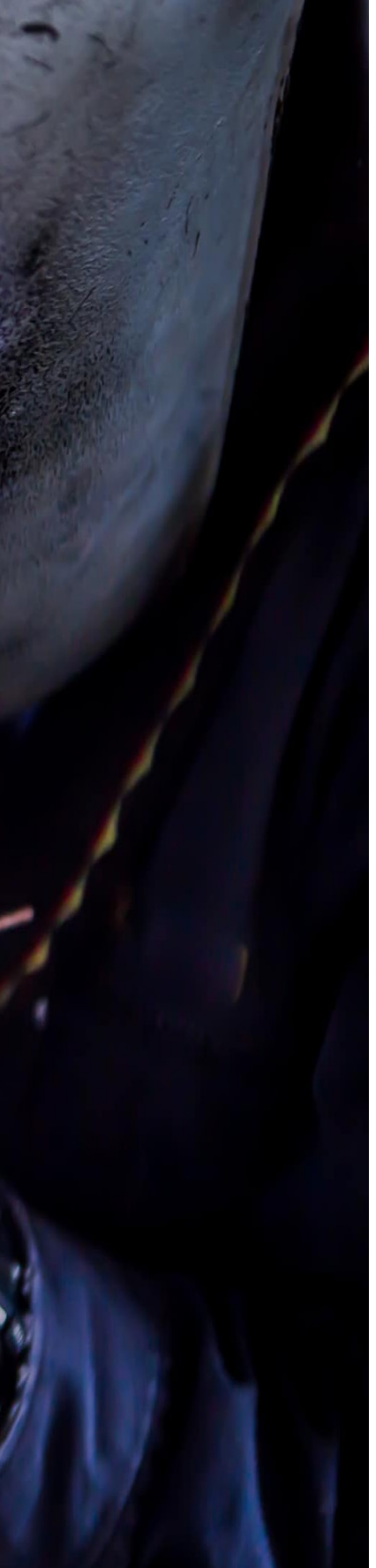
3G Handy Guide:

Welding

2nd Edition



CHAPTER 1

WELDING

Welding is a fabrication process that lets you join materials like metals by using heat at high temperatures. Welding uses high temperature to join the materials, whereas soldering and brazing do not allow the base metal to melt. After cooling, the base metal and the filler metal get attached.

The welding process came to light when there was a search for the technique for developing iron into useful shapes. Welded blades were the first result of welding in the early years—the carburization of iron produced hard steel that was very brittle for usage. Later interlaying the rigid and soft iron with high-carbon material and hammer forging resulted in a tough and durable blade.

IN THIS CHAPTER

The process of welding uses filler material. The filler material is the pool of molten material that aids in the formation of a strong link between the base metal. The shielding process after welding the metals protects both the base and filler components from being oxidized.

From gas flame to ultrasound, many energies are used in welding like electron beams, electric arc, LASER, and friction. Now let us understand various types of welding.

The welding technique—which involved interlayering relatively soft and tough iron with high-carbon material, followed by hammer forging—produced a strong, tough blade.

Welding technique used for joining metallic parts usually through the application of heat. This technique was discovered during efforts to manipulate iron into useful shapes. Welded blades were developed in the 1st millennium CE, the most famous being those produced by Arab armorers at Damascus, Syria. The process of carburization of iron to produce hard steel was known at this time, but the resultant steel was very brittle.

In modern times the improvement in iron-making techniques, especially the introduction of cast iron, restricted welding to the blacksmith and the jeweler. Other joining techniques, such as fastening by bolts or rivets, were widely applied to new products, from bridges and railway engines to kitchen utensils.

OVERVIEW OF 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.

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.

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.

Advantage of Welding

Almost all metals and alloys, many (thermoplastic) polymers, most if not all glasses, and some ceramics can be welded, with or without auxiliary filler. Still other advantages of welding are that -

- there are processes that can be performed manually, semi-automatically, or completely automatically;
- some processes can be made portable for implementation in the field for erection of large structures on site or for maintenance and repair of such structures and Equipment;

Continuous welds provide fluid tightness (so welding is the process of choice for fabricating pressure vessels).

- welding (better than most other joining processes) can be performed remotely in hazardous environments (e.g., underwater, in areas of radiation, in outer space) using robots; and
- for most applications, costs can be reasonable.

The exceptions to the last statement are where welds are highly critical, with stringent quality requirements or

involving specialized applications (e.g., very thick section welding).

Disadvantage of Welding

The single greatest disadvantage of welding is that it precludes disassembly. While often chosen just because it produces permanent joints, consideration of ultimate disposal of a product (or structure) at the end of its useful life is causing modern designers to rethink how they will accomplish joining.

A prime example is the need for the regulatory authorities in former West Germany to dismantle the nuclear reactors in former East Germany that have designs similar to the reactor that failed in Chernobyl in the former USSR.

A second major disadvantage of many welding processes is that the requirement for heat in producing many welds can disrupt the base material microstructure and degrade properties.

A third serious consideration, but not necessarily a disadvantage, is that welding requires considerable operator skill, or, in lieu of skilled operators, sophisticated automated welding systems. Both of these, along with the aforementioned specialized applications, can lead to high cost.

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.

Unbalanced heat input can also lead to distortion or the introduction of residual stresses that can be problematic from several standpoints.

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.

Welding Equipment

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

1. A.C or D.C machine
2. Welding power source
3. Electrode
4. Electrode holder
5. Ground Clamp
6. Cables, cable connector
7. Cable plug

Accessory Equipment

1. Chipping hammer
2. Earthing clamps
3. Wire brush

Safety or Protective Equipment

1. Helmet
2. Safety goggles
3. Hand gloves
4. Aprons, Sleeves etc.

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.

In fusion welding a heat source generates sufficient heat to create and maintain a molten pool of metal of the required size. The heat may be supplied by electricity or by a gas flame.

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.

In a multipass weld, this cast structure may be modified, depending on the particular metal that is being welded.

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.

Wood welding uses heat generated from friction to join the materials. The materials to be joined are subjected to a great deal of pressure before a linear friction movement creates heat to bond the workpieces together.

Polarity. Polarity is the manner in which the electrode holder and work piece 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 one of the oldest welding processes. It is used in a wide range of industries but notably for the assembly of sheet steel vehicle bodies. This is a type of resistance welding where the spot welds are made at regular intervals on overlapping sheets of metal. Spot welding is primarily used for joining parts that are normally up to 3 mm in thickness.

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.

A weld can be defined as a coalescence of metals produced by heating to a suitable temperature with or without the application of pressure, and with or without the use of a filler material.

Weld Groove. Weld groove refers to a V- or U-shaped groove created by the beveling of the work piece 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 work piece to fuse the two pieces together.

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.

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.

Welding processes are classified into following groups:

1. ***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.
2. ***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.
3. ***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.

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.

The material at the joint is heated to a molten state and allowed to solidify.

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

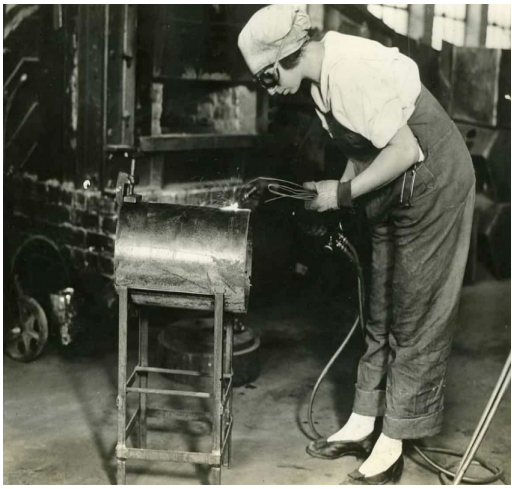
The History of Welding

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.

During the middle Ages, the art of blacksmithing was developed and many items of iron were produced that were welded by hammering. It was not until the 19th century that welding as we know it today was invented.

Middle Ages. Welding can trace its historic development back to ancient times. The earliest examples of welding come from the Bronze Age. Small gold circular boxes were made by pressure welding lap joints together. It is estimated that these boxes were made more than 2,000 years ago. During the Iron Age the Egyptians and people in the eastern Mediterranean area learned to weld pieces of iron together. Many tools were found that were made in approximately 1000 B.C.

1800. Edmund Davy of England is credited with the discovery of acetylene in 1836. The production of an arc between two carbon electrodes using a battery is credited to Sir Humphry Davy in 1800. In the mid-19th century, the electric generator was invented and arc lighting became popular. During the late 1800s, gas welding and cutting was developed.



Arc welding with the carbon arc and metal arc was developed and resistance welding became a practical joining process.

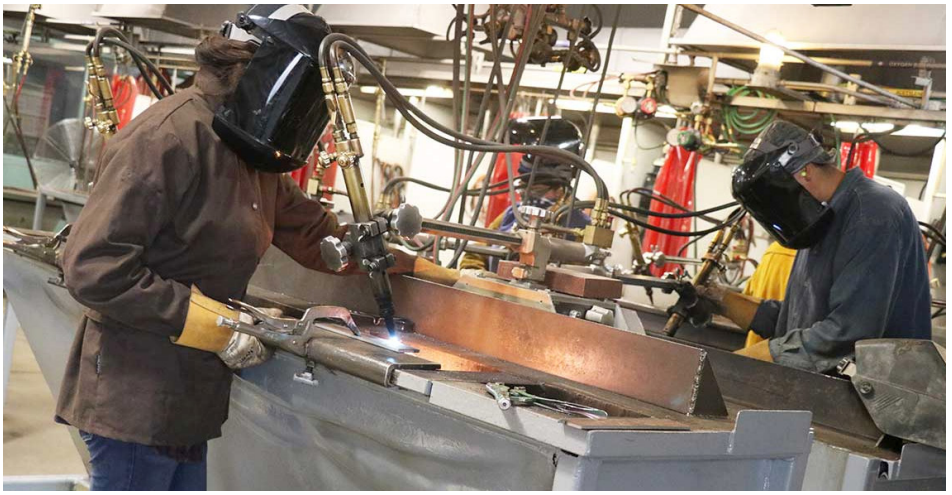
1880. Auguste De Meritens, working in the Cabot Laboratory in France, used the heat of an arc for joining lead plates for storage batteries in the year 1881. It was his pupil, a Russian, Nikolai N. Benardos, working in the French laboratory, who was granted a patent for welding.

He, with a fellow Russian, Stanislaus Olszewski, secured a British patent in 1885 and an American patent in 1887. The patents show an early electrode holder.

This was the beginning of carbon arc welding. Benardos' efforts were restricted to carbon arc welding, although he was able to weld iron as well as lead. Carbon arc welding became popular during the late 1890s and early 1900s.

1890. In 1890, C.L. Coffin of Detroit was awarded the first U.S. patent for an arc welding process using a metal electrode. This was the first record of the metal melted from the electrode carried across the arc to deposit filler metal in the joint to make a weld. About the same time, N.G. Slavianoff, a Russian, presented the same idea of transferring metal across an arc, but to cast metal in a mold.

1900. Approximately 1900, Strohmenger introduced a coated metal electrode in Great Britain. There was a thin coating of clay or lime, but it provided a more stable arc. Oscar Kjellberg of Sweden invented a covered or coated electrode during the period of 1907 to 1914. Stick electrodes were produced by dipping short lengths of bare iron wire in thick mixtures of carbonates and silicates and allowing the coating to dry.



Meanwhile, resistance welding processes were developed, including spot welding, seam welding, projection welding and flash butt welding.

Elihu Thompson originated resistance welding. His patents were dated 1885-1900. In 1903, a German named Goldschmidt invented thermite welding that was first used to weld railroad rails.

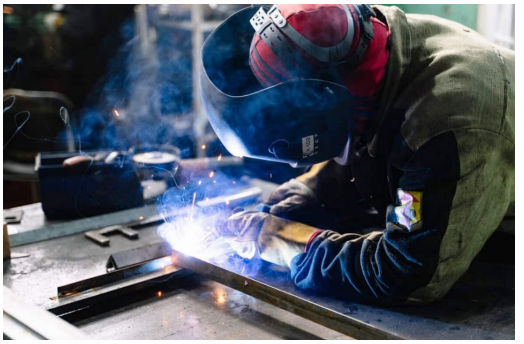
Gas welding and cutting were perfected during this period as well.

The production of oxygen and later the liquefying of air, along with the introduction of a blow pipe or torch in 1887, helped the development of both welding and cutting. Before 1900, hydrogen and coal gas were used with oxygen. However, in about 1900 a torch suitable for use with low-pressure acetylene was developed. World War I brought a tremendous demand for armament production and welding was pressed into service.

Many companies sprang up in America and in Europe to manufacture welding machines and electrodes to meet the requirements.

1919. Immediately after the war in 1919, 20 members of the Wartime Welding Committee of the Emergency Fleet Corporation, under the leadership of Comfort Avery Adams, founded the American Welding Society as a nonprofit organization dedicated to the advancement of welding and allied processes.

1920. In 1920, automatic welding was introduced. It utilized bare electrode wire operated on direct current and used arc voltage as the basis of regulating the feed rate. Automatic welding was invented by P.O. Nobel of the General Electric Company. It was used to build up worn motor shafts and worn crane wheels. It was also used by the automobile industry to produce rear axle housings.



During the 1920s, various types of welding electrodes were developed. There was considerable controversy during the 1920s about the advantage of the heavy-coated rods versus light-coated rods. The heavy-coated electrodes, which were made by extruding, were developed by Langstroth and Wunder of the A.O. Smith Company and were used by that