PROCESS PARAMETERSOPTIMIZATIONOF FRICTION STIR WELDEDAA5083

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ABSTRACT:

The single-response optimization of friction stir weldedAA 5083 for an optimum combination of parameters to give excellent ultimate tensile strength was the subject of this investigation. Taguchi's design of experiment and optimization technique was utilized to analyze the influence of process factors includingtool rotational speed (TRS), traverse speed (TS), and tool's shoulder diameter (TSD) on the tensile strength of FSWed AA5083. The Taguchi parametric design technique was used to discover the optimal values of process parameters. The findings show that the TRS, TS, and TSD are the most important factors in determining the joint's tensile strength.

Keyword: Aluminum alloy,FSW,UTS, Taguchi technique,ANOVA.

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1.Introduction

TWI (the research institute) invented friction stir welding (FSW) in 1990 as a solid-state welding approach. FSW is widely utilized in the commercial field to combine aluminum alloys for aerospace, marine automobile, and a variety of other applications. Friction stir welding uses a tool consist of a cylindrical pin that extends from a cylindrical shoulder to fuse two aluminum plates together. To prevent the butted joint from splitting, the plates are also held in a fixture. Due to the wear resistance of the FSW tool and the base material, frictional heat is generated. This heat softens the material without melting it, making it possible to move the tool along the weld line.

M. Ericsson et al. [1] investigated whether the travel speed affects the fatigue strength of FSWed AA 6082, as well as comparing the fatigue results to those obtained using traditional arc-welding procedures such asTIG and MIG-pulse. The findings of investigations on the mechanical characteristics and changes in the microstructureof Friction Stir WeldedAA 6082-T6 as a function of process parameters were evaluated by J. Adamowski et al. [2]. H. S. Patil et al. [3] investigated how the quality of AA6082-O welds was impacted by varying travel speeds and tool pin shapes. In this investigation, tri-flutes and screw thread taper pins were used as tool pin profiles. The taper pin with screw thread gives a tensile strength of 92.30 %that of the parent materialwith 27.58% of %elongation. Many researchers have looked at the effect of various factors on the strength of welding joints [4]. Taguchi approach has been utilized by several scientists in their respective areas to enhance process responses [5]. As a result, in many applications, process optimization is crucial for ensuring a high degree of safety. This paper makes an attempt to uncover beneficial data for FSW studies and improved joint strength.

2.Taguchi method

The Taguchi design approach is an experimental design methodology that is detailed in this study. Taguchi design is a collection of approaches created by Dr. Genichi Taguchi for taking into consideration the inherent unpredictability of materials and production processes during the design stage [6]. Although the Taguchi's design is comparable to the design of experiment (DOE), it only perform balanced experimental combinations, making it even more successful than a fractional factorial design. The Taguchi parameter design includes the following steps: selection of the appropriate

orthogonal array (OA) based on the number of parameters; executing trials using the OA; evaluating data; and determining the best circumstances [7].

3.Experimentation

Figure 1 shows how the trials were performed using a Universal milling machine. The milling machine's specifications include a table of 255x1380 mm^2, a spindle speed range of 80 to 3000 rpm, and a 3 HP motor.

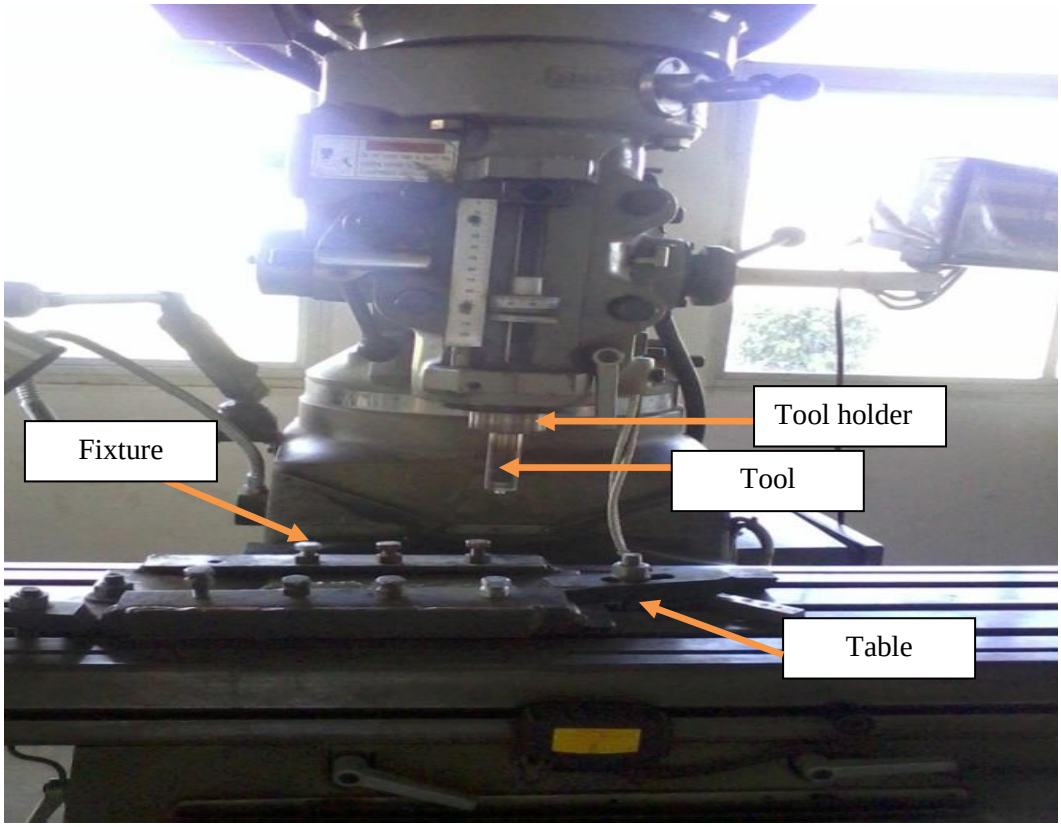

Figure1. Systematic diagram of friction stir welding

Table 1. Elemental Composition of AA 5083

S.No.	Elements	Wt%
1	Al	96.72
2	Mg	0.73
3	Si	0.87
4	Ti	0.02
5	Cu	0.74
6	Mn	0.09
7	Fe	0.62
8	Cr	0.04
9	Zn	0.17

3.1 Preparation of specimens

As shown in Figure 1, two AA 5083 plates of sizes 100mm, 80mm, and 6mm are installed on the fixture for manufacturing butt joints using the FSW, and the elemental composition is illustrated in the Table 1.

3.2 Tool preparation

FSW's welding tool AA 5083 is manufactured of high carbon tool steel. The tool is made up of three parts: a shank, a shoulder, and a pin. The tool shoulder generates heat through friction, and the pin, which is utilized to agitate the material during welding. A tool pin of cylindrical shape of 6 mm diameter is utilized during welding. The shank diameter is 19.5 mm to allow the tool to be held on the FSW machine.

3.3 Parameters selection

Tool rotation speed (TRS), traverse speed (TS), and tool shoulder diameter (TSD) were chosen as the variables for this experiment. [18-22] Table 2 lists the number of input parameters with their different levels. Several tests are performed in order to optimize the ultimate-tensile-strength (UTS). The experiments are statistically planned using Taguchi's robust DOE approach [8-10].

Table 2. Process parametersused for FSW

S. No	Parameters	Levels (L)	L-1	L-2	L-3
1	TRS (RPM)	3	800	950	1100
2	TS (mm/min)	3	30	45	60
3	TSD (mm)	3	20	22	24

The studies were statistically planned using Taguchi's robustDOE approach. One of the possible solutions for designing the trials has been the L9 orthogonal array. Table 3 shows the levels for each parameter throughout each experiment, which are more easily described using the experimenter's log sheet.

Table3.DOE obtained by L_9 OA

Experiment No.	TRS (rpm)	TS (mm/min)	TSD (mm)
1	800	30	20
2	800	45	22
3	800	60	24
4	950	30	22
5	950	45	24
6	950	60	20
7	1100	30	24
8	1100	45	20
9	1100	60	22

3.4 Experimentation

Table 3 shows the results of the study's investigation, which comprised of nine experimental runs. Table 4 shows the findings of ultimate tensile strength after welding.

Table 4:UTSof welded joints

Experiment No.	Column			UTS (Mpa)
	TRS	TS	TSD	
1	800	30	20	200.76
2	800	45	22	208.90
3	800	60	24	215.50
4	950	30	22	191.80
5	950	45	24	199.20
6	950	60	20	197.68
7	1100	30	24	188.70
8	1100	45	20	184.00
9	1100	60	22	194.70

4.Results and Discussion

The results of tensile strength were recorded and shown in Table 4 using the Taguchi design of experiments approach after executing the tests with various sets of input parameters. Taguchi's recommended standard technique was used to examine the reported findings. The following is the whole analytical description:

Table 5. Tensile Strength and S/N ration of weld specimens

S.NO	UTS (MPa)	UTS S/N Ratio
1	200.76	46.0535
2	208.90	46.3988
3	215.50	46.6689
4	191.80	45.6570
5	199.20	45.9858
6	197.68	45.9193
7	188.70	45.5154
8	184.00	45.2964
9	194.70	45.7873

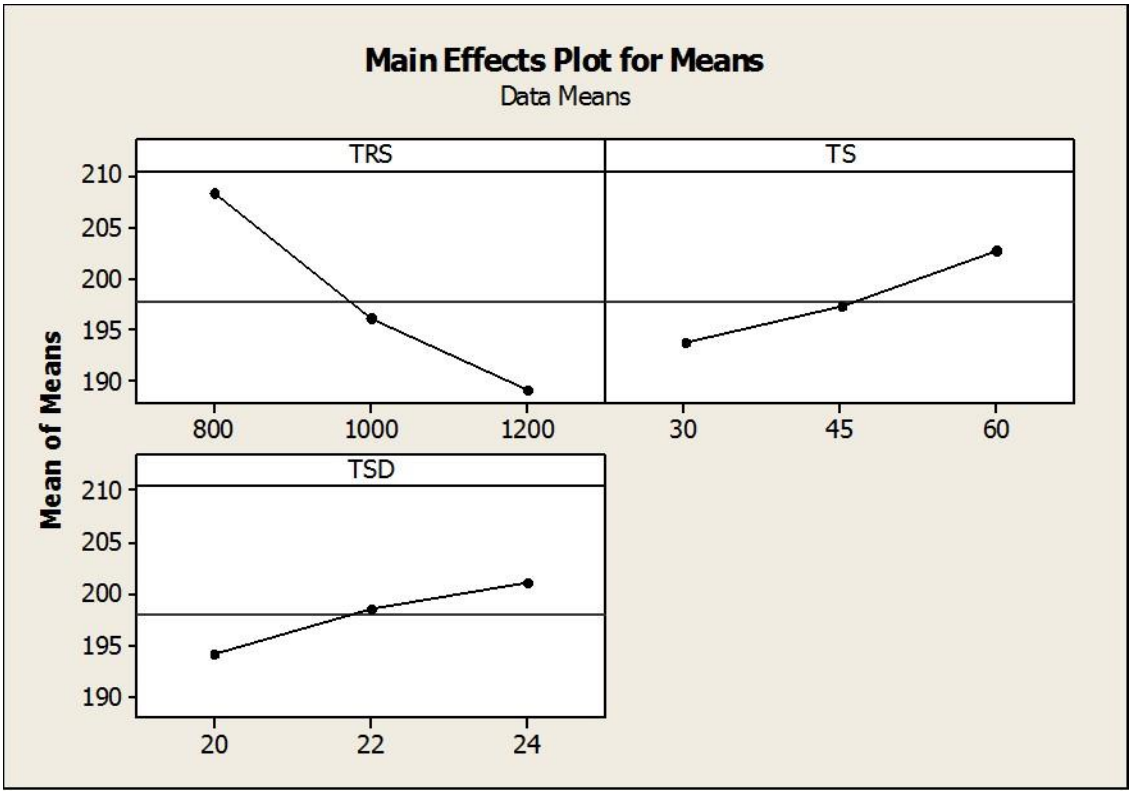

Figure2. Parameters effect on UTS (Means)

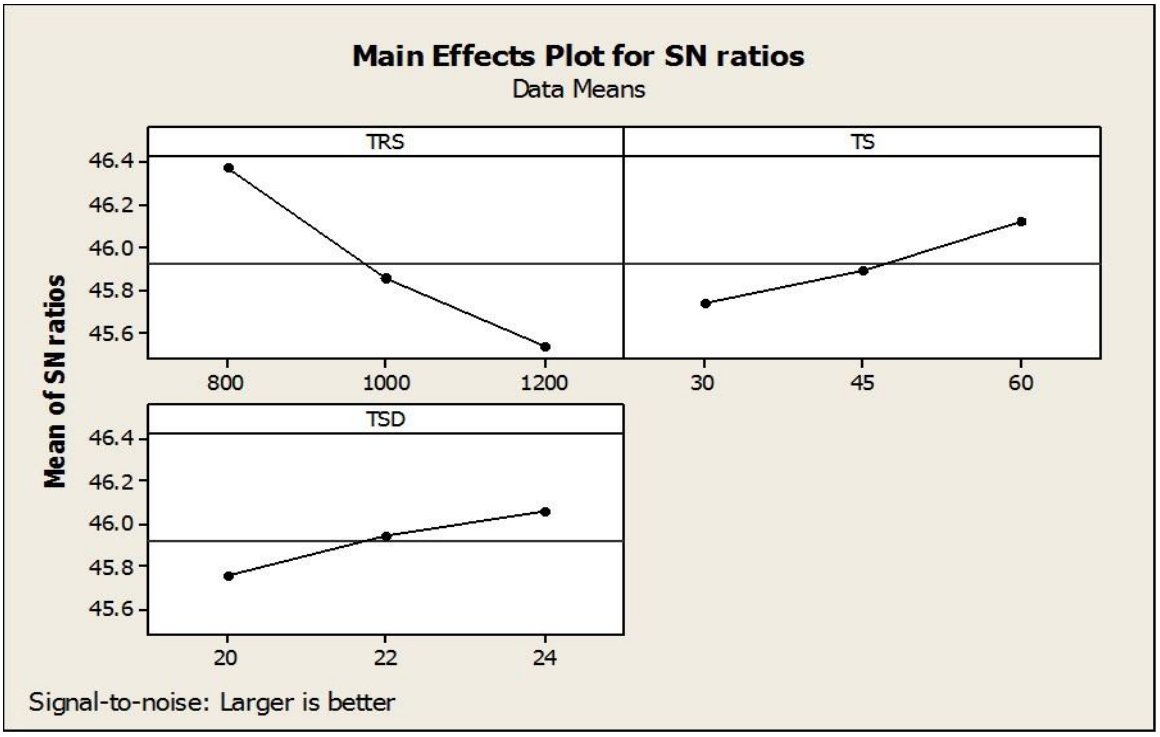

Figure3. Parameters effect on UTS (S/N Ratio)

4.1 Result Analysis for Single Response Optimization

Taguchi's approach is used to find the S/N ratio. The desirable value is represented by the phrase 'signal,' whereas the undesirable value is represented by the term 'noise' As a result, the S/N ratio denotes the degree of fluctuation in the performance characteristic. Table 5 shows the

S/N ratio values for several testing runs, as well as the mean tensile strength values.

Table 6. Response Table ofUTS (Means)

Level	TRS	TS	TSD
1	**208.4**	193.8	194.1
2	196.2	197.4	198.5
3	189.1	**202.6**	**201.1**
Delta	19.3	8.9	7
Rank	1	2	3

Table 7. Response Table ofUTS (S/N Ratio)

Level	TRS	TS	TSD
1	46.37	45.74	45.76
2	45.85	45.89	45.95
3	45.53	46.13	46.06
Delta	0.84	0.38	0.3
Rank	1	2	3

4.2 Analysis of Variance-ANOVA

As depicted in Table 8, an ANOVA test may be executed to find the significance of various process parameters on UTS. As a consequence, information on the significance of each process parameter's impact on UTS may be obtained. The findings of the UTS response for the mean and S/N ratio are illustrated in Tables 6 and 7.

Table 8.ANOVA for UTS (Means)

Source	DF	SeqSS	AdjSS	AdjMS	F	P
TRS	2	568.872	568.872	284.436	186.08	0.005
TS	2	119.46	119.46	59.73	39.08	0.025
TSD	2	74.587	74.587	37.294	24.4	0.039
Residual-Error	2	3.057	3.057	1.529		
Total	8	765.976				

5.DISCUSSION OF THE RESULTS

The TRS, TS, and shoulder diameter all have a substantial impact on the UTS, as seen in Figure 2. Furthermore, the various input parameters used in the experimentation, such as TRS, TS, and tool shoulder diameter, can be sorted in order of increasing UTS. From the Figure 5, thehighest UTS has been recorded with TRS at level 1 (800 rpm), TS and tool shoulder diameter at level 3 (60 mm/min and 24 mm, respectively). The TRS is the most important component for enhancing tensile strength in friction stir welding; TS is the second most important factor, and TSD is the third most important factor [11-15].

In terms of the S/N response, the highest S/N ratio values (Figure 3) were identified for the factor levels that corresponded to the maximum average response. As a result, these parameter's levels may be considered optimal in terms of average reaction and S/N response [16-17]. Because the S/N response considers both the amplitude and fluctuation of the response, the factor values that correspond to the highest S/N ratio are referred to as optimal. After analyzing the data, it was revealed that "$A_1B_3C_3$" is the best parameter setting for maximizing UTS. As a result, "input parameter values of TRS: 800 rpm, TS: 60 mm/min, and TSD: 24 mm are the optimum parameters for maximizing the UTS of in friction stir welded AA 5083.[18-22]

CONCLUSION

Basically, this study uses a vertical milling machine to examine the welding performance of FSWed AA 5083. Based on findings, the following conclusions can be drawn:

- The UTS of FSWed AA 5083 is significantly influenced by all of the

specified parameters, such as TRS, TS, and TSD.

- TRS has identified as the most significant process parameter in maximizing theUTS, while TS is the second most significant parameter and TSD is least significant.
- The results show that the input parameters of TRS: 800 rpm, TS: 60 mm/min, and TSD: 24 mm are the optimum parameters for maximizing UTS.

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