**SHIELDED METAL ARC WELDING/FUNDAMENTALS OF THE PROCESS**

**DEFINITION AND GENERAL DESCRIPTION**

SHIELDED METAL ARCwelding (SMAW) is an arc welding process in which coalescence of metals is produced by heat from an electric arc that is maintained between the tip of a covered electrode and the surface of the base metal in the joint being welded.

The core of the covered electrode consists of either a solid metal rod of drawn or cast material or one fabricated by encasing metal powders in a metallic sheath. The core rod conducts the electric current to the arc and provides filler metal for the joint. The primary functions of the electrode covering are to provide arc stability and to shield the molten metal from the atmosphere with gases created as the coating decomposes from the heat of the arc.

The shielding employed, along with other ingredients in the covering and the core wire, largely controls the mechanical properties, chemical composition, and metallurgical structure of the weld metal, as well as the arc characteristics of the electrode. The composition of the electrode covering varies according to the type of electrode.

**PRINCIPLES OF OPERATION**

SHIELDED METAL ARC welding is by far the most widely used of the various arc welding processes. It employs the heat of the arc to melt the base metal and the tip of a consumable covered electrode. The electrode and the work are part of an electric circuit. This circuit begins with the electric power source and includes the welding cables, an electrode holder, a work-piece connection, the workpiece (weldment), and an arc welding electrode. One of the two cables from the power source is attached to the work. The other is attached to the electrode holder.

Welding commences when an electric arc is struck between the tip of the electrode and the work. The intense heat of the arc melts the tip of the electrode and the surface of the the work close to the arc. Tiny globules of molten metal rapidly form on the tip of the electrode, then transfer through the arc stream into the molten weld pool. In this manner, filler metal is deposited as the electrode is progressively consumed. The arc is moved over the work at an appropriate arc length and travel speed, melting and fusing a portion of the base metal and continuously adding filler metal. Since the arc is one of the hottest of the commercial sources of heat [temperatures above 9000 degrees F(5000 degrees C) have been measured at its center], melting of the base metal takes place almost instantaneously upon arc initiation. If welds are made in either the flat or the honzontal position, metal transfer is induced by the force of gravity, gas expansion, electric and electromagnetic forces, and surface tension. For welds in other positions, gravity works against the other forces.

The process requires sufficient electric current to melt both the electrode and a proper amount of base metal. It also requires an appropriate gap between the tip of the electrode and the base metal or the molten weld pool. These requirements are necessary to set the stage for coalescence. The sizes and types of electrodes for shielded metal arc welding define the arc voltage requirements (within the overall range of 16 to 40 V) and the amperage requirements (within the overall range of 20 to *550*A). The current may be either alternating or direct, depending upon the electrode being used, but the power source must be able to control the level of current within a reasonable range in order to respond to the complex variables of the welding process itself.

**Covered Electrodes**

IN ADDITION TO establishing the arc and supplying filler metal for the weld deposit, the electrode introduces other materials into or around the arc, or both. Depending upon the type of electrode being used, the covering performs one or more of the following functions:

1. Provides a gas to shield the arc and prevent excessive atmospheric contamination of the molten filler metal.
2. Provides scavengers, deoxidizers, and fluxing agents to cleanse the weld and prevent excessive grain growth in the weld metal.
3. Establishes the electrical characteristics of the electrode.
4. 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.
5. Provides a means of adding alloying elements to change the mechanical properties of the weld metal.

Functions 1 and 4 prevent the pickup of oxygen and nitrogen from the air by the molten filler metal in the arc stream and by the weld metal as it solidifies and cools.

The covering on shielded metal arc electrodes is applied by either the extrusion or the dipping process. Extrusion is much more widely used. The dipping process is used primarily for cast and some fabricated core rods. In either case, the covering contains most of the shielding, scavenging, and deoxidizing materials. Most SMAW electrodes have a solid metal core. Some are made with a fabricated or composite core consisting of metal powders encased in a metallic sheath. In this latter case, the purpose of some or even all of the metal powders is to produce an alloy weld deposit.

In addition to improving the mechanical properties of the weld metal, electrode coverings can be designed for welding with alternating current (AC). With AC, the welding arc goes out and is reestablished each time the current reverses its direction. For good arc stability, it is necessary to have a gas in the arc stream that will remain ionized during each reversal of the current. This ionized gas makes possible the reignition of the arc. Gases that readily ionize are available from a variety of compounds, including those that contain potassium. It is the incorporation of these compounds in the electrode covering that enables the electrode to operate on AC.

To increase the deposition rate, the coverings of some carbon and low alloy steel electrodes contain iron powder. The iron powder is another source of metal available for deposition, in addition to that obtained from the core of the electrode. The presence of iron powder in the covering also makes more efficient use of the arc energy. Metal powders other than iron are frequently used to alter the mechanical properties of the weld metal.

The thick coverings on electrodes with relatively large amounts of iron powder increase the depth of the crucible at the tip of the electrode. This deep crucible helps to contain the heat of the arc and permits the use of the drag technique (described in the next paragraph) to maintain a constant arc length. When iron or other metal powders are added in relatively large amounts, the deposition rate and welding speed usually increase.

Iron powder electrodes with thick coverings reduce the level of skill needed to weld. The tip of the electrode can be dragged along the surface of the work while maintaining a welding arc. For this reason, heavy iron powder electrodes frequently are called *drag electrodes.*Deposition rates are high, but, because slag solidification is slow, these electrodes are not suitable for out-of-position use.

**Arc Shielding**

THE ARC SHIELDING action is essentially the same for all electrodes, but the specific method of shielding and the volume of slag produced vary from type to type. The bulk of the covering materials on some electrodes is converted to gas by the heat of the arc, and only a small amount of slag is produced. This type of electrode depends largely upon a gaseous shield to prevent atmospheric contamination. Weld metal from such electrodes can be identified by the incomplete or light layer of slag which covers the bead.

For electrodes at the other extreme, the bulk of the covering is converted to slag by the heat of the arc, and only a small volume of shielding gas is produced. The tiny globules of metal being transferred across the arc are entirely coated with a thin film of molten slag. This molten slag floats to the surface of the weld puddle because it is lighter than the metal. The slag solidifies after the weld metal has solidified. Welds made with these electrodes are identified by the heavy slag deposits that completely cover the weld beads. Between these extremes is a wide variety of electrode types, each with a different combination of gas and slag shielding.

Variations in the amount of slag and gas shielding also influence the welding characteristics of covered electrodes. Electrodes which produce a heavy slag can carry high amperage and provide high deposition rates, making them ideal for heavy weldments in the flat position. Electrodes which produce a light slag layer are used with lower amperage and provide lower deposition rates. These electrodes produce a smaller weld pool and are suitable for making welds in all positions. Because of the differences in their welding characteristics, one type of covered electrode usually will be best suited for a given application.

**PROCESS CAPABILITIES AND LIMITATIONS**

SHIELDED METAL ARC welding is one of the most widely used processes, particularly for short welds in production, maintenance and repair work, and for field construction. The following are advantages of this process:

(1) The equipment is relatively simple, inexpensive, and portable.

(2) The filler metal, and the means of protecting it and the weld metal from harmful oxidation during welding, are provided by the covered electrode.

(3) Auxiliary gas shielding or granular flux is not required.

(4) The process is less sensitive to wind and draft than gas shielded arc welding processes.

(5) It can be used in areas of limited access.

(6) The process is suitable for most of the commonly used metals and alloys.

SMAW electrodes are available to weld carbon and low alloy steels, stainless steels, cast irons, copper, and nickel and their alloys, and for some aluminum applications. Low melting metals, such as lead, tin, and zinc, and their alloys, are not welded with SMAW because the intense heat of the arc is too high for them. SMAW is not suitable for reactive metals such as titanium, zirconium, tantalum, and columbium because the shielding provided is inadequate to prevent oxygen contamination of the weld.

Covered electrodes are produced in lengths of 9 to 18 in. (230 to 460 mm). As the arc is first struck, the current flows the entire length of the electrode. The amount of current that can be used, therefore, is limited by the electrical resistance of the core wire. Excessive amperage overheats the electrode and breaks down the covering. This, in turn, changes the arc characteristics and the shielding that is obtained. Because of this limitation, deposition rates are generally lower than for a welding process such as GMAW(Gas Metal Arc Welding).

Operator duty cycle and overall deposition rates for covered electrodes are usually less than provided with a continuous electrode process such as FCAW(Flux Cored Arc Welding). This is because electrodes can be consumed only to some certain minimum length. When that length has been reached, the welder must discard the unconsumed electrode stub and insert a new electrode into the holder. In addition, slag usually must be removed at starts and stops and before depositing a weld bead next to or onto a previously deposited bead.

*Article reprinted from Welding Handbook Eighth Edition Volume 2 Welding Processes - AWS*