B. Friction Stir Welding of 2219 Aluminum: Behavior of Intermetallic Particles

By G. Cao and S. Kou, University of Wisconsin

Introduction

The present study was carried out to investigate the behavior of intermetallic particles in friction stir welding (FSW) of aluminum alloys using the binary alloy 2219 (Al-6.3Cu) as a model material. The objective was to observe the response of the intermetallic-compound particles Al_2Cu in alloy 2219 to the actions of friction heating and shearing during FSW, such as possible liquation due to eutectic reactions between the particles and the aluminum matrix and changes in the particle size and morphology. Some computer simulations have suggested that friction heating can cause liquation in some aluminum alloys during FSW, such as alloy 7075.

Procedure

Alloy 2219, which is essentially a binary Al-Cu alloy, was selected as the material for study because of its clear lower bound of the melting temperature range, that is, the eutectic temperature 548 ^oC at which the θ (Al_2Cu) particles react with the aluminum matrix to cause liquation. The workpiece was 20 cm long, 10 cm wide and 7.9 mm thick.

In addition to FSW, gas-metal arc welding (GMAW) of alloy 2219 was also conducted to provide a benchmark for checking liquation in FSW of alloy 2219.

The microstructure of the resultant welds was examined by both optical and scanning electron microscopy (SEM). The composition of the particles in the alloy was determined by energy dispersive spectroscopy (EDS) to help identify the particles.

Results and Discussion

It was found that in GMAW of alloy 2219, θ (Al_2Cu) particles acted as in-situ microsensors clearly indicating the onset of liquation by reacting with the surrounding aluminum matrix and forming distinct composite-like eutectic particles upon reaching the eutectic temperature.

In FSW, on the other hand, no evidence of θ-induced liquation was found as the welds contained θ particles alone and no eutectic particles, suggesting that the eutectic temperature was not reached during FSW.

However, in most friction stir welds large θ particles were observed, some exceeding 100 μm and even 1 mm in length as compared to the normal θ particles of only about 10-15 μm in length in both the base metal and the weld, that is, the stir zone or nugget. The large θ particles appeared to have formed during FSW from agglomeration of fractured θ particles and the smaller ones of the θ particles in the workpiece. No apparent correlation between the extent of agglomeration and the welding condition was found.

It was noticed that, when agglomerated Al_2Cu particles were found, they were often around the pin at the end of the weld. This suggests that the flow of the plasticized material around the pin during FSW might have encouraged the retention of agglomerated Al_2Cu particles around the pin. North and coworkers (1997, 1998) friction welded iron-based superalloy MA 956 and metal-matrix composite 6061/Al_2O_3 and observed both particle agglomeration and fracture. They suggested that the flow of the plasticized material promotes the retention of agglomerated particles (Y_2O_3, Al_2O_3 and Ti(CN)) and fractured particles (Al_2O_3), consistent with their calculated material flow

patterns. The effect of material flow on particle fragmentation, retention and agglomeration in friction welding may shed some light on how the agglomerated Al_2Cu particles have formed in alloy 2219 even though friction welding is different from FSW.

Conclusions

GMA welds of alloy 2219 shows that θ (Al_2Cu) particles act as in-situ microsensors for detecting the onset of liquation by forming distinct composite-like eutectic particles upon reaching the eutectic temperature.

There is no evidence of liquation in FSW of alloy 2219 because the welds contain θ particles alone and no composite-like eutectic particles.

Large θ particles can form during FSW of alloy 2219, some exceeding 100 μm and even 1 mm in length, as compared to 10 - 15 μm of θ particles in the base metal and normal θ particles in the friction stir weld.

The large θ particles are likely to have formed during FSW from agglomeration of fractured θ particles and the smaller ones of the θ particles in the workpiece.

Agglomerated θ particles, when they are found in friction stir welds, are often around the pin at the end of welding. This suggests possible retention of agglomerated θ particles by the flow of plasticized material around the pin during welding.

No apparent correlations have been found between the extent of agglomeration of θ particles in friction stir welds of alloy 2219 and the welding condition.