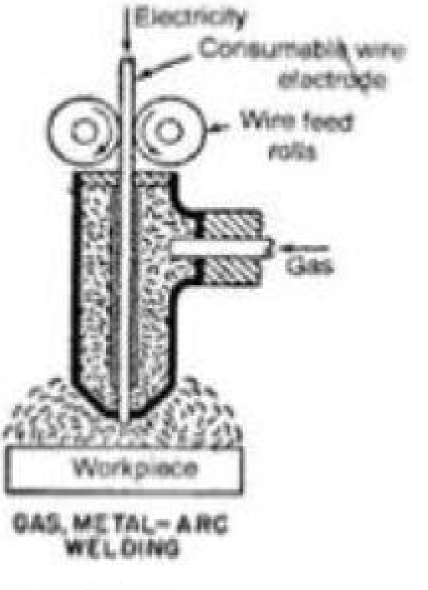


Figure 3.13Metal inert gas arc welding

- Metal inert gas arc welding (MIG) or more appropriately called as gas metal arc weldingGMAW) utilizes a consumable electrode and hence, the term metal appears in the title.There are other gas shielded arc welding processes utilizing

- the consumable electrodes,such as flux cored arc welding (FCAW) all of which can be termed under MIG.
- Though gas tungsten arc welding (GTAW) can be used to weld all types of metals, it is more suitable for thin sheets.
- When thicker sheets are to be welded, the filler metal requirement makes GTAW difficult to use. In this situation, the GMAW comes handy.
- The typical setup for GMAW or MIG welding process is shown in Fig. consumable electrode is in the form of a wire reel which is fed at a constant rate, through the feed rollers. Theweldingtorch is connected to the gas supply cylinder which provides the necessary inert gas.
- The electrode and the work-piece are connected to the welding power supply. The power supplies are always of the constant voltage type only.
- The current from the welding machine is changed by the rate of feeding of the electrode wire.
- Normally DC arc welding machines are used for GMAW with electrode positive (DCRP).
- The DCRP increases the metal deposition rate and also provides for a stable arc and smooth electrode metal transfer.
- With DCSP, the arc becomes highly unstable and also results in a large spatter. But special electrodes having calcium and titanium oxide mixtures as coatings are found to be good for welding steel with DCSP.
- In the GMAW process, the filler metal is transferred from the electrode to the joint. Depending on the current and voltage

used for a given electrode, the metal transfer is done in different ways.

Electrodes for arc welding

- An electrode is a piece of wire or a rod of a metal or alloy, with or without coatings. Anarc is set up between electrode and work piece.
- Welding electrodes are classified into following types

(1)**Consumable Electrodes**

(a)Bare Electrodes

(b) Coated Electrodes

(2**) Non-consumable Electrodes**

(a)Carbon or Graphite Electrodes

(b) Tungsten Electrodes

- Consumable electrode is made of different metals and their alloys.
- The end of thiselectrode starts melting when arc is struck between the electrode and work piece.
- Thusconsumable electrode itself acts as a filler metal. Bare electrodes consist of a metal or alloywire without any flux coating on them.
- Coated electrodes have flux coating which starts melting as soon as an electric arc is struck.
- This coating on melting performs many functionslike prevention of joint from atmospheric contamination, arc stabilizers etc.
- Non-consumable electrodes are made up of high melting point materials like carbon, pure tungsten or alloy tungsten etc.

- These electrodes do not melt away during welding. Butpractically, the electrode length goes on decreasing with the passage of time, because of oxidation and vaporization of the electrode material during welding.
- The materials of non-consumableelectrodes are usually copper coated carbon or graphite, pure tungsten

Resistance welding

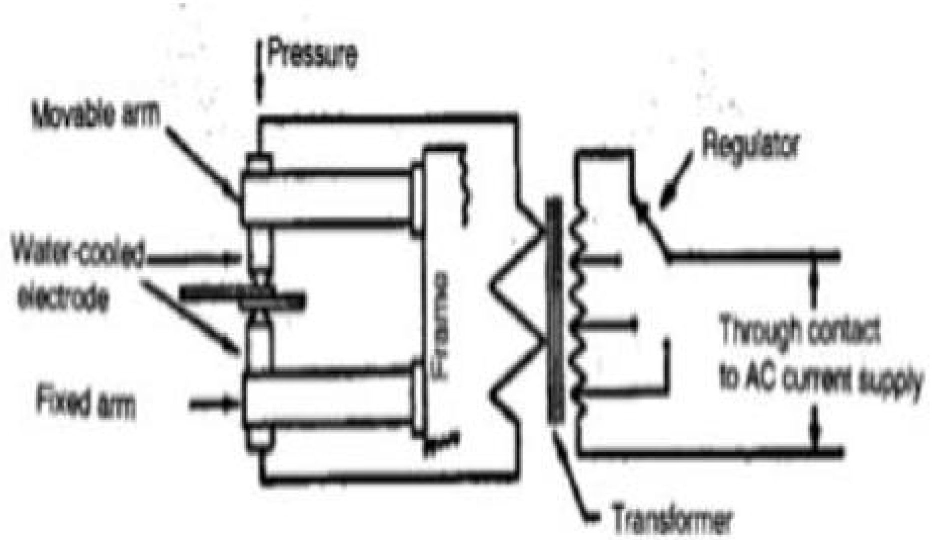


Figure 3.15Resistance welding

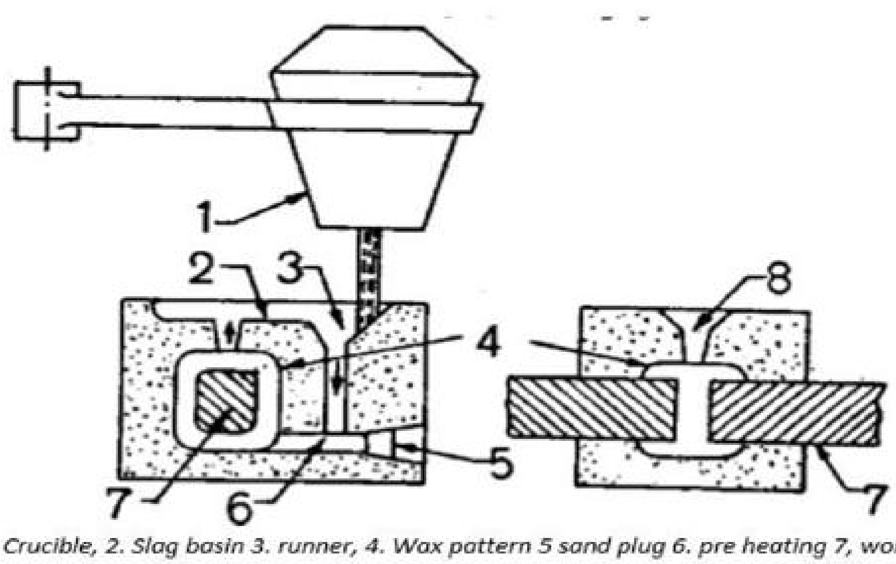
- Inresistance welding the metal parts to be joined are heated by their resistance to the flowof an electrical current.
- Usually this is the only source of heat, but a few of the weldingoperations combine resistance heating with arc heating, and possibly with combustion ofmetal in the arc.
- The process applies to practically all metals and most combinations of puremetals and those alloys, which have only a limited plastic range, are welded by heating theparts to fusion (melting). Some alloys, however, may welded without fusion; instead, the partsare heated to a plastic state at which the applied pressure causes their crystalline structuresto grow together.

- The welding of dissimilar metals may be accomplished by melting bothmetals frequently only the metal with the lower melting point is melted, and an alloy bondis formed at the surface of the unmelted metal.
- In resistance welding processes no fluxes are employed, the filler metal is rarely usedand the joints are usually of the lap type.
- The amount of heat generated in the work piecedepend on the following factors: (1) Magnitude of the current,

(2) Resistance of the current conducting path, and
Mathematically, H $= I^2 Rt$
H = heat generated in joules
I = current in Amp.
R = resistance in ohms
t = time of current flow in seconds.

Thermit welding

Thermit welding



1. Crucible, 2. Slag basin 3. runner, 4. Wax pattern 5 sand plug 6. pre heating 7, work piece 8. Riser

Figure 3.16 Thermit welding

Coalescence is produced by heating with superheated liquid metal and slag resulting from chemical reaction between aluminum and iron oxide.

- The liquid metal acts as a filler metal
- Thermit welding is based on casting foundry practice

$$8Al + Fe_3O_4 = 4\,Al_2O_3 + 9Fe$$

- It consists of welding by using a chemical reaction a volume of molten weld metal which is poured into the joint to be welded.
- Thermit is mixture of finely divided aluminum and iron oxide the ratio by weight 3 parts of iron oxide to one part of aluminum.
- Addition of inflammable powder composed largely of barium peroxide.
- A pattern of wax shaped around the parts to be welded.
- A sheet – iron box is shaped around the wax pattern and the space between the pattern and box is filled and rammed with sand.
- Pouring and heating gates, and risers, are cut in the sand and flame is directed into the heating opening.
- The wax pattern melts & drains out
- Heating is continued to raise the temperature
- Preheating is done before the liquid metal is poured into the mould.
- Burner is removed preheating gate is closed with sand.
- The superheated metal in crucible is poured into the mould surrounding the surfaces to be welded. Temperature 3000^0C.

Solid state welding

- Interatomic bonds may be established by bringing atoms of two surfaces in close enough proximity to assure adhesion.
- Relative movement of surface under pressure and controlled roughness are helpful Three methods

1. Diffusion
2. Ultrasonic
3. Friction

1.Diffusion welding

Figure 3.17 Diffusion welding

- It is a process where heat is not necessary to produce fusion welds.
- Rather it needs two kinds of surfaces that come in contact under pressure.
- This pressure is applied for a period of hours
- In this process, although heating is not essential, if the temperature is raised, the diffusion rate will be cut sufficiently.
- The individual peaks and valleys which make up the roughness are deformed by the application increasing pressure
- At places, where the surface move together shear , the films diffused and metal to metal contact take place.

- After that the atoms are within the attractive force fields of each other, hence joint resembles a grain boundary

2.Ultrasonic welding

- It is a solid state welding where coalescence is produced by the application by the high frequency vibratory energy to the w/p as they are held together under pressure. The w/p to be joined are clamped together under a static normal force to their interface and oscillating shear stresses of ultrasonic frequencies are applied parallel to plan for one second.
- The combined of pressure and vibration cause movement of the metal molecules are welded together.
- The welding is accomplished in solid state, without applying external heat filler rod or high pressure.
- Time 0.5 to 2 sec
- Vibratory action breaks up moistures, oxide and other coatings
- Frequency 20000 to 60000 Hz
- Overlapping metals are joined
- Parts to be joined are clamped between welding tip and supporting member under low static pressure
- High frequency vibratory energy is then transmitted into the weld area for brief interval
- this process Produces a sound bond without an arc or melting weld metal and absent of filler metal or flux
- Thickness 0.38 to 2.5 mm.

3.Friction welding

- Frictional energy generated when two bodies slide on each other is transformed into heat when the rate of movement is high and heat is contained in narrow zone welding occurs.
- The components to be weld are held in an axial alignment.
- One component held in chucking spindle is rotate and accelerated
- The stationary component is held in movable clamp which is moved forward to come into pressure contact with the rotating component

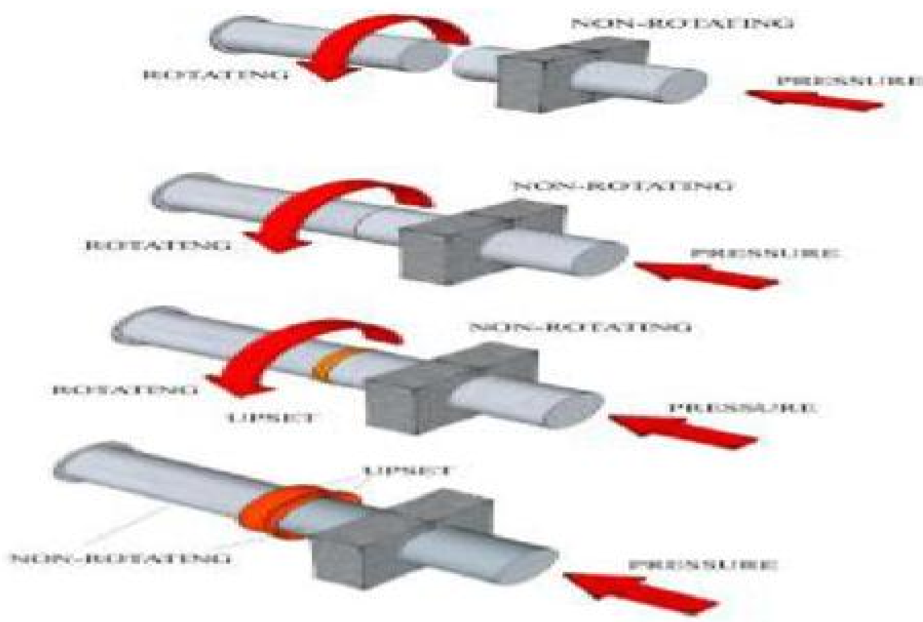


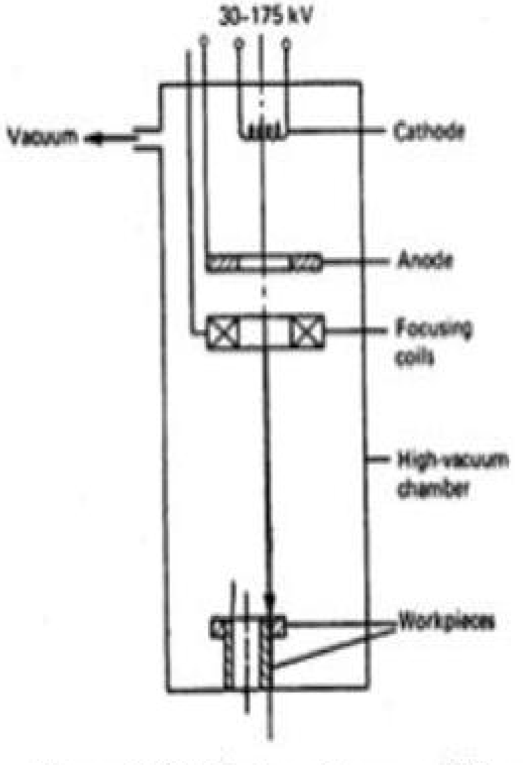
Figure 3.18 Friction welding

- Pressure & rotation are maintained until the resulting high temperature makes the component melt plastically for welding
- When sufficient heating has taken place the power drive is uncoupled brake is applied to stop the rotation and the axial force is generally increased to forged two components together

Electron beam welding

- Electron beam welding utilizes the energy from a fast moving beam of electrons focused on the work piece
- The electrons strike the metal surface which gives up kinetic energy almost completely into heat.

- In all types of electron beam machines, a tungsten filament which serves as cathode emits a mass of electron that are accelerated and focused 0.25 to 1 mm diameter of beam
- The heat is generated about 2500^0C.
- This is sufficient to melt and vaporize the work piece materials and thus fills a narrow weld gap even without filler rod
- It is Fusion welding process
- The high velocity electrons strike to the surface to be welded, their kinetic energy changes to thermal energy, hence causing w/p to be melt.
- The electrode beam is created in vacuum.
- If welding is done in such vacuum, then there is no need of electrodes, gases, filler metal that contaminates the weld.



.Figure 3.18 Electron Beam welding

Laser beam welding

- This means that many welds can now be made without electrode arrangement required for vacuum electrode
- Laser is a device for concentrating light waves are identical and parallel
- Laser is device for concentrating light waves into narrowly defined highly intense beam that can import energy on a small area for producing fusion welding.

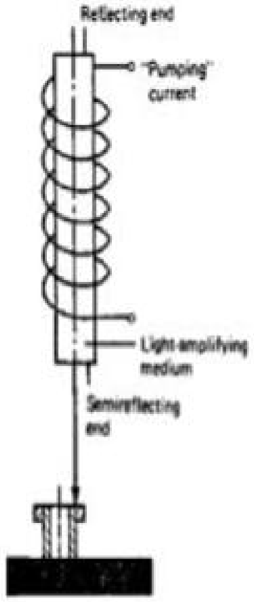


Figure 3.20 Laser Beam welding

- Laser is the term applied for phenomenon of amplification of light by stimulated radiation emission.
- In operation the optical energy radiated from the flash lamp is focused on the laser rod, from where it is reflected with the help of mirrors and accelerated in its path
- The reflected light is emitted in the form of slightly divergent beam.
- A lance is placed in the path of these beam of light which converges and focuses the light beam of the component to be welded.

material and due to this, it vaporizes

Defects in welding

1. Lack of Penetration
2. Lack of Fusion
3. Porosity
4. During the welding process
5. Slag Inclusion
6. Undercuts

1. Lack of Penetration

It is the failure of the filler metal to penetrate into the joint.It is due to

a. Inadequate de-slagging
b. Incorrect edge penetration

Incorrect welding technique.

2.Lack of Fusion:

Lack of fusion is the failure of the filler metal to fuse with the parent metal. It is duo to

a. Too fast a travel
b. Incorrect welding technique
c. Insufficient heat

3.Porosity

It is a group of small holes throughout the weld metal. It is caused by the trapping of gas during the welding process, due to

a. Chemicals in the metal

b. Dampness

c. Too rapid cooling of the weld.

5.Slag Inclusion It is the entrapment of slag or other impurities in the weld.

It is caused by

a. Slag from previous runs not being cleaned away,

b. 2. Insufficient cleaning and preparation of the base metal before welding commences.

6.Undercuts

These are grooves or slots along the edges of the weld caused by

1. Too fast a travel

1. Weld Crack
2. Porosity
3. Undercut
4. Incomplete Fusion
5. Incomplete Penetration
6. Slag Inclusion
7. Spatter

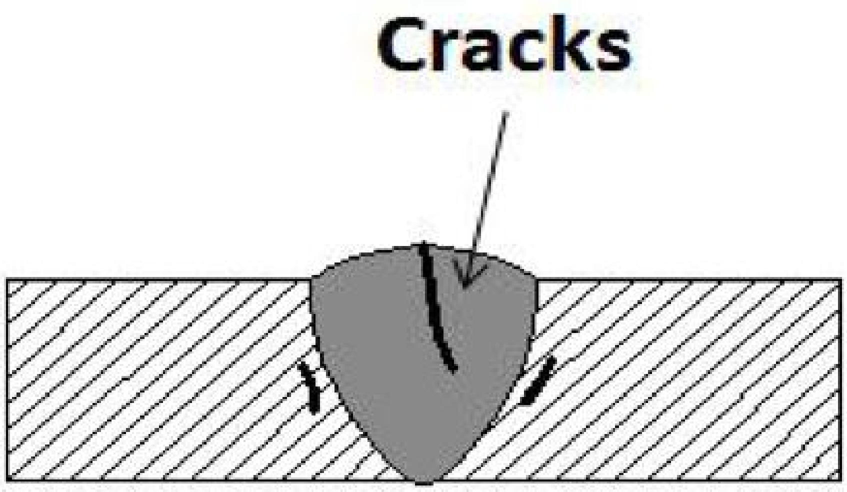
1.Weld Crack

The most serious type of welding defect is a weld crack and it's not accepted almost by all standards in the industry. It can appear on the surface, in the weld metal or the area affected by the intense heat.

There are different types of cracks, depending on the temperature at which they occur:

1.a.Hot cracks:

These can occur during the welding process or during the crystallization process of the weld joint. The temperature at this point can rise over 10,000C.



1.b.Cold cracks.

These cracks appear after the weld has been completed and the temperature of the metal has gone down. They can form hours or even days after welding. It mostly happens when welding steel. The cause of this defect is usually deformities in the structure of steel.

1.c.Crater cracks.

These occur at the end of the welding process before the operator finishes a pass on the weld joint. They usually form near the end of the weld. When the weld pool cools and solidifies, it needs to have enough volume to overcome shrinkage of the weld metal. Otherwise, it will form a crater crack.

1.Weld Crack

Causes of Weld Crack :

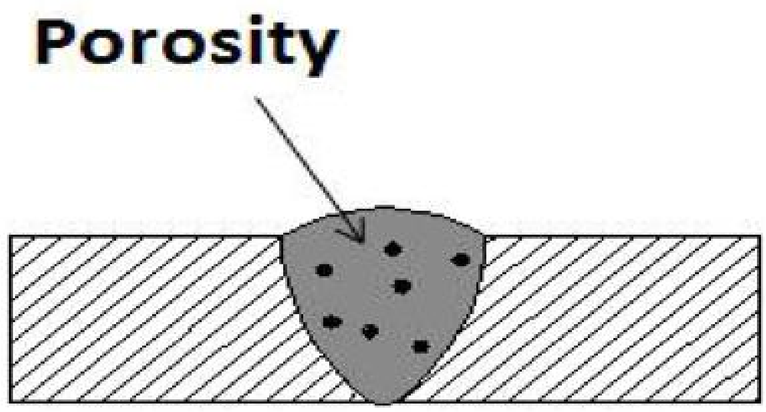
a. Use of hydrogen when welding ferrous metals.
b. Residual stress caused by the solidification shrinkage.
c. Base metal contamination.
d. High welding speed but low current.
e. No preheat before starting welding.
f. Poor joint design.
g. A high content of sulfur and carbon in the metal.

Remedies:

a. Preheat the metal as required.
b. Provide proper cooling of the weld area.
c. Use proper joint design.
d. Remove impurities.
e. Use appropriate metal.
f. Make sure to weld a sufficient sectional area.
g. Use proper welding speed and amperage current.
h. To prevent crater cracks make sure that the crater is properly filled.

2.Porosity

Porosity occurs as a result of weld metal contamination. The trapped gases create a bubble-filled weld that becomes weak and can with time collapse.



2. **Causes of porosity:**

a. Inadequate electrode deoxidant.

b. Using a longer arc.

c. The presence of moisture.

d. Improper gas shield.

e. Incorrect surface treatment.

f. Use of too high gas flow.

g. Contaminated surface.

h. Presence of rust, paint, grease or oil.

2.**PorosityRemedies:**

a. Clean the materials before you begin welding.

b. Use dry electrodes and materials.

c. Use correct arc distance.

d. Check the gas flow meter and make sure that it's optimized as required with proper with pressure and flow settings.

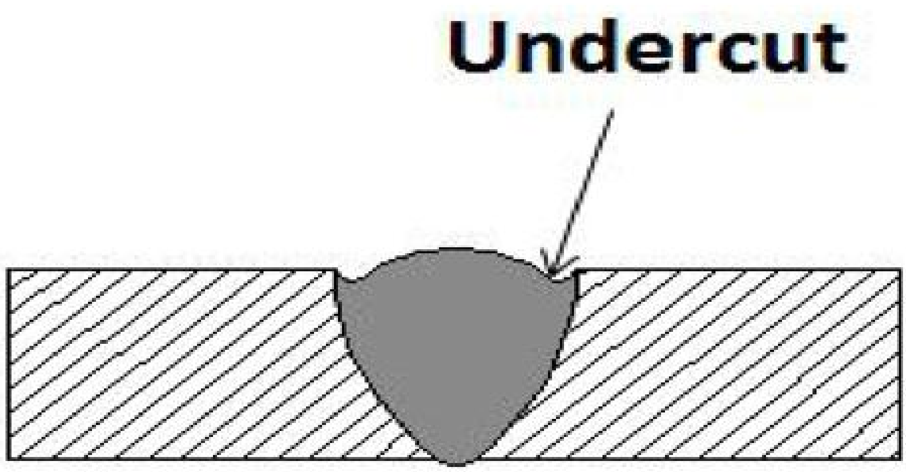
e. Reduce arc travel speed, which will allow the gases to escape.

f. Use the right electrodes.

Use a proper weld technique.

3.Undercut

This welding imperfection is the groove formation at the weld toe, reducing the cross-sectional thickness of the base metal. The result is the weakened weld and work piece.



Causes:

a. Too high weld current.

b. Too fast weld speed.

c. The use of an incorrect angle, which will direct more heat to free edges.

d. The electrode is too large.

e. Incorrect usage of gas shielding.

f. Incorrect filler metal.

g. Poor weld technique.

Remedies:

a. Use proper electrode angle.

b. Reduce the arc length.

c. Reduce the electrode's travel speed, but it also shouldn't be too slow.

d. Choose shielding gas with the correct composition for the material type you'll be welding.

e. Use of proper electrode angle, with more heat directed towards thicker components.

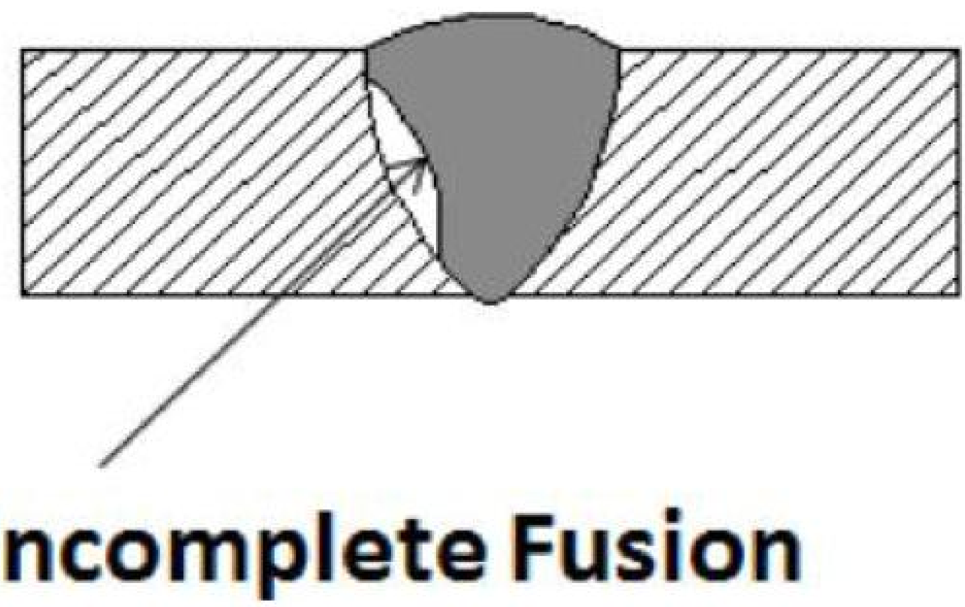
f. Use of proper current, reducing it when approaching thinner areas and free edges.

g. Choose a correct welding technique that doesn't involve excessive weaving.

h. Use the multipass technique

4.Incomplete Fusion

This type of welding defect occurs when there's a lack of proper fusion between the base metal and the weld metal. It can also appear between adjoining weld beads. This creates a gap in the joint that is not filled with molten metal.



Causes:

a. Low heat input.

b. Surface contamination.

c. Electrode angle is incorrect.

d. The electrode diameter is incorrect for the material thickness you're welding.

e. Travel speed is too fast.

The weld pool is too large and it runs ahead of the arc

Remedies:

a. Use a sufficiently high welding current with the appropriate arc voltage.

b. Before you begin welding, clean the metal.

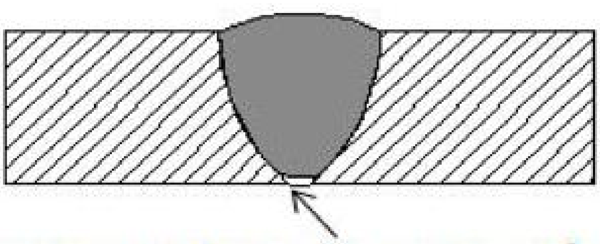
c. Avoid molten pool from flooding the arc.

d. Use correct electrode diameter and angle.

e. Reduce deposition rate.

5.Incomplete Penetration

Incomplete penetration occurs when the groove of the metal is not filled completely, meaning the weld metal doesn't fully extend through the joint thickness.



Incomplete Penetration

Causes:

a. There was too much space between the metal you're welding together.

b. You're moving the bead too quickly, which doesn't allow enough metal to be deposited in the joint.

c. You're using a too low amperage setting, which results in the current not being strong enough to properly melt the metal.

d. Large electrode diameter.

e. Misalignment.

f. Improper joint.

Remedies:

a. Use proper joint geometry.

b. Use a properly sized electrode.

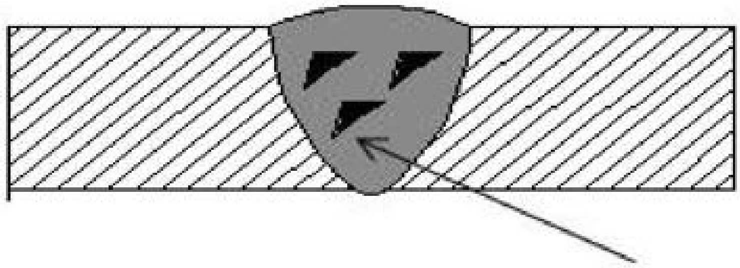
c. Reduce arc travel speed.

d. Choose proper welding current.

e. Check for proper alignment.

f. **6.Slag Inclusion**

g. Slag inclusion is one of the welding defects that are usually easily visible in the weld. Slag is a vitreous material that occurs as a byproduct of stick welding, flux-cored arc welding and submerged arc welding. Is can occur when the flux, which is the solid shielding material used when welding, melts in the weld or on the surface of the weld zone.



Slag inclusion

Causes:

a. Improper cleaning.

b. The weld speed is too fast.

c. Not cleaning the weld pass before starting a new one.

d. Incorrect welding angle.

e. The weld pool cools down too fast.

Welding current is too low.

Remedies:

Increase current density.

Reduce rapid cooling.

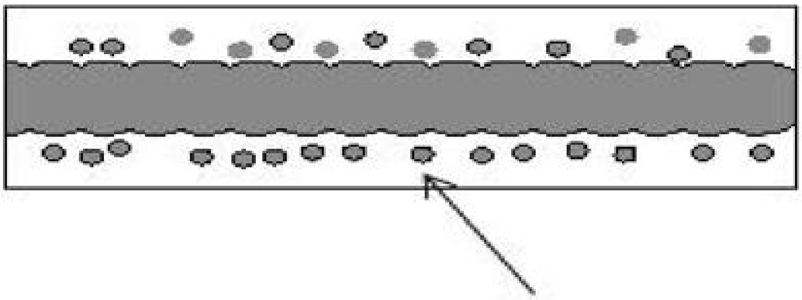
Adjust the electrode angle.

Remove any slag from the previous bead.

Adjust the welding speed.

7.Spatter

Spatter occurs when small particles from the weld attach themselves to the surrounding surface. It's an especially common occurrence in gas metal arc welding. No matter how hard you try, it can't be completely eliminated. However, there are a few ways you can keep it to a minimum.



Spatter

Causes:

a. The running amperage is too high.
b. Voltage setting is too low.
c. The work angle of the electrode is too steep.
d. The surface is contaminated.
e. The arc is too long.
f. Incorrect polarity.
g. Erratic wire feeding.

Remedies:

a. Clean surfaces prior to welding.
b. Reduce the arc length.
c. Adjust the weld current.
d. Increase the electrode angle.
e. Use proper polarity.
f. Make sure you don't have any feeding issues.

Heat-affected zone:

The heat-affected zone (HAZ) is the area of base material, either a metal or a thermoplastic which is not melted and has had its microstructure and properties altered by welding or heat intensive cutting operations.

The heat from the welding process and subsequent re-cooling causes this change from the weld interface to the termination of the sensitizing temperature in the base metal.

The extent and magnitude of property change depends primarily on the base material, the weld filler metal, and the amount and concentration of heat input by the welding process.

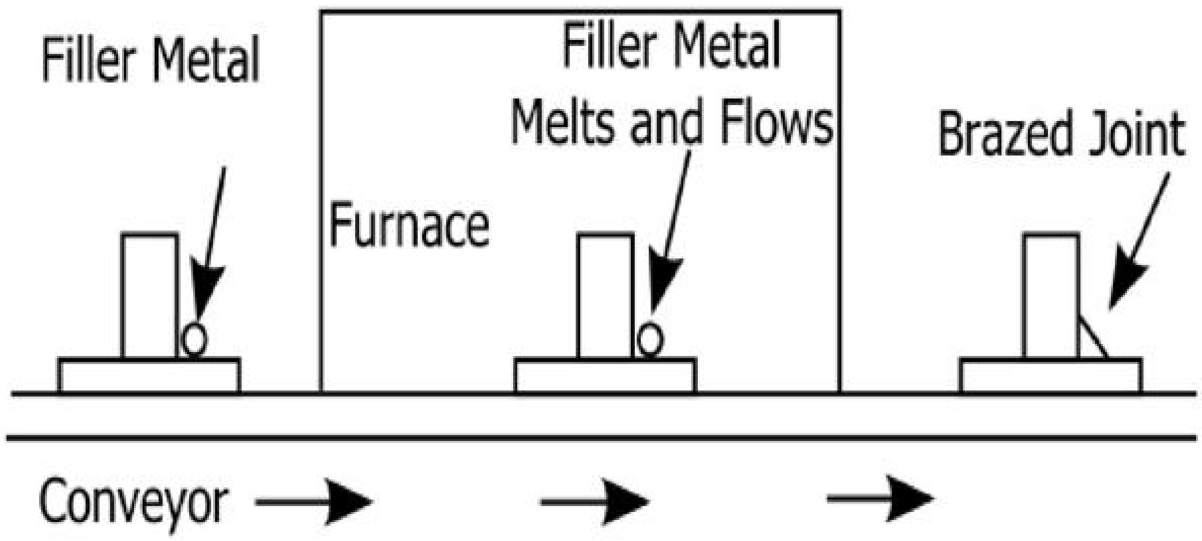
The thermal diffusivity of the base material plays a large role—if the diffusivity is high, the material cooling rate is high and the HAZ is relatively small.

Alternatively, a low diffusivity leads to slower cooling and a larger HAZ.

The amount of heat input during the welding process also plays an important role as well, as processes like ox fuel welding use high heat input and increase the size of the HAZ. Processes like laser beamweldingand electron beam weldinggive a highly concentrated, limited amount of heat, resulting in a small HAZ.

Brazing:

- Brazing is a metal joining process whereby a filler metal is heated above melting point and distributed between two or more close fitting parts by capillary action.
- In brazing, metallic parts are joined by joined by a non-ferrous filler metal or alloy.
- Brazing involves the melting of comparatively low melting point filler material against the base metal pieces to be joined while they are clean and free from oxides, oil grease, etc.



The molten filler material

1. Wets the base metal surfaces
2. Spreads along the joint by capillary action
3. Adheres and solidifies to from the brazed joint.

Brazing gives much stronger joint compare to soldering.

Filler material used in this processes are generally two types 1. Copper based alloy

2. Silver based alloy

The parts to be joined by brazing are carefully cleaned, the flux applied and the parts clamped in position for joining.

Borax is generally used as flux.

The parts to be joined are to be heated to a temperature above the melting point of the spelter, and molten spelter is allowed to flow by capillary action into the space between the parts and to cool slowly.

Advantages

- In brazing dissimilar metals or non-metals can be joined.
- Complicated component can also be brazed at low cost.

- It is suitable for mass production.
- Brazing produces clean joint.
- Brazing does not melt the base metal which allows much close control over the tolerances.

Disadvantages :

- Strength of brazed joints can be damaged under high service temperature.
- Strength of the brazed joints is less compare to welded joints.
- Filler metals used in this process are costly.
- The joint color is different than that of base metal which creates an aesthetic disadvantage.

Application:

Brazing is applicable to cast and wrought iron, steel, Cu, Al, Mg and their alloys.

Soldering

- Soldering is a method of joining two or more pieces of metal by means of a fusible alloy or metal, called solder, applied in molten state.
- Solders are essentially alloys of lead and tin. To improve the mechanical properties and temperature resistance, solders are added to other alloying elements such as zinc, cadmium and silver in various proportions. Solders are essentially alloys of lead and tin.
- To improve the mechanical properties and temperature resistance, solders are added to other alloying elements such as zinc, cadmiumand silver in various proportions.

- Solvent cleaning, acid pickling and even mechanical cleaning are applied before soldering.

Advantages :

- By soldering various dissimilar metals can be joined. It is simple and low cost method.
- Work piece with different thickness can be joined.
- The joined formed in the soldering, do not require machining.
- Soldering is a low temperature process; hence there is no change in the properties of metals.

Disadvantages

- The soldered joints are not suitable for high temperature service because of the low melting temperatures of the filler metals used.
- The soldering joints also need to be cleaned meticulously to provide chemically clean surfaces to obtain a proper bond.
- Corrosion resistance of solder joint is less.

Adhesive bonding:

- Adhesive bonding is the process of joining materials by using adhesives.
- In this processes surface preparation is done so that the adhesive applied on the surface which is free from foreign particles.
- A low viscosity primer is then applied in one or more coats by spraying and brushing.
- After primer is dried, the adhesive is applied.
- After that assembly of adhesive coated components is done.

Application :

- Assembly of electronic components
- Joints in wire

  Joints in sheet metal objects like food cans.