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Effect of Spindle Speed on the Bending Test of Al-1100 in Fraction Stir Welding Joints

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ABSTRACT
Currently, in the industrial world, many products or components are required to have strong but light properties. Therefore, aluminum material is increasingly being chosen as the main material in the industrial production process. Aluminum and its alloys are classified as light metals that have high strength, corrosion resistance, fairly good electrical conductivity, and are lighter than iron or steel. However, aluminum has a weakness in its welding ability which is not good when compared to other metals. This problem can be overcome by the Solid-State Welding (SSW) welding method. SSW itself is a welding process carried out when the metal is still solid, meaning that the metal does not melt. One of the SSW methods that is often used is Friction Stir Welding (FSW), which is a solid-state welding technology that is very suitable for joining materials such as aluminum. FSW does not require additional materials, but instead utilizes the heat from friction between the probe and shoulder of the welding tool with the surface of the workpiece. This research on Friction Stir Welding aims to determine the effect of variations in feed rate on the strength of 1100 aluminum joints through tensile tests. The pin tool used is made of carbide, cylindrical in shape with a length of 100 mm and a diameter of 3 mm. The test specimen used was aluminum 1100 with a thickness of 3 mm, a length of 200 mm, and a width of 20 mm, and was made into 9 samples. The FSW welding process and the manufacture of test specimens were carried out according to the ASTM E8 standard. During the welding process, the pin tool rotated at 2200 Rpm, and the feedrates used were 50 mm/min, 100 mm/min, and 150 mm/min. After welding, a tensile test was carried out on the FSW joint results. There were nine tensile tests, with each feedrate parameter tested on three samples. The average tensile strength of the FSW joint on a 2200 Rpm spindle with a feedrate of 50 mm/min was 12.34 MPa, at a feedrate of 100 mm/min was 21.53 MPa, and at a feedrate of 150 mm/min was 29.21 MPa.

Keywords: *Friction Stir Welding (FSW), Aluminum 1100, Tensile Test Strength, Feedrate.*

INTRODUCTION

The development of the industrial world today, many products or components that are needed must have strong characteristics but remain light. Along with the development of the industry, aluminium began to be chosen as the main material in the production process. This is because aluminium and its alloys are classified as light metals with high strength, are resistant to corrosion, have good electrical conductivity, and are lighter in weight than iron or steel[1]. Aluminium is widely applied in industry, including in heat exchangers, pressure vessels, pipes, and so on. However, aluminium and its alloys have several weaknesses compared to steel[2], such as high specific heat and conductivity[3], easily oxidized, and forms an aluminum oxide layer that has a high melting point [4]. This condition can inhibit the melting process between the base metal and the weld metal, and if the solidification process takes place too quickly, fine cavities can appear due to trapped hydrogen pockets.

The development of lightweight construction, materials and designs plays an important role in the economy and fuel consumption. Road, rail, water, and air transport are based on the use of aluminium and its alloys, for economic and ecological reasons. MIG and TIG welding processes are characterised by high heat input, the occurrence of thermal deformation problems and the formation of aluminium oxide. Riveted assemblies are more expensive to manufacture, have a higher weight than welded assemblies, and the holes required to insert the rivets cause stress concentrations. Another problem associated with riveted assemblies is that they are not tight and leak-proof. The introduction of FSW solved this problem[5] [6].

During the FSW process, a heat affected zone (HAZ), thermomechanical affected zone (TMAZ), and weld nugget area will be formed[7]. The temperature that occurs in the FSW process is below the melting temperature of the parent metal, so that the recrystallisation temperature will be different from conventional welding[8]. The HAZ formed in FZW is similar to conventional welding because this zone does not experience deformation. The FSW process produces TMAZ with the condition of the material in this zone experiencing plastic deformation due to the stirring process in addition to heat induction, so that it experiences microstructural changes[9] [10] [11]. In the welding area, heat and deformation occur at their highest[12], the parent metal is in a semi-solid condition, stirred and experiences significant grain refinement which can change or increase mechanical strength on the welding side[13].

Factors that affect the results of FSW welding are welding tools, tool speed speed, welding feed rate, and tool pressure force on the workpiece. If the right FSW parameters can be selected, this study aims to see the mechanical strength of the joint.

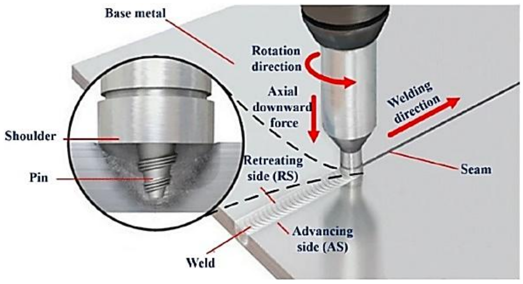

Figure 1. Schematic diagram of FSW[11]

METHODE

In this FSW welding process, a conventional machine is used, namely the Emco F3 4-axis milling machine, Figure 2. Where this research was conducted by making changes/research variables with a total of 9 specimens, each variable is 3 specimens, as shown in Table 2. Welding with the friction stir welding method is welding that occurs in a solid state using the Cylindrical Tool Pin type, as seen in Figure 3.

Figure 2. Emco F3 4 Axis milling machine

Table 1. Emco F3 Milling Machine Specifications

SPECIFICATION	
Worktable Range	: 300x200x350 mm
Tool Holder	: SK30.8
Spindle Speed	: 80-2200 Rpm
Dimensions	: 1,30 x 1,20 x 1,80 m

Figure 2. Cylindrical Tool Pin

Table 2. Research variables

Sample	Spindle Speed (Rpm)	Lengthy (mm)	Thicknes (mm)	Width (mm)
1	720/100 720/100 720/100	200	3,00	40
2	1100/100 1100/100 1100/100	200	3,00	40
3	2200/100 2200/100 2200/100	200	3,00	40

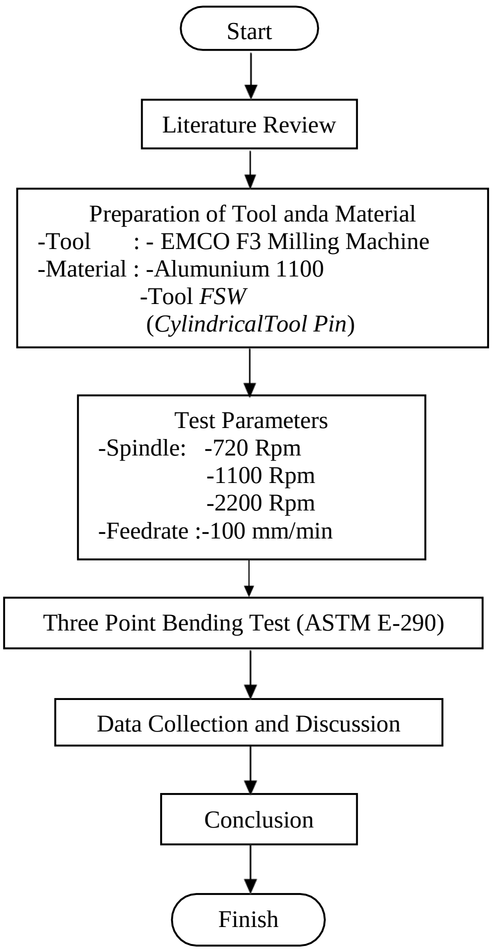

Figure 3. Flow chart research

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RESULTS AND DISCUSSION

Welding with the FSW method is welding that occurs in solid state conditions (solid state joining) by utilising friction from a rotating workpiece with another stationary workpiece so that it can melt the stationary workpiece and finally connect them. The results of welding using the friction stir welding method are shown in Figure 4 below. The results of this welding will later be tested for mechanical properties with destructive testing, namely the three-point bending test. The standard used in this study is the ASTM E-290 standard, for specimens with a sheet plate type with a thickness of 3 mm.

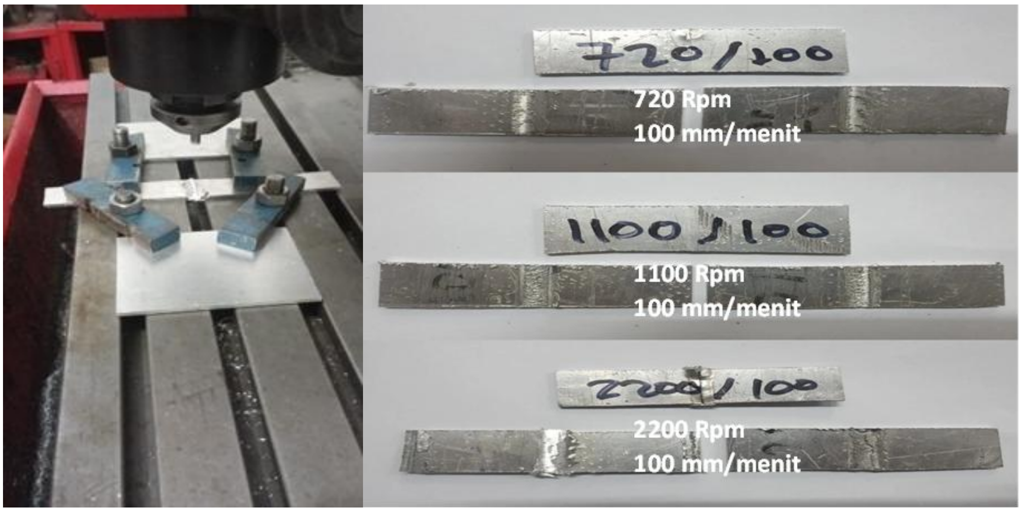

Figure 4. FSW welding results.

In this study, data were obtained through bending tests on Friction Stir Welding (FSW) joints. Bending tests were carried out using a three-point bending test machine, where the specimens were first formed according to applicable standards to ensure the validity of the test results. Each variation of speed (RPM) in the FSW process produced three bending test samples. Each sample was then tested three times to obtain more accurate and reliable data. The average value of the three tests was used as the final result for each RPM variation. The results of this bending test provide an overview of the strength and mechanical characteristics of the welded joints produced by the FSW method at various speeds. Complete data on the bending test results can be seen in Table 3.

Table 3. Three-point comparison test results

Sample	Spindle Speed (Rpm)	Lengthy (mm)	Thicknes (mm)	Width (mm)	Force (kgf)	Average (kgf)
1	720/100	200	3,00	40	58.98	
2	720/100	200	3,00	40	58.98	58.97
3	720/100	200	3,00	40	58.96	
Sample						
1	1100/100	200	3,00	40	62.68	
2	1100/100	200	3,00	40	62.67	62.67
3	1100/100	200	3,00	40	62.68	
Sample						
1	2200/100	200	3,00	40	73.96	
2	2200/100	200	3,00	40	73.96	73.96
3	2200/100	200	3,00	40	73.98	

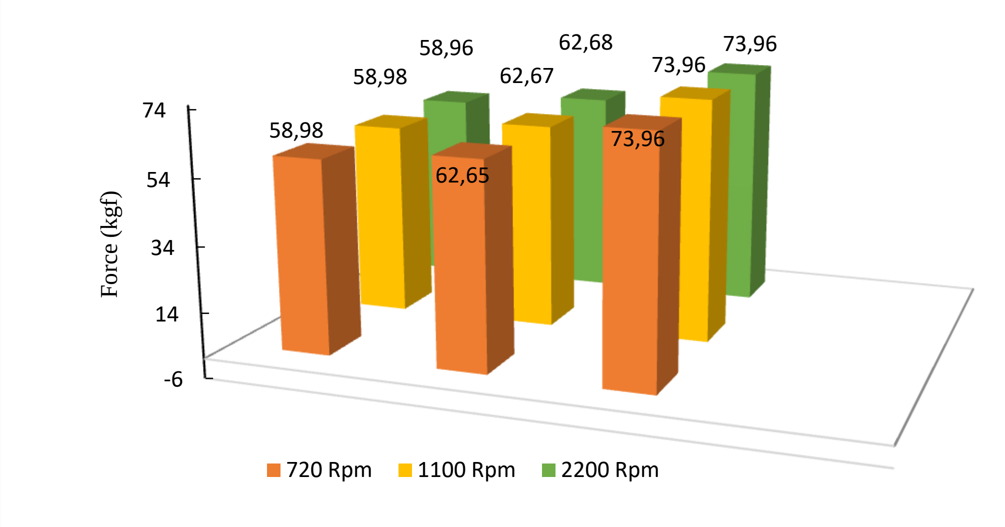

Figure 5. Three-point bending test results

Figure 5 above shows the results of the three-point bending test on Friction Stir Welding (FSW) weld joints with different speed speed (Rpm) variations, namely 720 Rpm, 1100 Rpm, and 2200 Rpm. Each colour group on the graph represents three test specimens for each variation of Rpm. At a speed speed of 720 Rpm, the three-point bending strength values obtained ranged from 58.96 to 58.98. Furthermore, at a speed of 1100 Rpm, the three-point bending strength value increased to around 62.65 to 62.68. Meanwhile, at the highest speed speed, namely 2200 Rpm, the three-point bending strength value reached the highest number, 73.96 in all three specimens. From these results, it can be concluded that increasing the speed speed (Rpm) in the FSW process has a significant effect on increasing the three-point bending strength of the weld joint. The higher the Rpm used, the greater the three-point bending strength value produced. This shows that the Rpm parameter has a significant influence on the mechanical quality of FSW joints, especially in terms of the resulting three-point bending strength.

Evaluation of bending test results on a material can be done using the bending strength formula. This formula provides the maximum stress value that can be withstood by the material before experiencing significant damage or deformation. The bending test itself aims to measure the strength of the material and its elastic properties when the sample is given a load. The calculation carried out will take the average value for each aluminium 1100 specimen.

– Bending strength analysis

The formula used to calculate bending strength is as follows:

$$S = \frac{3PL}{2bd^2}$$

Where:

S = Bending Strength $\left({kgf}/{mm^2} \right)$

d = Plate Thickness (mm)

b = Plate width (mm)

L = Specimen Length (mm)

P = Force (kgf)

$$S = \frac{3 \times 58.97 \times 200}{2 \times 40 \times 3^2}$$

$$S = 49.15 \, {kgf}/{mm}$$

From the results of the bending strength calculation by taking the average value of the experiment, the strength value can be seen in Figure 6. The figure shows the results of the bending strength test on three specimens at various speedal speeds (rpm). From the graph, it can be seen that increasing the speedal speed results in an increase in the bending strength value on all specimens. At a speed of 720 rpm, the bending strength value is 49.13 - 49.15 kgf / mm². When the speed is increased to 1100 rpm, the bending strength increases by 51.32 - 52.23 kgf / mm². The most significant increase occurs at a speed of 2200 rpm, where the bending strength reaches 61.63 - 61.65 kgf / mm².

Overall, this graph shows a positive relationship between speedal speed and material bending strength. The higher the speedal speed used in the process, the greater the bending strength value produced on the specimen. This data can be an important consideration in determining process parameters to obtain optimal bending strength on the material being tested.

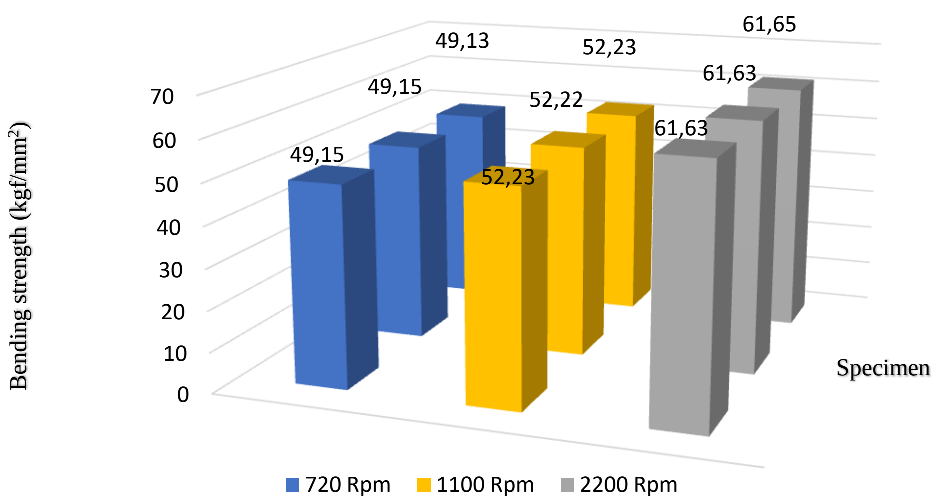

Figure 6. Bending strength

CONCLUSION

From the bending test results with a spindle speed of 720 rpm, a feed rate of 100, the results were 58.98 kgf. On the bending test results with a spindle speed of 1100 rpm, feed rate 100, the results were 62.68 kgf; on the bending test results with a spindle speed of 2200 rpm, feed rate 100, the results were 73.96 kgf. And from the bending strength calculation, the bending strength data can be an important consideration in determining process parameters to obtain optimal bending strength on the material being tested.

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