A. Variable Polarity Arc Welding Studies on 6061/Al_2O_3/10_w

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Introduction

Aluminum metal-matrix composites (Al-MMCs) combine the properties of a ductile Al alloy matrix with those of a suitable reinforcement, usually a higher modulus ceramic like Al_2O_3. Consequently, Al-MMCs offer higher specific modulus and specific strength relative to monolithic Al alloys. An improved understanding of welding of Al-MMCs is required for more widespread acceptance. Like Al alloys, Al-MMCs are commonly joined using various arc processes. Variable polarity (VP) is typically used for arc welding of Al alloys to remove surface layers of Al_2O_3 and enhance wetting. However, the effects of VP on the Al_2O_3 reinforcement have not been studied.

Technical Approach

Plates of 6061/Al_2O_3/10_w (1/4" thick) were supplied by Duralcan USA. Autogenous, bead-on-plate welds were made with both GTAW (DCSP and VP) and VPPAW processes using automatic equipment. A Hobart HPW 400 power supply with a custom designed torch (1/8" EWP) was used for VPPAW. VPPAW welds were made using 80 to 85 A and a travel speed of 9 ipm with different ratios of SP and RP times. GTA welds were performed using a Miller Synchrowave 500 AC/DC power supply using the following parameters (3/32" EWTH-2): 125 A (rms), 13 V (rms) and 10 ipm with varying percent of RP.

Results/Discussion

After welding, the welds were sectioned transverse to the welding direction, prepared for metallographic analysis using standard procedures and examined using an optical microscope. GTA welds made with DCSP exhibited arcs which appeared stiff and narrow. However, the arcs for VP GTA welds were erratic and very broad, much more so than when welding monolithic Al alloys. The surfaces traversed by the VP GTA arcs appeared "frosted", and the width of this area increased dramatically with increasing percent of RP. For example, at 66% RP, the width of the cleaned area was almost 1". The weld penetration also decreased severely with increasing percent of RP due to broadening of the arc. Metallographic sections of the GTA welds showed no depletion of the Al_2O_3 reinforcement. However, VP GTA welds showed small melt pools surrounding individual Al_2O_3 whiskers on the surface of the fusion zone and well onto the base metal. The melt pools are thought to be sites where a cathode root attaches momentarily to an oxide whisker during the RP cycle and causes momentary local melting.

Very different behavior was observed for VPPAW. For VPPA welds, large volumes devoid of Al_2O_3 reinforcement were evident along the top center portions of the fusion zone. The lack of Al_2O_3 is believed to result from cathodic cleaning by the narrow focused plasma arc in the keyhole during the RP cycle. The volume of the cleaned area appeared to increase with increasing ratios of RP to SP time.

Differences in cleaning behavior between GTAW and VPPAW for this material are thought to stem from process differences. VPPAW arcs are constricted and stiff. Consequently, the VPPAW arc does not spread, and Al_2O_3 reinforcement is cleaned throughout the volume intersected by the keyhole. Conversely, GTAW arcs are not constricted and widespread surface cleaning results.

Conclusions

Cathodic cleaning of Al_2O_3 reinforcement appears to occur during the RP cycle of VPGTAW and VPPAW of Al-MMCs. However, the processes exhibit different behavior owing to differences in the process physics. For GTAW, the arc became increasingly erratic and weld penetration decreased significantly with increasing percent of reverse polarity. For VPPAW, large volumes devoid of Al_2O_3 reinforcement were evident, and extent of the cleaned area appeared to increase with increasing RP times. Consequently, the percent of reverse polarity should be limited for VP arc welding of Al-MMCs to ensure proper penetration and retain stiffness in the fusion zone.