**Materials joining methods**

*Two methods used to join of materials permanent and semi-permanent, Different materials can be joined in many different ways depending on the joint needs to be permanent or semi-permanent*. They are (Welding, Brazing, Soldering, Riveting, Adhesives, Nuts and bolts and washers, Knock-down fittings, Screws).

• Permanent: This term refer to welding, brazing, soldering and adhesive bonding. In these processes a permanent joint between the parts is formed and cannot be separated easily, if separate these parts are damage.

• Semi-permanent: this type of joint is a method of joining that is designed to be permanent, this term refer to nuts and bolts and washers, knock-down fittings; however, it can be disassembled without damage the materials.

**Welding**

*the process of joining two similar or dissimilar materials by application of heat, with or without the application of pressure and with or without the use of filler metal****.*** Welding is a material joining process in which two or more parts are assembled (joined together) at their contacting surfaces by a suitable application of heat and/or pressure. Sometimes parts are united together by application of pressure only without external heat. In some welding process a *filler* material is added to facilitate united. Welding is used most commonly with metallic parts but for plastics also it is used.

The main method of permanently joining metals is by welding. Two main types of welding are *conventional and nonconventional* welding. There are many types of welding as MIG and TIG, oxyacetylene welding, electric arc and spot and seam welding, all involve permanently joining metals by the use of heat, causing the two main pieces of metal to become molten and using a joining material to mix them before they solidify, forming a permanent, strong joint.

**Riveting**

Rivets are used to join two sheets or plates of metal together. There are four main types of rivets: snap head, mushroom, pan head, countersunk, and the operation with join by rivets including;

1. The rivet is placed into a tool called a dolly that is held in a vice.

2. The plates are then placed over the rivet.

3. The rivet set is then placed over the rivet and pressed down to ensure that there are no gaps between the sheets/plates of metal.

4. The rivet set is tapped with a ball pein hammer. This closes any gaps and starts to form the rivet joint.

The ball pein hammer is then reversed to form the head of the rivet. The final stage is using a rivet snap to form a similar shaped dome on both sides of the joint. 

**Figure 27 Rivets are used to join**

**Nuts, bolts and washers**

Nuts and bolts are used to hold two or more pieces of materials together in a semi-permanent method of joining. Bolts tend to be made from high tensile steel and are threaded (square or hexagonal threaded) for all or part of the length of the shaft. Nuts used with bolts must have matching diameter and thread form. They come in various forms, from wing nuts (made for easy removal by hand) to hexagonal nuts and special locking nuts that resist coming loose. Types of washers: Washers are used to protect the surface when nuts are tightened. They spread the load applied to the surface and prevent loosening that can be caused by vibrations.

**Conventional Welding** **Classification**

*Welding processes usually divided into three main groups, solid state and liquid state welding, but there are third type namely solid/liquid state.* With three types the materials are joined together with these methods cannot separate easily and achieved by pressure, pressure and heat, or heat only.

Solid-state Welding Processes; In solid state welding such as friction welding, forge welding, explosion welding, etc. The surfaces to be joined are brought into close proximity by heating the surfaces without causing melting and applying normal pressure and providing relative motion between the two surfaces, after stop the motion is applying high pressure without heating. In these processes the materials remain in solid state and welding is achieved through the application of heat and pressure, or high pressure only.

Liquid State (Fusion) Welding Processes; arc welding, resistance welding, oxy fuel gas welding, etc. There are two inherent problems with fusion welding, effect of localized heating and rapid cooling on the microstructure of the parent metals and effect of residual stresses developed in the parent metals due to restrained expansion or contraction.

Solid / Liquid State Bonding; In this state low temperature joining methods are used when the metal to be joined cannot withstand to high temperature, or complex sections are to be joined, or dissimilar metals are to be joined, or weldability of material is poor. Also in these methods, the gap between the metal pieces to be joined is filled with molten filler material after heating the base metal. Melting point of filler material is much lower than base metals. The bonding is not due to melting of parent metal.

Filler material is drawn into the gap between the metal pieces to be joined by capillary action and the bond formation is started when the molten filler metal comes to contact with the solid surface as in solid state welding. The nature of bond formed is much complex here, there is some of inter-solubility between filler and base metals to produced resulting alloy. This inter-diffusion at the base metal surface and resulting alloy has a strength which is very close to that the base metal.

Also for a good joint strength the liquid filler metal; must flow into the gap between the metal pieces to be joined and cover the entire surface area, without gaps or blow holes. Usually to good bonding are doing the following:

– Clean base metal surfaces

– Maintain optimum gap.

– Heat the joining area above melting temperature of the filler material.

– Use fluxes for welding of base metal surfaces.

Welding which is the process of joining two components for the desired purpose, can be defined as the process of joining two similar or dissimilar materials components with the application of heat, with or without the application of pressure and with or without the use of filler metal. Heat may be obtained by chemical reaction, electric arc, electrical resistance, frictional heat, sound and light energy etc.

**Electric Arc Welding**

Electric Arc Welding provides the heat required for melting the parent as well as filler material. The workpiece and the electrode are connected to the power source (*The electrode is an electrical conductor used to make contact between cathode and anode to fuse or melt of workpiece*) and the arc is started with touching the electrode to the workpiece and then withdrawing it to a short distance (a few mm) from the workpiece. When the electrode and workpiece are in contact the current is flows. The arc is generated by the electrons emitted form cathode and moving towards anode and the arc changes electrical energy into heat and light.

****

**Figure 28 Electric Arc Welding**

About 70% of the heat emitted due to flux of electrons at anode raises the anode temperature to high values (5,000 to 30,000oC). This heat melts the base metal as well as tip of the electrode in the area surrounding the arc. A weld is formed when the mixture of molten base and electrode metal solidifies in the weld area.

Both direct current (DC) and alternating currents (AC) are used in arc welding. AC machines are less expensive to purchase and operate, but generally limited to welding of ferrous metals. DC equipment can be used on all metals with good results and is generally famous for better arc control. The used can be either non-consumable or consumable electrodes. Consumable electrode usually have a coating on its outer surface which on melting emitted gases like hydrogen or carbon dioxide to form covering around the molten pool.

The electrode also reacts to slag which is a liquid and lighter than the molten metal. The slag therefore is rises and floating on the surface and by solidification forms a protective covering over the hot metal. This also slows down the rate of cooling of the weld. The slag layer can be removed by light chipping or small hammering on the slag cover. Electric arc welding of this type is known as (Shielded Metal Arc Welding). More than 50% industrial arc welding is done by this method.

For continuous arc welding operations, the consumables electrode is wire in the form of a coil and the flux us fed into the welding zone, or the weld area is covered by an inert gas. In Submerged Arc Welding the electrode is shielded by granular flux supplied from a source, while is Gas Metal Arc Welding shielding of the area is provided by an inert gas such as argon, helium, carbon dioxide , etc.

Arc Welding (GTAW) is also called as Tungsten Inert Gas (TIG) welding. It uses tungsten alloy electrode and helium gas shield. Because of inert gas atmosphere tungsten is not consumed. Filler materials are supplied by a separate rod or wire in this case.