Effects of tool design and welding parameters on the properties of dissimilar magnesium/aluminium friction stir welded lap joints

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Abstract:
Friction stir welded lap joints between dissimilar WE43 magnesium and AA2024-T3 clad aluminium alloys were performed using various welding conditions including tool geometry, rotation and travel speeds. The microstructural features were analyzed by metallographic examination. Intermetallic phases were detected in the weld zone. Different microstructures were observed in the stir zone which can be attributed to using different travel and rotation speeds. Hook features and other imperfections were identified in the joints. The tool design as well as welding conditions that permitted to minimize these defects were established.

Keywords: Friction Stir Welding, dissimilar joints, lap joints, aluminium, magnesium.

Introduction

Weight reduction is an important issue for a wide variety of industries, such as aerospace and automotive industry. Aluminium alloys have been widely used for structural and non-structural applications. In the recent years, magnesium alloys are being searched and used to optimize the structure for increase strength and reduce weight. However, the welding of dissimilar aluminium and magnesium parts is difficult using traditional welding methods. Friction Stir Welding (FSW) has demonstrated a promising capability on joining aluminium and magnesium alloys because can significantly mitigate the challenges normally associated with fusion welding processes, including susceptibility to hot cracking, compositional segregation of alloying elements and precipitation of intermetallic compounds (IMC) [1][2].

Experimental procedure

1.8 mm thick WE43 magnesium alloy and 1.6 mm thick AA2024-T3 clad aluminium alloy sheets have been used for FSW lap joints. All the tests have been conducted with WE43 on the top. FSW welds have been performed in an I-STIR PDS4 machine using a tool with a threaded and three flats probe. The dimensions for the tool were a shoulder diameter of 12 mm and a probe diameter of 4 mm. Two different probe lengths have been used in order to analyse the effects of the tool design: 1.9 mm and 2.3 mm. Table 1 shows the different rotational and travel speed selected for each probe length.

Table 1. Welding conditions.

Tool probe length	Welding parameters
1.9 mm	800 rpm– 300 mm/min
	1000 rpm – 150 mm/min
	1400rpm – 40 mm/min
2.3 mm	800 rpm – 300 mm/min
	1000 rpm – 150 mm/min
	1400rpm – 40 mm/min

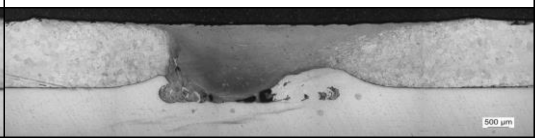
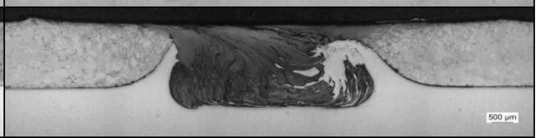
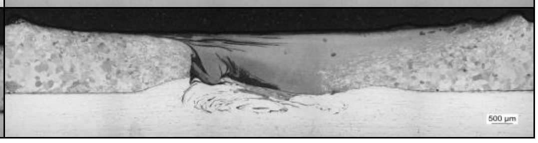
Metallographic examination of the welds have been conducted on cross-sectioned specimens that have been prepared following standard metallographic procedures, with final polishing using diamond paste of 1 µm particle sizes. Then, the samples have been etched in a solution of 10 ml acetic acid, 10 ml water, 6 gr picric acid and 100 ml ethanol for approximately 3 seconds, rinsed in water and dried in a warm airflow. Weld cross sectional features of the FSW lap joints have been investigated by an Olympus GX51 light optical microscope.

Microestructural results and discussion

Table 2 shows the cross-sectional macrographs of the welds. The hook sizes in the welds performed with a probe length of 1.9 mm are smaller than those performed by a probe length of 2.3 mm. Furthermore, for each probe length, the hook sizes achieved with cold conditions (low rotational speed and high travel speed) are generally smaller than those obtained in hot conditions. However, in the weld performed with a probe length of 2.3 mm and 1400 rpm – 40 mm/min welding condition, the hook size is not as big as expected. The vertical flow of aluminium observed in lower heat input conditions is not observed in this case. The reason behind this change in aluminium material behavior could be the higher heat input and temperatures obtained in welds performed with 1400 rpm – 40 mm/min, as the larger softening of the aluminium material prevents its vertical flow and penetration into the magnesium material. Regarding to microestructural features, in case of a probe length of 1.9 mm, there are more IMC in higher heat input conditions. For a probe length of 2.3 mm, typical features of FSW lap joints such as a hook at the advancing side as well as a cold lap at the retreating side can be observed. Moreover, a hook in the retreating side is noted for cold conditions. A wormhole defect can be observed in the condition of 800 rpm-300 mm/min resulting from the inappropriate material flow and consolidation. This defect disappears increasing the heat input.

Respect to the surface quality, it has been observed that an excessive toe flash is achieved in high heat input conditions.

Table 2. Cross sectional macrographs of the welds.

	L_{probe}= 1.9 mm	L_{probe}= 2.3 mm
800 rpm- 300 mm/min		
1000 rpm- 150 mm/min		
1400 rpm- 40 mm		

Conclusions

The welds performed with 800 rpm-300 mm/min-L_{probe} 1.9 mm and 1400 rpm-40 mm/min-L_{probe} 2.3 mm have the smaller hook sized and fewer amounts of IMC. Among these welds, the first one has the best surface quality.

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References

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