Shielded Metal Arc Welding (SMAW) Techniques

SHIELDED METAL ARC WELDING, commonly called stick welding, is a widely used welding practice. It can be traced all the way back to the 1800s. Over the years, many advances have been made. Yet it remains a viable and popular form of welding.

Objective:

Identify SMAW equipment, supplies, and best practices.

Key Terms:

alternating current (AC)
amperage
arc length
arc welding
conductor
crater
direct current (DC)
duty cycle
electricity
electrode
electrons
fillet weld
groove weld
padding
polarity
resistance
shielded metal arc welding
surface weld
voltage
weaving
weld root
welder
welding
weldor

Understanding Shielded Metal Arc Welding (SMAW)

When shielded metal arc welding, many pieces of equipment and supplies are needed, so you will need to learn to use them.

WELDING FUNDAMENTALS

You should learn basic fundamentals of welding to better understand the process. First, **welding** is the melting, flowing together, and freezing of metals under controlled conditions. Yet **arc welding** is a process that uses electricity to heat and melt metal. The process operates in a closed electric circuit in which electrons flow from a source—the welder—and return to the source when the circuit is completed. When the electrode is brought in close contact with the base metal, an electric arc jumps the gap to complete the circuit. The arc reaches temperatures around 6,500°F. The high temperature melts the base metal and filler metal, thus joining them and creating the weld.

FIGURE 1. SMAW on pipe.

TERMS

A **weldor** is the person doing the welding. In contrast, the **welder** is the machine doing the welding. **Shielded metal arc welding** is welding in which fusion is produced by heating with an arc between a consumable stick electrode and the workpiece. An **electrode** is a bare metal rod usually coated with chemical compounds called flux. The flux coatings burn in the intense heat and form a blanket of smoke and gas that shields the weld puddle from the air.

The electrode holder is a spring-loaded clamp mechanism used to hold the electrode and make it part of the circuit. The holder is attached to the welder by an insulated cable, and the handles of the holder are insulated to protect the weldor. A ground clamp is a spring-loaded clamp attached to the table or project. The ground clamp is needed to complete the circuit by being attached to the welder. The ground clamp is not insulated because it does not pose a shock hazard.

Electrical Terms

A basic understanding of electrical terms is necessary to fully understand shielded metal arc welding. Because SMAW involves working with electricity and heat, numerous safety procedures must be followed.

- **Electricity** is the flow of tiny particles called electrons through a conductor.

- **Electrons** are negatively charged particles.
- A **conductor** is an item that allows the flow of electrons.
- **Voltage** is a measure of electrical pressure. Most welders operate on a 220-volt source, and the welder changes or transforms the 220-volt pressure to a much lower pressure at the electrode, usually between 15 and 25 volts.
- **Amperage** is a measure of electrical current flowing through a circuit and is an indication of the heat being produced. The amount of current available is determined by the amperage setting on the welder.
- **Polarity** is the direction the current is flowing.
- **Resistance** is the opposition to the flow of current in a circuit; it is what causes the electric energy to be transformed into heat.

When electricity is conducted through a conductor, the movement of the electric energy heats the conductor due to the resistance of the conductor to the flow of electric current through it. The greater the flow of current through a conductor, the greater the resistance to it, and the greater the heat generated (the higher the amperage setting, the greater the heat produced).

Alternating current (AC) is a situation in which electrical current alternates or reverses the direction of electron flow. The arc is extinguished every half-cycle as the current passes through zero, usually at the rate of 120 times per second. **Direct current (DC)** is a situation in which electrons flow in one direction. Direct current is either straight polarity (DCSP) or reverse polarity (DCRP). It can be called direct current electrode negative (DCEN) and direct current electrode positive (DCEP). When the electrons flow from the electrode to the workpiece, it is straight polarity or electrode negative. When the electrons flow from the workpiece to the electrode, it is reverse polarity electrode positive.

WELDING HISTORY

The art of welding is ancient, but the science of shielded metal arc welding is relatively new.

- 1801—An English scientist discovered that an electric current would form an arc when forced across a gap.
- 1881—A French inventor used the carbon arc.
- 1887—A Russian inventor improved on the carbon arc and patented the process.
- 1887—Another Russian discovered that a bare metal rod would melt off by the heat of the arc and act as filler metal in a weld.
- 1889—A North American experimented with the metallic arc and received a patent. A bare electrode was difficult to use and resulted in a weld that was porous, brittle, and not as strong as the base metal.
- 1910—A Swede found that welds were stronger and easier to make when a chemical coating was put on the metal electrode. The coating was called flux because it cleaned the

metal and aided in mixing the filler metal with the vase metal. However, it was difficult to apply.

- 1927—A mass production method was developed to apply the flux to the bare metal rod.

FIGURE 2. Electrodes and electrode holder.

SELECTION OF EQUIPMENT AND SUPPLIES

Several types of equipment and supplies exist. Knowing the right items to utilize for the intended purpose is crucial to a successful outcome.

Welding Machine Classification

Welding machines are classified in several ways.

- The type of output current produced by the welder: AC, DC, or AC/DC
- The service
  - A limited input welder provides satisfactory operation and is fairly inexpensive to operate. The cost is approximately $1 per ampere of output.
  - A limited service welder is used where lower cost is desired because the operation is quite intermittent.
  - An industrial welder has a high-duty cycle, but the price is much higher.
- Power source
  - An electric motor-driven welder is self-contained and requires three-phase power. Electric power runs the motor, which turns a generator to produce DC welding current.
  - An internal combustion engine drives a generator that produces the power for the welder to run.
  - A line voltage welder runs on the power supplied by the power company.

Duty Cycle

Duty cycle is the percentage of a 10-minute period that a welder can operate at a given current setting and is another way to classify welders. A welder with a 60 percent duty cycle can be operated safely for 6 minutes of a 10-minute cycle repeated indefinitely.

Consumerism

When buying a new welder, consider only one made by a well-known manufacturer and distributed by a reliable dealer. Check the nameplate to see if the welder is National Electrical Manufacturers Association (NEMA) rated and approved and listed by Underwriters Laboratories (UL). Compare prices of welders, equal capacity, and the available accessories. Read the guarantee carefully, and ask questions.

Equipment and Supplies

Several other pieces of equipment and supplies are necessary to operate the shield metal arc welder. Two cables, No. 2 gauge, are required. The electrode holder grips the electrode during welding. It should be completely insulated and should have a spring-grip release. In addition, the jaws hold rods in 60-, 90-, 120-, and 180-degree positions in relation to the handle. The ground clamp is fastened to the work or to the welding table. The chipping hammer—with a straight peen and straight cone with a spiral wire-grip—is necessary to remove slag from the weld bead.

Safety Items

Use a wire brush to clean dirt, rust, and slag from metal. Yet you need pliers for handling hot metal. Welding gloves will be ruined by touching hot metal because moisture will be drawn out, so the leather will harden and shrink. Always remember safety glasses or goggles are required to protect your eyes when chipping hot slag and grinding or cleaning metal for joint preparation. Full gauntlet leather gloves should be worn. Also, upper body protection is necessary to protect against rays, heat, spatter, and slag while welding. A head shield is necessary for protection from the rays of the electric arc as well as the heat and spatter of the molten metal.

Filter Lenses

Use clearly labeled filter lenses with standard shade numbers, and be sure they meet the specifications of the welding being performed. For instance, a No. 10 lens meets applications up to 200 amps.

Flux

Electrodes convey electric current from the welding machine into a hot arc between its tip and the metal being welded. Electrodes are covered with flux that provides four important functions.

- Flux protects the molten metal from the atmosphere.
- The flux covering burns in the intense heat of the arc, forming a blanket or shield of gas around the bead. Air contains oxygen and nitrogen that would combine with the metal to cause it to be brittle and weak.

FURTHER EXPLORATION...

ONLINE CONNECTION: Stick Electrodes

Understanding electrodes is an important factor when welding, but it can be hard to figure out what all the numbers and letters mean. Search the Internet for articles that discuss the importance of choosing the right electrodes and how to read the AWS and ASTM numbering systems:

http://www.gowelding.org/welding/stick-smaw/

- Flux mixes with the weld metal, floating the impurities to the top in the form of slag. Slag covers the bead to protect it from the air and to slow the rate of solidification and cooling.
- Flux stabilizes the arc. After the arc is started, current flows across the gap between the end of the electrode and the work.

Electrode Classifications

Current does not jump the gap. It is conducted by a mass of ionized gas. The gas is produced when chemical substances are vaporized by the heat of the arc. Two classifications of electrodes are The American Welding Society (AWS) and the American Society for Testing Materials (ASTM). They have established standard numerical classifications for most electrodes. Every electrode has been assigned a specific symbol, such as E7014. The "E" indicates the electrode is used for electric welding, and the first two digits of a four-digit number indicate tensile strength in thousands of pounds per square inch.

An E7014 electrode produces a weld with 70,000 psi of tensile strength. However, an E6011 electrode produces a weld with 60,000 psi of tensile strength. If the number has five digits, the first three digits indicate tensile strength. The next-to-last digit indicates the welding position for which the electrode is recommended. The last digit indicates the operating characteristics of the electrode. The National Electrical Manufacturers Association (NEMA) has adopted color marking for some classes.

PREPARATION OF METAL

One of the most important and most often neglected parts of a welding job is metal preparation. The metal must be free of dirt, grease, rust, paint, and other impurities that may combine with a molten weld bead and cause it to be weakened. Metal should be cleaned by grinding, brushing, filing, or cutting before welding.

Types of Joints

Preparing the correct type of joint for each kind of metal is crucial to securing strong welded structures. The basic types of joints are the butt, lap, tee, corner, and edge. These joints may be applied to the various weld types: fillet, groove, plug, slot, and surface.

- A tee weld is a type of fillet weld. The **fillet weld** is a weld that has two surfaces at right angles, and the bead is triangular in shape.
- The **groove weld** is a weld made in a space between the two pieces of metal to be joined.
- The plug and slot welds are used to join pieces that overlap. The welds are placed in plug or slot holes. These types of welds commonly take the place of rivets in welded structures.
- The **surface weld** is a bead deposited on a metal surface for the purpose of building up the base metal.

Square Butt Joint

The square butt joint is used on metal sections no thicker than $^{3}/_{16}$ inch. This joint is strong in tension loads but is not good for repeated loads and impact forces.

Single V Butt Joint

The single V butt joint often is used on plate steel $^{3}/_{8}$ inch to $^{3}/_{4}$ inch in thickness. This joint is strong in loads with tension forces but is weak in loads that bend at the **weld root**, which is the bottom of the weld groove opposite the weld face.

Single-Bevel Butt Joint

The single-bevel butt joint is used on metals from $^{1}/_{8}$ inch to $^{1}/_{2}$ inch in thickness, and the bevel is 45 degrees.

Double V Butt Joint

The double V butt joint is fine for all load conditions and often is used on metal sections of more than $^{3}/_{4}$ inch in thickness.

Lap Joint

The lap joint is a type of fillet weld. Its strength depends on the size of the weld bead.

Single Lap Joint

The single lap joint is one of the stronger weld joints. It is used on metal up to $^{1}/_{2}$ inch in thickness.

Double Lap Joint

The double lap joint is almost as strong as the base metal.

T-Joint

The T-joint is a fillet weld and can be used on metals up to $^1/_2$ inch in thickness. It can withstand strong longitudinal shear forces. The T-joint can be square, beveled, or double beveled. The corner joints can be flush, half-open, or full-open.

- The flush corner joint is primarily used on sheet metal.
- The half-open joint can be used on metals heavier than sheet metal and for joints that will not have large fatigue or impact loads. This joint can be welded from one side.
- The full-open corner joint is used for the metals that will carry heavy loads; can withstand large fatigue and impact loads; and can be welded on both sides.

Edge Joints

Edge joints are used for metals less than $^1/_4$ inch in thickness and can only sustain light load applications.

SAFETY

The following are suggested practices and tips that will minimize or eliminate shop accidents when arc welding:

- Wear a welding helmet. In addition, wear leather or special fabric gloves at all times when arc welding to protect yourself from hot electrodes, particles of spatter and slag, and/or the metal being welded.
- Wear high-top shoes to protect your feet and ankles from burns caused by weld spatter. Do not wear clothing with turned up cuffs. Keep your collar and pockets buttoned. Do not wear ragged, oily, or greasy clothing. Also, never weld when your body is exposed (e.g., without a shirt or while wearing a short-sleeve shirt or shorts). If leather clothing is not available, wear woolen clothing rather than cotton. Wool does not ignite as readily and provides better protection from heat.
- Inspect welding cables for broken insulation and frayed conductors. Also, check electrode holder and ground clamps for positive connections before beginning to weld because loose connections and grounds may prove dangerous. In addition, have a dry wooden platform to stand on, or wear rubber-soled shoes when damp floors are present.
- Clear all combustible materials away from the welding area before beginning to weld because flying sparks from the spatter may ignite combustible material several feet from the welding operation. As a result, you should clear the welding area of rags, straw, paper, shavings, and other combustible items before starting to weld.
- Keep matches, lighters, papers, and cellophane wrappers out of your pockets because these items ignite quickly and/or may explode.

- Turn on an exhaust system before beginning to weld because welding fumes soon spread to all parts of the shop and may be injurious when inhaled. Take special measures to avoid noxious fumes that occur when welding or cutting metals containing zinc. Inhaling zinc fumes will cause you to feel ill for several hours after welding.
- Do not strike an arc before covering your face and eyes with the protective shield or helmet. The ultraviolet light rays given off by the arc are the same as those transmitted by sunlight, except they are more intense and concentrated. Exposure to these rays will cause a severe burn. Eye irritation and burn will result if your eyes are not shielded.
- Protect other workers by using a welding screen to enclose your area. Warn people standing nearby by saying "cover," so they cover their eyes when you are ready to strike an arc.
- Never look directly at the arc without protecting your eyes because the rays can penetrate through closed eyelids if you are welding at close range. Also, do not wear contact lenses while welding or around a welder.
- Do not weld barrels, tanks, or other containers that may have held combustible material. These operations are best performed by professional weldors.
- Do not chip slag from a weld unless your eyes and those of others near you are protected by safety glasses.
- Be alert for fires at all times. Because your helmet is lowered and your vision is obscured, your clothing may catch fire without being noticed. Depend on your senses of touch, smell, and hearing to indicate that something is wrong. In case of a clothing fire, strip off the article if possible. Do not run because running fans the flames. Wrap yourself in a fire blanket, or improvise with a coat or a piece of canvas. If there is nothing at hand to wrap in, drop to the floor and roll slowly.
- Handle all hot metal with tongs or pliers to prevent burning your hands or gloves. In addition, place all hot metal where no one will come in contact with it. Also, develop the habit of feeling all metal cautiously before picking it up. Do not leave hot metal where anyone may touch or step on it.
- Guard against saturation of clothing by perspiration or moisture, as this increases the shock hazard.
- Disconnect the welder when repairing or adjusting it.
- Always unplug the welder and put all equipment away when you have finished for the day.
- In case of eye or skin burns, get first-aid treatment. Report all burns and injuries immediately to your instructor.
- Protect fuel tanks and fuel lines when welding near motors or power units. Clean accumulations of dry trash, husks, lint, and chaff off of farm machinery before welding. The paint on machinery may start to burn from the heat of welding.

CREATION OF THE WELD

Good welds can be attributed to the correct selection and manipulation of the electrode and welding current. Welding takes a good bit of skill because multiple things have to happen at

once. Using the following skills in unison to perform your welds will help you achieve welds of acceptable quality. First, the proper amperage setting for any welding job is necessary for good penetration with minimum spatter. When the amperage is correct, a sharp crackling sound can be heard. A humming sound will indicate too low an amperage setting. As a result, the deposited electrode will pile up, leaving a narrow, high bead that has poor penetration and little strength. A popping sound will indicate too high an amperage setting, and the bead will be flat with excessive spatter. The electrode will become red hot, and the metal along the edge of the bead will be undercut. Determining correct amp settings depends on the thickness of the base metal and the diameter of the electrode.

FIGURE 3. This worker is welding.

Arc Length

Learning to maintain the correct arc length for the electrode you are using is necessary to be successful. **Arc length** is the distance from the tip of the bare end of the electrode to the base metal. It is equal to the diameter of the bare end of the electrode.

Angle

The correct angle of the electrode will depend on the type of weld you are doing. Hold the electrode at a 90-degree angle to the work—called work angle—as viewed from the end of the workpiece, and 5 to 15 degrees in the direction of travel—travel angle.

Speed

The correct speed of travel affects the amount of electrode deposited and the uniformity of the bead. It should produce a bead 1.5 to 2 times the diameter of the bare end of the electrode. Following proper procedures when preparing to weld and striking the arc will develop confidence in your abilities.

Final Check

When you are ready to weld, make a final check to see that flammable materials are out of the way and those unnecessary tools are not lying around. Make sure the machine is turned off, and set the machine to the desired amperage. Insert the bare end of the electrode in the electrode holder, and hold the end of the electrode about 1 inch above the metal at the point

where the weld is to be started. Then turn on the welder. Lower your helmet, and bring the electrode in contact with the work, removing it slightly. Current jumps this small gap and creates the electric arc. The moment the arc is struck, the concentration of intense heat—estimated between 6,000° and 9,000°F—melts the base metal and the end of the electrode to form a molten metal pool called a **crater**.

Starting the Arc

If you are having trouble starting the arc, you can use two methods: a striking movement similar to striking a match and a tapping movement where the electrode is quickly tapped on the surface of the metal to prevent it from sticking to the base metal. If your electrode is not instantly pulled away, it will fuse with the base metal and stick. However, if the electrode is pulled too far away, the arc will be extinguished.

Weaving and Padding

To make a wider bead or when doing out-of-position welding, use a motion of weaving or oscillating movements. **Weaving** is running a bead with a sideways or oscillating motion. It is used when covering a wide area with weld metal or to maintain a large molten weld crater. **Padding** is the process of building up several layers of weld deposit by running overlapping passes. It is used to rebuild worn pieces by building up the piece to an oversized condition and grinding or machining to the correct size.

WELDING POSITIONS

Welding cannot always be done in a nice flat position, so you must learn the other positions when welding: horizontal, vertical, and overhead. The flat position produces stronger welds than any other position.

The control of distortion, warping, and cracking is a major concern when welding because of forces that cause their shape or position to change. During the welding process, the arc heats the area being welded, causing it to become larger or expand. As heat is removed, the surrounding metal and air cause a cooling effect upon the heated area. This results in the metal becoming smaller or contracting. There is no way to avoid the laws of expansion and contraction, but ways exist to control it. For instance, use tack welds, or practice intermittent welding, where short beads are run and spaces are skipped between them. Use the back step method, in which each short pass is started ahead and run back into the previous weld. Balance the contraction of one bead by the contraction of another. Clamp material in a jig or other support, and preheat the material because it makes welding easier and decreases the possibility of cracks.

Summary:

Shielded metal arc welding is welding in which fusion is produced by heating with an arc between a consumable stick electrode and the workpiece. For arc welding to truly make sense, some basic understanding of electrical terms is necessary. With SMAW and all forms of welding, preparing the correct type of joint for each kind of metal is crucial to securing strong welded structures.

Checking Your Knowledge:

1. What is SMAW?
2. What is polarity?
3. List at least four safety procedures.
4. Explain arc length.
5. What are the two ways to start an arc?

Expanding Your Knowledge:

Visit a local welding shop to discuss the advantages and disadvantages of SMAW. Observe one of the professionals as he or she welds. Take note of the techniques used, and share your notes with your classmates.

Web Links:

Welding
http://www.lincolnelectric.com/assets/US/EN/interactive/elearning/htmls/index.htm

Welds
http://www.millerwelds.com/resources/improving-your-skills/stick/

Welding Electrodes
http://www.weldguru.com/welding-electrode.html