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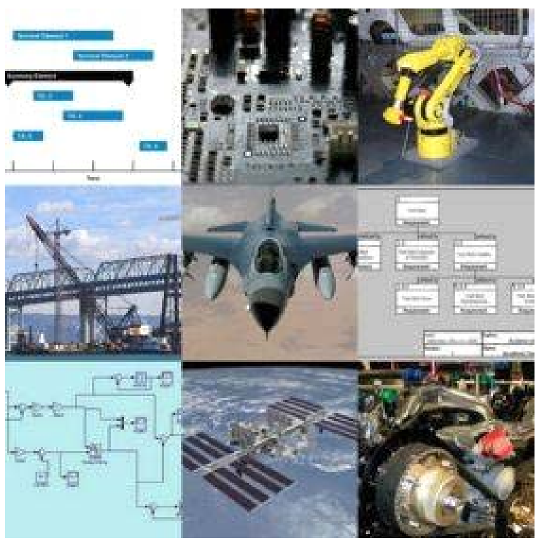
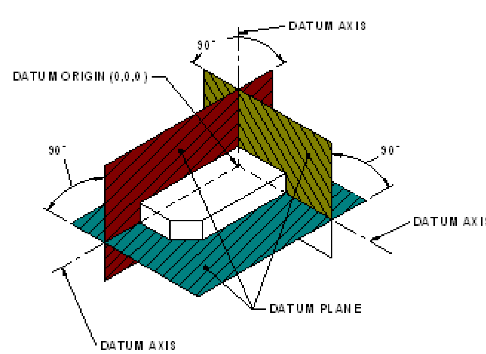




PDH Storm, by Engineers Edge, LLC

FUNDAMENTALS OF ARC WELDING

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 economies are achieved due to elimination of operations like drilling and punching, It also saves time in detailing and fabrication;
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, make changes and to correct mistakes during erection;
7. Welding is practicable for almost all types/shapes of joints; for example, connection of a steel pipe column to other members;
8. Welding offers air tight and water tight 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 the earlier days, combination of bolting, riveting and welding was not practiced. Structures were completely welded, bolted or riveted. Today, 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 is most commonly employed in industrial manufacturing.

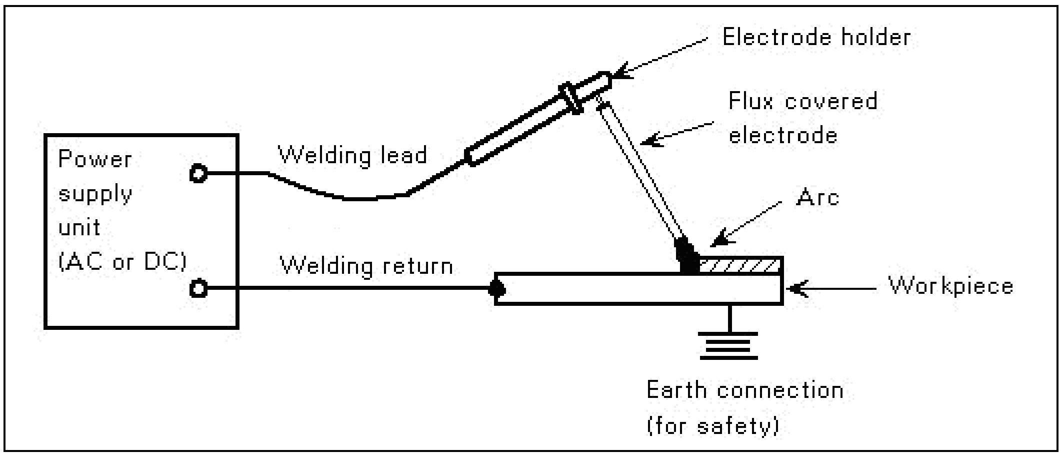
Gas welding is a non-pressure process using heat from a gas flame. In gas welding a mixture of oxygen and some combustible gas such as MAPP (methylacetylene-propadiene) or acetylene is burned at the tip of a torch. The flame produced is applied directly to the metal edges to be joined and to a filler 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 in 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 fuller metal to the joint. An example is the 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 diameter of 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 need rarely exceed 4mm to achieve sound welds. Similarly, a suitable 2.5mm electrode with 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 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 the electrode either positive or negative. 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:

- <u>Voltage Drop</u> - 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.

- <u>Low Current</u> - 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.

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.

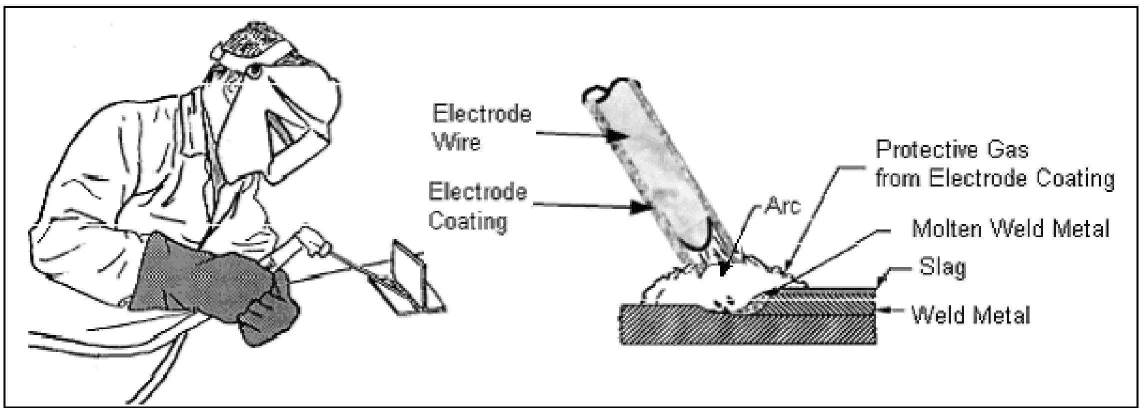
ARC WELDING PROCESSES

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 molten weld pool and therefore the process is called shielded arc welding. The flux also provides method of adding scavengers, deoxidizers and alloying elements to the weld metal. Depending upon the type of electrode being used, the covering performs one or more of the following functions:

- Provides a gas to shield the arc and prevent excessive atmospheric contamination of the molten filler metal as it travels across the arc.
- Provides scavengers, deoxidizers, and fluxing agents to cleanse the weld and prevent excessive grain growth in the weld metal.
- Establishes the electrical characteristics of the electrode.
- Provides a slag blanket to protect the hot weld metal from the air and enhance the mechanical properties, bead shape, and surface cleanliness of the weld metal.
- Provides a means of adding alloying elements to change the mechanical properties of the weld metal.



SHIELDED METAL ARC WELDING (SMAW)

In SMAW process, pressure is not used and filler metal is obtained from the electrode.

Type of operation: manual

Heat source: Arc

Shielding: Principally Flux: some gas generated by flux

Power source: AC or DC

Voltage: 16 to 40V

Current Range: 25 to 350 A

Heat Input: 0.5 to 11 KJ/s

Mode of operation:

First electrode should be selected properly based on the base metal properties, type of equipment, welding position etc. After selecting electrode size, the parameters of welding machines are to be set and the edge made ready for welding. The Welder establishes an arc between the end of the electrode and the parent metal at the joint line (To start the arc, generally two different methods are employed. In the first method, generally practiced by beginners, known as scratch method the electrode is moved in an arc so that it will scratch the work metal and thus establish the current flow. In the other method known as tapping start, the electrode is held vertically above the point where the welding is to start and in a swift motion it is moved down to contact the metal and then lifted as much as the arc gap). The arc melts the parent metal and the electrode to form a weld pool which is protected by the molten flux layer and gas generated by the flux covering of the electrode. The welder moves the electrode towards the weld pool to keep the arc gap at a constant length and at the same time move it sideways in a weaving motion to maintain the bead width. Electrodes are generally 460 mm long. When the electrode has been melted to a length of about 50 mm, the arc is extinguished. The solidified slag or flux is removed from the surface and the weld is continued with a fresh electrode.

Typical Applications:

The SMAW process can be used for welding most structural and alloy steels. These include low-carbon or mild steels; low-alloy, heat-treatable steels; high-alloy steels such as stainless steels and other alloys. SMAW is used in fabrication of pressure vessel, ships, structural steel work, pipelines, construction and repair of machine parts and any other general purpose welding.

Advantages:

- This process is highly versatile and economical;
- Equipment is least expensive and portable;
- Job of any thickness can be welded;

- SMAW can be used in all positions--flat, vertical, horizontal, or overhead--and requires only the simplest equipment. Thus, SMAW lends itself very well to field work.

Disadvantages:

The main disadvantages are slow speed. Slag removal, unused electrode stubs, and spatter add to the cost of SMAW. Unused electrodes stubs and spatter account for about 40 percent of the consumed electrodes. Another cost is the entrapment of slag in the form of inclusions, which may have to be removed. It also takes a considerable amount of practice to get the rod angle, welding amperage, and tip to work distance just right to get quality welds.

Electrode Classification System:

The SMAW electrode classification code contains an E and three numbers that signify “Strength, position, type of covering and diameter”.

Consider for example the tag E7018-1/8.

- The number 70 represents the minimum tensile strength of deposited metal in as-welded condition, which in this case is 70kPSI (70,000 PSI).
- The number 1 following the number 70 suggests that the weld can be done in all positions, horizontal, vertical and overhead. [Number 2 indicates the electrode is only suited to flat position welding and to horizontal position welding of fillet welds and number 4 indicates the electrode is suitable for vertical-down welding and for other positions as described in AWS A5.1].
- The 8 means low hydrogen flux covering. [The number "15" indicates that the covering of this electrode is a lime type, which contains a large proportion of calcium or alkaline earth materials. These electrodes are usable with dc reverse-polarity only. The designation "16" indicates electrodes that have a lime-or titania-type covering with a large proportion of titanium-bearing minerals. The coverings of these electrodes also contain readily ionizing elements, such as potassium, to stabilize the arc for ac welding].
- Finally, the 1/8 is the diameter of the electrode, 1/8 of an inch.

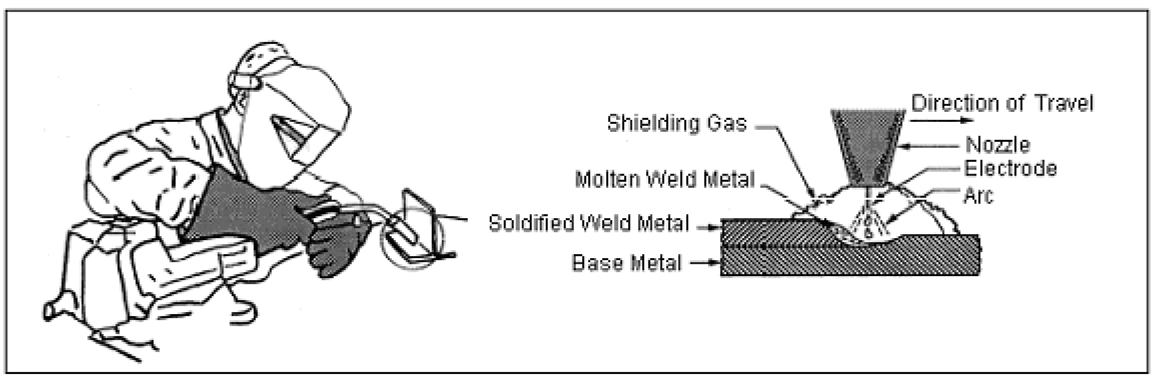
A welder must understand these numbers to know 'which is the proper rod to use for the specific job'. For other examples, refer to AWS Spec A5.1.

Weld Metal Mechanical Properties:

The AWS requires the deposited weld metal to have a minimum tensile strength of 60,000 to 100,000 psi (413,700 to 689,500 kPa) with minimum elongations of 20 to 35 percent.

GAS METAL ARC WELDING (GMAW)

In gas-metal arc welding (GMAW or MIG); a bare electrode is shielded from the air by inert gas (argon or carbon dioxide). The electrode is fed into the electric arc, and melts off in droplets to enter the liquid metal that forms the weld. Flux is not necessary to shield the pool; however, occasionally a flux - coated electrode is used to produce slag. The arc length is maintained by the power supply unit. This is sometimes also referred to as Metal Inert Gas (MIG) welding.



GAS METAL ARC WELDING (GMAW)

Type of operation: GMAW is basically a semi-automatic process, in which the arc length and the feeding of the wire into the arc are automatically controlled. Therefore operator's job is mainly to position the gun at a right angle and moving it at a controlled travel speed.

Basic equipment used consists of DC-power source, a wire feeder, a shielding gas supply, controls for governing wire drive, gas flow and cooling water and a welding gun.

In this process th
type or short-circ
density, shielding

Heat sources: ar

Shielding:

Different combin
combinations of w
pure gases – a
argon/Helium.

- Pure argo
welding A
improved
penetratio
- Pure CO_2
CO_2 provid
globular tr
better choi
penetratio
Oxygen cr
input at the
10%. Oxyg
wetting an

- Mixtures of argon/O_2, Argon/Helium and/or Argon/Helium/CO_2 are used for Stainless Steel. [An important attribute in welding stainless steel alloys is to combine good levels of penetration with good arc stability; the ideal shielding gas would be 98% argon + 2% O_2].
- Pure helium is generally NOT used for GMAW. [The helium content gases are usually more expensive and have a lower density than argon. Helium mixtures are sometimes used, which may increase welding speeds in some circumstances].