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Research Article

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Evaluation of Mechanical Behavior of AA6063 and AA2024 Dissimilar Aluminum Alloys by Friction Stir Welding Process

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Abstract

Friction stir welding (FSW) is based on a system of frictional heating and permanent deformation under molten heat of the materials. In this paper aims to improve the potential behavior of welding for different aluminum alloys of AA6063 and AA2024 were welded through FSW process. The speed, tool rate, and axial force were analyzed on hardness value of the welded joint. The results significantly show that all weld execute through threaded tool and obtained highest tensile strength value 57.7 N/mm^2 at second test plate. The optimum combination to obtain maximum tensile strength speed 900 rpm, tool-TR-25 mm/min and axial 10 kN. The maximum hardness results are obtained 63 HRB at speed 1000 rpm, tool-TR 20 mm/min, and axial 8 kN.

Keywords

AA6063, AA2024, Hardness strength, Tensile strength, Axial force

Introduction

FSW employs a revolving tool to create heat and plasticize the material, which is then solidified to form a weld, in contrast to traditional welding procedures, which use heat to melt and fuse the materials [1, 2]. This method has various advantages over traditional methods of welding, including low distortion, great strength, and the ability to fuse materials that are not identical. In light of this, the purpose of this study is to provide the results of an experimental investigation and an optimization of the process parameters for FSW using two aluminum alloys that are not similar to one another: AA2024 and AA7075. Because of the high ratio of their strength to their weight and their resistance to corrosion, these two alloys find widespread application in the aerospace and automotive industries. In order to determine how the process parameters impact the quality of the weld, it is necessary to design experiments as part of the process parameter optimization process [3]. Methods of statistical analysis like analysis of variance (ANOVA) are utilized in the process of determining the main elements that influence the quality of the weld. After that, response surface methodology is utilized in order to optimize the process parameters in order to produce welds of the highest possible quality. In a nutshell, the results of the experimental analysis and process parameter optimization of FSW with dissimilar aluminium alloys AA2024 and AA7075 can provide considerable benefits to a wide range of sectors. It is possible for manufacturers to create consistent welds of a high quality by optimizing the process parameters, which in turn reduces the possibility of faults and failures occurring [4]. Additionally, the utilization of aluminum alloys that are not identical to one another can potentially reduce the weight of the components while simultaneously improving their performance. It continues to advance until the shoulder makes full contact with all the surfaces of the work piece [5]. Mechanical and microstructure analysis of the friction stir welds between the

aluminum alloys AA2024 and AA7075 was done to discover how welding parameters such tool rotational speed and traverse speed affected the welds. Hardness and tensile strength were observed to improve alongside the tool's rotational and traversal speeds. The process parameter optimization and characterization of dissimilar friction stir welds between AA7075 and AA2024 aluminum alloys is studied by using response surface methodology to optimize the process parameters for FSW utilizing AA7075 and AA2024 aluminum alloys [6].

Aluminum alloys are increasingly replacing steel in applications where reduced weight and lower maintenance costs are desired. Nanoparticle reinforcement is an emerging field that provides great methods to create composite joints with improved joint characteristics. The strengthening mechanical effect was notably enhanced by utilizing specific concentration of small size particles, e.g., nanoscale particulates. On the contrary, unlike micro-sized particulate reinforced composites, the fabrication of nanocomposites is quite complicated, as generating a homogenous distribution of nano-sized particulates in base metal-matrix is hard to attain using molten liquid processing methods and powder metallurgy routes. More recently, FSW was successfully applied for the fabrication of 5052Al/Al_2O_3, 6061-T6/(SiC+Gr), 7005/Al_2O_3/10p, AZ91/SiC/10p, 6061/TiC/3 and 7p, 6063/B_4C/6 and 10.5p [7].

The microstructure and mechanical properties of the resultant welds were also discussed in the paper. Optimization of FSW parameters for dissimilar aluminum alloy AA2024 to AA7075 using Taguchi design approach. Taguchi was used to determine the optimal values for the FSW parameters used in the combination of AA2024 and AA7075. Welds with high tensile strength and minimum distortion were achieved by using the ideal process parameters. The use of electron probe microanalysis was employed in order to investigate the degree to which alloying elements diffuse into one another at the contact. The specimens were evaluated using tensile testing, which revealed that they have satisfactory mechanical qualities. It's possible that the improved tensile characteristics of the friction-stir-welded AA5052-AA6061 specimens were due to the inter diffusion of alloying elements and the establishment of comparable orientations in the nugget [8, 9].

Materials and Method

The primary alloy chosen in this experimental work is AA6063. It exhibits superb surface finish, high corrosion resistance, ready suitability for welding, and the ability to be quickly anodized. Although it is most usually found in the T6 temper, it has good formability when it is in the T4 state. Alloy 2024 aluminum is a heat-treatable aluminum alloy with copper as the primary alloying element. It is malleable in its entirely soft, annealed state and can be heat-treated to achieve high levels of strength after being formed. Due to its high strength-to-weight ratio, aerospace applications employ it extensively. FSW operation is done using the Czechoslovakian vertical milling machine. The quality of the welded joint is ascertained by visual inspection of weld bead and defect free joints along the weld region. Aluminum alloy was used as base metal to perform FSW in this study. The prepared samples were welded using a threaded tool with 6 mm profile size. Table 1 presents the experimental design.

Table 1: Process parameters and their levels.

Levels	Process parameters		
	Speed, rpm	Tool-TR, mm/min	Axial force, kN
1	800	20	8
2	900	25	9
2	1000	30	10

Results and Discussion

Hardness test

Because the definitions of metallurgical ultimate strength and hardness are fairly comparable to one another, it is safe to infer that a metal with a high strength will also be a metal with a high hardness. Figure 1 shows the signal to noise (S/N) ratio graph on hardness. The maximum hardness results are obtained at speed - 1000, tool-TR 20 mm/min and axial 8 kN has the hardness value of 68 HRB, the fourth sample obtained the lowest hardness strength of 48 HRB. The obtained results are shown in figure 2. Table 2 presents hardness and tensile test results. Table 3 shows the ANOVA results of hardness value. The axial force is the maximum contributing parameter which influences the hardness of the composites.

Tensile strength

Tensile testing is used to analyze the mechanical properties of friction-processed joints. Tensile qualities can be determined with the use of a tensile test, such as the tensile strength, the yield strength, the percentage of elongation, the

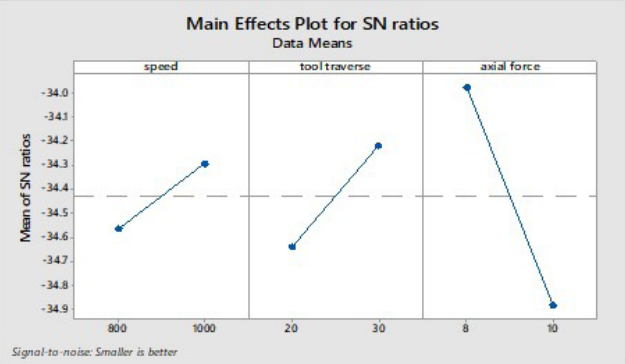


Figure 1: Effects plot for S/N ratios for hardness.



Figure 2: Hardness strength graph.

Table 2: Hardness and tensile test results.

S. No.	Speed, rpm	Tool-TR, mm/min	Axial force, kN	Hardness strength	TL, kN	TS, N/mm²
1	800	20	8	52	0.33	6.63
2	800	25	9	55	1.09	22.26
3	800	30	10	55	0.28	6.12
4	900	20	9	**48**	0.08	1.68
5	900	25	10	59	2.77	57.71
6	900	30	8	56	1.42	25.1
7	1000	20	10	56	2.16	45.2
8	1000	25	8	**68**	2.04	44.56
9	1000	30	9	52	1.09	21.81

Table 3: Analysis of variance – Hardness.

Source	DF	Seq SS	Adj MS	F	P	% of contribution
Speed	1	2.250	2.250	--	--	6
Tool traverse	1	6.250	6.250	--	--	16
Axial force	1	30.250	30.250	--	--	78
Error	0	--				0
Total	3	38.750				100

percentage of decrease in area, and the modulus of elasticity. Within the range that was accessible on the equipment, the welding parameters were arbitrarily selected. Figure 3 shows the S/N ratio graph for tensile strength. Figure 4 shows the tensile specimen, figure 5 shows the obtained tensile graph. The fifth sample obtained the highest tensile strength value of 57.7 N/mm², tensile strength - A_2 (Speed 900), B_1 (Tool-TR 20 mm/min), and C_3 (Axial 10 kN). Table 4 shows the ANOVA results of obtained tensile value shows the maximum contribution which influences the tensile strength is tool wear rate.

Microstructure analysis

The plates were welded with a straight cylindrical tool at 900 rpm, Tool-TR 25 mm/min, and axial force 8 kN using FSW process. During the tensile test, a minimum tensile strength of 57.7 MPa was determined, and all specimens fractured in the heat-affected region of the advancing side of the weld line due to their low hardness and fine particle formation shown in figure 6. Figure 7 depicts a photograph of the fractured specimen for minimum tensile strength. The macroscopic view of the destroyed surface depicted in figure 7 which reveals uniformly rough surface additionally minute dimples, facets, and elongated edges are plainly visible. Consequently, it is also discovered that the lowest tensile strength once correlates with other samples.

Regression equation

Tensile strength = 25.67 – 14.00 Speed_800 + 2.49 Speed_900 + 11.52 Speed_1000 – 7.84 Tool-TR_20 + 15.84 Tool-TR_25 – 8.00 Tool-TR_30 – 0.24 Axial force_8 – 10.42 Axial force_9 + 10.67 Axial force_10

Hardness = 52.75 + 0.7500 Speed_800 – 0.7500 Speed_1000 + 1.250 Tool traverse_20 – 1.250 Tool traverse_30 – 2.750 Axial force_8 + 2.750 Axial force_10

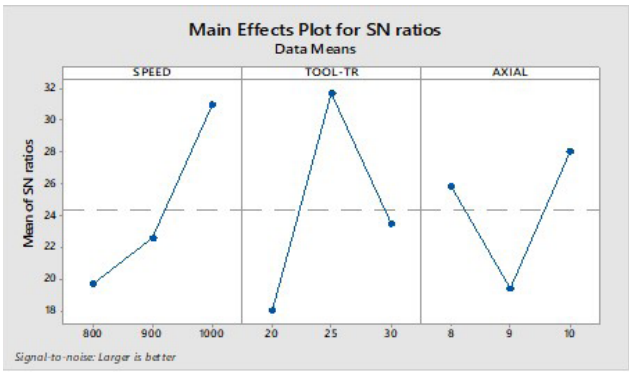


Figure 3: Effects plot for S/N ratios for tensile test.



Figure 4: Tensile test specimen.

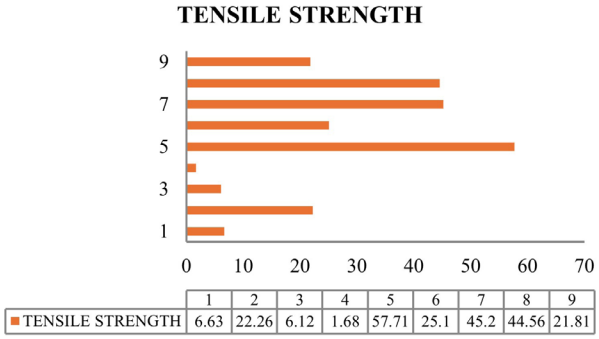


Figure 5: Tensile strength graph.

Table 4: Analysis of variance - Tensile.

Source	DF	Seq SS	Adj MS	F	P	% of contribution
Speed	2	1004.8	502.4	3.23	0.236	32
Tool traverse	2	1128.5	564.2	3.63	0.216	36
Axial force	2	667.7	333.8	2.15	0.318	22
Error	2	311.0	155.5			10
Total	8	3111.9				100

Conclusion

In this work the aluminum alloys of AA6063 and AA2024 were selected for solid state welding techniques without utilizing any filler materials. The L9 orthogonal array is used for

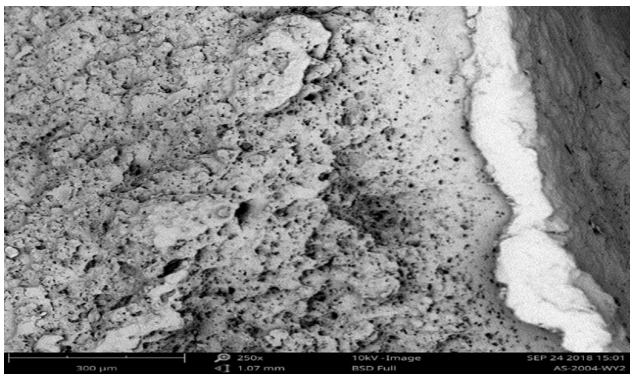


Figure 6: Photographic views of AA6063 and AA2024 tensile tested specimen (SCT - Minimum tensile strength).

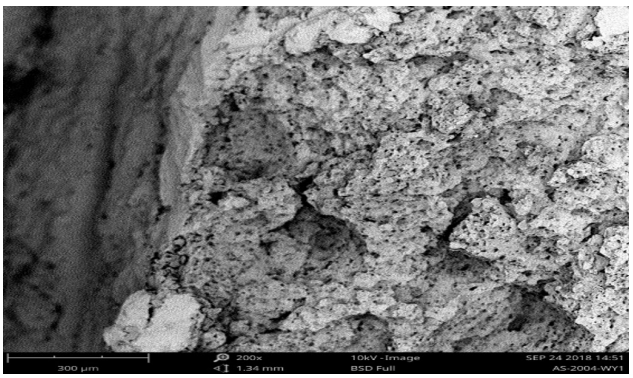


Figure 7: Photographic views of AA6063 and AA2024 tensile tested specimen (TCT - Maximum tensile strength).

experimental design work and there was not a single serious flaw detected in any of the welds. It was discovered that the welded samples contained intermixing metals as well. The obtained results were mentioned as the fifth sample obtained the highest tensile strength value of 57.7 N/mm^2 the lowest tensile strength value of 6.63 N/mm^2. The optimum combination to obtain maximum tensile strength speed 900 rpm, tool-TR-25 mm/min and axial 10 kN. ANOVA results of obtained tensile value shows the maximum percentage contribution which influences the tensile strength is tool wear rate. Meanwhile the fourth sample obtained the lowest hardness strength of 48 HRB. The maximum hardness results are obtained 63 HRB at speed 1000 rpm, tool-TR 20 mm/min and axial 8 kN. The axial force is the maximum percentage contribution which influences the hardness value obtained from ANOVA results.

Acknowledgements

None.

Conflict of Interest

None.

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