Arc Welding of Aluminum and Magnesium

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Aluminum and magnesium are commonly selected for applications requiring low weight and improved corrosion resistance. Aluminum is used in manufacturing of ships, automobiles, military vehicles, space vehicles, and airplanes. Lately, magnesium has seen increased use in a range of applications due to lightweighting initiatives. Arc welding processes are commonly selected to weld these alloys because the required equipment is widely available and relatively inexpensive, and there is a well-established knowledge base. The degree to which these alloys can be joined using arc-based processes is largely dependent on their specific alloy chemistries. Many magnesium alloys are readily arc welded, as are 2xxx, 5xxx, and 6xxx series aluminum alloys; however, 7xxx series aluminum alloys are not typically arc welded due to the high risk of micro-cracking in the heat affected zone.

Arc Welding Processes

Gas tungsten arc welding (GTAW) and gas metal arc welding (GMAW) are the most commonly used arc-based processes for welding aluminum and magnesium. GTAW is often selected for low-volume applications requiring superior weld quality. Welding of aluminum and magnesium alloys with GTAW is relatively straight-forward provided that joints are adequately cleaned, the wire is properly stored, and shielding gas recommendations are followed. Aluminum and magnesium can both be welded using argon, helium, or a combination of the two gases.

GMAW is often selected for high-volume applications requiring high productivity rates, with the process operated in a spray transfer or pulsed-spray transfer mode. Most welding equipment manufacturers provide programs for common aluminum wire types and diameters. While few have spray-transfer and pulsed-spray-transfer options available for magnesium, EWI has experience working with manufacturers to develop custom programs. An example of a multi-pass magnesium GMAW weld is provided in Figure 1.

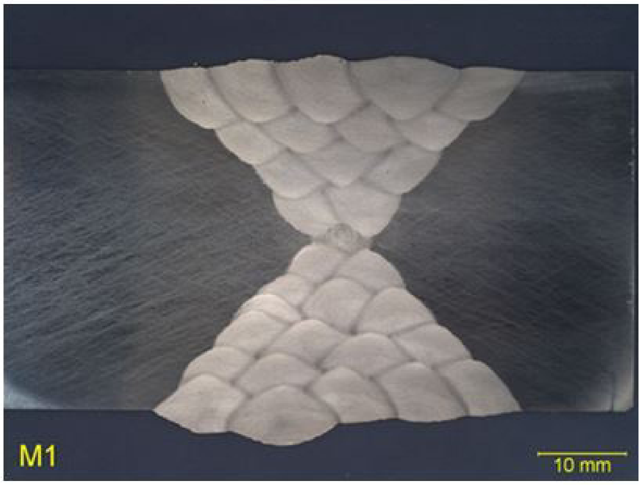

Figure 1: Multi-pass GMAW weld made on 1.5-in thick magnesium

Wire feeding is an important consideration since both material types are relatively soft. Conventional push-type wire feed systems may be suitable for high-strength alloy variations or large-diameter wires; however, pull-type and push-pull-type systems are preferred.

Alternative arc welding processes include plasma arc welding (PAW) and tandem gas metal arc welding (T-GMAW). The latter is used extensively for manufacturing aluminum trailers and aluminum liquid-natural-gas containers as it produces welds with quality comparable to GMAW at double the deposition rate and travel speed (Figure 2). GTAW, GMAW, and PAW can be deployed manually, mechanized or automated; however, T-GMAW is used exclusively with mechanized or automated equipment due to its high travel speeds and the need to maintain a consistent torch position with respect to the weld joint.

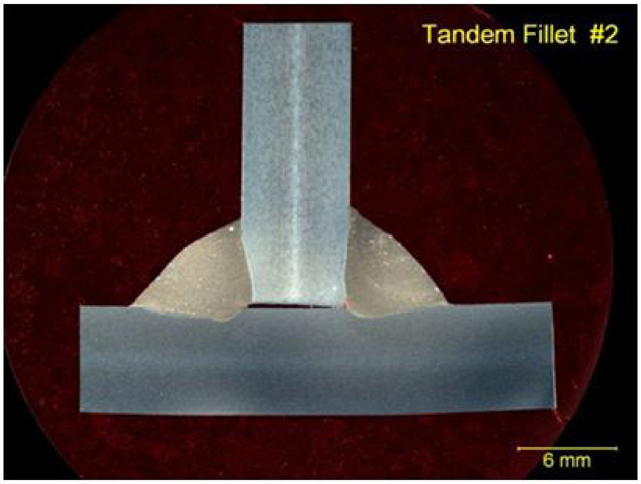

Figure 2: T-GMAW fillet welds made on ¼-in thick 6061 Aluminum at a travel speed of 60-ipm

Arc Welding Challenges

Porosity is a concern when arc welding aluminum and magnesium alloys since both material types have high solubility of hydrogen in the molten state and low solubility of hydrogen in the solid state. As a result, if the hydrogen level in the molten weld pool is above the solid solubility limit, excess hydrogen will form porosity as the weld pool cools and solidifies. Hydrated oxides on the wire surface and joint surfaces, contamination on the joint surfaces due to improper pre-cleaning methods, and inadequate gas shielding can all introduce hydrogen to the weld pool. As such, wire and joint surfaces must be free of hydrated oxides and contaminants, and the shielding gas must meet the required dew point levels.

Joint Preparation

Aluminum and magnesium both form tenacious oxides with melting temperatures significantly higher than the underlying base material. Since the presence of these oxides on the joint surface can lead to incomplete fusion defects, surfaces within one inch of the joint should be adequately cleaned prior to welding. Steel brushes and most grinding wheels and pads can embed contaminants and are therefore not recommended. Rotary powered stainless-steel wire wheels, manual stainless-steel wire brushes, carbide burrs, and carbide-tipped wheels are suitable since these tools don't embed contaminants.

Safety Considerations

Proper personal protective equipment should be worn when arc welding aluminum and magnesium. An appropriate face shield must be worn when preparing the joint, the correct arc welding lens should be used during welding, and skin should be covered to prevent exposure to the damaging ultra-violent light of the arc. Magnesium chips and dust burn readily, and should be removed from the area prior to welding. A "Class D" fire extinguisher or other suitable means for extinguishing magnesium fires should be available during the preparation and welding of magnesium.

Nick Kapustka is an applications engineer in EWI's Arc Welding group. He has built a successful reputation in the field of arc welding, specifically focusing on aluminum, titanium, magnesium, nickel-based alloys, and advanced high-strength steels (AHSS). Nick is proficient in applying gas metal arc welding (GMAW) processes for critical applications such as the repair of aerospace components, and has completed extensive work on the arc welding of magnesium and nickel-based alloys.