Structure and Mechanical Properties of ADC12 and A5083 Dissimilar Friction Stir Welded Joints†

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Abstract

Friction stir welding (FSW) is a relatively new solid-state joining process. This joining technique is a green technology due to its energy efficiency, environment friendliness, and versatility. In this study, the structure and mechanical properties of ADC12 die casting alloy and A5083 dissimilar joints welded by FSW under different welding conditions were systematically investigated. The micro-structural refinement of silicon particles was found obviously in the stir zone. The Vickers hardness levels of the ADC12 and A5083 base metal were 95±10 and 80±5 Hv0.1, respectively. Distinctly different Vickers hardness levels from 80 to 120 Hv0.1 were produced corresponding to various micro-structural features in the stir zone. The transverse tensile failure of the prepared sound joints occurred at the ADC12 base metal, which means that the tensile strength of the joints was higher than 250 MPa. Although the fractured surface of ADC12 base metal exhibited a few big river patterns, it showed mainly big dimple patterns in which small river patterns were observed. At the welding speed of 4.17 mm/s and downward force of 12.3 kN, the longitudinal tensile strength and elongation of the stir zone were 347 MPa and 11.6%, respectively.

KEY WORDS: (Friction stir welding), (Dissimilar welding), (ADC12), (A5083), (Mechanical properties).

1. Introduction

There has been a considerable effort over the past twenty years to develop advanced manufacturing techniques to join aluminum alloys, particularly related light-weight vehicles with high fuel efficiency by replacing steels. Friction stir welding (FSW) is a novel solid-state joining process and has been demonstrated to be especially effective in joining virtually any commercial 1xxx, 2xxxx, 5xxxx, 6xxxx, and 7xxxx aluminum alloy as well as virtually any dissimilar system of these alloys[1-4]. Furthermore, the application of FSW to aluminum die casting alloys has a significant practical concern for grain refinement, the fine dispersion of intermetallic compounds, cast defects and dendritic structure removals in the process. ADC12 aluminum alloy combines excellent die casting properties with satisfactory heat, wear and corrosion resistance currently used for transmission cases[5]. A5083 is a representative solid-solution-hardened Al-Mg based alloy which possesses many interesting characteristics as a structural material, such as low price, moderately high strength, good corrosion resistance, high formability in conjunction with superplasticity[6]. Therefore, the joints between wrought Al alloy and die casting Al alloy have high potential to make more efficient design for expanding the usage of Al alloys in vehicles. In this study, ADC12 and A5083 plates were welded by the load control type FSW machine and the structural and mechanical properties of dissimilar ADC12-A5083 joint were investigated and discussed.

2. Experimental procedures

ADC12 aluminum die casting alloy and A5083 plate with thickness of 4 mm were used as base materials in this study. The gas content of ADC12 was about 2.6ml/100g. **Table 1** lists the chemical compositions of the two base materials. A load control type FSW machine was used to join the dissimilar alloys. The tool consisted of a concave shoulder of 15 mm in diameter, and a cylindrical screw probe 5mm in diameter and 3.9 mm in length. The tool rotation speed in a clockwise direction was fixed at 1250 rpm according to the research results reported by Kim et al.[3], and the downward force and welding speed were varied.

Table 1 Chemical compositions (mass%) of ADC12 and A5083 base materials.

Alloy	Si	Cu	Fe	Zn	Mn	Mg	Pb	Ni	Cr	Ti	Al
ADC12	11.82	2.35	0.81	0.56	0.18	0.17	0.06	0.04	--	--	Bal.
A5083-O	0.08	0.02	0.26	0.01	0.62	4.63	--	--	0.08	0.02	Bal.

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3. Results and discussion

3.1 Macro- and microstructure of the joints

Figure 1 shows the macro- and microstructure of transverse cross sections of typical joints friction stir welded at the tool rotation speed of 1250 rpm, downward force of 9.8 kN and the welding speed of 4.17 mm/s. To investigate the micro-structural changes of the base metals of ADC12 and A5083 in FSW process, they are also included in the figure. The macro-image of the weld zone exhibited no weld defects and macro-structural continuity. The onion ring pattern of the stir zone indicated that the materials flow in complex vortex with swirl features like the other dissimilar FSW joint[7-9].The dendritic structure with an acicular type of eutectic Si in the ADC12 base metal disappeared in the stir zone. The Si particles became finer in the stir zone comparing with that in ADC12 base metal for the crumbling due to the intensive stirring of the tool. And it was finest in the bottom region for the high resistance of plastic flow related to its low temperature. Therefore, it was also found that the size of the Si particle was influenced by the plastic flow and temperature.

3.2 Mechanical properties of the joints

Figure 2 shows the mid-thickness Vickers hardness profile. The Vickers hardness levels of the ADC12 and A5083 base metal were 95±10 and 80±5 Hv0.1, respectively. Distinctly different Vickers hardness levels from 82 to 120 Hv0.1 were produced corresponding to various micro-structural features in the stir zone. The transverse tensile failures of the prepared sound joints occurred in the ADC12 base metal, which means that the tensile strength of the joints was higher than that of ADC12 base metal. The fractured surface of ADC12 base metal is shown in **Fig. 3**. Although the fractured surface exhibited a few big river patterns (Fig. 3(a)), it showed mainly big dimple patterns in which small river patterns were observed through the high magnification SEM image (Fig. 3(b)).

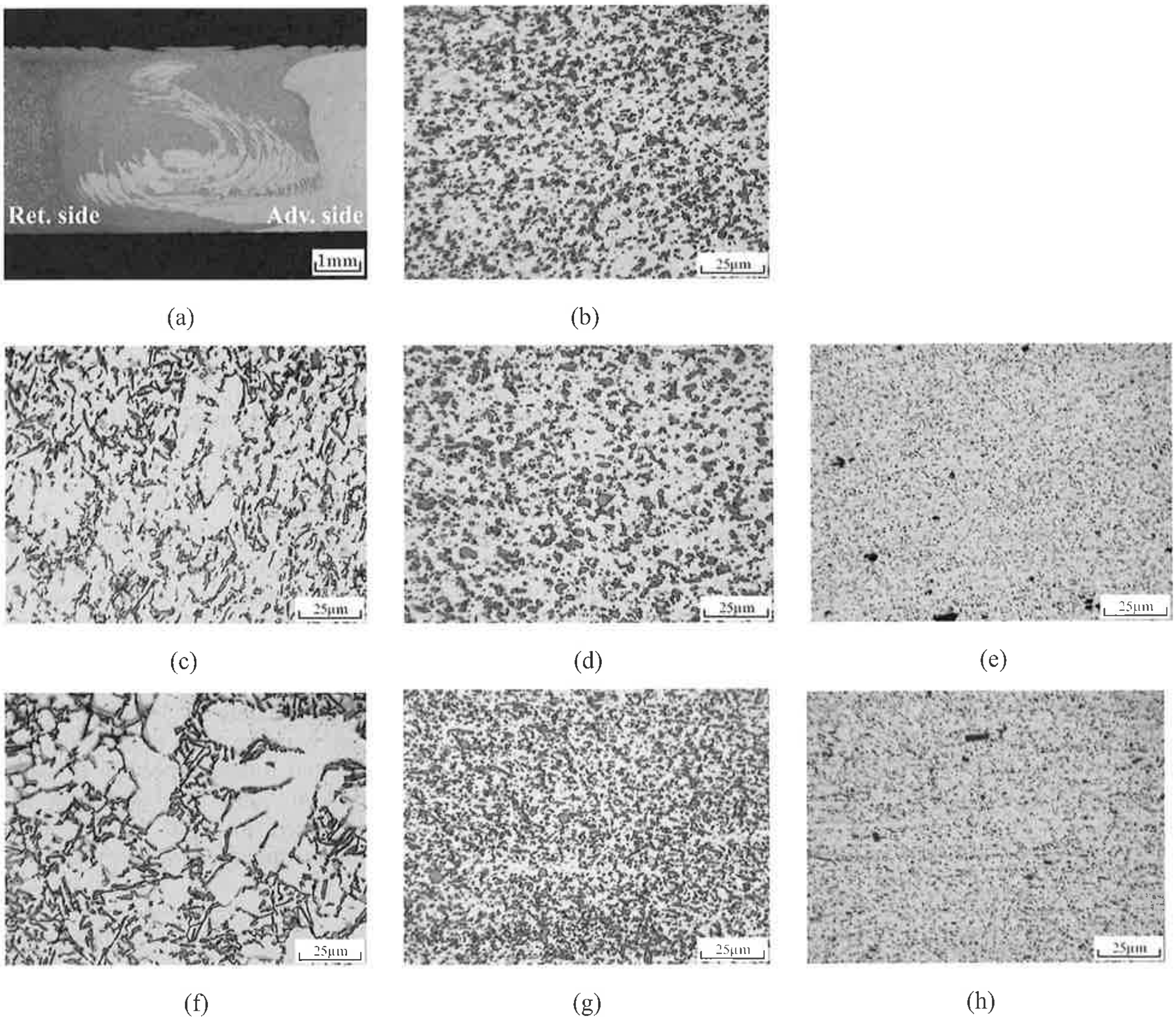


Fig. 1. Macrostructure of FSW joint (a) and microstructures of upper region of stir zone (b), TMAZ of retreating side (c), center region of stir zone (d), TMAZ of advancing side (e), ADC12 base metal (f), bottom region of stir zone (g) and A5083 base metal (h).

3.3 Tensile strength and elongation of the stir zone of the joints

Figure 4 shows the longitudinal tensile results of the stir zone at a tool downward force of 12.3 kN and various welding speeds compared with those of the base metals. At the welding speed of 4.17 mm/s, the tensile strength and elongation were 347 MPa and 11.6%, respectively. The tensile strength had a tendency to decrease with an increase of welding speed. At the welding speed of 12.50 mm/s, the standard deviation of the tensile strength became wider, which indicates that the materials did not flow smoothly somewhere. **Fig. 5** shows the relationship between the longitudinal tensile strength, elongation of the stir zone of FSW ADC12-A5083 joints and the tool downward force at a welding speed of 8.33 mm/s. At the tool downward force of 9.8 kN, the tensile strength and elongation were highest, which resulted from the favorable materials flow and heat input. As shown in **Fig. 6**, the fractured surface of the stir zone had the typical fine dimple characteristics and its average dimple size approximated to 1-3 μm.

4. Conclusions

The structure, mechanical properties and fractured surface of ADC12 die casting alloy and A5083 dissimilar joints welded by FSW under different welding conditions were investigated. The micro-structural refinement of silicon particles was found obviously in the stir zone. The Vickers hardness levels of the ADC12 and A5083 base metal were 95±10 and 80±5 Hv0.1, respectively. The Vickers hardness of the stir zone increased slightly. The transverse tensile failure of the prepared sound joints occurred in the ADC12 base metal, which means that the tensile strength of the joints was higher than 250 MPa. Although the fractured surface of ADC12 base metal exhibited a few big river patterns, it showed mainly big dimple patterns in which small river patterns were observed. At the welding speed of 4.17mm/s and tool downward force of 12.3 kN, the longitudinal tensile strength and elongation of the stir zone were 347 MPa and 11.6%, respectively.

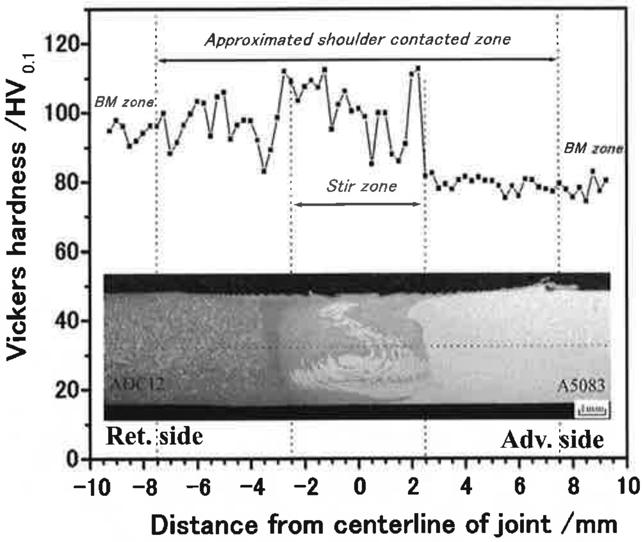
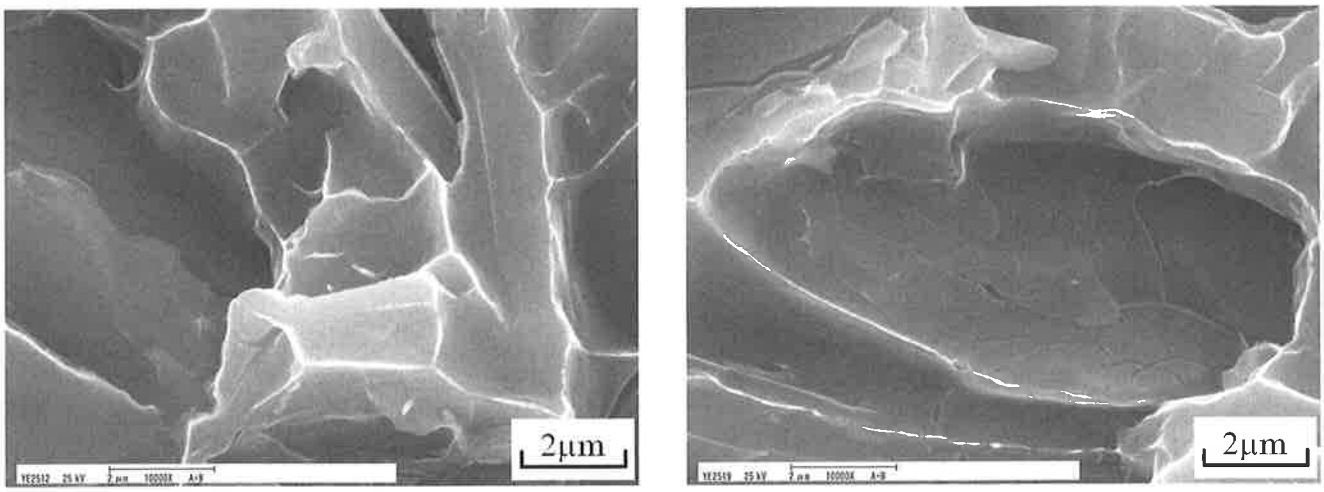


Fig. 2 Vickers hardness profile of a typical joint.



(a) (b)

Fig. 3 SEM images of typical fractured surface of the ADC12 base metal ((a) A few big river patterns, (b) Big dimple patterns where small river patterns existed.)

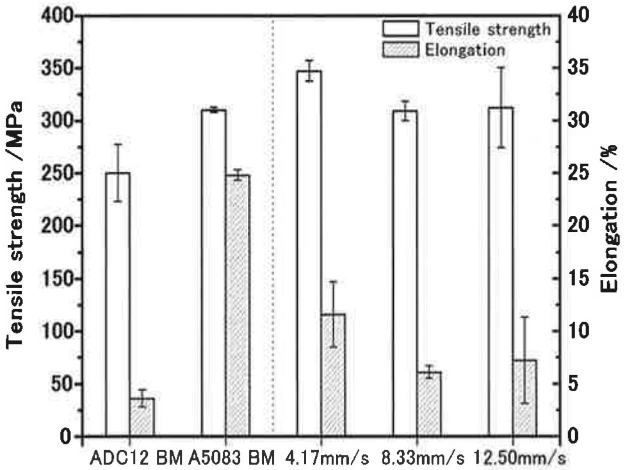


Fig. 4 The longitudinal tensile strength and elongation of the stir zone at tool downward force of 12.3 kN and various welding speed comparing with ADC12 and A5083 base metals.

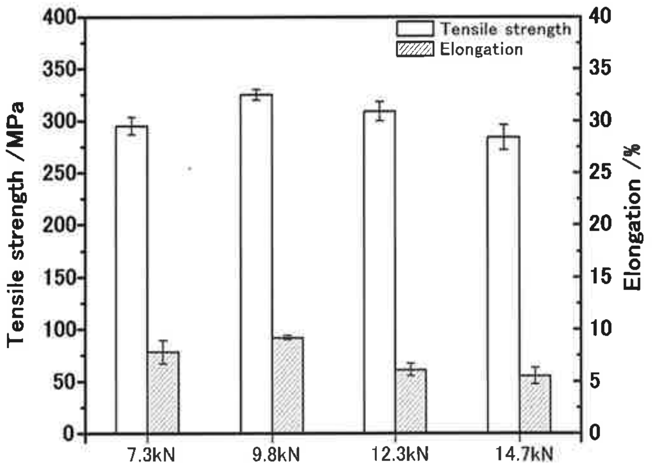
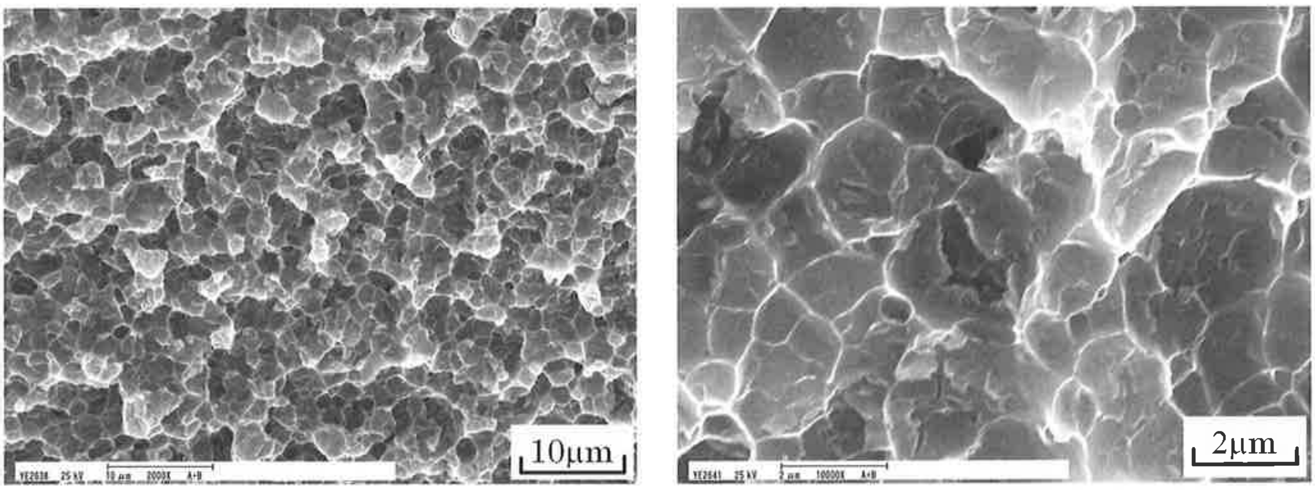


Fig. 5 The longitudinal tensile strength and elongation of the stir zone of the joints at a welding speed of 8.33 mm/s and various tool downward forces.



(a) (b)

Fig. 6 SEM images of typical fractured surface of stir zone of the ADC12-A5083 joint. ((a) Low magnification, (b) High magnification)

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