Design Analysis and Effect of Process Parameters on 'Fsbw' of Al (2618a)-SIC Alloy

K. Nagamani, P.V. Sanjeeva kumar, S. M. Saleemuddin, N. Jayakrishna

Abstract: ***The research in fabrication engineering is much focused on the new or betterment in the existing metal joining techniques. In the view of the demand in improvement of the quality , strength and efficiency of welded joins , the present research is focused on design for tensile strength and optimization of friction stir butt welding(FSBW)of aluminum(2618A) and silicon carbide alloy. The design analysis is carried out for tensile strength and hardness. . The functioning parameters such as tool rotational speed, transverse speed, plunge depth and tilting angle are considered. The Taguichi technique and ANOVA are used in optimization of process parameters. The high S/N ratios are mainly considered to analyze the results for tensile strength and hardness.***

Keywords: FSBW, Taguchi Technique, S/N ratios, ANOVA

I. INTRODUCTION

The joining of materials is an unavoidable operation in fabrication of a product. The joints are either permanent or flexible based on the design functionality of a product. The friction stir welding (FSW) is one of the emerging joining techniques in the welding technology. The soft materials like aluminium, copper and their alloys are widely welded by FSW. In the present work an attempt is made on to join the butt parts of the aluminium and silicon carbide alloy by using the FSW. The aluminium and silicon carbide alloys are widely found in the fabrication of aircraft and naval structures because of their high strength to weight ratio and anti corrosion properties. Hongjun Li et.al [1]are investigated the effect of friction stir welding on the thermal efficiency of the joints. Naseer sadeghian et.al[2] are done an experimental investigations in order to optimization of FSW parameters. W.Yuwan and R.s. Mishra [3] are pursued the investigation on the friction stir spot welds to study the effect on tool design and process parameters. Yuri Hovanski et.al[4] are given a good novelistic information on friction stir welding .

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R.Nandan ,T.Debroy[5] are quoted the recent advances in the friction stir welding on the weldment structure and its properties. P.Xue et.al [6] are investigated the dissimilar Al-Cu joints in order to study the effect of process parameters of FSW. The various studies [6-10] are on friction stir welding in order to determine its tensile strength, hardness and effect of process parameters will help to investigate the present work. The present study deals with identification of friction welding parameters and its influence on joint strength. Analysis of Variance carried out to analyze the friction stir welding parameter's influence on the responses.

II. MATERIALS

A. Base material details

Aluminium Alloy (2618A) is an engineering material having high strength to weight ratio .It is made by the combination of copper and magnesium. The resultant combination possesses the rich machinability and corrosion resistance. It is majorly found in applications such as aerospace and naval structures. The Physical Properties of aluminium 2618A is shown in table 2.1.

Table 2.1: Physical properties of 2618A

Copper	Magnesium	Iron	Nickel	Silicon	Titanium	Aluminium
2.30 %	1.60%	1.1 %	1.0%	0.18%	0.07%	93.7%

B. Silicon carbide (SiC)

Silicon carbide is the unique combination of carbon and silicon. It is obtained by the chemical reaction of both sand and carbon at elevated temperatures. Due to its high abrasive property, it is used in manufacturing of grinding wheels.

III. METHODOLOGY

The two main process parameters seriously affect the weld quality of FSW are:

1. Tool design
2. Welding parameters

A. Tool design

The tool selection and its design are very important in the FSW. The quality of the weld and efficiency of the joint is mostly depends up on the tool design. The welding speed also depends on the tool design. The material selections in the tool design are influencing the tool strength, its toughness and wear resistance. The important tool geometrical parameters are selected as per the literature standard and are shown in the table 3.1

Table 3.1: Tool geometry

S NO	PARAMETER	RANGE	UNITS
1	Shoulder diameter	21	mm
2	Pin diameter	3-6	mm
3	Pin length	4.5	mm

B. Welding parameters

The most influencing parameters during the FSBW are tool rotational speed, welding speed, plunge depth and tool tilt angel.

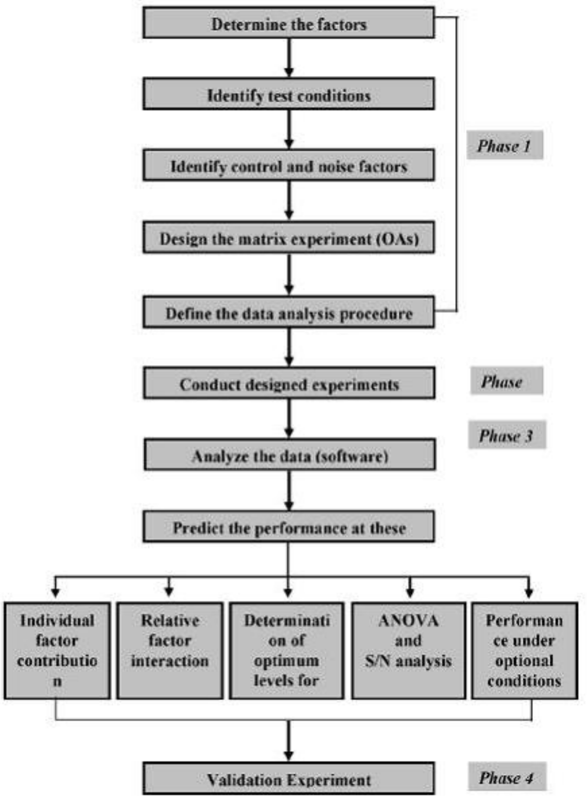
C. Execution of work

The present work is executed as follows:

- ❖ The vital process parameters are to be decided.
- ❖ Tool circular speed, welding speed and temperatures are to be executed with the specified limits.
- ❖ Generating the design matrix and perform the experiments as per the execution.
- ❖ Tabulate the responses for Tensile Strength (TS), Peak Load (LP), Hardness (HV)
- ❖ Compare the responds with the base metal.

D. Taguchi Methodology

The Taguchi is the most used technique in optimization of machining problems in research. The sequences of steps followed in this are given as in flow chart:



The process parameters and their levels, design levels for L9 array and the design of experiment are shown in respective tables 3.2, 3.3, & 3.4.

Table 3.2: Process Parameters and their levels

Process parameters	Range	Level 1	Level 2	Level 3
Tool Rotational Speed (N), rpm	700-1100	700	900	1100
Welding Speed(S), mm/min	16-25	16	20	25
Tool Tilt Angle (°)	1	1	1	1
Compositions (%)	50-100	2618A (Al_2O_3)	2618A (Al_2O_3+SiC)	2618A (SiC)

Table 3.3: Design Table (randomized)

Trail run no	1	2	3	4
1	-1	-1	-1	-1
2	-1	0	0	0
3	-1	1	1	1
4	0	-1	0	1
5	0	0	1	-1
6	0	1	-1	0
7	1	-1	1	0
8	1	0	-1	1
9	1	1	0	-1

Table 3.4: Design Matrix for Experiments

S. No	Rotational speed(rpm)	Traverse speed (mm/min)	Tilt angle (degrees)	Compositions added (%)
1	700	16	1	2618A(Al_2O_3)
2	700	20	1	2618A(SiC)
3	700	25	1	2618A(Al_2O_3+SiC)
4	900	16	1	2618A(SiC)
5	900	20	1	2618A(Al_2O_3+SiC)
6	900	25	1	2618A(Al_2O_3)
7	1100	16	1	2618A(Al_2O_3+SiC)
8	1100	20	1	2618A(Al_2O_3)
9	1100	25	1	2618A(SiC)

IV. EXPERIMENTAL WORK AND TESTING

Here the detailed information of Experimental set-up used in Present Work is discussed. The plates were cut to the required size by shearing. The plates were welded by using Friction Stir Welding process with 9 different level combinations of welding parameters. The welded plates are cut to the dimensions to suit tensile test and Hardness tests were performed accordingly. The main sequence of operations in the experimental work is given as:

- ➢ **Cutting and Job preparation:** The base metal sheets of dimensions 200mm x 100mm x 6mm was cut on shearing machine. The standards of specimen are considered in the FSW and as this the two 2618A of 6mm thickness plates (200mm x 100 mm) are prepared for the similar joint configuration.
- ➢ **Welding:** The tool has Threaded taper Pin with concave shoulder was used to fabricate the joints. The joint is obtained by holding the plates rigidly with clamps.

A. Friction Stir Butt Welding

In Friction Stir Welding, the two joining plates are butt each other and held rigidly in a fixture on the bed of the Vertical Milling machine. The tool is held in spindle of the milling machine and its pin to be penetrated in to the top of the joining pates at the junction. The tool to be rotated and slowly translated through the butt junction.

The friction is developed between the tool and work pieces hence the junction is gets heated to elevated temperature due to induced friction. The butt junction of plates to be melted to the plastic stage and both pieces to be gets in to weld. The federate of tool, its rotational and transverse speed are mainly influencing the quality of the weld and its mechanical properties.

The processing of joints and FSBW welded specimens are shown in figures 4.1&4.2.

Fig.4.1:Processing of the joint **Fig..4.2:FSBW welded specimens**

B. Tensile testing

The testing the butt joints to find the ultimate tensile strength is done with the Universal Testing Machine (UTM). The prepared specimens in to the size 20mm width and 200mm length are inserted in the grips of UTM and loading is to be followed until the specimens get failed after and the readings are recorded. The tensile properties of each weld were evaluated by a number of samples or tensile specimens cut from the different weld. The data obtained from the tensile test were tabulated and shown in table 4.1.

Table 4.1: Experimental Results of Ultimate tensile strength 2618A

Compositions Al_2O_3 and SIC (%)	Temperature (^{0}C)	Ultimate Tensile Load (KN)	Ultimate Tensile Strength (UTS) Mpa	S/N Ratio
2618A(Al_2O_3)	370	7.520	55.092	31.82
2618A(SiC)	371	10.520	88.560	38.94
2618A(Al_2O_3+SiC)	408	14.120	128.809	42.19
2618A(SiC)	422	10.480	78.761	37.92
2618A(Al_2O_3+SiC)	485	12.200	110.939	40.90
2618A(Al_2O_3)	422	7.680	65.362	36.30
2618A(Al_2O_3+SiC)	485	2.340	23.297	27.34
2618A(Al_2O_3)	426	11.440	86.990	38.78
2618A(SiC)	440	8.000	60.496	35.63

C. Hardness Testing

In the present work the hardness of the welded joint is determined by using the Brinell hardness tester. In this the test material is placed on elevating screw base, the screw is elevated upwards to make contact with the ball and set the pointer at red spot in dial for Brinell test then a load of 100kgf is applied. The duration of maximum load is for 10 to 15 seconds then released. The tested specimens after indentation kept under microscope and measure the size of indentation, and its average values are calculated and tabulated as shown in table 4.2

Table 4.2: Experimental Results of Hardness for 2618A

S.No	Temperature (^{0}C)	Compositions Al2O3 and SiC (%)	Hardness (BHN)	S/N Ratio
1	370	2618A (Al_2O_3)	53.6	31.8218
2	371	2618A (SiC)	69.6	38.9448
3	408	2618A (Al_2O_3+SiC)	59.3	42.1984
4	422	2618A (SiC)	58.4	37.9262
5	485	2618A (Al_2O_3+SiC)	80.8	40.9017
6	422	2618A (Al_2O_3)	72.8	36.3066
7	485	2618A (Al_2O_3+SiC)	75	27.3460
8	426	2618A (Al_2O_3)	64.6	38.7894
9	440	2618A (SiC)	60.4	35.6345

The Brinell hardness number is determined by the use of following relation

$$BHN=\frac{2P}{\pi D(D-\sqrt{D^2-d^2})}$$

Where: P = Applied Load; D = Diameter of ball; D = Mean diameter of impression

V. RESULTS & DISCUSSIONS

The friction stir butt welding is performed on the Al 2618A AMD SiC alloy under different process parameters such as tool rotational speed, welding speed, tool tilt angle. Taguchi Analysis is employed to optimize the Ultimate Tensile Load, Ultimate Tensile Strength and Hardness of the 2618A material for Friction Stir Butt Welding. Tables are presented for responses using Taguchi Analysis calculations.

A. Experimental results for Ultimate tensile strength for 2618A

The Ultimate tensile strength of each specimen is recorded and showed in table4.1.The values represents the results of the tensile tests conducted on Friction stir butt weld tensile specimens of 2618A. Through the usage of Minitab-18, the S/N ratio values are also evaluated. The S/N ratio values are used to determine the quality of weld. That means the weld which is having high S/N ratio value means it is good quality of a weld. The Minitab-18 is also used to plot the graphs like Main Effects of plot for means and S/N ratios for ultimate tensile strength. The Response Tables for Means and S/N ratios for Ultimate Tensile Strength are shown in tables 5.1 & 5.2 The response graphs for Means and S/N ratios for Ultimate Tensile Strength are shown in figures 5.1&5.2.The ultimate tensile strength is 128.809 MPa, determined at specimen weld gives nearer to base material strength is 440 MPa as compared to other specimen welds and its parameters are 700 rpm, 25 mm/min, and 2618A (AL_2O_3+SiC).The high S/N ratio value is 42.19, determined at specimen weld has good quality of weld, and its parameters are 900 rpm, 20 mm/min, 1 degree and 2618A(Al).

Table 5.1: Response Tables for Means

LEVEL	RS	WS	COMPOSITIONS
1	90.82	52.38	69.15
2	85.02	95.50	75.94

3	85.02	84.89	87.68
Delta	56.93	43.11	85.3
Rank	2	1	3

Table 5.2: Response Table for S/ N Ratios

LEVEL	RS	WS	COMPOSITIONS
1	38.66	33.36	36.64
2	38.33	39.55	37.50
3	33.92	38.05	36.82
Delta	4.73	6.18	0.86
Rank	2	1	3

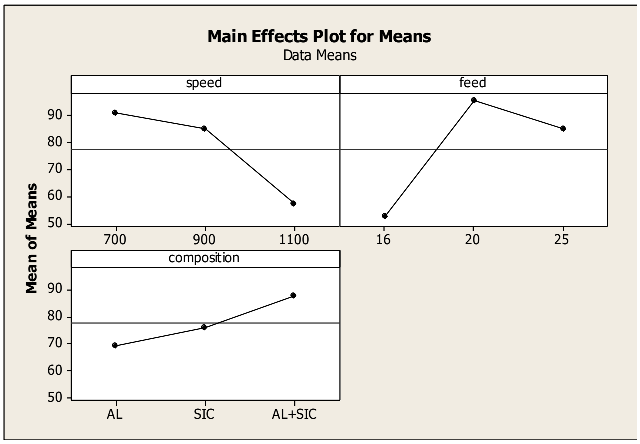


Fig 5.1: Graph of Means

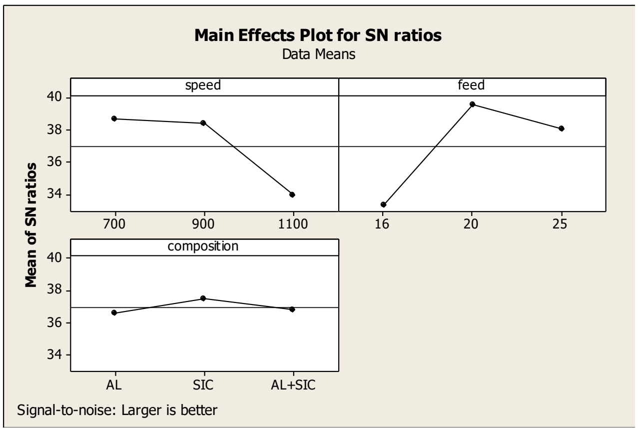


Fig 5.2: Graph of S/N ratios

From the Taguchi Analysis Table 5.1 and Table 5.2, the effect of parameters rank for Tool Rotational Speed (2), Welding Speed (1), and compositions (3)is obtained. From Fig 5.2 based on the highest values of the S/N ratio, the Mean Levels are the crucial factors for RS, WS and COMPOSITIONS the overall optimum condition thus obtained were 900 rpm, 20 mm/min10 and 2618A(Al2O3+SiC) respectively.

B. Experimental Results for Hardness for 2618A

The Hardness of each specimen is recorded and Presented in table 4.2.The values represents the results of the hardness tests conducted on Friction stir butt weld tensile specimens of 2618A. Through the usage of Minitab-18, the S/N ratio values are also evaluated. The S/N ratio values are used to determine the quality of weld. That means the weld which is having high S/N ratio value means it is good quality of a weld. The Minitab-18 is also used to plot the graphs like Main Effects of plot for S/N ratios.

The Response Tables for Means and S/N ratios for hardness are shown in tables 5.3&5.4 The response graphs for Means and S/N ratios for hardness are shown in figures 5.3&5.4The hardness of base material is 60.5 BHN is increased to 80.8 BHN at welded portion, determined at specimen weld no.5 and no.7 gives higher hardness as compared to other specimen welds and its parameters are 900 rpm, 20 mm/min, 1 degree and 2618A(Al_2O_3+SiC) and 1100 rpm, 16 mm/min, 1 degree and 2618A(Al_2O_3+SiC)respectively. The high S/N ratio value is 32.4443, determined at specimen weld no.5 and no.7 has good quality of weld.

Table 5.3: Response Tables for Means

LEVEL	RS	WS	COMPOSITIONS
1	60.83	62.33	63.67
2	70.53	71.53	62.80
3	66.67	64.17	71.57
Delta	9.7	9.2	8.77
Rank	1	2	3

Table 5.4: Response Tables for S/N Ratios

LEVEL	RS	WS	COMPOSITIONS
1	35.63	35.80	36.01
2	36.89	37.05	35.93
3	36.44	36.11	37.02
Delta	1.26	1.25	1.0
Rank	1	2	3

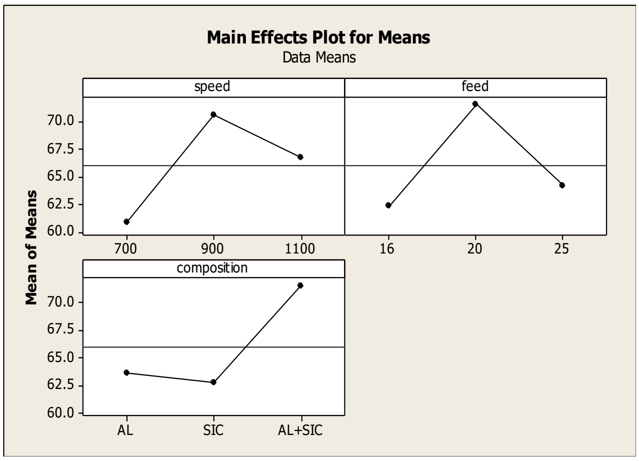


Fig. 5.3: Graph of Means

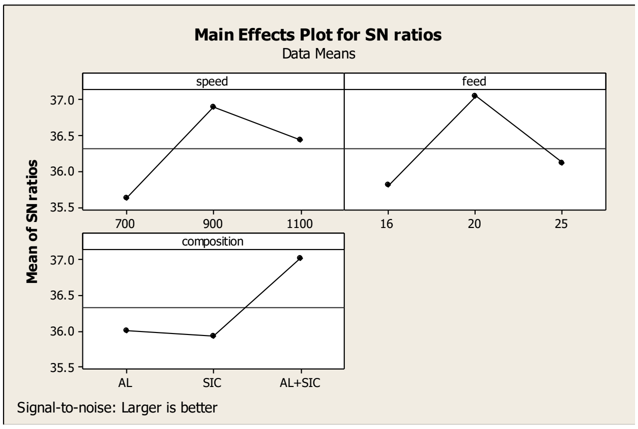


Fig. 5.4: Graph of S/N ratios

From the Taguchi Analysis Table 5.3 and Table 5.4, the effect of parameters rank for Tool Rotational Speed (1), Welding Speed (2) and compositions (3) is obtained. Since this analysis is a parameter based optimization design, from the above values it is clear that Tool Welding Speed is the Major Factor to be chosen effectively to obtain the high ultimate tensile strength. From Fig 5.4 considering the highest values of the S/N ratios , the Mean Levels are the crucial factors RS, WS and COMPOSITIONS the overall optimum condition thus obtained were 700 rpm 20 mm/min and 900 rpm, 20 mm/min, and 2618A(Al_2O_3+SiC) and 2618A(Al_2O_3) respectively.

VI. CONCLUSIONS

❖ From the results obtained for 2618A it can be concluded that

1) The ultimate tensile strength is 128.809 MPa, determined at specimen weld no.3 gives nearer to base material strength is 115.50 MPa as compared to other specimen welds and its parameters are 700 rpm, 25 mm/min, 1 degree and 2618A(Al2O3+SiC)
2) By increasing the Tool Rotational Speed, the Tensile Strength increases effectively and the same result will be observed from Welding Speed but when weld speed increases the Tensile Strength is fluctuates.
3) The hardness of base material is 60.5 BHN is increased to 80.8 BHN at welded portion, determined at specimen weld no.5 and no.7 gives higher hardness as compared to other specimen welds and its parameters are 900rpm, 20 mm/min, 1 degree and 2618A(Al2O3+SiC) and 1100 rpm, 16 mm/min, 1 degree and 2618A(Al2O3+SiC) respectively.
4) By increasing the Tool Rotational Speed the Hardness decreases, but the Hardness increases when Welding Speed increases.

❖ From the Taguchi for 2618A

1) From the main effect plot graph shown in Fig. 5.1 obtained from Taguchi, good Tensile Strength can be obtained at these optimum parameters i.e., 700 rpm, 25 mm/min 10 and 2618A(Al2O3+SiC) which is most significant and applicable value among all input parameters.
2) From the main effect plot graph shown in Fig. 5.3 obtained from Taguchi, higher Hardness can be obtained at these optimum parameters i.e., 900 rpm, 16 mm/min and 1100 rpm, 20 mm/min, 1o and 2618A(Al2O3+SiC)and 2618A(Al2O3+SiC), which is most significant and applicable value among all other parameters.

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