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EXPERIMENTAL INVESTIGATION OF FRICTION STIR WELDING OF 2024 ALUMINIUM ALLOYS JOINTS TESTING

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Abstract: Friction stir welding is a process of welding metals in a solid state, and it is routinely already used for joining metals that can not be welded by conventional fusion welding processes. A typical material that is almost unresponsive to conventional fusion welding procedures is the aluminum alloy AA2024 which has a wide application in the aviation industry. A study was conducted to study the influence of welding parameters on the mechanical properties of the FSW welded joint. An optimized tool was used for friction stir welding. There are welded plats of thickness of 6 mm. The following welding parameters were used: the tool rotational speed was constant and amounted to 750 rpm, and the welding speed was changed to 73, 116.150 mm / min. Welded joints are obtained without the presence of errors and with an acceptable flat surface of the compound.
Keywords: Friction stir welding (FSW), Aluminum AA2024 alloy, rotation speed, welding speed, mechanical properties

INTRODUCTION

Friction stir welding (FSW) was invented at The Welding Institute (TWI) of UK in 1991 as a solid–state joining technique, and it was initially applied to aluminum alloys [1]. The principle of obtaining inseparable joints by welding with friction stir welding is shown in the Figure 1.

The tool geometry plays an important role in material flow and in turn decides the traverse rate at which FSW can be carried out. A FSW tool has two basic functions: localized heating, and material flow. In initial stage of the tool plunge, the heating results primarily from the friction between pin and workpiece. The tool is plunged till the shoulder touches the workpiece. The friction between the shoulder and the workpiece results in the biggest component of heating.

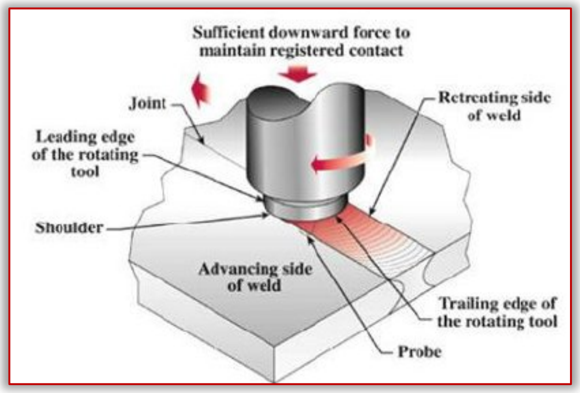

Figure 1. Illustrated scheme of friction stir welding

There have been a number of reports [2–5] highlighting the microstructural changes due to plastic deformation and frictional heat associated with FSW. Mechanical failure of the welds can take place in the SZ, TMAZ, or HAZ region depending on the amount of energy input which is controlled by the welding parameters such as rotational and travel speed [5]. Since the material flow behavior is predominantly influenced by the material properties such as yield strength, ductility and hardness of the base metal, tool design, and FSW process parameters, the dependence of weld microstructure on process parameters differs in different aluminum alloys for a given tool design.

The main goal of this research is analyse the FSW parmeters on the structural and mechanical properties FSW butt joint of aluminium alloy EN AW 2024–T351.

EXPERIMENTAL WORK

The experiment was aimed to find the influence of input kinematic parameters such as welding speed (v) and tool rotation speed (n) on metallurgical and mechanical characteristics of welded joints. Base material was aluminium alloy EN AW 2024–T351. Chemical composition of experimental plates is provided in Table 1 and mechanical properties in Table 2 [3].

Table 1. Chemical composition of AA 2024–T351

Chemical composition	Cu	Mg	Mn	Fe	Si	Zn	Ti
wt. %	4,70	1,56	0,65	0,17	0,046	0,11	0,032

Table 2. Mechanical properties of AA 2024–T351

Yield strength R_{eh} (MPa)	Ultimate tensile strength R_m (MPa)	Elongation A_5 (%)	Hardness HV
370	481	17.9	137

They are experimentally welded plates measuring 500 mm×65 mm×6 mm. The both sides of the welding plates are machined on the grinder at a thickness of 6 mm. When welding under the welding part, the base plate was made of austenitic steel. A milling machine was used for welding. The weld length was approximately 400 mm.

Figure 2 shows a machine and Figure 3 tool used for butt joint FSW.

Experimental Investigation of Friction Stir Welding Of 2024 Aluminium Alloys Joints Testing.

Figure 2. Machine for FSW welding

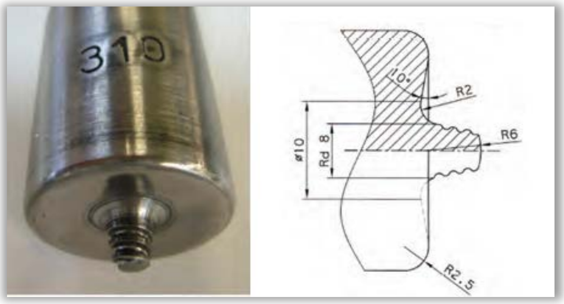

Figure 3. Fabricated FSW tools

Welding was made in accordance with the plan matrix of experiment, with variations in tool rotation speed (n) and welding speed (v), Table 3.

Table 3. Friction stir welding parameters

Sample	Rotation speed n (rpm)	Welding speed v (mm/min)	Ratio n/v (rev/mm)
A – I	750	73	10,27
B – II		116	6,47
C – III		150	5

After the welding process was completed, welds were tested. For that purpose, visual control was performed, on the weld face and root of the seam, as well as the radiographic control of samples. No defects were detected (visually, touch or magnifier).

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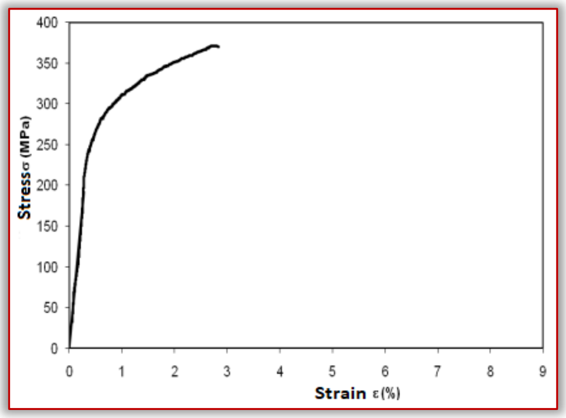
RESULTS AND DISCUSSIONS

Room–temperature tensile tests were carried out at a strain rate of 3.3×10^{-3} s^{-1} on ASTM E8M transverse tensile specimens. In order to assess the reproducibility, 2 specimens were tested and average value was reported.

Tensile testing was performed for all tree FSW joints. The tensile testing results FSW joints are given in Table 4. Among the tree FSW parameters studied, i.e., at 750/73, 750/116 and 750/150 rpm/(mm/min), the average tensile yield strength and ultimate tensile strength.

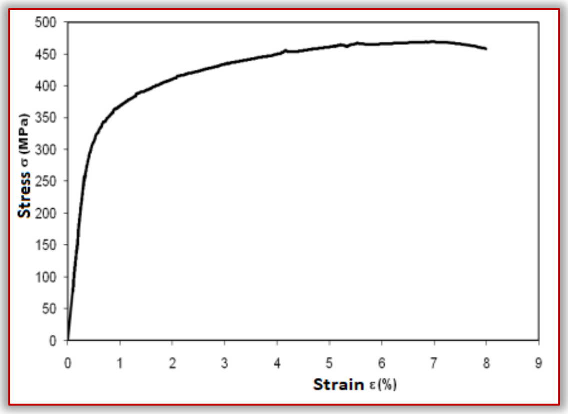
Table 4. Tensile testing results

A–I



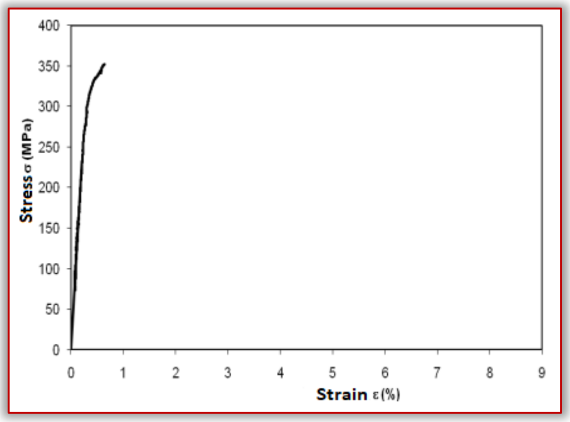
$R_{p0,2}$=281,9 MPa
R_m=371,00 MPa
Z=2,29%

B–II



$R_{p0,2}$=330,9 MPa
R_m=469,06 MPa
Z=7,43%

C–III



$R_{p0,2}$=337,6 MPa
R_m=352,03 MPa
Z=0,33%

This variation of tensile strength with rotational speeds for a given traverse speed appears to be linked to the energy of the welds. Joint efficiency as high as 97% of base metal could be achieved at 750/116 rpm/(mm/min). The highest ductility of the welded joint is achieved with the welding parameters 750/116 and is 7,2%.

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Bend testing was carried out according to EN 910 with joint centered over the mandrel. The bending specimens were tested using face and root side of the joint in tension.

The results of three–point bending test results FSW joints are given in Figure 4.The welded FSW joint has poor bending characteristics. Comparing the obtained bending test results, the largest bend angle to the first cracking phenomenon is for welding parameters 750/116 and amounts to 42°.

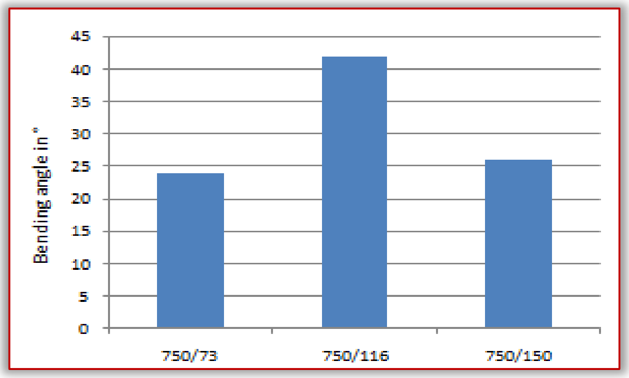

Figure 4. Results of three–point bending test

Vickers hardness measurement was conducted perpendicular to the welding direction, at cross section of weld joint, using digitally controlled hardness test machine (HVS–1000) applying 9.807 N force for 15 s. The hardness profiles were obtained along 3 horizontal and 63 vertical directions.

Figure 5 shows hardness distribution across the welded jointat different applied rotation speed (n) and welding speed (v).

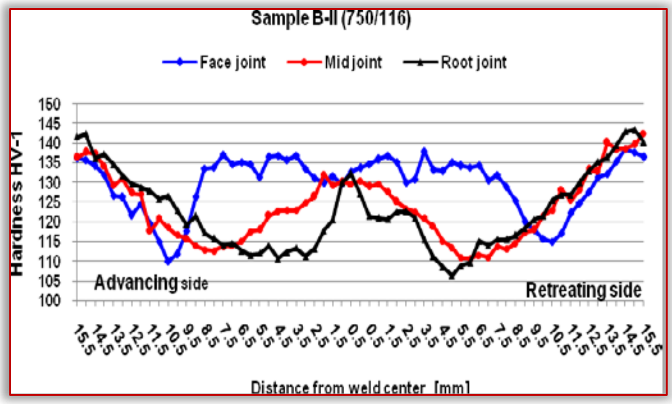

Figure 5. Hardness distribution across the welded jointfor sample B–II (750/116)

Comparing the hardness distribution for the welding parameter 750/150, 750/116 and 750/73, it is noted that the hardness of the sample A–I in the stir region is uniform across the entire height (Figure 6).

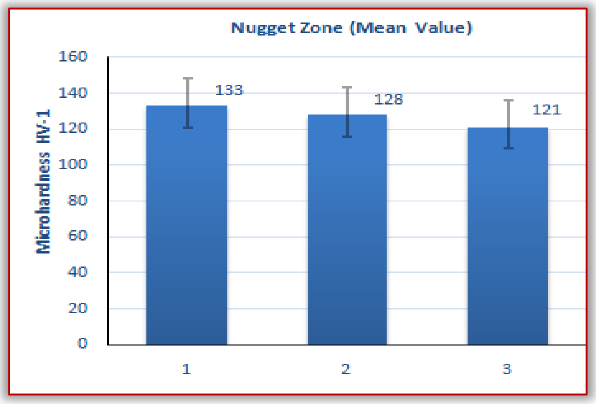

Figure 6. Microhardness results at different processing conditions (1–750/73; 2–750/116; 3–750/150) Bars the mean HV value in the NZ (error bars maximum and minimum HV in the same zone)

Charpy impact tests are carried out at room temperature using instrumented impact pendulum. The pendulum is equipped with load cells positioned on a striker edge. The impact energy values were measured in three points of the notch and that: in the weld center, the notch on the advancing side in the 4 mm position from the weld center (+4), and the notch on the side retreating at the 4 mm position from the weld center (–4).

The Charpy impact tests results FSW joints are given in Table 5. For all welded samples, the maximum impact energy values are measured for the score on the advancing side. The best characteristics of impact toughness have a welded pattern with welding parameters 750/116 (B+4) and a impact energy of 8.5 J and a impact toughness of 21.3 J / cm^2.

Table 5. Results of impact toughness

	KV / J/cm^2	E / J	E_i / J	E_p/ J
OM	19.5	7.8	3	4.8
A–S	12.62	5,05	1.64	3.41
A+4	17.1	6.8	3	3.8
A–4	13.6	5.5	2.1	3.4
B–S	12.62	6.7	1.7	5
B+4	21.3	8.5	3.2	5.3
B–4	11.1	4.5	1.4	3.1
C–S	14.2	5.7	2.4	3.3
C+4	20.7	8.3	3.1	5.2
C–4	12.8	5.1	1.9	3.2
A – 750/73; B – 750/116; C – 750/150				

CONCLUSIONS

On the basis of examinations performed, given results of the experiment and their comparison, the following conclusions can be provided:

Relation between the number of revolutions of tools n velocity of welding v directly influences the value of the fracture toughness and energy which is required for initiation and propagation of the crack;

The asymmetry of the welded joint and changes in metallurgical transformations occurring around the pin and under the shoulder of the tool during its combined moving, influence the value of impact strength in various areas of the welded joint;

Profile of distribution and allocation of micro hardness depends on the level of temperature and plastic deformation which is highest under the tool shoulder and around the pin;

This investigation points out that weld joint B–II (welded by 750/116 rpm/(mm/min)) achieves better properties and microstructure than weld joint A–I and C–III (welded by 750/73 and 750/150 rpm/(mm/min)).

Note:

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