Welding Magnesium Alloys by GTA, Flux-Assisted GTA (A-TIG) and Laser Processes

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Introduction

Magnesium is a potential structural material for future applications. The recent interest in this light metal has drawn some attention toward its welding. Magnesium alloys typically melt between 600 and 640°C and only require two-thirds the energy required to melt aluminum. In theory, they are consequently weldable by any process used for aluminum, particularly gas-tungsten-arc-welding (GTAW) and laser beam welding (LBW). As with other materials, the weldability of magnesium alloys is influenced by both the process (and its heat flow) and the material (composition and initial microstructure) and can be discussed accordingly. The use of chemical fluxes to improve GTA welding, mainly by increasing weld penetration, is also discussed.

Experimental Procedure

The bead-on-plate welding of die-cast AZ91 alloy and extruded magnesium alloys (AZ21, AZ31, AZ61, AZ80) was investigated. GTA and flux-assisted GTA (A-TIG) welding were performed with a DC electrode negative. For flux-assisted GTA welding, various metal chlorides were selected based upon their potential alloying effect. For comparison, bead-on-plate welds were also produced with both a 1.2 Nd:YAG laser and a 6-kW CO_2 laser. The welds were prepared for standard metallographic examination (optical and electron microscopy), X-ray diffraction, glow discharge spectroscopy, micro-hardness testing and tensile testing.

Results and Discussion

The few alloying elements added to magnesium, including aluminum and zinc in the AZ alloys, promote eutectic transformation as a final stage of solidification. The eutectic partitioning also leads to intermetallic phases that contribute to the enhanced properties of magnesium alloys (as compared to pure magnesium).

Alloying affects weldability, starting with the melting efficiency. Because the intermetallic phases reduce thermal diffusivity considerably, the fusion zones in alloy AZ91 are larger than in alloy AZ21. Also, the intermetallic phases have low melting temperatures, a factor that causes liquation in the heat-affected zone. Alloy AZ91 is thus more susceptible to liquation than a leaner alloy like alloy AZ21.

When compared to the base metal, the weld fusion zone is often significantly harder, because finer microstructures and macro-segregation of alloying elements (such as aluminum) occurred at high welding speed and high cooling rates respectively. When keyhole welding at high power density, fusion zone composition can be changed due to evaporation. Despite vapor losses in magnesium and zinc, laser welds almost invariably exhibited higher mechanical properties than GTA welds.

GTA welding with chemical fluxes has been proposed to boost the efficiency of GTA welding closer to that of the laser welding process. It was found that fluxes could increase the penetration of the weld pool over one hundred percent. Criteria for selecting adequate GTA welding fluxes are discussed with respect to knowledge of the welding metallurgy of magnesium alloys.

Conclusions

GTA, flux-assisted GTA and the laser welding processes all produced sound welds in all AZ magnesium alloys investigated. For a given alloy, weldability depended strongly on the welding process and its associated thermal history. Laser welding generated welds with better properties than arc welding. GTA welding can be improved with the use of chloride fluxes.