Engineering International Conference "UNNES Conservation" 2013 Proceeding
p- ISBN: 979-25-2783
January 08, 2013, Semarang, Indonesia

OPTIMATION OF MECHANICAL AND PHYSICAL PROPERTIES OF FRICTION STIR WELDED WITH VARIATION OF PREHEAT TEMPERATURE

Yustiasih Purwaningrum, Lulu Supriyanto

Mechanical Engineering Department, Faculty of Industrial Engineering
Islamic University of Indonesia, Jl. Kaliurang Km. 14,5 Yogyakarta
Tel: (0274) 895287 ext 147. Fax: (0274) 895007
E-mail: yustiasih2003@yahoo.co.nz

***Abstract*—** *The aimed of this research is to reached the optimum mechanical and physical properties of friction stir welded metals with various preheat temperature. A series of beads were made on 4 mm thick Aluminium Alloy 6063 T6 series. The temperatures used were 100 °C, 150°C, and 200°C. The welding process performed on flat position with 4000 rpm of rotational tool and 12.5 mm/min of translation speed. The mechanical properties were measured with respect to the strength, hardness and toughness using Universal Testing Machine, Vickers Microhardness, and Charpy method respectively. The physical properties were examined based on the microstructure using Optical Microscope. The micrograph show that weld metal, HAZ, and base metals with various translation speed have the similar structure.The toughness of weld metals with preheat temperatures 100 °C, 150°C, and 200°C are 0.254; 0.259; and 0.216 J/mm^2 respectively. The results of tensile test show that weld metals with preheat temperature 150°C has the highest value (130.6 MPa).*

***Keywords* —** *Friction Stir Welding, Preheat Temperature, Toughness, Microstructure, Hardness*

I. INTRODUCTION

Friction stir welding (FSW) is a relatively new joining process that is presently attracting considerable interest[1]. FSW is a fairly recent welding technique, invented by Wayne Thomas of The Welding Institute (TWI), Cambridge, United Kingdom[2]. This technique was developed primarily for welding metals and alloys that hertofore had been difficult to weld using more traditional fusion techniques (for ex. Aluminium and aluminium alloys.[3]

This technique utilizes a nonconsumable rotating welding tool to generate frictional heat at the workpiece (Fig 1), thereby affecting the formation of a joint, while the material is in the solid state. The principal advantages of FSW, being a solid-state process, are low distortion, absence of melt-related defects and high joint strength, even in those alloys that are considered nonweldable by conventional techniques.[4]

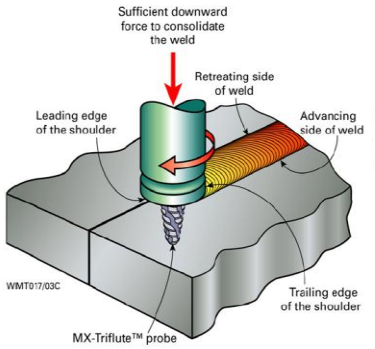


Fig. 1 Schema of FSW

II. MATERIALS AND EXPERIMENTAL PROCEDURE

II.1. Materials

Aluminium sheets (Al 6063 T6) of size 300 mm x 100 mm and 4 mm thickness were welded by FSW at the Manufacture System Laboratory Islamic University of Indonesia. Before the welding processes, the preheat was carried out. The temperatures of preheat that used were 100°C, 150°C dan 200°C.

Tabel 1. Chemical Compositition of Al 6063 T6

	Chemical Composition (%)								
Alloy	Si	Fe	Cu	Mg	Mn	Cr	Zn	Ti	Al
6063 T6	1,20	0,33	0,07	0,84	0,48	0,02	0,05	0,01	97,0

Tabel 2. Chemical Composisition of tool W 302 H 13 (Bohler Grade Steel)

	Chemical Composition (%)						
Alloy	C	Si	Mn	Cr	Mo	V	Fe
W 302	0,39	1,10	0,40	5,20	1,40	0,95	90,56

II.2. Welding Processes

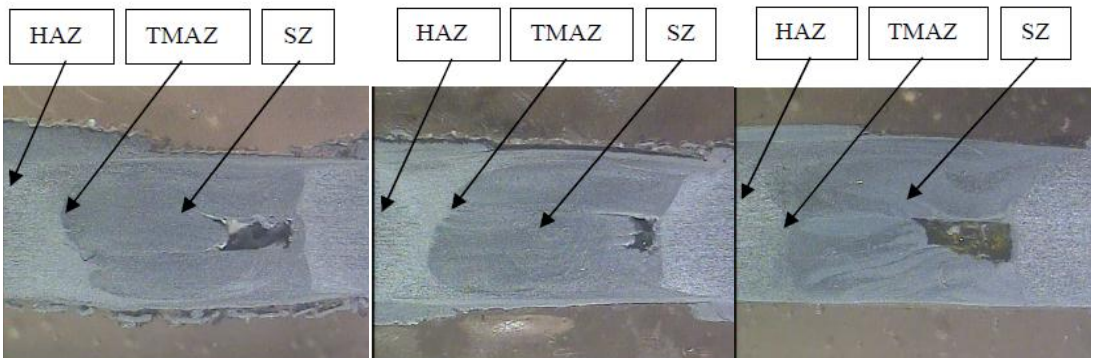
All welds used in the study were made on a converted CNC milling machine with a simple FSW tool. The sheet materials were joined by using FSW as a but joint. The translation speed of RSW that used was 12.5 mm/min and the rotational speed of tool that used was 4000 rpm.

II.3. Measurements

The effects of various preheat temperature on the physical and mechanical properties of the material were investigated by metallographic examination and hardnes, toughness,and tensile strength measurement. Microstructural changes of the weld zone were evaluated using optical microscopy. Vickers hardness was measured at the cross section perpendicular to the weld centre using a microhardness tester (100 g, 10 s). Tensile testing was carried out at room temperature using an universal testing machine.

III. RESULTS AND DISCUSSION

Figure 2 shows macrostructures of friction stir welded Al 6063 T6 alloy for various preheat temperature. A smallest defect could be observed at preheat temperature 150°C. All defects defect was observed near the retreating side.



(a) (b) (c)

Fig. 2. Macrostructure of Weld Metal with preheat Temperature (a) 100°C (b) 150°C (c) 200°C

III.1. Microstructural Characterterizations

The microstructure of friction stir welded Al 6063 welded alloy joined at various preheat temperature are shown in Table 3. The weld zone of friction stir welded was composed of five region (Fig 3).

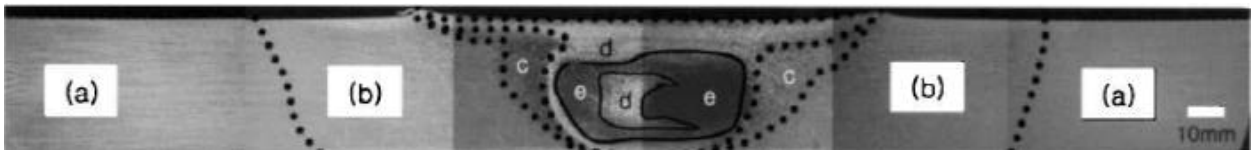
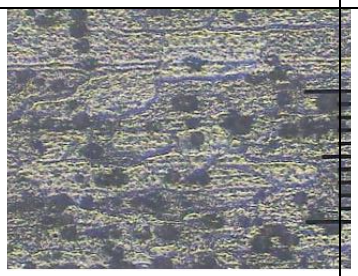
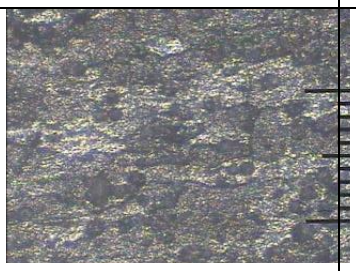
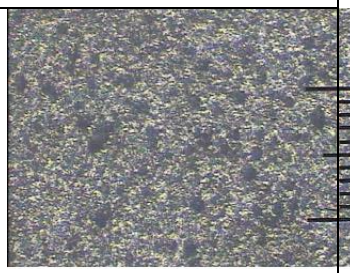
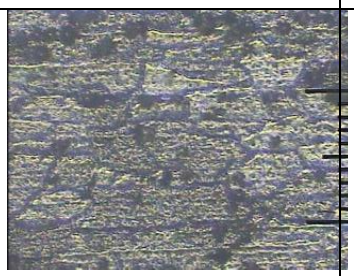
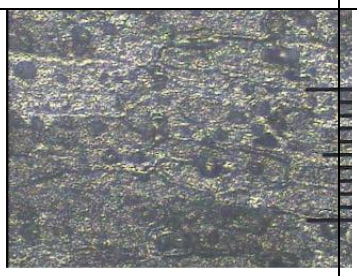
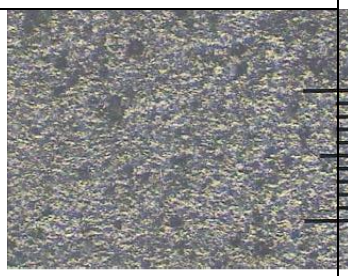
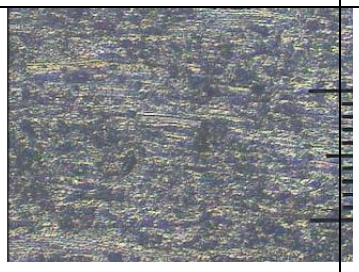
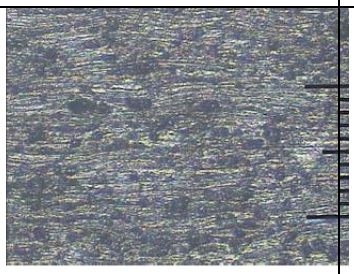
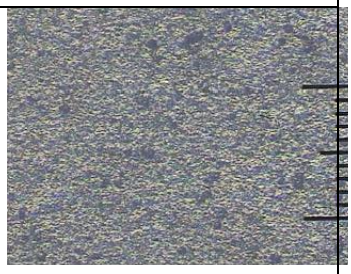


Fig 3. The region of friction stir weld zone [5]

(a) Base metal (BM)
(b) Heat Affected Zone (HAZ)
(c) Thermomechanically affected zone (TMAZ)
(d) (e) Stir Zone (SZ)

The BM contained very fine, equiaxed grain. These structure had been formed during previos wrought working process. The HAZ was characterized by slight grain growth, while twin and shear structure remained.The grain size of SZ at alluminium alloy welded was smaller than base metal. This was a result of the annealing effect induced by welding heat during the FSW process

Table 3. Microstructure of Al 6063 T6 welded with various preheat temperature

	Base Metal (BM)	**Heat Affected Zone (HAZ)**	**Stir Zone (SZ)**
100° C			
150° C			
200° C			

III.2. Tensile Strength

Figure 4 shows the effect of preheat temperature on the tensile strength of friction stir welded Al 6063 T6 alloy with various preheat temperature. The highest joint strength was attained for friction weld with preheat temperature 150°C. Because in this condition the defect is smaller than the others various preheat temperature that used. All of friction weld with various preheat temperature have higher tensile strength tensile strength than friction weld without preheat.

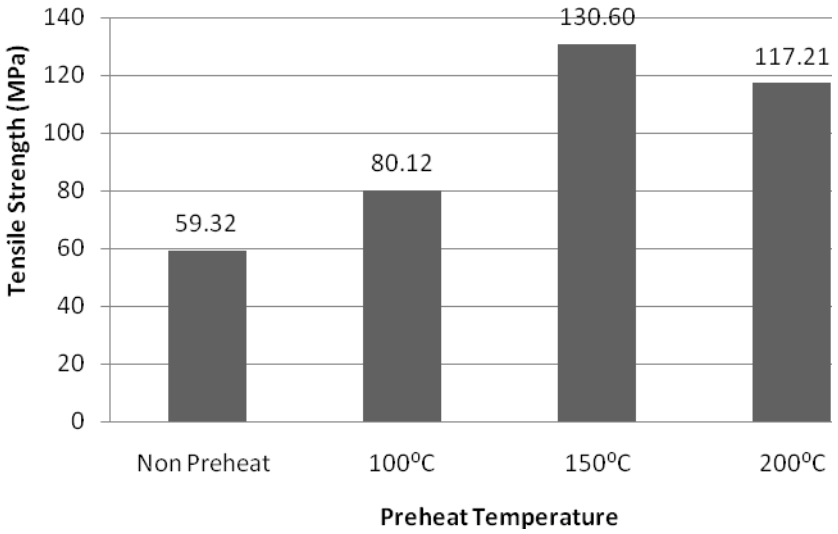


Fig. 4. The strength of Weld Metal with preheat Temperature

Percentage elongation of joints was more than 200 % of that of weld metal without preheat for all welding condition (various preheat temperature) (Fig 5).

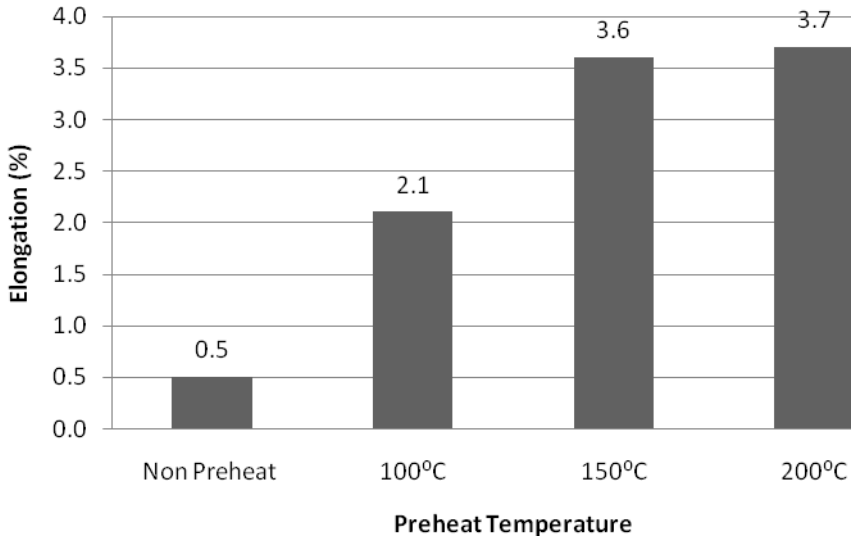


Fig. 5. The elongation of Weld Metal with preheat Temperature

III.3. Toughness

The toughness of friction stir welded of Aluminium alloys shows on fig 6. All of friction welded with various temperatures have similar impact energy. The values of impact energy approximately 2.5 J/mm^2, which was 46 % of that of weld metal without preheat.

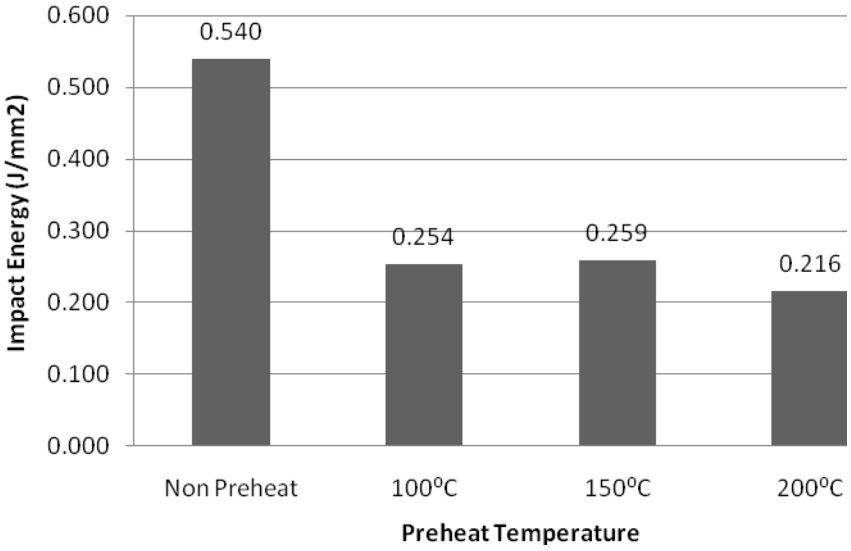


Fig. 6. The toughness of Weld Metal with preheat Temperature

III.4. Hardness Number

Fig 7 shows that stir zone for all friction stir welding condition have lower hardness number than base metal zone. Because friction stir welding cause a softened region around the stir zone in the case of precipitation hardened aluminium alloys.[6] The hardness profile was strongly affected by precipitate distribution rather than grain size in the weld and softening was caused by dissolution and growth of precipitates during the thermal cycle of welding.[7]

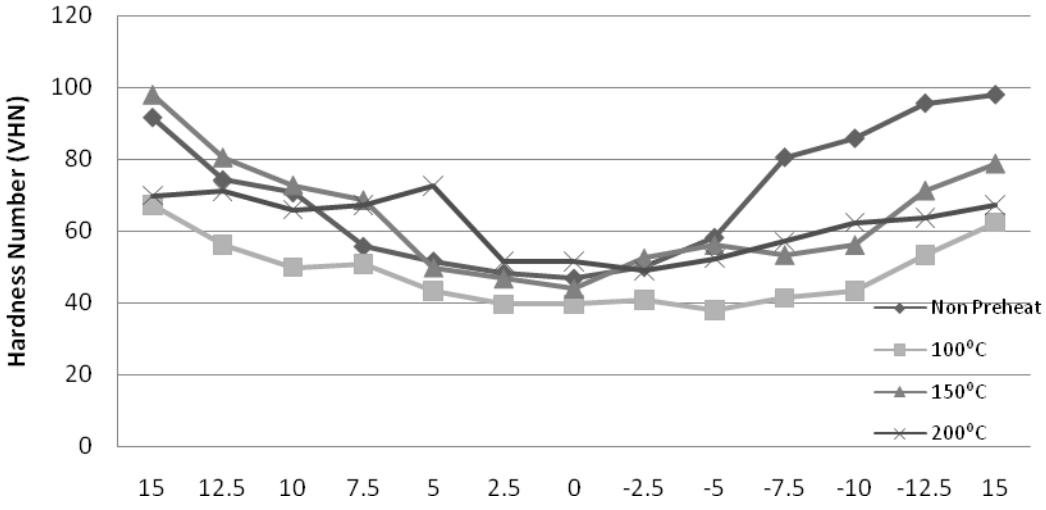


Fig. 7. The Hardness Number of Weld Metal with preheat Temperature

IV. CONCLUSION

The main results related to mechanical and physical properties of friction stir welded with various preheat temperature are summarized as follows:

1. The macrostructure examination shows that friction stir welded with 150°C has the smallest defects.
2. The annealing effect induced by welding heat during FSW process affected the grain size of SZ at alluminium alloy welded was smaller than base metal.
3. The maximum joint strength was 130.6 MPa, ~266% of that of weld metal without preheat. Percentage of elongation was higher than that of weld metal without preheat for all welding with various preheat temperature.
4. The values of impact energy approximately 2.5 J/mm^2, which was 46 % of that of weld metal without preheat.
5. The stir zone have lowest hardness number for all friction stir welding condition.

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