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ORIGINAL ARTICLE

The role of pin eccentricity in friction stir welding of Al-Mg-Si alloy sheets: microstructural evolution and mechanical properties

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Abstract

In friction stir welding, geometrical and motion features of the tool or pin greatly influence the interaction between the tool and workpiece as well as the resulting joint microstructure and mechanical properties. In order to enhance the material flow by optimizing the tool geometrical features, a new strategy was proposed in this study to introduce eccentric motion by offsetting the pin from the tool shoulder, and thin Al–Mg-Si aluminum alloy plates were friction stir welded by varying the pin eccentricity. The material flow and mixing characteristic were analyzed by optical microscope and tracer material method. The grain size and micro-texture of the stir zone were analyzed by electron backscatter diffraction. Uniaxial tensile tests and digital image correlation were conducted to evaluate the mechanical properties and observe the in situ strain evolution. The results show that pin eccentricity has a positive effect on promoting the material flow and grain refinement in the stir zone. The texture intensity was increased as pin eccentricity was introduced, and the dominant texture component converted from C $\{001\}<110>$ (without eccentricity) to B/$\overline{\text{B}}$ $\{112\}<110>$ when eccentric pin was used. However, no discerning change can be seen in the thermal history between samples. Despite the variation in softening of the stir zone with eccentricity, the ultimate tensile strength change was negligible. The average ultimate tensile strength reached approximately 198 MPa regardless of the pin eccentricity, and all joints fractured at the heat-affected zone. However, the softened stir zone caused by pin eccentricity resulted in an obvious increase in the joint elongation. It can be concluded that pin eccentricity significantly improved the material flow and grain refinement in the stir zone as well as enhanced the toughness of the weld joint.

Keywords Friction stir welding · Aluminum alloy · Microstructure · Mechanical properties · Eccentricity

1 Introduction

Friction stir welding (FSW) is a relatively novel solid-state welding technique invented by The Welding Institute (TWI) of UK in 1991 [1]. It has been widely recognized that FSW is an environmentally friendly, energy-effective, and versatile joining technology [2, 3]. Compared with the conventional fusion welding techniques, FSW can lower heat input, reduce distortion, narrow heat HAZ, and increase mechanical properties. FSW technique has shown its advantages in welding some

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