Welding Skills

1.1 WELDING

Welding is the process of joining metals by melting the parts and then using a filler to form a joint. It can be done using different energy sources, from a gas flame or electric arc to a laser or ultrasound.

Until the beginnings of the 20th century, welding was done via a process known as **forge welding**, which consists of heating up the pieces to be fixed together and then hammering them until they amalgamate. With the advent of electricity, the process became easier and faster, and it played an important part of the industry scene during World War I and II.

Forge welding is a solid-state welding process that joins two pieces of metal by heating them to a high temperature and then hammering them together.

There are different welding processes in use in modern times:

- Arc welding is done through the use of an electrical current, and can be performed by using inexpensive equipment.
- Gas Welding is widely used for repair work, especially in anything involving pipes and tubes. It is common in the jewelry industry, as well as for connecting plastics and other materials that cannot stand higher temperatures.
- Resistance welding involves the use of additional sheets of metal to encase the pieces to be welded together. It is the most environmentally-friendly of all methods, but it requires costly equipment that cannot be used in all situations.
- Energy beam welding, also known as laser beam welding, is one of the most modern techniques used. This

method is fast and accurate, but the high equipment cost makes it prohibitive for many industries.

Welding cannot be done with all types of metals, as some materials, such as stainless steel, are prone to cracking and distortion when overheated. Alloys are particularly problematic, since it's hard to know the exact chemical composition of the metal. Welding has become highly automatized over the last decade, and the use of robots is now commonplace in certain industries, such as the automotive manufacturing plants.

It is possible to weld items in unusual conditions, including underwater and in outer space. Underwater welding is widely used in the repair of pipelines and ships, while that performed in space is currently being researched as a possible way to put together space stations and other structures.

1.1.1 Definition of Welding

"Welding is the process of joining together two pieces of metal so that bonding takes place at their original boundary surfaces". When two parts to be joined are melted together, heat or pressure or both is applied and with or without added **metal** for formation of metallic bond.

1.1.2 Need for Welding

With ever increasing demand for both high production rates and high precision, fully mechanized or automated welding processes have taken a prominent place in the welding field. The rate at which automation is being introduced into welding process is astonishing and it may be expected that by the end of this century more automated machines than men in welding fabrication units will be found. In addition, computers play critical role in running the automated welding processes and the commands given by the computer will be taken from the programs, which in turn, need algorithms of the welding variables in the form of mathematical equations. To make effective use of the automated systems it is essential that a high degree of confidence be achieved in predicting the weld parameters to attain the desired mechanical strength in welded joints.

To develop mathematical models to accurately predict the weld strength to be fed to the automated welding systems has become more essential.

Metal is a material that is typically hard when in solid state, opaque, shiny, and has good electrical and thermal conductivity.

1.1.3 Advantages of Welding

- A good weld will be stronger than the parent or base metal.
- Faster process compared to riveting and casting.
- Complete rigid joints can be provided with the welding process.
- Applicable to all metals and alloys.
- Difficult shapes can be produced by welding.
- Welding equipment is portable and can be easily maintained.
- No noise is produced during the welding process as in the case of riveting.
- The welding process requires less workspace in comparison to riveting.
- Any space of joint can be made with ease.

1.1.4 Disadvantages of Welding

- Gives out harmful radiation, fumes, and spatles (sudden sprinkle of spark).
- Welded joints are more brittle and therefore their fatigue strength is less than the members joined.
- Results in distortion and induces internal stresses.
- Requires necessary jigs and fixtures to hold metals properly.
- Skilled labor and electricity are required for welding.
- The inspection of welding work is more difficult and costlier than the riveting work.

If the wire and the base material get too close, the current will rapidly increase, which in turn causes the heat to increase and the tip of the wire to melt, returning it to its original separation distance.

1.1.5 Application of Welding

The application of welding is so varied and extensive that it would be no exaggeration to

say that there is no metal industry and no branch of engineering that does not make use of welding in one form or another namely automobile industry, shipping, aerospace and construction.

It is majorly used for fabrication.

Some of the application are:

- Shipbuilding
- Railway coaches
- Automobile chassis and bodybuilding
- Earthmover bodies
- Window shutters
- Doors, gates
- All type of fabrication work.

1.2 WELDING EQUIPMENT

The most commonly used equipment for arc welding consists of the following:

- A.C or D.C machine
- Welding power source
- Electrode
- Electrode holder
- Ground Clamp
- Cables, cable connector
- Cable plug

1.2.1 Accessory Equipment

- Chipping hammer
- Earthing clamps
- Wire brush

1.2.2 Safety or Protective Equipment

- Helmet
- Safety goggles
- Hand gloves
- Aprons, Sleeves etc.

1.2.3 Common Terms of Welding

There is a large vocabulary of specific welding terms. Knowing these terms is essential to learning about welding as well as understanding how to weld.

Arc Burn

Arc burn is a metallurgical notch caused by ground clamps or striking an arc on the base metal at any point other than the weld groove or immediate area that will be covered with the weld cap.

Base Metal

The base metal is the metal that is to be welded or cut. It is commonly referred to as the workpiece.

Butt Weld

A butt weld is a joint between two workpieces that are aligned on the same plane.

Cover Pass

The cover pass finishes the welded joint. It is higher than the adjacent surface and overlaps the groove.

Filler Pass

The filler pass follows the hot pass and fills the weld groove flush, or almost flush, with the surface of the workpieces.

Fillet Weld

A fillet weld is the joining of two workpieces with triangular cross-sections at approximately 90 degrees.

Heat-Affected Zone

The heat-affected zone is the area of metal near the weld metal that was not melted during welding, but did experience changes in its mechanical properties and/or microstructure due to the heat applied.

Hot Pass

The hot pass is the pass immediately following the stringer pass.

Joint

Joint is a point or edge where two or more pieces of metal or plastic are joined together.

Plug Weld

Plug welding is filling a hole or gap in one piece with weld or

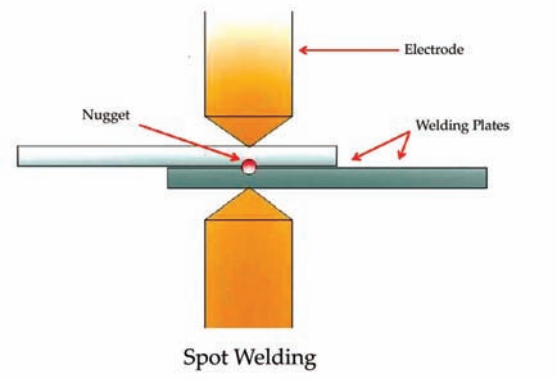
filling a hole and attaching the piece with the hole to the surface of another base piece.

Polarity

Polarity is the manner in which the electrode holder and workpiece connect to the electrical supply. This can be either direct current electrode negative, or DCEN, meaning straight polarity or direct current electrode positive, or DCEP, meaning reverse polarity.

Spot Weld

Spot welding is the process in which the weld pieces are pressed together with pressure, then a current is passed through them in a small spot and the two pieces are melted together at that location. Spot welding can be performed on metals from 0.5 to 3 mm.



Spot Welding

Stringer or Root Bead

The stringer pass, or root bead, is the first pass in the weld. It is typically made without any weaving motion.

Weld Groove

Weld groove refers to a V- or U-shaped groove created by the beveling of the workpiece edges that will be joined.

Weld Metal

The weld metal is the portion of the base metal that is melted during the welding process.

Weld Pass

A weld pass is a single progression of welding along the joint. After a complete pass, it is referred to as a weld bead.

Welding Electrode

In **arc welding**, the electrode is used to pass current through the workpiece to fuse the two pieces together.

Arc welding is a process that is used to join metal to metal by using electricity to create enough heat to melt metal, and the melted metals when cool result in a binding of the metals.

1.2.4 Classification of Welding Processes

Welding is a process in which two or more parts are joined permanently at their touching surfaces by a suitable application of heat and/or pressure. Often a filler material is added to facilitate coalescence. The assembled parts that are joined by welding are called a weldment. Welding is primarily used in metal parts and their alloys.

Welding processes are classified into following groups:

- ***Solid-state welding***: In this process, joining of parts takes place by application of pressure alone or a combination of heat and pressure. No filler metal is used. Commonly used solid-state welding processes are: diffusion welding, friction welding, ultrasonic welding.

- ***Plastic Welding or Pressure Welding***: When the metal piece acquires plastic state on heating, external pressure is applied. In this process, externally applied forces play an important role in the bonding operation. "A group of welding processes which produces coalescence at temperatures essentially below the melting point of the base materials being joined without the addition of a filler metal" is Pressure Welding Process. Without melting the base metal, due to temperature, time and pressure coalescence is produced. Some of the very oldest processes are included in solid state welding process. The advantage of this process is the base metal does not melt and hence the original properties are retained with the metals being joined.
- ***Fusion Welding or Non-Pressure Welding***: In this process, base metal is melted by means of heat. Often, in fusion welding operations, a filler metal is added to the molten pool to facilitate the process and provide bulk and strength to the joint. Commonly used fusion welding processes are: arc welding, resistance welding, oxyfuel welding, electron beam welding and laser beam welding.

The material at the joint is heated to a molten state and allowed to solidify. In this process the joining operation involves melting and solidification and any external forces applied to the system do not play an active role in producing coalescence. Usually fusion welding uses a filler material to ensure that the joint is filled. All fusion welding processes have three requirements: Heat, Shielding and Filler material.

1.2.5 Types of Welding

Welding process can also be classified as follows:

1. Gas Welding
   - Oxy Acetylene Welding
   - Oxy Hydrogen Welding
   - Pressure Gas Welding
2. Arc Welding
   - Carbon Arc Welding

- Shield Metal Arc Welding
- Submerged Arc Welding
- Metal Inert Gas Welding
- Tungsten Inert Gas Welding
- Electro Slag Welding
- Plasma Arc Welding

3. Resistance Welding

- Spot Welding
- Flash Welding
- Resistance Butt Welding
- Seam Welding

4. Solid State Welding

- Forge Welding
- Cold Welding
- Friction Welding
- Explosive Welding
- Diffusion Welding
- Ultrasonic Welding

5. Thermo-Chemical Welding

- Thermit Welding
- Atomic H_2 Welding

6. Radiant Energy Welding

- Electron Beam Welding
- Laser Welding

Electron beam welding is a fusion welding process in which a beam of high-velocity electrons is applied to two materials to be joined.

1.2.6 The History of Welding

Welding is a method of repairing or creating metal structures by joining the pieces of metals or plastic through various fusion processes. Generally, heat is used to weld the materials. Welding equipment's can utilize open flames, electric arc or laser light.

Middle Ages

The earliest evidence of welding can be traced back to the Bronze Age. The earliest examples of welding are welded gold boxes belonging to the Bronze Age. The Egyptians also learnt the art of welding. Several of their iron tools were made by welding. During the middle Ages, a set of specialized workmen called blacksmiths came to the fore. Blacksmiths of the middle Ages welded various types of iron tools by hammering. The welding methods remained more or less unchanged until the dawn of the 19th century.

1800

In the 19th century, major breakthroughs in welding were made. The use of open flames (acetylene) was an important milestone in the history of welding since open flames allowed the manufacture of intricate metal tools and equipment's. Englishman Edmund Davy discovered acetylene in 1836 and acetylene was soon utilized by the welding industry. In 1800, Sir Humphrey Davy invented a battery operated tool which could produce an arc between carbon electrodes. This tool was extensively used in welding metals.

1880

In 1881, French scientist Auguste De Meritens succeeded in fusing lead plates by using the heat generated from an arc. Later, Russian scientist Nikolai N. Benardos and his compatriot Stanislaus Olszewski developed an electrode holder for which they secured US and British patents.

1890

During the 1890's, one of the most popular welding methods was carbon arc welding. Around the same time, American C.L. Coffin secured a US patent for metal electrode arc welding. N.G. Slavianoff of Russia used the same principle for casting metals in molds.

1900

Coated metal electrode was first introduced in 1900 by Strohmenger. A coating of lime helped the arc to be much more stable. A number of other welding processes were developed during this period. Some of them included seam welding, spot welding, flash butt welding, and projection welding. Stick electrodes became a popular welding tool around this time as well.

1919

After the end of World War I, the American Welding Society was established by Comfort Avery Adams. The aim of the society was the advancement of welding processes. CJ Holstag also invented the alternating current in 1919. However, alternating current was first commercially utilized by the welding industry only in the 1930's.

1920

Automatic welding was first introduced in 1920. Invented by P.O. Nobel, automatic welding integrated the use of arc voltage and bare electrode wires. It was used for repairing and molding metals. Several types of electrodes were also developed during this decade.

1930

The New York Navy Yard developed stud welding. Stud welding was increasingly used for the construction industry and also for shipbuilding. It was during this time that the National Tube Company developed a welding process called smothered arc welding. In the sector of shipbuilding, the stud welding process was replaced by the more advanced submerged arc welding.

The history of joining metals goes back several millennia. The earliest examples of this come from the Bronze and Iron Ages in Europe and the Middle East.

1940

A new type of welding for seamlessly welding aluminum and magnesium was developed in 1941 by Meredith. This patented process came to be known as Heliarc welding. The gas shielded metal arc welding or GTAW was another significant milestone in the history of welding which was developed in Battelle Memorial Institute in 1948.

1950

The CO_2 welding process popularized by Lyubavskii and Novoshilov in 1953 became a welding process of choice for welding steels, as it was comparatively economical. Soon, electrode wires of smaller diameter were launched. This made welding of thin materials more convenient.

1960

There were several advancements in the welding industry during the 1960's. Dualshield welding, Innershield, and Electroslag welding were some of the important welding developments of the decade. Plasma arc welding was also invented

by Gage during this time. It was used for metal spraying. The French also developed electron beam welding, which is still used by the aircraft manufacturing industries of the United States.

Most Recent

Some of the recent developments in the welding industry include the friction welding process developed in Russia, and laser welding. Friction welding, which uses rotational speed and upset pressure to provide friction heat, was developed in the Soviet Union. It is a specialized process and has applications only where a sufficient volume of similar parts is to be welded because of the initial expense for equipment and tooling. This process is called inertia welding.

Laser welding is one of the newest processes. The laser was originally developed at the Bell Telephone Laboratories as a communications device. Because of the tremendous concentration of energy in a small space, it proved to be a powerful heat source. It has been used for cutting metals and nonmetals. Continuous pulse equipment is available. The laser is finding welding applications in automotive metalworking operations.

1.3 WELD JOINTS

The weld joint is where two or more metal parts are joined by welding. There are five common types of weld joints used in all types of welding: corner joints, edge joints, lap joints, tee joints, and butt joints.

1.3.1 Corner Joint

When two pieces are perpendicular to each other and one piece's edge meets the end of the other piece's surface, it is referred to as a corner joint. Common corner joints are edge to edge, flush corner, and half overlap, each with their own benefits.