



A COMPARATIVE STUDY BETWEEN FRICTION STIR WELDING AND METAL INERT GAS WELDING OF 2024-T4 ALUMINUM ALLOY

Haitham Kassim Mohammed

Department of Mechanical Engineering, Nahrain University, Baghdad, Iraq

E-Mail: haitham.almalki@yahoo.com

ABSTRACT

In this paper, the mechanical properties of welded joints of 2024-T4 aluminium alloy obtained using friction stir welding (FSW) with four rotation speed (450,560,710 and 900 rpm) and conventional metal inert gas welding (MIG) are studied. FSW welds were carried out on a milling machine. The performance of FSW and MIG welded joints were identified using tensile, hardness and microstructure. Properties FSW and MIG processes were also compared with each other to understand the advantages and disadvantages of the processes for welding applications of the Al alloy. Better tensile strength was obtained with FSW welded joints. The width of the heat affected zone of FSW was narrower than MIG welded joints. The results show that FSW improves the mechanical properties of welded joints.

Keywords: 2024-T4 aluminum alloy, frictions stirs welding, MIG welding, mechanical properties.

1. INTRODUCTION

Aluminum welding still represents a critical operation due to its complexity and the high level of defect that can be produced in the joint. The main problems are related to the properties of aluminum that is high thermal conductivity, high chemical reactivity with oxygen and high hydrogen solubility at high temperature. All these factors can cause the presence of defects on the weld bead [1]. In the FSW process, a special tool mounted on a rotating probe travels down through the length of the base metal plates in face-to-face contact, the interference between the welding tool and the metal to be welded generates plastically deformed zone through the associated stirring action. At the same time, the thermo-mechanical plasticized zone is produced by friction between the tool shoulder and the top plate surface and by contact of the material with the tool edges, inducing plastic deformation. The probe is slightly shorter than the thickness of the work piece [2]. The FSW joint is created by friction heating with simultaneous severe plastic deformation of the weld zone material. The stirring of the tool minimizes the risk of having excessive local amounts of inclusions, resulting in a homogenous and void-free weld. Since the amount of heat supplied is smaller than during fusion welding, heat distortions are reduced and thereby the amount of residual stresses. The deformation control is therefore easier [3]. The microstructure in the stir zone is influenced by FSW parameters. It is therefore considered that the formability of FS-welded material is influenced by FSW parameters [4]. Aluminum alloys find wide applications in aerospace, automobile industries, railway vehicles, bridges, offshore structure topsides and high speed ships due to its light

weight and higher strength to weight ratio. In all cases, welding is the primary joining method which always represents a great challenge for designers and technologists. As a matter of fact, many difficulties are associated with this kind of joint process, mainly related to the presence of a tenacious oxide layer, high thermal conductivity, high thermal expansion coefficient, solidification shrinkage and, above all, high solubility of hydrogen, and other gases, in the molten state [5]. The objective of this investigation is to determine the mechanical properties of FSW of dissimilar aluminum alloys, and to compare the results with conventional arc-welding method metal inert gas welding (MIG).

2. MATERIALS AND METHODS

2.1. Material

The material, as is well known, is substantially an alloy of aluminum and copper; it had undergone a T4 heat treatment which is composed of a solubilization, a quench in cold water and a natural ageing [6]. The base material used in this investigation is 2024-T4 Aluminum alloy. The copper (Cu) gives substantial increases in strength, permits precipitation hardening, reduces corrosion resistance, ductility and weld ability. This series of aluminum alloys is difficult to weld by liquid state join because many of these series are thermal cracking sensitive.

Chemical analysis and mechanical properties have been conducted for the material used to check the composition of the Al-alloy type and compare it with the standard composition, as shown in Table-1.

**Table-1.** Chemical of Al alloy used in this study.

Material type	2024-T4 Aluminum alloy (Measured)	2024-T4 Aluminum alloy (Standard)[7]
Chemical composition	Cu = 4.2%	Cu = (3.5-4.5)%
	Ni = 2.0%	Ni = (1.7-2.3)%
	Mg = 0.3%,	Mg = (0.45-0.09)%
	Si = 0.7%	Fe = 1.0%, Si = 0.9%
	Al=Rem	Zn = 0.25%, Mn = 0.20%
	-	Cr = 0.10%, Al= Rem

2.2. Welding

The plates of 2024-T4, aluminum alloys are cut into the required size (150mm×75mm×3.8mm) by power hacksaw cutting and grinding the plate edge to ensure that there is no gap between the two plates. The friction stir welded are made using a milling machine. The process was performed with a conventional tool: pin with a diameter of 6 mm, shoulder with a diameter of 20 mm (Figure-1). The tool rotational speed was set to (450,560,710 and 900) rpm and travel speed was 20 mm/min. The welding direction of aluminum alloy was parallel to the rolling direction of the plate. Friction stir butt welding process of materials is shown in Figure-2.

**Figure-1.** Friction stir welding tool.**Figure-2.** Frictions stir welding.

Butt joints with an I-groove were used. In this case AlSi was chosen as filler metal and argon was used as shielding gas as shown in Figure-3. Friction stir welding of the welding plate was shown in Figure-4.

**Figure-3.** MIG welding.**Figure-4.** Frictions stir welding.



2.3. Tensile test

The tensile test was carried out by WDW 200 testing machine. Specimen dimensions were chosen according to the standard ASTM [8]. The dimensions of the tensile specimens are shown in Figure-5.

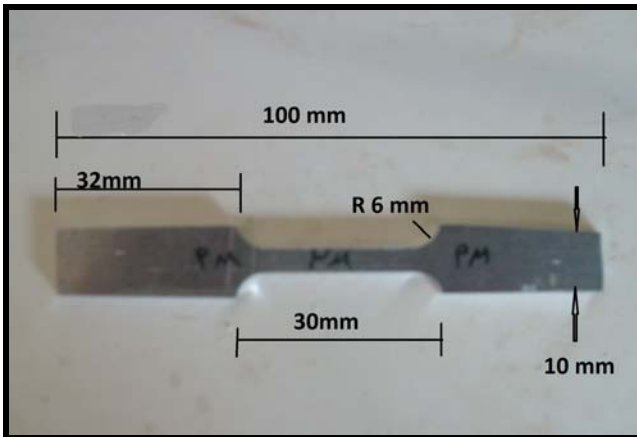


Figure-5. Dimensions of tensile specimens.

3. RESULTS AND DISCUSSIONS

3.1. Tensile properties

The tensile properties such as tensile strength, percentage of elongation tensile strength of AA2024-T4 aluminum alloy joints were evaluated. In each rotation speed, three specimens were tested. The tensile strength of unwelded parent metal is 318 (N/mm²). However, tensile strength of MIG joints is 213.85(N/mm²). However, tensile strength of FSW joints is 165.9 (N/mm²), 192.47 (N/mm²), 248.82 (N/mm²), and 51.30 (N/mm²), respectively for four rotation speed (450,560,710 and 900) rpm, respectively. These results show that increasing tool rotation from 450 rpm to 710 rpm for other parameter fixed increase tensile strength as shown in Figure-6 and that in four frictions stir rotation speed, the 710 rpm exhibited higher strength values. For the two types of welded joints, the joints fabricated by FSW process exhibited higher strength values due to higher heat intensity in the MIG process negatively affects the mechanical properties of the welded material [9] see Figure-7.

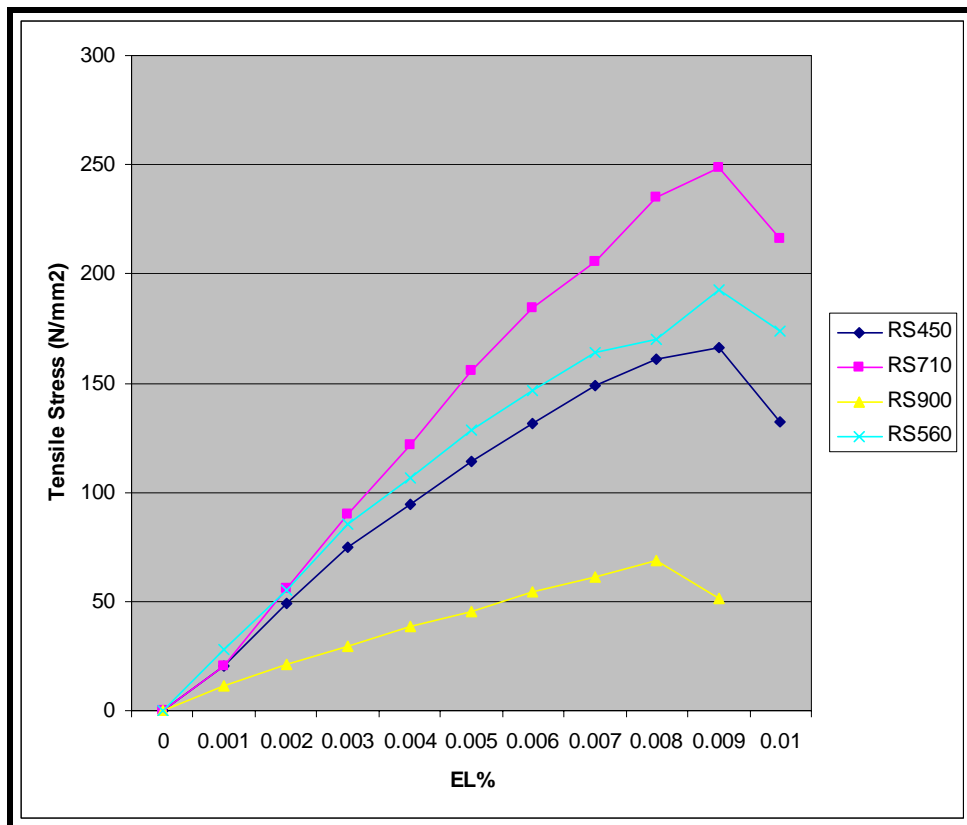


Figure-6. Tensile strength of FSW welding.

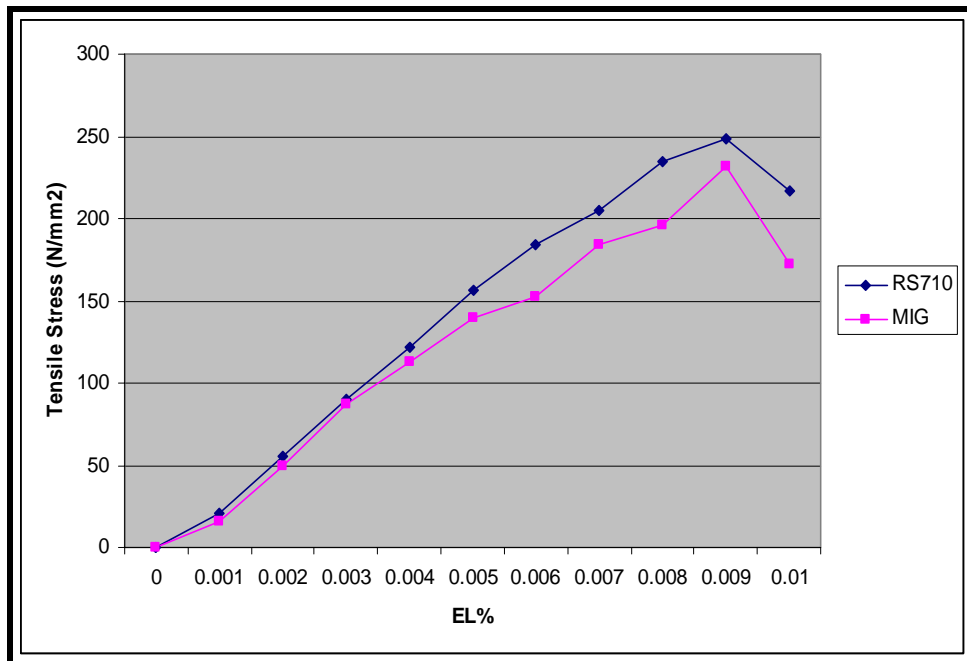


Figure-7. Tensile strength of FSW and MIG welding.

3.2. Microstructure

Microstructure of all the joints was examined at different locations but most of the tensile specimens failed in the weld metal region. The base metal contains coarse and elongated grains with uniformly distributed very fine precipitates [10] (Figure-8). The fusion zone of MIG shown in Figure-9 joints contain dendritic structure and this may be due to the fast heating of base metal [9] and fast cooling of molten metal due to welding heat. The spacing of weld region is marginally wider in MIG joint. However, the weld region of FSW joint contains very fine, equiaxed grains and this may be due to the dynamic recrystallisation that occurred during FSW process.

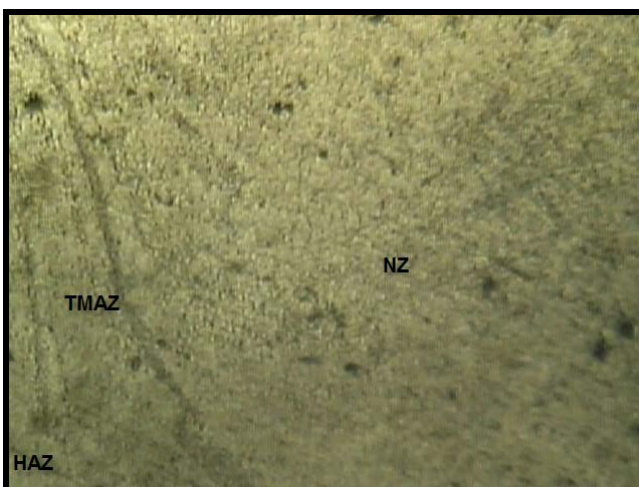


Figure-8. Microstructure of FSW joint.



Figure-9. Microstructure of MIG joint.

3.3. Hardness

Microhardness results show small increase in hardness values toward the weld center (see Figure-10). The increased values found at the center of the weld are retained by the weld nugget and are may be related to the small grain size.

Another observation of the microhardness results the hardness on one side of weld center differs from the other side (unsymmetrical weld). This difference can be explained as follows: In the leading side (advancing side) for the rotating tool where the rotational velocity vector and the forward motion vector are in the same direction and due to this there is higher heating on one side of the weld center and hence higher the hardness.

The MIG welded specimens have a large hardness reduction in the weld compared with FSW, which is due to a higher heat input into the weld zone.

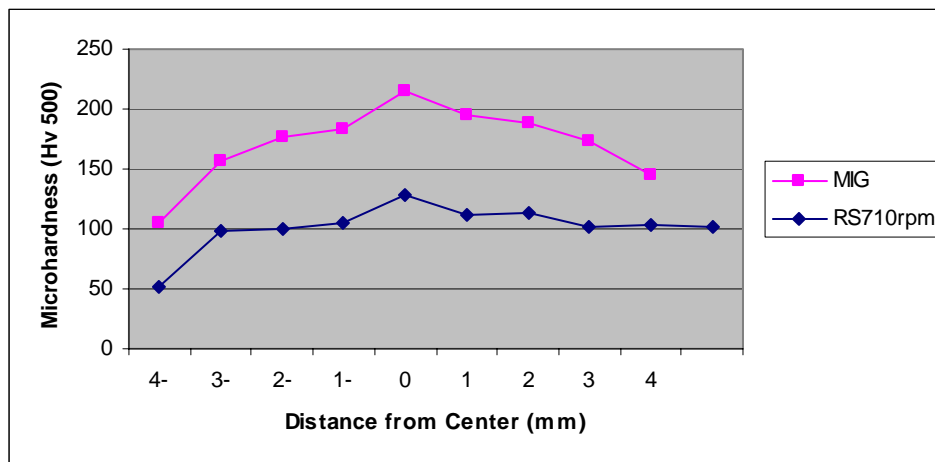


Figure-10. Micro hardness results of FSW and MIG welding.

4. CONCLUSIONS

The conclusions can be summarized as follows:

- Aluminum alloy (2024-T4) is weldable using different (FSW) tool rotation speed;
- Increasing tool rotation speed from (450 to 710) rpm with fixed other parameter causes increasing in mechanical properties of the welds joint;
- In the stirred zone, fine equi-axed grains of size ranging are transformed from the parent metal grain structure;
- The tensile strength of welded joints can be increased using the FSW process compared MIG;
- Hardness change in the welded material is affected by the amount of the heat input during the welding process;
- The heat-affected zone of FSW process is narrower than that of the MIG process; and
- Higher heat intensity in the MIG process negatively affects of the mechanical properties of the welded material.

REFERENCES

- [1] Stefano Maggiolino and Chiara Schmid. 2007. Corrosion resistance in FSW and in MIG welding techniques of AA6XXX. *Journal of materials processing technology*. pp. 237-240.
- [2] Cavalierea Nobilea, F.W. Panellaa and A. Squillaceb. 2005. Mechanical and microstructural behaviour of 2024-7075 aluminium alloy sheets joined by friction stir welding. *International Journal of Machine Tools and Manufacture*.
- [3] M. Ericsson Sandstro. 2002. Influence of welding speed on the fatigue of friction stir welds and comparison with MIG and TIG. *International journal of fatigue*. pp. 1379-1387.
- [4] Tomotake Hirata, Taizo Oguri, Hideki Hagino, Tsutomu Tanaka Sung Wook Chung, Yorinobu Takigawa, Kenji Higashi. 2006. Influence of friction stir welding parameters on grain size and formability in 5083 aluminum alloy. *Materials Science and Engineering*. pp. 344-349.
- [5] A. K. Lakshminarayanan and V. Balasubramanian and K. Elangovan. 2007. Effect of welding processes on tensile properties of AA6061 aluminium alloy joints. *Springer*. pp. 286-296.
- [6] Manoj Kumar Shivaraj and Vijay Dinakaran. 2010. Frictional Stir Welding on Aluminum Alloys AA2024-T4 and AA7075-T6. *IEEE*.
- [7] ASM. *Properties and Selection: Nonferrous Alloys and Special - Purpose Materials*. ASM International. Vol. 2.
- [8] ASTM. 1988. *Metals-Mechanical Testing Elevated and Low - Temperature Tests; Metallography*. Annual Book of ASTM Standards. Vol. 3(1).
- [9] Mustafa Kemal Kulekci. 2006. Experimental Comparison of MIG and Friction Stir Welding Processes for EN AW-6061-T6 (Al Mg1 Si Cu) Aluminum Alloy. *The Arabian Journal for Science and Engineering*. 35: 321-330.
- [10] Zhou H. Liu, W. Liu. 2009. Effect of process parameters on stir zone microstructure in Ti-6Al-4V friction stir welds. *Springer Science*. pp. 39-45.