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Investigation on the effect of Friction Stir Processing Parameters on Micro-structure and Micro-hardness of Rice Husk Ash reinforced Al6061 Metal Matrix Composites

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Abstract. Friction stir processing (FSP) is an alternative way to produce the surface composites of aluminium alloy in order to modify the microstructure and improve the mechanical properties. In this experiment, Al6061 aluminium alloy has been chosen to be used as the matrix base plate for the FSP. Al606 has potential for the use in advanced application but it has low wear resistance. While, the reinforced used was rice husk ash (RHA) in order to produce surface composites which increased the micro hardness of the plate composites. The Al6061 was stirred individually and with 5 weight % of RHA at three different tool rotational speeds of 800 rpm, 1000 rpm and 1200 rpm. After running the FSP, the result in the distribution of particles and the micro hardness of the specimens were identified. The result showed that Al6061 plate with the existing 5 weight % of RHA reinforced at the highest of tool rotational speeds of 1200rpm has the best distribution of particles and the highest result in average of micro hardness with 80Hv.

1. Introduction

In the field of surface modification, friction stir processing (FSP) is used to improved surface properties. Basically, FSP helped so much in improvising the surface properties of metal alloys such as aluminium alloys, to improve its ductility, strength, increase the hardness and formability and fatigue life without changing the bulk metal properties [1]. FSP use a non-consumable tool which plunge into the work piece and moved in direction of interest [2]. The friction between tool and work piece generates the heat. The material become soft and flows around the work piece when it is being heated [3].

FSP also is a technique for creating a composite surface and this method does not deal with melting. This new method which is being derived from the FSW is a novel solid state processing technique for microstructural modification. By referring to the material condition, the dispersion of reinforcement particles on metal surface and the control of its dispersal are more difficult to attain by conventional surface modification technique [4-5].

Methodically, this project works involves the process of the intense of plastic deformation and the mixing by the pressure heat. In addition, it also can improve the surface properties such as abrasion resistance, hardness, toughness, corrosion resistance. With reference to this method, this project is a way to combine between Al6061 aluminium alloy with rice husk ash (RHA). It is intended to produce a composite surface to identify the level of particle distribution, analyse the surface structure and hardness property. It will also adopt a number of parameters such as rotation speed and transverse speed of tool movement to achieve the objectives of the project study.

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2. Methodology

Friction stir processing (FSP) is an alternative used to improve the mechanical properties of material especially for alloy. This section provides the procedure in conducting the experiment systematically as shown in figure 1.

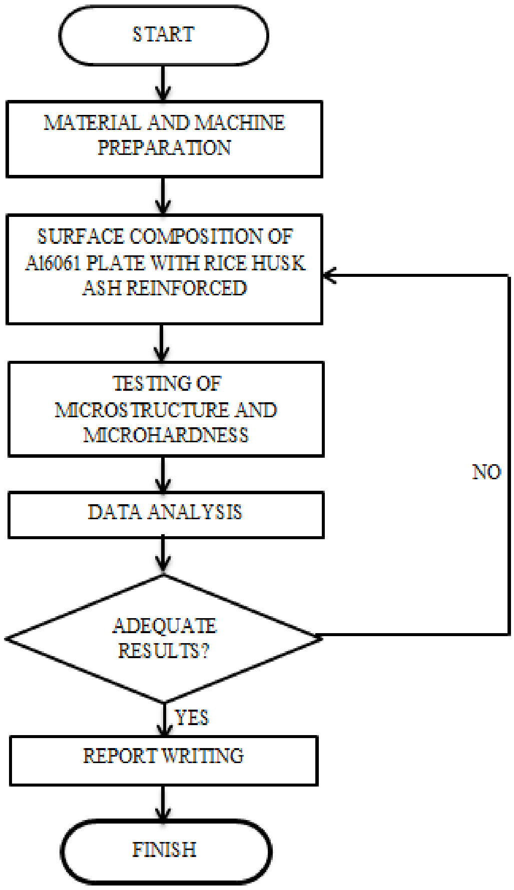


Figure 1. Flow chart of the research.

The experiment was designed for preliminary studies on the effect of RHA addition to Al6061 alloy, additionally on the effect of three different tool rotation speeds. The tool material used in this experiment of FSP is made from steel H13. This H13 tool steel is a versatile chromium-molybdenum hot work steel that is widely used in hot work and cold work tooling applications. The hot hardness (hot strength) of H13 steel resists thermal fatigue cracking which occurs as a result of cyclic heating and cooling cycles in hot work tooling applications. The variable parameter used in this research was tool rotational speed and the constant parameter is transverse speed. Tool rotational and transverse speeds will specify the amount of heat generated in the work piece. Interaction of rotating tool with work-piece generates temperature rise due to friction and plastic deformation. For this investigation, the matrix base material Al6061 alloy and the chemical composition is presented in table 1. Rice husk as (RHA) was utilized as the reinforcement, its composition is clarified in table 2. RHA has high silica contents (87–97 weight % SiO2), high porosity, lightweight and very high external surface area which is a valuable material for industrial applications. RHA contain high silicon content as potential reinforcement for MMC and CMCs [6]. The RHA was heat-treated in order to reduce carbonaceous and volatile substance. In this experiment the amount of tool rotational speed was varied to 800rpm, 1000rpm and 1200rpm while, the traverse speed was constant at 100mm/min.

Table 1. The chemical composition of Al6061 [7].

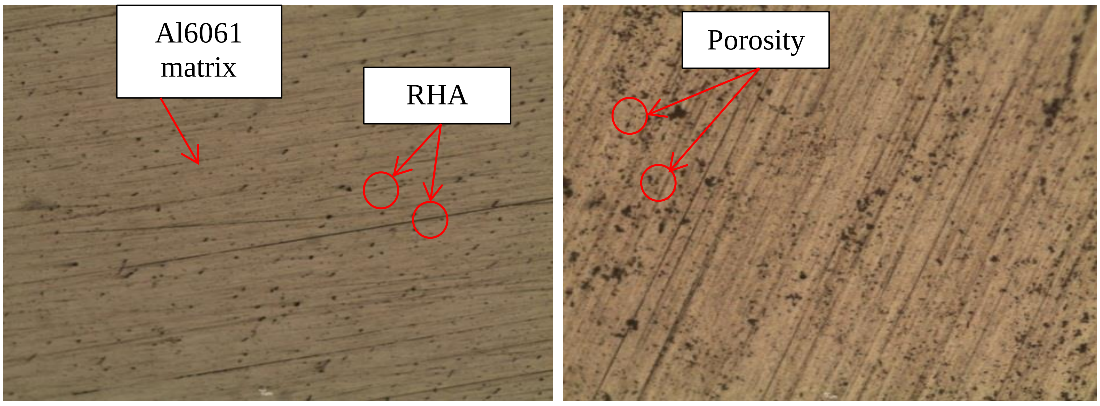
Element	Mg	Fe	Si	Cu	Mn	V	Ti	Al
Percentage	1.08	0.17	0.63	0.32	0.52	0.01	0.02	Balance

Table 2. The oxide composition of rice husk ash (RHA).

Oxide composition	**Percentage**
SiO_2	88.32
Al_2O_3	0.46
Fe_2O_3	0.67
CaO	0.67
MgO	0.44
Na_2O_3	0.12
K_2O	2.91
LOI	5.81
Others	2.11

3. Results and discussions

The results obtained from the experiments of friction stir processing for Al6061 without reinforced and with reinforced at different rotation speed of 800rpm, 1000rpm and 1200rpm with constant tool travel speed at 100mm/min. The grain distribution of these specimens and the micro-hardness will be discussed on this section. The heat generates between the plates Al6061 with the tool rotational speed of FSP would causes the plate to obtain its melting point and mixture the reinforced with the plate. This lead to the distribution of the reinforced within the NZ area and would increase the grain growth. Figure 2 show the optical micrograph of Al6061 with RHA reinforced and Al6061 without RHA reinforced at 800 rpm. Figure 3 show the optical micrograph of Al6061 with RHA reinforced and Al6061 without RHA reinforced at 1000 rpm. While, figure 4 show the optical micrograph of Al6061 with RHA reinforced and Al6061 without RHA reinforced at 1200 rpm.



(a) **(b)**

Figure 2. Optical microstructures (10x) of the surface a) Al6061 with RHA b) Al6061 without RHA at 800 rpm

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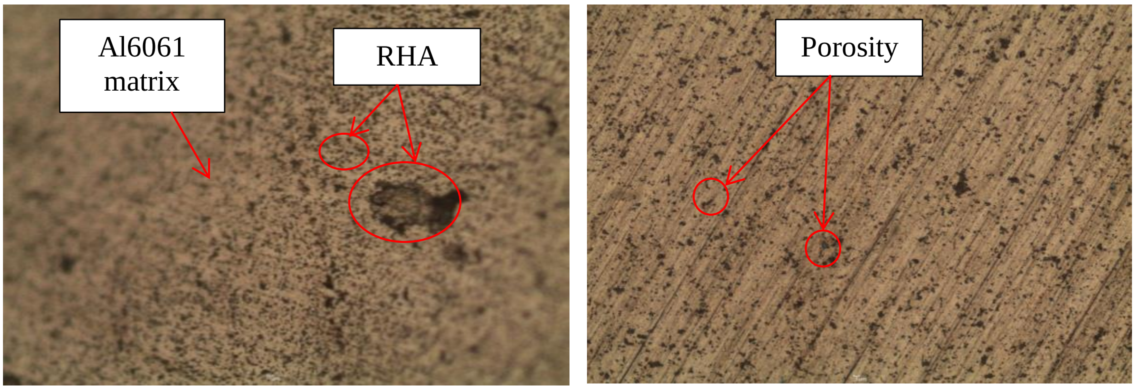
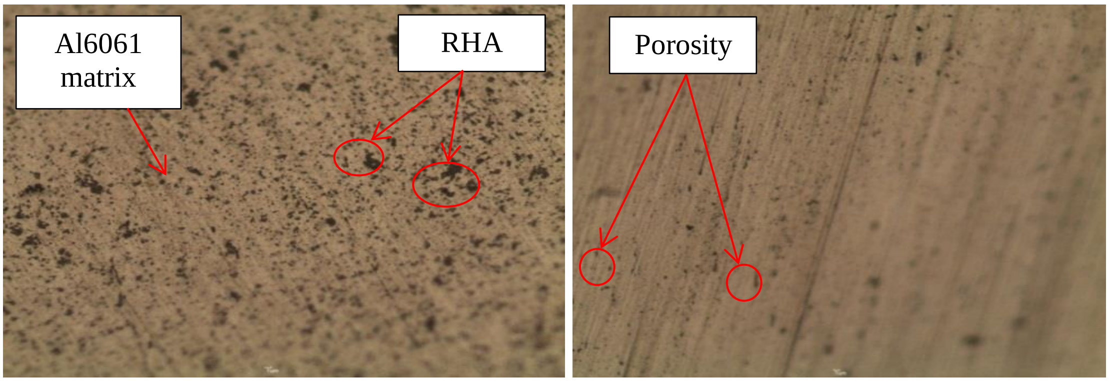


(a) **(b)**

Figure 3. Optical microstructure (10x) of the surface a) Al6061 with RHA b) Al6061 without RHA at 1000 rpm.



(a) **(b)**

Figure 4. Optical microstructure (10x) of the surface a) Al6061 with RHA b) Al6061 without RHA at 1200 rpm

Grain size is an important material characteristic. The material becomes stronger when the average size decreases and opposite effect on strength occurs when the grain size increases. In general, ductility increases with grain size but strength decreases it is happening because the smaller the grains, the shorter the distance for the dislocations to be move. Therefore the smallest the grain size is better for the properties of the material. The plate with RHA reinforced were observed, it shows that the particles dispersed uniformly in NZ area because it was affected by rotating the tool that gives sufficient heat generation and force the particles to distribute the reinforcement particles in wider area. FSP plate without RHA reinforced in surface shows that the porosity occupied the area. After, RHA reinforced in been stir in Al6061 plate, it shows that the porosity has been fully occupied with the reinforcement.

The average micro hardness of Al6061 at three different stage of tool rotational speed with constant traverse speed was observed. The value of tool rotational speed is 800 rpm, 1000 rpm and 1200 rpm while the value of traverse speed is 100 mm/min. The value of micro hardness has been taking at three different areas which are at the surface of FSP, at depth of 2.5mm and at depth of 5mm. Figure 5 show the chart of average micro hardness value when there is existing 5 weight % of RHA reinforced and without RHA reinforced at the surface.

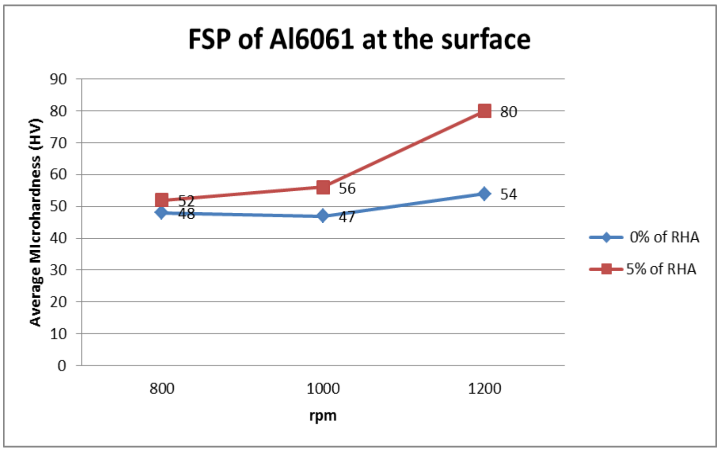


Figure 5. The chart of average micro hardness of specimens at the surface for three different tool rotational speeds.

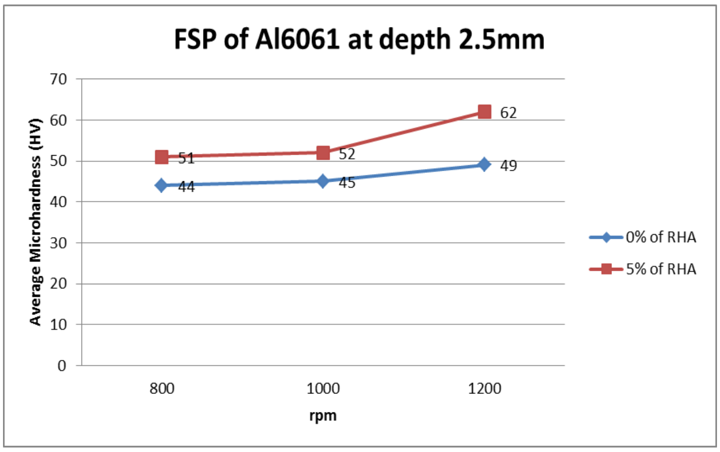


Figure 6. The chart of average micro hardness test of specimens at the depth of 2.5mm for three different tool rotational speeds.

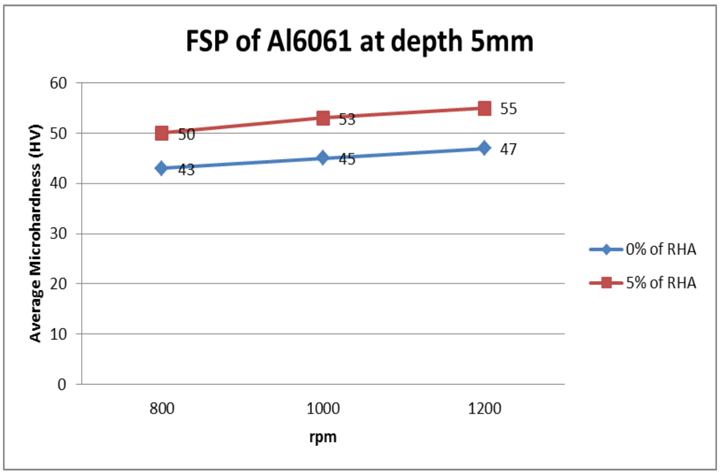


Figure 7. The chart of average micro hardness test of specimens at the depth of 5mm for three different tool rotational speeds.

In all specimens of FSP with RHA, it shown that the micro hardness is significantly increased with reduction of grain size and presence of RHA particles in Al6061 matrix. The overall result shows that the micro hardness value for the Al6061 at the surface and at the depth of 2.5 mm until 5 mm with existing of 5 weight % RHA were higher compared to the value of specimens without RHA reinforcement. In addition, the tool rotational speed also affecting the micro hardness value of the Al6061. By increasing the tool rotational speed, the micro hardness value also increased with or without the existing of RHA. Here the parameter plays an important role. With the increase of the micro hardness value, the size of grain decrease. This is because, when the tool stirs the surface of Al6061 it causes the Al6061 melt and deformation occurred. The distribution of RHA reinforced is uniform and the presence of RHA particles in FSP effected layer compared to the other region.

4. Conclusion

The objectives were successfully achieved which was to fabricate the Al6061 composites reinforced RHA. This was performed using friction stir processing (FSP) with three different tool rotational speed at 800 rpm, 1000 rpm and 1200 rpm with constant feed rate of 100mm/min. Plain specimen undergo FSP also been produced with the same tool rotational speed of 800 rpm, 1000 rpm and 1200 rpm with constant feed rate of 100mm/min. From the experiment, the microstructure of Al6061 with 5 weight % RHA reinforced show the uniform distribution at 1200 rpm compared to other speeds. In addition, the micro hardness of Al6061 with 5 weight % RHA reinforced was higher compared to the micro hardness of Al6061 no RHA reinforcement. The result from the micro hardness test at three different regions of surface, depth of 2.5mm and depth of 5mm using the micro hardness test were analysed. At the surface region showed the higher reading of micro hardness for the rotation speed 1200 rpm with 80Hv in average.

Acknowledgement

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