Parametric Optimization of Spot Welding metal by Taguchi Approach

[1]Mr. Nagsen D. Jadhav, [2]Mr. Rahul A. Patil, [3]Mr. Rajshekhar R. Patil
[1]Assistant professor, [2]Assistant professor, [3]Assistant professor
Department of Mechanical Engineering, Ashokrao Mane Group of Institutions, Vathar, Kolhapur, Maharashtra, India.

***Abstract* - This paper investigates the development of weld zone in resistance spot welding (RSW) which focuses on weld nuggets and strength. In order to study the significance of process parameters i.e. namely welding current, total cycle time and electrode force to get desired weld quality in resistance spot welding the weld quality based on weld nugget and weld strength. The experimentation is conducted for Stainless Steel (SS-204) plate thickness of 16 gauges. Whereas optimum welding parameters are investigated using the Taguchi method with L9 orthogonal array. A significant level of the welding parameters was further obtained by using analysis of variance (ANOVA).This study helps us to find out optimum value for three parameters for resistance spot welding for16 gauge. Optimum value of the response variables are obtained through the conformation test with 95 % confidence level.**

***Index Terms* - Resistance spot welding (RSW), Analysis Of Variance (ANOVA), Stainless Steel (SS), Tensile Strength (T S)**

I. INTRODUCTION

Resistance Spot Welding (RSW) is one of the most important manufacturing processes in automotive industry for assembling bodies. Quality and strength of the welds are defined by the quality of the weld nuggets [1]. The quality is best judged by the nugget size, Heat Affected Zone (HAZ) and joint strength.[3] Therefore, it is of important to select the welding process parameters for obtaining, optimal size of the weld nugget. Welding input parameters play a very significant role in determining the quality of weld nugget and HAZ formation. Usually, the desired welding process parameters are determined based on experience or from handbooks. However, this does not ensure that the selected welding process parameters can produce an optimal weld nugget for that particular welding machine and environment. In order to overcome this problem, various optimization methods can be applied to define the desired output variables through developing mathematical models to specify the relationship between the input parameters and output variables. One of the optimization methods is by using Design of Experiment (DoE). [4]

The operating parameters were optimized using Taguchi Method. Taguchi methods have proved to be successful over the last fifteen years for the improvement of product quality and process performance. Based on the review of past researches, most of the investigations focused on modeling and optimizing single quality characteristic which may deteriorate other characteristics. As the main objective of the manufacturing process is always to improve the overall quality of a product, it is necessary to optimize multiple quality characteristics simultaneously.

Spot welding parameters and heat generation

The three main parameters in spot welding are current, contact resistance and weld time. In order to produce good quality weld the above parameters must be controlled properly. The amount of heat generated in this process is governed by the formula,

$Q = I^2$RT………………….Equation1.

Principle of experimental planning method

The Taguchi design method is a simple and robust technique for optimizing the process parameters. In this method, main parameters which are assumed to have influence on process results are located at different rows in a designed orthogonal array (OA). With such an arrangement, completely randomized experiments can be conducted [5]. An advantage of the Taguchi method is that it emphasizes a mean performance characteristic value close to the target value rather than a value within certain specification limits, thus improving the product quality. [6].In this method, main process parameters or control factors which influence process results are taken as input parameters and the experiment is performed as per specifically designed OA. The optimum condition is selected so that the influence of uncontrollable factors (noise factors) causes minimum variation to system performance. Orthogonal arrays, ANOVA, S/N ratio analysis and F-test are the essential tools for parameter design.

II. MATERIALS AND METHODS

Materials

Stainless steel (SS-202) having chemical composition of (w_t %) C≤ 0.15, P≤ 0.060, S≤ 0.030, Ni=4-6, Mn=7.50-10, Cr 17- 19, Fe=68 .A batch of sheet samples in dimensions of 100mm × 30mm × 1mm were used for spot welding in order to determine weld quality in-term of strength. Copper Electrode was use in this experiment.

Experimental Process

In this study, the electrode size was set to be constant throughout the investigation on welding two plates of various thicknesses. Three welding parameters such as welding current, total cycle time, electrode force were selected for experimentation with three levels of each factor. The value of the welding process parameter at the different levels is tabulated in Table 2. These values were obtained with the help of pilot experiments and tensile test. For 16 Gauge Process parameters with their values at three Levels are as below.

Table1. Process parameters with their values at three Levels

Factors	Unit	Level 1	Level 2	Level 3
Current(power)	KVA	4	6	8
TCT	Cycles	16	18	27
Electrode Force	KN	1.5	2.25	3

Selection of orthogonal Array:

Any nonlinear relationship among the process parameters, if it exists can only be revealed if more than two levels of parameters are considered [2]. Thus each parameter is selected at three levels. According to Taguchi method based on robust design, a L9 orthogonal array is employed for the experimentation.

III. ANALYSIS OF EXPERIMENTAL RESULTS

Signal to Noise Ratio

According to Taguchi method, S/N ratio is the ratio of "Signal" representing desirable value, i.e. mean of output characteristics and the "noise" representing the undesirable value i.e., squared deviation of the output characteristics. In general, signal to noise ratio represent quality characteristics for the observed data in the taguchi design of experiment. Usually there are three characteristics in the analysis of the S/N ratio; smaller is the better, higher is the better and nominal is the best. From this according to output variable, the appropriate ratio is selected.[9][10]. HB includes T-S strength and Nugget diameter which desires higher values. Similarly LB includes Heat Affected Zone (HAZ) for which lower value is preferred

Nominal is Best =$-10log_{10}\sigma$

Smaller is better =$-10log_{10}(l/n \sum_{i=1}^{n} y_i^2)$

Larger is better = $-10log_{10}(l/y^2/n)$

Where,

yi and σ represent observed data at i_{th} trial and n= no of trials.

Experimentation

Experimentation is the important step in the total analysis. Total 9 runs of experiments based on randomized OA were done. Current, Total Cycle Time, electrode force are varied as per values for each level mentioned in Table-1. Responses are taken for each setting. The experimental data is given in Table-2.

Table: 2. Experimental data for tensile shear strength.

Ex. No	Material Thickness	Variable Parameter			Tensile Strength (KN)
		Current (amp)	TCT (cycles)	Electrode Force (KN)	
1	16 Gauge (1.29 mm)	4	15	2.00	14.22
2		4	18	2.25	14.20
3		4	27	3.00	14.24
4		6	15	2.25	14.28
5		6	18	3.00	14.35
6		6	27	2.00	14.30
7		8	15	3.00	14.24
8		8	18	2.00	14.25
9		8	27	2.25	14.20

Analysis of variance: *(ANOVA)*

The Taguchi method also provides a better feel for the relative effect of the different parameters/factors that can be analyzed by the analysis of the variance (ANOVA). It is a statistical method to estimate quantitatively the relative significance factors on quality characteristics [7][8]. If the p-value is less than the significance level, the factor is then regarded to be statistically significant. The relative significance of factors is often represented in terms of F-ratio or in percentage contribution. Greater the F-ratio indicates that the variation of the process parameter makes a big change on the performance. ANOVA for S/N ratio parametric optimization in spot welding at 95% confidence level is given in table

Table-3 : ANOVA, F test value and % contribution (% C) for T-S strength.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Current	2	0.014600	0.014600	0.007300	73.00	0.014
TCT	2	0.000800	0.000800	0.000400	4.00	0.200
Ele. Force	2	0.003800	0.003800	0.001900	19.00	0.050
Residual Error	2	0.000200	0.000200	0.000100		

Total	8	0.019400				

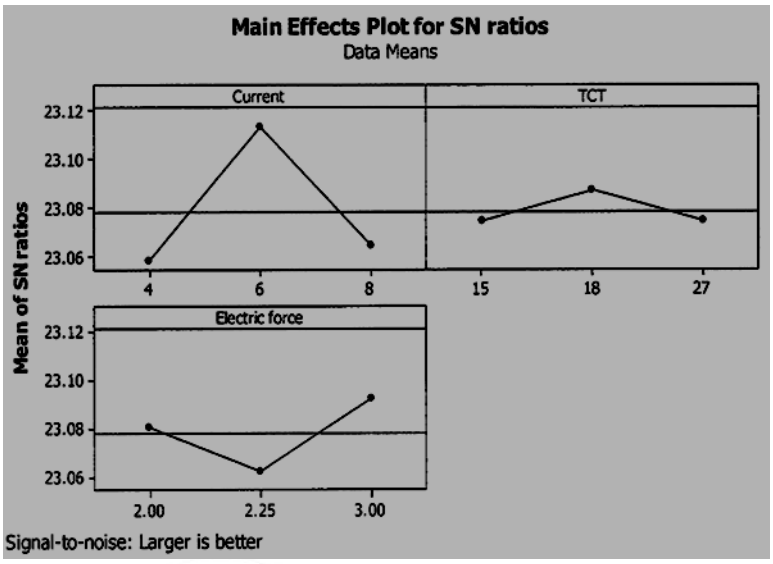

Fig No.1: Graph of Signal to Noise ratio Vs Parameter

IV. RESULTS AND DISCUSSIONS:

From the result is found that, only current is most significant parameter for the best tensile strength and desired size of spot weld, which is responsible to increase heat and finally to change microstructure of metal. The parameter i.e total cycle time is less significant as compared to current and electrode force is not more significant. In this way various parameter has different values of probability of significance for optimization of spot weld at 95% confidence level.

- The contribution of different control factors is welding current (76.20%), total cycle time (19.79%) and electrode force (4.16%).
- The highly effective parameter for the development weld strength is the welding Current.
- The martensite presence in steel structure contributes to increase in strength.

The optimum parameters for nominal weld strength (14.35 KN) are: welding current at level 2 (6.0 kA), weld time at level 2 (18 cycles) and electrode force at level 3(3 KN)

V. CONFIRMATION EXPERIMENT

In this study, after determining the optimum conditions and predicting the response under these conditions, a new experiment was designed and conducted with the optimum levels of the welding parameters. The final step is to predict and verify the improvement of the performance characteristic. [2] After conducting these experiments the tensile shear strength is found same.

VI. CONCLUSION

This paper has presented an investigation on the optimization and the effect of welding parameters on the tensile shear strength of spot welded SS-202 Stainless steel. The level of importance of the welding parameters on the tensile shear strength is determined by using ANOVA. Based on the ANOVA method, the highly effective parameters on tensile shear strength were found as welding current and welding time, whereas electrode force is less effective factor. The results showed that welding current was about Three times more important than the second factor weld time for controlling the tensile shear strength. An optimum parameter combination for the maximum tensile shear strength was obtained by using the analysis of S/N ratio. The confirmation tests indicated that it is possible to increase tensile shear strength. The experimental results confirmed the validity of Taguchi method for enhancing the welding performance and optimizing the welding parameters in resistance spot welding operations.

REFERENCE:

[1] H.Eisazadeh,M.Hamedi, "New parametic study of negget size in resistence sopt welding process using finite element method, "Material and design ,Vol.31,pp149-157,2010.

[2] A.g.Thanur,T.E.Rao,M.S.Mukhedkar,V.M.nandedkar, "Application of Taguchi method for resistance spot welding of galvanized steel", ARPN Journal of Engineering and Applied Sciences, VOL. 5, NO. 11, NOVEMBER 2010 ISSN 1819-6608 ARPN Journal.

[3] A.G.Thanur,V.M.nandedkar, "Application of Taguchi method to determine resistance spot welding conductions of austenitic stainless AISI 304 ",Journal of scientific & Industrial research Vol 69(2010)pp680-683

[4] U.Esme," Application of taguchi method for optimizing of resistance spot welding process", The Arabian Journal of science and engineering,Vol 34 (2009),519-528

[5] J.S.Kwak, "Application of taguchi and response surface methodologies for geometric in surface grinding process", International Journal of Machine Tools & Manufacture,45(2005),327-334.

[6] S.Fraley, J.Z.Date, "Design of experiment Via Taguchi Method: Orthogonal Array", Open Text Book (2006)

[7] J.S.Son, I.S.Kim, “A Study on the prediction of bead geometry in the robotic”, Journal of Mechanical Science and Technology,21(2007),1726-1731

[8] S.C.Juang and Y.S.Tarng, “Process parameter selection for optimizing the weld pool geometry in the tungsten inert gas welding of stainless steel”, Journal of material processing Technology,122(2002),33-37.

[9] A.k.Dubey and V.yadava, “Multi-objective optimization of laser beam cutting process”, Optics and Laser Technology,40(2008),562-570.

[10] A.k.Dubey and V.yadava, “Multi-objective optimization of Nd: YAG laser cutting of nickel-based super alloy sheet using orthogonal array with principle component analysis”, Optics and laser Technology, 46(2008), 124-132.