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STUDY OF FRICTION STIR SPOT WELDING PARAMETERS FOR AN ALUMINUM ALLOY AA2024- T3

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Abstract. *This work presents a study of the friction stir spot welding (FSSW) parameters used for an AA2024-T3 aluminum alloy for aircraft structures. The welding was performed on a milling machine with rotations ranging from 1000, 2000, 3000 and 4000 rpm. The chemical composition and microstructures of welded joints were evaluated as well as its mechanical properties. The dispersive energy X-ray spectroscopy (EDS) analysis showed that the heating due the friction did not promote any change on chemical composition along the weld zones. The Vickers microhardness also showed that there was no hardening promoted due this process. It was verified that the 3000 rpm rotation promoted the best mechanical performance due to its high shear strength, 99.7 MPa and better adhesion when compared to the other rotations and to riveted joint. The FSSW process allows to achieve up to 70% mechanical resistance obtained to rivets, so this process can replace the rivet in many applications.*

Keywords: *Spot welding, Friction stir welding, Shear, Aluminum AA2024- T3, strength*

1. INTRODUCTION

Frequently, there is a need to join two elements in mechanical design, whether metallic or not, for the purpose of manufacturing parts, assemblies or performing repairs and maintenance. There are several ways to promote this joint, such as welding, riveting, screw joint and bonding. Friction stir welding (FSW) can be illustrated in Figure 1, which shows a pin-like tool which has a function of heating and mixing the parts to be joined. The tool also has a shoulder which does not participate in the welding, but turns on the part, generating friction and consequently heating and plasticising the material (THOMAS, 1991). There are several important parameters in friction welding such as feed speed, rotation speed, tool geometry, tool material, feed force, tool tilt angle, tool penetration, and tool shoulder. In this sense this work aims to evaluate the influence of rotation during the FSSW process on the microstructure and mechanical behaviour of AA2024-T3 aluminum alloy plates for aircraft structures and compare it to usefull rivets.

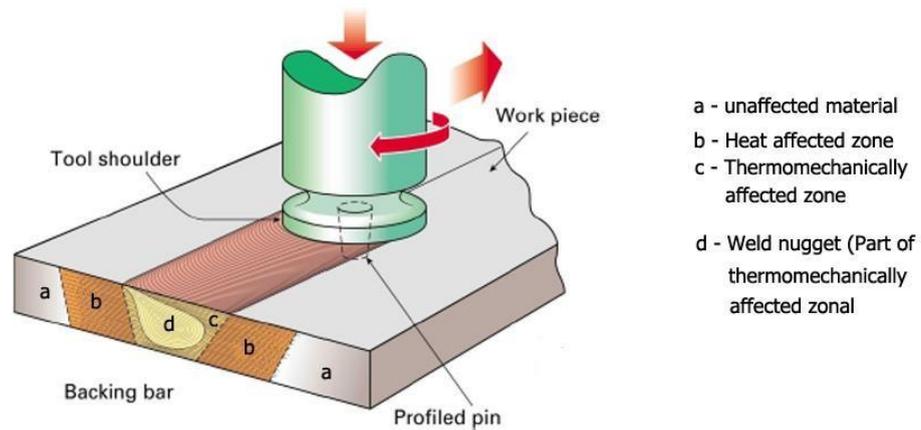


Figure 1. Friction stir welding (TWI,2016)

2. EXPERIMENTAL PROCEDURE

The friction stir spot welding (FSSW) procedure was carried out using a Romi Discovery 560 CNC milling machine to weld the aluminum parts. An AISI H13 steel tool was machined for the welding process, as shown in Figure 2. The machine rotation parameters for the FSSW were 1000, 2000, 3000 and 4000rpm. After determining these parameters, the friction welding was done generating four batches according to the variation of the welding rotation.

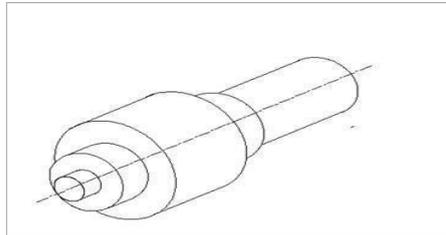


Figure 2. Drawing of the tool for welding FSW

It was used Aluminum AA2024-T3 plates with the following dimensions: 25mm x 100mm, with 1mm thickness. For welding, the parts were fixed to the milling machine, superimposed according to Figure 3.

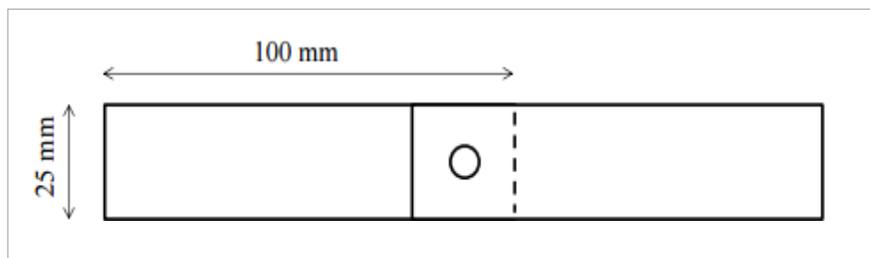


Figure 3. Schematic drawing of specimens to be welded

In the FSSW process, axial force variables should be considered, however in welding on adapted milling machines, control by axial force monitoring is not necessary, since the equipment and fastening system have enough rigidity and the tool moves perpendicular to the surface. It means that the axial force will be constant (COOK, 2003). After fixing, the advance speed and the depth of weld was determined. It was used a 5mm/min speed from 0,0 mm to 0,95 mm and 2 mm/min from 0,95 mm to 1mm. In this sense could be guaranteed that the tool remained 2 seconds upon reaching the

maximum depth on the plates, which was 1mm. This procedure is in accordance with Lathabai (2006), who proves that the advance speed does not affect the mechanical strength to values above 1s.

After welding it was carried out metallographic analyses in all samples. After the conventional gridding and polishing the samples were etched with modified Vilella etchant, which contains 17% nitric acid, 33% fluoridric acid and 50% glycerin. The etching was done during 10s immersion at room temperature. Optical and electron scanning microscopy were performed to verify the microstructure and the adhesion of the welded parts and also to check the chemical composition through the welded joint.

The mechanical tests were carried out on the welded parts. It was used a Shimadzu Vickers microhardness tester with a magnification capacity of 400x was used with an applied load of 98.7mN. Shear tests were carried out in a universal tensile testing machine 23-100 INSTRON/EMIC

3. RESULTS AND DISCUSSION

The macrographs (Figure 4) and the micrographs (Figure 5) showed the plates union and the different zones, respectively, for each sample with different rotations. In figure 5 is possible to verify through the welded region the base metal (MB), the thermally affected areas (ZTA), the thermomechanically affected area (ZTMA) and the transition zone (ZT). They presented different sizes of zones and different grain sizes for the AA2024-T3 aluminum

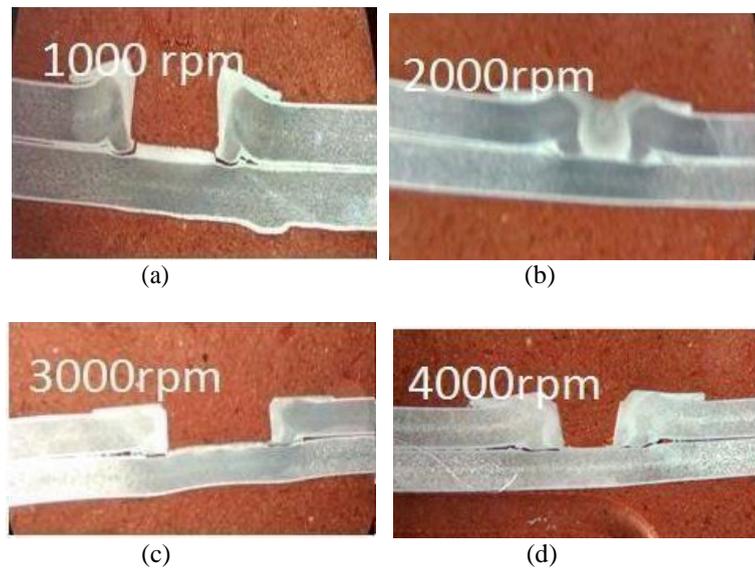
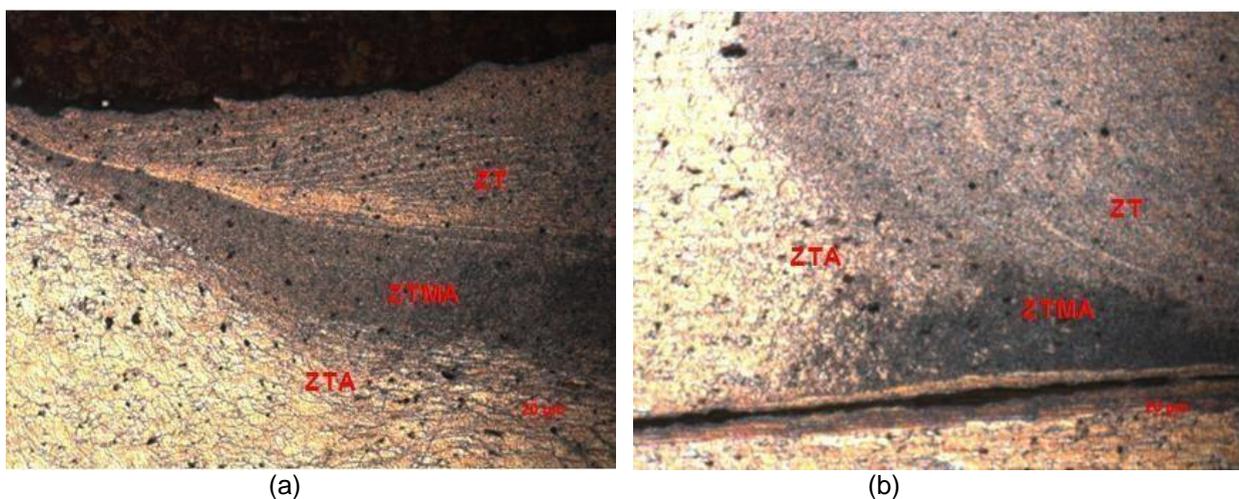


Figure 4. Macrography of welded parts a) 1000rpm; b) 2000rpm; c) 3000rpm; d) 4000rpm.



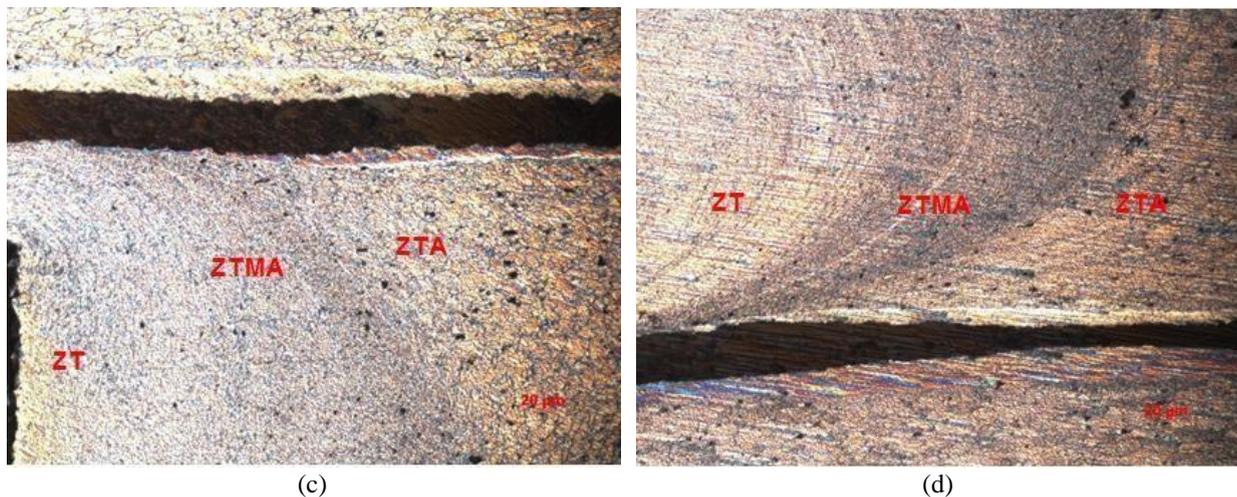
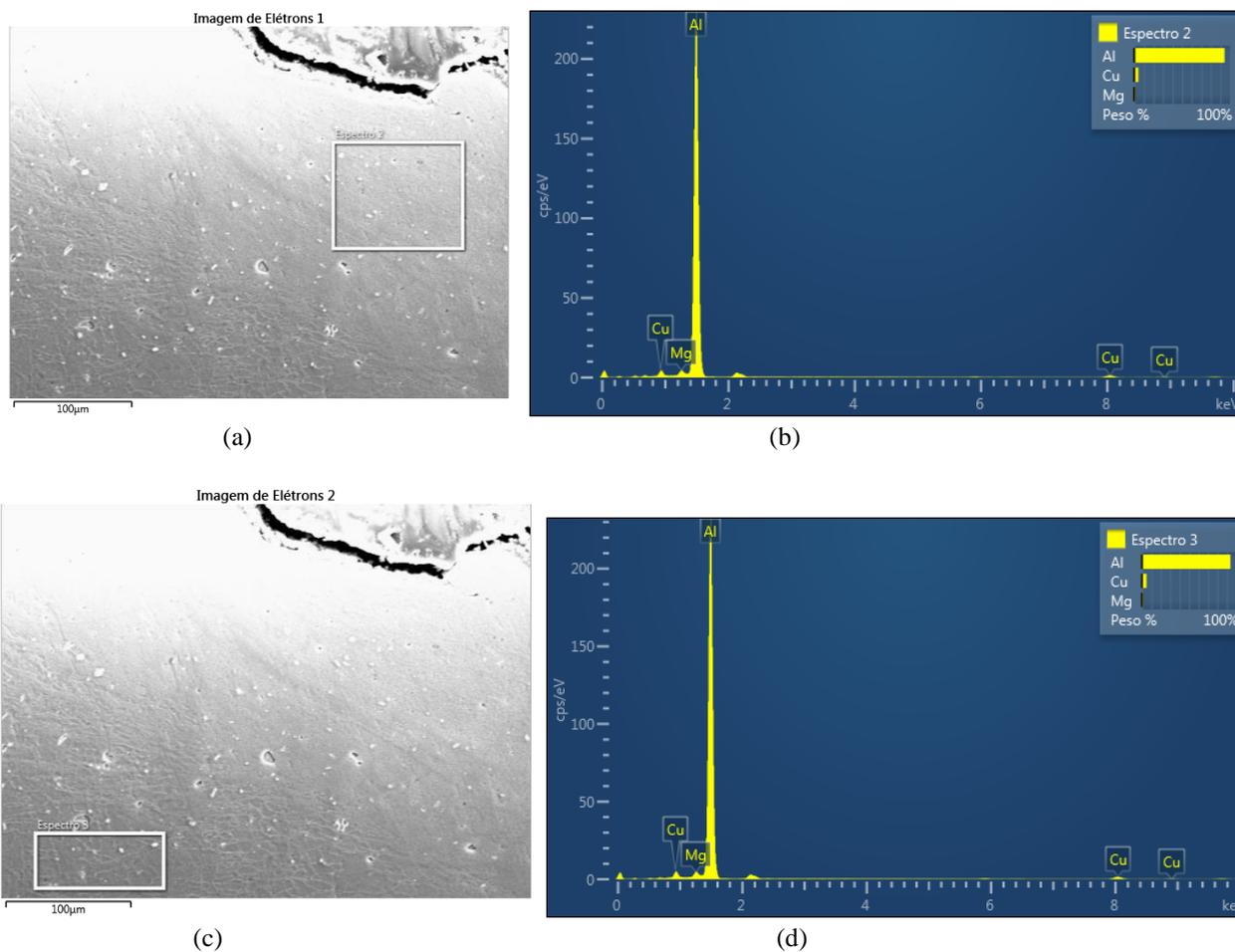


Figure 5. Optical microscopy with 200x magnification for (a) 1000rpm (b) 2000rpm (c) 3000rpm and (d) 4000rpm samples. Three different zones, ZT, ZTA and ZTMA.

Scanning Electron Microscopy (SEM) and Energy-dispersive X-ray Spectroscopy (EDS) analysis prove that there was no variation on chemical composition due atomic diffusion among the zone close to the weld and the base material, as expected for FSW. (R.S.MishraaZ.Y.Mab, 2005). These analyses are shown on Figures 6.



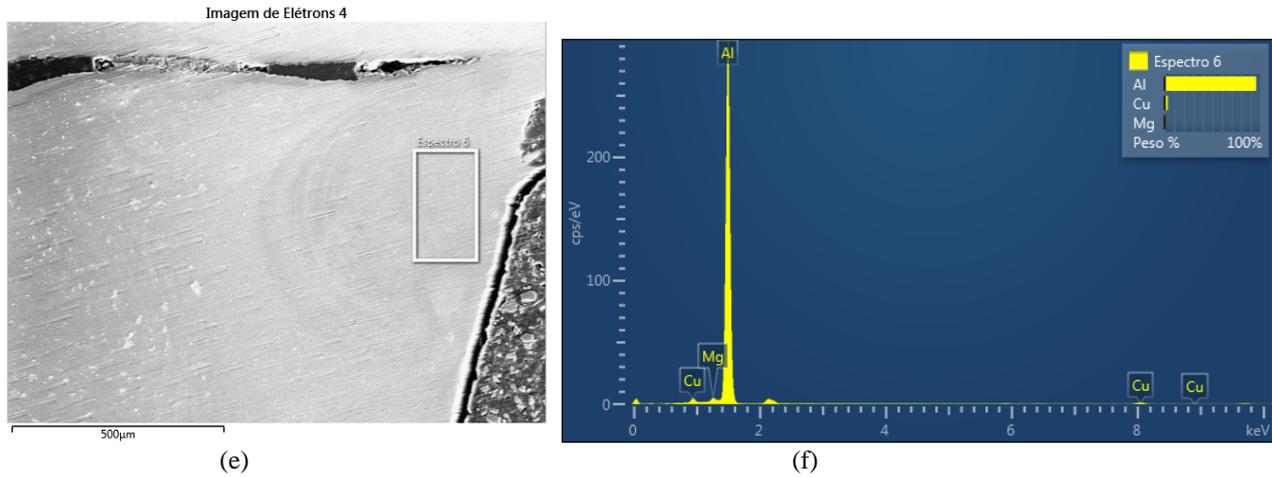


Figure 6 Sample of 1000rpm: a) region analyzed by EDS; b) obtained (Prepared by the authors themselves); c) region analyzed by EDS; d) spectrum obtained (Prepared by the authors themselves). Sample of 4000rpm: e) region analyzed by EDS; f) spectrum obtained (Prepared by the authors themselves).

The shear test showed that the best welding performance occurred for the 3000 rpm rotation sample. Figure 7 presents a comparison among all shear results for different welded samples as well as to the riveted.

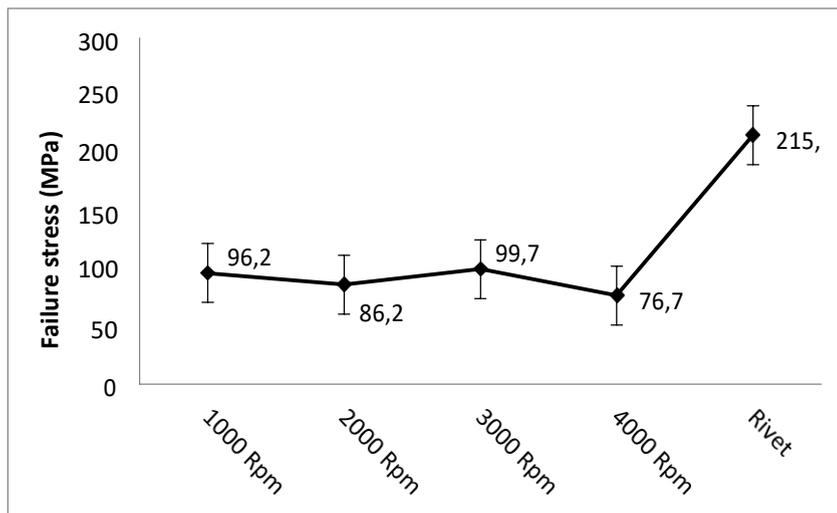


Figure 7. Shear strength to rivet and welded samples with 1000, 2000, 3000 and 4000 rpm rotations.

According to the figure 8 it was possible to check that there were no significant variations in the Vickers microhardness values along the welded section.

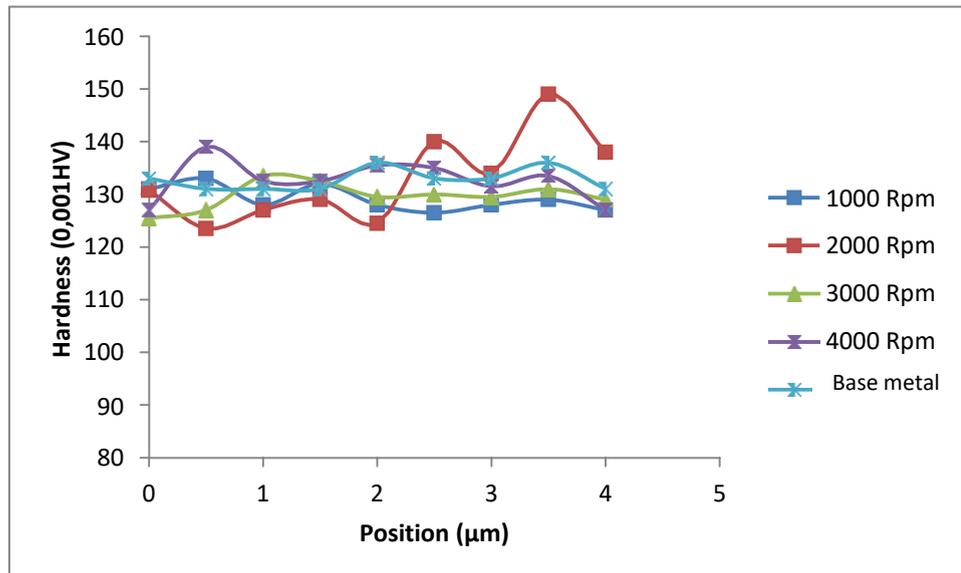


Figure 8 – Microhardness Vickers using 98.7 N during 20s.

4. CONCLUSIONS

It was possible to define through the microstructures the modified zones due the friction stir welding process (FSSW). According to the various rotations it was see some features changes through the ZM, ZTA and ZTMA. Each rotation presented different sizes for modified zones and different grain sizes for the AA2024-T3 aluminum.

It was observed that the chemical composition of the welded samples by FSSW process had no changings due to the heating, benefiting the welding of aluminum that undergoes great chemical changes in other welding processes.

The 3000 rpm promoted the best results when compared to the other rotations, but had a lower rupture stress when compared to the riveted plate. In addition, there was no significant variation on hardness values through the different modified zones.

Finally, it was possible to verify that the rotation of 3000 rpm, had the best performance for the friction welding in AA2024 - T3 aluminum plates. Once this process can reach up to 70% in relation to conventional riveting, it can replace the rivet in many industry applications.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

- COKK, G. E ; et al. Robotic friction stir Welding, *Industrial robot: An International Journal*, v.31, p. 55-63, 2004
- LATHABAI, S; et al. Friction spot joining of an extruded Al–Mg–Si alloy. *Scripta Materialia*, v. 55, p. 899-902, 2006.
- MISHRA, R.S. MA. Z.Y Friction stir welding and processing; *Materials Science and Engineering: R: Reports*; Elsevier; 31 August 2005
- THE WELDING INSTITUTE (TWI). Friction stir welding. Available in: < <http://www.twi-global.com/capabilities/joining-technologies/friction-processes/friction-stir-welding/>>. Access in 29 April. 2016
- THOMAS, W. M. et al, “Friction Stir Butt Welding, International Patent Appl. n°. PCT/GB92/02203 and GB Patent Appl. n°. 9125978.8”, Dec. 1991, U.S. Patent n°.5,460,317

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