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Research paper



Hardness of Welded Al 6082 and Al 8011 Plates by Controlling Tilt Angle of Tool in FSW

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Abstract

In this study, aluminum alloy 6082 and 8011 were welded using friction stir welding technique on vertical milling machine. Tool speed, Tool shape and tilt angle of tool are considered as input parameters. In the present study, hardness test was carried out to identify the surface property of welded joint, while bend test was carried out to find out bend behaviour of welded samples. Taguchi design with L_9 orthogonal array was employed to obtain optimum input parameters for better hardness. Hardness for Al6082-Al8011 joint is better for triangular tool shape and minimum rpm i.e. 560 rpm as the smoothness of tool and tool rpm increases there is decrement in the hardness. While, hardness for Al6082-Al8011 joint is better for triangular tool shape and 0^0 tilt angle as the tool smoothen and the tilt angle increases the hardness decreases.

Keywords: *FSW; Tool speed; Tool shape; tilt angle; L_9 orthogonal array; Bend Test*

1. Introduction

Aluminium is one of the most challenging materials in welding. In traditional welding, aluminium produces lots of burn gases which produce defects inside the weld material. Friction stir welding is a solid state welding process. In this process, materials are welded in solid state. While, in fusion welding process, materials are welded in mushy zone. There are various advantages of friction stir welding over fusion welding.

In fusion welding, aluminium is one of the most challenging materials during welding. Friction stir welding is solid state welding, which easily weld aluminium plates as its melting temperature is lower than iron. Usually, during the friction stir welding, two main phases are observed. One is the heat affected zone (HAZ), second one is the TMAZ. TMAZ is produced near the HAZ. TMAZ and HAZ are the one of the most responsible phases in enhancing the mechanical behaviour of welded zone portion.

It was observed from the literature that tilt angle is one of the most important factors in friction stir welding process. Keeping these fact in the mind tilt angle was also optimized by considering other parameters such as tool speed and tool shape.

2. Materials and Methods

2.1. Selection of Materials

In this study, Aluminium alloy 6082 and 8011 were taken as base material for welding via friction stir technique on milling machine. Controlling parameters of FSW is shown in Table 1.

2.2. Friction Stir Welding Process

Friction stir welding technique was used to weld aluminium alloy 6082 and 8011. Tool speed, tool shape and cutting fluid are considered as input parameters. Vertical milling machine was used to weld the plates. Input parameters and their ranges are shown in Table 1.

Table 1: Control factors of the experiment

Parameters	Level 1	Level 2	Level 3
Tool speed	560	920	1460
Tool shape	Triangular	Square	Circular
Tilt Angle	0	2	4

2.3. Taguchi's Technique

In this study, Taguchi technique was used to obtain the optimum combination of tool parameters of friction stir welding. L_9 Orthogonal array was used to identify the process parameters effect on hardness of welded portion. Usually, hardness of welded part must be higher than parent metal. In this study, tool speed of FSW was kept in the range of 560 RPM to 1460 RPM. Three different tool shape (square, triangular, circular) were considered for friction stir welding. In the same way, zero degree, 2 degree and 4 degree were taken tilt angle in FSW process

Table 2: L_9 Orthogonal Array Table

Exp. Run	A: Tool Shape	B: Tool Speed (RPM)	C: Tilt Angle (Degree)
1	Triangular	560	0
2	Triangular	920	2
3	Triangular	1460	4
4	Square	560	2

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5	Square	920	0
6	Square	1460	4
7	Circular	560	4
8	Circular	920	2
9	Circular	1460	0

Table 3: Hardness table for Al6082-Al8011

Experimental Run	Sample 1	Sample 2	Sample 3	Average
1	76	75	74	74
2	67	64	63	64.67
3	70	70	69	69.66
4	59	59	58	58.66
5	70	69	68	69
6	60	59	59	59.33
7	48	47	46	47
8	59	59	58	58.66
9	46	45	44	45

3. Results and Discussion

It can be observed that hardness forAl6082-Al8011 joint is better for triangular tool shape and minimum rpm i.e. 560 rpm as the smoothness of tool and tool rpm increases there is decrement in the hardness. The hardness for Al6082-Al8011 joint is better for minimum tool rotational speed i.e. 560 rpm and 0^0 tilt angle as the tool speed and tilt angle increases and the hardness decreases. Hardness forAl6082-Al8011 joint is better for triangular tool shape and 0^0 tilt angle as the tool smoothen and the tilt angle increases the hardness decreases.

Table 4: Analysis of Variance for Hardness Al6082-Al8011

Source	Degree of freedom	Sum of squares	Mean sum of squares	F value	P value
A	2	12.830	6.4150	9.62	0.094
B	2	1.441	0.7205	1.08	0.481
C	2	2.475	1.2374	1.86	0.350
Residual Error	2	1.334	0.6669		
Total	8	18.08			

Main effect plots for hardness of welded 6082-8011 alloy were shown Figure 1 and Figure 2 respectively.

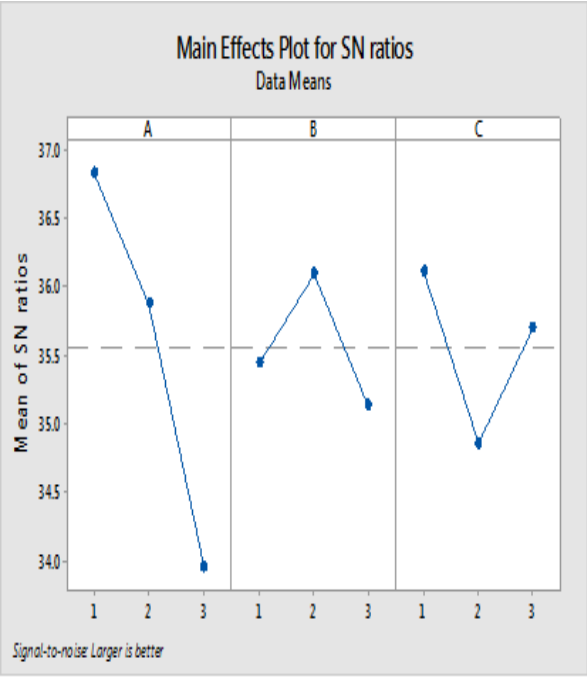


Fig.1: Main effect plot for S/N ratios

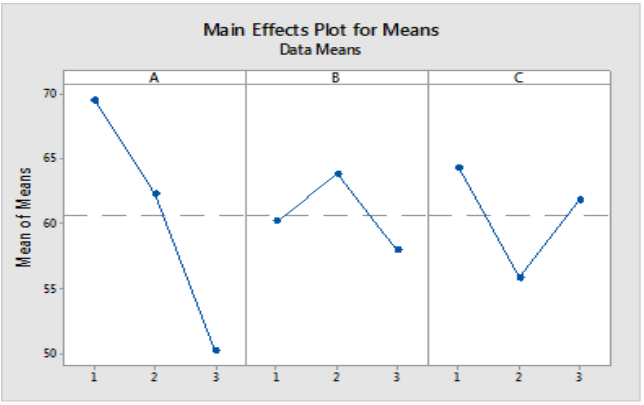


Fig.2: Main effect plot for Means

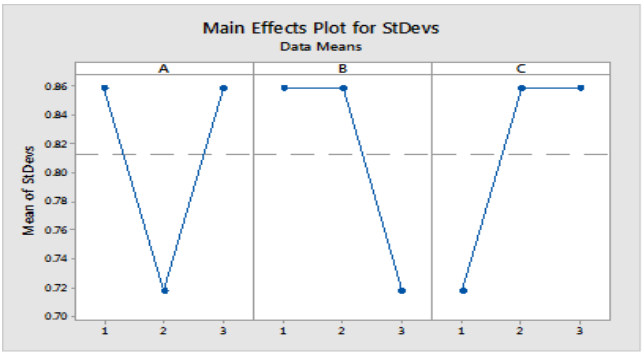


Fig.3: Main effect plot for Standard Deviation

Contour plot of parameters for hardness were shown in Figure 4, Figure 5 and Figure 6.

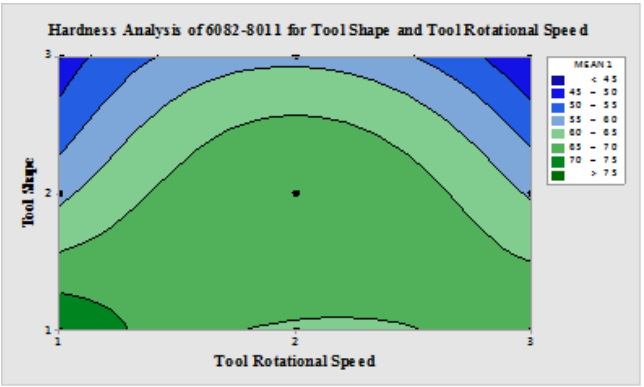


Fig. 4: Hardness Analysis of Al6082-Al8011 for Tool Shape and Tool Rotational Speed

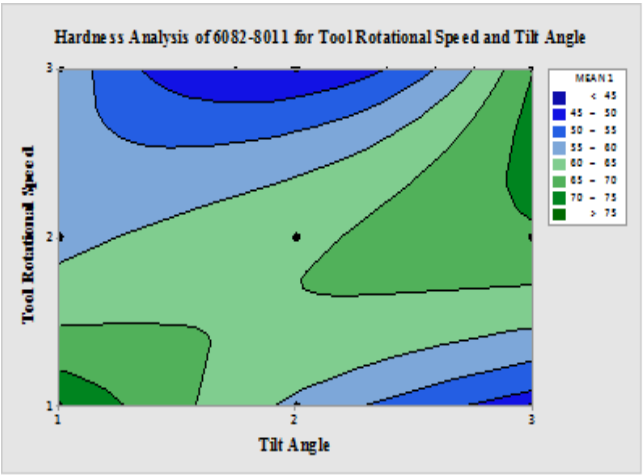


Fig. 5: Hardness Analysis of Al6082-Al8011 for Tool Rotational Speed and Tilt Angle

Predicted value of hardness for welded joint between (Al6063-Al8011) is:

$\mu^{\hat{}}{}_{1,2,3}$ = H+ (A_1-H) (B and C are insignificant)

=60.77+ (69-60.77)

=60.77+8.222

=69

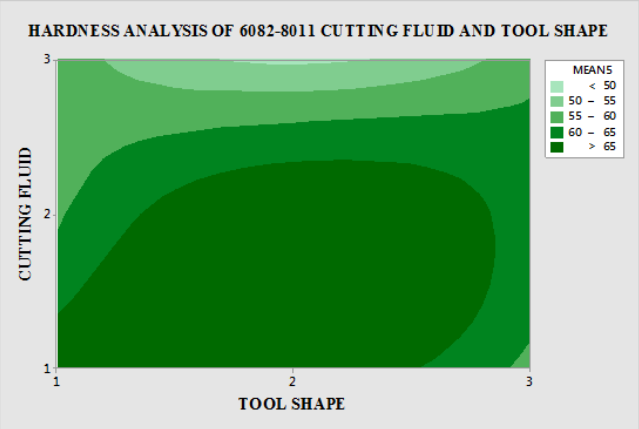


Fig. 6: Hardness Analysis of Al6082-Al8011 for Tool Shape and Tilt Angle

4. Conclusions

Aluminium alloy 6082 and 8011 were successfully welded through the friction stir welding technique. Friction stir process was carried out on vertical milling machine. Tool speed, Tool shape and tilt angle are considered as controlling input parameters. Hardness (6082-8011) is better for better for minimum tool rotational speed i.e. 560 rpm and 0^0 tilt angle

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