Minimizing Defects in Submerged Arc Welding

Understanding and controlling the submerged arc welding process can help you reduce or avoid defects

BY DAN GERBEC

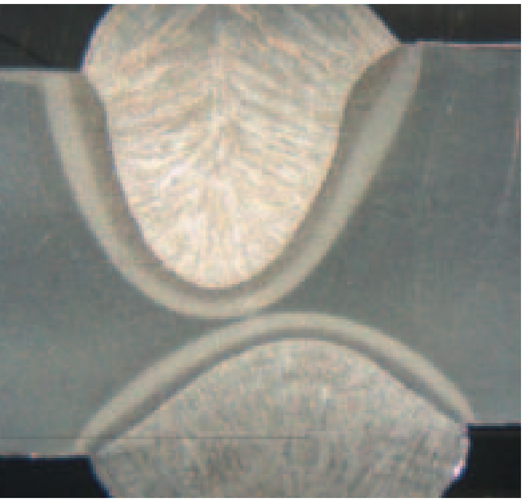

Fig. 1 — Excessive voltage or travel speed, insufficient current, or improper joint design can lead to insufficient penetration in the weld.

DAN GERBEC (dgerbec@esab.com) *is product manager, Submerged Arc Consumables, ESAB Welding & Cutting Products, Hanover, Pa.,* www.esabna.com.

Submerged arc welding (SAW) can be a highly productive tool for fabricators, but as with most welding technologies, defects can occur. This leads to rework and a reduction in overall productivity.

Defects can be reduced or avoided by understanding and controlling the process. Many defects can be eliminated in the preweld stage. Let's take a look at the process and some common defects and how they can be avoided.

The SAW Process

The submerged arc welding (SAW) process was first patented in 1935 and licensed by Union Carbide a year later. Union Carbide marketed the process and related products under the "Unionmelt" trademark. Since that time, many advances have been made to the process, including multiwire, cored wire, and cladding applications, but the fundamentals remain the same: an arc is created using a bare wire under a granular flux covering. The flux contributes to the mechanical properties of the weld, deoxidizes the base metal, and protects the molten weld metal from atmospheric contaminants. When the weld is complete, it is covered by an easily removed layer of slag. Submerged arc welds are typically made using some form of automation, although it is possible to make a subarc weld with a hand-held torch.

Submerged arc welding offers many advantages over other welding processes, including the following:

- High weld quality
- High deposition rate
- Deep penetration
- High-speed welding on thin sheet steels
- Almost no fume or light emission.

Nothing is perfect, however, and subarc welding does have its limitations. This form of welding is limited to the flat and horizontal positions, requires precise joint preparation, and does not allow observation of the arc and the process during the weld. Despite its limitations, the submerged arc process is popular in a number of industries, notably shipbuilding, wind tower fabrication, ASME vessel fabrication, pipe mills, and fabrication of utility poles and trailer beams.

The Role of Flux

Submerged arc fluxes are generally grouped into neutral and active fluxes. Many fluxes alloy some Si and Mn to the weld metal while others melt off these elements. The intensity of this chemical reaction depends on the quantity of flux interacting with the wire. An increase in voltage or arc length will lead to increased alloying or melt-off of these elements. Neutral fluxes are used in multilayer welding of unlimited plate thickness with appropriate wires. The alloying of elements, especially Si and Mn, is carefully controlled.

Active fluxes add a significant amount of Si, acting as a deoxidizer, and Mn to the weld metal. They enhance resistance to porosity and improve bead appearance and toughness in high-dilution applications. Active fluxes are primarily used for single-pass or multilayer welding with limitation of layers, with three to five layers normally the maximum.

Process Variables

Submerged arc welding can be done with either direct current (DC) or alternating current (AC) power supplies. Direct current is the most commonly used because it is easiest to control and provides the best arc starting and stability, except at high currents, when arc blow can be a problem. Direct current electrode positive, or reverse polarity, is used most often and yields the deepest penetration. Direct current electrode negative, or straight polarity, provides up to 25% less penetration but offers the highest deposition rates and is useful in cladding applications or applications with poor joint fitup. The characteristics of AC power fall between straight polarity and reverse polarity but offer the benefit of eliminating arc blow because the rapidly changing polarity prevents magnetic fields from forming.

Once the polarity of the power supply is chosen, amperage, voltage, travel speed, wire size, and electrode extension all play a role in the shape, size, and quality of the weld deposit.

Amperage is directly related to deposition rate and depth of penetration, so an increase in amperage will increase both deposition rate and penetration.

Arc voltage is a measure of arc length and has an inverse relationship to depth of penetration and a direct relationship to bead width. An increase in arc voltage, therefore, will cause a decrease in penetration and an increase in bead width.

Travel speed, also known as feed rate, is inversely related to bead size and penetration, so a reduction in travel speed increases bead size and penetration.

Wire size also affects deposition rate and penetration, but contrary to popular belief, a larger-diameter wire may not be better than a smaller-diameter wire. A small-diameter wire has a smaller cross-sectional area, and therefore, at the same current, a smaller-diameter wire will provide a faster melt-off and consequently a higher deposition rate and increased penetration vs. a larger wire.

Electrode extension is the distance from the end of the contact tip to the surface of the workpiece. As a rule of thumb, electrode extension should be about eight times the wire diameter. For example, the electrode extension for a ⅛-in.-diameter wire should be approximately 1 in. Using a longer electrode extension will result in reduced penetration and increased deposition. The increased deposition is caused by the I^2R resistive heating of the wire.

Identifying Submerged Arc Welding Defects

In most cases, a SAW defect has more than one cause and more than one possible cure. The cure to the problem is often to do the opposite. For instance, if the defect is caused by excess current, simply lowering the current will usually resolve the defect. But selecting the proper cure will depend on your objective. For example, melt-through can be resolved by decreasing the welding current, increasing travel speed, or reducing the bevel angle. In most cases, reducing the bevel angle is not a realistic option, so you must either reduce the current or increase travel speed. Since most fabrication applications favor higher productivity, it generally makes sense to increase travel speed.

Here are some common weld defects and their most likely causes:

- **Insufficient penetration.** Caused by low current, high voltage, high travel speed, and/or improper joint design — Fig. 1.
- **Melt-through.** Caused by high current, too great a bevel angle, too small a root face or root opening, and/or slow travel speed.
- **Porosity.** Caused by joint contamination by rust or moisture, a shallow flux burden, insufficient penetration into the backing weld, a contaminated backing weld, improper joint fitup, flux fines, and/or flux moisture — Fig. 2. In the cases where porosity is caused by joint contamination or a high level of atmospheric moisture (humidity), the problem may be solved by using a more active flux or preheating to remove moisture.
- **Surface pock marks.** Can be caused by joint contamination, moisture on the plate, and/or moisture in the flux. Surface pock marks can be avoided by using an active flux, preheating the plate, and keeping the flux in an oven at 250°–300°F.
- **Arc blow.** Caused by an imbalance in the magnetic field surrounding the workpiece. Arc blow is typically experienced at high DC welding currents and can be cured by reducing the current, using AC, and demagnetizing the fixture.

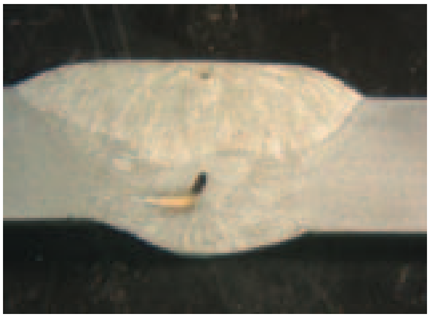

Fig. 2 — Porosity is most commonly caused by the presence of moisture in the weld.

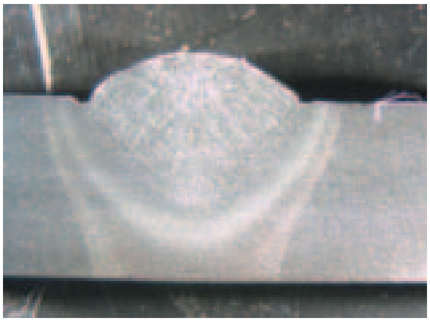

Fig. 3 — Undercut generally occurs when the amount of wire deposited is not great enough to fill the gaps in the material caused by the voltage. This can be avoided by reducing travel speed, increasing current, or decreasing voltage.

- **Reinforcement, or bead, rollover.** Typically caused by high current, low voltage, or low travel speed.
- **Undercut.** Occurs when there is insufficient molten metal added to the pool to fill the gaps in material created by the voltage — Fig. 3. The simplest ways to fix undercut are to reduce travel speed, increase current, or decrease voltage. Improper wire alignment may also be the culprit and is easy to remedy.
- **Slag sticking.** Slag will tend to stick in a deep groove, especially if the weld is concave. The cure is usually to reduce voltage. Increasing travel speed and decreasing current may also work.

Understanding the SAW process and understanding your own objectives in using that process are the keys to successfully dealing with submerged arc welding defects. ◆