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The Effect of Tool Rotation Speed Variation to Hardness and Microstructure in The Welding of Composite Alsitib-7,5%Sic by Friction Stir Welding Method

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Abstract — Friction Stir Welding method is a welding method which utilize friction between rotate cutting tool which pressed to material, so it will generate local heat and make material soften and will be integrated or merged. The aim of this study is to understand the effect of rotational speed (808 rpm, 1087 rpm, 1570 rpm) to hardness and microstructure of composite AlSiTiB-7.5%SiC welding by using a tool which have conical pin shaped, with welding speed is 0.02 mm/s. The results showed a significant increase in hardness value in the stir zone (nugget) region and TMAZ-HAZ interface region to hardness value of base metal. Rotational speed using 1087 rpm has highest average value of hardness in the area of the stir zone (nugget) with value 126.4 HV, while at 808 rpm the hardness value is 118.1 HV and at 1570 rpm is 74.6 HV. The microstructure result at 1087 rpm rotational speed showed no defects or wormhole occured if compare with 808 rpm and 1570 rpm rotational speed which has defect or wormhole.

Keywords*— friction stir welding, tool conical pin, stir zone (nugget), TMAZ-HAZ interface, wormhole.*

I. INTRODUCTION

One of the important process in industrial development is welding process, this is due to welding has important role in engineering and producing of metal product. Welding is a integration or joining process between two part of metal or more by using heat energy. Welding is a technique that widely used to joining a metal, such as construction of steel building and machinery construction. To select appropriate welding process which will be used, we have to look at welding joint in the construction. High efficiency, low cost, labour and energy saving is several basic considerations that should be concern to selected appropriate welding process [1].

Friction Stir Welding (FSW) is welding method that relatively new which established in 1991 by Wayne Thomas in The Welding Institute (TWI) of United States. FSW consist of tool with pin or probe which rotating and a material which have plate shaped or metal sheet. The work principle of FSW as follow the tool part will be pressed to plate shaped or metal sheet material, then it will make a friction, this friction will generate local heat which will make material to be soften and integrated or merged. Welding process with FSW method affected by some parameter such as welding speed, rotation of tool, and pressure of tool. Friction stir welding has advantage such as lower cost compared to other welding process. This is due to FSW only need low energy input and not used a filler metal. The result of Friction Stir Welding (FSW) have smoother or

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fine surface and the surface is also flat compared to other welding process. This process also more friendly to environment because no steam or arc occurred and no arc glare [2].

II. MATERIAL AND METHOD

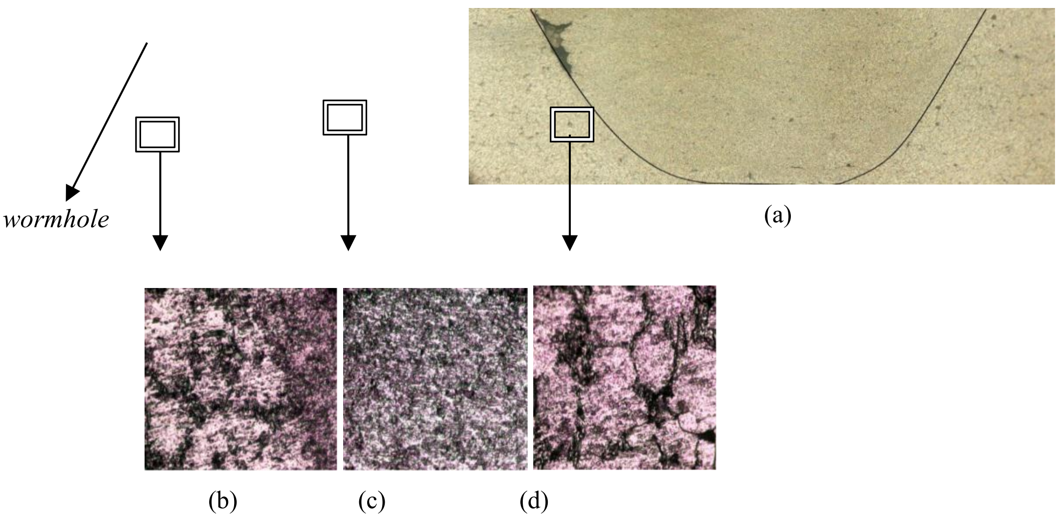
There are some preparation that should be done before start the experiment, such as preparation of milling machine which already modified in tool holder part (with addition of electric motor and inverter), conical pin tool, AlSiTiB-7,5%SiC Composite as a material and tachometer to measure the rotational speed.

Friction Stir Welding (FSW) process have been done at Production Process Laboratory in Mechanical Engineering of Diponegoro University. The first step to do Friction Stir Welding (FSW) process is prepared all the tool and material that have been mentioned before. Secondly put the material or sample on the table of milling machine with position joggle or intersect each other. Then install the conical pin tool on drill chuck, adjust the position of sample and tool in order to have the same direction to welding line. Turn on milling machine and adjust the rotational speed using tachometer with value 808 rpm, 1087 rpm and 1570 rpm. After that, adjust speed of welding rate process by set the frequency on inverter. In this study, the welding rate that will be used is constant on 0.02 mm/s. Then start the FSW process, the tool will be rotate and probe or pin will be rubbing against the sample or material, probe or pin in the tool stretched in the same direction welding region. After welding process, the sample will be characterized using hardness test, microstructure test, and porosity test to strengthen the result of hardness test.

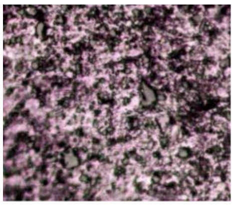
III. **RESULT AND DISCUSSION**

III.1 Metallography Result

The purpose of micrograph test is to observing the macrostructure and microstructure of the result of FSW welding with rotational speed variations (808 rpm, 1087 rpm, and 1057 rpm). Micrograph test characterized using optic microscope Olympus BX41M with 200x and 500x magnification.



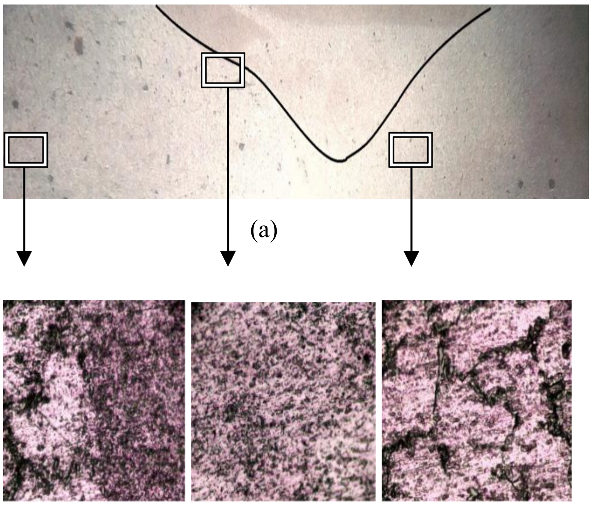
200X Magnification



(e)

500X Magnification

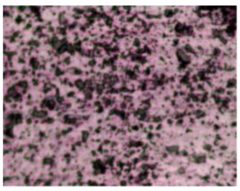
Figure 1. (a) macrostructure of AlSiTiB-7,5%SiC with 808 rpm rotational speed, (b) TMAZ-HAZ interface with 200x magnification, (c) stir zone (nugget) with 200x magnification, (d) base metal with 200x magnification, (e) stir zone (nugget) with 500x magnification.



(a)

(b) (c) (d)

200X Magnification

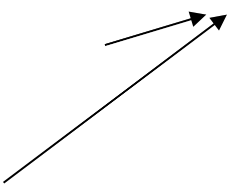


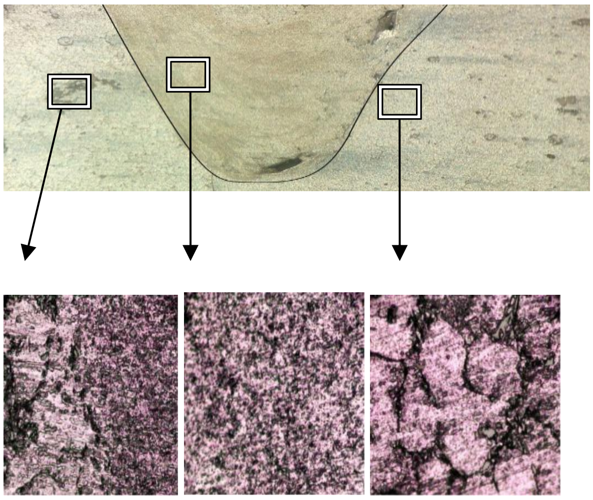
(e)

500X Magnification

Figure 2. (a) macrostructure of AlSiTiB-7,5%SiC with 1087 rpm rotational speed, (b) TMAZ-HAZ interface with 200x magnification, (c) stir zone (nugget) with 200x magnification, (d) base metal with 200x magnification, (e) stir zone (nugget) with 500x magnification.

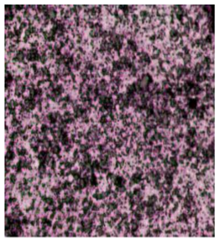
wormhole





(b) (c) (d)

200X Magnification



(e)

500X Magnification

Figure 3. (a) macrostructure of AlSiTiB-7,5%SiC with 1570 rpm rotational speed, (b) TMAZ-HAZ interface with 200x magnification, (c) stir zone (nugget) with 200x magnification, (d) base metal with 200x magnification, (e) stir zone (nugget) with 500x magnification.

Based on macrostructure observation, wormhole occurred in welding product with rotational speed 1057 rpm and 808 rpm, while at 1087 rpm no wormhole occurred in welding result. Stir zone (nugget) region have smaller grain size and dense grain boundary, also SiC distributed more equally than in TMAZ-HAZ interface and base metal. This result appeared due to the stir zone region is stirring region when process took place, so SiC will be split into smaller part from previous size. On stir zone (nugget) region the largest grain size found at welding product with 808 rpm rotational speed. While at 1087 rpm and 1570 rpm the grain size and SiC distribution relatively same or no significant difference. From this result, it can be concluded that greater rotational speed applied to welding process, the grain that obtained will be smaller.

III.2 The Result of Hardness test

Hardness was characterized using microhardness vickers Mitotoyo HM20 in UPT Laboratorium Terpadu Diponegoro University. This microhardness test was based on ASTM E 384 standard - micro range (10 gr to 1000 gr). The hardness test was observed along welding line with 25 spots including 0 spot, with distance of each spot is 0.5 mm.

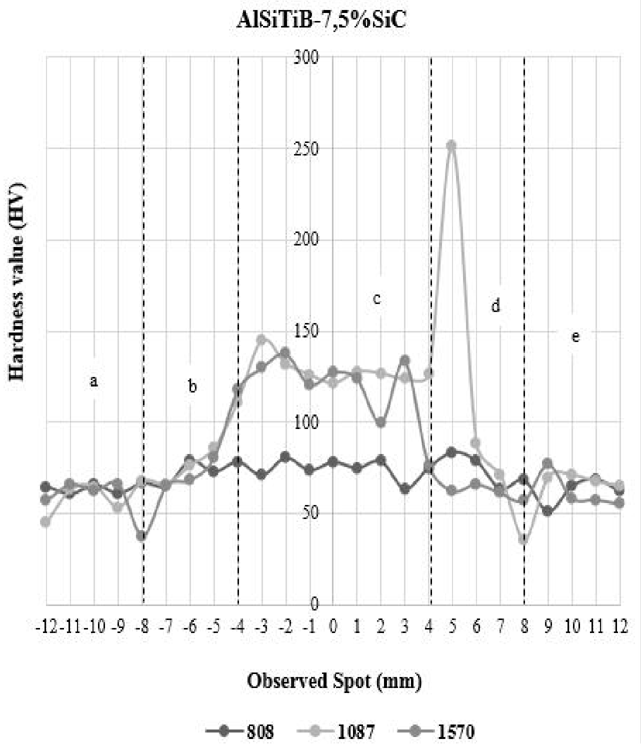


Figure 4. AlSiTiB-7,5% SiC Hardness Comparison between 808, 1087, 1570 rpm

Additional information of the figure 4 :

a and e : base metal

b and d : TMAZ-HAZ interface

c : stir zone (nugget)

Figure 4 showed that welding product with the highest average hardness value obtained in welding region with rotational speed 1087 rpm, with value in stir zone 126.4 HV, while at 1570 rpm and 808 rpm the average hardness value in stir zone (nugget) region is 118.1 HV and 74.6 HV respectively. In 808 rpm rotational speed, hardness value didn't increase significantly, meanwhile at 1570 rpm the hardness value increase on stir zone (nugget) region, but no bigger than at 1087 rpm. This is due to at 808 rpm and 1570 rpm wormhole occurred in welding product.

III.3 The Result of Porosity Test

Porosity test was carried out to strengthen the analysis of micrograph test result and hardness test result. Porosity test was performed at welding product of base metal material with rotational speed variation 808 rpm, 1087 rpm and 1570 rpm

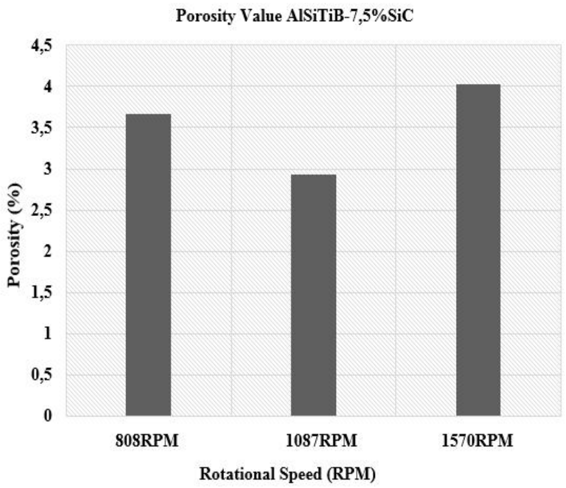


Figure 5. Porosity Variation of AlSiTiB-7,5% SiC

Figure 5 show that the highest porosity was obtained by 1570 rpm rotational speed with porosity value 4.03 %. Meanwhile at 808 rpm and 1087 rpm the porosity value is 3.66 % and 2.93 % respectively. It can be concluded that the bigger porosity of a material, the hardness of the material will decrease or smaller.

IV. CONCLUSION

From this study, it can be concluded that:

1) Based on macrostructure, the wormhole occurred in 1570 rpm and 808 rpm rotational speed, while on 1087 rpm no wormhole occurred. The microstructure in stir zone (nugget) region have smaller grain size and the grain boundary is dense if compared to TMAZ-HAZ interface and base metal. In the stir zone (nugget) region the largest grain size appeared in welding with rotational speed 808 rpm, while at 1087 rpm and 1570 rpm the grain relatively same, have small grain size and dense grain boundary.

2) Based on hardness test, the average hardness value in stir zone (nugget) region have higher value than in TMAZ-HAZ interface and base metal. The highest average hardness value appeared on stir zone (nugget) region with value 126.4 HV using rotational speed 1087 rpm. While at 1057 rpm and 808 rpm the average hardness value is 118.1 HV and 74.6 HV respectively.

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