Fundamentals of Arc Welding

An Online Continuing Education Course for Engineers

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FUNDAMENTALS OF ARC WELDING

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Welding is the process of joining two pieces of metal by intense heating with or without the application of pressure or by the application of pressure alone (without heating) and with or without the use of filler material. It is distinguished from other forms of mechanical connections, such as riveting or bolting, which involves friction or mechanical interlocking.

Welding offers many advantages over riveting or bolting:

1. Welded structures are more rigid compared to structures with riveted and bolted connections;
2. Welding gives the appearance of a one-piece construction as against the cluttered surface of bolted or riveted connections;
3. Welded structures allow the elimination of a large percentage of the gusset and splice plates necessary for riveted or bolted structures.
4. Welding saves up to 15% of the steel weight, and costs are saved due to the elimination of operations like drilling and punching. Time spent on detailing and fabrication is also saved;
5. The strength of the welded joint equals or exceeds the strength of the original base metal, thereby placing no restriction on the joints;
6. Weld connections offer the designer more freedom for innovation in his design, making changes, and for correcting mistakes during erection;
7. Welding is practicable for almost all types/shapes of joints; for example, the connection of a steel pipe column to other members;
8. Welding offers airtight and watertight joining of plates and hence ideal for oil storage tanks, ships, etc.

<u>Some disadvantages:</u>

1. Skilled manpower is needed for operation and inspection of welded connections;
2. Welded joints are highly prone to cracking under fatigue loading - non-destructive evaluation may have to be carried out to detect defects in welds;
3. Costly equipment is essential to make welded connections;

4. Proper welding can not be done in the field environment;
5. Large residual stresses and distortion are developed in welded connections.

In earlier days, a combination of bolting, riveting, and welding was not practiced. Structures were completely welded, bolted, or riveted. Today, a combination of bolting, riveting, and welding is commonly used in steel structures, but generally, combination techniques are not used in one and the same joint. The present trend is to use welding for workshop connections or splices, and high strength bolts for field joints.

There are over 50 different welding processes, but gas and arc welding are most commonly employed in industrial manufacturing.

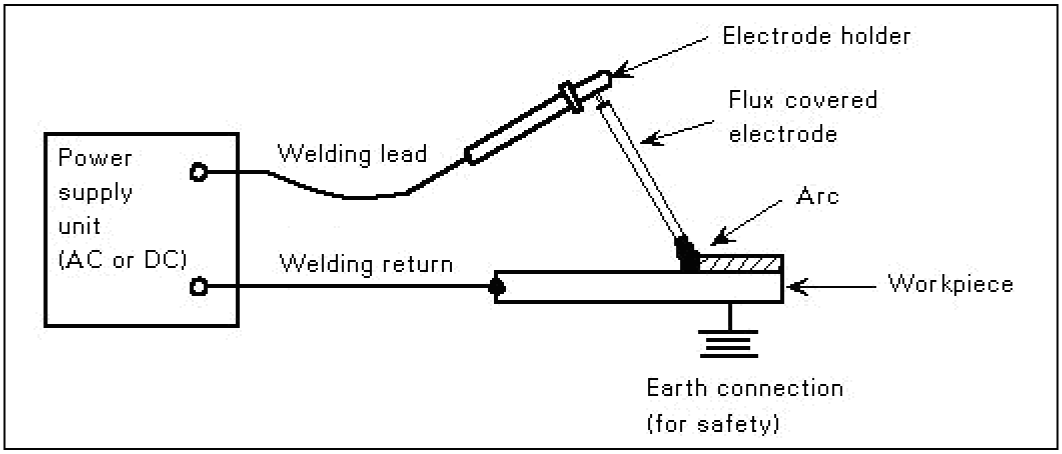
Gas welding is a non-pressure process using heat from a gas flame. In gas welding, a mixture of oxygen and some combustible gas such as MAPP (methylacetylene-propadiene) or acetylene is burned at the tip of a torch. The flame produced is applied directly to the metal edges to be joined and to a filler metal, which is melted to the joint. Gas welding has the advantage of involving equipment that is portable and does not require an electric power source. It is widely used in maintenance and repair work because of the ease of transporting oxygen and fuel cylinders. But, the process is slow compared to other means of welding.

Electric arc welding is by far the most popular fusion process for joining metals in commercial welding practices. In this process, the workpieces are heated to the fusion temperature by an electric arc, causing two parts to be melted and intermixed. Upon cooling and solidification, a metallurgical bond is created. Since the joining is an intermixture of metals, the final weldment potentially has the same strength properties as the metal of the parts.

Almost all structural welding is arc welding. This course is particularly concerned with the arc welding processes commonly used in structural work.

SECTION 1: BASIC ARC WELDING PROCESSES

In arc welding, the intense heat needed to melt metal is produced by an electric arc. The arc is a continuous spark formed between the actual work and an electrode (stick or wire) when a large current at a low voltage is discharged between the electrode and the base metal through an ionized column of gas. The resistance of the air or gas between the electrode and the objects being welded changes the electric energy into heat. A temperature of 3300°C to 5500°C is produced in the arc.



ARC WELDING CIRCUIT

The welding rod is connected to one terminal of the current source that is manually or mechanically guided along the joint. The electrode can either be a rod with the purpose of simply carrying the current between the tip and the work. Filler metal is melted into the space between the joint from a separate rod or wire.

Two types of filler metals commonly used in welding are welding rods and welding electrodes.

The term **welding rod** refers to a form of filler metal that does not conduct an electric current during the welding process. The only purpose of a welding rod is to supply filler metal to the joint. This type of filler metal is often used for gas welding.

In electric-arc welding, the term ***electrode*** refers to the component that conducts the current from the electrode holder to the metal being welded. Electrodes are classified into two groups: consumable and non-consumable.

- Consumable electrodes progressively melt away due to the heat of an electric arc held between it and the work. It not only provides a path for the current, but they also supply filler metal to the joint. An example is an electrode used in shielded metal-arc welding.

- Non-consumable electrodes are only used as a conductor for the electrical current, such as in gas tungsten arc welding. The filler metal for gas tungsten arc welding is a hand-fed consumable welding rod.

Electrode size is nominated by the diameter of the core wire and is determined by the amperage and the heat input into the job. Electrodes are available from 2mm to 6mm diameter. Within limits, larger electrodes permit more economical welding on heavy jobs, but with correct techniques, the maintenance welder rarely requires an excess of 4mm to achieve sound welds. Similarly, a suitable 2.5mm electrode with an appropriate technique can weld down to 1.5mm material, although on the flat, a 2mm size may be desirable. The specification covering the requirements for welding electrodes is the American Welding Society (AWS) **AWS A - 5.1**, and the code that covers the welding of steel structures is **AWS D1.1.**

Power Source

Arc welding may be done with alternating current (AC) or direct current (DC) with either a positive or negative electrode. Each current type has its advantages and limitations, and these must be considered when selecting the type of current for a specific application. Factors which need to be considered are as follows:

- Voltage Drop - Voltage drop in the welding cables is lower with AC. This makes AC more suitable if the welding is to be done at long distances from the power supply. However, long cables, which carry AC should not be coiled because the inductive losses encountered in such cases can be substantial.

- Low Current - With small diameter electrodes and low welding currents, DC provides better operating characteristics and a more stable arc.

- Arc Starting - Striking the arc is generally easier with DC, particularly if small diameter electrodes are used. With AC, the welding current passes through zero each half cycle, and this presents problems for arc starting and arc stability.

- Arc Length - Welding with a short arc length (low arc voltage) is easier with DC than with AC. This is an important consideration, except for the heavy iron powder electrodes. With those electrodes, the deep crucible formed by the heavy covering automatically maintains the proper arc length when the electrode tip is dragged on the surface of the joint.

- Arc Blow - Alternating current rarely presents a problem with arc blow because the magnetic field is constantly reversing (120 times per second). Arc blow can be a significant problem with DC welding of ferritic steel because of unbalanced magnetic fields around the arc.

- Welding Position - Direct current is somewhat better than AC for vertical and overhead welds because lower amperage can be used. With suitable electrodes, however, satisfactory welds can be made in all positions with AC.

- Metal Thickness **-** Both sheet metal and heavy sections can be welded using DC. The welding of sheet metal with AC is less desirable than with DC. Arc conditions at low current levels required for thin materials are less stable on AC power than on DC power.

A review of a welding application will generally indicate whether alternating or direct current is most suitable. Power sources are available as DC, AC, or combination AC/DC units. The power source for the SMAW process must be a constant-current type rather than a constant voltage type because it is difficult for a welder to hold the constant arc length required with constant-voltage power sources. If DC is chosen, the polarity also becomes an important factor. For example, the effects of polarity in GTAW are directly opposite the effects of polarity in SMAW; in SMAW, the distribution of heat between the electrode and work, which determines the penetration and weld bead width, is controlled mainly by the ingredients in the flux coating on the electrode. In GTAW, where no flux coating exists, heat distribution between the electrode and the work is controlled solely by the polarity.

From welding point of view the **voltage** is only really important in as much as sufficient "pressure" is required to make the current flow through a circuit. The arc must be ignited. This is caused by supplying an initial voltage high enough to cause a discharge. In any circuit of a given resistance, it is the current which primarily determines the amount of heat generated. The **current** controls heat input. The minimum value is fixed by the need to fuse the plate and to keep the arc stable; the specified minimum, however, this may be higher to avoid cracks. The maximum current depends on operating conditions. Usually, as high a current as possible is used to achieve faster welding, and hence lower costs. *The use of maximum current may be restricted by position; in the overhead position, for example, currents above 160 amps cannot be used.*

The current is also chosen to match the electrode diameter. The upper limit is usually determined by the ability of the electrode to run out its full length without deterioration of its running characteristics or weld metal properties. On lighter material, currents may be reduced to reduce penetration or overheating of the base material.

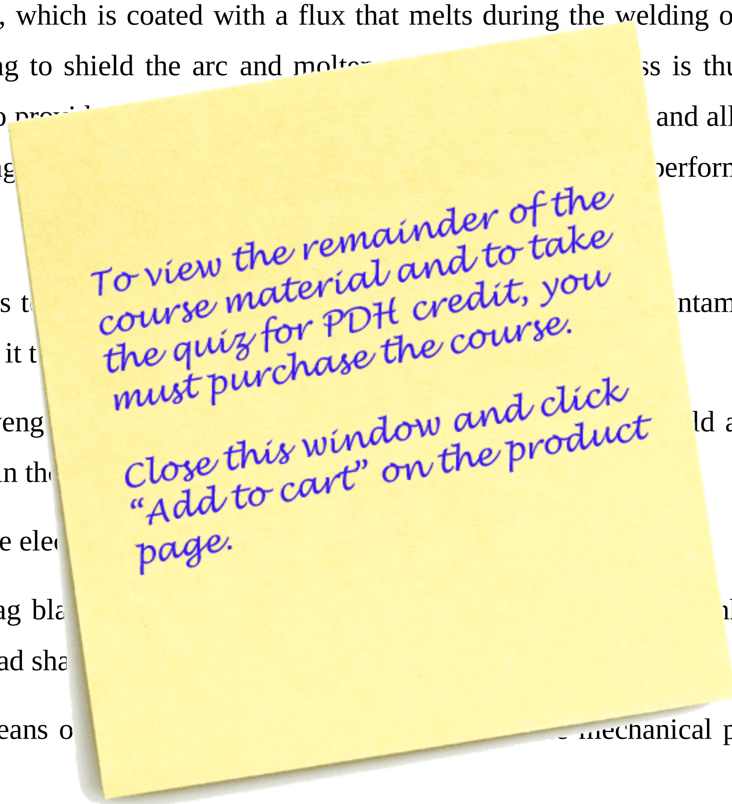
It is very important that, while we can use small cables on the high voltage-low amperage (primary) side of our AC arc welder, we must have low resistance heavy conductors for the high amperage low voltage (secondary) welding circuit or else the leads will overheat. Similarly, a secondary lead which is too long or too small will cause such a drop in voltage that it can no longer maintain a stable current across the arc between the electrode and the work.

ARC WELDING PROCESSES

Different processes of arc welding are explained in the following paragraphs:

SHIELDED METAL ARC WELDING (SMAW)

Shielded Metal Arc Welding (SMAW) is the most extensively used manual welding method for general welding applications. It is frequently referred to as stick or covered electrode welding. SMAW uses a consumable electrode, which is coated with a flux that melts during the welding operation. The coating forms the gas and slag to shield the arc and molte… …ss is thus called shielded arc welding. The flux also provi… …and alloying elements to the weld metal. Depending… …performs one or more of the following functions:



- Provides a gas t… …ntamination of the molten filler metal as it t…
- Provides scaveng… …ld and prevent excessive grain growth in th…
- Establishes the ele…
- Provides a slag bla… …nhance the mechanical properties, bead sha…
- Provides a means o… …mechanical properties of the weld metal.