

FRICION STIR WELDING OF AA6082 AND AA7175 ALLOYS, MECHANICAL BEHAVIOR AND OPTIMAL PARAMETRIC ANALYSIS BY USING TAGUCHI BASED ANOVA ANALYSIS

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ABSTRACT

Friction stir welding (FSW) is a new joining method and is used to join two dissimilar materials AA6082 and AA7175 aluminum plates of 6 mm thickness, which enables the advantages of solid state welding. The hardness optimal parametric values of tensile, micro-hardness and toughness are obtained by using Taguchi grey based approach. The L9 orthogonal array has been used to design the experiments, and the experiments have been conducted in a laboratory stage vertical milling machine by varying tool rotational speed of (560, 710, 900) RPM, feed rate (20, 30, 40) mm/sec and pin shoulder diameter (18, 20, 22) mm. After friction stir welding, the micro-hardness test was conducted on the friction stir welded specimens. The obtained tensile, micro-hardness and toughness values are considered for Taguchi based optimization technique. The optimal combinations are obtained by using output values of signal to noise(S/N) ratios. The parameters which influence the tensile, micro hardness and toughness are obtained by ANOVA analysis.

Keywords: Friction Stir welding, dissimilar alloys, Taguchi Method & ANOVA analysis.

1. INTRODUCTION

Friction Stir Welding (FSW) is a framework in welding in which an characteristic tool is used to create frictional warmth at the welding region where metal material will be changed over into solid state [1]. Friction Stir Welding is a moderately new strong state joining process [2]. This joining procedure is energy efficient, environment well disposed, and adaptable [3]. Specifically, it can be utilized to join high-quality aviation aluminum alloys and different composites of metal that are difficult to be welded by traditional combination welding [4]. FSW is thought that it is best method of welding and most significant for the improvement in metal joining. This procedure is principally utilized on aluminum and regularly on substantial pieces, which can't be effortlessly warm treated, post weld to recoup temperature attributes [5]. The Friction Stir Welding is really, another innovation in the high execution aviation and car application. In contrast with conventional welding systems, FSW unequivocally lessens the nearness of contractions [6]. Aluminum alloys are basically used in industry due to its better corrosion resistance, high electrical and thermal conductivity [7].

FSW technique can be used to produce lap, butt, corner, T, spot, fillet and hem joints as well as to weld hollow objects, such as pipe/tube and tanks and parts with 3-dimensional contours[8]. Replacement of mechanical fastened joints with FS welded joints can lead to significant weight and cost savings, attractive for many industries [9]. By using FS welded joints instead of fastened joints can also eliminate the stress

concentration effects associated with fastener holes, improve corrosion performance by eliminating the fasteners as a source of dissimilar metal contact[10].

2. EXPERIMENTAL PROCEDURE



Figure 1: Cylindrical Taper Shape pin Tool used for Experiments

Table 1: Chemical composition for aluminum alloys AA6082 and AA7175 (wt %)

Component	AA6082	AA7175
Si	13	0.15
Fe	0.5	0.20
Cu	0.1	1.6
Mn	01.0	0.10
Mg	1.2	2.5
Zn	0.2	5.6
Ti	0.1	0.10
Cr	0.25	0.23

The aluminum plates were cut into rectangular shapes of 100X70X6 mm and Friction Stir Welding was carried out using a vertical milling machine. The welding tool used in H13 High Carbon steel, with Cylindrical Taper Shape pin Tool profile having shoulder diameters 18, 20,22 mm of and pin diameter of 2.5 mm. The process parameters are considered in three levels Each as shown in table 2.

Table 2: FSW Process Parameters and Levels

Process parameters	Level 1	Level 2	Level 3
Tool rotational speed (r.p.m)	560	710	900
Tool feed rate (mm/sec)	20	30	49
Tool pin shoulder diameter	18	20	22

A milling machine was used for joining of aluminum alloys (AA6082) and (AA7175) for friction stir welding. Specification of milling machine used for friction stir welding is shown as below table 3.

Table 3: Specification of the FSW machine

Specifications	Values
Make	PACMILL
Range	100-4650 rpm on 50 Hz,
Type	Vertical
Longitudinal bed range	900mm
Cross bed range	600mm
Traverse feed range	12-900 mm/min.

Motor	3H.P, 1450 rpm
Tool holder diameter	50 mm



Figure 2: milling machine Figure 3: welding samples

The L9 orthogonal array Taguchi’s method was used to find the design of experiments later ANOVA analysis was carried out to determine the percentage contribution of each input parameters. The schematic FSW operation of the dissimilar AA6082 and AA7175 are performed on a vertical milling machine shown in figure2.

3. EXPERIMENTAL RESULT

The welded specimens were cut according to the ISO standard and tensile tests were performed using the Tensile testing machine with a constant speed in room temperature to evaluate tensile strength of weld joints for analysis. Micro Vicker’s Hardness tests were carried out and the average value is considered for analysis. Later Charpy impact tests were carried out and the value is considered for analysis.



Figure 4: Micro Vicker’s Hardness Machine

Figure 5: Samples

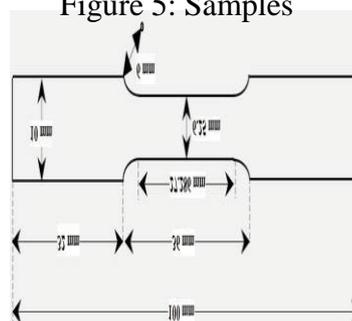


Figure 6: Tensile Testing Machine

Figure 7: ISO Standard

Figure 6: Samples

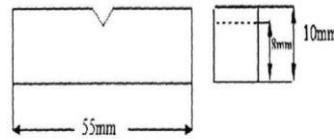


Figure 8: Charpy Testing Machine Figure 9: ISO Standard

Figure 10: Samples

Table 4: Process Parameters with Experimental Results

S. No	Tool Rotational Speed, rpm	Welding Speed, mm/min	Pin shoulder Diameter mm	Tensile Strength, N/mm ²	Average Hardness Value, VH	Charpy impact value
1	560	20	18	0.179	47.697	2.218
2	560	30	20	0.124	51.363	1.6
3	560	40	22	0.040	49.756	1.818
4	710	20	18	0.176	47.863	1.618
5	710	30	20	0.075	63.235	1.890
6	710	40	22	0.125	46.333	1.545
7	910	20	18	0.116	78.024	2.563
8	910	30	20	0.155	74.775	2.569
9	910	40	22	0.137	65.846	1.781

4. RESULTS AND DISCUSSIONS

For the 9 specimens with all the different combinations of input parameters are used to obtain the tensile strength and are shown in the table to analysis the FSW process parameters and tensile strength values were analyzed using Taguchi’s method to find the influence of parameters, signal to noise ratios are calculated in this process, the large S/N ratio value means the better the response. Response optimization will give a better combination of input parameters.

The values are calculated by using the MINITAB software and analyzed the S/N values for the combinations.

Table 5: ANOVA Table for Tensile Strength

source	D.F	Sum of Squares	Mean Sum of Squares	F-Value	P-Value	Percentage

A	2	0.001	0.001	8.76	0.102	3
B	2	0.014	0.007	79.62	0.012	36
C	2	0.023	0.011	131.22	0.008	59
Error	2	0.001	0.009			0.4
total	8	0.004				

From the table 5, it can be concluded that the tool rotational speed has a contribution of 3% and followed feed 36% and pin shoulder diameter 59%.

Table 6: Shows Response Table for Tensile Strength

Level	Speed (N) (RPM)	Feed(F) (mm/min)	Pin Shoulder diameter (D) (mm)
1	-20.34	-16.25	-16.40
2	-18.55	-18.94	-17.41
3	-17.97	-21.68	-23.06
Delta	2.37	5.43	6.66
Rank	3	2	1

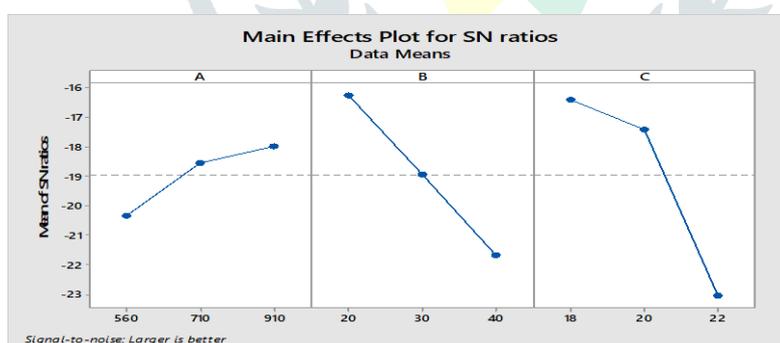


Figure11: Signal To Noise Ratios Response Table For Tensile

From the table 6 and figure 11, it can be calculated that tool rotational speed of 710 rpm, welding speed of 20 mm/min and tool pin shoulder diameter of 18mm is the optimum welding condition to get good tensile strength.

HARDNESS

Hardness of the material is defined as the resistance to plastic deformation. We need higher hardness value to resist for deformation. Thus we use larger-the-better to calculate S/N ratio. Table 8, shows the ANOVA table for average hardness at weld zone

Table 7: ANOVA Table for Hardness

source	D.F	Sum of Squares	Mean Sum of Squares	F-Value	P-Value	Percentage
A	2	3.957	1.978	189.73	0.005	78
B	2	0.544	0.272	26.11	0.037	10
C	2	0.544	0.272	26.10	0.037	10
Error	2	0.020	0.010			0.4
total	8	5.067				

From the table 7, it can be concluded that the tool rotational speed has a contribution of 78% and followed feed 10% and pin shoulder diameter 10%.

Table 8: Shows Response Table for Hardness

Level	Speed (N) (RPM)	Feed(F) (mm/min)	Pin Shoulder diameter (D) (mm)
1	33.91	35.00	34.79
2	34.31	35.90	34.73
3	37.23	34.54	35.93
Delta	3.32	1.36	1.21
Rank	1	2	3

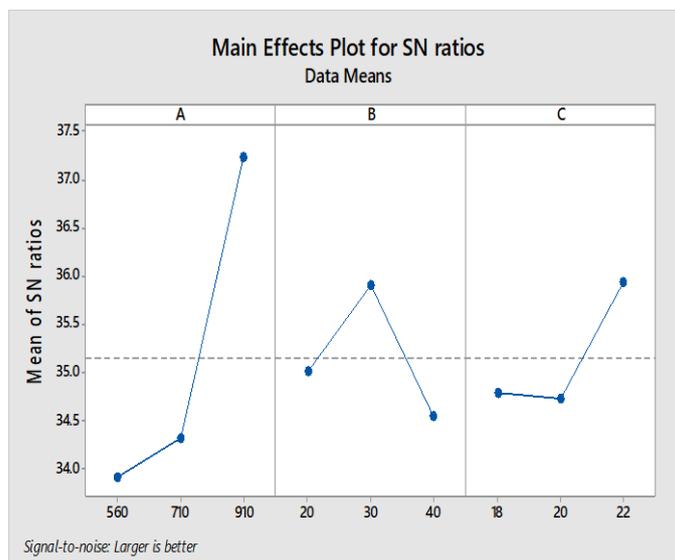


Figure12: Signal To Noise Ratios Response Table For Hardness

From the table 6 and figure 12, it can be calculated that tool rotational speed of 560 rpm, welding speed of 30 mm/min and tool pin shoulder diameter of 22 mm is the optimum welding condition to get good hardness at weld zone.

CHARPY TEST

Toughness of the material is defined as the resistance to plastic deformation. We need higher toughness value to resist for deformation. Thus we use larger-the-better to calculate S/N ratio. Table 6, shows the ANOVA table for Toughness.

Table 9: ANOVA Table for Toughness

source	D.F	Sum of Squares	Mean Sum of Squares	F-Value	P-Value	Percentage
A	2	0.064	0.032	40.19	0.024	45
B	2	0.032	0.016	20.25	0.047	22
C	2	0.043	0.021	26.85	0.036	30
Error	2	0.001	0.008			1
total	8	0.142				

From the table 9, it can be concluded that the tool rotational speed has a contribution of 45% and followed feed 22% and pin shoulder diameter 30%.

Table 10: Shows Response Table for Toughness

Level	Speed (N) (RPM)	Feed(F) (mm/min)	Pin Shoulder diameter (D) (mm)
1	5.398	6.425	6.171
2	4.496	5.809	4.425
3	7.001	4.661	6.299
Delta	2.505	1.763	1.874
Rank	1	3	2

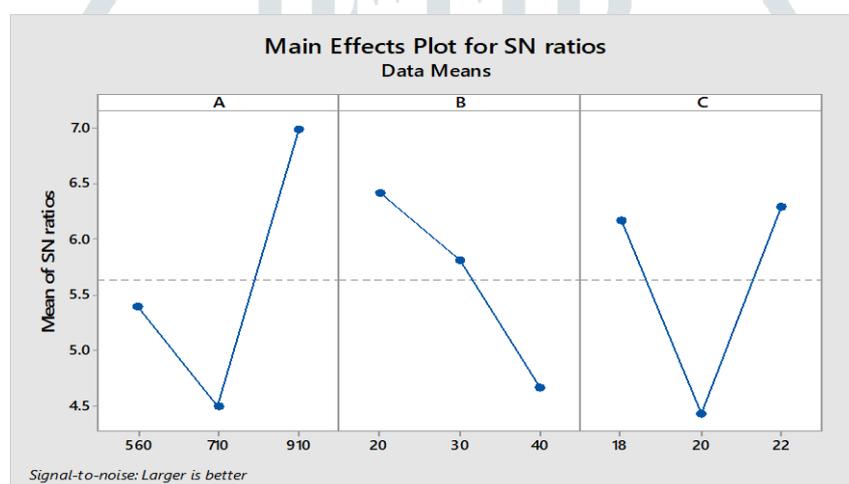


Figure13: Signal To Noise Ratios Response Table For **Toughness**

From the table 10 and figure 12, it can be calculated that tool rotational speed of 910rpm, welding speed of 20 mm/min and tool pin shoulder diameter of 22 mm is the optimum welding condition to get good toughness.

5. CONCLUSIONS

- The butt joining of Aluminium alloy was successfully carried out using FSW. The samples were characterized by mechanical properties like tensile strength, hardness and toughness.
- The optimum Operating conditions of FSW have been obtained for two plates of aluminium alloy AA6082 and AA7175 welded in butt joint.
- The parameters like Speed, Feed and Pin shoulder diameter are optimized by using Taguchi method for mechanical behavior of Hardness, Toughness and Tensile.
- From the obtained results, the major parameter effecting the Hardness is pin shoulder diameter 18 mm followed by feed 560 rpm and then speed 20 mm .
- From the obtained results, the major parameter effecting the Toughness is pin shoulder diameter 22mm followed by speed 910 rpm and then feed 20mm.

- From the obtained results, the major parameter effecting the Tensile strength is speed 710 mm followed by feed 20 mm and then pin shoulder diameter 22 mm.
- From the ANOVA ANALISIS major parameter effecting the Hardness is speed followed 78% by feed 10% and then pin shoulder diameter 10%.
- From the ANOVA ANALISIS major parameter effecting the Toughness is speed 45% followed by pin shoulder diameter 30% and then feed 22%.
- From the ANOVA ANALISIS major parameter effecting the Tensile strength is pin shoulder diameter -23.06% followed by feed -17.41% and then speed -16.40%.

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