International Journal of Mechanical Engineering and Technology (IJMET)
Volume 9, Issue 9, September 2018, pp. 1475–1481, Article ID: IJMET_09_09_161
Available online at http://www.iaeme.com/ijmet/issues.asp?JType=IJMET&VType=9&IType=9
ISSN Print: 0976-6340 and ISSN Online: 0976-6359

FATIGUE BEHAVIOR AND SOME MECHANICAL PROPERTIES OF ALUMINUM 2024-T3 SHEETS WELDED USING FRICTION STIR WELDING METHOD

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ABSTRACT

Friction stir welding (FSW) is recently discovered, it's one of the relatively modern types of welding process. In the current research, 2024- T3 aluminum alloy sheet was used to joint together by using this technique. The thickness of the sheet was 3 mm. Traditional milling machine was used to prepare the specimens of the welded sheets. The rotational speed of the spindle was 900 rev\ min. Three patterns of welds were utilized, the first was the base metal of 2024-T3 aluminum sheet, the second was the pattern (as welded), while the last one was welded followed by heat treatment. Some of mechanical tests were inspected which were tensile test, micro hardness test and fatigue test. The results showed, the ultimate tensile strength of as welded specimen was 63% of the base metal while was 70% for the specimen welded and followed by heat treatment. The micro hardness results were noted that the lower value of hardness was at the welded zone. Fatigue test was done in this research, the value of fatigue limit was 190MPa for the base metal of 2024-T3, while was 120 and 150MPa for as welded and welded followed by heat treatment respectively.

Key words: Friction stir welding; 2024-T3 aluminum alloy; Fatigue test; micro hardness.

Cite this Article: Ahmed Sahib Mahdi, Fatigue Behavior and Some Mechanical Properties of Aluminum 2024-T3 Sheets Welded Using Friction Stir Welding Method, *International Journal of Mechanical Engineering and Technology* 9(9), 2018, pp. 1475–1481.
http://www.iaeme.com/IJMET/issues.asp?JType=IJMET&VType=9&IType=9

1. INTRODUCTION

Aluminum alloys are widely used in the industry all over the world [1]. The designers and technologists were focused about these alloys. Traditional welding methods cause many defects in welding zone such as cracks and impurities. In addition, phase transformations are taken place at the welded zone in the conventional methods, therefore its lead to significant

strength deterioration. Therefore, Non-conventional welding methods were discovered and used in the industry to avoid the defects [2].

Friction stir welding (FSW) is a recently discovered [3]. It's classified as solid state welding. Low cost and high quality joints are given by this technique [4], especially for heat-treatable aluminum alloys. Moreover, the porosity and voids are observed as a little amount due to absence of a filler material [5]. So, the mechanical properties are identified higher values due to the process is conducted below the melting point [6, 7]. On the other hand, the solid state welding is appeared as environment friendly while the fusion welding is produced smoking at the welding zone [8]. The temperature is the most important parameter, so it has to reach to 70 – 90% of the melting point. In the current research, aluminum 2024-T3 sheet was used as a material sample [9, 10]. Heat treatment process was performed to improve the mechanical properties for the suggested weld.

2. EXPERIMENTAL PROCEDURE

In this section, the procedure of the research was explained. Material type, specimen, welding process and heat treatment process are a brief explanation as the following:

2.1. Material

Aluminum alloys are classified as light alloys; In addition, there are some positive properties for these alloys such as corrosion resistance, high strength-to-weight ratio, high electrical and thermal conductivities and machinability.

Aluminum alloys 2024-T3 was used as the material in the current research due to it's a wide uses in the industry such as aircraft structure, extruded bars, section sheets and rivets.

Energy Dispersive X-Ray Analysis (EDX) was used to inspect the chemical composition of the material. Table.1 shows the results of the test.

Table.1 Chemical composition of 2024-T3

Elements %	Nominal value	Wt%
Si	0.5 max	0.15
Fe	0.5 max	0.29
Cu	3.8 - 4.9	4.1
Mn	0.3 - 0.9	0.61
Mg	1.2 - 1.8	1.3
Zn	0.25	0.17
Cr	0.1	0.009
Al	Bal	Bal

2.2. Friction Stir Welding Process

A rotating tool was utilized to perform the welding process in FSW. The rotating tool consists of a small pin and a larger shoulder. Plastic deformation and high temperature were created upon the stirred zone.

A vertical milling machine was utilized for this technique. The dimensions of the work piece were 300, 100, 3 mm for long, width and thickness respectively. Mechanical pieces of equipment were used to fixture the work piece on the table of the machine. Fig.1 illustrates working diagram of FSW.

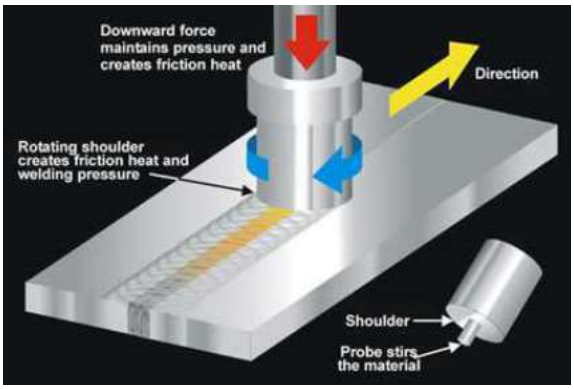

Figure.1 working diagram of FSW

The rotational speed and feed rate were performed as conditions in this technique which were 900 rpm and 16 mm\sec respectively. The backing plate and fixtures were manufacturing from the steel. So, tool steel type (AISI type S-5) was utilized to manufacture the tool. Figure 2 represents the tool dimension.

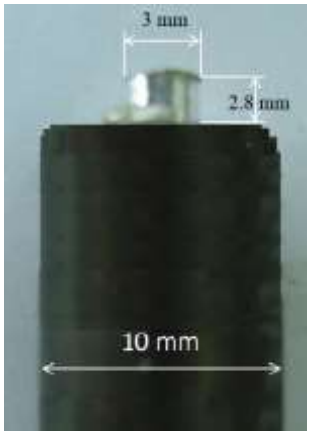

Figure 2 the tool dimension.

2.3. Heat Treatment Process

An electric furnace was used in the heat treatment. The maximum temperature was observed for this furnace is 750 °C. The procedure of heat treatment was summarized as the following: After putting the specimens inside the furnace, the temperature was increased to 495 °C with heating rate 5°C/ min, and then soaking time for 30 min. After that, it was quenched by water to room temperature. Finally, it was left 7 days in ambient air which called the natural ageing.

3. RESULTS AND DISCUSSION

3.1. Tensile Test

Tensile test was carried out for the suggested specimen in the current research. Hydraulic tension apparatus was used in this process. The tensile test was carried out according to the American Society for Testing Material (ASTM) B557M. Rectangular tensile specimens were of the geometry and dimensions as shown in Fig. 3. Table 2 illustrates the results of tensile test. Three patterns were classified according to the material and heat treatment. It can be seen that the ultimate tensile strength of base metal 2024-T3 was 480 MPa. After the welding process, it was 302 MPa for the specimen as welded, while the ultimate tensile strength was 335 MPa for the specimen welded followed by heat treatment. The process efficiency for the

specimen as welded was 63% of the base metal, whereas it was 70% for the specimen welded followed by heat treatment.

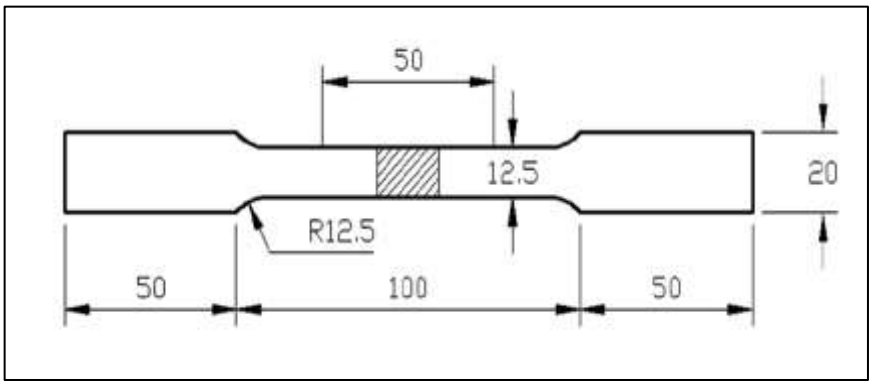

Figure 3 Tensile specimen dimension

Table 2 The results of tensile test

specimen	Yield stress (σy) MPa	Ultimate tensile strength (σu) MPa	Elongation (%)
2024-T3 Base metal	320	480	14
2024-T3 + 2024-T3 As welded	270	302	1.9
2024-T3 + 2024-T3 Welded + HT	240	335	5.1

3.2. Roughness Test

The roughness of the surface often gives knowledge of nature about the entire surface. Therefore, roughness test is quite significant for the results of the fatigue test. Portable surface roughness tester (Type pocket sorf) was used for this test. In this test, three values of roughness were measured, and then the mean value was taken as roughness value for entire surface. Table 3 shows the values of roughness before and after surface finishing.

Table 3 The values of roughness

Specimen	Roughness value (μm)
Case 1	0.12
Case 2	0.16
Case 3	0.19
Without surface finishing	2.24

3.3. Micro Hardness Test

Perpendicular line on the weldment plane was taken to inspect the micro hardness values for both sides. Digital micro Vickers hardness tester (type TH714) was used for this test. Applied load and duration time were 200g and 15 sec respectively. Twenty values of micro hardness were tested for both sides of the welded specimen. Figure 4 illustrates the micro hardness values for the specimen.

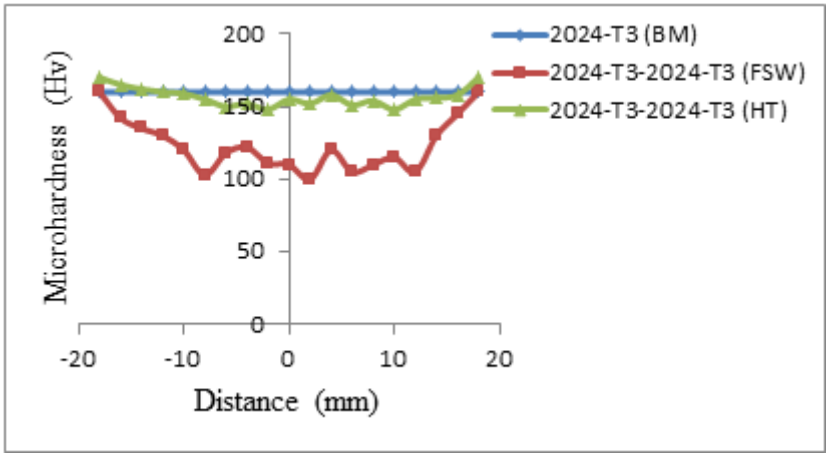

Figure 4 The micro hardness values for the specimen.

It can be seen, the FSW specimens have been gotten the smallest values of micro hardness due to the grain size in heat affected zone was exposed to high temperature, this temperature was caused by friction between the tool and work piece. Consequently, high temperature was increased the grain size. Then, the micro hardness was decreased. On the other hand, the micro hardness value was increased when the distance of the welded line was increased. Otherwise, the welded specimens followed with heat treatment was resulted higher micro hardness than without heat treatment due to the quenching process was decreased the grain size in the heat affected zone, therefore the micro hardness was increased.

3.4. Fatigue Test

Cycling loading was linked with the fatigue phenomena. When the fluctuating stresses and strain are occurred, the fatigue fractured is done. Hi-Tech alternative bending machine was executed for this test under constant amplitude of loading. The length of the specimen was 70 mm, so the width and height were 10 mm and 3 mm respectively as shown in fig.5.

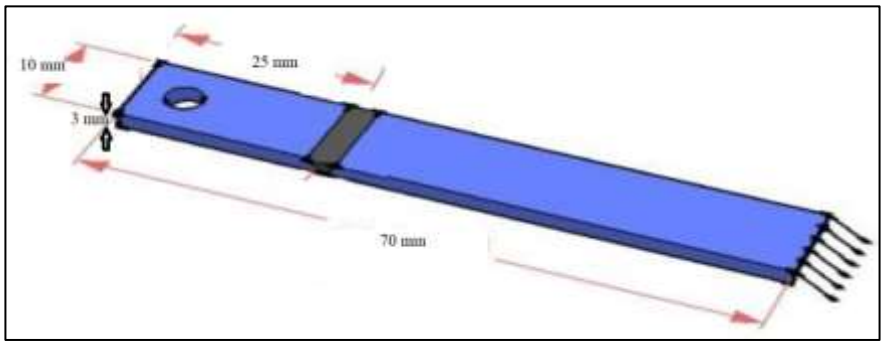

Figure 5 Fatigue specimen

Applied load was subjected perpendicular on the specimen axis. So, bending moment was created by this load. When the cycling loading was applied, compression- tension on the surface of the welded zone was created. In the current research, three patterns were inspected. The first was the base metal of 2024- T3. The second was as welded between 2024-T3 with 2024-T3. The last pattern was as welded followed with heat treatment. Fig.6 represents the relationship between alternative stress and number of cycle of the specimen. By the results, the lower values of number of cycles were concluded for the specimen as welded compare with others. The fatigue limit was 120 MPa for the specimen as welded, whereas it was 150

MPa for the specimen welded followed by heat treatment. Improvement ratio was appeared when the heat treatment was applied, the improvement ratio was 25%.

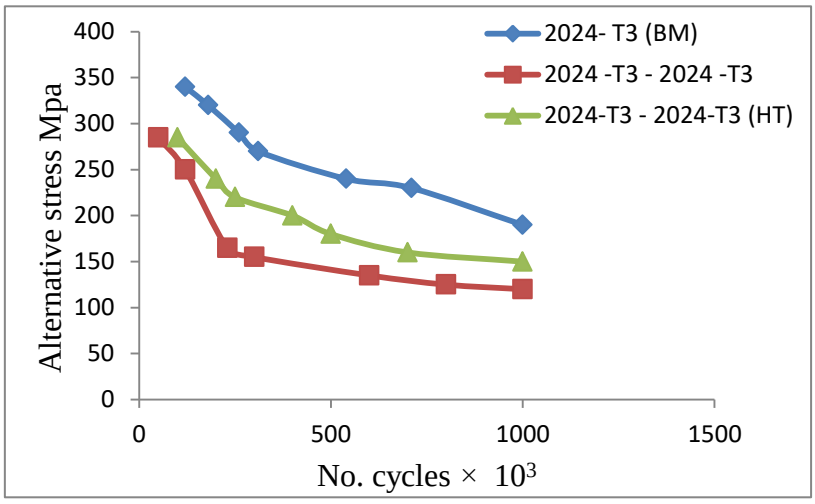

Figure.6. Alternative stress against number of cycle

4. CONCLUSIONS

The current research reveals the friction stir welding process of aluminum alloy 2024-T3 with fatigue behavior and some mechanical properties. Three patterns of samples were taken. The first was the base metal of alloy. The second was the specimen as welded with same metal 2024-T3. The last was the specimen as welded followed by heat treatment. By the results, the fatigue limit for the base metal was 190 MPa, while was 120 and 150 MPa for the specimen as welded with same metal 2024-T3 and the specimen as welded followed by heat treatment respectively. The efficiency process of the specimen as welded with same metal 2024-T3 was 63% according to base metal process, whereas was 79% for the specimen as welded followed by heat treatment

ACKNOWLEDGMENT

The author would like to recognize Southern technical university to provide the suitable laboratories to complete the current project.

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