MODELING AND OPTIMIZATION OF DIFFUSION BONDING PARAMETERS FOR ALUMINIUM AA6061 – SIC COMPOSITES USING RESPONSE SURFACE METHODOLOGY

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Abstract

The Diffusion Bonding (DB) process parameters play an important role in joining characteristics of similar and dissimilar metals. Response surface methodology (RSM) technique is used to predict Lap shear strength of the diffusion bonded Aluminium AA6061-SiC composites (ASC). The experiments were conducted based on three factors namely bonding temperature, bonding pressure and bonding time. Using RSM technique empirical relationship developed by utilizing the parameters such as bonding temperature, bonding pressure and bonding time on lap shear.

Keywords; Diffusion bonding, Aluminium Silicon carbide composites, Lap shear strength, ASC, RSM

I. INTRODUCTION

Aluminium reinforced Silicon carbide used for military, aerospace and manufacturing industries because of their high modulus, strength, wear and fatigue resistance (1). Diffusion bonding techniques useful for joining metals when the metals not possible to join the conventional welding methods and it join similar and dissimilar metals (2). The quality of a diffusion bonding depends on its lap shear strength, for getting the maximum strength, selection of the process parameter is essentially one. Many researchers proved through the various statistical methods to maximize the output variables. Among the various optimization methods RSM useful for analysis the performance characteristics effectively (3-5).In this study to predict lap shear strength of diffusion bonded Aluminium AA6061-SiC composites using response surface methodology.

II. MATERIALS AND EXPERIMENTAL PROCEDURE

AA6061 Aluminium alloy used in this study and its chemical composition is shown in Table 1. Reinforcement used in this study was silicon carbide and its mesh size. The Aluminium reinforced with silicon carbide (6%) prepared by stir casting process. The fabricated ASC composite samples (45mmX45mmX8mm) were joined by DB process and the machine setup shown in Figure1 .Experimental factor and their levels are presented in Table 2.

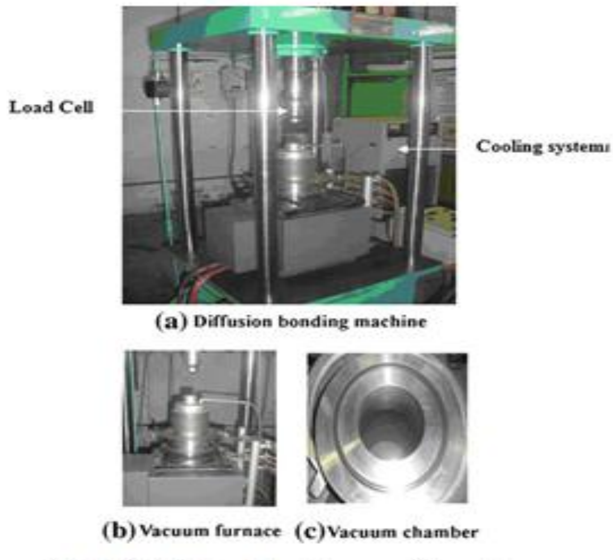

Fig.1. Diffusion Bonding machine setup

Table1. Chemical composition of Aluminium AA6061

Mg	Si	Fe	Mn	Cu	Ti	Cr	V	Al
0.9	0.68	0.18	0.03	0.22	0.01	0.09	0.01	Bal

Table.2. Process parameters and their levels

Parameters	Unit	Range	Notation	Level		
				1	2	3
Bonding temperature	ºC	450 - 500	A	450	475	500
Bonding pressure	MPa	10 – 14	B	10	12	14
Bonding time	Min	30 - 60	C	60	45	30

III. DESIGN OF EXPERIMENTS

In the present work bonding parameters viz. bonding temperature, bonding pressure and bonding time on lap shear strength of ASC bonded joints were evaluated. L27 orthogonal array was used with three process parameters and three levels and it was tabulated in Table 3.

IV. RESPONSE OF THE EXPERIMENT

Lab shear strength:

The lap shear strength of the diffusion bonded samples was measured by the Universal testing machine. In this analysis, Diffusion bonded joints were not enough of a standard test specimen. For that a non standard diffusion bonded test samples was used and its specimen diagram as shown in Fig 2.The optical micrographs of Experiment No 25. shows in Fig.3.

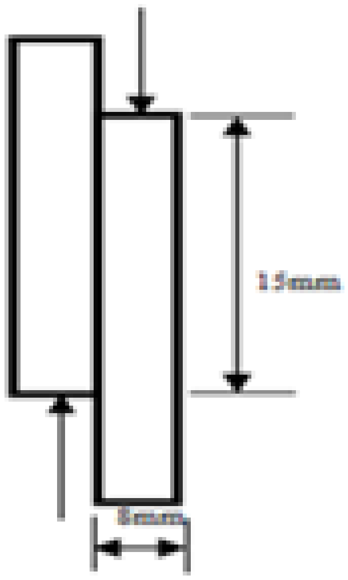

Fig 2 Lap shear test specimen diagram

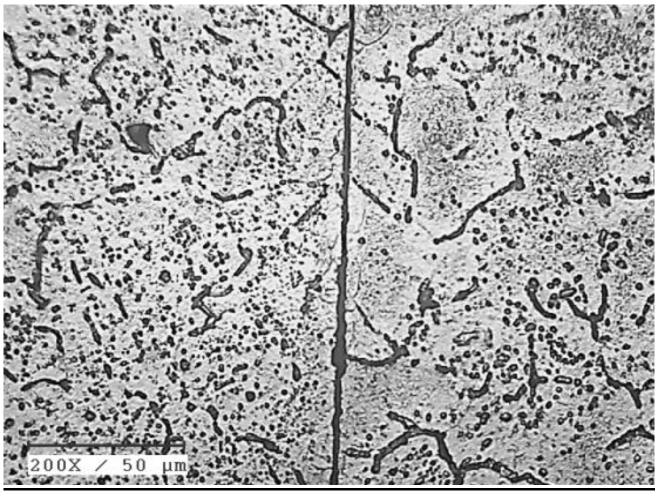

Fig 3. Optical micrographs of Experiment No 25

V. RESULTS AND DISCUSSION

Mathematical Model for lap shear strength

Response surface methodology is a combination of statistical and mathematical method to develop a response by the influence of input parameters and it is expressed as follows;

$$LS = -1174.1 + 4.690\,A + 17.50\,B - 0.293\,C - 0.004800\,A*A - 0.500\,B*B - 0.00015\,C*C - 0.01667\,A*B + 0.001053\,A*C - 0.0061\,B*C \quad (1)$$

ANOVA was used to examine the adequacy and the confidence interval of the mathematical model (6). In the ANOVA analysis F value is used to examine the adequacy of the mathematical model. Calculated F value is greater than F table value and satisfies 95% confidence levels which improve that this model is an adequate one. Table 4 shows Adequacy checking by ANOVA. The calculated R-squared (R^2) value is 96.23% and it indicated the goodness of fit the model. The actual and predicted value also shows less difference. Table 5 shows R-squared (R2) value.

Effect of process parameters on Lap shear strength

Among the various statistical methods desirability approach resolve the response problems effectively (6). It is simple, flexible and easily accessible in MINTAB 17.It has dimensionless number it between 0 to 1.The predicted optimal results from the desirability value on lap shear strength as 22.96MPa and the composite desirability values is 0.9953. Fig 4.shows the optimization plots.

Table3. Experimental data for Lap shear strength

S.NO	Bonding Temperature	Bonding Pressure	Bonding Time	Lap shear strength
1	450	8	45	18
2	450	8	30	16
3	450	8	20	15
4	450	9	45	19
5	450	9	30	17
6	450	9	20	16
7	450	10	45	20
8	450	10	30	18
9	450	10	20	17
10	475	8	45	22
11	475	8	30	21
12	475	8	20	18
13	475	9	45	23
14	475	9	30	21
15	475	9	20	20
16	475	10	45	22
17	475	10	30	20
18	475	10	20	19
19	500	8	45	20
20	500	8	30	17
21	500	8	20	16
22	500	9	45	21
23	500	9	30	18
24	500	9	20	16
25	500	10	45	20
26	500	10	30	18
27	500	10	20	16

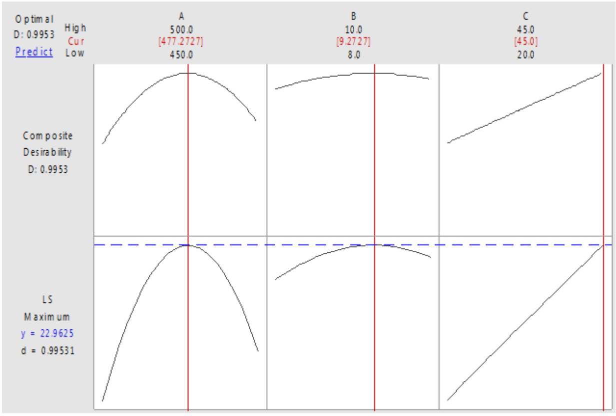

Fig 4. Optimization plot

In normal probability, data's are placed approximately in a straight line and it gives good correlation between the predicted and actual values and it shows in Fig 5. In residual versus predicted value shows minimal variation between them and it shows in Fig 6.

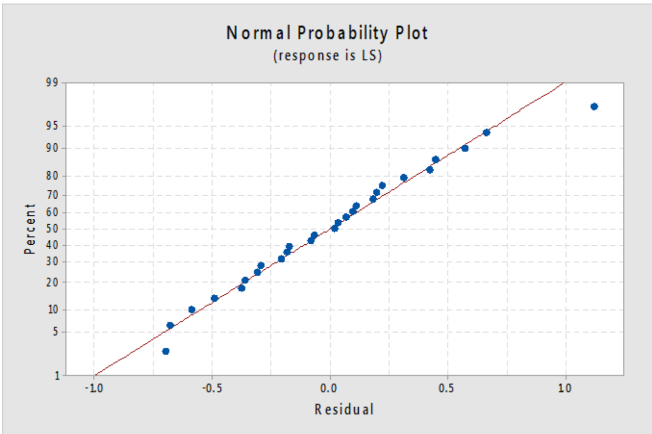

Fig 5. Normal Probability plot for lap shear strength

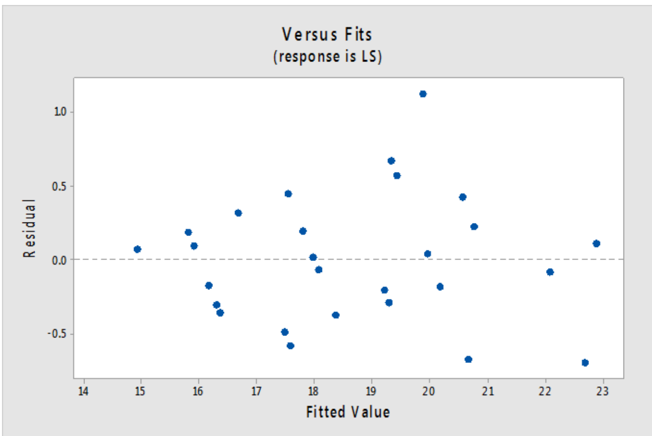

Fig.6. Residuals versus Fitted value for lap shear strength

Table 4. Adequacy checking (ANOVA)

Source of variation	Degree of freedom	Sum of squares	Mean sum of square	F – value (calculated)
Regression	9	121.249	13.4721	48.20
Residual error	17	4.751	0.2745	

Table 5. Tests on the three factors, square effects and their interactions for lap shear strength

Effect	Coefficient	t – value	Probability	R^2
constant	-1174	-13.93	0.000	96.23%
A	4.690	14.08	0.000	
B	17.50	3.60	0.002	
C	-0.293	-1.08	0.297	
A^2	-0.004800	-13.90	0.000	
B^2	-0.500	-2.73	0.033	
C^2	-0.00015	-0.10	0.920	
A*B	-0 01667	-2.73	0.014	
A*C	0.001053	2.17	0.044	
B*C	-0.0061	-0.51	0.619	

VI. CONCLUSIONS.

The optimum range of bonding parameters for high quality diffusion bonded joints of ASC composite has been achieved. RSM is used as a technique to optimize the diffusion bonded parameters to obtain the optimum lap shear strength. From these investigations, the following conclusions have been achieved. The relationship between the bonding parameters for diffusion bonding of ASC composites has been established using RSM technique and it was checked by the ANOVA test, Normality diagrams and scatter diagrams was found to be satisfactory.

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