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Optimisation of Process parameter for Friction Stir Welding of Aluminium alloy using cylindrical pin profile

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Abstract

***Objective**: Friction Stir Welding is a solid state joining process combining deformation heating and mechanical work to obtain high quality, defect free joints. The objective of the present work is to evaluate the tensile properties of FSW butt joint.*
In this work, three process parameters such as spindle speed, welding speed and plunge depth were considered for friction stir welding .As it is difficult to perform number of experiments to find out the level combinations which yield good mechanical properties like tensile strength, TaguchiL9 orthogonal array is used to reduce the number of experiment. The material is bought and are cut into specific material and polished. They are then welded based on the different experiment obtained from Taguchi method. After welding is done the metals are cut as per the specific standard. The results are then analyzed using Taguchi method
Keywords: Aluminum Alloys, Axial Force, Friction-Stir Welding, Microstructure, Tensile Strength

1. Introduction

Friction Stir Welding (FSW) was invented at The Welding Institute (TWI) of the United Kingdom (Cambridge) in 1991 as a solid state joining technique and was initially applied to Aluminum Alloys (Dawes C and Thomas W, TWI Bull, 1995; Thomas W M, *etal.*, 1991). Friction Stir Welding is a solid state joining process combining deformation heating and mechanical work to obtain high quality, defect free joints. Friction Stir Welding is especially well suited to joining Aluminum Alloys in a large range of plate thickness and has particular advantages over fusion welding when joining of highly alloyed Aluminum is considered.[1]. The heat input into the material and the resulting welding temperature can be controlled by adapting process parameters like the down-force, rotational speed or welding speed as shown in Fig. 1

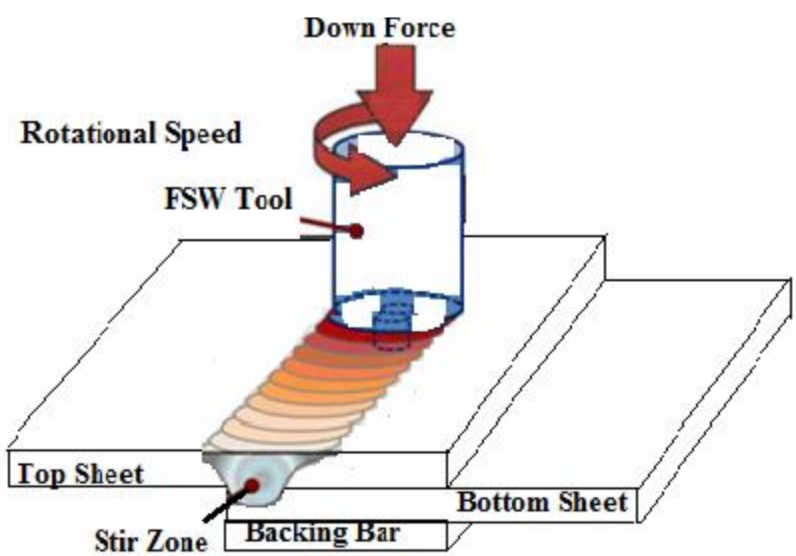

Fig. 1 Principle drawing of the FSW process for joints with indication of the main parameters

A method of solid state joining on a workpiece offers a tool pin of material harder than the base metal's continuous surface which causes relative cyclic movement between the pin and the base metal. The frictional heat is generated as the pin stirs the workpiece so as to create a plasticized region in the metal around the probe, stopping the relative cyclic movement, and allowing the plasticized material to solidify around the probe.[2]

2. Literature Survey: Effect of Various Welding Parameters on FSW

Sr. No	Author Name	Substrate material	Parameter selected for study	Conclusion
1	Shashi prakash dwivedi [3]	A356/C355 Alumnium Alloy	Welding speed, tool speed, Axial force	Based on tool rotational speed, axial force and welding speed were found to be suitable for tensile strength with regression p-value less than 0.05 & lack of fit more than 0.05
2	Adil sheikh, K.D.Bhatt, AlokB. Choudhary[8]	HDPE with 4% filler material	Rotational speed and welding speed	Although the tensile strength of the welded specimens was about 45MPa which is almost 80 % that of the base plate, the FSW process can be employed to weld HDPE plates with 4% filler minerals. Increasing the work linear speed from 14 to 56 mm/min had a decreasing effect on tensile strength
3	L. Suvarna Raju, Dr Adep kumar, Dr P. Indrewaraiah[7]	Cu plates of 200*100mm	Axial force, tool speed, Welding speed	Weldment made by FSW at the tool rotation speed of 900rpm and weld speed 40mm/min exhibited better mech properties. This is due to sufficient heat generation and proper mixing of material in the weld zone
4	M.P.Meshram, Basant kumar, [12]	Austinitic stainless steel 120*80*4mm	tool speed, Welding speed	A defect free weld with parameters of 1100rpm and traverse speed 8mm/min showed tensile strength of Base material with 37% elongation
5	H. Ahmadi, N.B.Mostafa arab F.Ashenai Ghasami[4]	Plates of PP composites With 20% CF 100*50*4 mm	Welding speed, Rotational speed, Tilt angle	The welding speed was the most significant welding process parameter whereas the tilt angle was the least significant one affecting the tensile-shear strength
6	G.Elatharasan V.S.Senthil kumar[5]	AA6061-T6 And AA7056-T6	Welding speed, Rotational speed, Axial force	Ultimate tensile strength of FSW joints increases with increase in tool rotational speed and welding speed upto a max value and then decreases.

3. **Experimental Set up**: The base material used in the investigation is 1100 Aluminium alloy and rolled plates of 6mm thickness have been used as the base material for preparing single pass welded joints. It has got good mechanical properties and exhibits good weldability.

Table2 shows its Chemical composition.

Alloy	Al	Cu	Si+Fe	Mn	Zn	Others total
1100	99 min	0.20 max	0.95	0.05 max	0.10 max	0.10 max

The Friction Stir welding technique uses a non consumable rotating tool to make the joint. The tool consist of body shoulder, probe or pin. The tool used in this process was made of High speed steel which has a cylindrical pin profile. Vertical Machine Centre is used to fabricate the required joints. It is equipped with high precision and heavy loading series linear guideways on 3 axes.

Fig. 2 Experimental setup describing FSW using VMC machine

3. Methdology

: Three process parameter Tool rotational speed (N), Welding speed(S), Axial force(F) which contribute to heat input and subsequently influence friction stir welded aluminium joints, were selected for this study and were optimized using taguchi design concept.

Table -3: Factors and levels

Process parameter	Level 1	Level 2	Level 3
Tool rotational speed (N),	900	1000	1100
Welding speed(S)	75	100	125
Axial force(F)	3	4	5

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.

4.1 Results

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.

According to Table 4, 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.

Exp no.	Tool rotational speed (N),	Welding speed(S)	Axial force(F)	Tensile strength
1	900	75	3	66.46
2	900	100	4	87.12
3	900	125	5	111.35
4	1000	75	4	88.39
5	1000	100	5	112.48
6	1000	125	3	105.66
7	1100	75	5	154.45
8	1100	100	3	74.46
9	1100	125	4	79.88

Table- 4: Standard L9 orthogonal arrays as per Taguchi's suggestion

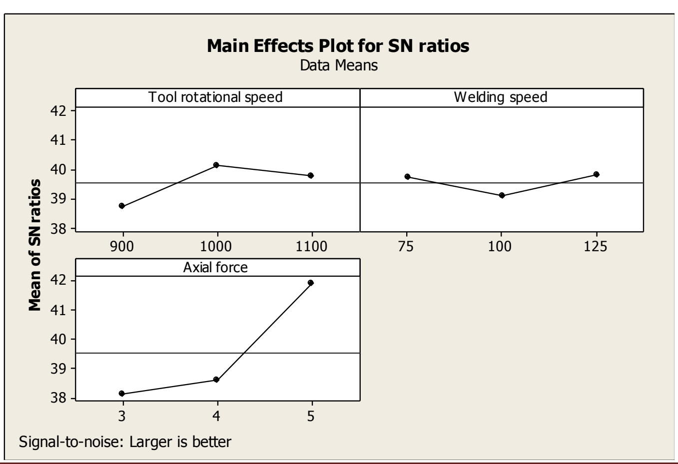

Table 5: Response Table for Signal to Noise Ratios

Level	Tool rotational speed (N),	Welding speed(S)	Axial force(F)
1	38.73	39.72	38.12
2	40.14	39.09	38.59
3	39.75	39.82	41.91
Delta	1.41	0.73	3.79
Rank	2	3	1

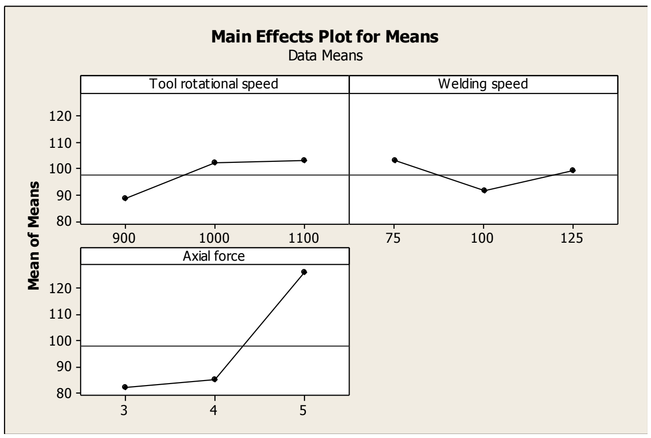

Table 6: Response Table for Means

Level	Tool rotational speed (N),	Welding speed(S)	Axial force(F)
1	88.31	103.10	82.19
2	102.18	91.35	85.13
3	102.93	98.96	126.09
Delta	14.62	11.75	43.90
Rank	2	3	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 axial force calculated by minitab software indicated that axial forrce was at maximum.

The optimum process parameter is found to be a combination of Spindle speed of 1100 rpm, welding speed of 75mm/min, and axial force 126.09

5. Conclusion

FSW is the best process to welding of different alloys of aluminum for long lengths with an excellent quality.
Axial force 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. The optimum process parameter is found to be a combination of Spindle speed of 1100 rpm, welding speed of 75mm/min, and axial force 126.09

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