The Role of The Temperature and Width of The Heating Plate of The Heating Plate in The Friction Stir Welding Jig on The Strength of Aluminium Alloy 1100 Welded Joint

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Abstract. This paper discusses the role of temperature and the width heating plate in the FSW jig on the strength of the aluminum alloy 1100 welded joint. FSW welding for aluminum alloy 1100 (AA 1100) material at this time has not yet produced optimal weld joint strength, so it necessary to study to improve the quality of the weld joint strength. The purpose of this study was to find the optimum strength of welded joints for aluminum alloy 1100 (AA 1100) with the FSW welding process. The process of determining the optimum value of the weld joint strength is carried out by varying the temperature of the heating plate and width of the heating plate contained in the FSW jig used. The method used in this study is an experimental method, the variation values used for temperature of the heating plate are: 175o C, 200o C, 250o C, and 300o C, and for the width of the heating plate, are: 10 mm, 20 mm, and 30 mm. To obtain data, tensile and impact test were carried out using standard specimen of ASTM E8-13a and ASTM E 23. The result of this study were the highest tensile strength and impact strength values were 62.64 M Pa and 0.5037 J/mm2 , respectively (58.66% and 75.19% of the strength of aluminum alloy 1100 without connection). These value were obtained from the combination of the temperature of heating plate is 250oC and a heating plate width is 10 mm.

Keywords: aluminum alloy 1100, friction stir welding, heating plate, jig, heating plate, temperature, width

1 Introduction

The development of welding is very rapid year to year, from conventional to non-conventional welding and from fusion welding to solid state welding. Welding failures often occur so that development in the world of welding are continuously improved in order to obtain maximum welding result and are aimed at reducing the impact of pollution from welding result [1].

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Friction Stir Welding has succeeded in reducing the cost of the welding process so that it become cheaper because this welding only requires low energy input and does not use additional material (filler material) [2].
The use of a heated base plate which is placed on the bottom surface of the HDPE sheet joint to be joined by the friction stir welding method, where the heater under the connection are can be adjusted to its temperature value before and during the welding process, in fact it can increase the tensile strength and homogeneity of the HDPE sheet weld joint. From this study obtained the maximum tensile strength is 94.80% of the maximum tensile strength of HDPE material without connection, the condition is obtained at the heating temperature of base plate is 141o C [3].
Preheating the material in the FSW AA 7075 process at temperature of 100o C produces optimal tensile strength and efficiency of welded joints, the tensile strength of welded joints is higher than the joining process without preheating [4].
The heat treatment of the material in the 6061 T-6 aluminum joining process with the friction stir welding method produces a higher tensile strength of the welded joint than without heat treatment (room temperature). From this study, the maximum tensile strength was 54.017% of the maximum tensile strength of 6061 T-6 aluminum material without connection, this condition was obtained at a heating temperature variation of 200 o C [5].
Conditioning the temperature of the material in the process of joining HDPE sheets with the hot-gas welding method where the material is heated by a heater contained in the base plate produces a welded connection strength characteristic that is better than the condition of the material without heating. The interaction of the heating temperature value of the base plate of 150o C and hot air flow of 250o C in the process of joining HDPE sheet with the hot-gas welding method resulted in the optimum characteristic of the weld strength, where the tensile strength and impact strength were 85.65% and 89.74% when compared to the tensile strength and impact strength of parent metal [6].
In the weld joint there is an area called the HAZ (Head Affected Zone) area, the HAZ area is area adjacent to the welding area that undergoes a thermal cycle, namely heating and cooling quickly so that this area is the most critical of the welded joint [7].
Therefore, it is necessary to conduct research aimed at increasing the strength and homogeneity of the welded joints of aluminum alloy 1100 using a heated base plate friction stir welding jig by varying the temperature and width of heating plate.

2 Research Methods

In this study, the material that was joined by the friction stir welding (FSW) process was aluminum alloy 1100 with a size of 60 mm x 150 mm. The FSW process uses a milling machine where the parameters of translation speed and spindle rotation are 10 mm/minute and 1750 rpm. The welding tool is a pin-shoulder made of AISI H13 material. Size of diameter of pin and shoulder are 5 and 20 mm. The heater is coil of heating wire with a power of 500 Watt housed inside heating plate of FSW jig. Function of the heating wire is heating material at start and during the FSW process.

To control the temperature of heating plate on the FSW jig using a digital temperature controller type PID Rex C400 output SSR, with the following specification display: dual display for Celsius (o C), thermocouple input: type K range: 0-400o C, main output: SSR-PID cooling/heating control, individually programmable PID control parameter/ on-off control, digital filter coefficient, and more, accuracy: 0.5%.
For tensile testing using the ASTM E 8-13A standard [8] and the impact testing using the ASTM E 23 standard [9] for the welding joint of aluminum alloy 1100 material (AA 1100).

3 Heating Plate Research Setup

The heating plate which will be used as an auxiliary tool on the friction stir welding jig as show in Fig. 1.

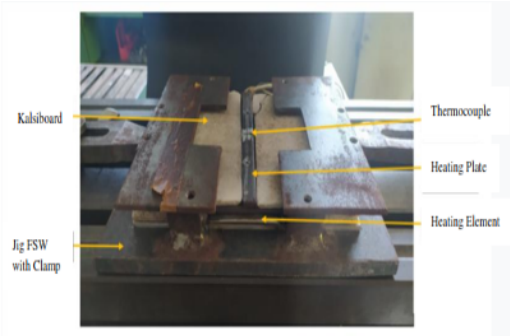


Fig. 1. Heating plate on the friction stir welding jig

The schematic of the friction stir welding research installation with aluminum alloy 1100 material as show in Fig. 2.

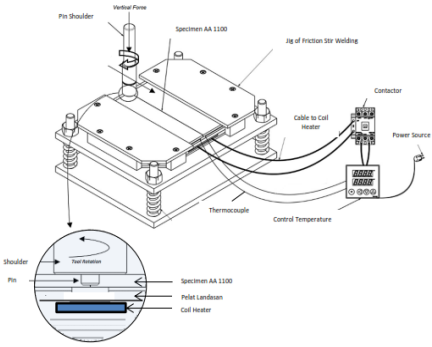


Fig. 2. The schematic of the friction stir welding research installation

Analysis of the effect of independent variable on the dependent variable in this study in this study in case the effect of variation in the temperature and with of the heating plate on the strength of the weld joint.

4 Result and Discussion

4.1 Tensile Strength

The result of the tensile strength test (ASTM E8-13A standard) on the welded join of the AA 1100 material as show in Fig. 3.

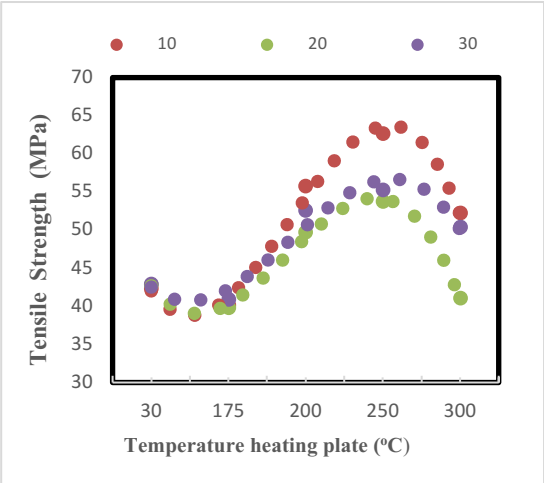


Fig. 3. The relationship between the temperatures (C) on the width of the heating plate each (10 mm (red), 20 mm (green), 30 mm (blue)) with the tensile strength welded joint (M Pa) of AA 1100 material.

Fig. 3 shows that relationship between the temperatures on the width of the heating plate with the tensile strength of the welded joint of AA 1100 material. It shows that there is no linear relationship between the temperature of heating plate and the tensile strength of the welded joint. Starting from a temperature of 175º C to 250º C the tensile strength tends to increase, after that from a temperature of 250º C to 300º C it tends to decrease. The trend graph looks the same in each variation of the width of heater, but what interesting in the graph in Fig. 3 is the highest tensile strength value is variation in the width of the heater 10 mm, while for variation in the width of the heating plate 20 mm the tensile strength value is the lowest, for variation in the width of the heating plate 30 mm the tensile strength is the middle. The highest value of strength of welded joint is 62.64 M Pa and the lowest value of tensile strength of welded joint is 39.79 M Pa.

4.2 Impact strength

The result of the impact strength test (ASTM E23 standard) on the welded join of the AA 1100 material as show in Fig. 4.

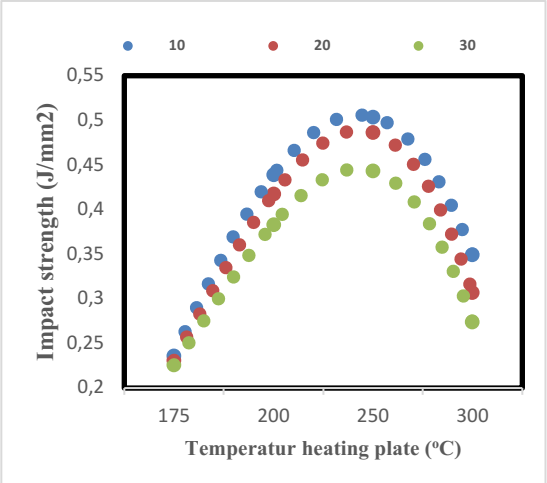


Fig. 4. The relationship between the temperatures (o C) on the width of the heating plate (10 mm (blue), 20 mm (red), 30 mm (green)) versus the impact strength welded joint (J/mm2)

Fig. 4 shows that relationship the temperatures on the width of the heating plate with the impact strength of the welded joint of AA 1100 material. It shows that there is no linear relationship between the temperature of heating plate and the impact strength of the welded joint. Starting from a temperature of 175o C to 250o C the impact strength tends to increase, after that from a temperature of 250o C to 300o C it tends to decrease. The trend graph looks the same in each variation of the width of heater, but what interesting in the graph in Fig. 4 is the highest impact strength value is variation in the width of the heater 10 mm, while for variation in the width of the heating plate 20 mm the tensile strength value is the middle, for variation in the width of the heating plate 30 mm the tensile strength is the lowest. The highest value of impact strength of welded joints is 0.5037 J.mm2 and the lowest value of the impact strength is 0.2160 J/mm2.

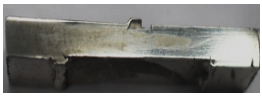
From Fig. 4 and 5 the maximum value of the strength of the welded joint, both tensile strength and impact strength, is obtained at the combination of the temperature variation of the heating plate 250o C and variation of width of the heating plate 10 mm.

Macrostructure photo of AA 1100 welding joint

Observation of macrostructure photos were carried out to determine the welding defect that occurred due to the welding process using the friction stir welding method. In the picture below (Fig. 5 to 6) show the result of macrostructure photos for friction stir welding with variations in the temperature of the heating plate and the width of the heating plate.

Temperature of heating plate 175° C

Temperature of heating plate 200° C



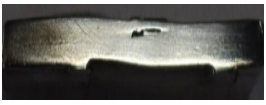
Temperature of heating plate 250° C

Temperature of heating plate 300° C

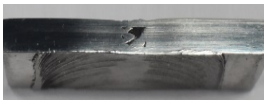
Fig. 5. Photos of the cross section macrostructure on welded joint in a heating plate width of 10 mm.

Temperature of heating plate 175° C

Temperature of heating plate 200° C



Temperature of heating plate 250° C

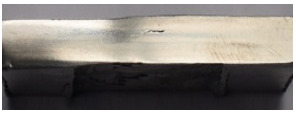


Temperature of heating plate 300° C

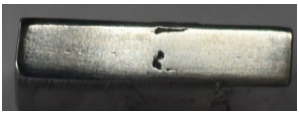
Fig. 6. Photos of the cross section macrostructure on welded joint in a heating plate width of 20 mm.

Temperature of heating plate 175° C

Temperature of heating plate 200° C



Temperature of heating plate 250o C



Temperature of heating plate 300o C

Fig. 7. Photos of the cross section macrostructure on welded joint in a heating plate width of 30 mm.

From the macrostructure photo in Fig. 5 to 7, it shows that the welding result have tunnel defects or worm holes in each variation of the variable temperature and width of the heating plate. Worm holes welding defect occur because the temperature in the mixing area is not evenly distributed and does not reach the ideal point during the welding process. The high input temperature generated by the combination of the rotation of the shoulder and the heating plate will result in over heating in the Nugget zone, this overheating will also result in tunnel defect or worm holes welding defects.

The biggest worm hole defect are found in the welded joints with variations in the temperature of heating plate 175° C and the width of heating plate 20 mm in Fig. 6 and when viewed from the values of tensile strength and impact strength of the welded joint, it have the lowest value.

The smallest worm hole defect are found in welded joints with variations in the temperatures of heating plate 250° C and the width of the heating plate 10 mm in Fig. 5 and when viewed from the value of the tensile strength and impact strength in Fig. 3 and 4 each have the highest value.

5 Conclusion

The conclusion that can be obtained from the research that han been done are as follows:

1. Variation in the temperature of the heating plate on the friction stir welding jig affect the strength of the welded joints of aluminum alloy 1100 (AA 1100). The characteristic of the strength of the welded joint which include tensile and impact strength increased from variations in the temperature of the heating plate 175° C to 250° C, and decreased from the temperature variation of heating plate 250° C to 300° C. The highest average tensile strength and impact strength value are found in the temperature variation of heating plate of 250° C friction stir welding jig affect the strength of the welded joints of aluminum alloy 1100 (AA 1100)., the lowest average value is found in variation of the temperature of heating plate of 175° C
2. Variation in the width of the heating plate on the friction stir welding jig affect the strength of the welded joints of aluminum alloy 1100 (AA 1100). The characteristic of the strength of the welded joint which include tensile strength and impact strength decreased from variation in the width of the heating plate from 10 mm to 20 mm, and increased from variation in with of heating plate from 20 mm to 30 mm. The highest average value of tensile strength and impact strength in found in the variation of heating plate width of 10 mm, the lowest average value in found in the variation of the heating plate temperature of 20 mm.
3. The characteristic of the best (optimum) aluminum alloy (AA 1100) welded joint strength which include tensile strength and impact strength are 62.64 M Pa and 0.5037 J/mm2, respectively when compare to strength of aluminum alloy 1100 (AA 1100 without welded joint in percent are 58.66% and 75.19%. The highest value of welded joint strength is obtained from variation of the temperature heating plate and the width heating plate is 250° C and 10 mm.
4. The addition of a heater to the base plate contained in the friction stir welding jig can increase tensile strength and impact strength of the weld joint for aluminum al-

loy 1100 (AA 1100) material. The heating plate temperature value and heating plate width value to obtain the highest tensile strength and impact strength of the weld joint were 250° C and 10 mm.

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