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Optimization of Input Parameters in Friction Stir Welding of Al Alloy 2014

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***Abstract*—**Friction stir welding (FSW) process is one of the type of solid state joining process in which the material that is being welded does not melt and recast. To obtain the desired strength, it is essential to have a complete control the relevant input parameters to increase the tensile strength on which the quality of welded joint is depend. Therefore, it is essential to have control the welding process parameter for obtaining maximum strength. In the present investigation an optimization of Friction stir welding parameters has been carried out using Taguchi method. The parameters involved are Tool rotational speed, welding speed, Dwell time and Tool pin profile. Tensile strength was taken as response criteria for linear welding. The optimum input parameters were determined for tensile strength and lap shear fracture force of the joint. The result shows that in FSW of Aluminium alloy 2014 Tool pin profile was the most dominant welding parameters followed by tool rotational speed and welding speed. .

Keywords- *Friction stir welding (FSW), Optimization, Taguchi Method, Anova, AL Alloy 2014.*

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I. INTRODUCTION

Friction stir welding (FSW) is a solid state welding process and it considered the most significant development developed by the welding Institute (UK) in 1991 and now being used increasingly for joining aluminum alloys for which fusion welding is often difficult[1]. A non-consumable rotating tool with profiled pin and shoulder is inserted into the edges of the plates to join. The pin traverses along the joint line and the shoulder touches the plates. Due to friction, the tool generate the heat on the workpiece and moves the material from a side to the other. Material plastic deformation increases the heat and melt the parent material around the tool. during the rotation of tool and translation of tool welded joint was formed.Generally, the quality of a weld joint is directly influenced by the welding input parameters during the welding process; therefore, welding can be considered as a multi-input multi-output process[3]. Most of the manufacturer facing the problem to control over the process input parameters to obtain the excellent output from the process. It has been necessary to determine the weld input parameters for every new welded product to obtain a welded joint with the required specifications. In order to overcome this problem various optimization technique can be applied to define the desired output variables through developing mathematical models to specify the relationship between the input parameter and output variables. In this study the optimization of process parameter is done by using Taguchi Method. Aluminum is very important material in automotive regarding high weight to strength ratio, corrosion resistance, emissions, safety and sustainability. Aluminum is most widely used in automobile industries due to light weight and replace by steel components. It has good weldability, machinability, corrosion resistance and higher strength. A high thermal and electrical conductivity cause problems in fusion and resistance welding of aluminum alloys to avoid this problem FSW plays important role.[5]

Taguchi technique has been used widely for product or process on determining parameters and their performance measure with minimum variation[10]. This optimization can improve the performance of the product, process, design to reduce time and cost

Recently some reports have been available on the FSW of Aluminum alloy and their optimization by Taguchi Method but no study has been reported on optimization of FSSW of HDPE sheets by using RSM and very few literature is available for FSW of Aluminum alloy 2014 so that this material is select for further study.

II. EXPERIMENTAL WORK

In this study three level process parameters tool rotation speed, welding speed and tool pin profile were analyzed and from initial experiments their levels are decided as shown in Table 1. Trial experiments were carried out according to according to the principle of the Design of the experiments in order to determine the effect of the main parameters. An L_9 orthogonal array with four columns and nine rows was applied. The experimental layout for the three welding parameters using the L_9 orthogonal array is shown in Table 2. The experimental studies were performed on Aluminum alloy 2014. The specimen of dimension (200×75×4) mm are prepared for welding as shown in fig 1.

Table I: Levels of parameters

Sr No	Process Parameters	Level 1	Level 2	Level 3
1	Rotational speed (rpm)	560	900	1400

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2	Welding speed (mm/min)	10	16	22
3	Tool Pin Profile	Taper Cylindrical	Taper with concavity	Straight With Concavity

Table II: L9 Orthogonal array

Experiment Number	Welding Parameters		
	Rotational speed	Welding speed	Tool Pin Profile
1	560	10	Taper Cylindrical
2	560	16	Taper with concavity
3	560	22	Straight With Concavity
4	900	10	Taper with concavity
5	900	16	Straight With Concavity
6	900	22	Taper Cylindrical
7	1400	10	Straight With Concavity
8	1400	16	Taper Cylindrical
9	1400	22	Taper with concavity

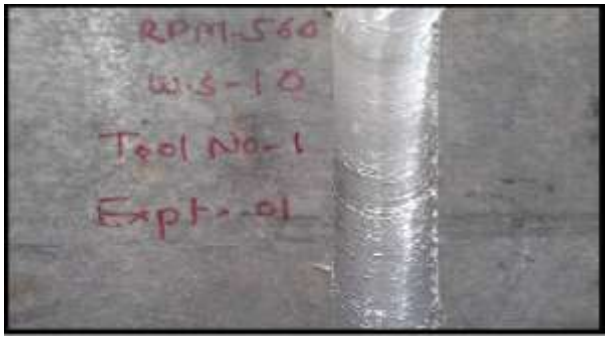

Fig1-Welded specimen of Al alloy 2014

The tools used for welding are made up of hot die steel H13. The tools are shown in Fig 2

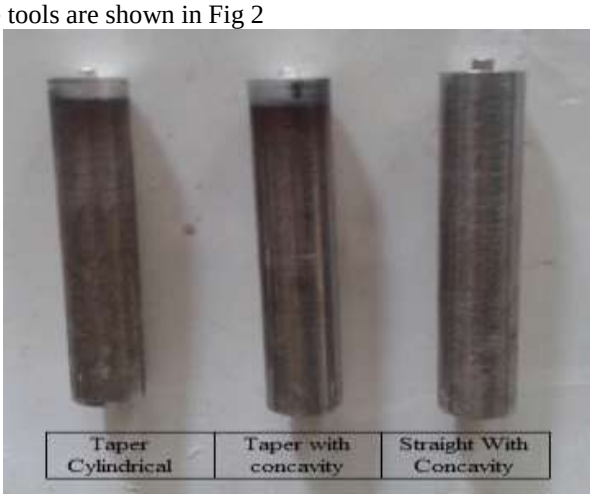

Fig 2: Tools For Aluminium alloy 2014

III. RESULT AND DISCUSSION

A. *Analysis of Experimental data*

As per the design of matrix 9 trials were conducted. Each experiment is performed 2 times on same parameters to minimize the machining error and mean of the response i.e. tensile strength recorded in following table.

Table III: Experimental data of AA 2014

Experiment No	Tensile Strength 1(Mpa)	Tensile Strength 2(Mpa)	Mean	S/N ratio
1	192.5	193	192.75	45.6999
2	150.5	154.73	152.615	43.6694
3	128.979	134.891	131.935	42.4007
4	125.192	128.158	126.675	42.0520
5	91.68	95.48	93.58	39.4183
6	159.15	164.85	162	44.1863
7	66.485	69.285	67.885	36.6299
8	125.035	126.835	125.935	42.0023
9	101.089	104.591	102.84	40.2395

B. *Signal to noise ratio*

Taguchi technique utilizes the S/N ratio approach to measure the quality characteristic deviating from the desired value. The S/N ratio characteristics can be divided into three stages: the nominal- the better, the smaller-the better, and the higher-the better when the quality characteristics are continuous for engineering analysis. Since the objective of this study is to maximize tensile strength optimum process parameters in friction stir welding, higher-the better quality characteristic is employed in this study. The formula used for calculating the SN ratio is given below.

Larger is better

$$\frac{S}{N} = -10 \log_{10} \frac{1}{N} \sum_{i=1}^{n} \frac{1}{y_i^2}$$

Where y_i is the value of tensile strength for the i^{th} test, n is the number of tests and N is the total number of data points. The tensile strength of the friction stir welding joints values is
Analyzed to study the effects of the FSW process parameters. The experimental data are converted into S/N ratio. The calculated S/N ratio values are tabulated in Table 4.1.3. The analyses are made using the software known as MINITAB 14. Table 4.1.4 shows the mean S/N ratio for each level of the welding parameters. This table is named as the S/N response table for the weld strength. The larger S/N Ratio corresponds to the better quality characteristics. Based on S/N ratio values the optimum level setting was obtained at 560 rpm of rotational speed (A1), 22 mm/min welding speed (B3), and Taper cylindrical tool (A1). Similarly the Table 4.1.5 shows the mean of mean for the welding parameters.

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Table IV: Response Table for Signal to Noise ratio

Level	Rotational speed	Welding speed	Tool Pin Profile
1	**43.92**	41.46	**43.96**
2	41.89	41.70	41.99
3	39.62	**42.28**	39.48
Delta	4.30	0.81	4.48
Rank	2	3	1

Table V: Response Table for Means

level	Rotational speed	Welding speed	Tool Pin Profile
1	**159.10**	129.10	**160.23**
2	127.42	124.04	127.38
3	98.89	**132.26**	97.80
Delta	60.21	8.21	62.43
Rank	2	3	1

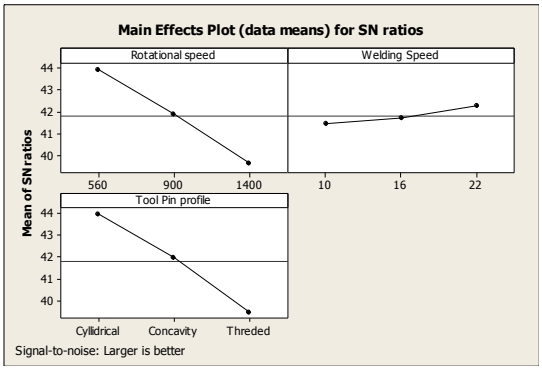

Fig 3 Main effect plot for SN ratio

C. *Analysis of Variance (ANOVA)*

Analysis of variance (ANOVA) test was performed to identify the process parameters that are statistically significant. The purpose of the ANOVA test is to investigate the significance of the process parameters which affect the tensile strength of FSW joints. The ANOVA results for tensile strength of means and S/N ratio are given in Table VI and VII. In addition, the F-test named after Fisher can also be used to determine which process has a significant effect on tensile strength. Usually, the change of the process parameter has a significant effect on the quality characteristics, when *F* is large (Table VI and VII). The results of ANOVA indicate that the considered process parameters are highly significant factors affecting the tensile strength of FSW joints in the order of rotational speed, axial force and traverse speed. Effects of interaction between process parameters are not significant

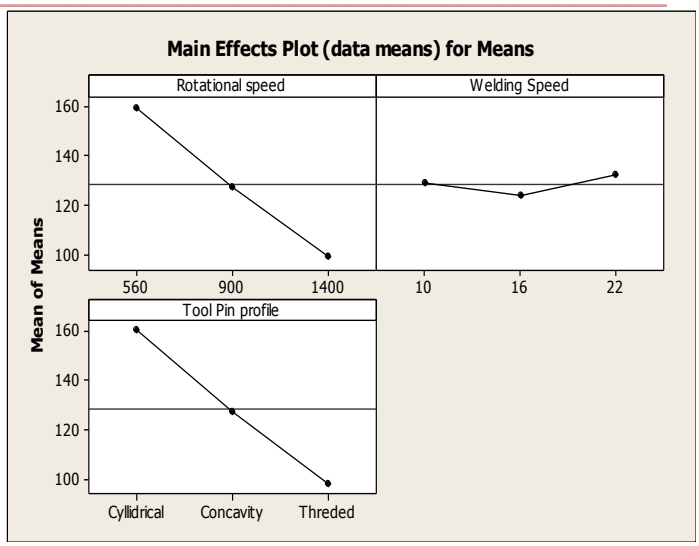

Fig 4 Main effect plot for Mean

Table VI: Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Rotational speed	2	27.7528	27.7528	13.8764	42.75	0.023
Welding speed	2	1.0547	1.0547	0.5274	1.62	0.381
Tool Pin Profile	2	30.2429	30.2429	15.1215	46.59	0.021
Residual Error	2	0.6492	0.6492	0.3246		
Total	8	59.6996				

D. *Taguchi Analysis*

Table VII shows the result of the ANOVA on the weld strength. The F value of a welding parameter shows the effectiveness of the parameter.The welding parameter which has the highest degree is the most important parameter . The F value of the tool pin profile is highest . It is found that the tool pin profile is very important parameter because it has the greatest F value the rotational speed is found to be second important welding parameter. The welding speed was found to be the least effective factor on the weld strength because it has the lowest F value. Optimal welding parameters can be determined by using the graphs of fig.3 in which the highest mean of S/N ratio is obtain at parameter level A1B3C1 which is A1-rotational speed-560 rpm B3-welding speed-22 mm/min and Tool pin profile-Taper cyllindrical. Once the optimal level of the design parameters has been determined the final step is to predict and verify the improvement of the quality characteristic using optimal level of the design parameters. The optimum level parameters for prediction of the output are shown in following table. Taguchi analysis gives the predicted output of tensile strength 194.65 Mpa at optimize process parameters.Predicted value of output is confirmed by performing the experimnt on optimize input parameters. The predicted value is shown in follwing table with its S/N ratio.The result of confirmation experiment is shown in Table 4.1.10 in which the difference between the predicted value and actual value is 5.56 . 2.84 % error is occurred between the predictedd value and experimental value.

Table VII:Analysis of Variance for Means (Tensile Strength)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Rotational speed	2	5443.4	5443.43	2721.71	699.25	0.001
Welding speed	2	103.0	103.04	51.52	13.24	0.070
Tool Pin Profile	2	5851.3	5851.31	2925.65	751.65	0.001
Residual Error	2	7.8	7.78	3.89		
Total	8	11405.6				

Table VIII: Factor levels and predicted values

Factor levels for predictions		
Rotational speed	Welding speed	Tool Pin Pofile
560 rpm	22 mm/min	Taper Cyllidrical

Predicted Values			
S/N Ratio	Mean	St Dev	Log(St Dev)
46.5398	194.65	3.05219	0.506412

Table IX :Results of confirmation Experiment

	Optimal Estimaion	Experimental Condition	Difference	Difference (%)
Level	A1B3C1	A1B3C1	---	---
T.S.	194.65	200.19	5.56	2.84%
S/NValue	46.5398			

IV. CONCLUSION

In this work the Design of Experiment is used for conducting the experiments by Taguchi method and Response Surface Methodology. Taguchi method gives the optimize process parameter combination while Response surface methodology gives the mathematical model to predict the responses. The results obtain by Taguchi method and Response Surface Methodology are summarize as followsOptimum parameter settings obtain from S/N ratio plot are Rotational speed 560 rpm , Welding speed 22 mm/min and Tool pin profile Taper cylindrical. Confirmatory experiment has been performed and found a good agreement between predicted and experimental value.

Tool rotational speed, welding speed and tool pin profile were effective on joint strength of Aluminium alloy 2014. Tool pin profile was the most dominant welding parameters followed by tool rotational speed and welding speed.

- In FSSW of HDPE sheets the effect three process parameters rotational speed, dwell time and tool pin profile studied on LSFF of HDPE welded joint is studied through response surface analysis.
- A mathematical relationship has been developed to predict the LSFF of friction stir welded HDPE sheets by incorporating FSW process parameters using statistical tools such as design of experiment, ANOVA and regression analysis
- Based on the regression models the effects of FSW parameters on Lap shear fracture force of friction stir welded joints were presented and interpreted in detail
- The joints fabricated using Taper cylindrical profile tool with rotational speed of 900 rpm and 60 sec dwell time exhibited superior Lap shear fracture force compared to other joint.

REFERENCES

[1] Friction Strir Welding Technical Handbook, www.esab.com
[2] Indira Rani M, MarpuR.N, A.C.S. Kumar, "A study of process parameters of friction stir welded AA 6061 Aluminum alloy in 0 and T6 condition", ARP Journal of Engineering and Applied Sciences, Vol.6, no.2, 2011
[3] N Rajamanickam, V Balusamy, "Effects of process parameters on mechanical properties of friction stir welds using design of experiments", Indian Journal of Engineering & Material Sciences, Vol .15, 2008,pp.293-299
[4] Yan-hua Zhao, San-bao Lin, Lin Wu, Fu-xing Qu, "The influence of pin geometry on bonding and mechanical properties in friction stir weld 2014 Al alloy", Material Letters 59, 2005, pp.2948-2952
[5] Mohamed-Ali Rezgui, Ali-Chedli Trabelsi, Mahfoudh Ayadi, Khaled Hamrounic "Optimization of Friction Stir Welding Process of High Density Polyethylene", International Journal of Production and Quality Engineering, Vol. 2, No. 1, January-June 2011, pp. 55-61
[6] Amir Mostafapour,Ehsan Azarsa, "A study on the role of processing parameters in joining polyethylene sheets via heat assisted friction stir welding: Investigating microstructure, tensile and flexural properties", International Journal of the Physical Sciences, Vol. 7(4), 23 January 2012, pp. 647 – 654
[7] K.Elangovan,V. Balasubramanian,"Influences of tool pin profile and welding speed on the formation of friction stir processing zone in AA2219 aluminium alloy", journal of materials processing technology, Vol. 200, 2008 ,pp 163–175.
[8] Mustafa Kemal Bilici, "Application of Taguchi approach to optimize friction stir spot welding parameters of polypropylene", Materials and Design, Vol.35, 2012, pp.113–119.
[9] M. Koilraj, V. Sundareswaran, S. Vijayan, S.R. Koteswara Rao, "Friction stir welding of dissimilar aluminum alloys AA2219 to AA5083 –Optimization of process parameters using Taguchi technique", Materials and Design, Vol.42, 2012, pp.1-7.
[10] M Jayaram, R Sivasubramanian, V Balasubramanian, A K Lakshminarayanan, "Optimization of process parameters for friction stir welding of cost aluminium alloy A319 by Taguchi method", Journal of Scientific & Industrial Research, Vol. 68,2009,pp.36-43.
[11] A. K. Lakshminarayanan, V. Balasubramanian, "Process parameters optimization for friction stir welding of RDE-40 aluminium alloy using Taguchi technique", Transactions of Nonferrous Metals Society of China, Vol.18, 2008, pp.548-554.
[12] Jawdat A. Al-Jarrah, Sallameh Swalha, Talal Abu Mansour, Masoud Ibrahim, Maen Al-Rashdan, "Optimization of Friction Stir Welding Parameters for Joining Aluminum Alloys Using RSM", Adv. Theor. Appl. Mech., Vol. 6, no. 1, 2013, pp.13-26.
[13] V. Balasubramanian, K. Elangovan, S. Babu, "Developing an Empirical Relationship to Predict Tensile Strength of Friction Stir Welded AA2219 Aluminum Alloy", Journal of Materials Engineering and Performance, Vol. 17(6), 2008, pp.820-830.
[14] R. Palanivel, P. Koshy Mathews, N. Murugan, "Development of mathematical model to predict the mechanical properties of friction stir welded AA6351 aluminum alloy", Journal of Engineering Science and Technology, Vol. 4(1), 2011, pp. 25-31.