Arc welding on a stainless steel tube mill

Tips for gaining maximum output

By Bernard Mannion

Tube mills produce pipe and tube by roll forming a continuous strip of material until the edges of the strip meet together at a weld station. At this point, the welding process melts and fuses the edges of the tube together, and the material exits the weld station as welded tube.

Many times the main limitation to product output is the welding speed. The welding speeds at which tube mills operate thus are usually more than 10 times the welding speeds for other applications. It is with these significantly higher-than-normal welding speeds that many tubing manufacturers must struggle to gain a competitive edge.

Arc Welding Stainless Steel Tube

GTAW. Manufacturing stainless steel tubing with arc welding usually employs the gas tungsten arc welding (GTAW/Tig) process as the source of the electric arc that melts the base material and forms the weld. In the GTAW process, an electric arc is established between a tungsten electrode and the part to be welded. To start the arc, a high-voltage signal (usually 3.5 to 7 kilovolts) is used to break down (ionize) the insulating properties of the shield gas and make it electrically conductive for a tiny amount of current.

A capacitor dumps current into this electrical path, which reduces the arc voltage to a level at which the power supply then can supply current for the arc. The power supply responds to the demand and provides weld current to keep the arc established. The metal to be welded is melted by the intense heat of the arc and fuses together.

Plasma Arc. In the plasma welding torch, the tungsten electrode is located within a copper nozzle that has a small opening at the tip. A pilot arc is initiated between the torch electrode and nozzle tip. This arc then is transferred to the metal to be welded.

By forcing the plasma gas and arc through the constricted orifice of the nozzle, the torch delivers a high concentration of heat to a small area. This can produce a stiff arc that offers good arc stability and consistent welds. Given that the tungsten electrode is protected within the copper nozzle, the plasma process usually allows for many more hours of welding before maintenance on the electrode is required.

Whether using the GTAW or plasma arc process, the output of the tube mill depends on the arc welding speed and total time spent welding. Therefore, for maximum tube mill output, these important welding issues should be considered:

1. **Material weldability**
2. **Shielding gas**
3. **Tube mill consideration**–the ability of the tube mill to provide consistent, high-quality material edge presentation under the welding arc
4. **Welding system considerations**–the ability of the welding system to provide a consistent welding arc for optimum weld quality and maximum number of hours of welding

Material Weldability

Weldability is a word used only in the welding industry, and a search for it in Webster's dictionary will be fruitless. The word “weldability” usually means the ease with which a metal material melts and flows together to form a weld joint that exhibits almost as much mechanical, thermal, and corrosion resistance properties as the base metal.

Weldability also implies an ability to produce an acceptable weld speed under the welding arc, and this can vary greatly according to the material. In general, the 300 stainless steels used in tubing possess a high degree of weldability. The 400 series stainless steels also are weldable, but post-weld treatment is an issue to consider. Copper, aluminum, nickel-based alloys (INCONEL®, MONEL®, and HASTELLOY®), titanium, and other precious metals possess some degree of weldability but may present challenges with surface oxides and molten metal flow.

Shielding Gas

Mixing small percentages of hydrogen with the argon shield gas (90 to 98 percent argon, 10 to 2 percent hydrogen) can have a beneficial effect on the resultant weld for these reasons:

1. The hydrogen acts like a lubricant within the molten weld material, thus increasing the wettability of the weld joint. The result of this effect is that the two edge materials flow together faster, and thus welding speed can be increased.

2. The hydrogen becomes a part of the energy transfer process to the weld, producing a deeper weld profile with less energy from the arc. This means that less weld current and a smaller weld puddle can be used for the same weld penetration. The physical size of the weld pool is a speed limitation, so a smaller weld puddle offers higher weld speeds.

3. The hydrogen has a scrubbing effect on the weld, producing a cleaner weld.

Naturally, with every benefit comes a drawback. A hydrogen addition is not suitable for welding all tube materials, especially some exotic alloys, because it can cause hydrogen embrittlement in the resultant weld. However, for the more commonly used stainless steels, there is no issue with embrittlement.

Adding hydrogen to the shield gas reduces the life of a standard 2 percent thoriated tungsten welding electrode. Under these conditions, some manufacturers use 1.5 percent lanthanated tungsten, which can more easily accommodate the hydrogen addition.

Tube Mill Considerations

It is important for the tube mill to provide consistent, high-quality material edge presentation under the welding arc. The mill should provide clean edge material mated together without any sway of the weld seam under the welding arc, even at high speeds. Failure to accomplish this will result in decreased weld quality and most likely a reduction in tube mill speed to achieve the required quality.

Weld joint fit-up depends on the weld specification requirements. Tubing is produced according to loose or rigid tolerances, depending on the application for which the tube is to be purchased. When the two edges of the tubes are butted together for welding, two of the main considerations are mismatch and gaps.

Usually, the tube mill weld box will be set up to ensure that the weld box rollers or shoes guide the tube endings together and hold them in position under the welding arc.

The weld produced by any tube mill is a function of the heat input for a given length of tubing. For a given welding amperage, the tube mill must maintain mill welding speed within close tolerances. Products are available that tie the welding current amperage exactly to the tube mill actual speed rather than the programmed speed. These systems also have assisted in minimizing the scrap tubing produced at tube mill shutdown and start-up.

Welding System Considerations

With any welding system, the equipment used must provide a stable welding arc within close tolerances to produce consistent-output weld quality. The parameters under which a tube mill performs are even more critical because of the welding speeds involved.

By examining more closely all the elements of the welding system, tube suppliers can reduce or eliminate some of the reasons that welding systems seem to develop a personality of their own. A typical welding system comprises many of the following elements.

Power Supply/Arc Starter. The engine behind the arc, the power supply, and arc starter provide the means to initiate the welding arc and provide stable power by which the tube material is fused together. At first, these power supplies were simple, large transformers delivering brute force to the arc. Many of these systems now have been replaced by power supplies of greater efficiency and accuracy. Recently, high-power linear amplifiers have offered tube producers a constant-current power supply capable of correcting arc instabilities in milliseconds.

Arc Distance Control. The quality and repeatability of welding depend to a great extent on the arc shape and voltage, which are proportional to the distance between the torch electrode and the workpiece. The arc gap distance should be kept constant during welding. Arc distance controllers offer the ability to preset and maintain the arc gap within closely defined tolerances.

Arc distance control in conventional welding provides the ability to hold constant the distance the electrode remains from the part to be welded. This normally is a means to accommodate part runout or to move back the electrode as the part is built up through the addition of filler material to the weld zone. Arc distance control for tube mill welding provides a means to position and modify the electrode arc gap quickly on changing electrodes and to modify the position of the electrode to accommodate some amount of electrode wear.

Magnetic Arc Control. Tube mill weld speeds are so high, and the material moves so rapidly under the arc, that magnetic arc control systems sometimes are used to hold the welding arc in a precise and repeatable position over the material to be welded. This prevents the arc from moving around or from being attracted to the high-speed weld pool moving away below. With a simple setup, a magnetic arc control unit easily can add at least 5 percent to the output speed of a tube mill.

Tungsten Electrode. The tungsten welding electrode, the source of the welding arc, is one of the most important elements of the welding system, but it also is one of the most commonly ignored by tube mill users. Each time the mill shuts down and starts up again, a certain amount of scrap is produced, and the issue of getting the whole system stable again for continuous output becomes paramount.

Some tubing producers continue to grind their tungsten electrodes manually and then wonder why they get inconsistent results. For tube mill welding, keeping close tabs on the tungsten welding electrode is one step that can improve the consistency of welding output with minor effort. Many tube mill users now purchase their electrodes preground by a supplier. This helps to eliminate the variability of operators grinding the electrodes with slightly different geometries.

Modifying tungsten electrode material, keeping electrode tip geometry consistent, and using polished electrode surface finishes can improve electrode arc starting ability, improve arc stability, and increase electrode life.

Recommendations for Improving Weld Performance

Given the ever-increasing weld quality requirements of the tubing industry, more and more companies are looking for ways to ensure that their weld quality is up to snuff. The easiest way to improve weld quality and consistency is to improve quality right at the arc. Suggestions include the following:

1. Use an arc distance control system to maintain the correct distance from the electrode to the tube when performing GTAW. This is likely to improve arc and weld output consistency.
2. Consider using the plasma weld process to improve arc stability, weld penetration, weld speed, and electrode arc life.
3. Use specialty electrode materials such as lanthanated tungsten with optimized tungsten tip geometry and polished electrode tip surface.
4. Install a magnetic arc control system to hold the arc as stable as possible. This allows for higher welding speeds and increased tube mill output.
5. Consider using shield gas mixtures such as argon/hydrogen or others to improve the wetting of the metals when they are in the molten form. This can allow for increases in welding speed and improve overall tube mill output.

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Elderfield & Hall / PRO-FUSION
10901 McBride Lane, Knoxville TN, 37932.
Phone: 865.671.7682. Fax: 865.671.7686.
Email: sales@pro-fusiononline.com
Website: www.pro-fusiononline.com