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Research paper

Effects of Friction Stir Welding Parameters on Hardness of Welded Al 6082 and Al 8011 Plates

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Abstract

Aluminum alloy 6082 and 8011 were welded using friction stir welding technique on milling machine. Tool speed, Tool shape and Cutting fluid are considered as input parameters, while hardness of weld samples was considered as response. Taguchi design with L_9 orthogonal array was employed to obtain optimum input parameters for better hardness. Hardness (6082-8011) is better for brine solution and kerosene with minimum and maximum tool speed and least for lubricant oil at any tool speed. Hardness (6082-8011) is better for kerosene and brine solution with square and triangular tool shape but least for lubricant oil with triangular tool shape.

Keywords: *FSW; Tool speed; Tool shape; Cutting fluid; L_9 orthogonal array.*

1. Introduction

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 the friction welding technique, very few amount of porosity is developed inside the heat affected zone. 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.
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.
From the literature it was observed that very few researchers welded Aluminum alloy 6082 and 8011 via friction stir welding process. Keeping these facts in the mind, aluminium alloy 6082 and 8011 alloy were welded by controlling the parameters tool speed, tool shape and cutting fluid using L_9 orthogonal array by considering hardness as response

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	920	1460	2260
Tool shape	Square	Triangular	Circular
Cutting fluid	Kerosene	Brine solution	Lubricant oil

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 920 RPM to 2260 RPM. Three different tool shape (square, triangular, circular) were considered for friction stir welding. In the same way, kerosene, brine solution and lubricant oil were taken as cutting fluid in FSW process.

Table 2: L_9 Orthogonal Array Table

S.No	Tool Shape	Tool Speed	Cutting Fluid
1.	Square	920	Brine Solution
2.	Square	1460	Kerosene
3.	Square	2260	CO_2 Coolant
4.	Triangular	920	Kerosene
5.	Triangular	1460	CO_2 Coolant
6.	Triangular	2260	Brine Solution
7.	Circular	920	CO_2 Coolant
8.	Circular	1460	Brine Solution

9.	Circular	2260	Kerosene

Table 3: Hardness table for Al6082-Al8011

S.No	Hardness 1	Hardness 2	Hardness 3	Average
1	69	70	70	69.66
2	55	57	58	55.66
3	62	61	63	62
4	67	66	66	66.33
5	60	61	60	60.33
6	68	68	70	68.66
7	71	72	71	71.33
8	60	61	60	60.33
9	63	62	63	62.66

3. Results and Discussion

Hardness (6082-8011) is better for minimum and maximum rotational tool speed (i.e. 920rpm & 2260rpm) and least for 1460rpm with any tool shape. Hardness (6082-8011) is better for brine solution and kerosene with minimum and maximum tool speed and least for lubricant oil at any tool speed. Hardness (6082-8011) is better for kerosene and brine solution with square and triangular tool shape but least for lubricant oil with triangular tool shape.

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	0.1968	0.09839	1.26	0.443
B	2	2.7808	1.39039	17.77	0.053
C	2	0.5305	0.26523	3.39	0.228
RESIDUAL ERROR	2	0.1565	0.07824		
TOTAL	8	3.6645			

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

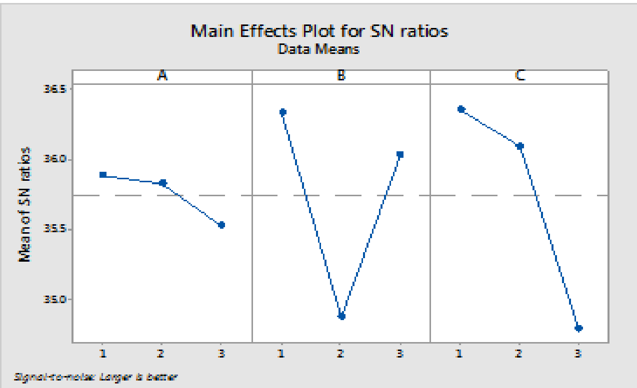

Fig.1: Main effect plot for S/N ratios

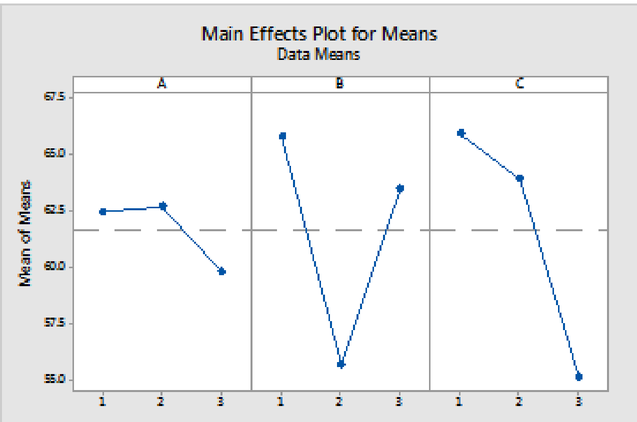

Fig.2: Main effect plot for Means

Contour plot of parameters for hardness were shown in Figure 3, Figure 4 and Figure 5.

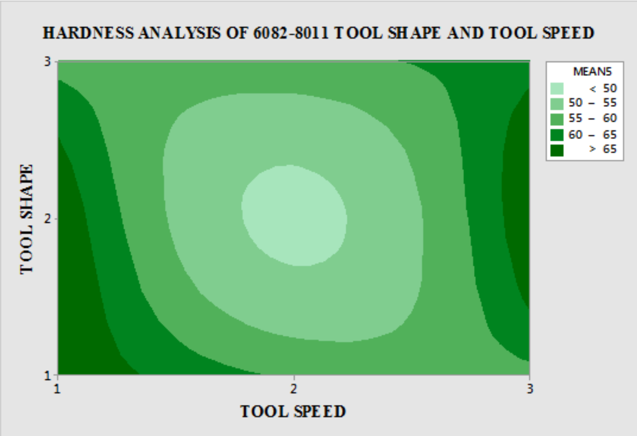

Fig. 3: Contour curves of tool shape and tool speed

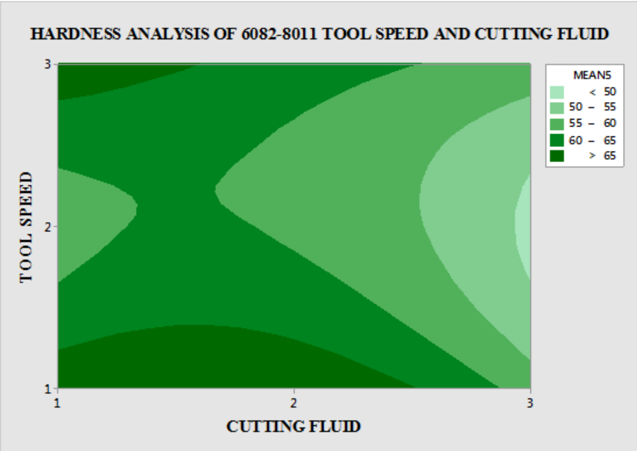

Fig. 4: Contour curves of tool speed and cutting fluid

Best combination of parameters for Hardness (6082-8011) is shown in sample no. 4 and the values are:

Tool shape (A_2): triangular

Tool rotational speed (B_1): 920 rpm

Cutting fluid (C_3): kerosene

Predicted value = $H + (A_2\text{-}H) + (B_1\text{-}H)+(C_3\text{-}H)$

H (average) = 62

A_2= Not significant

B_1= 66

C_3= Not significant

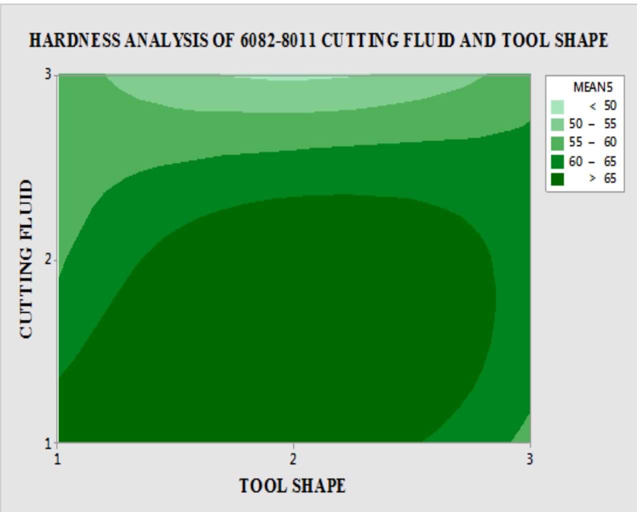

Fig. 5: Contour curves of cutting fluid and tool shape

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 Cutting fluid are considered as controlling input parameters. Hardness (6082-8011) is better for kerosene and brine solution with square and triangular tool shape but least for lubricant oil with triangular tool shape

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