Module V

5. Welding processes

5.1 Tungsten inert gas (TIG) welding

This process is also known as gas tungsten arc welding (GTAW) is named so because it uses a) electrode primarily made of tungsten and b) inert gas for shielding the weld pool to prevent its contamination from atmospheric gases especially when joining high strength reactive metals and alloys such as stainless steel, aluminium and magnesium alloys, wherever high quality weld joints need to be developed for critical applications like nuclear reactors, aircraft etc. Invention of this process in middle of twentieth century gave a big boost to fabricators of these reactive metals as none of the processes (SMAW and Gas welding) available at that time were able to weld them successfully primarily due to two limitations a) contamination of weld from atmospheric gases and b) poor control over the heat input required for melting (Fig. 5.1). Moreover, welding of aluminium and its alloys) with shielded metal arc welding process can be realized using halide flux coated electrodes by overcoming the problems associated with Al2O3, however, halides are very corrosive and therefore welding of aluminium is preferable carried out using inert shielding environment with the lerp of processes like GTAW and GMAW. Despite of so many developments in the field of welding, TIG process is invariably recommended for joining of thin aluminium sheets of thickness less than 1mm.

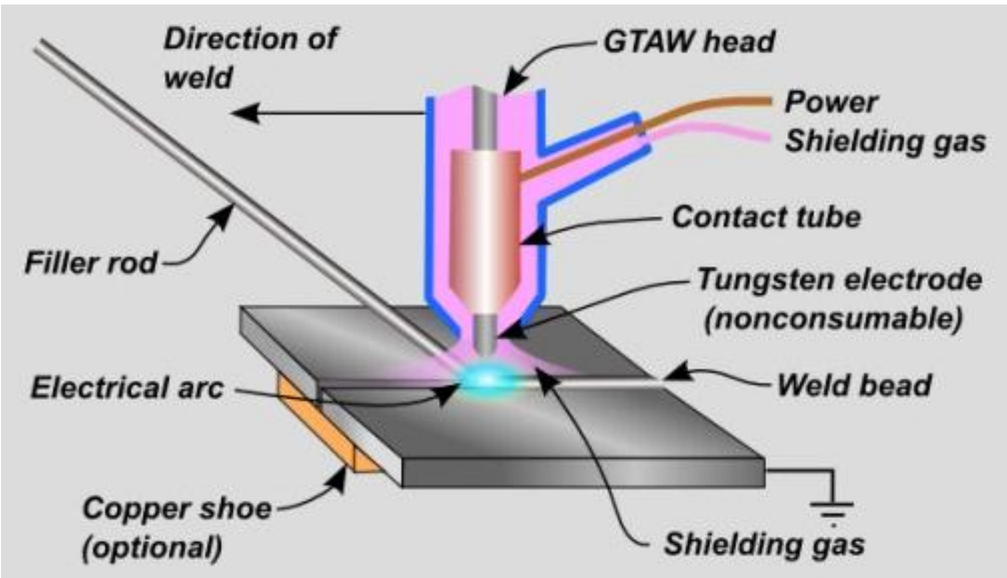

Fig.5.1 Schematic of tungsten inert gas welding process

5.2 Metal inert gas welding (MIG)

This process is also termed as gas metal arc welding (GMAW). This process is based on the principle of developing weld by melting faying surfaces of the base metal using heat produced by a welding arc established between base metal and a consumable electrode. Welding arc and weld pool are well protected by a jet of shielding inactive gas coming out of the nozzle and forming a shroud around the arc and weld. MIG weld is not considered as clean as TIG weld. Difference in cleanliness of the weld produced by MIG and TIG welding is primarily attributed to the variation in effectiveness of shielding gas to protect the weld pool in case of above two processes. Effectiveness of shielding in two processes is mainly determined by two characteristics of the welding arc namely stability of the welding arc and length of arc besides other welding related parameters such as type of shielding gas, flow rate of shielding gas, distance between nozzle and work-price. The MIG arc is relatively longer and less stable than TIG arc. Difference in stability of two welding arcs is primarily due to the fact that in MIG arc is established between base metal and consumable electrode (which is consumed continuously during welding) while TIG welding arc is established between base metal and nonconsumable tungsten electrode. Consumption of the electrode during welding slightly decreases the stability of the arc. Therefore, shielding of the weld pool in MIGW is not as effective as in TIGW.

Metal inert gas process is similar to TIG welding except that it uses the automatically fed consumable electrode therefore it offers high deposition rate and so it suits for good quality weld joints required for industrial fabrication. Consumable electrode is fed automatically while torch is controlled either manual or automatically. Therefore, this process is found more suitable for welding of comparatively thicker plates of reactive metals (Al, Mg, Stainless steel). The quality of weld joints of these metals otherwise is adversely affected by atmospheric gases at high temperature.

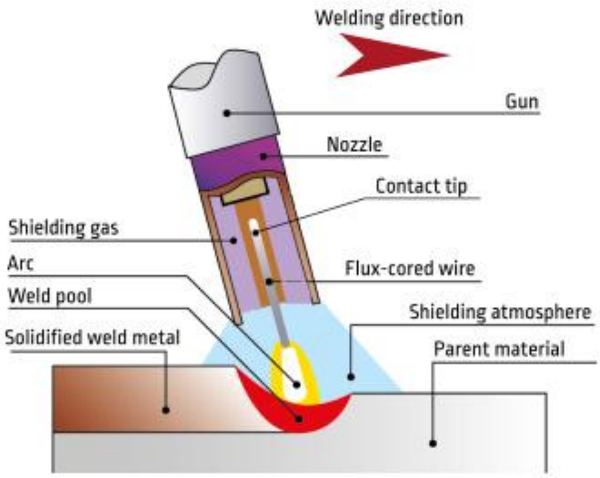

Fig.5.2 Schematic of GMAW process

5.3 Submerged Arc Welding (SAW):

Submerged arc welding (SAW) is an arc welding process in which heat is generated by an arc which is produced between bare consumable electrode wire and the workpiece. It is possible to use larger welding electrode (12mm) as well as very high currents (4000 A) so that very high metal deposition rates of the order of 20 kg/h or more can be achieved with this process. Also, very high welding speeds (5 m/min) are possiblein SAW. The arc and the weld zone are completely covered under a blanket of granular, fusible flux which melts and provides protection to the weld pool from the atmospheric gases.

The molten flux surrounds the arc thus protecting arc from the atmospheric gases. The molten flux flows down continuously and fresh flux melts around the arc. The molten flux reacts with the molten metal forming slag and improves its properties and later floats on the molten/solidifying metal to protect it from atmospheric gas contamination and retards cooling rate.

A continuous consumable wire electrode is fed from a coil through contact tube which is connected to one terminal of power source. Wires in the range 1 – 5 mm diameters are usually employed and with wires at the lower end of this range (upto 2.4 mm) constant-potential DC power source can be used allowing arc length control by the self-adjusting effect. For higher diameter electrodes constant current DC source is used.

Submerged arc welding head may be mounted on self-propelled tractors carrying a flux hopper and the coiled electrode. A suction device may also be carried to recover the unused flux for reuse.

Since the end of the electrode and the welding zone are completely covered at all times during the actual welding operation, the weld is made without the sparks, spatter, smoke or flash commonly observed in other arc welding processes.

Power source requirement may be DC or AC. Normally electrode is connected to positive terminal of DC power source. Sometime depending on the nature of flux AC can be used with single electrode wire or with multiple electrodes where one electrode may be connected to DC and other to AC if independent power sources are to be used.

Electrode wires and fluxes are two major consumables. Wires of structural steel are coated with copper to protect it from atmospheric corrosion and increasing its current carrying capacity while stainless steel wires are not coated with copper.

Fluxes are fused or agglomerated consisting of MnO, SiO_2, CaO, MgO, Al_2O_3, TiO_2, FeO, and CaF_2 and sodium/potassium silicate. Particular flux may consist of some of these constituents and other may not be present.

Application: Submerged arc welding is mainly being used for different grades of steels. It is widely being used in shipbuilding, offshore, structural and pressure vessel industries. General fabrication such as fabrication of pipes, penstocks, LPG cylinders, bridge girders and other structures are produced by SA welding. Surfacing for reclamation of worn out parts or for deposition of wear or corrosion resistant layers or for hardfacing layers also employ submerged arc process.

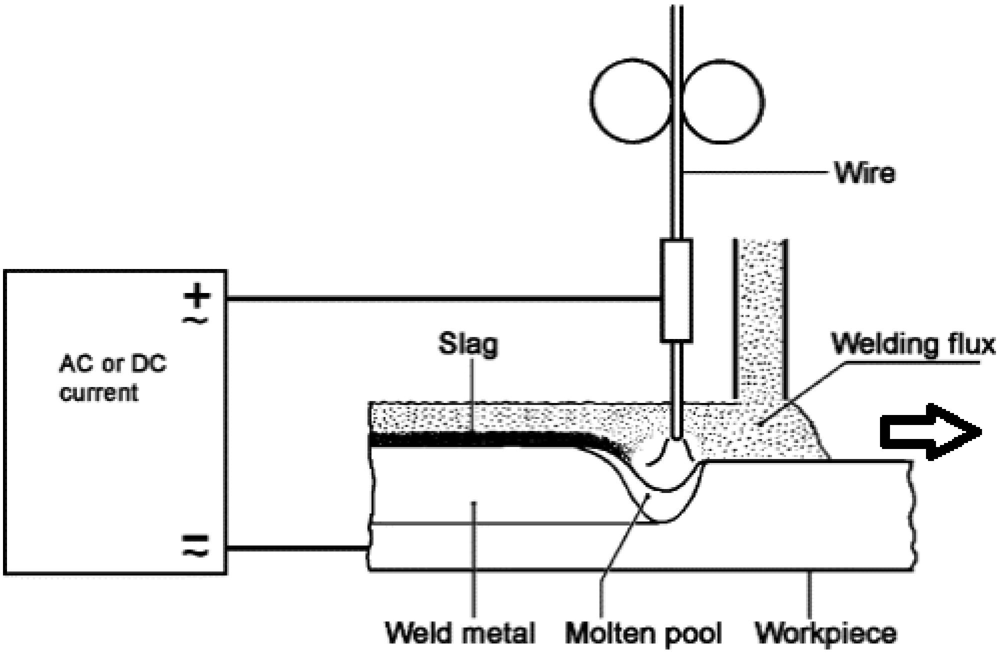

Fig.5.3 Schematic of Submerged arc welding process

5.4 Resistance Welding

Resistance welding processes are pressure welding processes in which heavy current is passed for short time through the area of interface of metals to be joined. This high amperage heats the joint, due to the contact resistance at the joint and melts it. The pressure on the joint is continuously maintained and the metal fuses together under this pressure.

These processes differ from other welding processes in the respect that no fluxes are used, and filler metal rarely used. All resistance welding operations are automatic and, therefore, all process variables are preset and maintained constant. Heat is generated in localized area which is enough to heat the metal to sufficient temperature, so that the parts can be joined with the application of pressure. Pressure is applied through the electrodes.

The heat generated during resistance welding is given by following expression:

$$H = k I^2 R T$$

Where, ***H*** is heat generated

I is current in amperes

R is resistance of the joints, ohm

T is time for which the electric current is passing through the joint or joints.

K is a constant to account for the heat losses from the welded joint.

The process employs currents of the order of few KA (e.g.15 KA), voltages range from 2 to 12 volts and times vary from few ms to few seconds. Force is normally applied before, during and after the flow of current to avoid arcing between the surfaces and to forge the weld metal during post heating. The necessary pressure shall vary from 30 to 60 N mm^{-2} depending upon material to be welded and other welding conditions. For good quality welds these parameters may be properly selected which shall depend mainly on material of components, their thicknesses, type and size of electrodes.

Apart from proper setting of welding parameters, component should be properly cleaned so that surfaces to be welded are free from rust, dust, oil and grease. For this purpose components may be given pickling treatment i.e. dipping in diluted acid bath and then washing in hot water bath and then in the cold water bath. After that components may be dried through the jet of compressed air. If surfaces are rust free then pickling is not required but surface cleaning can be done through some solvent such as acetone to remove oil and grease.

The current may be obtained from a single phase step down transformer supplying alternating current. However, when high amperage is required then three phase rectifier may be used to obtain DC supply and to balance the load on three phase power lines.

The material of electrode should have higher electrical and thermal conductivities with sufficient strength to sustain high pressure at elevated temperatures. Commonly used electrode materials are pure copper and copper base alloys. Copper base alloys may consist of copper as base and alloying elements such as cadmium or silver or chromium or nickel or beryllium or cobalt or zirconium or tungsten. Pure tungsten or tungsten-silver or tungsten-copper or pure molybdenum may also be used as electrode material. To reduce wear, tear and deformation of electrodes, cooling through water circulation is required.

Commonly used resistance welding processes are spot, seam and projection welding which produce lap joints except in case of production of welded tubes by seam welding where edges are in butting position. In butt and flash welding, components are in butting position and butt joints are produced.

5.4.1 Spot Welding

In resistance spot welding, two or more sheets of metal are held between electrodes through which welding current is supplied for a definite time and also force is exerted on work pieces. The principle is illustrated in Fig. 5.4.

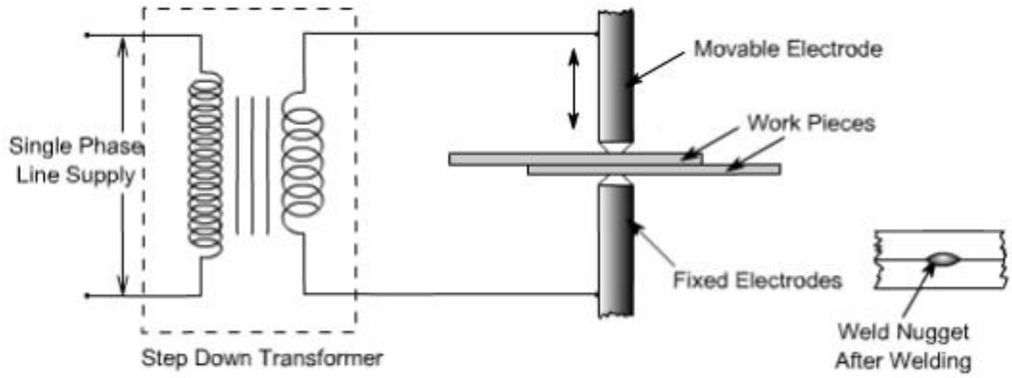

Fig 5.4 Principle of Resistance spot Welding

The welding cycle starts with the upper electrode moving and contacting the work pieces resting on lower electrode which is stationary. The work pieces are held under pressure and only then heavy current is passed between the electrodes for preset time. The area of metals in contact shall be rapidly raised to welding temperature, due to the flow of current through the contacting surfaces of work pieces. The pressure between electrodes, squeezes the hot metal together thus completing the weld. The weld nugget formed is allowed to cool under pressure and then pressure is released.

Application: Most of the industrial metal can be welded by spot welding, however, it is applicable only for limited thickness of components. Ease of mechanism, high speed of operation and dissimilar metal combination welding, has made is widely applicable and acceptable process. It is widely being used in electronic, electrical, aircraft, automobile and home appliances industries.

5.4.2 Seam Welding:

In seam welding overlapping sheets are gripped between two wheels or roller disc electrodes and current is passed to obtain either the continuous seam i.e. overlapping weld nuggets or intermittent seam i.e. weld nuggets are equally spaced. Welding current may be continuous or in pulses. The process of welding is illustrated in Figure 5.5.

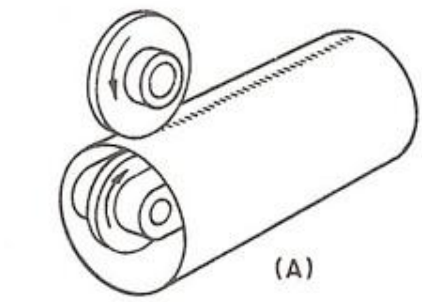

Fig 5.5 Process of Seam welding

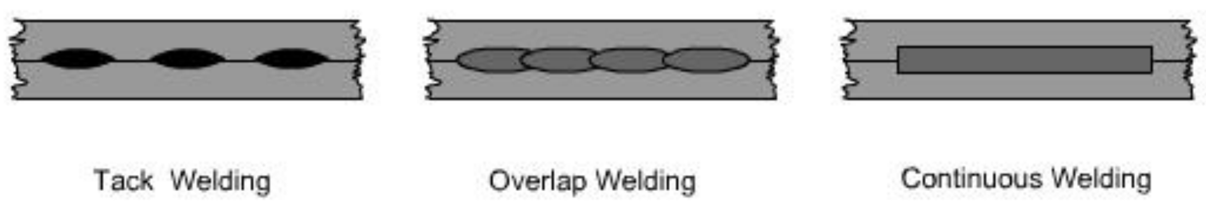

Fig 5.6 Type of Seam Welds

Overlapping of weld nuggets may vary from 10 to 50 %. When it is approaching around 50 % then it is termed as continuous weld. Overlap welds are used for air or water tightness.

It is the method of welding which is completely mechanized and used for making petrol tanks for automobiles, seam welded tubes, drums and other components of domestic applications.

Seam welding is relatively fast method of welding producing quality welds. However, equipment is costly and maintenance is expensive. Further, the process is limited to components of thickness less than 3 mm.

5.4.3 Projection Welding:

Projections are little projected raised points which offer resistance during passage of current and thus generating heat at those points. These projections collapse under heated conditions and pressure leading to the welding of two parts on cooling. The operation is performed on a press welding machine and components are put between water cooled copper platens under pressure. Fig. 5.7 and 5.8 illustrate the principle of resistance projection welding.

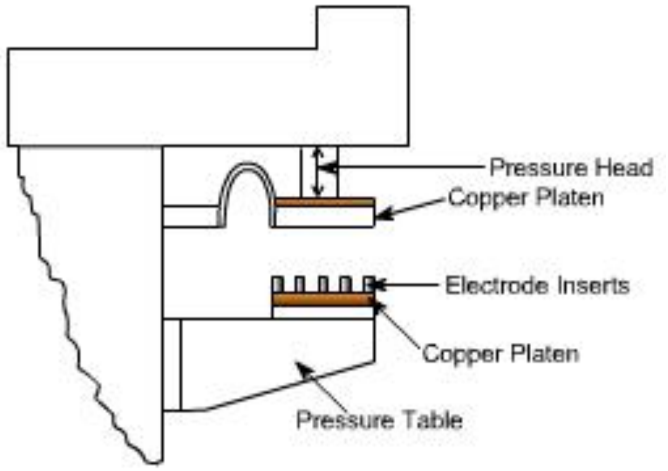

Fig 5.7 Resistance Projection Welding Machine

These projections can be generated by press working or machining on one part or by putting some external member between two parts. Members such as wire, wire ring, washer or nut can be put between two parts to generate natural projection.

Insert electrodes are used on copper platen so that with continuous use only insert electrodes are damaged and copper platen is safe. Relatively cheaper electrode inserts can be easily replaced whenever these are damaged.

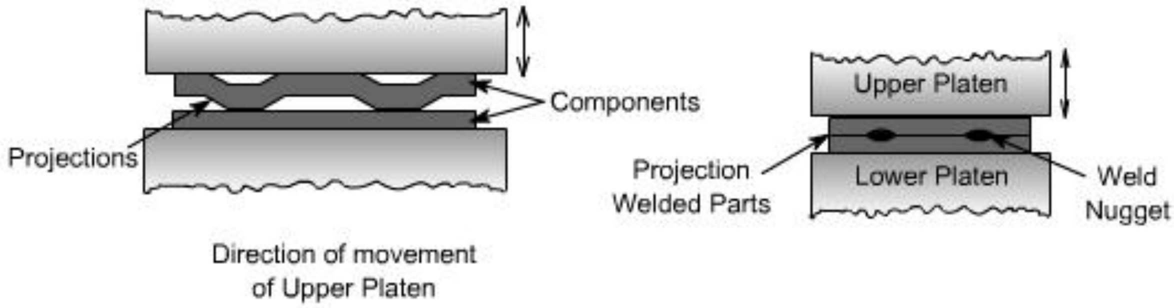

Fig 5.8 Formation of Welds from Projections on Components

No consumables are required in projection welding. It is widely being used for fastening attachments like brackets and nuts etc to sheet metal which may be required in electronic, electrical and domestic equipment.

5.5 Brazing and Soldering

Both brazing and soldering are the metal joining processes in which parent metal does not melt but only filler metal melts filling the joint with capillary action. If the filler metal is having melting temperature more than 450°C but lower than the melting temperature of components then it is termed as process of brazing or hard soldering. However, if the melting temperature of filler metal is lower than 450°C and also lower than the melting point of the material of components then it is know as soldering or soft soldering.

During brazing or soldering flux is also used which performs the following functions:

• Dissolve oxides from the surfaces to be joined.

• Reduce surface tension of molten filler metal i.e. increasing its wetting action or spreadability.

• Protect the surface from oxidation during joining operation.

The strength of brazed joint is higher than soldered joint but lower than welded joint. However, in between welding and brazing there is another process termed as ‘braze welding'.

Soldering:

The soldering filler metal is called solder. The most commonly used solder is lead and tin alloy containing tin ranging from 5 to 70% and lead 95 to 30%. Higher the contents of tin, lower the melting point of alloy. Other filler metal are tin-antimony solder (95% tin and 5% antimony), tin-silver solder (tin 96% and silver 4%), lead-silver solder (97% lead, 1.5 tin and 1.5 silver), tin-zinc solder (91 to 30% tin and 9 to 70% zinc), cadmium-silver solder (95% cadmium and 5% silver). These are available in the form of bars, solid and flux cored wires, preforms, sheet, foil, ribbon and paste or cream.

Fluxes used in soldering are ammonium chloride, zinc chloride, rosin and rosin dissolved in alcohol.

5.6 Welding Defects

The defects in the weld can be defined as irregularities in the weld metal produced due to incorrect welding parameters or wrong welding procedures or wrong combination of filler metal and parent metal.

Weld defect may be in the form of variations from the intended weld bead shape, size and desired quality. Defects may be on the surface or inside the weld metal. Certain defects such as cracks are never tolerated but other defects may be acceptable within permissible limits. Welding defects may result into the failure of components under service condition, leading to serious accidents and causing the loss of property and sometimes also life.

Various welding defects can be classified into groups such as cracks, porosity, solid inclusions, lack of fusion and inadequate penetration, imperfect shape and miscellaneous defects.

i. Cracks

Cracks may be of micro or macro size and may appear in the weld metal or base metal or base metal and weld metal boundary. Different categories of cracks are longitudinal cracks, transverse cracks or radiating/star cracks and cracks in the weld crater. Cracks occur when localized stresses exceed the ultimate tensile strength of material. These stresses are developed due to shrinkage during solidification of weld metal.

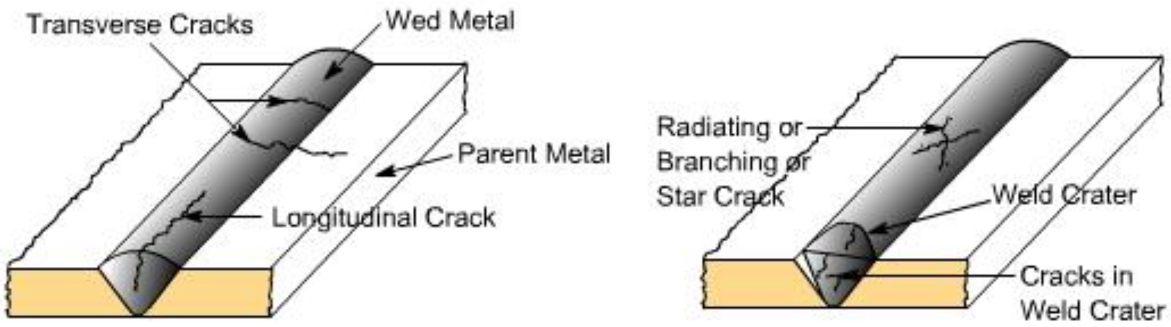

Fig 5.9 Various Types of Cracks in Welds

Cracks may be developed due to poor ductility of base metal, high sulpher and carbon contents, high arc travel speeds i.e. fast cooling rates, too concave or convex weld bead and high hydrogen contents in the weld metal.

ii. Porosity

Porosity results when the gases are entrapped in the solidifying weld metal. These gases are generated from the flux or coating constituents of the electrode or shielding gases used during welding or from absorbed moisture in the coating. Rust, dust, oil and grease present on the surface of work pieces or on electrodes are also source of gases during welding. Porosity may be easily prevented if work pieces are properly cleaned from rust, dust, oil and grease.Futher, porosity can also be controlled if excessively high welding currents, faster welding speeds and long arc lengths are avoided flux and coated electrodes are properly baked.

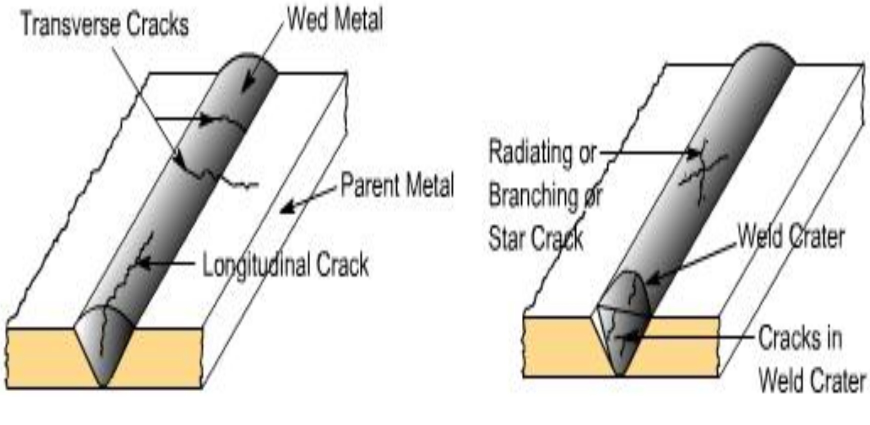

Fig. 5.10 Different Forms of Porosities

iii. Solid Inclusion

Solid inclusions may be in the form of slag or any other nonmetallic material entrapped in the weld metal as these may not able to float on the surface of the solidifying weld metal. During arc welding flux either in the form of granules or coating after melting, reacts with the molten weld metal removing oxides and other impurities in the form of slag and it floats on the surface of weld metal due to its low density. However, if the molten weld metal has high viscosity or too low temperature or cools rapidly then the slag may not be released from the weld pool and may cause inclusion.

Slag inclusion can be prevented if proper groove is selected, all the slag from the previously deposited bead is removed, too high or too low welding currents and long arcs are avoided.

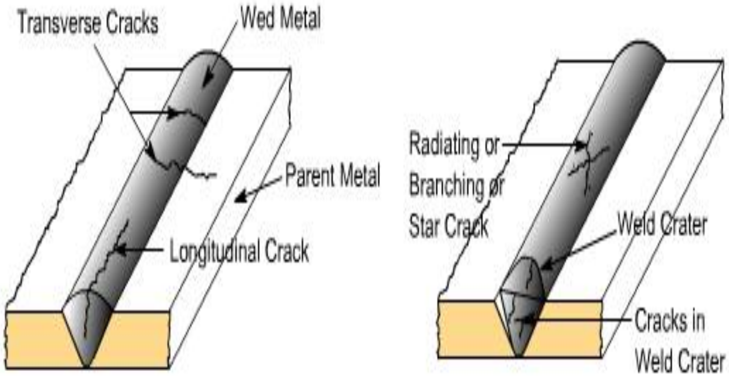

Fig.5.11 Slag Inclusion in Weldments