Dissimilar Aluminium Alloys Welding by Friction Stir Processing and Reverse Rotation Friction Stir Processing

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Abstract. Processing of friction is a method derived from the welding of stir , gives fine grains. In the present work, new methods were used, namely friction stir processing (FSP) and the reverse of rotation of stir processing. This work aims to investigate the effect of (FSP) and (RFP) techniques on the properties of welded specimens. The results obtained were good in comparison with the friction stir welding (FSW) which includes a one pass of the welded sample, (FSP) engaging two passes of welding in the same rotational direction, and the third method which also engages two passes of welding the first pass with a rotational speed in a counter clockwise and the second in clockwise. The joining of dissimilar AA 5052 and AA7075-T6, (3 mm) thickness was accomplished by using (FSP) and (RFSP) to be compared with (FSW) process in order to investigate the effect of these techniques on the properties of welded samples. The rotational speeds are (710, 1000 and 1500) RPM and one traverse speed of (60) mm/min. The tool which has been used in this process was steel tool (X38) with (18 mm) shoulder diameter and (4 mm x 3.5 mm) taper pin diameter. The results of the two techniques were compared with the results of (FSW) by using (tensile test and micro hardness). In the tensile test, the results of (FSP) and (RFSP) were higher than that of (FSW) for all the rotational speeds of welding. In the micro hardness test , the values for all samples at the stir zone are higher than base metal of AA7075-T6 and lower than base metal of AA5052, the hardness of (FSP) and (RFSP) at speed of (710, 1000 and 1500) RPM was about one and half higher that of the metal of base for AA7075-T. The efficiency of tensile strength about (73.6%) for (FSP) and about (79.2 %) for (RFSP) as compared with the tensile strength of (FSW) and it is about (51.4%) at a speed of rotation (1000 rpm).

Keywords: Friction, stir, welding, processing, dissimilar, reverse, rotation, aluminium

1. Introduction

The structures of many industrial applications such as airplanes, rockets, pipelines, frames and many types of the storage tanks need to be of high strength and low weight. These types of structures use aluminium alloys, AA2024 and AA6061. In welding processes, the dissimilar joining is considered as a difficult process in comparison to the similar material joining. This is due to the variation of chemical and mechanical properties of the base material [1] and for this purpose the friction stir welding (FSW) and friction stir processing (FSP) are used in the welding applications [2]. Figure 1 shows a surface of the FSW working surface/material and the FSP is a modification o FSW. The friction stir processing is used to eliminate the local defects and refine the microstructure of the alloys and obtaining an acceptable mechanical properties which have an important industrial applications [3].

Friction stir technique involves the changing the mechanical properties of the local intense of the plastic deformation of the material which keeps the phase constant and creates a microstructure with a fine, and eqiaxed grains which improves the microstructure properties of metals [4].

In this work, two new methods will be employed in joining dissimilar aluminium alloys by using friction stir processing and reverse rotation friction stir processing to investigate their effectiveness in the mechanical properties o welded specimens.

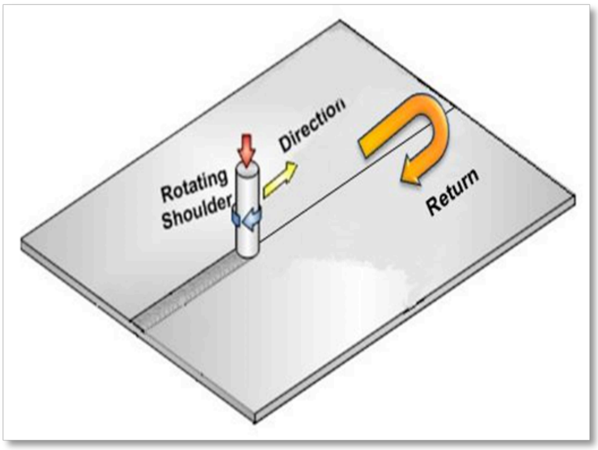

Figure 1. FSP of Plates Schematic Diagram.

2. Experimental part

The plates used in this work are AA5052 and AA7075-T6 of size (200*100) mm and of 3 mm thickness. The Aluminium samples were prepared by using a press and grinding machine. In this work, dissimilar joints are achieved for the above alloys using three techniques. The first one includes a single pass of welding, which is called FSW. The second technique used two passes of welding; the first pass in going stage (forth) from the weld start, and the second pass in returning stage (back) to the first point of the weld start, both passes in the same rotational direction (figure1), and this technique is called FSP. The third one was carried out using various approaches, two passes but the rotational speed of the first pass is in anti-clockwise direction and the second pass in clockwise direction, which is known as (RFSP). The above three methods are considered as important because of their higher efficiency and acceptable results of welded line in comparison with the commercial one. The other characteristic of these welding techniques, is the availability of the milling machines used in FSW, FSP, and RFSP. The clamping fixture in the used MIDM milling machine is used to achieve the work, where the tool is fixed on the machine spindle. A dial gauge is used to ensure the stratification of the plates in order to obtain a perfect welding line. Figure 2 shows the dissimilar joining of AA5052 and AA7075-T6 aluminium alloys.

FSW and FSP parameters and tool dimensions used in this work are listed in table 1. The rotating tool was made of steel X38. The tapered cylindrical tool with displacement controlled process was used through the process to join the two plates is the same for welding of stir and processing friction stir , to improve the localized structure of the alloy. The tool geometry has an important factor in the process of welding. It has tapered cylindrical shape (not threaded) of 18 mm shoulder diameter with a taper pin diameter of 4.5 mm*3.5 mm and 209 mm length which is equal to the penetration depth in the plate as shown in figure 3, [5-7].

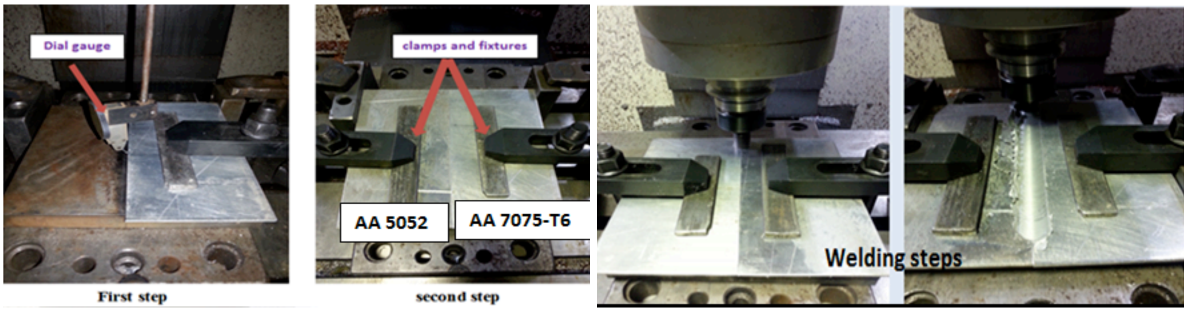

Figure 2. Welding process for two sheets

Table 1. Welding Parameters and Tool Geometry

No	Process variable(s)	Value(s)
1	Speeds of rotation (RPM)	710, 1000,1500
2	Feed speed (mm/min)	60
3	Pin length (mm)	2.9
4	Shoulder diameter (mm)	18
5	Pin taper diameter (mm)	D1=4, D2=3.5

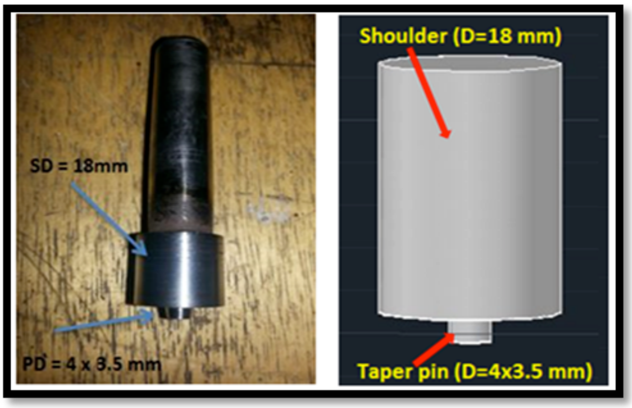

Figure 3. FSW, FSP, and RFSP tool design

3. Welded Samples Tests

3.1. Tensile Strength Determination

The tensile test is according to the ASTM standard, [8-20], then, by according ASTM E8M, flat plates are prepared. The measurements of the tensile strength of the samples of the welded joints and for the base metal are achieved in the transverse direction to the welding line. Figure 4 shows the sketch of the tensile specimen. The samples were cut by using a C-TEK milling machine. The tensile machine of speed 1 mm/min was used for tensile testing of dissimilar aluminium alloys 2024 T3 and 6061 T6.

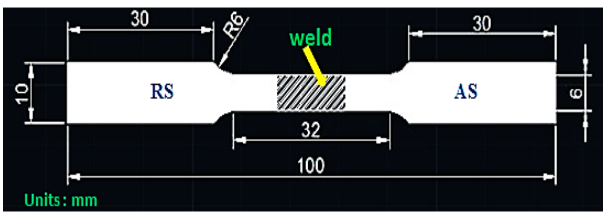

Figure 4. Tensile sample geometry (ASTM E8M)

3.2. Micro hardness Test

A micro hardness testing machine type INNOVA was used, to estimate the resistance of samples to indentation and scratching. This test was achieved at the nugget zone (NZ), heat effected zone (HAZ), thermo heat effected zone (TMAZ) and base metal (BM) [21] with a (1.5 mm) distance between two micro hardness tests, and the load used was (200 gm).

4. Results and Discussions

4.1. Results of (FSW), (FSP) and (RFSP)

Figures 5, 6, and 7 show the welding lines of FSW, FSP, and RESP of the dissimilar aluminum alloys 2024 T3, and 6061 T6. By using the fusion welding conventional technique in aluminum alloys welds, it is difficult to achieve the welding process due to the presence of the defects of hot cracking, porosity and distortion. This can be solved by using the friction stir welding as a solid state joining. In this respect, the heat generation is used to melt the material and the soft material is moved to bond the specimens. Figures 5 to 7 show the cross sections of the weld joints, they are free of defects i.e. good welding quality which was achieved by using FSP and RFSP in comparison with the FSW.

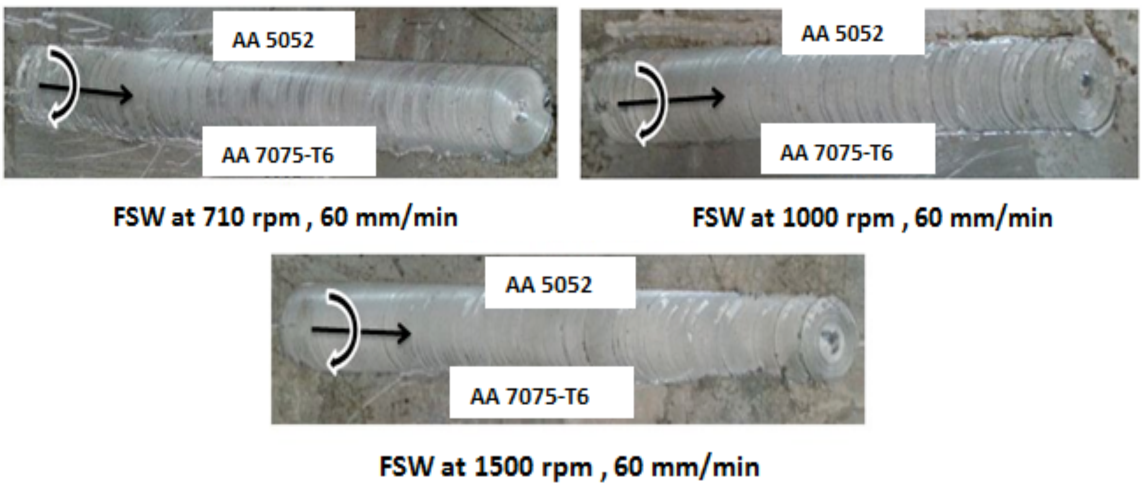

Figure 5. Welding Line Surfaces for All FSW Specimens

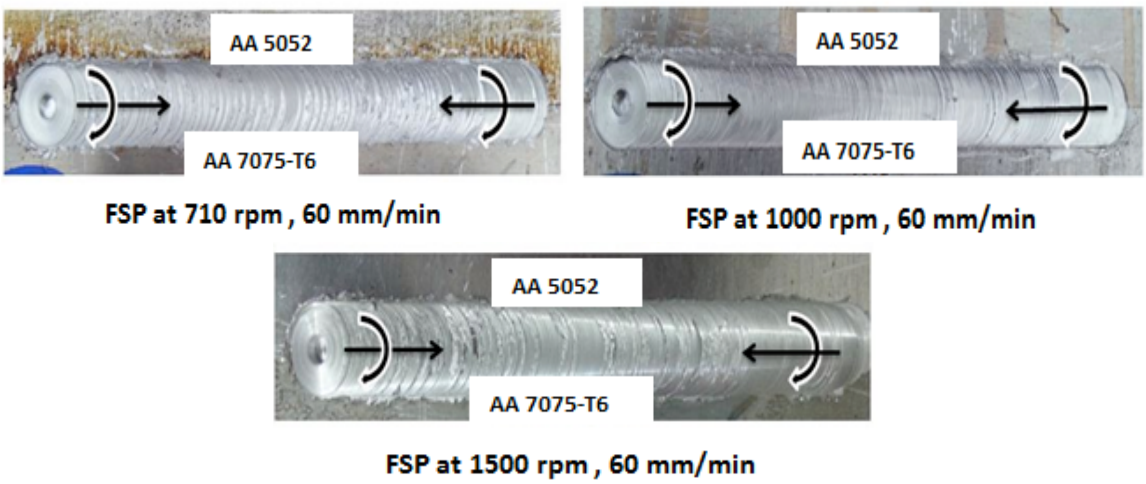

Figure 6. Welding Line Surfaces for All FSP Specimens

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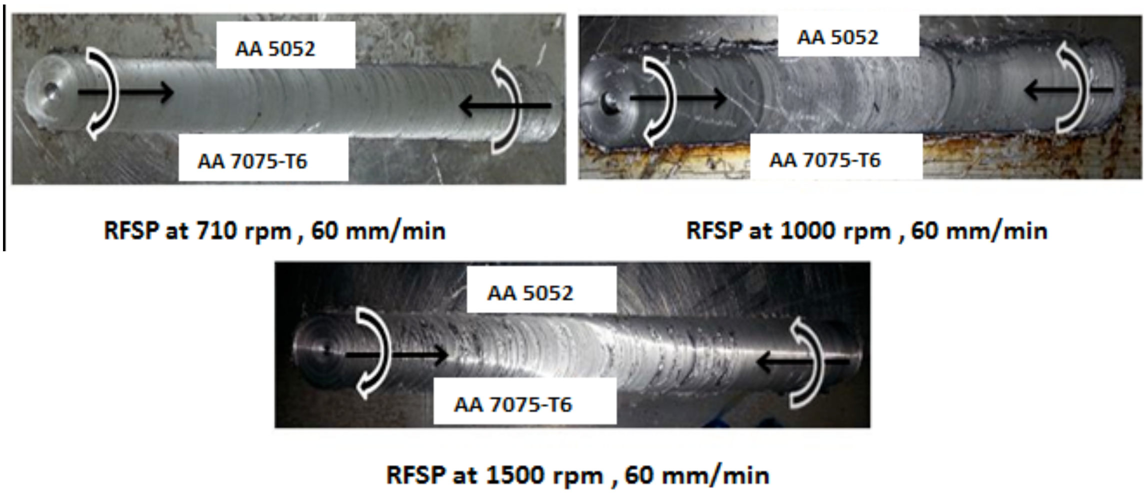

Figure 7. Welding line Surfaces for All RFSP Specimens

4.2. Tensile Test Results

Table 2 shows the results of tensile test of FS welded specimens. The samples were AA 5052 and AA 7075 – T6 aluminium alloys. Figure 8 presents the ultimate tensile strength test samples by using FSW, FSP, and RFSP. The materials were AA5052 and AA 7075-T6 aluminium alloy and BM AA 5052 (193 MPa).

Table 2. Tensile Results of Welding AA 5052, AA 7075-T6

Samples	Welding type and speed condition	Average value of ultimate tensile strength (MPa)	Efficiencies of FSW, FSP and RFSP (%)
A1	FSW:710RPM,60mm/min	83.7	43.4
A2	FSW:1000RPM,60mm/min	99.2	51.4
A3	FSW:1500RPM,60mm/min	87.1	45.1
B1	FSP:710RPM,60mm/min	115.8	60
B2	FSP:1000RPM,60mm/min	142	73.6
B3	FSP:1500RPM,60mm/min	123.9	64.2
C1	RFSP 710 RPM,60mm/min	143	74.1
C2	RFSP 1000 RPM,60mm/min	152.8	79.2
C3	RFSP 1500 RPM,60mm/min	122.07	63.2

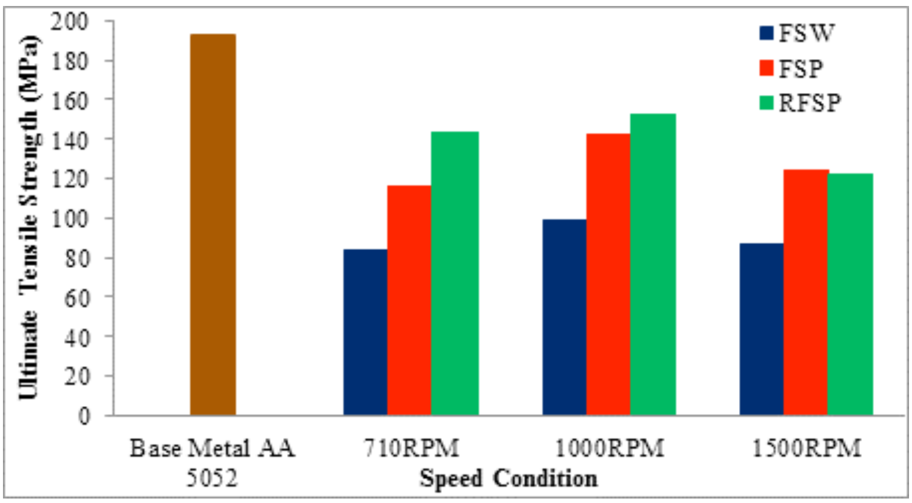

Figure 8. Results of the Tensile Strength of FSW, FSP and RFSP

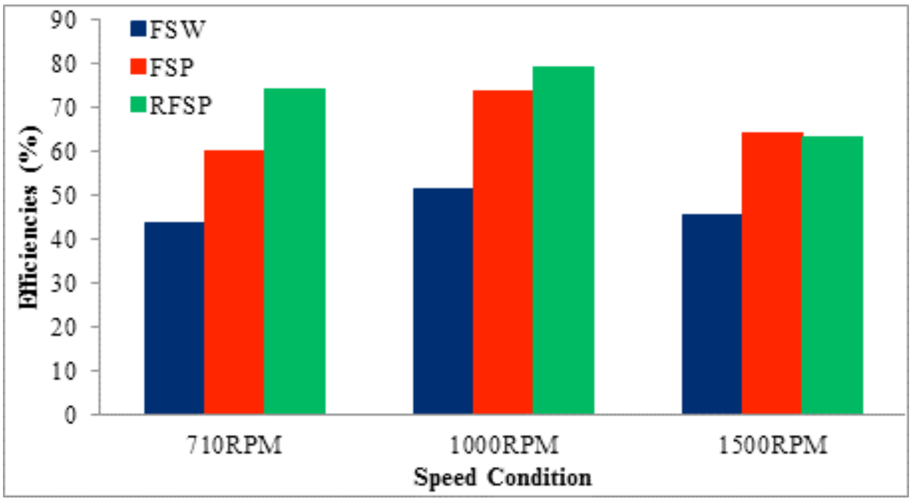

Figure 9. Efficiencies of FSW, FSP and RFSP for Dissimilar Alloys

To assess the performance of FSW of dissimilar AA5052 and AA7075-T6 aluminium alloys, tensile tests are performed on the base metal using rotational speed 1600 rpm and a travel speed 60 mm/min. The results indicate that the ultimate tensile strength of FSW, FSP, and RFSP reaches 51.4%, 73.6% and 79.2% of the base metal respectively. The measurement of the higher joint efficiencies of dissimilar RFSP and a rotational speed is 1000 rpm and the travel speed is 60 mm/min which becomes 69.03% of the strength of the AA 5052 base metal (BM). This is because that the speed 1000 rpm is suitable to obtain a reasonable correlation between the grain and the heat generated for the plasticizer of the granules. For AA7075-T, the efficiency of tensile strength about (73.6%) for (FSP) and about (79.2%) for (RFSP) as compared with value of (FSW) and it is about (51.4%) at rotation speed of (1000 rpm).

4.3. Micro hardness Results

Figure 10 presents the micro hardness profiles across the sections of dissimilar AA 5052 and 7075-T6 materials, where the welding has been achieved by FSW, FSP, and RFSP using the best efficiency of rotational speed 1000 rpm . The results explain the micro structure and the mechanical properties of the generated welds. Figure 10 shows the results of measurements of Vickers hardness carried out across the sections of the welded joints for the welding techniques FSW, FSP, and RFSP at 1000 rpm rotational speeds and a travelling speed of 60 mm/min respectively. In the NZ region, it was observed that a higher hardness value was obtained and slowed down at thermo mechanically affected zone (TMAZ), heat affected zone (HAZ)for all types of welding. The presented results indicate that the higher value of hardness is at the NZ region and decreased at the TMAZ, and HAZ regions for all the above types of welding. A decline was noticed for the hardness values for the samples using RFSP welding technique. This is because of the roughness granules in the HAZ region which causes a reduction in the hardness at this region. The comparison of the results of the hardness values in the nugget zone (NZ), TMAZ and HAZ regions shows that their values are lower than those of the base metal.The higher hardness measured in the RFSP and FSP results in a hardness of the weld nugget higher than that of AA5052 base material and the thermo mechanically effected zone. The measured hardness values in the nugget region using RFSP and FSP are higher than those of AA7075T6 base metal and TMAZ. Also, these results are lower than those of AA 5052 base metal.

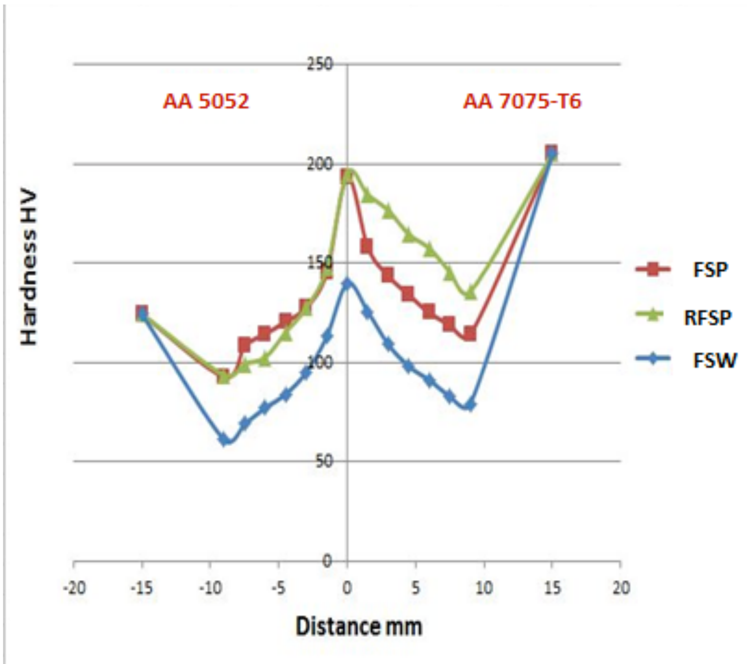

Figure. 10. Variation of Hardness Along the Distance of FSW, FSP and RFSP Welding Line for Dissimilar AA5052,AA7075-T6 AA using 1000 rpm.

Since the FSW gives coarse grains, a decrease in the values o the micro hardness is obtained. In this case, a dynamic recrystallization is occurred due to the tool rotation and the feed rate. This will cause a new fine grains [22]. Figure 10 presents the Variation of Hardness along the distance of FSW, FSP and RFSP Welding Line for dissimilar AA5052,AA7075-T6 AA using 1000 rpm. It is observed that the friction stir processed area has a value of Vickers hardness higher than that in the friction stir welded area. This is because that the FSP results in grain refinement. This is coincide with the Hall-Patch theory which states that as the grain sizes decrease, the hardness increases [23].

5. Conclusions

1. The processing of friction stir (FSP) and reverse of friction stir processing (RFSP)of dissimilar welding of AA5052 and AA7075- T6 are better than friction stir welding (FSW) because of the transfer of heterogeneous microstructure to a homogenous refined microstructure and improved mechanical properties.
2. The efficiency of tensile strength was about (73.6%) for (FSP) and (79.2 %) for (RFSP) as compared with value of (FSW) which was about (51.4%)
3. The modification of the microstructure of FSP and RFSP results in an improvement in mechanical properties in a good quality of welding with long life for the both welding techniques.
4. The microhardness graphics exhibited that the values of hardness were varied through the cross section of weld line because of the change in micro structural properties. The results showed that the hardness values at the NZ for FSP and RFSP are higher than that of FSW due to the grain refinement obtained using the new techniques of welding.

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