Journal Home page : http://dergipark.gov.tr/ejens
EJENS
European Journal of Engineering and Natural Sciences
DergiPark AKADEMİK
CODEN: EJENS

The Investigation and Comparison of Friction Stir Spot Welding and Electrical Resistance Spot Welding of AA2024 Aluminium Alloy Joints

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Abstract

Both Friction Stir Spot Welding (FSSW) and Electrical Resistance Spot Welding (ERSW) are contemporary techniques for joint of the thin sheet materials. But FSSW is more modern technique than RSW. FSSW is used a lot of area which are from marine to aerospace industries. Aluminium alloy has a lot of advantages of the other materials. One of them is weight. In this study, AA2024 sheets are chosen for FSSW and RSW joint. FSSW is effected with tool rotational speed, tool transverse speed, dwell time and tool plunge depth. Two sheets were joined under the tool rotational speed for 1040 rpm and dwell time for 10 second. The same samples joints with under RSW for 39 kA and dwell time for 0.5 second. These parameters are optimized for both welding techniques. Afterwards FSSW and RSW are compared about lap shear tensile test for aluminum alloy joints with plane thickness of 1.6 mm. So that FSSW is more suitable joining process than ERSW. As a results of test and analyses are showed that FSSW is better mechanical properties than RSW. Eventually, These results are verified by many experiments.

Key words

Friction Stir Spot Welding, Electrical Resistance Spot Welding, Aluminium alloys, Mechanical properties,Welding parameters.

1. INTRODUCTION

The ERSW method group (group of pressure welding method) has a wide range of applications in the automotive industry. This welding operation takes place in the solid phase. Especially, the ERSW used in automobile body sheet production is made by robots because this method is suitable for serial production [1]. ERSW is welding method which heat from the resistance of the materials against the electric current passing through the work pieces and at the same time applying the pressure. Apart from the heat generated by the electric current passing through the material, no heat treatment is applied to the work pieces. The heat is generated around the welded zone and pressure on this welded zone by applied through the electrodes [2]. However, the difficulties welding aluminum alloy which is a soft material with the RSW, have delayed widespread use of aluminum alloys in the automobile body sheet production [3]. A schematic presentation of the ERSW process is shown in Fig. 1 [4].

FSSW method recently advanced as an alternative to ERSW and developed from the traditional friction stir welding (FSW) method, it is one of the latest developments in joining technology [4].

In Figure 2, the steps of the FSSW technique is shown. The process is used for joined two metal plates. A non-consumable rotating tool with a specially designed pin plunges into upper plate. A support tool underneath the lower plate provides the force against the shoulder and pin (Fig. 2a). The tool accomplish two important function: heat generation hereabouts weld zone, and movement of material to produce the weld (Fig 2b). The heating is served by friction between the tool and the plastic deformation of the plates (Fig 2c) [5].

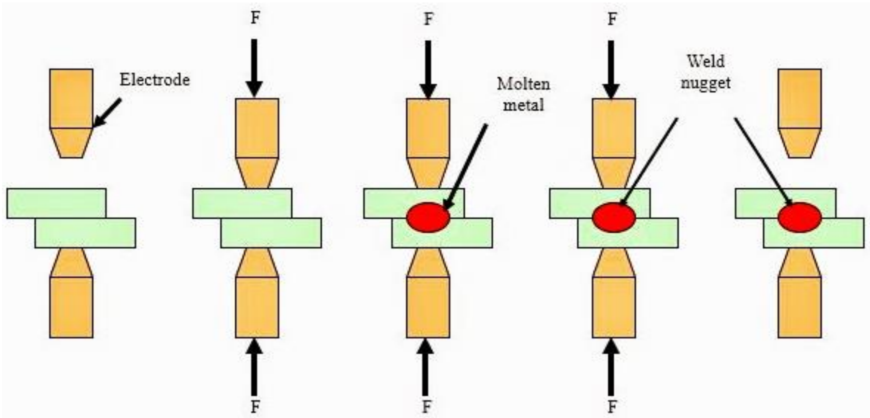

Figure 1. A schematic presentation of the ERSW process [5].

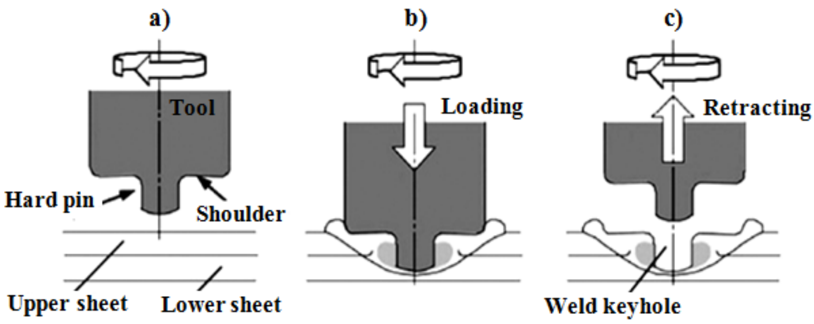

Figure. 2. A schematic presentation of the FSSW process: (a) plunging; (b) bonding; (c) drawing out [6].

After the FSSW process, the weld zone is observed as shown Figure 3. Two special segment can be identified from weld zone. The first segment is the thickness of weld nugget (X) which is a determiner of the weld (bond) section (Figure 3a and 3b). The bond section size is changed of depending of nugget thickness. The second segment is thickness of subject to shoulder operation on the upper plate (Y). The size of these segment establish the strength of a FSSW joint [7].

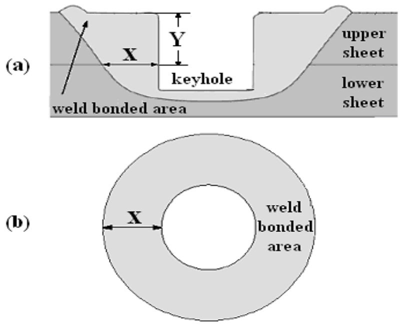

Figure. 3. (a) Schematic presentation of the cross section of a FSSW and (b) geometry of the weld bonded area; x: nugget thickness and y: the thickness of the upper sheet [7].

A new solid state welding technique, FSSW has been developed by Mazda Motor Corporation and Kawasaki Heavy Industry, as an extension of FSW for joining aluminum alloys [8-9]. Mazda reported a great reduction in energy consumption and equipment investment compare to ERSW for aluminum [10]. The only energy consumed in FSSW is the electricity needed to rotating and drive the tool. Compared to ERSW, the energy consumption has reduced by 99% for FSSW of aluminum and 80% for steel [11].

Since FSSW is a solid state welding process, no compressed air and coolant are need, and less electricity is required than ERSW. FSSWs have higher strength, better fatigue life, lower distortion, less residual stress and better corrosion resistance. Unlike ERSW, there is no traverse movement after plunging a rotating non-consumable tool into the work pieces. Tools used for FSSW have two parts, a pin and a shoulder. The pin is projected to throw the faying surface of the work pieces, shear and transport the material around it and produce deformational and frictional heat in the thick work pieces. The tool shoulder produces a majority of frictional heat to the upper surface and lower plate zones of the work pieces. Also the shoulder constrains the flow of plasticized material and produces the downward forging action [12].

In this study, sheet materials AA2024-T3 were selected for the ERSW and FSSW methods used in the industry. These selected sheets were separately welded with RSW and FSSW. The tensile test of welded joins was carried out. In addition, these test results were examined comparatively.

2. EXPERIMENTAL STUDY

2.1. Materials

In this study, 2 mm thickness AA2024-T3 plates were used for dissimilar FSSW and ERSW. The chemical composition of these alloy sheets is shown in Table 1.

Table 1. The mechanical properties and chemical composition of the aluminum plates.

Alloy	Mechanical properties		Chemical composition (wt. %)								
	Tensile strength (MPa	Elongation (%)	Al	Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr
AA2024-T3	435	17	93.11	0.07	0.14	4.5	0.65	1.5	0.01	0.02	-

Aluminium plate dimension is 25x100 mm. The welding zone is fixed as 25x25 mm for all test specimens.

All the FSSW experiments were carried on FSW adjusted milling machine as shown in Fig 4.

Figure 4. FSSW process: a) rotating tool prior to penetration into the lap joint; b) tool shoulder makes contact with the part, making heat and the joint zone; c) retraction of the tool from the lap joint zone.

2.2 Preparation and Joint of Experimental Specimens

The FSSW tool was made of Aluminum Titanium Nitrate (AlTiN) coated, 1.2344 hot work tool steel and had a hardness of 58 HRC. FSSW tool had a shoulder diameters of 18 mm, a pin diameter of 6 mm and a pin length of 3.80 mm. Joint configuration was used to produce the FSSW joints where the rolling direction of the plates. All the welding processes were done at the room temperature. FSSW process rotating tool have a constant speed that 1040 rpm. Dwell time of the tool was determined as 10s.

During the ERSW process, the specimens were joined at the current values of 39 kA with constant welding time of 0.5s and a constant electrode force of 1710 N which is the same in each joining.

2.3 Lap Shear Tensile Test

Welded plate pairs are tested with 250 kN capacity tester at 30 mm/min. tensile speed. The test equipment's trade-mark is ZWICK Z010. The lap-shear tensile tests (LSTT) were carried out at room temperature by Zwick Z010 universal type tensile test machine at a constant crosshead speed of 5 mm/s. The load and displacement were simultaneously recorded during the test.

Figure 5. Zwick Z010 lap-shear tensile tests machine.

Three specimens were tested for each parameter from the specimens joined by ERSW and FSSW and the averages were taken. ERSW and FSSW welded specimens plates (AA2024) are shown in Figure 6a and 6b.

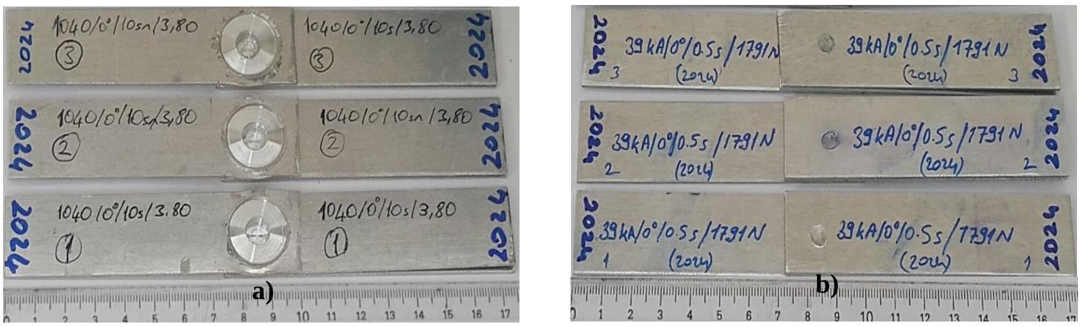

Figure 6. Lap-shear tensile tests specimens: a) Before test of FSSW specimens; b) Before test of ERSW specimens.

3. RESULTS AND DISCUSSION

3.1 Results of LSTT

The LSTT results of specimens joined with ERSW and FSSW are shown in Table 2. The results are given graphically in Figure 7. Increasing the weld current value causes inner heat rising and result of this operation nucleus grows.

Weld nucleus diameter is smaller in lower weld time and weld current values. It is also reported in other studies that heat input increases when weld current and time increased as formulated below; [13].

$Q = I^2 \cdot R \cdot t$

where Q is the generated heat (J), I the current (Ampere), R the resistance of the work (Ω) and t the time of current (s).

The expansion of weld nucleus and heat affected zone with increase in heat input is an expected result [14-19]. Bonding occurred at 9kA - 40kA but bonding was not happened at 3kA - 10 kA cycles. Bonding occurred at higher heat input. Rising the weld metal size increases the tensile-shear force. As the current continues to rise, the size of the weld metal decreases due to excessive melting and splashing and therefore the tensile-shear force is also reduced [13].

Aslanlar et al. 2006 showed that In low welding currents achieved by increasing the welding time, the amount of fused metal to form a nucleus increase, so the nucleus diameter increases and the height of the nucleus nearly reaches the sheet thickness [13].

LSTT was performed to obtain information on the joint strength of AA2024 plates joined with FSSW technique and ERSW technique. Thus, the yield strength, tensile shear strength and % elongation value of the material were determined. During the tensile tests a time must be given to distribute the uniformity of the applied stress uniformly throughout the sample.

Table 2. The LSTT results.

Materials	**LSTT (kN)**	
	FSSW	**ERSW**
AA2024	4.74	2.07
	8.31	3.38
	7.3	2.72

In FSSW process, the tool plunge depth up to 3.80 mm increases of tensile-shear force and decreases after this depth. The reason for this, the tool excessively depth process on the Al-alloy plate during the FSSW that causes thinning in the weld zone on the top surface of the plate [20].

The variation in pin length and pin profiles has direct impact on material mixing, flow etc. The commonly used pin profiles are cylindrical, conical, threaded, square, octagonal etc [21]. During FSSW process, the plunge depth and dwelling time of the tool determine the flow of metal around the stirrer tip, heat generation, weld strength and geometry [22].

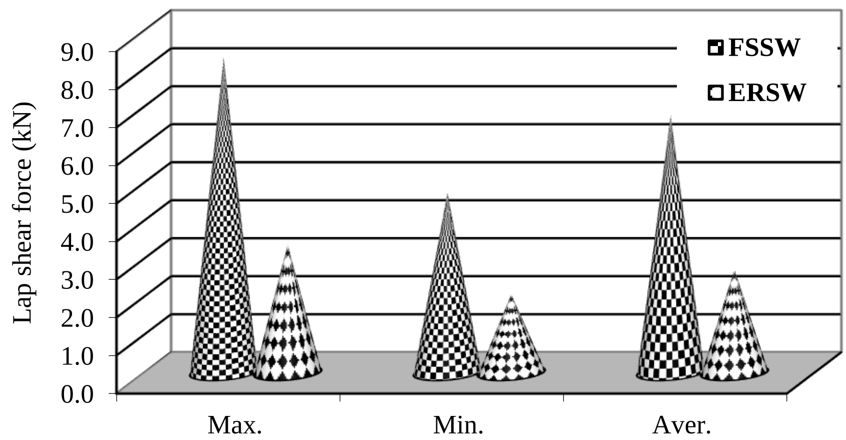

Figure 7. The lap-shear test results of specimens Joined with RSW and FSSW.

The weld metal is similar to the tool pin used in FSSW process. The shoulder of tool causes burr formation during the plunge. This situation is compatible with literature because it is formed in this way in all studies and is allowed to collapse on surface of upper material [4].

4. CONCLUSIONS

In this study, AA2024 Aluminium alloy sheets were joined with FSSW and ERSW methods. Maximum and minimum LSTT were determined. During the ERSW process, maximum LSTT force was determined to be 3.38 kN, a current value of 39 kA, a welding time (constant) of 10 s, an electrode force (constant) of 1710 N. During the FSSW process, maximum lap-shear force was determined to be 8.31 kN, a tool rotation speed of 1040 rpm, a dwelling time of tool of 10 s and a plunge depth of 3.80 mm. When these results were evaluated, FSSW method is given better results than ERSW method. As a result of increasing the welding current, the heat input and size of weld nucleus increased.

ACKNOWLEDGMENT

This study is granted by Marmara University, BAPKO project numbers: FEN-C-YLP-150218-0059.

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