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Interfacial Microstructure of Friction Stir Welded A7075 Aluminum Alloy†

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Abstract

The interfacial structure of an A7075 friction stir welded joint was investigated using optical microscopy. Three different structures appear at the center of the FSW nugget; a stir zone by the shoulder and the pin on the top, a stir zone by the pin in the middle and a thermo-mechanically affected zone on the bottom.

KEY WORDS: (friction-stir welding), (7075 aluminum alloy), (interfacial microstructure)

1. Introduction

A7075 alloy is the major material for aerospace body structures. Those structures are designed under severe demand of weight-saving with retained strength. The development and improvement of welding techniques for this material is the most effective way to satisfy the requirements. However, welding of A7075 alloy is difficult[1]. That is why only riveting has been used for joining A7075. Recently, Friction Stir Welding[2] (FSW) has become one of the most attractive welding techniques for aluminum alloys. Some papers have dealt with the FSW of A7075 aluminum alloy[3, 4]. Summarizing those reports, A7075 can be welded by FSW. However, A7075 FSW joint possesses 25% lower ultimate strength, 45% lower yield strength and 50% lower elongation than the base material. Furthermore, those deteriorated properties do not recover after post weld heat treatment. The results imply that welding process and resultant microstructure of the welds must be controlled precisely. However, the weld formation mechanism is still not clear since FSW process is a complicated combination of friction heating and plastic flow of materials. Solution of these problems are required for a detailed understanding and optimization of the FSW process.

As the first step to clarify the weld formation mechanism of FSW, the interfacial microstructure of an A7075 FSW joint was investigated.

2. Experimental Procedure

A7075-T651 aluminum alloy plates, which thickness, length and width are 5.0 mm, 200 mm and 70 mm, respectively, were used in the present study. The plates were butt-welded using the FSW technique with tool rotation rate of 25 s^{-1}, welding speed of 5.0 mm s^{-1}, tool plunging depth of 4.50 mm and tool tilt of 3.0° forward. The diameters of the shoulder and the pin of the FSW tool were 15.0 mm and 6.0 mm, respectively. Then samples for metallographic observation were taken from the joints. The joints were cut perpendicular to the welding direction, polished with colloidal silica suspension and etched with Dix-Keller reagent. The samples were observed by optical microscope.

3. Results and Discussion

Fig. 1 shows an interfacial microstructure of A7075 FSW, welded with tool rotation rate of 25 s^{-1}, welding speed of 5.0 mm s^{-1} and plunging depth of 4.50 mm. The advancing side and the retreating side are on the left side and the right side of the figure, respectively. In the center of the joint interface, a fine-grained region with concentric oval contrasts is observed. On the top of this region, another fine-grained region without concentric oval contrasts exists. The retreating side of this region appears as a mixture of coarse grains and fine grains. These two fine-grained regions are both called the Stir Zone without classification. However, these two regions are expected to have different mechanical properties because they have different microstructures. Therefore, it is proposed to call the regions by different names; e.g., the stir zone by pin (SZP) for the former and the stir zone by shoulder and pin (SZS) for the latter. The SZS is spread over the top surface of FSW bead as a thin layer. On the other hand, the bottom region beneath the SZP has a similar structure to the base metal. At the boundary between this region and the SZP, a 0.30 mm-thick thermo-mechanically affected zone (TMAZ), which is

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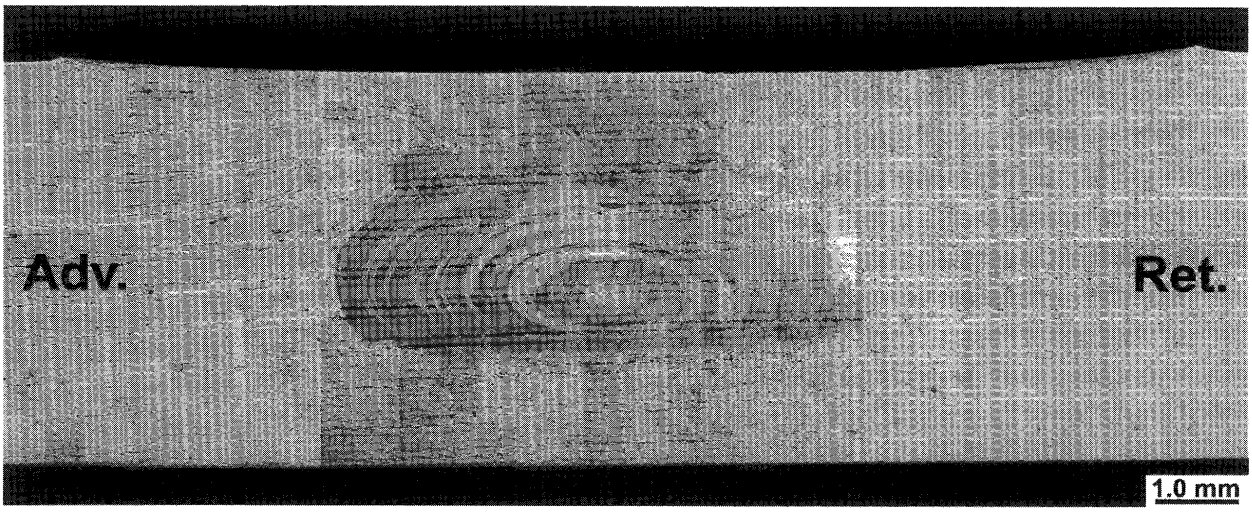

Fig. 1 Interfacial microstructure of A7075 / A7075 FSW joint welded with tool rotation rate of 25 s^{-1}, welding speed of 5.0 mm s^{-1} and plunging depth of 4.50 mm. Advancing side is on the left.

spread over both sides of SZP and SZS, is observed. The original interface is observed as a kissing-bond defect on the retreating side of this region. Although the FSW tool position is adjusted on the center of the contacting interface, the center of the weld bead is shifted 1.14 mm to the advancing side. This result implies that the FSW tool suffers a counter force directed from the retreating side to the advancing side during the FSW operation. Furthermore, in the region where the tip of the FSW tool has passed, sufficient stir for grain refinement and bonding is not achieved.

4. Conclusion

The following points were clarified by observation of the interfacial microstructure of an A7075 FSW joint.

(1) Three different structures appear on the center of the FSW nugget; SZS on the top, SZP in the middle and TMAZ on the bottom.
(2) The FSW tool suffers a counter force directed from retreating side to advancing side during the FSW operation.
(3) The tip part of the FSW tool does not stir and weld the work material sufficiently.

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