Evrimata: Journal of Mechanical Engineering
Vol. 01, No. 04, December, 2024, hal.97 – 100 e-ISSN: 3047-6305

The Effect of Pin Length and Compression Force in Double Side Friction Stir Welding on Tensile Strength of AA1100

Mochamad Andiansyah[1], Agus Setiawan[2*]

[1,2] State Polytechnic of Malang, Indonesia

mochamadandiansyah46@gmail.com, agus.setiawan@polinema.ac.id

Article Information

Manuscript Received 2023-07-21
Manuscript Revised 2024-12-25
Manuscript Accepted 2024-12-25
Manuscript Online 2024-12-31

ABSTRACT

Friction Stir Welding (FSW) is solid state welding without additives and does not produce pollution. There are two FSW welding methods, namely single side (FSW) and double side (DFSW). The FSW process in previous studies using aluminum materials, especially AA 1100 type, has not obtained optimum joint strength. Therefore, it is necessary to conduct a research study on improving the quality of tensile strength of welding results using the DFSW method on AA1100. The purpose of this study is to determine the effect of variations in pin length and compressive force on the maximum tensile strength of the results of Double Side Friction Stir Welding Aluminum Alloy 1100 welding joints. The method used in this research is experimental. The welding process uses Double Side Friction Stir Welding, by varying two independent variables namely pin length 1.5 mm, 2 mm, 2.5 mm and compressive force 30 kg, 35 kg, 40 kg, 45 kg. The controlled variables used include travel speed (10 mm/min), heating temperature (250℃), shoulder diameter (25 mm), heating plate width (10 mm), and Aluminum AA1100 plate thickness (3.5 mm), with butt joint type welding. The data analysis used is Factorial Design of Experiment (DOE). The results of this study indicate that pin length and compressive force affect the tensile strength of AA1100 material welds. The maximum tensile strength value of DFSW welding results is 90.16 MPa or 80.5% of the tensile strength of the parent material. The maximum tensile strength value was obtained from the interaction of 2 mm pin length and 45 kg compressive force.

Keywords: aluminum alloy 1100, compressive force, double side friction stir welding, pin length, tensile strength.

1. INTRODUCTION

The development of the industrialization era from year to year is increasing, especially those related to the production and connection of materials. At present, the welding process is one type of manufacturing process that is often used in industry, such as the automotive, aerospace and shipping industries [1], [2]. Many new methods have been determined to solve material joining problems related to the material being joined, one of which is aluminum [3], [4]. Aluminum and aluminum alloys include light metals that have high strength, resistance to rust a fairly good conductor of electricity and aluminum is lighter than iron or steel [5], [6]. The use of aluminum, especially type AA1100 in the industrial world is widely used for heat exchangers, pressure vessels, pipes and others. In general, aluminum connections use the rivet and TIG welding methods [7], [8]. Both of these connections are very limited when viewed from several aspects, for example, rivet connection results will increase thickness, use added material and there is also material wasted from the rest of the drilling. When viewed from the technology being developed, it is not effective [9], [10].

One alternative for joining aluminum is to use friction stir welding (FSW). Friction stir welding is a welding method discovered by Wayne Thomas at The Welding Institute (TWI), UK in 1991. FSW is welding without filler because it utilizes the friction of the tool rotation with the workpiece so that it can melt the workpiece and finally connect it together [11], [12], [13].

For now FSW has a new welding method, namely Double Side Friction Stir Welding (DFSW), the working principle of this welding method is that the friction between the workpiece and the rotating tool is carried out on two sides, namely the upper and lower sides of the workpiece so as to melt the workpiece and the heat generated is higher when compared to FSW resulting in a higher Ultimate Tensile Strength value [14], [15].

Increasing the temperature of the anvil plate in the FSW welding process results in the maximum tensile strength of the HDPE material welding joint increasing and resulting in increased homogeneity of the welding joint [16], [17].

Variations of pin depth 0.9 mm, 1.9 mm and 2.9 mm on aluminum 5083 get the maximum tensile strength at a pin depth variation of 1.9 mm, where the depth of the pin is not too deep and not too shallow so that the heat generated is evenly distributed [18].

By varying the pressing force on the AZ61A magnesium alloy material, the tensile strength results increase. In this case, it shows that the pressing force has a major effect on the FSW process, due to changes in grain size in the stir zone and hardness increases as the tensile strength value increases [19].

2. RESEARCH SIGNIFICANCE

Currently the welding process is a manufacturing process that is widely used in the industrial world. Many welding methods have been found to obtain optimum connection results and reduce pollution from the results of the welding process process, one of the materials that is often done welding is aluminum. Currently, the aluminum welding process uses the TIG welding method and the connection process uses rivets. However, the joining process causes air pollution and additional material.

Therefore, an environmentally friendly welding method is needed, namely the welding process with the friction stir welding method. The principle of friction stir welding (FSW) is to utilize the heat from the friction of the tool and the material being joined. The tool of FSW must be harder than the material to be joined. Currently there are two methods of FSW, namely single side and double side. The double side friction stir welding (DFSW) process is to perform a two-sided welding process on the material. Currently the DFSW welding process has not yet obtained the optimum joint strength. For this reason, it is necessary to conduct research on double side friction stir welding by determining the pin length and compressive force.

3. RESEARCH METHODS

3.1 Research Installation schematic

Figure 1 is a schematic of the double side friction stir welding (DFSW) research installation for Aluminum Alloy 1100 (AA1100) material.

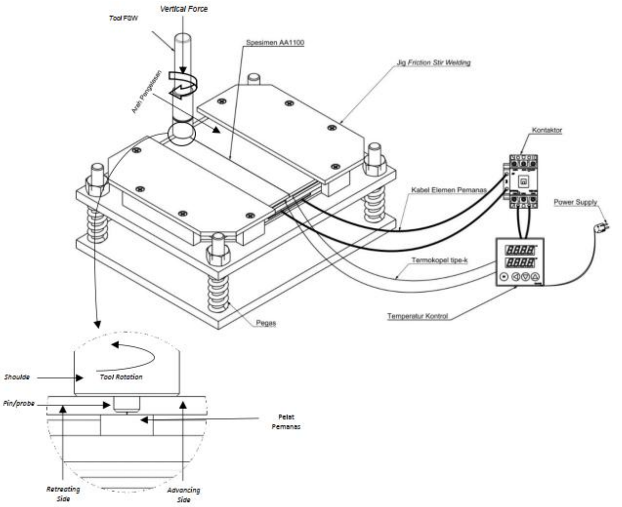

Figure 1. Research installation schematic

Figure 2 is the DFSW jig with the addition of a spring at the bottom of the jig, Figure 3 is the tool preparation for DFSW welding with varying pin lengths, and Figure 4 is the welding process of the AA1100 specimen.

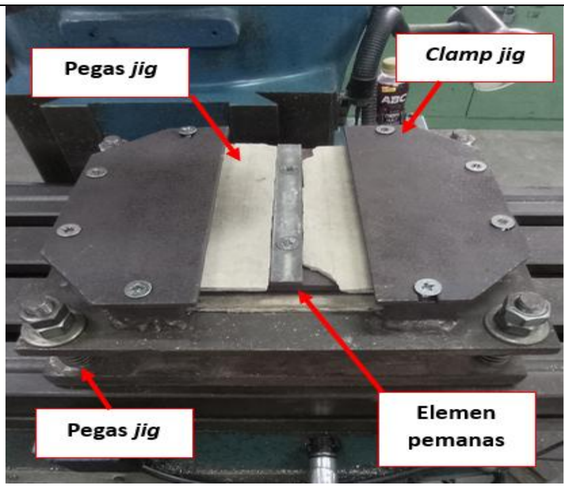

Figure 2. Jig double side friction stir welding

Figure 3. Tool double side friction stir welding

Figure 4. The process welding

3.2 Research Methodology

In this research, the material joined by the Double Side Friction Stir Welding (DFSW) process is Aluminum Alloy 1100 (AA1100) with a size of 150 x 100 x 3.5 mm each, where the mechanical specifications of the material are shown in table 1. The DFSW process uses a milling machine where the translational speed parameter is 10 mm/min and the spindle rotation is 1750 rpm. The DFSW tool is made of AISI H13 steel. The size of the shoulder diameter is 25 mm and the pin diameter is 5 mm with the tool tilt angle set at 0°. A 500 Watt heating element is placed inside the heating plate of the DFSW jig. The function of the heating element is to heat the material at the beginning of the welding process. The width of the heating plate is 10 mm and the heating plate temperature is controlled at 250°C. For tensile testing using the ASTM E8 - 13A standard [7], which can be seen in Figure 5.

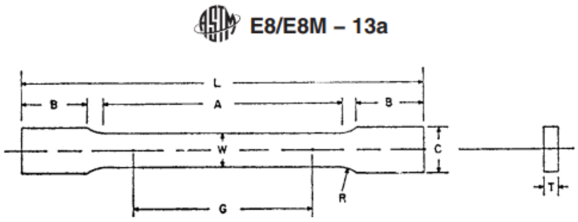

Figure 5. Tensile test standard ASTM E8-13A

The description of Figure 5 for the dimensions of the tensile test specimens is provided in Table 1.

Table 1. ASTM E8-13A tensile test piece dimensions

Width (W)	12,5 ± 0,2 mm
Overall length (L)	200 mm
Gauge length (G)	50 ± 0,1 mm
Length of reduce section (A)	57 mm
Radius of fillet (R)	12,5 mm
Width of grip section (C)	20 mm
Length of grip section (B)	20 mm

4. RESULTS AND DISCUSSION

Table 2 is the tensile test data of AA1100 material welded joint specimens with variations in pin length and compressive force according to ASTM E8-13A standards.

Table 2. Tensile testing data of AA1100

No	Pin Length	Compressive Force	Tensile Strength (MPa)				Average
			I	II	III	IV	
1	No Connection		112	112	112	112	112
2	1,5 mm	30 kg	59.56	59.40	58.64	59.24	59.21
		35 kg	60.16	59.22	59.06	62.07	60.13
		40 kg	65.45	66.56	65.84	65.95	65.95
		45 kg	71.70	71.08	69.67	70.74	70.80
3	2 mm	30 kg	78.84	78.56	77.24	79.00	78.41
		35 kg	82.70	82.81	80.69	81.99	82.05
		40 kg	87.87	85.14	86.35	86.24	86.40
		45 kg	90.43	90.81	90.27	89.13	90.16
4	2,5 mm	30 kg	40.89	41.00	40.94	41.81	41.16
		35 kg	43.88	41.49	43.42	43.39	43.05
		40 kg	47.70	48.21	46.17	45.30	46.85
		45 kg	50.11	51.61	51.00	51.89	51.15

The effect of pin length and compression force on the tensile strength of AA1100 joints can be seen in Figure 6, respectively.

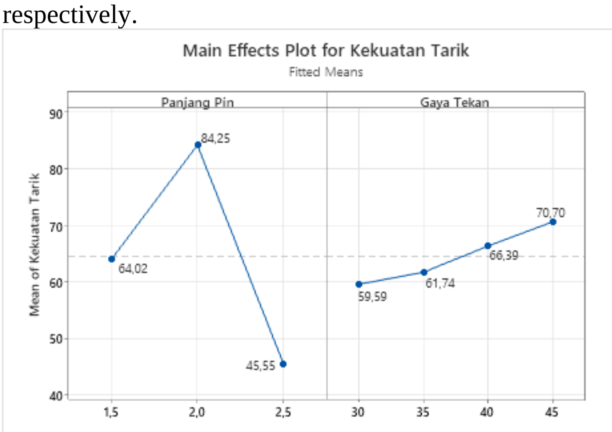

Figure 6. Graphic main effects plot

From the graph in Figure 6 shows that the variation in pin length affects the tensile strength, there is a difference in tensile strength between the pin length variations. The 1.5 mm pin length variation has an average tensile strength of 64.02 MPa and the 2 mm pin length variation has the highest tensile strength of 84.25 MPa. Then the 2.5 mm pin length variation experienced a decrease in tensile strength with an average of 45.55 MPa and was the lowest tensile strength obtained. It is suspected that this is due to the proper stirring and forging process in the 2 mm pin length variation, where the immersion is not too deep and not too shallow so that the heat generated is more stable.

While the variation of pressing force when viewed in Figure 6 graph, the variation of pressing force affects the tensile strength linearly and it can be seen that the tensile strength also increases as the pressing force increases. At a compressive force of 45 kg, the highest tensile strength is obtained with an average of 70.70 MPa and at a compressive force of 30 kg, the lowest tensile strength is obtained with an average of 59.59 MPa.

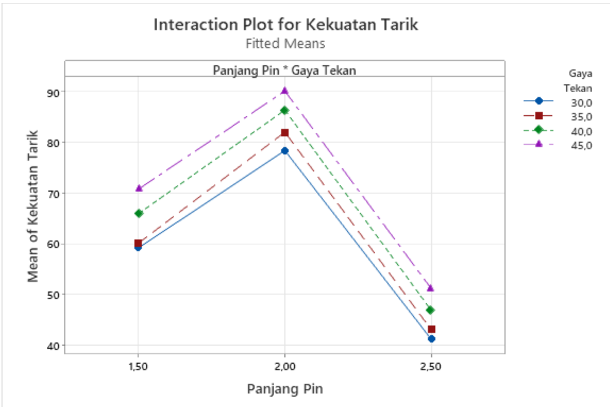

Figure 7. Graphic interaction plot

Figure 7 shows the interaction between the variable pin length and compressive force has a significant effect on the tensile strength value. At a compressive force of 30 kg with pin lengths of 1.5 mm and 2 mm the tensile strength increased by 78.41 MPa and the tensile strength decreased with a pin length of 2.5 mm by 41.16 MPa, and was the lowest tensile strength value. At a compressive force of 35 kg with a pin length of 1.5 mm and 2 mm, the tensile strength increased by 82.05 MPa and the tensile strength decreased with a pin length of 2.5 mm by 43.05 MPa. At a compressive force of 40 kg with a pin length of 1.5 mm and 2 mm, the tensile strength increased by 86.40 MPa and the tensile strength decreased with a pin length of 2.5 mm by 46.85 MPa. While at a compressive force of 45 kg and a pin length of 2 mm is the highest tensile strength value of 90.16 MPa, then the tensile strength value decreased at a pin length of 2.5 mm with a tensile strength value of 51.15 MPa.

5. CONCLUSIONS

After the discussion above, the following conclusions are drawn:

1. Pin length has a significant effect on the tensile strength value of double side friction stir welding on AA1100. The relationship between pin length and tensile strength

is not linear. The greater the pin length value from 1.5 mm to 2 mm has an impact on increasing the tensile strength value of welded joints, but the increasing pin length from 2 mm to 2.5 mm has a decreasing impact on the tensile strength value of welded joints.
2. Compressive force has a significant effect on the tensile strength value of double side friction stir welding on AA1100. The relationship between compressive force and tensile strength is linear, with increasing compressive force resulting in increasing weld joint strength.
3. The interaction between pin length and compressive force showed that the maximum value of tensile strength of double side friction stir welding on AA1100 was obtained under the condition of 2 mm pin length and 45 kg compressive force with a tensile strength value of 90.16 MPa or 80.5% of the tensile strength of AA1100 without welding process (112 MPa).

6. ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to all those who have helped in this research. Their participation in sharing their time and experience was invaluable in providing the data needed to carry out this research. providing the data needed to carry out this research.

7. AUTHOR CONTRIBUTIONS

- Conception and design: Mochamad Andiansyah, Agus Setiawan
- Methodology: Mochamad Andiansyah, Agus Setiawan
- Data acquisition: Mochamad Andiansyah
- Analysis and interpretation of data: Mochamad Andiansyah, Agus Setiawan
- Writing publication: Mochamad Andiansyah, Agus Setiawan
- Approval of final publication: Agus Setiawan
- Resources, technical and material supports: Mochamad Andiansyah, Agus Setiawan
- Supervision: Mochamad Andiansyah

8. REFERENCES

[1] J. Chen, T. Miura, K. Ushioda, and H. Fujii, "Effects of microstructure and phosphorus segregation on tensile properties of friction stir welded high phosphorus weathering steel," Mater. Sci. Eng. A, vol. 916, no. September, 2024, doi: 10.1016/j.msea.2024.147315.
[2] P. Pankaj, P. Biswas, and D. Kim, "Metallurgical characteristics and mechanical properties of dissimilar friction stir welded DH36 steel and UNS G10080 steel joints," Manuf. Lett., vol. 41, pp. 384–394, 2024, doi: 10.1016/j.mfglet.2024.09.046.
[3] H. SU, J. CHEN, and C. song WU, "3D modeling for effect of tool eccentricity on coupled thermal and material flow characteristics during friction stir welding," Trans. Nonferrous Met. Soc. China (English Ed., vol. 34, no. 10, pp. 3309–3325, 2024, doi: 10.1016/S1003-6326(24)66610-0.
[4] Y. Guishen et al., "Tensile-shear mechanical properties of friction stir spot weld bonding hybrid joint in welding prior to and after adhesive curing for vehicle using," Int. J. Adhes. Adhes., vol. 134, no. July, p. 103769, 2024, doi: 10.1016/j.ijadhadh.2024.103769.
[5] W. Fan, X. Yang, Q. Chu, and W. Li, "An efficient synergistic double-sided friction stir spot welding method: A case study on process optimization, interfacial characteristics and mechanical properties of 2198-T8 aluminum-lithium alloy joints," J. Manuf. Process., vol. 131, no. September, pp. 213–232, 2024, doi: 10.1016/j.jmapro.2024.09.025.
[6] I. Sabry, "Exploring the effect of friction stir welding parameters on the strength of AA2024 and A356-T6 aluminum alloys," J. Alloy. Metall. Syst., vol. 8, no. September, p. 100124, 2024, doi: 10.1016/j.jalmes.2024.100124.
[7] G. Li et al., "Tailoring macrostructure and texture in bobbin-tool friction stir weld via manipulation of deformation behaviour of plasticised metal during welding enabled by modifying tool profile," Int. J. Mach. Tools Manuf., vol. 201, no. August, p. 104198, 2024, doi: 10.1016/j.ijmachtools.2024.104198.
[8] G. Dai et al., "Unveiling the influence mechanism of splat cooling on the microstructure evolution and mechanical properties of friction stir welded ZK61M magnesium alloy," Mater. Charact., vol. 218, no. 2024, pp. 1–16, 2024, doi: 10.1 016/j.matchar.2024.1 1 4555.
[9] J. Zhang, Q. Liu, and Y. Huang, "Influence of heat input on pinless friction stir spot welding of aluminum-copper dissimilar materials," Mater. Charact., vol. 218, no. 2024, pp. 1–10, 2024, doi: 10.1016/j.matchar.2024.114456.
[10] D. Wagner, M. Bernardi, F. G. T. Chen, K. Schimanskid, L. Bergmann, and B. Klusemann, "Analysis of mechanical properties and microstructure of single and double-pass friction stir welded T-joints for aluminium stiffened panels," Mater. Des., vol. 247, no. 2024, pp. 1–11, 2024, doi: 10.1016/j.matdes.2024.113438.
[11] Z. Wang and Y. Xu, "A quasi-in-situ EBSD study on abnormal grain growth alloy friction stir welded joints during post-weld heat in 2219 aluminum treatment," Mater. Des., vol. 247, no. 2024, pp. 1–13, 2024, doi: 1l0.1 016/j.matdes.2024.1 1 3386.
[12] W. Xuea, L. Xiao, C. Huang, D. He, and X. Ren, "Asymmetric study on the microstructure and mechanical properties of friction stir welded joints: Finite element simulation and experiment," CIRP J. Manuf. Sci. Technol., vol. 55, no. 2024, pp. 108–128, 2024, doi: 10.1016/j.cirpj.2024.09.006.
[13] M. Kabirmohammadi;, S. Y. A, T. Saeid;, and M. Pouranvari, "Microstructural evolution and mechanical performance of friction stir spot welded ultrafine carbide-free bainitic steel: Role of dwell time," J. Mater. Res. Technol., vol. 33, no. 2024, pp. 4033–4066, 2024, doi: 10.1016/j.jmrt.2024.10.092.
[14] A. Wollum, J. D. Gipson, A. Sabasaba, M. I. Brooks, and C. Moucheraud, "'I am forced to just give it to her because she is the one who wants it': A qualitative study of providers' perspectives on contraceptive counseling in Tanzania," SSM - Qual. Res. Heal., vol. 6, no. October, p. 100505, 2024, doi: 10.1016/j.ssmqr.2024.100505.
[15] R. Phaoniam and K. Lawanwong, "Effect of weld-line position on springback behavior in advanced high-strength steel tailor-welded blanks on hat-shaped bending application," J. Adv. Join. Process., vol. 10, no. August, p. 100241, 2024, doi: 10.1016/j.jajp.2024.100241.
[16] V. Igwemezie, A. Mehmanparast, and S. Ganguly, "Assessment of fatigue crack growth resistance of newly developed LTT alloy composition for the repair of high strength steel structures," J. Adv. Join. Process., vol. 10, no. May, p. 100226, 2024, doi: 10.1016/j.jajp.2024.100226.
[17] A. A. d. Albuquerque, H. Louche, D. F. d. Oliveira, and I. C. A. Brito, "Rotary friction welding applied to Cu11.8Al0.45Be shape memory alloy," J. Adv. Join. Process., vol. 10, no. June, p. 100233, 2024, doi: 10.1016/j.jajp.2024.100233.
[18] A. Kubit, H. A. Derazkola, K. Faes, and M. Korzeniowski, "Fatigue properties of spot joints of metal-plastic composites with DP 800 steel prepared by ultrasound resistance spot welding," Thin-Walled Struct., vol. 201, no. PA, p. 111992, 2024, doi: 10.1016/j.tws.2024.111992.
[19] S. Xu, C. Jia, S. Maksymov, Z. Cai, and C. Wu, "Modeling the coupled bubble-arc-droplet evolution in underwater flux-cored arc welding," Int. J. Mech. Sci., vol. 284, no. September, p. 109754, 2024, doi: 10.1016/j.ijmecsci.2024.109754.