International Journal of Advance Research in Science and Engineering
Vol. No.5, Issue No. 09 , September 2016
www.ijarse.com

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

EXPERIMENTAL INVESTIGATION AND OPTIMIZATION OF SPOT WELDING PROCESS PARAMETERS FOR MAXIMUM TENSILE STRENGTH

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ABSTRACT

This experimental study is based on an investigation of the effect and optimization of welding parameters on the tensile shear strength in the Resistance Spot Welding (RSW) process. The experimental studies were conducted under varying forces, currents, and times. The settings of welding parameters were determined by using the Taguchi experimental design of L9 Orthogonal array method. The combination of the optimum welding parameters have determined by using the analysis of Signal-to-Noise (S/N) ratio. The confirmation test performed clearly shows that it is possible to increase the tensile shear strength of the joint by the combination of the suitable welding parameters. Hence, the experimental results confirmed the validity of the used Taguchi method for enhancing the welding performance and optimizing the welding parameters in resistance spot welding operations.

Keywords: Resistance Spot Welding (RSW), Tensile strength, Taguchi method, S/N ratio, Optimization.

I. INTRODUCTION

Resistance spot welding (RSW) is a process in which metal surfaces are joined in one or more spots by resistance to the flow of electric current through work pieces that are held together under force by electrodes. The process is used for joining cold rolled carbon sheet materials and uses shaped copper electrodes to apply pressure and convey the electrical current through the work piece. Heat is developed mainly at the interface between two cold rolled carbon sheets, eventually causing the two material being welded to melt, forming a molten pool, the weld nugget. The resistance spot welding has the advantage which is great speed and suitable for automation. Resistance spot welding is getting significant importance in car, bus and railway bodies etc. due to automation and high speed process. The major factors controlling this process are current time, electrode force, contact resistance, property of electrode material, sheet materials, surface condition etc. the quality is best

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ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

judged by nugget size and joint strength. This study presents a systematic approach to determine effect of process parameters (electrode force, weld time and current) on tensile shear strength of resistance weld joint of mild steel using Taguchi method. A general introduction for principle, working and parameters of spot welding is given below. Resistance Spot Welding (RSW) is among the oldest of the electric welding method that used in the industry and it is useful and accepted method in joining metal.

II. LITERATURE REVIEW

Optimization for the austenitic stainless steel AISI 301L in RSW (Mr. Niranjan Kumar Singh , 2012) [1]. A two-dimensional model is utilized to predict temperature and stress fields during and after resistance spot welding process, Increase welding voltage leads to an increase in the weld nugget size. Welding time has the same role, however, increasing the welding time causes to enhance heat transfer to the surroundings and therefore less heat is consumed in the formation of weld nugget (I. RanjbarNodehetal, 2008) [2]. To study of mechanical strength for three test geometry lap-shear, cross-tension and coach-peel, For lap shear strength, a strong relationship with weld nugget diameter was observed; which discrete strength levels were found for coach-peel test geometry. For cross tension strength there is a relationship with nugget dia. but the data are sensitive to nugget periphery defects (L. Han M. Thornton, D. Boomer, M. Shergold, 2011) [3]. Tests of thin-walled beams joined by spot welding (Rusi´nski et al, 2004)

III. METHODOLOGY

Taguchi design methodology was Adopted. The experiments were conducted using L9 Orthogonal Array (OA) with three parameters (electrode force, weld current, weld time) with three levels (level 1, level 2 and level 3).The process parameters, their symbols and their values at different levels are shown in the table 1 Optimization of process parameters is the very important in Taguchi method to achieving high quality without increasing cost. This is because optimization of process parameters should improve quality and the optimal resistance spot welding process parameters obtained from the Taguchi method are sensitive to the variation of environmental conditions and other noise factors. An advantage of the Taguchi method is emphasizes a mean performance value close to the target value rather than a value within certain specification thus improving the product quality.

Table 1: Process Parameters and their Values

Thickness	S.	parameter	unit	L1	L2	L3
1.2 mm	A	Force	KN	0.78	0.83	0.92
	B	Current	KA	9	10	11
	C	Time	S	5	10	15
1.5 mm	A	Force	KN	1.15	2.22	2.90
	B	Current	KA	10	11	12
	C	Time	S	5	10	15

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ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

Additionally, Taguchi's method for experimental design is straight and forward and easy to apply many engineering situations, making it a powerful yet simple tool. The main disadvantage of the Taguchi method is the results obtained are relative and do not exactly indicate which parameter has the highest effect on the performance characteristic value. Also, since orthogonal array do not test all variable combination, this method should not used with all relationships between all variables. A large number of experiments have to be carried out when the process parameters increases. To solve this task Taguchi method uses a special design of orthogonal arrays to study the entire process parameters space with only a small number of experiments. Using an orthogonal array to design the experiment would help the designers to study the influence of multiple controllable factors on the average of quality characteristics and the variations in a fast and economic way. all the specimens are welded using the design of experiment shown in the Table 2

Table 2 : Experimental layout using L9 orthogonal array

Experiment	Electrode force (KN)	Welding current (KA)	Welding Time (cycle)
1	0.78	9	5
2	0.78	10	10
3	0.78	11	15
4	0.83	9	10
5	0.83	10	15
6	0.83	11	05
7	0.92	9	15
8	0.92	10	05
9	0.92	11	10

A. finding tensile shear strength

Tensile shear strength finding By using universal testing machine. The result are as follows.

Table 3: Experimental result for the tensile shear strength

Experiment No.	Tensile shear strength (KN)	
	1.2 mm	1.5 mm
1	7.00	22.45
2	8.20	23.75
3	9.25	24.40
4	6.00	22.00
5	8.35	22.25
6	10.6	23.30
7	7.50	10.15
8	8.00	11.00
9	8.65	11.55

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As we have seen before that all the specimens are welded using the taguchi method and now tensile shear testing of all the specimens has performed using a Universal testing machine. The tensile shear results of all the specimens are shown in the Table 3.A loss function is then defined to calculate the deviation between the experimental value and the desired value. Taguchi recommends the use of the loss function to measure the deviation of the quality characteristic from the desired value. The value of the overall loss function is further transformed into a Signal to-Noise (S/N) ratio. Usually, there are three categories of the quality characteristic in the analysis of the S/N ratio, i.e., the lower-the the better,

the larger-the-better, and the more nominal- the-better. The S/N ratio for each level of Process parameters is computed based on the S/N analysis. Regardless of the category of the quality characteristic, a larger S/N ratio corresponds to a better quality characteristic. Therefore, the optimal level of the process parameters is the level with the highest S/N ratio. The loss function of the larger the better quality characteristics can be expressed as

$$\left(S/_{N}\right) = -10\log\left(1/_{n\sum_{i}^{n} y_i^2} \right)$$

where,
Lj = Overall loss function
n = Number of tests
yi = Experimental value of the ith quanlity characteristic
nj = S/N Ratio
By using the above equations
corresponding to overall loss function for each experiment was calculated and given in Table 4

B. S/n Ratio analysis

In order to quantify influence of each level of parameters, mean of S/N ratio for A were computed by averaging S/N ratio for experiment Number 1, 2, 3 for level 1 and 4, 5, 6 for level 2 and 7, 8, 9, 16 for level 3. Mean of S/N ratio for each level of other welding parameters were calculated in a similar way. Parameters with large difference indicate high influence to weld ability as its level is changed. In this study, parameter B had largest difference following its levels, whereas each level of parameter A showed less effect to output.

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Table 4: overall loss function and its S/N ratio

Experiment No.	S/N Ratio (db)	
	1.2 mm	1.5 mm
1	16.90	27.02
2	18.27	27.51
3	19.32	27.74
4	15.56	26.84
5	18.43	26.94
6	20.50	27.34
7	17.50	20.12
8	18.06	20.82
9	18.74	21.25

Based on S/N ratio, new operation parameters were obtained through maximum level of each parameter. Then the prediction of S/N ratio and tensile shear strength is calculated by using the following relationship

$$\eta = \eta_m + \sum_{i-1}^{n}(a-m)$$

Where,

η = Predicted S/N ratio

η_m = Total mean of S/N ratio

a = Mean of S/N ratio at the optimal level

n = The number of main welding parameters,

That significantly affects the performance.

Table 5: S/N Responses for the Tensile Shear Strength

Thickness	Symbol	process parameter	S/N Ratio (db)			Maximum-minimum
			Level 1	Level 2	Level 3	
1.2 mm	A	Electrode force	18.17	18.17	18.10	0.07
	B	Welding current	16.66	18.26	19.52	2.87
	C	Time	18.49	17.53	18.42	0.96
1.5 mm	A	Electrode force	23.53	22.52	10.90	12.63
	B	Welding current	18.20	19.00	19.75	1.55
	C	Time	18.92	19.10	18.93	0.18

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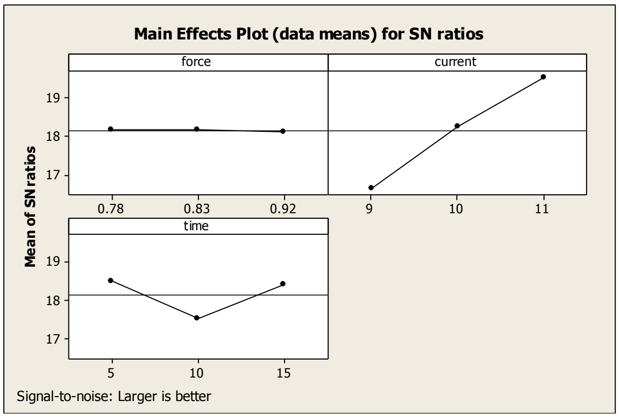
C. Variation in S/N Ratio with process parameter

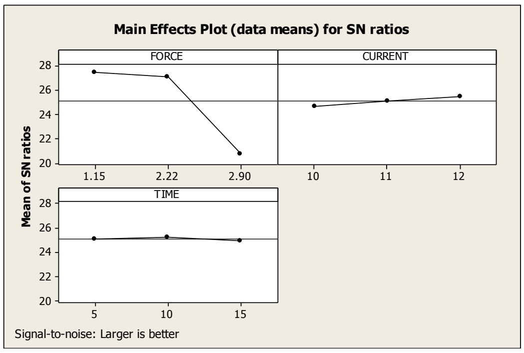
The graph drawn below shows the variation in S/N ratio with the process parameters. The graph shows the effect of the parameters.



Graph 1: Force, Current, Time vs. S/N Ratio for 1.2 mm

Table 6: Result of the confirmation result

Thickness		Initial process parameter	Optimal process parameter		Improvement in S/N Ratio
			Prediction	Experiment	
1.2 mm	Level	$A_1B_1C_3$	$A_1B_3C_1$	$A_1B_3C_1$	1.83
	Tensile strength	08.20	08.80	08.75	
	S/N (db)	18.27	19.85	20.10	
1.5 mm	Level	$A_1B_1C_1$	$A_1B_3C_2$	$A_1B_3C_2$	1.71
	Tensile strength	22.25	23.40	23.47	
	S/N (db)	26.94	28.20	28.65	



Graph 2: Force, Current, Time vs. S/N Ratio for 1.5 mm

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

The results of experimental confirmation are shown in the Table 8. Using optimal welding parameters and comparison of the predicted tensile shear strength with the actual tensile Shear strength using the optimal welding parameters are shown in Table. The improvement in S/N ratio from the starting welding parameters to the level of optimal welding parameters is 1.74 dB and 1.65 dB for 1.2 mm and 1.5 mm sheets respectively. The tensile shear strength is increased by 0.60 and 1.15 times for 1.2 mm and 1.5 mm sheets Respectively. Therefore, the tensile shear strength is greatly improved by using the Taguchi method. From the experiment it is found that the parameters of the spot welding are very important factors for the tensile shear strength of the welding joint. In this experiment it is found that the welding current is the main parameter, which may affect more to the strength of a welding joint. The change in process parameters from the initial parameters results an increase in the strength of the welding joint.

IV. Conclusions

This experiment was based on the optimization of spot welding process parameters to find out the maximum tensile shear strength of the spot welded joint. The mild steel sheets of 1.2 mm and 1.5 mm of dimensions 28 mm × 250 mm have used as the work piece. The Taguchi Method of L9 orthogonal array has used to perform the experiment. All the specimens are spot welded using the taguchi design of experiment. Then the tensile shear strength of work pieces is found out using a tensile testing machine. An optimum parameter combination for the maximum tensile strength was obtained by using analysis of (S/N) ratio. The confirmation tests indicated that it is possible to increase tensile shear strength by using the suitable parameters. The experimental results confirmed the validity of the used Taguchi method is for enhancing the welding performance and optimizing the welding parameters in resistance spot welding operations. The experimental results show that welding parameter are the important factors for the shear strength of the welded joint. which may increase or decrease the strength of the welding joint so we can say that the combination of the suitable parameters is necessary for the maximum strength of the spot welded joint.

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