



Friction stir welding (FSW) process on aluminum alloy 6082-T6 using taguchi technique

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Abstract

This study focused on the single response optimization of friction-stir-welding (FSW) process by using vertical milling machine on AA 6082-T6 for an optimal parametric combination to yield favorable ultimate tensile strength using the Taguchi techniques. To find the parametric effect of tool rotational speed, welding speed, tool shoulder diameter and tool pin's profile on ultimate tensile strength of weld joint of aluminum alloy 6082-T6 done by friction stir welding. The results found that the rotational speed of 1200 rpm, welding speed of 30mm/min and tool of cylindrical threaded pin profile with shoulder diameter of 16mm gives the maximum UTS.

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Keywords: Friction stir welding (FSW), Tool rotation speed (TRS), Welding speed (WS) .Green Technology

1. Introduction

Friction-stir-welding was developed by TWI in 1990. FSW is broadly used for joining aluminum alloys for aerospace, naval, automotive and many other applications in marketable field. In FSW the two metal plates are joined together by the mixing the material of both the plates with the help of frictional heat produced by a rotating cylindrical tool. In this study the four process parameters i.e. TRS (Tool rotation speed), WS (welding-Speed), Pin profile and shoulder diameter with four levels are used to join aluminum alloy 6082. Taguchi design of experimentation of OA L16 was used in this study to get optimized ultimate tensile strength (UTS).

1.1 Literature Review

M. Ericsson et al. [1] determined that the fatigue strength of AA 6082 welded by FSW is mostly affected by welding speed and this study consisting the comparison between FSW with TIG and MIG welding. J. Adamowski et al. [2] showed the results consisting of mechanical properties with microstructural changed done by FSW of AA 6082 and also finds the effect of variation of the process parameters on the mechanical properties of the joint. H. S. Patil et al. [3] investigated that welding speed and the different pin profiles effects the weld quality of the joint and the result also showed that Tri-flutes and taper screw thread pin were used in this study. The taper screw thread pin profile gives the

UTS of 92.30% of the base metal ultimate strength and %elongation of 27.58%. G. Raghu Babu et al. [4] investigated the effect of parameters on the weld quality and the microstructural study was also investigated. And the result showed that the process parameters affect the mechanical properties of the weld joint. A. Scialpi et al. [5] studied the effect of three different shoulder profiles scroll and fillet, cavity and fillet and only fillet on the joining of AA 6082 of thickness 1.5 mm by FSW. The response parameters used in study were visual inspection, microhardness, bending test, transverse and longitudinal tensile test. The investigation results showed that the best joint has been welded by a shoulder with fillet and cavity. Zhang et al. [6] joined the plate of AA 6061-T6 using FSW having tool of pin radius of 3mm and the shoulder radius of 7.5 mm. The welding plates were of 100*30*3 mm in length, width and thickness respectively. Kulekci et al. [7] made lap joints by FSW of AA 5754 plates by using a semi-automatic conventional milling machine. The AA 5754 plates were of thickness 3 mm, length 200 mm and width 100 mm. Raghu Babu et al. [8] performed friction stir welding on AA 6082 to analyze the effect of FSW processing parameters on mechanical properties of AA 6082 T6 weld joint. Bahemmat et al. [9] studied how the different process parameters in friction welding affect the welding quality of the different AA2024-T4 / AA7075-O. Rajakumar et al. [10] predicted the value of hardness and grain size of nugget region of friction stir welded AA-6061 weld joints. AA 6061 has huge applications in the production of light weight structures with good

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corrosion resistance and high strength/weight ratio. Liu et al. [11] carried out welding of aluminum 2219-T6 alloy using FSW and investigated effects of transverse speed on mechanical and micro structural properties. Ravindra [12] studied the effect of the tool rotation speed (rpm) and the tool probe profile on Friction Stir Processing in AA5083 of 2.5 mm thick. The experimentation was carried out using five different cylindrical, straight, square, triangular and conical pin profiles and using three tool rotation speeds that were 900, 1400 and 1800 rpm with a constant transverse speed of 16 mm / min. Yuvral et al.[13] investigate the effect of parameters and reinforcement of TiC nano particles of size 10-30nm . Shuhan et al. [14] made defect-free butt welds of titanium alloy with steel by FSW. Wwas done at TRS varied at 600 and 950 rpm with a constant weld speed of 47. mm/min. the result showed that increment in TRS increase the thickness of intermetallic compound layer. Wenya et. Al [15] improve the tensile properties of magnesium AZ31 joining by friction stir welding zone by using a stationary shoulder. Husain Mehdi et. al., [16-20], analyzed that the mechanical properties of FSW joint are mainly dependent on chemical composition and processing parameters of alloying element. The microstructural analysis of FSW joints shows the formation of new grain size in the weld zone with different amount of heat input by controlling the processing parameter.

2. Experimentation

The experiments were carried out on a universal vertical milling machine of table size 250 x 1350 mm with a speed range from 1200 to 4600 in four step pulley arrangement as shown in fig. 1.



Figure 1: Pictorial Front view of Universal Vertical Milling Machine

The tools used for this research were made of high carbon steel. The shoulder diameter and tool pin geometry is used as a parameters for welding AA6082-T6. The tool pin used during welding are cylindrical, cylindrical with threaded, Square, trapazoidal.the pin dia is 6mm in cylindercal tool pin, 6mm side in case od sqaure tool pin, and in trapezoidal 6mm side of base and tapered to 3mm at the tip.

The tools are made of max. dia them dia is reduce according to parameters requied by design of experiments.after manufacturing the tools the tip of the tool is annealed and oil quenched.All the four parameters have four levels and the design of experiment is designed by statically design given by Taguchi with OA of L16 shown in table 1. The after experiments the joined pieces made by sixteen trails are shown in fig.2. And the pieces extracted for ultimate tensile testing are shown in fig.3.



Figure 2: Plate after friction stir welding

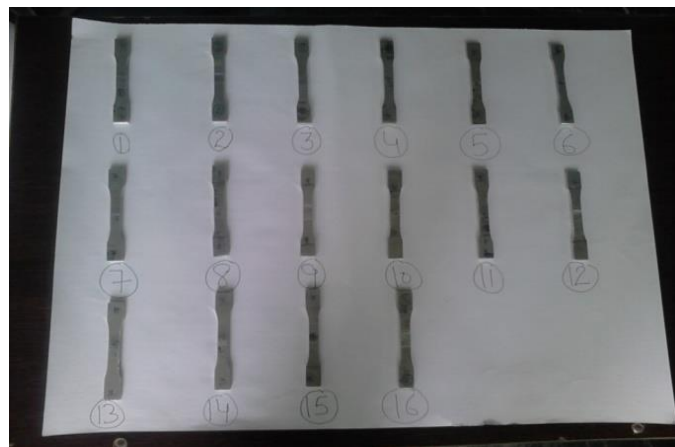


Figure 3: Specimen (16) for the UTS

The result of ultimate tensile strength obtained after testing are shown in table 1. The analysis for optimization of parameters is also done by Taguchi analysis procedure [14]. The values of S/N ratio obtained by analysis are also shown in table 1.

Table 1. Taguchi's L16 Standard OA for UTS

Experiment No.	Column				UTS (Mpa)	UTS S/N Ratio
	TRS (A)	WS (B)	Pin profile (C)	Shoulder dia. (D)		
1	1200	20	Cylindrical	14	228.42	47.1747
2	1200	25	Cylindrical-threaded	16	241.85	47.6709
3	1200	30	Square	18	244.86	47.7784
4	1200	35	Trapezoidal	20	240.08	47.6071
5	1950	20	Cylindrical-threaded	18	222.66	46.9528
6	1950	25	Cylindrical	20	225.98	47.0814
7	1950	30	Trapezoidal	14	239.45	47.5843
8	1950	35	Square	16	247.20	47.8610
9	3080	20	Square	20	209.24	46.4129
10	3080	25	Trapezoidal	18	221.94	46.9247
11	3080	30	Cylindrical	16	233.64	47.3709
12	3080	35	Cylindrical-threaded	14	232.86	47.3419
13	4600	20	Trapezoidal	16	202.67	46.1358
14	4600	25	Square	14	213.96	46.6067
15	4600	30	Cylindrical-threaded	20	217.34	46.7428
16	4600	35	Cylindrical	18	213.68	46.5953

Table 1 shows the values of UTS against the input parameter setting for L16 orthogonal array. This array is prepared by using Minitab 16 software. The fig.4 is also concluded that the ultimate tensile strength increases as the welding speed is increased. But when the tool rotation speed is increased, the ultimate Tensile strength decreases.

3. Results and Discussion

The effect of individual process parameters on the UTS mean and S/N ratio are shown in fig. 4 and fig .5. It can be observed from fig.4 that the Tool rotation speed affects the UTS most significantly. Moreover, the different input parameters used in the experimentation can be arranged in the order of increasing UTS as welding speed, tool shoulder diameter, tool rotation speed and least one is tool pin profile

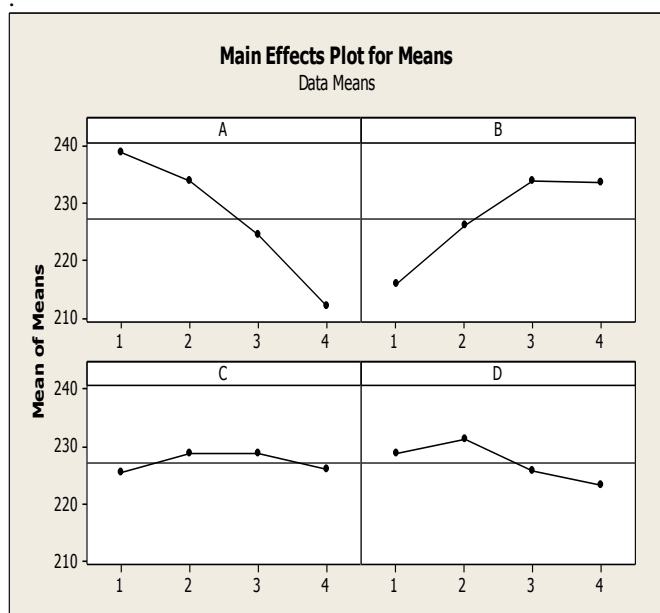


Figure 4: Effects of Parameters on UTS

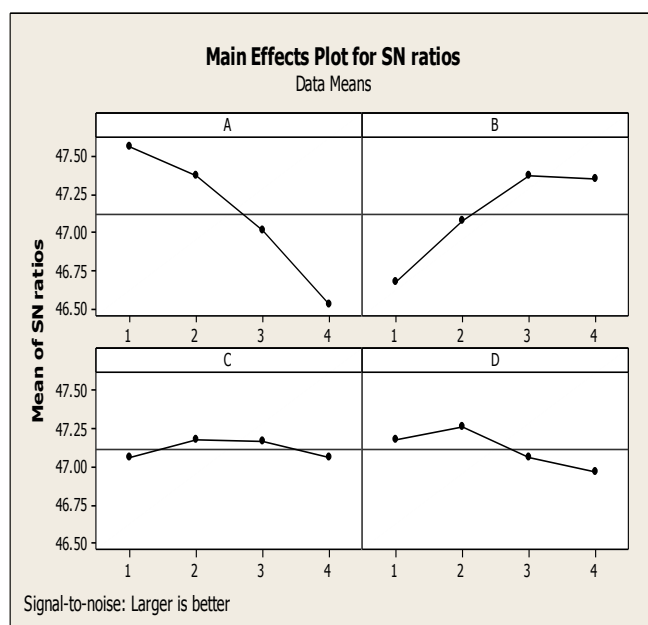


Figure 5: Effects of Parameters on UTS (S/N Ratio)

The response table for mean and S/N ratio is shown in table 2. The mean of response for S/n ratio table gives the optimum vales of process parameters. For UTS the response is taken for “larger is better” and for larger is better highest the value of S/N ratio highest will be the average response. So for UTS maximization highest value of S/N ratio are taken

Table 2(a). Response Table for Ultimate Tensile Strength (Means)

Level	A	B	C	D
1	238.8	215.7	225.4	228.7
2	233.8	225.9	228.7	231.3
3	224.4	233.8	228.6	225.8
4	211.9	233.5	226.0	223.2
Delta	26.9	18.1	3.4	8.2
Rank	1	2	4	3

Table 2(b). Response Table for S/N ratio

Level	A	B	C	D
1	47.56	46.67	47.06	47.18
2	47.37	47.07	47.18	47.26
3	47.01	47.37	47.16	47.06
4	46.52	47.35	47.06	46.96
Delta	1.04	0.70	0.12	0.3
Rank	1	2	4	3

3.1 Analysis of Variance (ANOVA)

ANOVA is used to estimate the percentage contribution of process parameters on the selected response parameters. Thus, information about how significant the effect of each controlled parameter is on the quality characteristic of interest can be

obtained.

The ANOVA results also showed that Tool rotational speed effects most effectively by 61.52 % then welding speed by 31.60 %, pin profile by 01.36 % and that of shoulder diameter by 05.51 %. It can also be concluded that the UTS increases with the decrease in tool rotation speed and Tool shoulder diameter and it decreases with the increase in welding speed. The analysis of results showed that "A₁B₃C₂D₂" is the optimal parameter setting for the Maximization of UTS. Hence, it can be concluded from this discussion that "input parameters settings of 1200 rpm tool rotation speed, 30mm/min welding speed with tool of cylindrical threaded pin and shoulder diameter of 16mm have given the optimum results of UTS; in Friction stir welding on AA 6082-T6.

Table 3. Analysis of Variance for Ultimate Tensile Strength (Means)

Ssource	DF	Seq SS	Adj SS	Adj MS	F	P
A	3	1679.62	1679.62	559.874	101.24	0.002
B	3	862.97	862.97	287.657	52.01	0.004
C	3	37.1	37.1	12.367	2.24	0.263
D	3	150.5	150.5	50.167	9.07	0.052
Residual error	3			16.59	16.59	5.53
Total	15	2730.19				

4. Conclusions

Basically, this study evaluates the welding performance of friction stir welding by using vertical milling machine on AA 6082. The following conclusions are drawn based on the performance of welding characteristics studied in this research work namely, Ultimate tensile strength (UTS)

- All the selected parameters i.e. Tool rotation speed, welding speed, Tool Pin profile, Tool Shoulder Dia. significantly affect the Ultimate tensile strength in Friction stir welding on AA6082.
- With regarding to the average response, Tool rotational speed effects most effectively by 61.52 % then welding speed by 31.60 %, pin profile by 01.36 % and that of shoulder diameter by 05.51 %.
- It can be concluded from the result that input parameters settings of 1200 rpm tool rotation speed, 30mm/min welding speed with tool of cylindrical threaded pin and shoulder diameter of 16mm have given the optimum results of UTS.

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