LECTURE NOTES
4th Semester B. Tech/2019-20
TH:MATERIALS PROCESSING
BRANCH:METALLURGICAL AND MATERIALS ENGINEERING

DISCLAIMER

MODULE-IV

METAL JOINING PROCESSES

Metal Joining is defined as joining of two metal parts either temporarily or permanently with or without the application of heat or pressure.

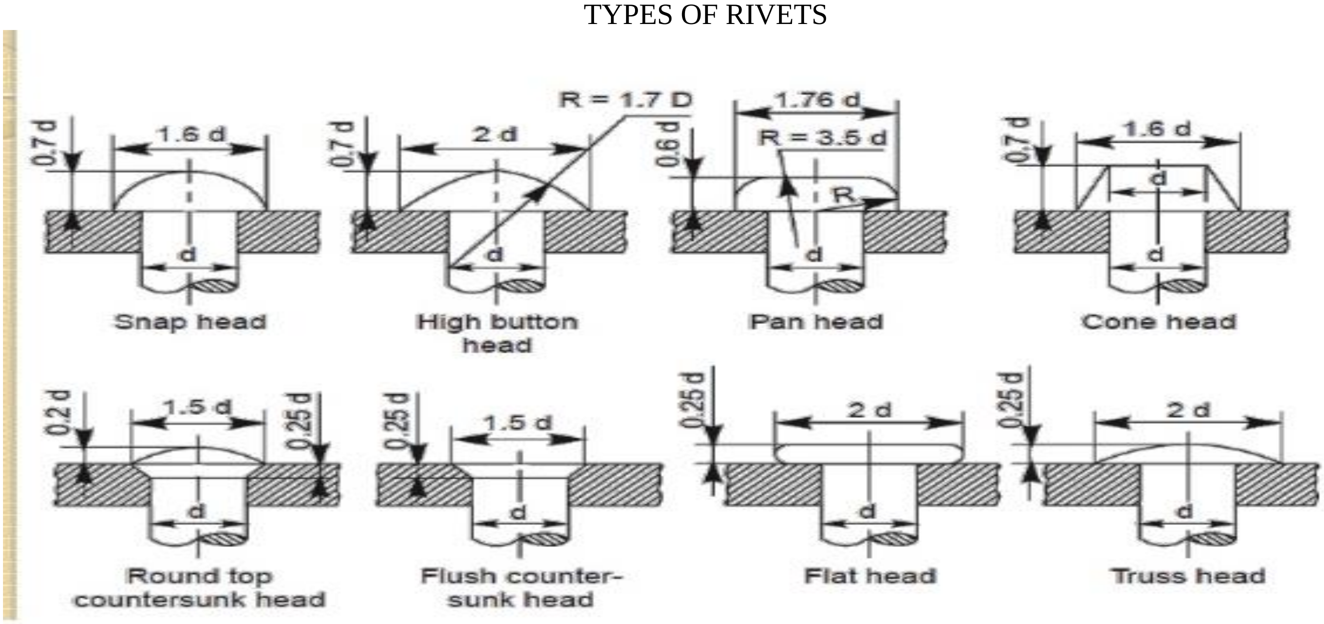
1. WELDING- PERMANENT JOINT
2. BRAZING -PERMANENT JOINT
3. SOLDERING -PERMANENT JOINT
4. ADHESIVE BONDING -SEMI-PERMANENT
5. MECHANICAL ASSEMBLY

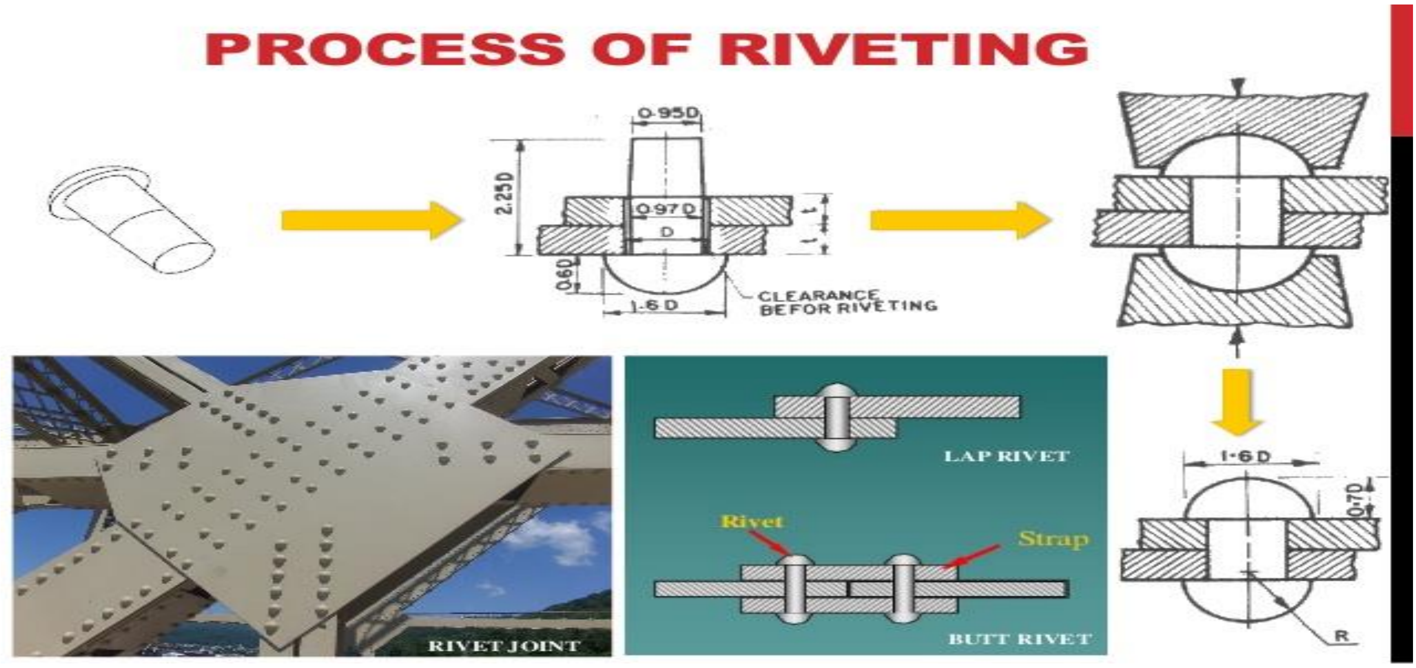
a) BOLT & SCREW: NON-PERMANENT
b) RIVETING: PERMANENT
c) CLAMPING: NON-PERMANENT

Riveting

Riveting Its is metal joining Process in which the two metallic parts are joined by the use of rivets. In this process, the metallic parts to be joined do not undergo any change in their physical structure or atomic structure. However Force is required for riveting. Riveting is used widely in automobile and aerospace industry and in many other applications where we require permanent/semi-permanent bonding and where bolting and welding is not an option. Mostly done for low thickness sheet metals and Aluminium.

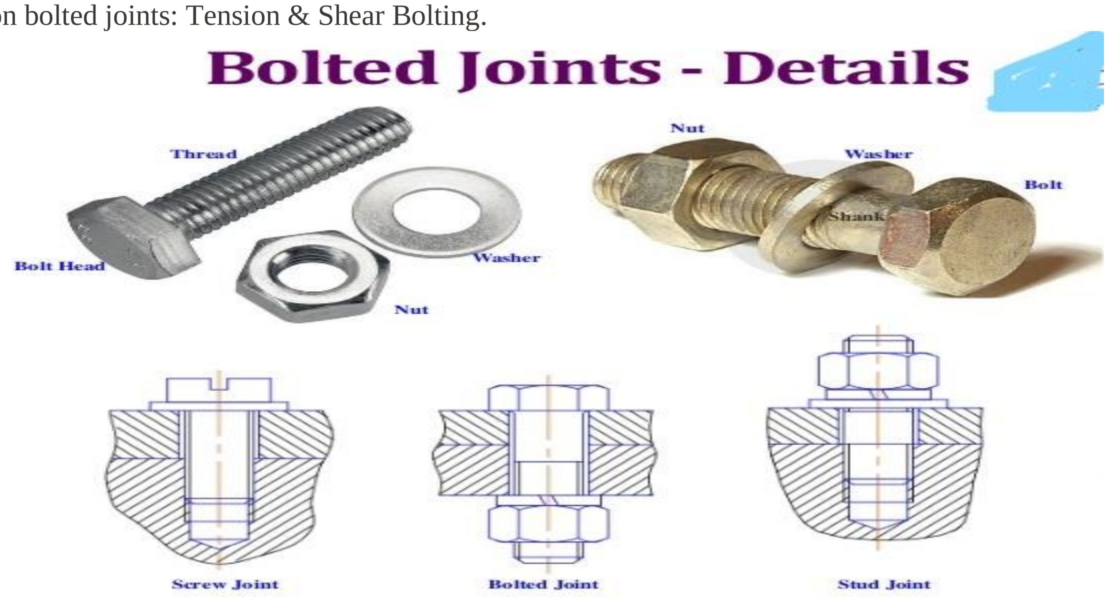
TYPES OF RIVETS





BOLTING:

In this metal joining process, the metallic parts are joined together by means of Bolt/Screw (and/or nut). This Process is widely used in assembling of parts are to be joined temporarily or joints which require periodic maintenance. Two main types of loads on bolted joints: Tension & Shear Bolting.



Components of a Bolted Joints 1. Bolt 2. Washer 3. (and/or) Nut . Different combinations of the above may be used for a joint depending on the load.12.9 Class Bolt/Nut Means 12 . 9
; 12×100 = 1200 MPa is UTS 9×10= 90% of 1200 = 1080 MPa is YS Similarly for 10.9/8.8/4.4 etc

WELDING

In this metal joining process the two parts that are to be welded are fused together by application of heat and pressure (sometimes). Permanent Fusion happens between joining metals . The welding processes depends on many factors depending on the type of welding process: Oxy-acetylene welding , SMAW ,GMAW, GTAW , FCAW; SAW; ESW; ERW etc…. Welding

Welding is a process of permanently joining materials. Welding joins of different metals/alloys with a number of processes, in which heat is supplied either electrically or by means of a torch. Welding is done by application of heat or both heat and pressure. The most essential requirements is Heat. Pressure may be employed, but this is not in many processes essential. The welding process evolves applying heat to the work piece. The heat applied should be such that the work piece should melt, i.e. the temperature at which welding is done, should be more than the melting point of the work piece to be welded.

Classification Of Welding Processes

Welding process are classified as

1. Gas welding:-
   - -Air acetylene welding
   - -Oxy acetylene welding
   - -Oxy hydrogen welding
   - -Pressure gas welding
2. Arc welding:-
   - -Carbon arc welding
   - -Shielded metal work welding
   - -Flux cored arc welding
   - -Submerged arc welding
   - -TIG(GTAW) welding
   - -MIG(GMAW) welding
   - -Plasma arc welding
   - -Electro slag welding or electro gas welding
3. Resistance welding:-
   - -Spot welding
   - -Seam welding
   - -Percussion welding
   - -Flash butt welding
   - -Resistance butt welding
4. Solid state welding:
   - -Cold welding
   - -Diffusion welding
   - -Explosive welding
   - -Friction welding
   - -Hot pressure welding
   - -Ultrasonic welding
5. Thermo chemical welding:
   - -Thermit welding
   - -Atomic hydrogen welding .
6. Radiant energy welding:
   - -Electron beam welding
   - -Laser beam welding

According to modern method the welding may be classified as

I. Pressure welding(plastic welding)

II. Non pressure welding(fusion welding)

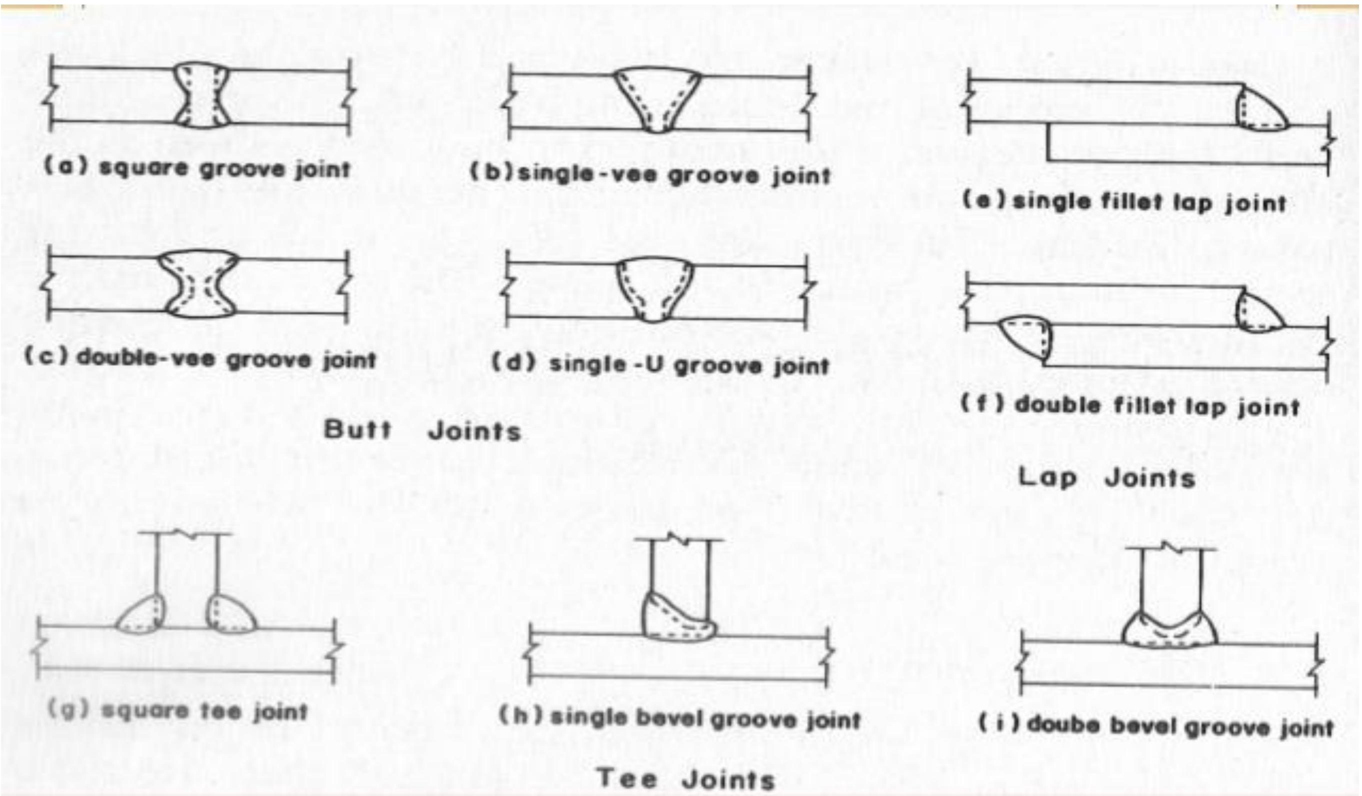
Pressure welding:- In pressure welding the piece of metal to be joined are heated to a plastic state and then force together by external pressure. Ex:-Resistance welding, Hot pressure welding, Diffusion welding

Non pressure welding:- In non pressure welding the material at the joint is heated to the molten state and allowed to solidify. Ex:-Gas welding, Arc welding

Basic Requirements of Welding Processes

1. The Two Metal (work pieces) should be either in contact with each other or closely placed (concept of root gap).
2. The weld surfaces should be free from oxides, paint, oil, dirt, grease etc.
3. Energy Source, Electrode and Filler Metal rod/ wire.
4. Shielding: During Welding if the metal is exposed to air directly the Oxygen in air reacts with the metal to form oxide which results in poor welding. In order to avoid the shielding gas is used.

TYPES OF WELD JOINTS



Some important definition in the welding are:

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

Base Metal: The metal to be joined or cut is termed the base metal.

Bead or weld bead: Bead is metal added during a single pass welding.The bead appears as a separate material from the base metal.

Crater: In Arc welding , a crater is the depression in the weld –metal pool at the point where the arc strikes their base metal plate.

Puddle: The portion of the weld joint that is melted by the heat of welding is called puddle.

Weld face: It is the exposed surface of the weld.

Root: It is the point at which the two pieces to be joined by welding are nearest.

<u>There are three distinct zones formed in a typical weld joint:</u>

Fusion zone:

The area of base metal and filler metal that has been completely melted.

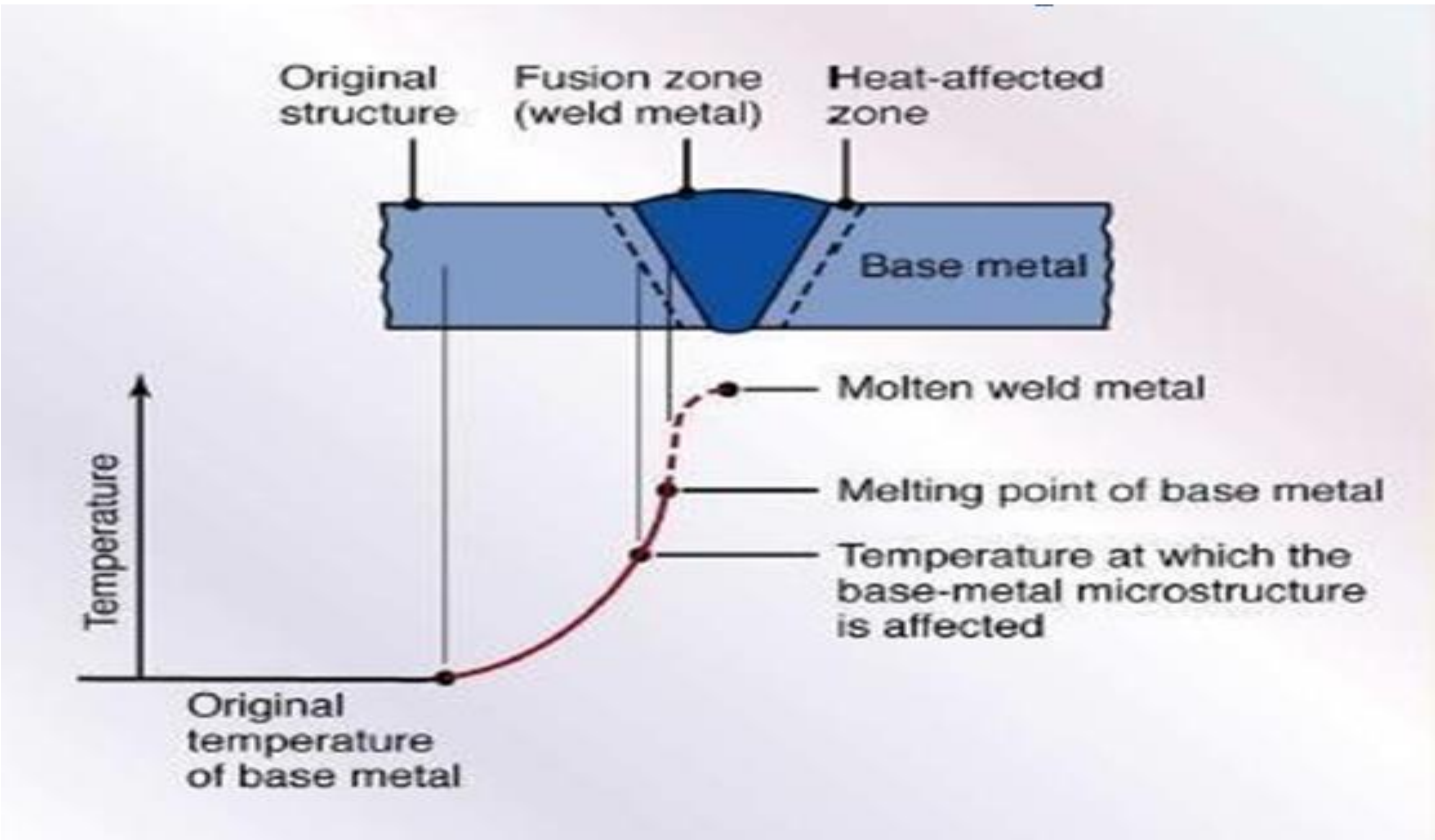
Weld interface:

A thin area of base metal that was melted or partially melted but did not mix with the filler metal.

Heat affected zone:

The surrounding area of base metal that did not melt, but was heated enough to affect its grain structure.

The metallurgy and properties of the heat affected and weld quality greatly depend on the type of metals joined, the particular joining process, the filler metals used (if any), and welding process available. Characteristics of a typical fusion weld zone in oxyfuel-gas and arc welding is shown in Figure:



The heat-affected zone is the narrow region of the base metal adjacent to the weld bead, which is metallurgically altered by the heat of welding. It has a microstructure different from that of base metal prior to welding. The heat-affected zone is usually the major source of metallurgical problems in welding. The width of the heat-affected zone depends on the amount of heat input during welding and increases with the heat input. The properties and microstructure of the HAZ depends on the rate of heat input and cooling and the temperature to which this zone was raised.

Effect of HAZ

If the workpiece material was previously cold worked, this HAZ may have experienced recrystallization and grain growth, and thus a diminishment of strength, hardness, and toughness. The strength and hardness of HAZ depend partly on how the original strength and hardness of the base metal was developed prior to the welding. Upon cooling, residual stresses may form in this region that weakens the joint. It can also lead to loss of corrosion resistance in stainless steels and nickel-base alloys. For steels, the material in this zone may have been heated to temperatures sufficiently high so as to form austenite. Upon cooling to room temperature, the microstructural products that form depend on cooling rate and alloy composition. For plain carbon steels, normally pearlite and a proeutectoid phase will be present. For alloy steels, one micro-structural product phase may be martensite, which is ordinarily undesirable because it is so brittle.

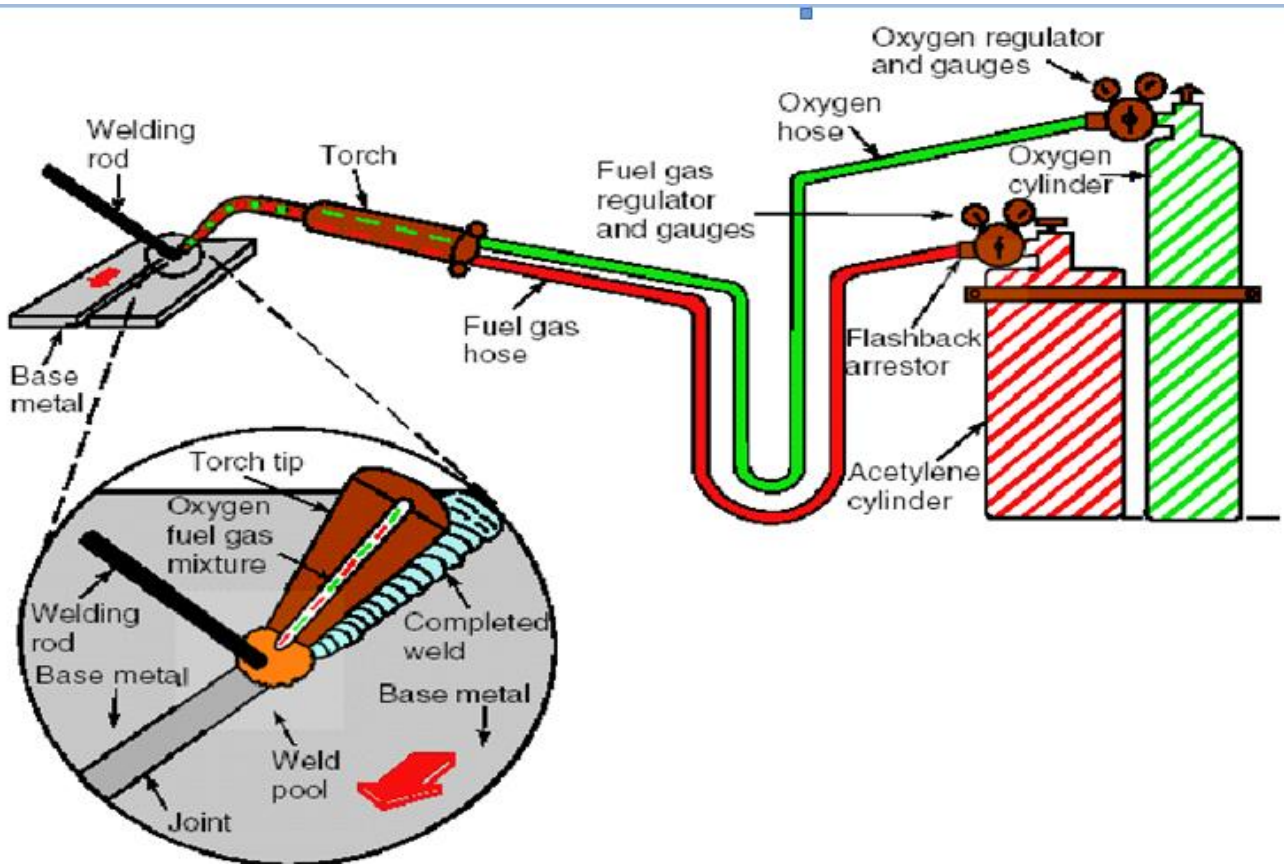
Gas Welding :

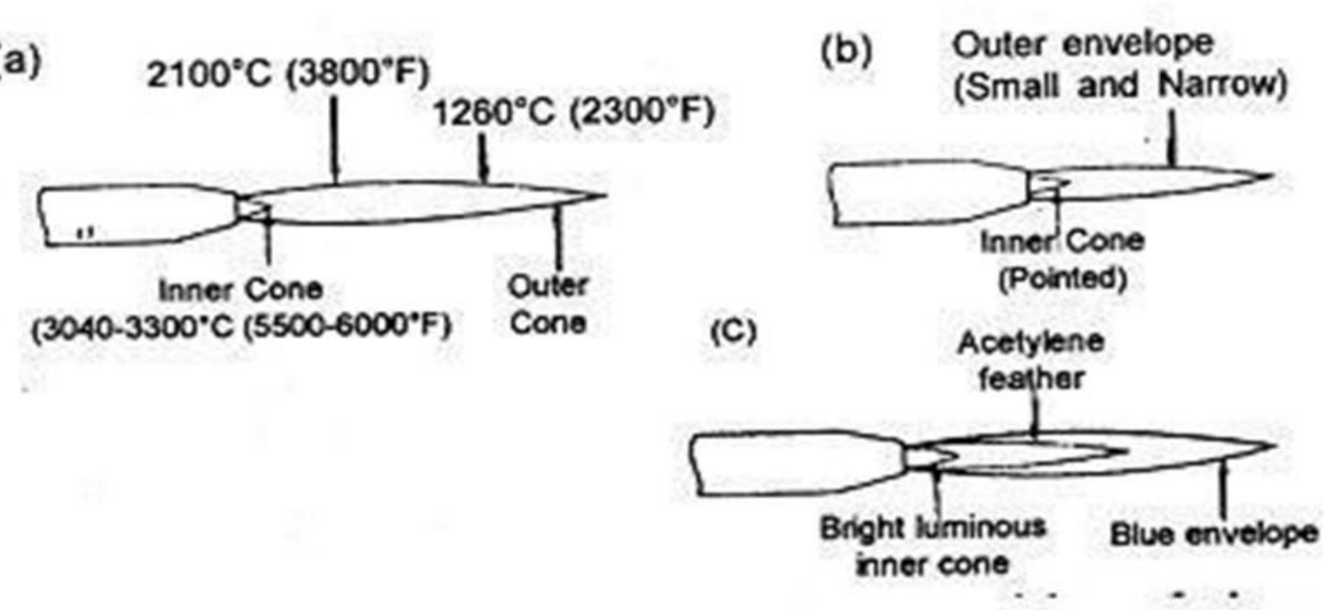
Gas Welding is a fusion welding process. It joins metals, using the heat of combustion of oxygen/air and fuel gas mixture. The intense heat thus produced melts and fuses together the edges of the parts to be welded, generally with the addition of a filler metal. Application of Gas Welding i) For joining thin metals. ii). For joining materials in whose case excessively high temp. or rapid heating and cooling of the job would produce unwanted or harmful changes in the metal iii.) For joining most ferrous and non-ferrous metals, i.e. Al, Cu, Ni, Mg, and its alloys etc.

As the name implies gas welding is also called oxy fuel gas welding, derives the heat from the combustion of fuel gas such as acetylene in combustion with oxygen.The procress is called fision welding process where the join is completely melted to obtain the fusion. The heat produced by the combustion of gas is sufficient to melt and as such is universally applicable.

Oxy-acetylene welding(OAW)

The oxyacetylene welding process uses a combination of oxygen and acetylene gas to provide a high temperature flame



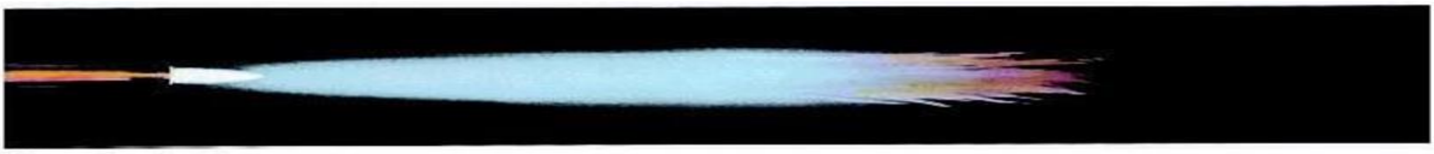


The first reaction takes place when the fuel gas such as acetylene and oxygen mixture burns releasing intense heat.

For oxy acetylene welding ,the following reaction takes place C_2
H_2+O_2 ----------> $2CO+H_2+448$kj/mol
The carbon monoxide(CO) and hydrogen produced in the first stage ,further combine with atmospheric oxygen and gives rise the outer bluish flame, with the following reaction.
$4CO+2H_2+3O_2$ ------------->$4CO_2+2H_2O+812$kj/mol

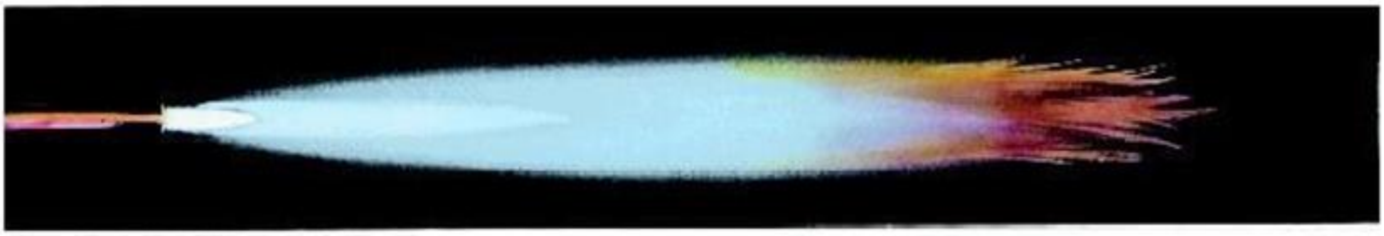
Though higher amount of heat is produced in the second stage ,since it is distributed over a large area ,the temperature achieved is small(of the order of 1200 to 2000^0c) in the flame, which may be used for the preheating the steels. The inner white cone is of the order of 3100^0c which is used for directly melting the steel.

Types of flame:



Neutral Flame
(Acetylene and oxygen.) Temperature 5589˚F (3087˚C). For fusion welding of steel and cast iron.

Oxidizing Flame
(Acetylene and excess oxygen.) For braze welding with bronze rod.



Carburizing Flame
(Excess acetylene with oxygen.) Used for hard-facing and welding white metal.

Flame definition:

The **neutral** flame is produced when the ratio of oxygen to acetylene, in the mixture leaving the torch, is almost exactly one-to-one. It’s termed “neutral” because it will usually have no chemical effect on the metal being welded. It will not oxidize the weld metal; it will not cause an increase in the carbon content of the weld metal.

The **excess acetylene** flame as its name implies, is created when the proportion of acetylene in the mixture is higher than that required to produce the neutral flame. Used on steel, it will cause an increase in the carbon content of the weld metal.

The **oxidizing flame** results from burning a mixture which contains more oxygen than required for a neutral flame. It will oxidize or “burn” some of the metal being welding.

<u>Welding Equipments:</u>

Acetylene gas

• Virtually all the acetylene distributed for welding and cutting use is created by allowing calcium carbide (a man made product) to react with water.

• The nice thing about the calcium carbide method of producing acetylene is that it can be done on almost any scale desired. Placed in tightly-sealed cans, calcium carbide keeps indefinitely for years, miners’ lamps produced acetylene by adding water, a drop at a time, to lumps of carbide.

Before acetylene in cylinders became available in almost every community of appreciable size produced their own gas from calcium carbide.

Acetylene Cylinder

• Acetylene is stored in cylinders specially designed for this purpose only.

• Acetylene is extremely unstable in its pure form at pressure above 15 PSI (Pounds per Square Inch)

• Acetone is also present within the cylinder to stabilize the acetylene.

Acetylene cylinders should always be stored in the upright position to prevent the acetone form escaping thus causing the acetylene to become unstable.

• Cylinders are filled with a very porous substance “monolithic filler” to help prevent large pockets of pure acetylene form forming

• Cylinders have safety (Fuse) plugs in the top and bottom designed to melt at 212° F (100 °C)

Acetylene Valves:

Acetylene cylinder shut off valves should only be opened 1/4 to 1/2 turn .
This will allow the cylinder to be closed quickly in case of fire.

Typical torch styles:
A small welding torch, with throttle valves located at the front end of the handle. Ideally suited to sheet metal welding can be fitted with cutting attachment in place of the welding head shown.

Welding torches of this general design are by far the most widely used. They will handle any oxyacetylene welding job, can be fitted with multiflame (Rosebud) heads for heating applications, and accommodate cutting attachments that will cut steel 6 in. thick.

A full-size oxygen cutting torch which has all valves located in its rear body. Another style of cutting torch, with oxygen valves located at the front end of its handle.

Arc Welding:

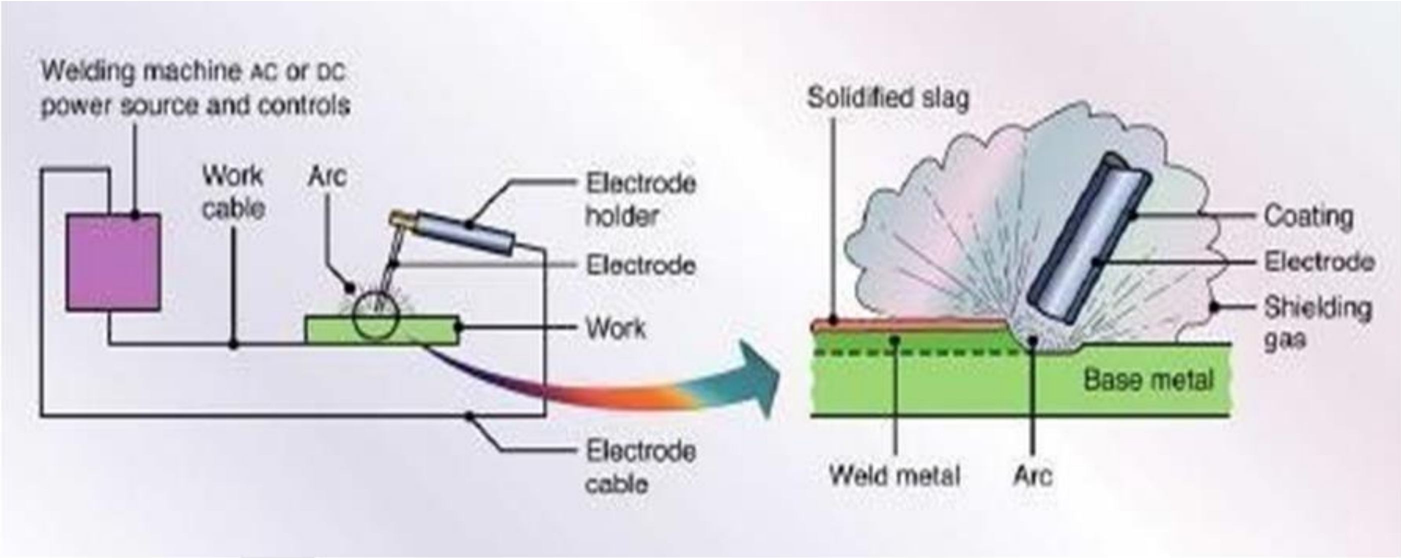
Arc Welding is a group of welding processes, wherein fusion is produced by heating with an electric arc or arcs, mostly without the application of pressure and with or without the use of filler metal depending upon the base plate thickness.
Welding arc: The arc occurs when electrons are emitted from the surface of the negative pole (cathode) and flow across a region of hot electrically charged plasma to the positive pole (anode), where they are absorbed. The polarity change affects the weld penetration DCEN Deep penetration (narrow melted area). DCEP Shallow penetration (wide melted area).

General characteristics of arc welding processes:
These processes are associated with molten metal. Arc welding processes use an electric arc as a heat source to melt metal. The arc is struck between an electrode and the work piece to be joined. The electrode can consist of consumable wire or rod, or may be a non-consumable tungsten electrode. The process can be manual, mechanized, or automated. The electrode can move along the work or remain stationary while the workpiece itself is moved. A flux or shielding gas is employed to protect the molten metal from atmosphere. If no filler metal is added, the melted weld is referred to as autogenous. If the filler metal matches the base metal, it is referred to as homogenous. If the filler metal is different from the base metal, it is referred to as heterogeneous. The common arc welding processes used to weld metals are: shielded metal arc welding or SMAW, gas metal arc welding GMAW, sometimes called MIG welding; flux cored arc welding FCAW; submerged arc welding SAW; and gas tungsten arc welding GTAW, sometimes called TIG welding.

Shielded metal arc welding (SMAW):

Arc is developed between electrode and the component. Flux creates a gas shield and the metal slag prevents oxidation of the underlying metal.SMAW is the most widely used welding process for joining metal parts because of its versatility, its less complex, more portable and less costly equipment .Metals commonly welded by SMAW Carbon and low alloy steels Stainless steels and heat resistance steels. DCEN (Direct Current Electrode Negative) (reverse polarity) can be used of all steels. Melting and deposition rates are higher than with DCEP (Direct Current Electrode Positive) (straight polarity). The multiple-pass approach requires that the slag be cleaned after each weld bed 3- 20 mm thick.

A schematic illustration of SMAW is shown in Figure (Source: Manufacturing Engineering and Technology, Fifth Edition, by Serope Kalpakjian and Steven Schmid).This is typically a manual welding process where the heat source is an electric arc which is formed between a consumable electrode and the base material. The electrode is covered by a coating, which is extruded on the surface of the electrode. During welding, the electrode coating decomposes and melts, providing the protective atmosphere around the weld area and forming a protective slag over the weld pool



Advantages of SMAW

Equipment relatively easy to use, inexpensive, portable Filler metal and means for protecting the weld puddle are provided by the covered electrode Less sensitive to drafts, can be used on carbon steels, low alloy steels, stainless steels, cast irons, copper, nickel, aluminium.

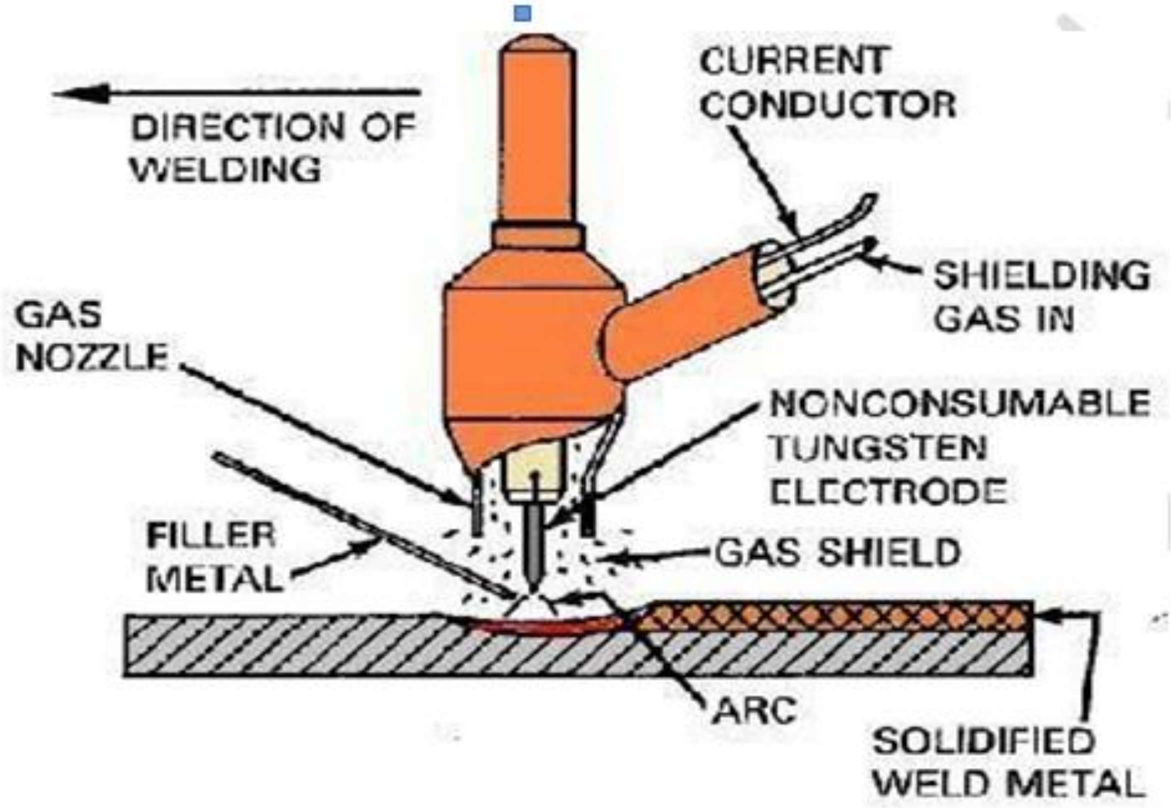
Limitations of SMAW

SMAW has a low weld metal deposition rate compared to other processes. This is because each welding rod contains a finite amount of metal. As each electrode is used, welding must be stopped and a new rod inserted into the holder. A 12-inch electrode may be able to deposit a bead 6-8 inches long. The overall productivity of the process is affected by: Frequent changing of electrodes, Inter pass cleaning (grinding, brushing, etc.), Grinding of arc initiation points and stopping points, Slag inclusions which require removal of the defect and re-welding of the defective area. The heat of the welding arc is too high for some lower melting metals. And the shielding of metals that react aggressively with the atmosphere is inadequate.

Tungsten Inert Gas welding (TIG)

Principle of TIG: The process utilizes the heat (≈6100 ºC)of an arc between a non consumable tungsten electrode and the base metal, that is melted to form a melted pool. Filler metal is not added when thinner materials, edge joints and flange joints are welded. This is called as autogenous welding. For thicker materials an externally fed or cold filler rod is generally used. The arc area is protected from the atmosphere by the inert shielding gas flown from the nozzle of the torch. The shielding gas displaces the air, so that the oxygen and the nitrogen of the air do not come in contact with the molten metal or the hot tungsten electrode. There is little or no spatter and little or no smoke. The resulting weld is smooth and uniform and requires minimum finishing.

Tungsten Inert Gas Welding, also known by its acronym as TIG welding, is a welding process that uses the heat produced by an electric arc created between non consumable tungsten electrode and the weld pool. This electric arc is produced by the passage of current trough a conductive ionized inert gas that also provides shielding of the electrode, molten weld pool and solidifying weld metal from contamination by the atmosphere. The process may be used with or without the addition of filler metal using metal rods. The welding current continiously changes between two levels. During the period of high- pulsed current, heating and fusion take place, during the low-pulsed current period, cooling and solidification take place.



Electrode

In TIG welding, *tungsten* refers to the element used on the electrode.The function of the electrode is to serve as one of the electric terminals which supplies the heat t required to the weld, for this reason tungsten is chose en because, as a pure element, it as the highest melting point in close to which it gets thermionic becoming a ready source of electrons. Great care must be taken so that the tungsten electrode does not contact the weld pool in any way or the gas flow rate is sufficient to protect it, in order to avoid its contamination resulting on faulty weld. Some other elements may be added to the tungsten, like cerium, lanthanum, thorium and zirconium creating electrode alloys that improve arc stability, emissivity and bring higher melting points. Tungsten electrodes may be used with a variety of tip configurations and finishing’s depending on its welding applications.

Shielding gases:

Argon and helium or mixtures of both are the most common inert gases used for shielding, although argon is more extendedly used providing excellent arc stability and having a cleaning action in certain materials. Helium, unlike argon, as a high thermal conductivity which results in a deeper penetrating arc, however because helium is a light gas it is less higher than argon in order to provide the same shielding, adding the fact helium cost is considerably more higher then argon, helium welding becomes more expensive and as to be weighed against the penetration increase and increased travel speeds, making it more suitable for thick materials, metals with high thermal conductivity or high speed mechanized welding. Mixtures of both the gases are used when is useful to balance the two gas characteristics.

The arc shielded with helium has more power (heat) and can do more work. The helium shielded arc column is; **Larger, More penetration, Higher travel speed, Weld heavier base metals.**

Metal Inert-Gas welding (MIG)

In GMAW, formerly known as metal inert-gas (MIG) welding is an arc welding process in which the heat for welding is generated by an arc between a consumable electrode and the work metal. The consumable bare wire is fed automatically through a nozzle into the weld arc by a wire-feed drive motor. In GMAW, the weld area is shielded by an effectively inert atmosphere of argon, helium, carbon dioxide or various other gas mixtures.

Advantages: If GMAW Can weld almost all metals and alloys, stainless steel. All positions of welding DCEP which provides stable arc, smooth metal transfer, relatively low spatter and good weld bed characteristics. Due to automatic feeding of the filling wire (electrode) the process is referred to as a semi-automatic. The operator controls only the torch positioning and speed. No slag produced High level of operator skill is not required.

Further advantages of GMAW : High productivity All positions of welding and reliability .Wide area applications All ferrous and nonferrous can be welded .

Limitations of GMAW: Expensive and non-portable equipment Less skilled workers can operate this process, however this can lead to poor setup of the welding parameters, in turn this can lead to defects in the finished weld such as lack of fusion and porosity. More heat is generated in MIG than TIG; this will mean that the HAZ is larger around a weld of this type. Equipment is heavy and not particularly portable; the operator is limited to about 4.5m to 6m from the power source due to potential complications with the wire feed. Extended-reach wire feeders are now available which means the operator can be up to 15m away from the power source (Smith, 1986), but the extra equipment means that portability is further restricted.

Methods of metal transfer in GMAW:

Spray transfer: small, molten metal droplets from the electrode are transferred to the weld area at a rate of several hundred droplets per second. Spray is achieved at higher welding currents and voltages with argon or argon- rich gas mixture Helium based shielding gas (over 80% Ar). The average current required in GMAW process can be reduced by using a pulsed arc, which superimposes high-amplitude pulses onto a low, steady current. Pulsing the current allows for better control for out of position welding. This mode produces little or no spatter and is known for the high deposition rate (higher productivity).

Short circuiting transfer: the metal is transferred in individual droplets (more than 50 per second), as electrode tip touches the molten weld metal and short circuits. At low current and voltages, short circuit transfer occurs. The weld is a shallow penetrating weld with low heat input. Using GMAW in this mode allows welding in all positions since the weld puddle is so small. In comparison to the other modes of transfer, this method is slowest (low productivity). Used primarily for sheet metal applications. This mode produces large amounts of spatter if welding variables are not optimized. This mode is also known as short arc or dip transfer.

Shielded gases Contamination of the weld pool, by the atmosphere, can cause weld defects. These defects can have an adverse effect on the joint efficiency, which may lead to failure. Therefore, the weld pool should be protected from the atmosphere until it has completely solidified. The primary purpose of shielding gases is to protect the molten weld metal and the HAZ from oxidisation and other contamination. Shielding gas forms a protective atmosphere over the molten weld pool to prevent contamination Inert shielding gases, argon or helium, keep out oxygen, nitrogen, and other gases Active gases, such as oxygen and carbon dioxide, are sometimes added to improve variables such as arc stability and spatter reduction. Shielding gas can be a single pure gas or a mixture of two or more gases. Inert gases, as the name implies, do not react with the weld metal. Argon is often used in the flat and horizontal position, since it is heavier than air. Helium can be used in the overhead position, since it is lighter than air. Helium has a characteristic of producing a "hotter" arc than argon. Active gases, such as oxygen and carbon dioxide, are often added to inert gases in order to improve arc properties. These properties include arc stability and spatter reduction. Shielding gases should be free of moisture, which decompose to hydrogen and oxygen in the arc. Moisture in the gas can result in porosity, and in steels, hydrogen can lead to cracking.

Main shielded gases used in GMAW

Argon: Argon is 38% heavier than air, which is advantageous for welding in flat and horizontal fillet positions. Pure argon virtually can be used in all metals.

Helium: It is lighter than air and because of this, high gas flow rate must be used to maintain adequate shielding. Helium is used primarily on aluminum, magnesium and copper.

Carbon-dioxide: This is widely used in the welding of steel by the short circuiting mode of metal transfer.

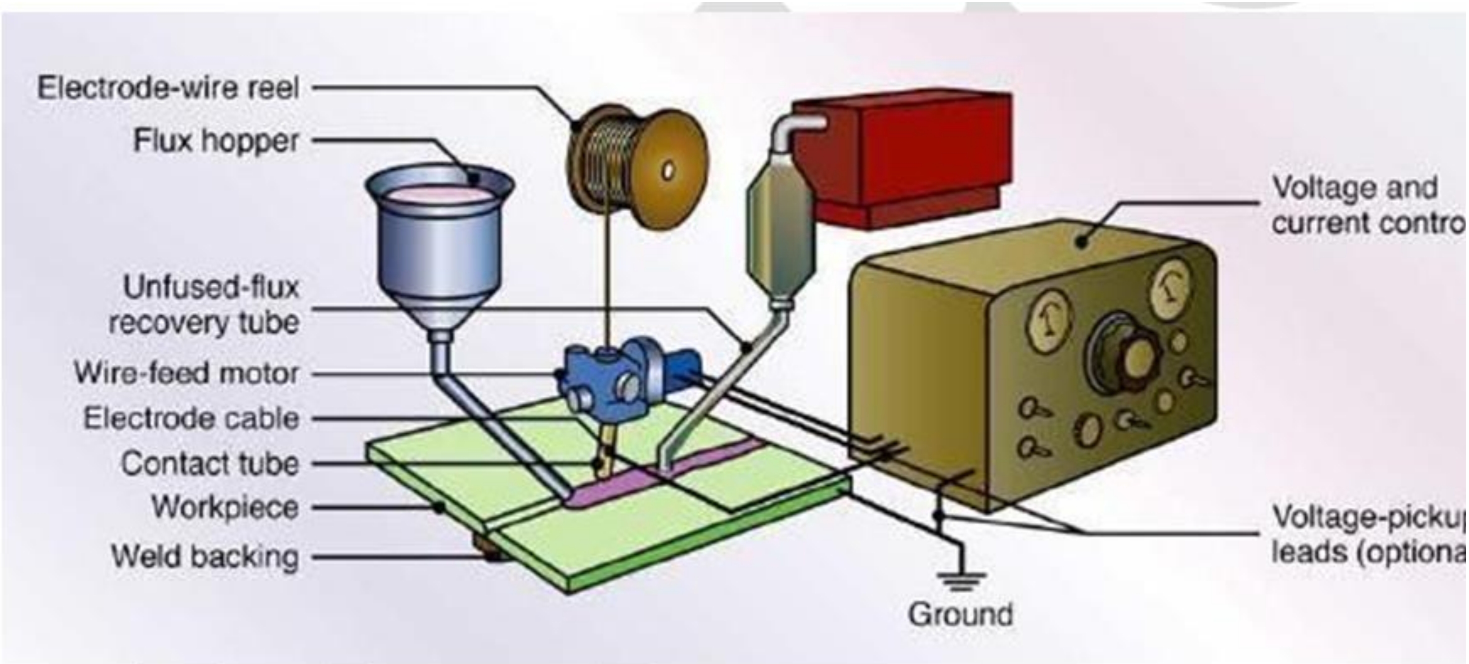
Mixtures: Argon-carbon dioxide mixtures, argon helium mixtures, argon oxygen mixtures, helium-argon-carbon dioxide mixtures.

Submerged-Arc Welding (SAW)

In SAW, the weld arc is shielded by a granular flux consisting of lime, silica, manganese oxide, calcium fluoride, and other compounds. A schematic illustration of submerged-arc welding process is shown in the Figure.

The flux is fed into the weld zone from a hopper by gravity through a nozzle:

The functions of the flux: Prevents spatter and sparks; Suppresses the intense ultraviolet radiation and fumes characteristics of the SMAW. It acts as a thermal insulator by promoting deep penetration of heat into the workpiece. The unused flux can be recovered, treated and reused. The filler metal is a continuously-fed wire electrode like GMAW and FCAW. However, higher deposition rates can be achieved using SAW by using larger diameter electrodes and higher currents (650-1500 Amperes). Since the process is almost fully mechanized, several variants of the process can be utilized such as multiple torches and narrow gap welding. Because of the flux is gravity fed, the SAW process is limited largely to welds in flat or horizontal position. This process can be automated and use to weld a variety of carbon and alloy steel and stainless steel sheets or plates as high as 5m/min. The quality of weld is very high, provides high productivity in ship building and for pressure vessels.



Submerged-Arc Welding

Advantages of submerged welding (SAW): This process can be automated and use to weld a variety of carbon and alloy steel and stainless steel sheets or plates as high as 5m/min. The quality of weld is very high, provides high productivity in ship building and for pressure vessels. High deposition rates no arc flash or glare minimal smoke and fumes flux and wire added separately - extra dimension of control Easily automated Joints can be prepared with narrow grooves can be used to weld carbon steels, low alloy steels, stainless steels, chromium-molybdenum steels, nickel base alloys .SAW has the highest deposition rate of the entire deep penetrating arc welding processes making it ideal for thick section and multi-pass welding. Variations of the process can utilize dual arc welding, twin arc welding, multiple torches, and narrow groove welding to increase productivity. Since the arc is completely submerged in the flux, there is no arc radiation. Screens or light filtering lenses are not needed. Additionally, the smoke and fumes are trapped within the flux and thus minimizing smoke and fumes. Since the process is simple to mechanize and easily automated, it is extremely consistent once a procedure is qualified. And it can be used on a wide variety of materials.

Limitations of submerged welding (SAW): Because of the flux is gravity fed, the SAW process is limited largely to welds in flat or horizontal position. The flux which shields the arc and weld pool in SAW also obstruct the operator's view of the joint and molten weld pool. This makes observation of the pool and joint impossible during welding; thus, correction of problems during welding can be very difficult. Because of the high current levels common to this process, it is normally not suited for thinner materials. Due to the presence of a granulated flux, submerged arc welding is limited to the flat and horizontal positions. As with SMAW and FCAW, SAW produces a slag which must be completely removed after each pass. Finally, additional flux handling equipment is required.

Flux- cored arc welding (FCAW)

Flux Cored Arc Welding (FCAW) uses a tubular wire that is filled with a flux. FCAW is similar to GMAW, except the electrode is tubular in shape and filled with flux (hence the term flux-cored). The arc is initiated between the continuous wire electrode and the work piece. The flux, which is contained within the core of the tubular electrode, melts during welding and shields the weld pool from the atmosphere. Direct current, electrode positive (DCEP) is commonly employed as in the FCAW process. Cored electrode produces a more stable arc, improve weld contour, and produce a better mechanical properties of the weld metal. The FCAW process combines the versatility of SMAW with the continuous and automatic electrode- feeding feature of GMAW

Advantages of FCAW:

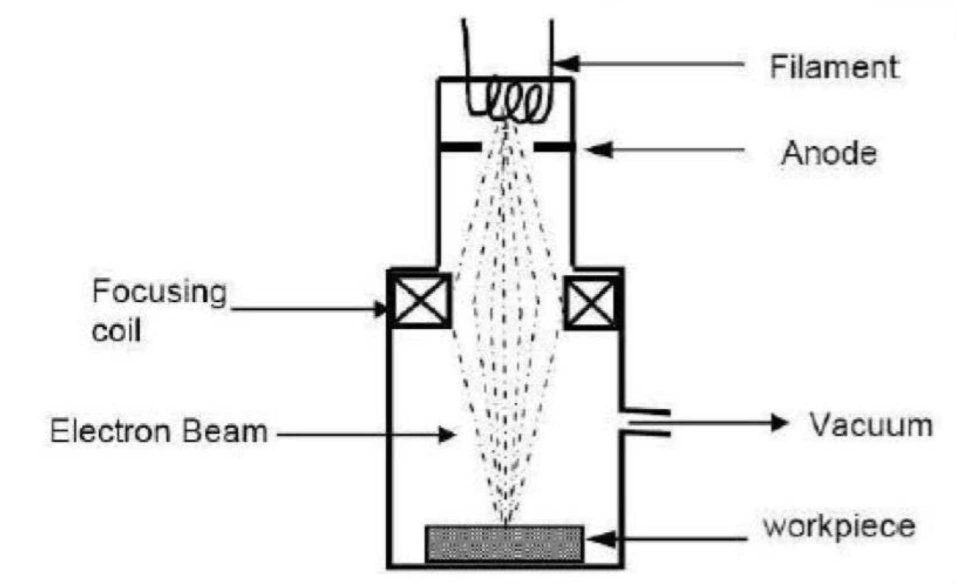
Specific weld-metal chemistries can be developed by adding alloying elements to the flux core, all alloy composition can be produced. Easy to automate and readily adaptable to flexible manufacturing and robotics.

Disadvantages of FCAW:

The slag formed during welding must be removed between passes on multipass welds. This can reduce the productivity and result in possible slag inclusion discontinuities. For gas shielded FCAW, porosity can occur as a result of insufficient gas coverage. Large amounts of fume are produced by the FCAW process due to the high currents, voltages, and the flux inherent with the process. Increased costs could be incurred through the need for ventilation equipment for proper health and safety. FCAW is more complex and more expensive than SMAW because it requires a wire feeder and welding gun. The complexity of the equipment also makes the process less portable than SMAW and it can be used on a wide variety of materials.

Electron-Beam Welding (EBW)

In EBW, developed in 1960s, the heat used for welding the two materials is generated by high velocity narrow-beam (concentrated) electrons is fired through the work, this transfers kinetic energy to the particles of metal causing them to heat up and melt to form a weld. A schematic illustration of EBW is shown in Figure. EBW process requires special equipment to focus the beam on the workpiece, typically in a vacuum. The higher the vacuum, the more the beam penetrates, and the greater the depth-to-width ratio can be achieved. There are three methods in EBW as far as vacuum is concerned: EBW-HV (for high vacuum) EBW-MV (medium vacuum) EBW-NV (no vacuum)



Schematic Illustration Of EBW

In aircraft industry alloy grade Ti is used. Electron Beam Welding (EBW) is extensively employed. Much better joints can be obtained by EBW of alloy grade Ti. By welding in a vacuum chamber, gas absorption is prevented. The HAZ is very narrow and influence of welding on structure is minimal. Complicated work-pieces can be welded without distortion. Components with large wall thickness as well as thin walled components can also be successfully welded.

Advantages of EBW

-Narrow welds can be made on thicker sections with deeper penetration with minimal thermal disturbances.
-This makes the process suitable for welding in titanium, niobium, tungsten, tantalum, beryllium, nickel alloys and magnesium, mostly in aerospace and space research sectors.
-Because welding is performed in a vacuum, there is no atmospheric contamination; accurate control of welding parameters is possible by controlling the electron beam power and accurate beam focus.
-Excellent welds can be made even on more reactive metals.
-Lack of thermal disturbance in the process means that there is minimum shrinkage and distortion.

Limitations of EBW

-The process usually takes place in a vacuum; this means that the work piece must be setup in a vacuum chamber which then must be evacuated before the welding can take place. This can be time consuming and reduces the production efficiency of the system.
- Electron beam equipment is very expensive compared to conventional welding equipment.
- If welding in a vacuum the size of the material to weld must be smaller than that of the vacuum chamber, meaning larger and more expensive equipment is required to weld large pieces.

Laser Beam Welding (LBW)

LBW utilizes a high-power laser beam as the source of heat, to produce a fusion weld. Because the beam can be focused on to a very small area, it has high energy density and deep-penetrating capability.

Advantages of LBW

-LBW produces welds of good quality with minimum shrinkage and distortion
-Laser welds have good strength, generally low hardness (ductile) and free of porosity
-The process can be automated
-Narrow welding seam
-Low energy input per seam length
-Reduced heat affected zone (HAZ)
-Very high welding speed (ranges from 2.5 m/min to as high as 80 m/min)

Friction Welding

Friction welding uses pressure and frictional heat caused by mechanical rubbing, usually by rotation.
In this process, the parts are rotated at high speed and brought together. The heat generated on contact causes the parts to fuse together. Typical use: Automotive components, agriculture equipment, joining high speed steel ends and twist drills. Process can be automated.
Economics: Capital costs are high but tooling costs are low.

Resistance welding (RW)

Resistance Welding is a welding process in which work pieces are welded due to a combination of a pressure applied to them and a localized heat generated by a high electric current flowing through the contact area of the weld. Different metals and alloys such as low carbon steels, aluminium alloys, alloy steels, medium carbon and high carbon steels can be welded by resistance welding. However, for high carbon contained steels, the weld bed can be harder (less brittle). Resistance Welding (RW) is used for joining vehicle body parts, fuel tanks, domestic radiators, pipes of gas oil and water pipelines, wire ends, turbine blades, railway tracks.

Advantages of resistance welding

-High welding rates;
-Low fumes;
-Cost effectiveness;
-Easy automation;
-No filler materials are required;
-Low distortions.

Disadvantages of resistance welding

-High equipment cost;
-Low strength discontinuous welds;
-Thickness of welded sheets is limited - up to 6 mm.

Spot welding

Spot Welding is a Resistance Welding process, in which two or more overlapped metal sheets are joined by spot welds. The method uses pointed copper electrodes providing passage of electric current. The electrodes also transmit pressure required for formation of strong weld. Diameter of the weld spot is in the range 3 - 12 mm. Spot welding is widely used in automotive industry for joining vehicle body parts.

Flash welding

Flash Welding is a Resistance welding process, in which ends of rods (tubes, sheets) are heated and fused by an arc struck between them and then (brought into a contact under a pressure) producing a weld. The welded parts are held in electrode clamps, one of which is stationary and the second is movable. Flash Welding method permits fast (about 1 min.) joining of large and complex parts. Welded parts are often annealed for improvement of toughness of the weld. Steels, Aluminium, Copper alloys, Magnesium alloys and Nickel alloys may be welded by flash welding. Thick pipes, ends of band saws, frames, and aircraft landing gears are produced by Flash Welding.

Resistance butt welding

Resistance Butt Welding is a Resistance Welding process, in which ends of wires or rods are held under a pressure and heated by an electric current passing through the contact area and producing a weld. The process is similar to Flash Welding however in Butt Welding pressure and electric current are applied simultaneously in contrast to Flash Welding where electric current is followed by forging pressure application.

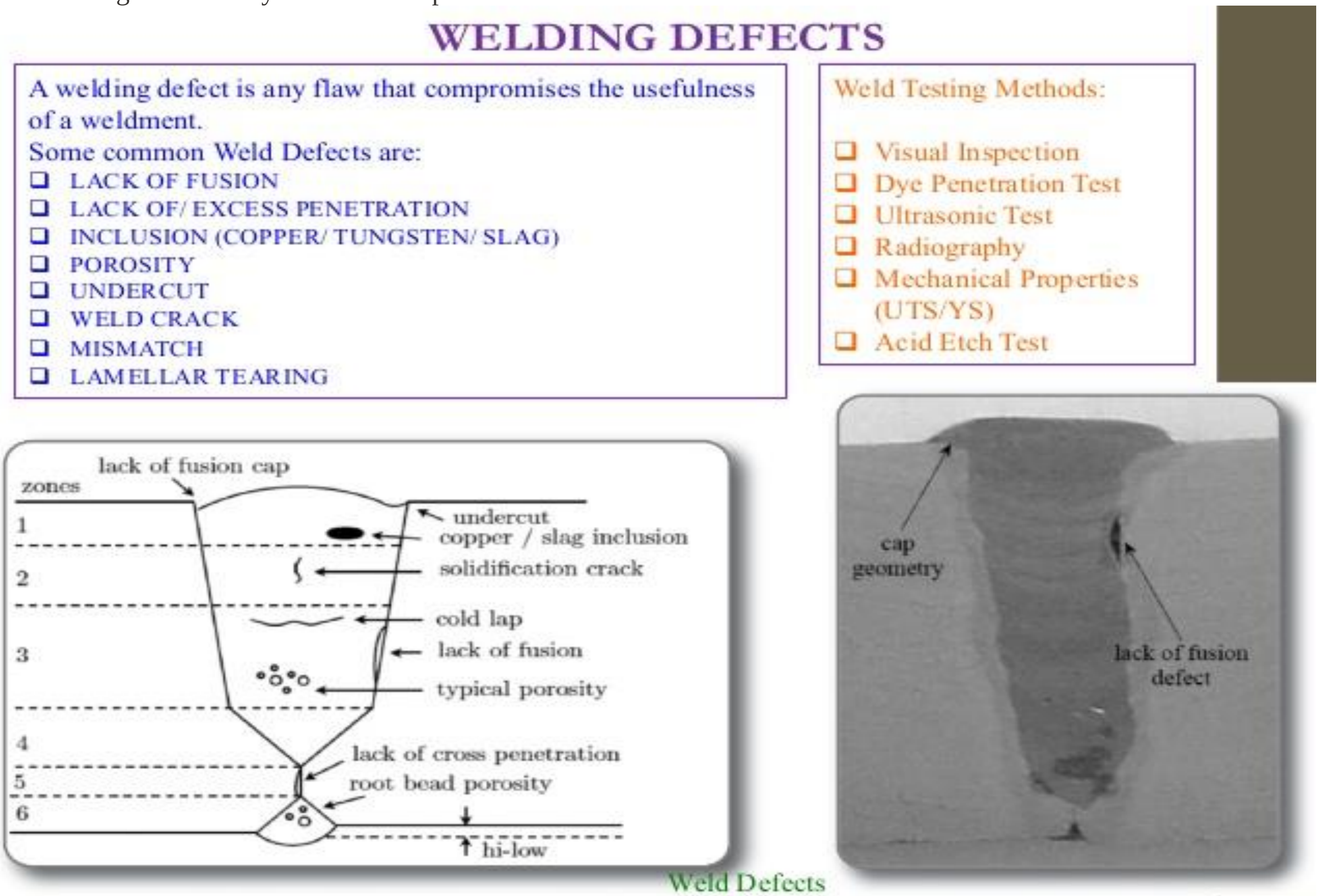
Resistance seam welding

Seam welding is a Resistance Welding process of continuous joining of over lapping sheets by passing them between two rotating electrode wheels. Heat generated by the electric current flowing through the contact area and pressure provided by the wheels are sufficient to produce a leak-tight weld.

The Major Discontinuities Found In Arc Welded Joints are:

WELDING DEFECTS

A welding defect is any flaw that compromises the usefulness of a weldment. Some common Weld Defects are:



Slag inclusions

Slag inclusions are compounds such as pieces of slag trapped inside solidified weld pool; may result from excessive stirring in weld pool, or failure to remove slag from prior weld. If shielding gases are not effective during welding, contamination from the environment also may contribute to such inclusions.

Slag inclusions can be prevented by:

Cleaning weld bed surface before the next layer deposited by providing sufficient shielded gases, Proper designing of joints.

Porosity

Porosity or fine holes or pores within the weld metal can occur by absorption of evolved gases and chemical reaction. Metals susceptible to porosity are those which can dissolve large quantities of gas contaminates (hydrogen, oxygen, nitrogen etc) in the molten weld pool and subsequently reject most of the gas during solidification. Aluminium alloys are more susceptible to porosity than any other structural material. Weld cooling rates substantially affects the volume of porosity.

Remedies

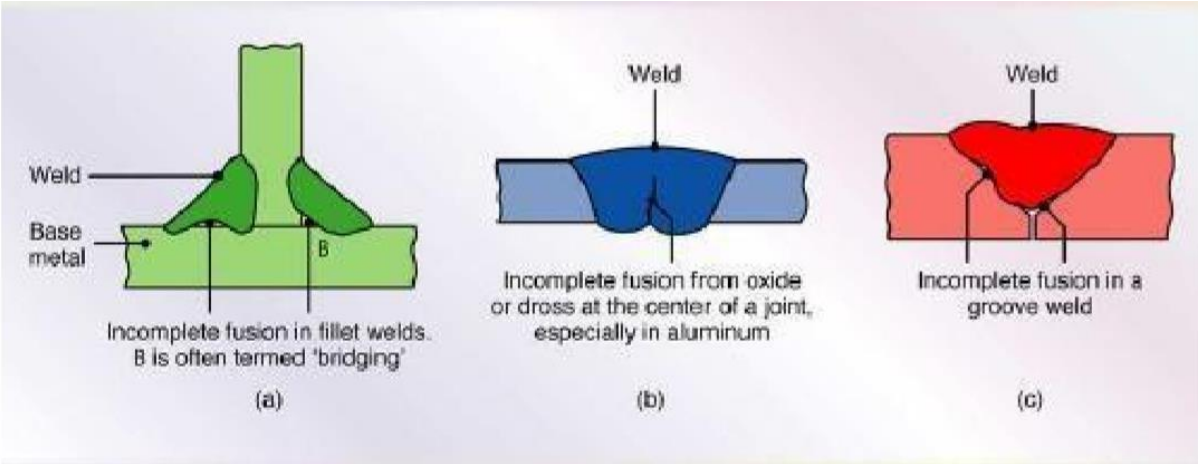
-At fast cooling rates, the level of porosity can be low

-Similarly, at slow cooling rates, porosity is minimal because bubbles have ample time to coalesce, float, and escape from the weld pool.

-At intermediate cooling rates, the greatest volume of porosity in a weld is observed, as conditions are optimum for both formation and entrapment of virtually all of the evolved gases in the weld.

Incomplete Fusion And Penetration

-Incomplete fusion is termed as fusion which does not occur over the entire base metal surfaces intended for welding and between adjoining weld beads. Incomplete fusion can result from insufficient heat input or the improper manipulation of the welding electrode. While it is a discontinuity more commonly associated with weld technique, it could also be caused by the presence of contaminants on the surface being welded. Incomplete penetration occurs when the depth of welded joint is insufficient. A schematic illustration of various discontinuities in fusion welds is shown in Figure.



Incomplete fusion and penetration can be improved by:
- Raising the temperature
-Cleaning the weld area before welding
-Modifying the weld design
-Providing sufficient shielding gases
-Reducing the travel speed during the welding

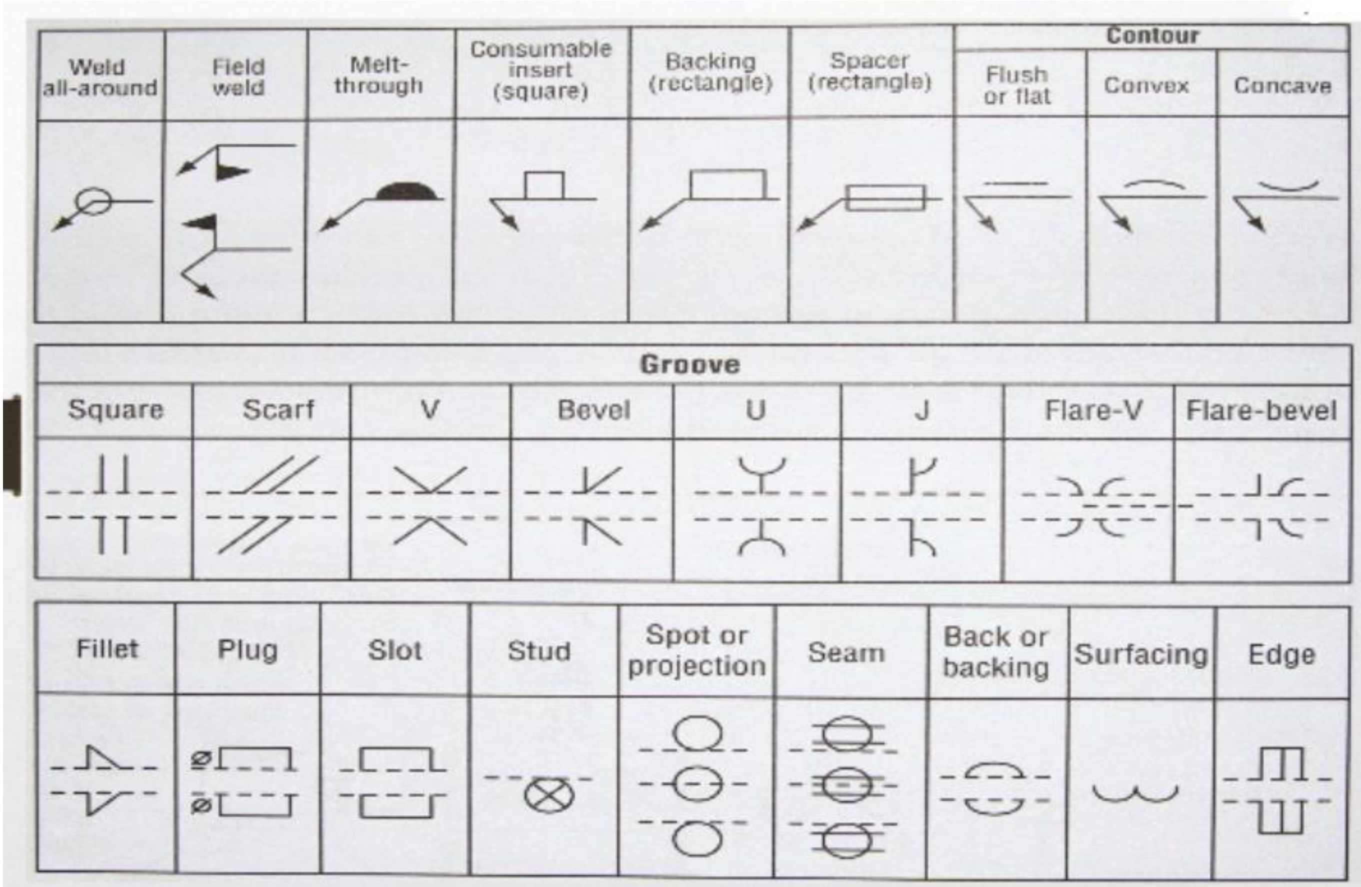
Cracks
Cracks in welding occur is various locations and directions in the weld area as a result from hot tearing or cold cracking. Hot tearing or hot cracks (solidification crack) occurs when shrinkage during solidification tears mushy (liquid – solid) weld
– Physical constraints against shrinkage may exacerbate the problem. Hot cracking results from internal stress developed on cooling following solidification. This defect occurs at a temperature above the solidus of an alloy. Cold cracking or hydrogen cracking typically occurs after weld freezes, and residual stresses are sufficient to cause cracks

Remedies
-By poor ductility of the deposited weld metal, or by a high coefficient of thermal expansion coupled with low-heat conductivity in the parent metal Methods to minimize hot cracking.
Maintenance of adequate manganese-to-sulfur ratio.
Reduction of sulfur, phosphorus, carbon and niobium to minimal amounts Reduction of the tensile restraint exerted on the weld Hydrogen cracking or cold cracking occurs in the heat-affected zone of some steels as hydrogen diffuses into this region when the weld cools. Hydrogen cracking is caused by atomic hydrogen. Methods of minimising hydrogen cracking
-Using low-hydrogen electrodes, which includes baking and storing them in a low temperature oven.
-Preheating the surface of the steel before welding to remove moisture
Undercut And Underfill
Undercut – combination of underfill and overly aggressive arc; leaves a sharp- edged hole in surface. Underfill – insufficient filler metal used in welding; may result from excessive welding velocity. Residual stresses
Due to localised heating and cooling during welding, the expansion and contraction of the weld area causes residual stresses. At completion of the weld thermal cycle the weldament either distorts or if restrained will contain residual stress. Residual stress fields are complex, Stresses may need to be removed by a stress relief heat treatment process.

Thermo chemical Welding
Thermo chemical welding process comprises of producing fusion by heating with superheated liquid metal and slag resulting from chemical reaction between a metal oxide and aluminum, with or without the application of pressure. The liquid metal acts a filler metal too. Thermo chemical welding is used chiefly in repair of assembly of large parts such as fractured rails, large fractured crankshafts, replacing broken teeth on large gears, etc.

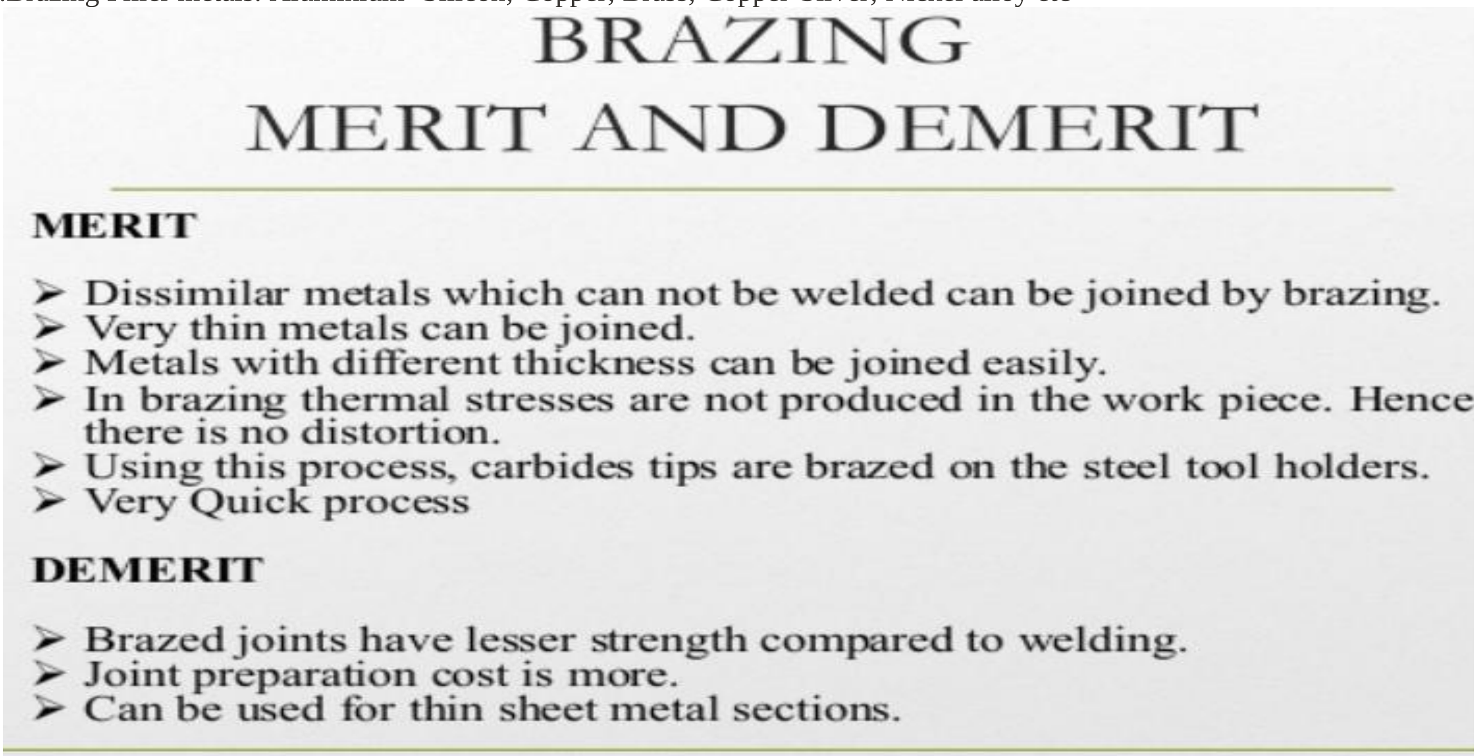
Radiant Energy Welding
Radiant Energy consists of fusion by focusing an energy beam on the work piece. The heat is generated when the energy beam strikes the work piece. It is used for joining highly reactive materials like titanium, zirconium etc. In this process, welds can be made even at those points that are virtually inaccessible for other welding processes. It is used for welding airplane, aerospace and other types of equipment where especially low distortion is desired.

WELDING SYMBOLS



Brazing

Brazing is metal joining Process in which the filler metal or alloy is heated to a temperature above 450degC and melted Only filler metal melts and deposits fusing the workpiece. Workpiece doesn’t melts. Base Metal is heated and filler metal is distributed between two close fitting parts by capillary action Torch/ Dip/ Furnace/ Induction/ Salt-bath .Brazing Filler metals: Aluminium- Silicon; Copper; Brass; Copper-Silver; Nickel alloy etc



Soldering

- Solder is an alloy of Tin (63%) & Lead (37%)
- 60/40 Solder melts at 361 F
- Soldering is metal joining Process in which the filler metal or alloy is heated to a temperature below 450^{O}C and melted
- Only filler metal melts and deposits fusing the workpiece.
- Extensively used in electronics and jewelry industry
- Merits and Demerits same as Brazing