Microstructure and hardness performance of AA6061 aluminium composite using friction stir processing

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Abstract. Rice husk ash (RHA) is an industrial waste that has become a potential reinforced material for aluminium matrix composite (AMCs) due to low cost and abundantly available resources. Friction stir processing (FSP) has been introduced as a method to modify surface properties of the metal and alloy including theirs composite as well. The present work reports the production and characterization of AA6061 and AA6061/5 vol% RHA using FSP using parameters rotation speed 1000 rpm and traversed speed 25 mm/min. The microstructure was studied using optical microscopy (OM). A homogenous dispersion of RHA particles was obtained in the composite. No agglomeration or segregation was observed. The produced composite exhibited a fine grain structure. An improvement in hardness profile was observed as AA6061/5 vol% RHA improves in hardness compared to FSPed of AA6061 without reinforcement.

Keywords - Friction stir processing; aluminium matrix composite; rice husk ash; microstructure; hardness

1. Introduction

Surface modification technique such as plasma spray, chemical vapor deposition (CVD), physical vapor deposition (PVD), electron beam welding (EBM), plasma transferred arc welding (PTAW), thermal spraying and laser beam techniques will generate the formation of unfavorable phase which degrades the properties of the composite. Consequently, all of these techniques are conducted in high temperature which they will produce a detrimental phase meaning difficult to avoid reaction between matrix and reinforcement [1]. In recent studies, friction stir processing (FSP) has been introduced to modify the upper surface of metallic materials [2]. FSP has been developed for use with aluminium alloys, with the goal of high-strain-rate processing [3]. FSP is a fast method with simple processing and low cost to in situ synthesizes particulate-reinforced composites especially in aluminium alloy [4-5] as the composite materials promote better properties including mechanical properties [6]. FSP enhanced the distribution of the reinforced particles which resulting more homogeneous and thermodynamically more stable in metallurgical properties as the matrices and reinforcement have a strong interfacial bonding [7].

Aluminium matrix composites (AMCs) become potential materials for various applications including in aerospace and automotive as they required a high strength and lightweight components [8-9]. Rice husk ash (RHA) has been introduced as reinforced material in AMCs. RHA offered such as high silica contents (87– 97 wt% SiO_2), high porosity, lightweight and very high external surface area which is a valuable material for industrial applications. Rice husks contain high silica content as potential reinforcement for metal matrix composites (MMCs) and ceramic matrix composites (CMCs) [10].

Few studies were reported on fabrication of AMCs with RHA as the reinforced material. A study done by Dinaharan et al. on AA6061 reinforced with 18 vol% of RHA using FSP resulting a homogenous dispersion with no agglomeration and segregation of RHA particles in the composite. AA6061/18 vol% RHA composite demonstrated a fine and equiaxed grain structure. RHA particles fragmented during FSP. An improvement in the tensile strength was observed subsequent to reinforcement of RHA particles. The UTS of AA6061 and AA6061/18 vol% RHA were found to be 220 MPa and 285 MPa, respectively. The fracture surface was dispersed with fractured RHA particles confirming excellent interfacial bonding with the aluminum matrix [11]. A work done by Zuhailawati et al. on aluminium 1100 reinforced with RHA reported that FSP has refined the silica particle associated with excellent distribution in the matrix. Reduction in wear rate of FSPed Al1100 with improved hardness was believed to be due to the presence of hard silica with high interfacial strength and high hardness of recrystallized aluminum grains in the stir zone. The SEM observation of the worn surface of the alloy with added amorphous silica particles showed no deboning between the particles and the matrix [12].

In the present work, a challenge is made to introduce FSP for surface modification of aluminium AA6061 and AA6061 reinforced with RHA. Further studies were conducted in order to investigate the effect on their microstructure and hardness behavior.

2. Experimental procedure

The plates of aluminium alloy AA6061 with dimension of length 100 mm, width 50 mm and thickness 10 mm were used for this experiment. A net of holes were designed on the surface of the plates which corresponding to 5 vol% of RHA particle (40 μm).

Rice husk (RH) was collected from rice mill, BERNAS Rompin. The RH then were washed with distilled water and dried at room temperature for 1 day. Dried RH was heated to 200 °C for 1 hour in order to remove the moisture and organic matter. The color of RH was changed from yellowish to black. Then RH was continued heated at 600 °C for 12 hours to remove carbonaceous matter. During this operation the color of black RH has been change to greyish white ash [13-15]. Table 1 represents the composition of RHA.

Table 1. The composition of RHA.

Constituent	SiO_2	K_2O	P_2O_5	CaO	SO_3	MgO	MnO	Fe_2O_3	ZnO	Rb_2O	MoO_3	SrO
%	43.87	2.18	2.00	1.49	0.61	0.51	0.20	0.10	0.06	0.03	0.02	0.01

The tool was made of H13 tool steel with a shoulder diameter of 16 mm, probe length of 4 mm, probe height 5 mm and probe diameter of 6.25 mm. All samples were subjected to single pass of FSP either with or without reinforced with parameter of rotation speed of 1000 rpm and traversed speed of 25 mm/min. FSP was accomplished by using vertical milling machine (MAKINO).

All samples were prepared for microstructural and mechanical characterization. All the specimens were cut from the cross section, grinded together with polished using standard metallographic technique and etched with Weck reagent. The hardness profile of the thickness cross section samples was determined by using a Vickers indenter at load of 1000 g and dwell time of 15 s.

3. Results and discussion

Aluminium alloy AA6061 with and without reinforced with RHA particulates were successfully produced using friction stir processing. The microstructure and mechanical characterization of both FSPed AA6061 and FSPed AA6061/5 vol% RHA are discussed below.

3.1. Microstructure of FSPed AA6061 and FSPed AA6061/RHA

The micrographs were recorded within the stir zone of FSP. The optical micrograph of the produced AA6061 and AA6061/5 vol% RHA are shown in Figure 1. Figure 1(a) represents the microstructure of FSPed AA6061. Figure 1(b) show clearly the uniform distribution of RHA in the matrix, and no void and discontinuities were observed. There was a good interfacial bonding between the particles and matrix material. Furthermore, in Figure 1(b), the stirred zone showed fine grain compared to FSPed AA6061. This fine structure was produced by dynamic recrystallization and static grain growth after the stirring process, caused by the influence of frictional heat and plastic deformation. The alloy matrix grain size decreased slightly in the presence of silica particles, which may have limited the extent of grain growth during FSP [12].

There are no agglomerations and segregations of RHA particles in the stirred zone. In order to get isotropic properties, the composite need to have a homogeneous dispersion between matrix and reinforcement. The rubbing tool shoulder and shearing action of the pin surface will produced the fractional heat which leads the aluminum matrix to plasticize. The holes are sheared off during material flow. The composite will be fabricated as the rotating action of the tool enhanced the compacted particles to mix with the plasticize aluminium. Since FSP is a solid state process, thus the aluminum matrix does not melt during the process. After the composite is formed in the solid state, the free movement of reinforcement particle due to density gradient with the aluminum matrix is restricted. On the other hand, due to density gradient in molten aluminum, the reinforcement particle will tend to float up or sink down. This has been the major obstacle of stir casting which is overcome by FSP. Both of the matrix and reinforcement, aluminium and RHA particles are subjected to the severe plastic strain induced by the FSP process. The strain developed during FSP is much higher compared to conventional severe plastic deformation processes. Reinforcement particles commonly breakdown and undergo a change in shape and size [11].

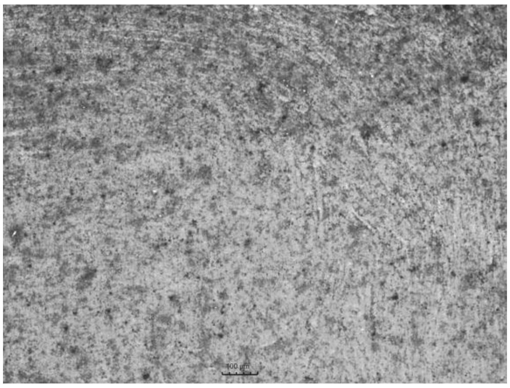

Figure 1 (a). Microstructure of FSPed AA6061 (5X).

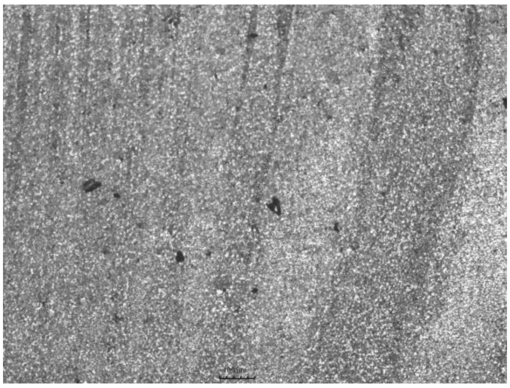

Figure 1(b). Microstructure of FSPed AA6061/5 vol% RHA (5X)

3.2. Hardness profile of FSPed AA6061 and FSPed AA6061/RHA

Figure 2 shows that the harness value for within stirred zone for FSPed of AA6061 and AA6061/5 vol% RHA at 1000 rpm at different point. The harness value for FSPed AA6061 is lower compared to AA6061/5 vol% RHA, as in average of 114.1 Hv and 131.7 Hv, respectively. As the RHA is incorporate within AA6061 matrix, these will influenced the formation of new recrystallization of aluminium grains which lead to refine the grain in the stirred zone [12].

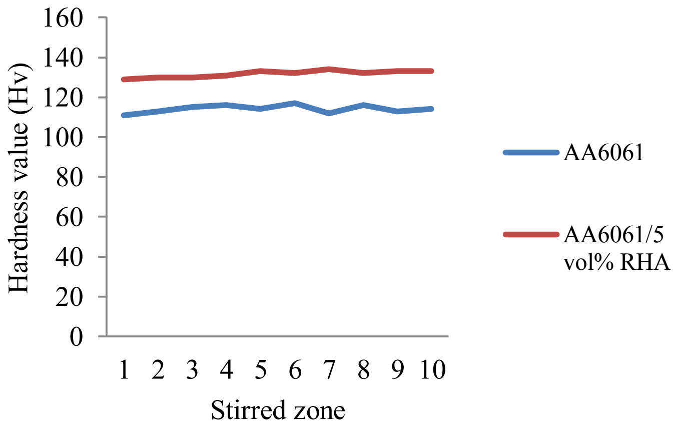

Figure 2. Hardness value in stirred zone.

4. Conclusions

RHA has been introduced in aluminium matrix AA6061 using FSP. RHA particles were homogenously distributed within the AA6061 matrix across the stirred zone. There was no agglomerations and segregation of the reinforced particles within the composite. A homogeneous dispersion lead to grain refinement within the composite. RHA particles improved the harness profile of the composite. In future work, FSP is suitable process to produce RHA reinforced AMCs by altering the processing parameters and compositions.

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