Microstructure evolution and mechanical properties of double-sided friction stir welded AZ31B Mg alloy

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Introduction

As the lightest structural metal, the magnesium alloy has many advantages, such as high specific strength and stiffness, realizing the goal of lightening, energy saving and consumption reduction. Friction stir welding (FSW), a relatively new solid-state joining technique, is the optimum choice for magnesium alloys with inferior formability. However, there are still some aspects that should be improved in FSW, such as the speed, efficiency and possibility of welding thick plates. At the same time, eliminating the kissing bond and incomplete root penetration and randomizing the strong texture formed by FSW are also required. The double-sided FSW (DFSW) can improve the welding speed and efficiency. The reduction in torque and enhanced deformation could be achieved during DFSW. In the present study, the AZ31B Mg alloy was welded by the DFSW, and the microstructure and mechanical properties after the DFSW were investigated.

Experimental procedures

The extruded AZ31B (Mg-3%Al-1%Zn) plates with 4mm thickness were welded by the DFSW. The upper rotating tool made of SKD61 had a shoulder with a diameter of 15mm and a threaded probe with a height of 3.8mm and a diameter of 5mm. The tool having only a flat shoulder with a 15mm diameter was used as the lower tool. The DFSW was conducted at a rotation rate of 300rpm and travel speed of 300-500mm/min, with the upper tool tilt of 3°. The upper tool rotated by counterclockwise (CCW) and clockwise (CW) while the lower tool always rotated CCW. The microstructural examination of the samples was carried out on a cross section perpendicular to the welding direction (WD). The tensile test was used to study the mechanical properties of the joints.

Results and discussion

The cross-sectional macrostructure of the one-sided FS welded joint with the optimum welding parameters and double-sided FS welded joints (500mm/min travel speed) with different rotation directions of the upper tool (CCW or CW) during the DFSW are shown in Fig.1. The size of the stir zone (SZ) of the DFSW joint is larger than that of the one-sided FS welded joint. The diverse material flows and shapes of the SZ are formed by the different welding parameters and heat-input for the DFSW.

A fine grained structure was found in the SZ of the DFSW joints. The grain size decreased with an increase in the travel speed. For the CCW joints, the equiaxed grains of the SZ were smaller than that of the CW joints which was due to more deformation heat caused by the different material flows in the SZ. There were many recrystallized fine grains in the thermo-mechanical affected zone (TMAZ, as shown in Fig.1) of the CCW joint, whereas large deformed grains were found in the TMAZ of the CW joint. The EBSD analysis results indicated that there were
oriented grains with high Shimid’s factor in the TMAZ, while the middle region has a relatively lower texture intensity and oriented grains with low Shimid’s factor in the CCW joint. Fig.2 shows the EBSD maps and pole figures of the middle place in the SZ (as shown in Fig.1) of the CCW (Fig.2 (a) and (b)) and the CW (Fig.2 (c) and (d)) double-sided FSW joints. From Fig.2 (a) and (b), it is found that the grains mainly with the orientation on the <0001> direction are nearly parallel to the welding direction in the middle of the SZ of the CCW joint. For the CW joint, it is found that the grain orientation in the middle of the SZ is more complicated from Fig.2 (c) and (d). Because the different material flows caused by the upper and lower tool may meet at this location, that makes the grain orientations different. Therefore, the texture intensity of this location is relatively lower.

Fig.3 indicates that the tensile strength increased with an increase in the travel speed for the CCW joint. The CCW joint welded at a 500mm/min travel speed has the highest tensile strength. The relatively fine grains in TMAZ cause the fracture location far from TMAZ. The CW joints had relatively lower tensile strengths which may due to the defect, coarse grains and high Shimid’s factor at the TMAZ. The optimized welding parameter for the CW joint should have a higher mechanical property.

Conclusions
The different rotation directions of the upper tool and travel speeds caused the diverse material flows and different shapes of the SZ of the DFSW joints. The different material flows and heat-input during DFSW affected the microstructure and mechanical properties of the joints.