Journal of Metallurgical and Materials Engineering, Vol.29, No.1, 2018.

In Situ production of Al/Al_3Mg_2 Composite on Al-1050 via Friction Stir Processing

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1- Introduction

In general, aluminum alloys are used in industry because of their low weight and good strength. The properties of these materials are very important. The FSP was developed in England in 1991 as an efficient method for improving the properties of aluminum. In this method, a hard tool is used to rotate on a piece of aluminum causing stirring and severe plastic deformation and recrystallization which results in better properties in the friction stir processed zone. In recent years, many researchers have focused on the procedure. They have realized that by adding ceramic or metallic powders, an alloy can be obtained with better properties. In this project it is intended to add magnesium metallic powder to Al-1050 alloy and study the in-situ formation of Al-Mg intermetallic to improve the mechanical properties of the alloy.

2- Experimental

In this study, Al-1050 alloy with Al-0.25Si-0.40Fe-0.5Cu-0.03Ti-0.05Mn (wt.%) and <40µm Mg powder were used as the substrate and secondary hardening particles, respectively. Friction Stir Processing (FSP) was carried out via milling machine and H13 tool. The effect of number of FSP passes on the structure and developed phases was studied. Furthermore, FSP samples were subjected to post-FSP heat treatment (1 hour at 360ºC) to increase the reaction between magnesium and aluminum.

Metallographic samples were cut perpendicular to the FSP path and electro-etched after surface preparation via 5^{ml} HBF_4+200^{ml} distilled water at 15V for 180 seconds. Microstructural studies were carried out by using optical and scanning electron microscopes. The phases in the FSP area were studied via XRD analysis and their chemical composition was determined via EDS analysis.

Micro-hardness and tensile tests were used to evaluate the mechanical properties of FS-processed samples.

3- Results and Discussion

Al-1050 is non-heat treatable, and therefore, we have tried to improve its surface property via developing an Al/Mg composite. Al/Mg composite was successfully formed on the surface via FSP. Optical studies from the stirred zone (SZ) showed that by applying one pass FSP without magnesium, the column structure of the base metal changed to fine equiaxed grains with a diameter of 50±10µm. The grain size of the SZ decreased by number of passes (32±4µm in the 4^{th}-pass FSP samples). Microstructural studies showed that the addition of magnesium resulted in further grain refinement of the SZ down to 6±2µm after the 4 FSP passes with Mg (Fig. 1).

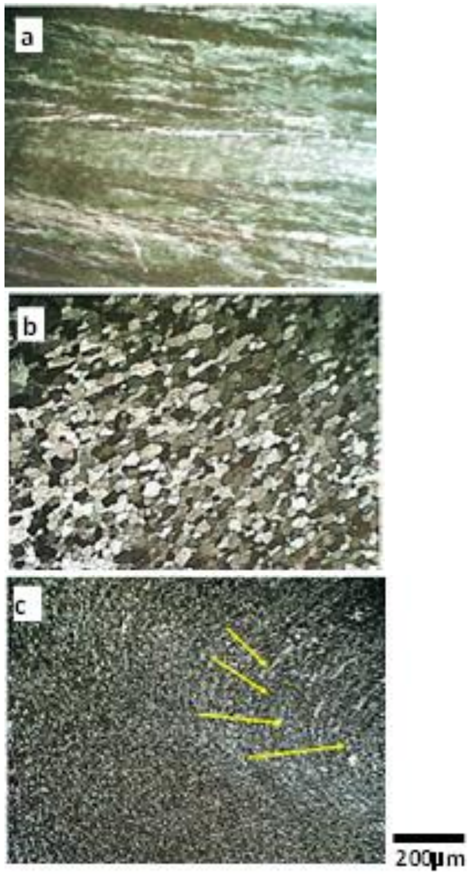

Fig. 1 Optical images of the microstructure of (a) base metal; (b) SZ of 4-pass FSP sample, (c) SZ of 4-pass FSP sample with Mg particles; arrows in (c) indicate onion rings

Grain coarsening occurred in TMAZ with increasing the number of FSP passes (62±10µm after first pass to 78±14µm after 4 passes), as shown in Fig. 2. This could be related to the increased heat input by increasing the number of FSP passes.

Scanning electron microscopy with EDX studies showed the formation of intermetallic Al_3Mg_2 after applying 4 passes of FSP. XRD phase analysis also confirms the formation of this phase in the sample (Fig. 3).

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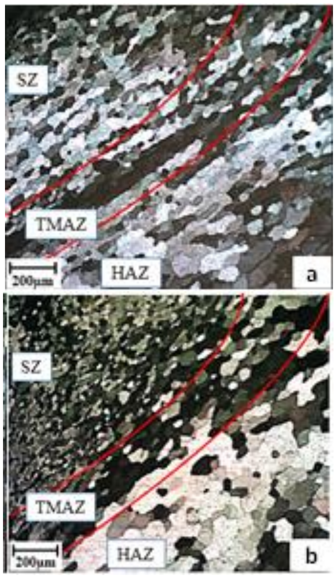

Fig. 2 Effect of number of FSP passes on grain size of different zones (a) 1st pass; (b) 4th pass

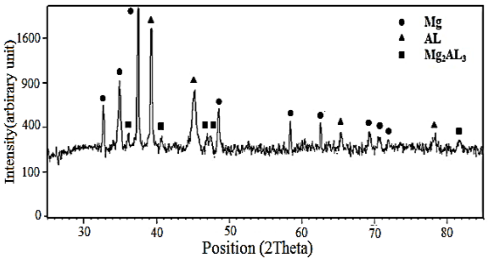

Fig. 3 XRD diffraction pattern of the 4pass FS-processed sample

Microhardness results showed that maximum hardness of samples without magnesium to be 27±3Hv and the maximum hardness of samples with magnesium to be 60±5Hv, while the base metal had a hardness value of 20±5Hv. Tensile tests also indicated an improvement in strength from 55±3MPa in the base metal to 60±3MPa after applying 4 FSP passes. Also, tensile strength increased to 110±5MPa by adding magnesium powder and 4 passes of FSP.

4- Conclusions

Friction stir processing was carried out successfully to develop in-situ Al/Mg composite on the surface of Al-1050 substrate. FSP with addition of magnesium to the surface of Al-1050 substrate caused grain refinement and formation of equiaxed gains in the stirred zone. Evaluation of mechanical properties indicated the significant improvement of hardness and tensile strength of the FS-processed sample containing magnesium particles.