

Optimization of Friction Stir Welding Process Parameters of AA6063 and AA6082

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Abstract— In this paper two dissimilar metals AA6063 and AA6082 Aluminium alloys having 6mm thickness were joined using friction stir welding. Process parameters were optimized using Taguchi L9 approach. Three different tool pin profiles (taper, square & threaded pin) were employed with three different welding speeds (30, 50 & 70 mm/min) and three different tool rotation speeds (1100, 1400 & 1700 rpm) to analyze their effect on the mechanical properties. Effect of tool pin profile, tool rotation speed and welding speed on various mechanical properties were investigated (tensile strength, Vickers hardness and impact strength).

Key words: Friction stir welding, process parameters, Taguchi L9 approach

welding process in which the frictional heat produced by the rotating tool is utilized to create a weld joint. Now those metals are now can be joined easily which are difficult to join in the past. Aluminium alloys, AA6063 and AA6082 having plate thickness 6 mm are welded using friction stir welding. So much work has been done in the past on different aluminium alloys but no work has been done AA6063 and AA6082. Previous work study shows that the optimum process parameters for welding the dissimilar aluminium alloys are tool rotation speed 1100-1700 Rpm, welding speed 30-70 mm/min and tool pin profile. Tool pin profile has an important role in welding of dissimilar metals. Tool with different pin profiles are widely used. Tool pins with taper, threaded and square profile are very much efficient to transfer the metal from one side to another side due to its shoulder and stirring action. Chemical composition of the base metals which is considered in research work is indicated in table 1.

I. INTRODUCTION

A new solid state joining method known as friction stir welding is emerging as a new technique for the joining of two dissimilar metals. Friction stir welding is a solid state

Weight%	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al	Other Each	Others Total
6063	0.2-0.6	0.35	0.10	0.10	0.45-0.90	0.10	0.10	0.10	Bal	0.05	0.15
6082	0.7-1.3	0.50	0.10	0.40-1.0	0.60-1.20	0.25	0.20	0.10	Bal	0.05	0.15

Table: 1 Chemical composition of AA6063 & AA6082

II. EXPERIMENTAL PROCEDURE

AA6063 and AA6082 plates having 6mm thickness are used in the experimental work and their chemical compositions are shown above in Table 1. Samples of rectangular shape were cut from the plates into size of 100 x 50 mm and then friction stir welding was done using CNC vertical milling machine. The welding tool used in the experimental work is made of High Speed Steel-H60. Different types of tool pin profiles were used in the work which includes taper pin, threaded pin and square pin as shown in Figure 1 to 3. Different process parameters used in the present work are given in Table. 2. AA6082 was placed on the advancing side due to its higher mechanical properties. The tool pin is placed in center of joint line. To study the effects on tensile strength, Vickers hardness and impact strength of the weldment, the samples were made according to ASTM standards and tests were carried out. Taguchi L9 experimental design for the work is illustrated in Table 3.



Fig. 1: Taper Pin



Fig. 2: Square Pin



Fig. 3: Threaded Pin

	A	B	C
Parameters	Tool Pin Geometry	Tool Rotation Speed (RPM)	Work Table Feed (mm/min)
Level 1	Taper	1100	70
Level 2	Square	1400	50
Level 3	Threaded	1700	30

Table: 2 Parameters and their levels

Sr. No.	A Tool Pin Geometry	B Tool Rotation Speed (RPM)	C Work Table Feed (mm/min)	FSW Designation
1	Taper	1100	70	FSW-111
2	Taper	1400	50	FSW-122
3	Taper	1700	30	FSW-133
4	Square	1100	50	FSW-212
5	Square	1400	30	FSW-223
6	Square	1700	70	FSW-231
7	Threaded	1100	30	FSW-313
8	Threaded	1400	70	FSW-321
9	Threaded	1700	50	FSW-332

Table 3: Experiment Layout of Taguchi L9 Orthogonal Array

III. RESULTS AND DISCUSSION

In this section, we are discussing the effect of FSW process parameters (tool pin profile, welding speed and tool rotation speed) on the basis of response characteristics (impact strength, tensile strength and Vickers hardness). The average value of mean data response characteristics and S/N ratio for each parameter and at all levels is calculated from table 4, table 6 & table 8. MINITAB 16 SOFTWARE is used to plot these effects.

A. Tensile Strength:

Average value of tensile strength is calculated from raw data is 149.72 MPa. It is verified from the S/N plots that the maximum Signal to Noise ratio occurs corresponds to A2, B3, and C1. Therefore, the optimum value will correspond to these factors but only the significant factor will be chosen. ANOVA table will be selected for these factors.

LEVEL NO.	TOOL PIN PROFILE	TOOL ROTATIONAL SPEED (RPM)	TOOL FEED RATE (MM/MIN)
1	36.11	39.41	40.89
2	42.25	40.32	38.81
3	41.74	40.38	40.41
DELTA	6.14	0.98	2.08
RANK	1	3	2

Table 4: Response table for S/N ratio (Larger is better)

LEVEL NO.	TOOL PIN PROFILE	TOOL ROTATIONAL SPEED (RPM)	TOOL FEED RATE (MM/MIN)
1	64.14	96.03	116.63
2	133.60	111.14	90.54
3	122.27	112.83	112.83
DELTA	69.46	16.80	26.09
RANK	1	3	2

Table 5 Response table for mean

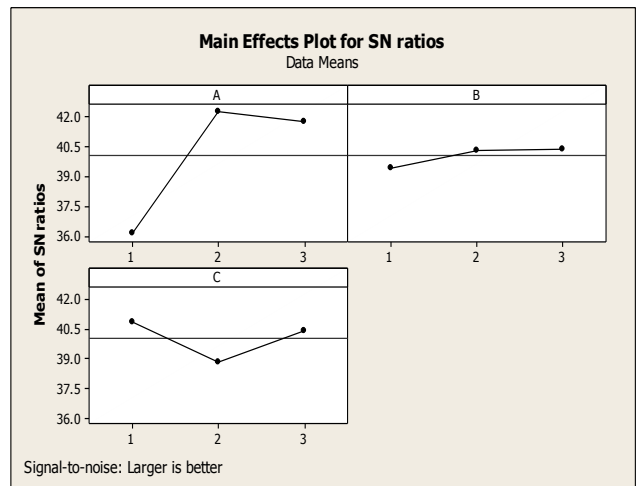


Fig. 4: Main effects plot for S/N ratio (Tensile strength)

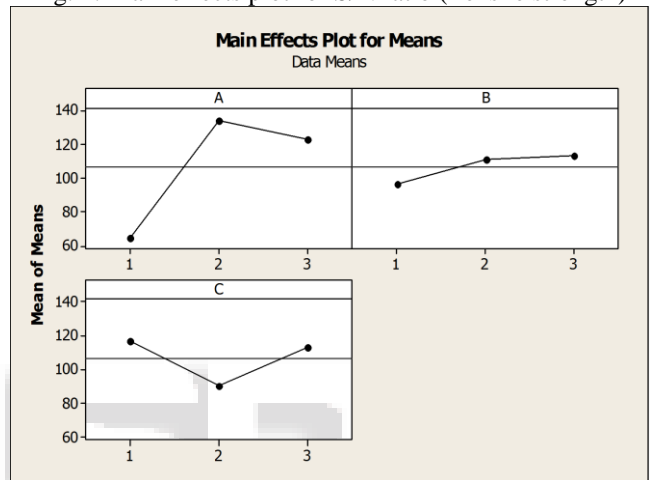


Fig. 5: Main effects plot for Means (Tensile strength)

B. Vickers Hardness:

Average value of Vickers hardness is calculated from raw data is 62.21. It is verified from the S/N plots that the maximum Signal to Noise ratio occurs corresponds to A3, B3 and C2. Therefore, the optimum value will correspond to these factors but only the significant factor will be chosen. ANOVA table will be selected for these factors.

LEVEL NO.	TOOL PIN PROFILE	TOOL ROTATIONAL SPEED (RPM)	TOOL FEED RATE (MM/MIN)
1	34.35	34.93	34.84
2	34.62	34.55	35.00
3	35.56	35.05	34.69
DELTA	1.22	0.49	0.31
RANK	1	2	3

Table 6: Response table for S/N ratio (Larger is better)

LEVEL NO.	TOOL PIN PROFILE	TOOL ROTATIONAL SPEED (RPM)	TOOL FEED RATE (MM/MIN)
1	52.17	55.94	55.34
2	53.92	53.56	56.30
3	60.03	56.62	54.48
DELTA	7.87	3.07	1.82
RANK	1	2	3

Table 7: Response table for mean

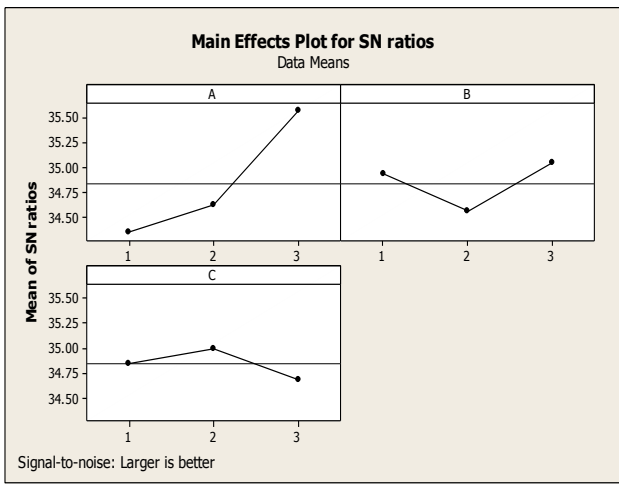


Fig. 6: Main effects plot for S/N ratio (Vickers Hardness)

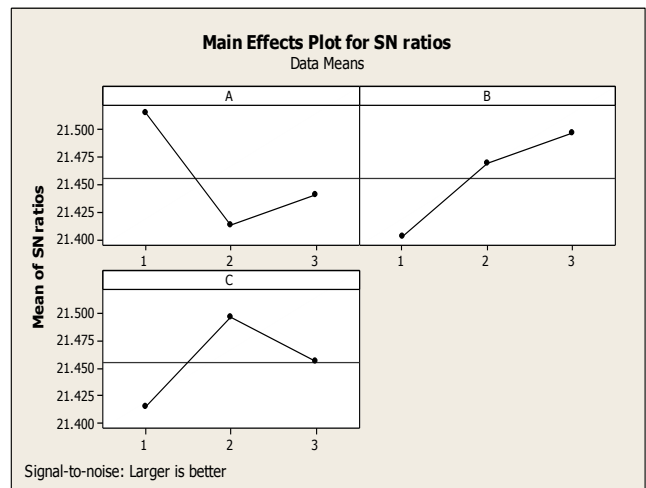


Fig. 8: Main effects plot for S/N ratio (Impact strength)

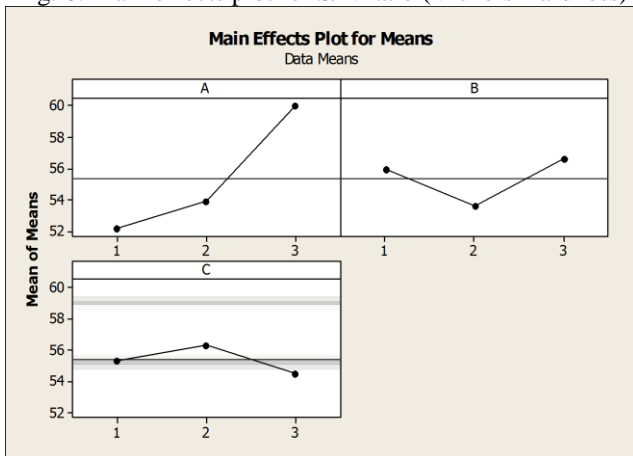


Fig. 7: Main effects plot for Means (Vickers Hardness)

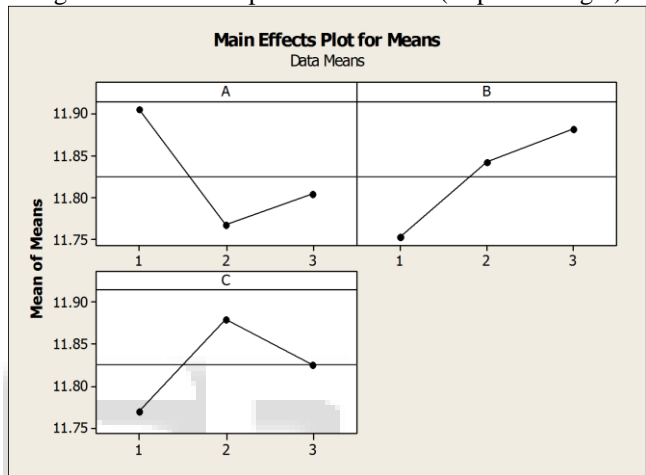


Fig. 9: Main effects plot for Means (Impact strength)

C. Impact Strength:

Average value of impact strength is calculated from raw data is 12.01 J/mm². It is verified from the S/N plots that the maximum Signal to Noise ratio occurs corresponds to A1, B3 and C2. Therefore, the optimum value will correspond to these factors but only the significant factor will be chosen. ANOVA table will be selected for these factors.

LEVEL NO.	TOOL PIN PROFILE	TOOL ROTATIONAL SPEED (RPM)	TOOL FEED RATE (MM/MIN)
1	21.51	21.40	21.42
2	21.41	21.47	21.50
3	21.44	21.50	21.46
DELTA	0.10	0.09	0.08
RANK	1	2	3

Table 8: Response table for S/N ratio (Larger is better)

LEVEL NO.	TOOL PIN PROFILE	TOOL ROTATIONAL SPEED (RPM)	TOOL FEED RATE (MM/MIN)
1	11.91	11.75	11.77
2	11.77	11.84	11.88
3	11.80	11.88	11.83
DELTA	0.14	0.13	0.11
RANK	1	2	3

Table 9: Response table for mean

IV. CONCLUSION

It is conducted for the tensile strength, impact strength and Vickers hardness. The experimental values obtained at the optimal setting of parameter are:

- Tensile strength = 153.76 MPa
- Vickers hardness = 59.42 HV
- Impact strength = 12.37 J/mm².

V. RESULT

- 1) Tensile strength is mostly affected by tool tip.
- 2) Hardness is mostly affected by tool tip.
- 3) Impact strength is mostly affected by tool tip and tool rotation speed.

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