THE JOINT CHARACTERISTICS OF FRICTION STIR WELDED AZ91D MAGNESIUM ALLOYS

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ABSTRACT

A study was carried out to grow an understanding of the microstructural development of friction stir welds on an AZ91D magnesium alloy, and to evaluate the mechanical properties of the welds. AZ91D plates with the thickness of 4mm were used, and the microstructural development of the weld zone was investigated using optical and scanning electron microscopes. Square butt welding joint with good quality was obtained at the conditions of under 187mm/min of travel speed with 1100 to 1250 rpm of tool rotation speed. The microstructure within the weld region consisted of fine equiaxed grains with no evidence of the original dendritic structure. The hardness tests showed slightly increased harness in the weld region, and the minimum hardness measured is in that of the parent material. Tensile strength of the weld zone was remarkably improved due to very fine recrystallized structure. XRD pattern of weld zone revealed the removal of β intermetallic compounds, $Mg_{17}Al_{12}$, which had been distributed in the base metal

KEYWORDS

Friction Stir Welding, FSW, Magnesium Alloy, AZ91D, Ingot

1. Introduction

Magnesium alloys represent unique structural materials combining high specific strength with the capability to absorb shock and vibration energy [1, 2]. For instance cast Mg alloy AZ91D containing 9%Al and 1%Zn is most widely used in aircraft and engine building industries due to its high castability, low density, and good mechanical properties. However, the principal drawback of Mg alloy as a structural material is its high chemical activity leading in many cases to a low corrosion resistance. This means that in the conventional welding process there should be such a pre-treatment procedure before welding Mg alloys. And that is the reason why conventional fusion welding methods were rarely used in welding Mg alloys. It is, thus, very desirable that new joining technologies should be developed and made accessible for industrial usage [3, 4]. Friction Stir Welding (FSW) seems to be such a reasonable welding process at this point.

FSW was developed and patented in the early 1990s and then has rapidly become an important industrial joining process [5]. This new technique had resulted in low distortion and high joint strength compared to other techniques. Moreover FSW is capable of joining all kinds of Al alloys. But very little is known about weldability of Mg alloys since recent studies have nearly restricted to that of Al alloys [6-10]. There have to be more knowledge about weldability of Mg alloys.

The objectives of this work are to develop an understanding of the microstructural development of friction stir welds on an AZ91D Mg alloy, and to determine the mechanical properties of the welds.

2. Experimental procedures

The material selected for this investigation was 4mm thick as-cast AZ91D Mg alloy. The plates ware cut to 140mm long and 70mm wide. The material was a commercial Mg alloy AZ91D with a nominal composition of 85%Al, 0.75%Zn, 0.3%Mn, Fe and Ni below 0.001%, and Mg as a balance. The complete chemical composition is exhibited in table 1.

Table 1. Chemical composition of AZ91D Mg alloy (in wt%)

Al	Mn	Ni	Cu	Zn	Ca	Si	K	Fe	Mg
9.1	0.17	0.001	0.001	0.64	<0.01	<0.01	<0.01	<0.001	Bal

The range of travel speed for the welds investigated was between 32 and 187 mm/min, whereas the spindle speed varied from 1100 to 1800 rpm. Microstructural investigation and analytical studies were carried out using optical and scanning electron microscopy, EDS and XRD.

Transverse and longitudinal tensile tests were carried out to determine the strength of the weld zone. The schematic illustration of the transverse and longitudinal tensile test specimens used in this test was as shown in figure 1.

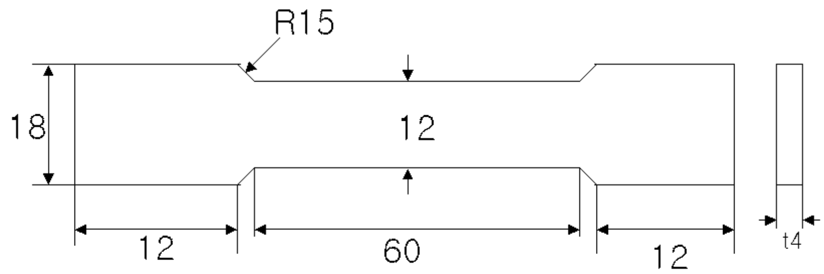

Figure 1. Schematic illustration of transverse and longitudinal tensile test specimens

Microvickers hardness tests were carried out to evaluate the hardness of each zone, such as stir zone (SZ), thermomechanically affected zone (TMAZ), heat affected zone (HAZ), and base metal (BM)

3. Results

Figure 2 shows top surfaces of the welded specimens. AZ91D Mg alloy butt joints had good surfaces and root appearance after FSW in conditions of 1100 to 1250 rpm of tool rotation speed and 41 to 187 mm/min of travel speed. No exterior defect on surface of all the joints was observed.

Figure 3 shows macrostructures of the conditions of 41 mm/min of travel speed with 1600 and 1800 rpm of spindle speed. In the weld nugget, there is a defect like tunneling void. This is mainly due to brittleness of

AZ91D and not caused by insufficient heat input. At the all conditions of over 1600 rpm rotation speed, there is a defect.

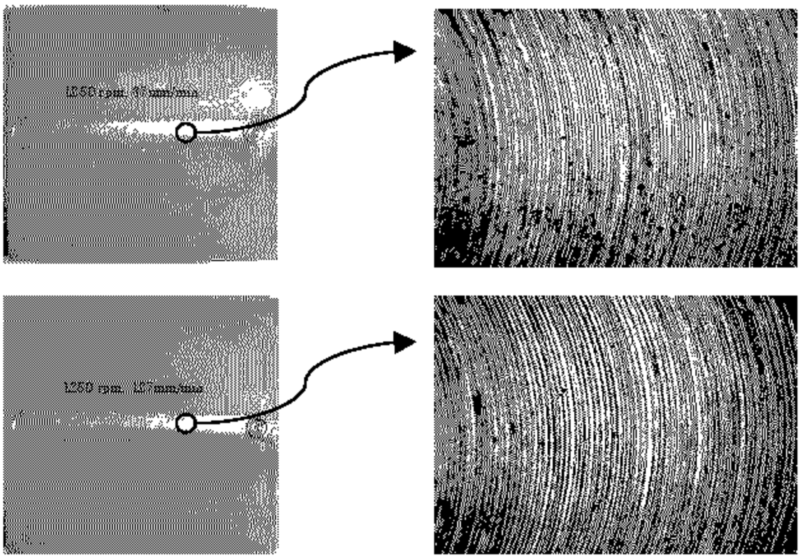

Figure 2. Top surfaces of the welded specimens

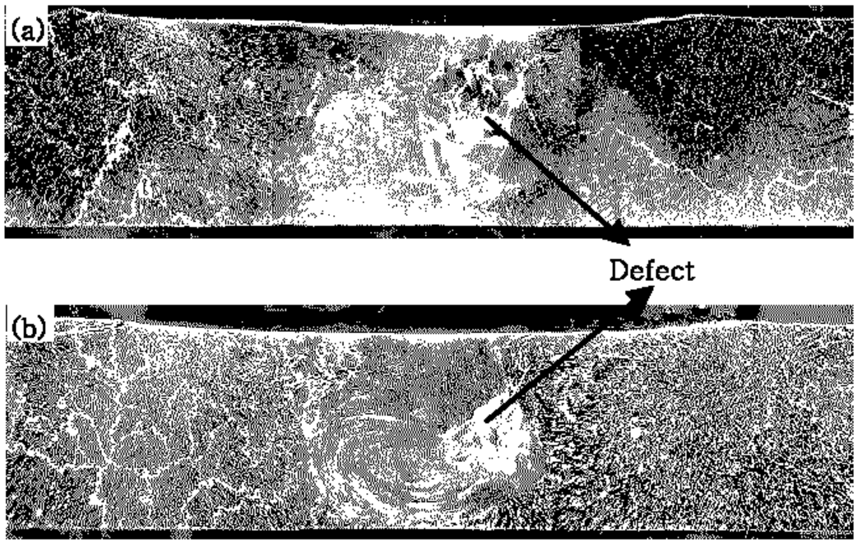

Figure 3. Macrostructures of 41mm/min with (a) 1600rpm and (b) 1800rpm

Figure 4 shows a macrostructure and horizontal hardness profiles of a condition of 1250 rpm with 41mm/min in the transverse cross section of the weld joint. No tunnel pore was detected in the weld zone. Hardness of the weld is slightly increased and showing relatively uniform distribution. These kinds of tendencies are most likely to be due to refinement of the as-cast microstructure [11]. On the contrary, irregular hardness distributions were observed in TMAZ and BM arisen from coarse β intermetallic compounds.

Figure 5 shows a microstructure of the weld joints. The SZ consisted of fine recrystallized grain, while the base metal exhibits a dendritic microstructure which is composed of Mg solid solution and β intermetallic compounds. The microstructure of TMAZ was characterized by partially recrystallized and elongated grain structure. HAZ consisted of similar structure of BM.

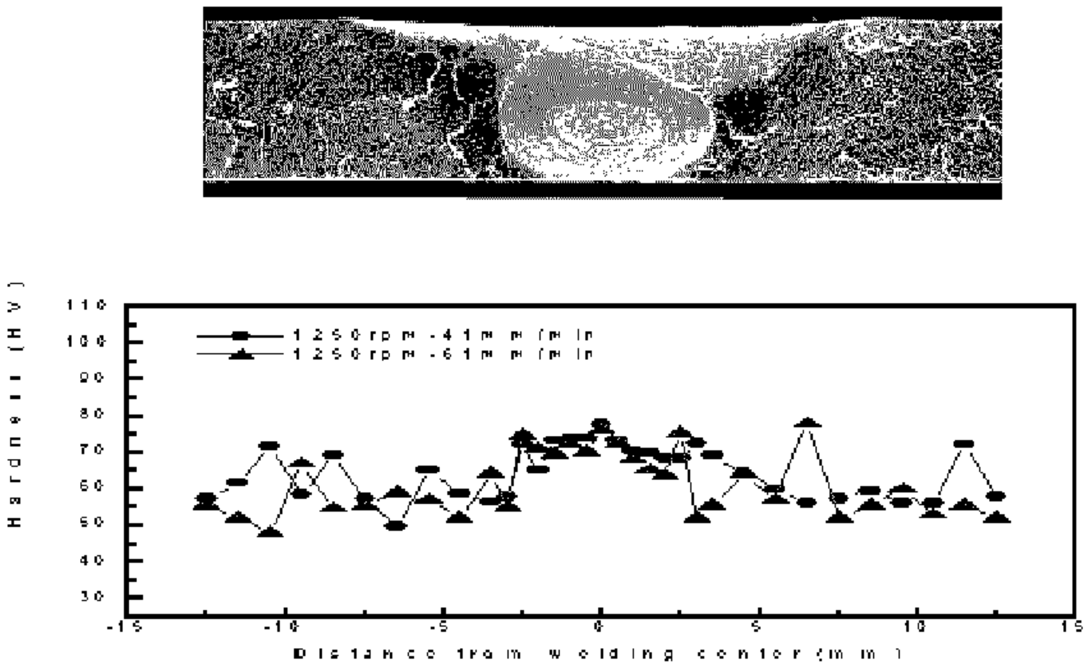

Figure 4. Macrostructure and horizontal hardness distribution

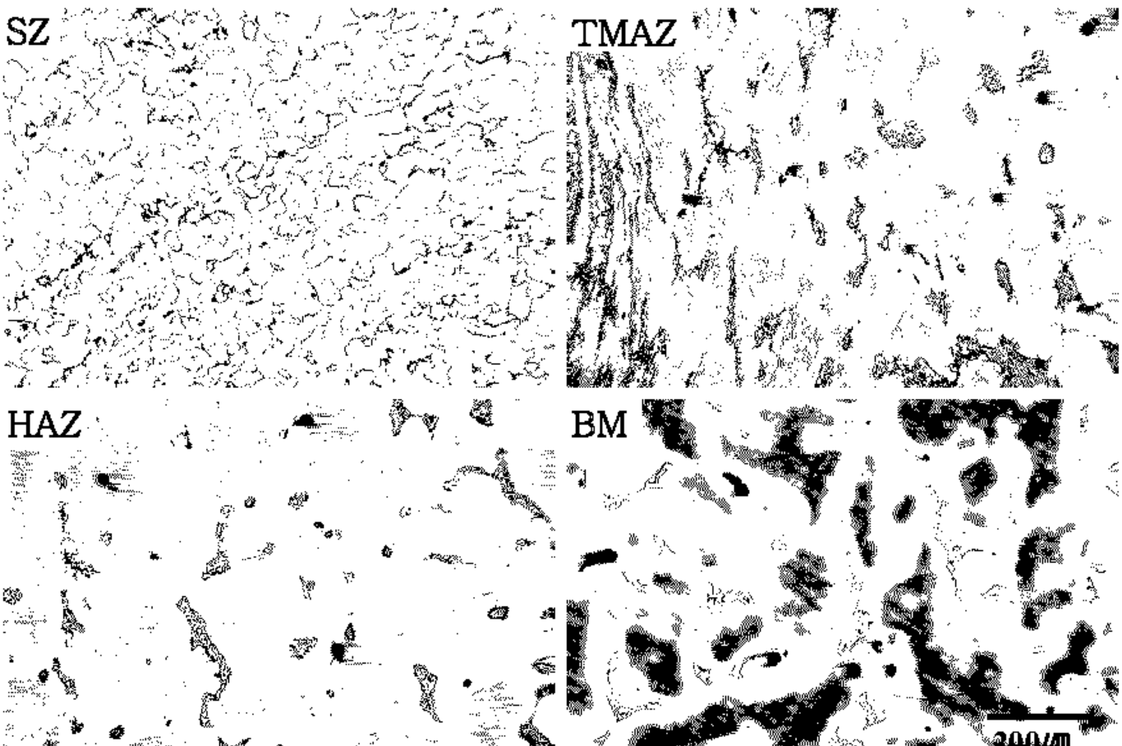

Figure 5. Microstructures of the SZ, TMAZ, HAZ, BM, respectively

Figure 6 shows the longitudinal tensile test results of the SZ at the conditions of 1250 rpm rotation speed with varying welding speed. In case of transverse tensile test, the joint efficiency is 100%. These results mean that the welding conditions were close to optimum for this material and tool design. In the longitudinal tensile tests, the strength of the joints was remarkably improved due to fine recrystallized structure of the SZ.

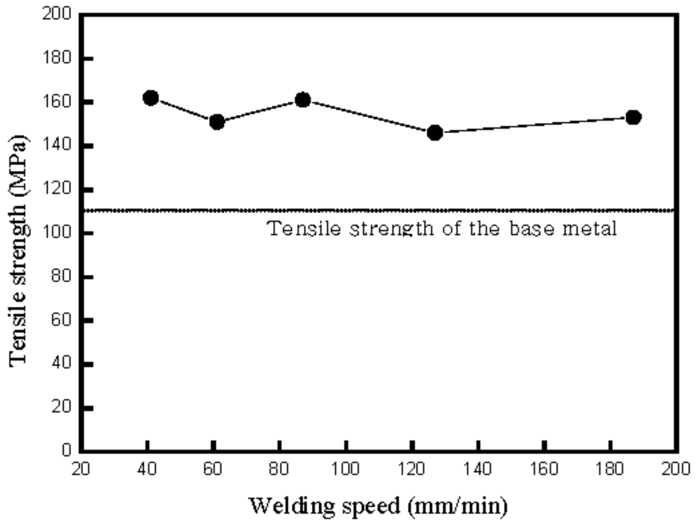

Figure 6. Relation between welding speed and tensile strength

4. Conclusion

In this study, the microstructural development and mechanical properties of the friction stir welded AZ91D 4mm thick plates have been determined. The results obtained are summarized as follows.

(1) Mg alloy AZ91D was successfully joined using friction stir welding at the optimum conditions of 41 to 187 mm/min of welding speed with 1100 to 1250 rpm of the tool rotation speed.

(2) It has been confirmed that the original base metal grain structure becomes completely eliminated and replaced by very fine and equiaxed grains in the weld nugget.

(3) The mechanical properties, such as hardness and tensile properties, were improved due to the refinement of the structure.

(4) At the optimum conditions, β-intermetallic phase which was in the base metal was dissolved by frictional heat input.

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