Optimization of Process parameters of Friction Stir Welding of Dissimilar Aluminium Alloys (AA6063-AA5052)

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Abstract - *Friction stir welding, a solid state joining technique, is widely being used for joining Al alloys. FSW is used to produce products with better mechanical properties. Nowadays aluminium alloys have been widely used in industrial applications such as aerospace and automobile due to their light weight, good mechanical properties and high corrosion resistance. In this work, three process parameters such as spindle speed, welding speed and plunge depth were considered for friction stir welding. Friction stir butt welding was carried out between dissimilar aluminium alloy plates (AA6063 and AA5052). The tensile strength of the welded joint was evaluated. The optimum level setting and the major parameters that influence the strength were obtained by taguchi method.*

Key Words*: *Friction Stir Welding, Spindle Speed, Welding Speed, Plunge Depth, Tensile Strength, etc

1. INTRODUCTION

Friction stir welding (FSW) is a solid state joining process, the joints are created by the combined action action of frictional heating and mechanical deformation using a special rotating tool. The rotation of the tool heats up and plasticizes the material it is in contact with and, as tool travels along the joint line, the material from the front of the tool is swept around the plasticized annulus to the rear, so eliminating the interface.

1.1 6063-T6 and 5052 H32 Aluminium Alloy Selection

6063-T6 aluminium alloy is a precipitation hardening aluminium alloy, containing magnesium and silicon as its major alloying elements. It has good mechanical properties and exhibits good weldability. It is one of the most common alloys of aluminium for general purpose use. It is a versatile heat treatable extruded alloy with medium to high strength capabilities.

5052-H32 Aluminium alloy contains nominally 2.5% magnesium & 0.25% chromium. It has good workability, medium static strength, high fatigue strength, good weldability, and very good corrosion resistance, especially in marine atmospheres. It also has the low density and excellent thermal conductivity common to all aluminium alloys.

1.2 Taguchi method

Taguchi techniques have been used widely for optimization and measuring the effect of various process parameters on their performance with minimum variation. The processing parameters have a major influence on the target properties. In the current study Taguchi approach has been carried out to optimize the process parameters on the tensile strength of weld bead. Taguchi recommends the use of S/N ratio to measure the quality characteristics deviating from the desired values. The S/N ratio for each level of process parameters is computed based on the S/N analysis

2. EXPERIMENTAL WORK

The Aluminium alloy plates (AA6063 and AA5052) have been cut into the required size (200×75×6mm) by power hacksaw cutting, butt joint was configured. Before welding the plates, side and edge preparation done to fabricate FSW joints. The experiments were conducted on a vertical milling machine where a tool is mounted in an arbor with a suitable collate (fig.1). The vertical tool head can be moved along the vertical guide way (Z-axis), the horizontal bed can be moved along X and Y axis.

Fig. 1: Experimental Setup describing clamping of FSW plate

Taguchi design with L9 orthogonal array which composed of 3 columns and 3 rows were employed to optimize the FSW parameters (table 1). The selected FSW parameters for this study were: spindle speed, welding speed, Plunge depth. The Taguchi method was applied to the experimental data and the signal to noise ratio (S/N) for each level of process parameters is measured based on the S/N analysis. Regardless of the category of the quality characteristic, a higher S/N ratio corresponds to a better quality characteristic.

A welding tool hexagonally faced including a shoulder and a pin with diameters of 18 mm and 5.5 mm, respectively, was made from HCCr steel. The tensile test samples were prepared in a perpendicular direction to the welding direction according to ASTM-E8-04 standard (Fig 1).

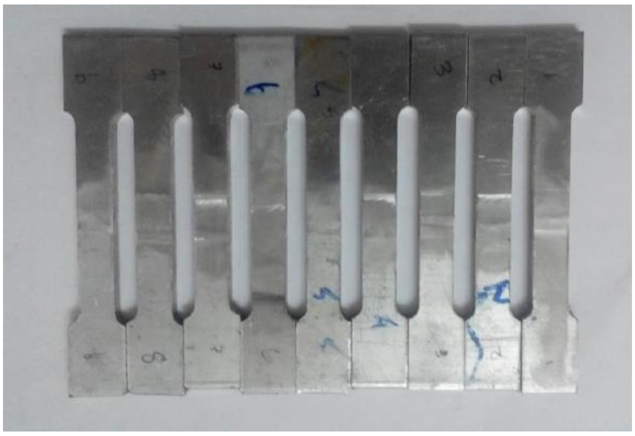

Figure 2: Tensile Specimen

Table -1: Factors and levels

Factors	Level 1"	Level 2	Level3
Spindle Speed (Rpm)	1800	1400	900
Welding Speed (mm/min)	135	100	65
Plunge Depth (mm)	0.2	0.15	0.1

3. RESULTS

3.1. Signal to Noise ratio analysis

In this study, tensile strength had been investigated as main parameter in order to achieve a joint with proper quality. Signal to noise analysis was used to minimize fluctuations in ultimate tensile strength values. Therefore final results of strength values were more applicable and comparable. Proper ratio of S/N was considered based on experiment, knowledge and perception of whole process. Purpose of this study was to achieve maximum tensile strength of joints for mentioned alloys. Therefore, the optimal level of the process parameters is the level with the highest S/N ratio and for "higher the better" quality characteristics the S/N ratio is calculated using the formula 1.

$$\frac{S}{N} = -\log\left(\frac{1}{n}\right)\left(\sum 1/y^2\right) \quad (1)$$

According to Table 2, 9 main values for tensile strength and 9 corresponding values of S/N (orthogonal array OA) were obtained. Optimal combination of factors and levels were obtained by analyzing each calculated main values, in order to achieve the maximum tensile strength.

Table- 2: Standard L9 orthogonal arrays as per Taguchi's suggestion.

Exp no.	Spindle speed (rpm)	Welding speed (mm/s)	Plunge Depth (mm)	Ultimate Tensile Strength (N/)	Percentage elongation
1	1800	135	0.2	56.869	1.720
2	1800	100	0.15	133.612	14.920
3	1800	65	0.1	87.986	3.780
4	1400	135	0.15	115.169	10.660
5	1400	100	0.1	122.713	13
6	1400	65	0.2	107.037	7.480
7	900	135	0.1	115.523	16.160
8	900	100	0.2	117.573	8.940
9	900	65	0.15	48.667	1.620

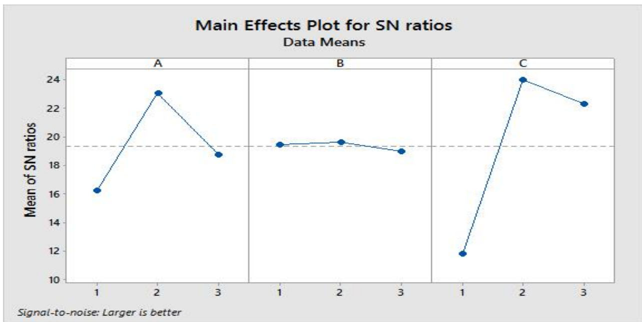

Chart.1: Main effects plot for S/N ratios

Table-3 : Main effect of tensile strength(S/N ratio)

Parameter	Level 1	Level 2	Level3	Delta	Rank
Spindle speed	16.23	23.08	18.77	6.84	2
Welding speed	19.45	19.62	19.01	0.61	3
Plunge Depth	11.79	23.99	22.30	12.20	1

Analysis of mean for experiments gives better combination of parameter levels. Means response refers to average value of performance characteristics for each parameter at different levels. Analyzing means and S/N ratio of various process parameters it is observed that a larger S/N ratio corresponds to better quality characteristics. Therefore, Effect of process parameter is level highest S/N ratio. Mean effect and S/N ratio Plunge depth calculated by minitab software indicated that Plunge depth was at maximum.

The optimum process parameter is found to be a combination of Spindle speed of 1400 rpm, welding speed of 100mm/min, and plunge depth of 0.15mm.

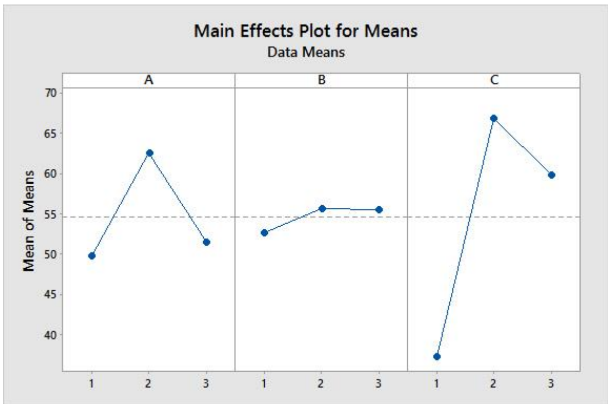

Chart 2: Main effects plot for means

Table 4 : Main effect of tensile strength (means)

Parameter	Level 1	Level 2	Level3	Delta	Rank
Spindle speed	49.82	62.59	51.41	12.77	2
Welding speed	62.59	55.67	55.46	2.97	3
Plunge Depth	37.23	66.82	59.77	29.58	1

4. CONCLUSIONS

The analysis presents effect of spindle speed, welding speed and plunge depth on weld quality. Tensile strength and yield strength of friction stir welded dissimilar aluminium alloy have been evaluated under different conditions using Taguchi experimental design.

Plunge Depth has found to be the most dominant parameter which affects tensile strength. The other parameters which influence the tensile strength in order of ranking are Spindle speed, Welding speed.

Optimum condition for high tensile strength are found to be Spindle speed= 1400 rpm, Welding speed =100mm/min, Plunge Depth= 0.15mm.

REFERENCES

[1] S. M. Bayazid, H. Farhangi A. Ghahramani 2015 , "Investigation of friction stir welding parameters of 6063-7075 Aluminium alloys by Taguchi method" 5th International Biennial Conference on Ultrafine Grained and Nanostructured Materials,UFGNSM15

[2] M. Koilraj , V. Sundareswaran , S. Vijayan, S.R. Koteswara Rao,2012 "Friction stir welding of dissimilar aluminium alloys AA2219 to AA5083 – Optimization of process parameters using Taguchi technique". Materials and Design 42 (2012) 1–7

[3] R. Palanivel, P. Koshy Mathews, I. Dinaharan, N. Murugan, 2014, "Mechanical and metallurgical properties of dissimilar friction stir welded AA5083-H111 and AA6351-T6 aluminium alloys"

[4] Ravikumar S, SeshagiriRao. V, Pranesh .R. V,2014 "Effect of welding parameters on Macro and Microstructure of friction stir welded dissimilar aluminium butt joints between AA7075-T651 and AA6061- T651 alloys."

[5] R.I. Rodriguez, J.B. Jordon, P.G. Allison, T.Rushing , L. Garcia,2015 " Microstructure and mechanical properties of dissimilar friction stir Welding of 6061-to-7050 aluminium alloys." Materials & Design 83 (2015) 60–65

[6] RajKumar.V, VenkateshKannan.M, Sadeesh.P 2014 ,"Studies on effect of tool design and welding parameters on the friction stir welding of dissimilar aluminium alloys AA 5052 – AA 6061". MRS Singapore - ICMAT Symposia Proceedings Advanced Structural and Functional Materials for Protection