16th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2012, Dubai, UAE, 10-12 September 2012

RESEARCH OF FRICTION STIR WELDED 7049 ALUMINUM ALLOY

Ph.D. Nikola Šibalić
Ph.D. Milan Vukčević
Ph.D. Mileta Janjić

University of Montenegro
Faculty of Mechanical Engineering
Džordža Vašingtona bb, 81000 Podgorica
Montenegro

ABSTRACT
In this paper the experimental research were performed, in order to determine the mechanical parameters in the process of joining of materials using FSW process. The paper presents the joining of 7049 sheet aluminum alloy, with thickness of 5 mm. Experimental studies are made on the basis of the adopted multifactoral orthogonal plan, with varying of factors on two levels and repetition in the central point of the plan. Values varied in the experiment are: welding speed, rotation speed of tool, angle of pin slope, pin diameter and shoulder diameter. Based on the adopted geometric parameters the family of tools is provided. The experiment was carried out under laboratory conditions, which are similar to production.
Keywords: Shoulder, Pin, Friction Stir Welding - FSW, Tensile Strength.

1. INTRODUCTION

Friction Stir Welding - FSW was invented The Welding Institute (TWI) of the England in 1991 as a solid-state joining technique and was initially applied to aluminum alloys [1, 2, 3, 4, 5]. Method of FSW has very quickly found its application in shipbuilding, aviation and space industry [5, 6, 7, 8]. Tools used in the FSW process are cylindrical and consisted of two concentric parts, which rotate at high speed. Part of the tool with larger diameter is called the shoulder, while the part with smaller diameter is called the pin [9, 10, 11, 12, 13]. Tool and workpieces that are welded are shown in Figure 1.

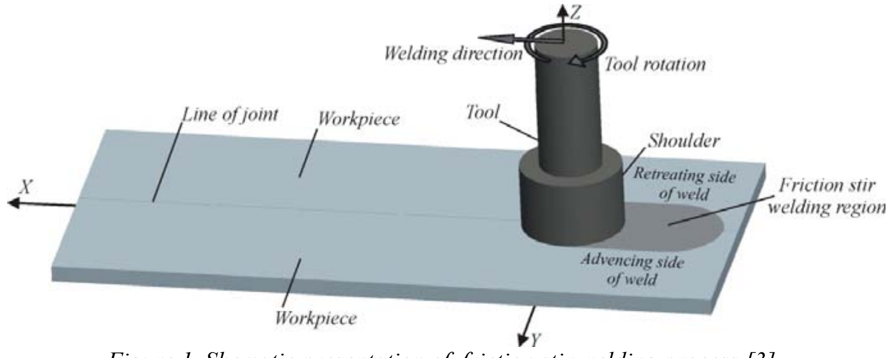


Figure 1. Shematic presentation of friction stir welding process [3].

Tool shoulders are designed to produce heat to the surface and subsurface regions of the workpiece. Friction stirring pins produce deformational and frictional heating to the joint surfaces [4]. The pin is designed to disrupt the faying, or contacting, surfaces of the workpiece, shear material in front of the tool, and move material behind the tool [4]. Cylindrical pins were found to be sufficient for aluminum plate up to 12 mm thick, but researchers wanted to friction stir weld thicker plates at faster travel speeds. A simple modification of a cylindrical pin is a truncated cone [4]. Truncated cone pins have lower transverse loads [4]. This form of pins can be used for welding of aluminum alloy 7049.

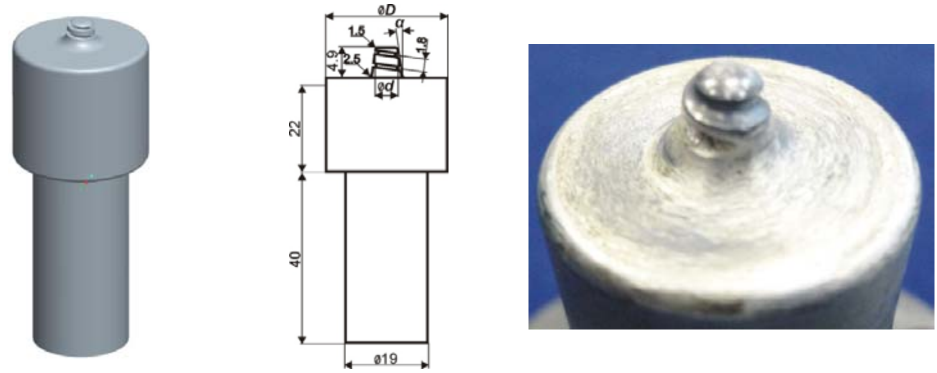
2. EXPERIMENTAL RESEARCH

For experimental research vertical milling machine was used, friction stir welding is performed in laboratory conditions, which are similar to the production conditions. Material used in the experiment includes a plate of aluminium alloy, whose chemical composition is given in Table 1. Workpieces of dimensions 1950 x 45 mm, are obtained by cutting the plate with the thickness of 5 mm.

Table 1. Chemical composition of aluminum alloy plate 7049.

Chemical composition u %								
% Al	% Fe	% Si	% TI	% Cu	% Zn	% Cr	% Mn	% Mg
87.97	0.35	0.25	0.10	1.35	7.32	0.17	0.19	2.30

Material of welding tool was 1.2343 steel according to the standard EN 10027-2. The tool was designed in Pro/Engineer, using a program for parametric modelling (Figure 2.a). For welding of sheet of aluminium alloy the family of tools is adopted where the geometrical parameters are varied. The tool is axisymmetrical and consisted of the workpiece and body of the tool. The body of the tool is adjusted to the jaws of the machines used in the experiment. The general appearance of the family of tools for FSW process is given in Figure 2.b. Based on preliminary researches, the multifactor orthogonal plan with varying of factors on two levels, and repetition in the central point of plan n_0=4 times is adopted. For input values, factors of the welding regime are adopted: $X_1=v$ mm/min (welding speed), $X_2=\omega$ rpm (rotation speed of tool) and geometrical factors of tools: $X_3=\alpha$ ^{o} (angle of pin slope), $X_4=d$ mm (diameter of the pin) and $X_5=D$ mm (diameter of the shoulder). Levels of variation of input factors are adopted and given in Table 2. Presentation of tools in a central point of the plan is given in Figure 2.c.



a) b) c)

Figure 2. Friction stir welding tools.

Table 2. Levels of variation of input factors.

Input factors	Lower level:	Basic level:	Upper level:
X_1	80	125	200
X_2	630	800	1000
X_3	3	3.87	5
X_4	3.5	3.97	4.5
X_5	20	22.36	25

Macrostructure of the alloy 7049 is shown in Figure 3, while Figure 4 shows the complete process of friction stir welding with basic tools and materials with supporting equipment. For mechanical testing of welded joints, tensile tests are used. The testing is performed with the standard testing machines and test pieces. For the tensile tests, MEST EN 10002-1:2008 standard was used [14], and testing is performed at a ambient temperature. Testing machine is used when testing with module of 200 KN. Samples which are cropped from welded workpieces were taken from y - directions (normal to the direction of welding - side direction). Figure 5. provides a schematic view of test pieces, and Figure 6. provides the samples of the test piece in the central point of the plan in y - direction.

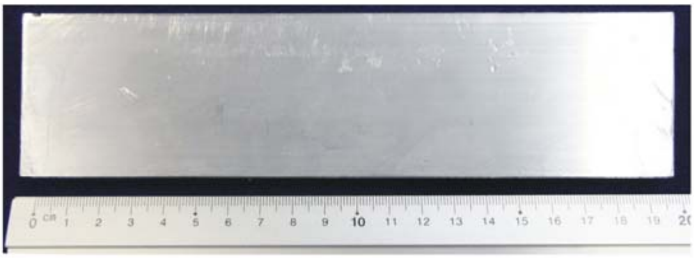


Figure 3. Macrostructure of alloy 7049.

Figure 4. Machine performing FSW.

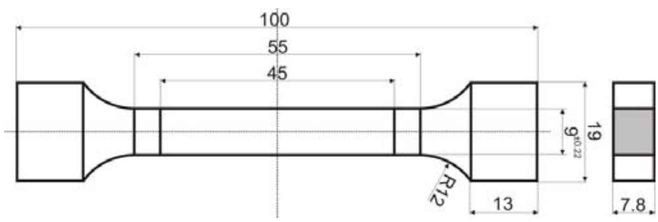


Figure 5. Specimen - Schematic view [14].

Figure 6. Specimen for tensile testing, y - direction normal to the welding direction.

Figure 7. A stretched test piece, y - direction.

Figure 7, presents a stretched test piece cut from y - direction. Figure 8. shows the diagram of stretch in the central point of plan, test pieces from y - directions, with values of tensile strength Rm.

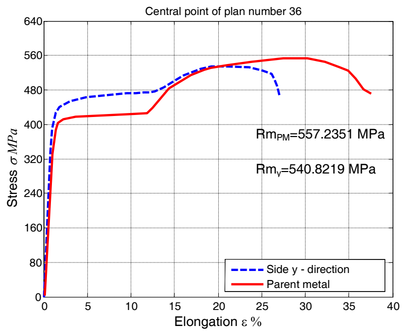


Figure 8. Diagram: Stress - Percentage Elongation.

3. CONCLUSION

The experimental research successfully completed the joining of aluminum alloy 7049 using friction stir welding procedure (FSW). Experimental research has established that the dimensions of tools (shoulder diameter, pin diameter and angle of pin slope) have large effect on the quality of weld as well as regimes of welding (welding speed and rotation speed). The paper presents FSW process and mechanical tests were performed - determination of the tensile strength of welded joints. Based on the experimental results of FSW welding joints of aluminum alloy 7049, it can be concluded that this procedure with the use of optimal parameters of welding, welded joints with good characteristics can be obtained. For further researches, good experimental conditions are made, and information base, which promise significant results in research that follows.

4. REFERENCES

[1] Thomas M. W.: et al 1991 Friction Stir Butt Welding international Patent Application No PCT/GB92/02203. Thomas M. W., et al 1995 Friction Stir Butt Welding GP Patent Application No 9125978.8. Thomas M. W., et al 1995 Friction Stir Butt Welding UP Patent 5.460 317.,

[2] Dawes C., Thomas W.: Friction Stir Joining of Aluminium Alloys, TWI Bulltin 6, 1995., pp. 124-127.,

[3] Mishra R., Mahoney M.: Introduction, Friction Stir Welding and Processing. ASM International 2007. 1-5,

[4] Fuller C.,: Friction Stir Tooling: Toll Materials and Designs, Friction Stir Welding and Processing. ASM International 2007. 7-35,

[5] Vukčević M., Savićević S., Janjić M., Šibalić N.: Measurement in Friction Stir Welding Process, 15th International Research/Expert Conference, TMT 2011, Prague, Czesh Republic, 2011.,

[6] Vukčević M, Plančak M, Janjić M, Šibalić N.: Research and analysis of friction stir welding parameters on aluminium alloys (6082-T6), Journal for Technology of Plasticity, 34-1-2, 2009., 49-57.,

[7] Neuman T., Zettler R., Vileca P., dos Santos J., Quintino L.: Analysis of Self-Reacting Friction Stir Welds in a 2024-T351 Alloy, Friction Stir Welding and Processing IV, A Publication of TMS, 2007. 55-72,,

[8] Zelttler R., Lomolino S., dos Santos J., Donath T., Beckmann F., Lippman T., Lohwasser D.: A Study on Material Flow in FSW of AA2024-T351 and AA6056-T4 Alloys, 5th FSW Symposium, Metz, France, 2004.,

[9] Stahl A., Sorensen C.: Experimental Measurments of Load Distributions on Friction Stir Weld Pin Tools, Friction Stir Welding and Processing III, A Publication TMS 2005.,179-190,

[10] Janjić M., Vukčević M., Mandić V., Pavletić D., Šibalić N.: Microstructural Evolution During Friction Stir Welding of AlSiMgMn Alloy, Metalurgija 51, 2012. st. 29-33.,

[11] London B., Mahoney M., Bingel W., Calabrese M., Waldron D.: Experimental Methods for Determining Material Flow in Friction Stir Welds, Third International Symposium on Friction Stir Welding, Kobe, Japan, 2001.,

[12] Soundararajan V., Kovacevic R.: FSW of Steel to Al Alloy, 6th International Symposium on Friction Stir Welding D.A. Burford, et al. Saint-Sauveur, Canada, 2006.,

[13] Chen C., Kovacevic R.: Joining of Al 6061 Alloy to AISI 1018 Steel by Combined Effects of Fusion and Solid State Welding, International Journal of machine Tools & Manufacture 44, 2004. 1205-1214.,

[14] MEST EN 10002-1:2008.