THE EFFECT OF ROTATIONAL SPEED ON WEAR RATE OF FRICTION STIR WELDING FOR JOINNING ALUMINIUM COMPOSITE AlSi-SiC

by Sulardjaka Sulardjaka

THE EFFECT OF ROTATIONAL SPEED ON WEAR RATE OF FRICTION STIR WELDING FOR JOINNING ALUMINIUM COMPOSITE AlSi-SiC

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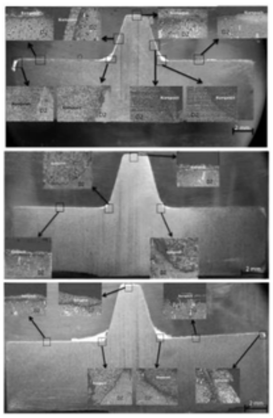


Abstract

The purpose of this investigation is to study the effect of contact between tool and composite on wear rate of the tool shoulder and temperature in FSW process. Wear rate was investigated from weight loss of the tool shoulder after each the welding process of composites. Temperature was measured to reveal the relationship between temperature and wear phenomenon. Visual and microstructure studies are utilized to observe the topography in the each tool surface wear phenomenon. FSW process was done at 1080 RPM rotational speed with translational velocity of 5.652 cm/s produces a low wear rate. The elevated temperature showed 269.9 °C at 5 wt.% SiC, 212 °C at 7.5 wt.% SiC and 258.3 °C at 10 wt.% SiC, at 1080 RPM rotational speed with the translational speed 5.652 cm/s on advancing side. Higher elevated temperature decreases the wear rate. This study explains that butt joint process produced high temperature at advancing side than retreating side in each SiC particle composition. Visual and microstructure study mention that at operating speed of 1080 RPM fewer adhesive layer is found and the measurement for the thickness shows value of 0.2331 mm.

Keywords: friction stir welding, metal matrix composite, wear

1.0 INTRODUCTION

Friction stir welding (FSW) was invented by The Welding Institute (TWI) of Cambridge, England in 1991 [1]. FSW process is a solid-state joining technique, this method has grown rapidly in a wide variety of industries such as: railway, aerospace and transportation industries. FSW process often used on low melting point metal alloys such as aluminium [2-6], copper [7], titanium [8-9] and even iron [10-12] and its alloys.

The FSW process has three phenomena: heating generation from friction of tool shoulder and work metals, plastic deformation, and forging. The tool shoulder is a non consumable rotating tool, consisting of a probe and shoulder. The shoulder of the tool is forced against the plates. The rotating tool shoulder causes friction and heating of the work piece which in turn lowers their mechanical strength. The microstructure of a friction stirs weld is unlike fusion weld in that no solidification products are present and the grains in the weld region are equiaxed and highly refined [13].

Some researcher have been investigated of the tool wear in the FSW process [14-15] but that occurs in the FSW process to join the Metal Matrix Composite materials is rarely found [13,16-24], especially today where the FSW process for composites more widely used.

To improve the productivity and efficiency of FSW, a study to determine the wear rate of the tool shoulder in the FSW process of MMC is needed. Wear of the tool shoulder reduced the quality of FSW joining. Controlling wear is done by determining the efficient parameters and the suitable tool material to join the composite material. This study is investigating the effect of rotational speed on the wear rate of the tool shoulder in the FSW process for AlSi-wt.% SiC composite. In this research also observed effect of the gain in heat (elevated temperature) generated from the FSW process.

2.0 EXPERIMENTAL

The FSW process was conducted on the modified milling machine. The translational speed moved on the x-axis of milling machine. Rotational speed was varied with translational velocity that works effectively on each of them. The parameter is used to determine the effective translational speed of the welding parameters on every variation each the rotational speed : 808 RPM (7.065 cm / s); 1080 RPM (5.642 cm / s); and 1540 RPM (4.329 cm / s).

AlSi-SiC composites are joined in this study, with variations of SiC percentage 5 wt.%; 7.5 wt.%; and 10 wt.%. This composites were produced by semisolid stir casting method in the previous research. The composite material used is plate-shaped with dimensions (p = 5.4 cm; l = 4 cm; and t = 5 mm). Tool material is AISI D2. Tool specifications with a pin-shaped conical with dimension (l_{total}) = 50 mm, ($l_{shoulder}$) = 16 mm, (l_{pin}) = 4 mm, and the diameter of specimens ($d_{shoulder}$) = 20 mm, ($d_{pin\ end}$) = 2 mm and ($d_{pin\ base}$) = 4.14 mm.

The FSW method that used in this research is the parameter process of joining AlSi-SiC composites with appropriate parameters already mentioned above. The temperature of FSW was measured on the surface of the plate in every welding process. Temperature datas were collected by data aquisition. After each welding process some tests were performed include: weight loss, visual observations and microstructure of tool soulder. The weight loss of tool shoulder was evaluated to calculate the wear rate of tool shoulder. Microstructure was done to observe adhesive layer that sticks to the surface of the tool at every rotational speed parameter.

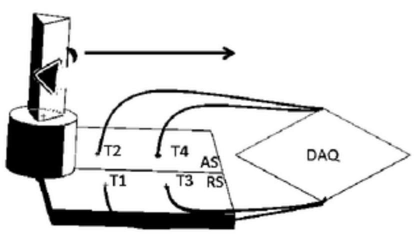


Figure 1. Schematic of temperature measurement

Welding temperatures were measured on each side of every composites, 2 sensor were placed on the advancing side (T2,T4), another 2 were placed on the retreating side (T1,T3). T1, T2 sensor was placed at a distance 1.8 cm from the initial welds. T3,T4 were placed at a distance 3.6 cm from the initial welds as shown on **Figure 1**. Visual (macro) study show which tool was the thickest one. Microstructure study to support the macro study and to show the topography of the surface in every surface of the tool. The microstructure examination were also used for showing the microstructure of the tool after the welding process then calculating the thickness of adhesive layer.

3.0 RESULTS AND DISCUSSION

3.1 Tool Weight Loss Measurement

The data were obtained after the measurement, showed the relationship between wear rate and number of welds, also showed the relationship between wear rate and the rotational speed of the respective percentage of SiC. **Figure 2a** showed the wear rate on each number of weld. The rotational speed is increased then the wear rate decreased [18,25]. The different wear rate on each number of weld because of the different materials, those are AlSi-5 wt.% SiC, AlSi-7.5 wt.% SiC and AlSi-10 wt.% SiC. The different percentage of SiC is shown in **Figure 2b**.

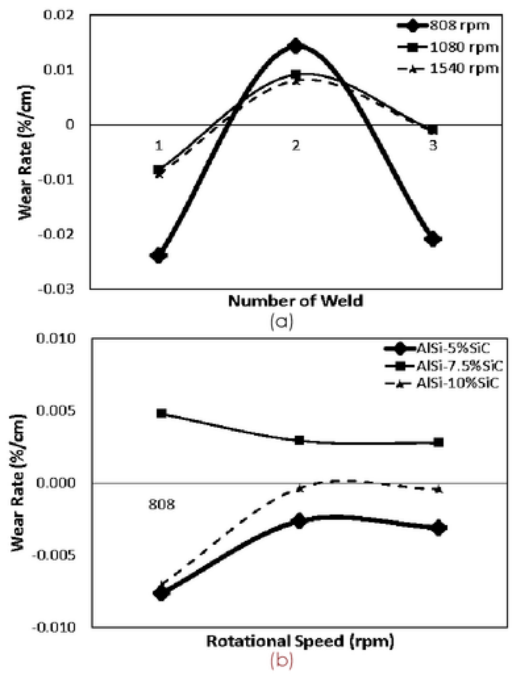


Figure 2 Wear rate diagram (a) wear rate vs number of weld (b) wear rate vs rotational speed.

In the second weld process the wear rate has positive value. It can be concluded that at second weld, adhesive layer on the surface of tool decreased because it contacted with silicone carbides on every side of this material. the previous study was mentioned that the silicone carbide dispersed evenly [26]. It caused friction in the adhesive layer after first weld and became abrasive wear. Best weld parameters were found at 1080 RPM of rotational speed with 5.652 cm/s of translational speed.

3.2 Elevated Temperature Measurement

The temperatures were measured during the welding process of AlSi-SiC composites with the arrangement on the plate T1, T2 at a distance 1.8 cm from the initial weld distance and T3, T4 at a distance of 3.6 cm from the initial weld distance. T1, T3 were placed on the retreating side and T2, T4 were placed on the advancing side.

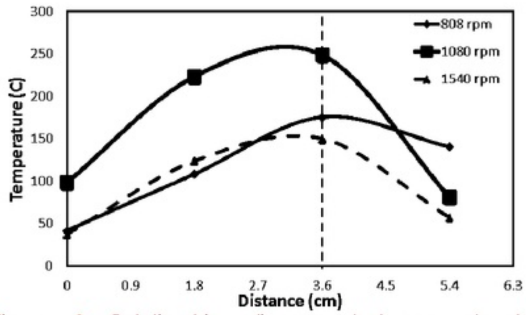
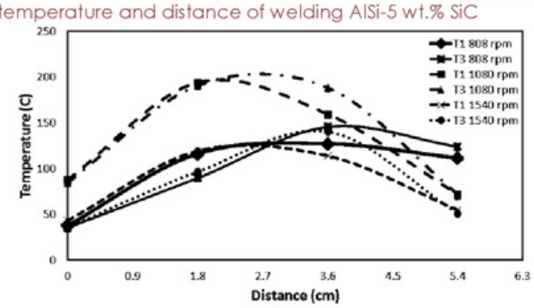
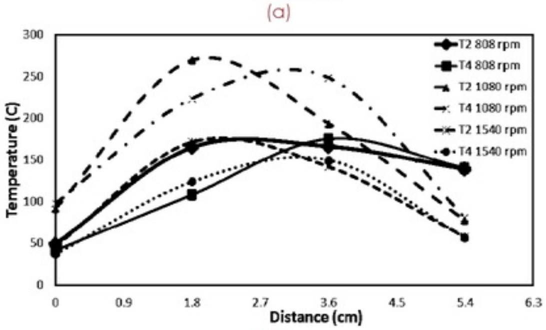


Figure 3 Relationship diagram between elevated temperature and distance of welding AlSi-5 wt.% SiC



(a)



(b)

Figure 4 Elevated temperature vs distance diagram composite AlSi-5 wt.% SiC on (a) retreating side (b) advancing side

The highest peak temperature measured on each composite was at 1080 RPM of rotational speed with 5.652 cm/s translational speed. Higher temperatures decrease the yield strength of the material surface and improve the continuity and thickness of the protective oxidation layer on the surface, the friction occurred and reduced the direct contact between the metal [25]. **Figure 3** until **Figure 8**, the temperature showed at 0 cm weld distance, temperatures were in the range of 30-50 °C.

At 1.8 cm from the initial weld position or tool position is in the center between the sensors T1 and T2. The high temperature was on T1 (retreating side) and T2 (advancing side), than T3 and T4 were lower. T1 and T2 decrease after passing half way as well as T3 and T4 increase, the tool was at distance 3.6 cm or tool position was on between T3 and T4, showed that T3 (retreating side) and T4 (advancing side) were higher than T1 and T2. The temperature at 1080 RPM of rotational speed has the highest temperature at advancing side for butt joint welding [27].

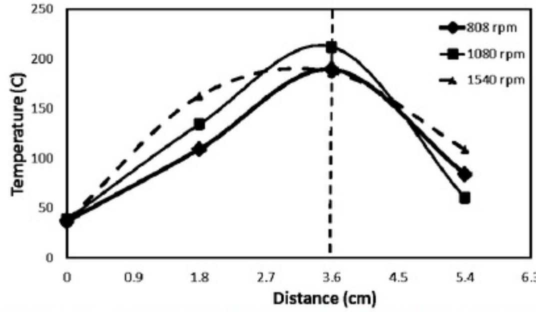
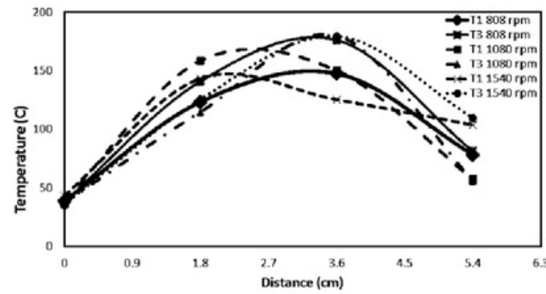
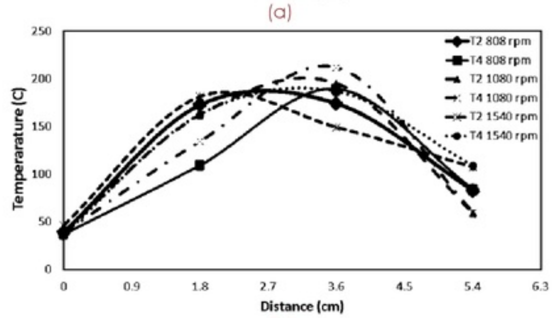


Figure 5 Relationship diagram between elevated temperature and distance of welding AlSi-7,5 wt.% SiC



(a)



(b)

Figure 6 Elevated temperature vs distance diagram composite AlSi-7,5 wt.% SiC on (a) retreating side (b) advancing side

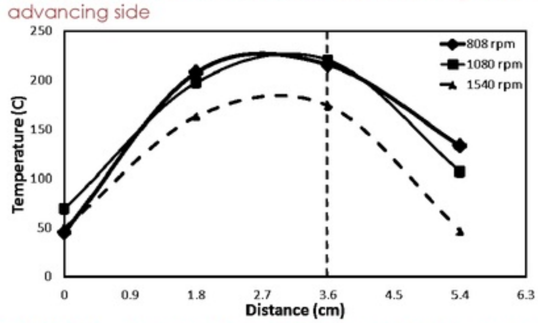
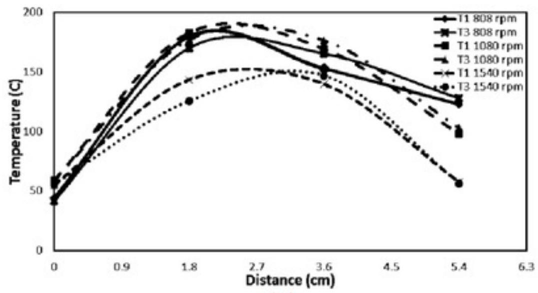
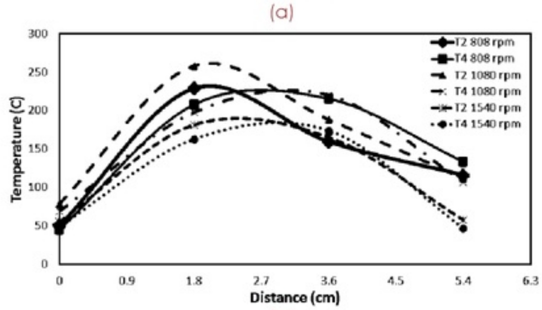


Figure 7 Relationship diagram between elevated temperature and distance of welding AlSi-10 wt.% SiC



(a)



(b)

Figure 8 Elevated temperature vs distance diagram composite AlSi-10 wt.% SiC on (a) retreating side (b) advancing side

3.3 *Microstructure and Topography Study*

Visual and microstructure test was conducted to determine the wear phenomenon as a result of adhesive layer on the tool surface.

(a) (b)

Figure 9 Micostructure of AISI D2 tool steel (a) before hardening (b) after hardening

Figure 9 shows the microstructure of the tool steel (a) before hardening and (b) after hardening. Carbides have a larger size after hardening treatment. Tool Material that didn't harden the carbides were formed along the ferrite matrix [28], but after hardening visible light colored was a martensite structure [29]. It made the improvement of hardness, when the hardness increase, the wear phenomenon decreases.

Figure 10 and 11 shows the adhesive layer that sticks to the surface of the tool at 808 RPM rotational speed. Existing adhesive layer evenly spread over the entire surface of the tool such as in the shoulder, the angle between the pin and the shoulder and also at pin head.

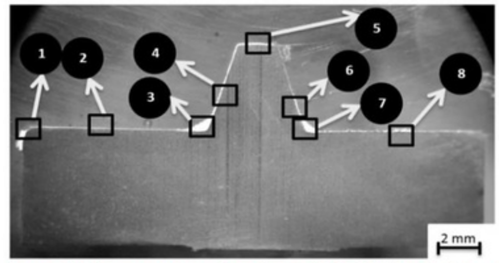


Figure 10 Topography of surface at 808 RPM rotational speed

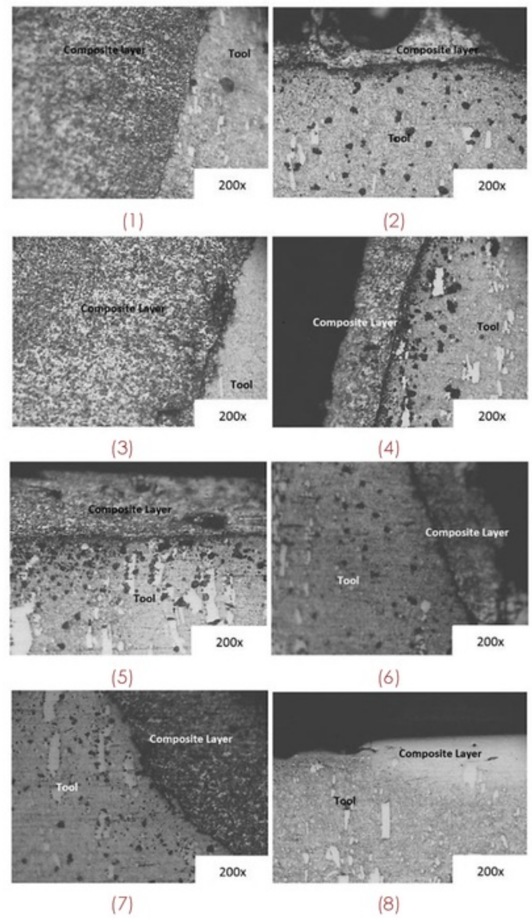


Figure 11 Microstructure each point at 808 RPM rotational speed

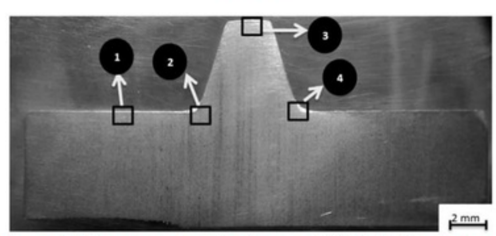


Figure 12 Topography of surface at 1080 RPM rotational speed

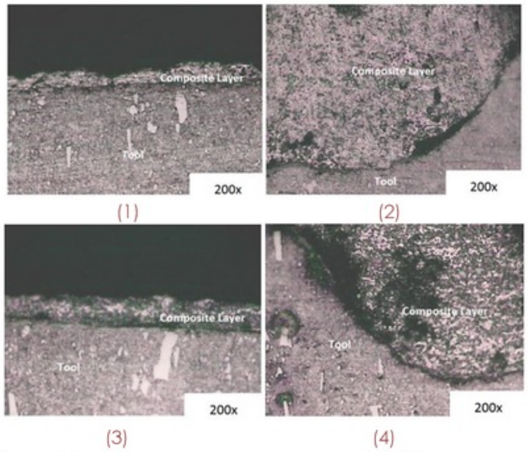


Figure 13 Microstructure each point at 1080 RPM rotational speed

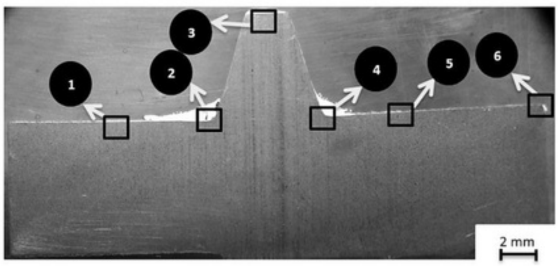


Figure 14 Topography of surface at 1540 RPM rotational speed

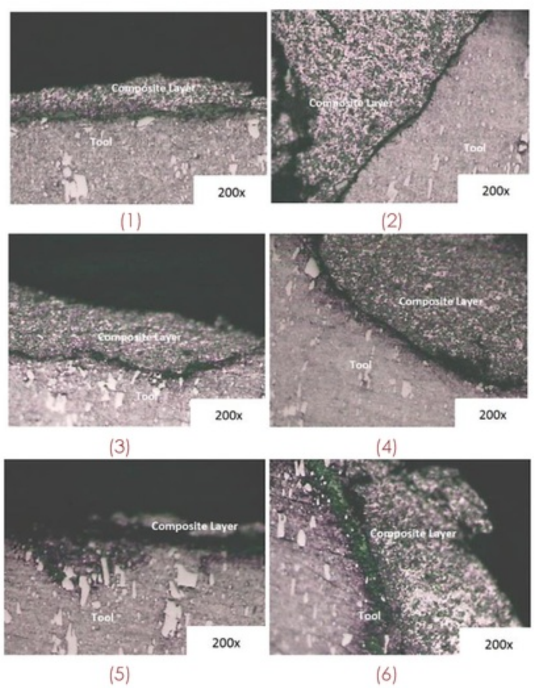


Figure 15 Microstructure each point at 1540 RPM rotational speed

Adhesive layer as shown in **Figure 12** and **Figure13** attached to the tool with 1080 RPM rotational speed look thin on the surface of the tool. The wear rate on this tool was the thinnest compared with the other.

Figure 14 and **Figure 15** showed the adhesive layers at some point which are thick on three areas: right and left angle between tool and pin, and also at the pin head, there is a hollow at the adhesive layer on the left side of angle so the adhesive layers can not define by its look.

The thickness of adhesive layer on each cutting tool was shown in **Figure 16**, there was less adhesive layer at 1080 RPM rotational speed with the value of 0.2231 mm.

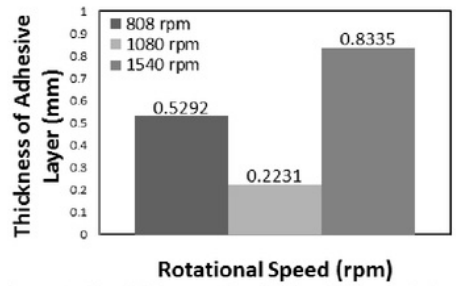


Figure 16 The thickness of adhesive layer each tool

4.0 CONCLUSION

These study can be concluded that the smallest wear rate was in the tool at 1080 rpm of rotational speed with 7.065 cm/s of translational speed. Adhesive wear appeared In the first weld for the composition of 5 wt.% SiC showed the highest value of wear rate, then the second weld for the composition of 7.5 wt.% SiC wear rate decreases. The third weld for composition of 10 wt.% SiC wear rate rises back. At1080 RPM rotational speed for 7,5 w.t% SiC composition has good mechanical properties. Then the tool weight decreased and adhesive layer reduced. The temperature measurement also showed higher at advancing side. The microstructure and topography image showed that 1080 rpm of rotational speed has less adhesive layer on every surface and the thickness was calculated, it showed less thickness.

Acknowledgement

The authors would like to express their gratefulness to the Rector of Diponegoro University who funded this research. With number of research grants : 314-26/UN7.5.1/PG/2015.

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