

Optimization of Process parameters for Tensile strength and Nugget diameter in Resistance Spot welding

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Abstract: The welding current, welding cycle and Pressure are the essential factors that are controlled so as to give the fundamental mix of Heat and pressure to form the weld. The impact of different parameters on Weld quality of Hot rolled E-34 material is decided by utilizing Minitab 16 software and using Design of experiment. Response surface methodology is chosen to design the experiments. The highly significant factor was determined by Analysis of Variance. In the analysis, it was observed that predicted and experimental results were in good agreement and the coefficient of determination were found to be 0.967 and 0.955 for Tensile strength and Nugget diameter implies adequacy of derived model. The objective of research to find out progression in welds strength and also reduces different welding defects.

Keywords: Resistance Spot Welding (RSW), Response Surface Method (RSM), Tensile Strength, Nugget Diameter, Analysis of Variance (ANOVA).

I. INTRODUCTION

It is a productive joining process broadly utilized for the creation of sheet metal assemblies. Resistance welding is gathering of welding forms which produce blend of metals with the heat got from opposition offered by the work piece to the progression of electrical flow through the parts being joined. In this process, heavy electric current is passed through the metals to be joined. This causes local heating to increase temperature to plastic state over limited area of contact. Mechanical pressure is applied to join the metals completely. No additional filler metal is required. The current is passed through the electrodes which incorporate very low resistance in the circuit and the resistance at the joints of metals is very high. Thus maximum heating is produced at the point of contact where weld is to be made. Resistance welding is used for welding of sheet metals of all engineering metals in Steel cabinets, boxes, cans and furniture automobile industry, air craft industry, and pipe and tubing production.

II. LITERATURE REVIEW

The present paper research work related to optimization of process parameter of Resistance spot welding machine and reducing defects in process. The Literature review is given as:

S.M. Hamidinejad et.al. [1] Carried out the modeling and process analysis of resistance spot welding on galvanized steel sheets used in car body manufacturing. Dawei Zhao et.al [2] Investigate and optimized process parameter like welding time, welding current and Electrode force for improvement in failure energy and spot weld quality of spot welded titanium alloy. L. Han et.al. [3] Concluded experimental Correlation Study of Mechanical Strength of Resistance Spot Welding of AA5754. Aluminium Alloy. Nizamettin Kahraman [4] has carried out outcome of experimental investigations to assess the performance of commercially pure (CP) titanium sheets (ASTM Grade 2) were welded by resistance spot welding at different welding parameters and under different welding environments. S. Aslanlar [5] has experimentally study the change in Nucleus size ratio for tensile peel strength and Tensile shear strength were investigate and optimum welding condition for parameters like weld current and time were find out. M. Vural et.al. [6] have aimed to analyze the Effect of welding nugget diameter on the fatigue strength of the resistance spot welded joints of different steel sheets.

Material:

Material used in this study is Hot rolled E-34 steel sheet. Material is cut in samples of dimensions 100×20×2 mm.

Table 1. Chemical Composition of HR E-34

Element	%C	%Mn	%S	%P	%Si	%Al	%Nb	%Ti	%V	Iron
Composition (Wt. %)	0.1	0.7	0.03	0.03	0.2	0.02- 0.06	0.055	0.045	0.095	Balance

III. DOE

DOE (Design of experiment) is use to know the Nature of any system. Experiments were carried out with the help of DOE method. By using DOE, it can predict the result of output maximum or output minimum. In DOE, Response surface Methodology is used for mathematical modeling. Box –Behnken design was used to set experimental runs. The Input process parameters were weld Current, Weld time, Pressure for research work. Nugget diameter and Tensile strength were output parameters. For every experimental run parameter were fit and alter with respect design table. Parameter ranges are decided on the basis of Literature review. Recommended and machine feasibility and specifications given by BAJAJ Materials department Bajaj auto Ltd,Akrudi.

Resistance Spot Welding Machine Specifications

75 KVA Spot welding machine is employed for experimentation .Weld, current, pressure used for responses like nugget diameter and strength of weld. Following figure 1 shows set up of resistance spot welding.



Fig. 1: Resistance Spot welding Machine set up

Experimentation

Welding is carried out with resistance spot welding machine with Supply 415 Volt, Frequency -50 HZ with water cooled Chromium copper electrodes. Specimens are prepared of size 100×20×2 mm and trial taken by spot welding process with above mentioned parameters. Later on same specimens are tested for tensile strength on UTM machine

$$\text{Weld strength} = \text{Breaking Load} / \text{Nugget shearing Area} = P / 2\pi Dt$$

Where D is Nugget diameter & t= Thickness of specimen, P=Breaking Load

IV. RESULTS AND DISCUSSION

Regression Analysis of Nugget Diameter

The mathematical model depicted by equation x is obtained by performing regression analysis on generated data during experimentation. The regression equation is

$$\text{Nugget diameter} = 2.56 + 0.0075 \text{ Weld Cycle} + 0.330 \text{ Current} - 0.390 \text{ Pressure}$$

Model Adequacy Test for Nugget Diameter

Table 2: Pre ANOVA Model Summary Statics of Nugget Diameter

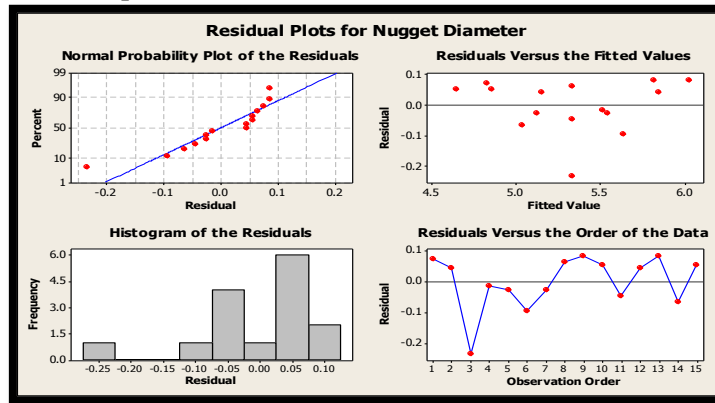
Predictor	Coef	SE Coef	T	P
Constant	2.5603	0.4761	5.38	0.000*
Weld Cycle	0.0075	0.01738	0.43	0.674*
Current	0.33	0.02318	14.24	0.000*
Pressure	-0.39	0.06954	-5.61	0.000*
* Denotes significant terms				

$$S = 0.0983377 \quad R\text{-Sq} = 95.5\% \quad R\text{-Sq}(\text{adj}) = 94.3\% \quad R\text{-Sq}(\text{pred}) = 92.98\%$$

Table 3: ANOVA Model Summary Statics of Nugget Diameter

Source	DF	Contribution	Adj SS	Adj MS	F-Value	P-Value	Remark
Model	3	95.52%	2.2662	0.7554	78.12	0	
Linear	3	95.52%	2.2662	0.7554	78.12	0	
Weld cycle	1	0.08%	0.0018	0.0018	0.19	0.674	Less Significant
Current	1	82.62%	1.9602	1.9602	202.7	0	Most Significant
Pressure	1	12.82%	0.3042	0.3042	31.46	0	More Significant
Error	11	4.48%	0.10637	0.00967			
Lack-of-Fit	9	2.54%	0.06031	0.0067	0.29	0.922	
Pure Error	2	1.94%	0.04607	0.02303			
Total	14	100.00%					

Interpretation of Residual Graph



Graph 1: Residual Plots for Nugget Diameter

Analysis of Nugget Diameter

The responses can be expressed graphically called surface plot or contour plots. Surface and contour plot can be obtained by taking responses in suitable plane against variables. Figure 5 depicts a 3-dimensional surface which shows the effect of current and Weld cycle time on the value of Nugget Diameter under the pressure 4.5.

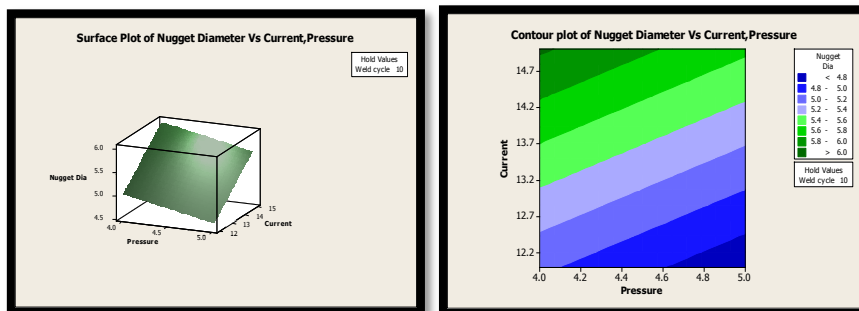


Fig.2: Surface Plot showing Effect of Current and Pressure on Nugget Diameter

Regression Analysis of Tensile Strength

The mathematical model depicted by equation x is obtained by performing regression analysis on generated data during experimentation. The generated regression equation for Tensile strength is given by
 Tensile Strength = 160 + 3.91 Weld Cycle - 6.59 Current + 19.5 Pressure

Model adequacy test for Tensile Strength

Table 4: Pre ANOVA Model Summary Statics of Tensile Strength

Predictor	Coef	SE Coef	T	P
Constant	159.63	12.11	13.18	0*
Weld Cycle	3.9069	0.4421	8.84	0*
Current	-6.5855	0.5895	-11.17	0*
Pressure	19.481	1.769	11.01	0*

*Denotes Significant Term

S = 2.50113 R-Sq = 96.7% R-Sq (adj) = 95.8%
R-Sq (pred) = 93.12%

Table 5: ANOVA Model Summary Statics of Tensile Strength

Source	DF	Contribution	Adj SS	Adj MS	F-Value	P-Value	Remark
Model	3	96.72%	2028.06	676.019	108.06	0	
Linear	3	96.72%	2028.06	676.019	108.06	0	
Weld cycle	1	23.29%	488.44	488.438	78.08	0	Less Significant
Current	1	37.23%	780.64	780.639	124.79	0	Most Significant
Pressure	1	36.20%	758.98	758.98	121.33	0	More Significant
Error	11	3.28%	68.81	6.256			
Lack-of-Fit	9	3.14%	65.78	7.309	4.82	0.184	
Pure Error	2	0.14%	3.04	1.518			
Total	14	100.00%	2096.87				

Analysis of Tensile Strength

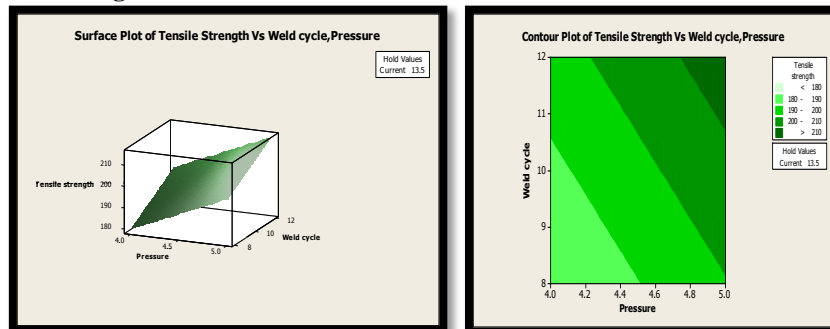


Fig.3: Surface Plot an Contour Plot d showing Effect of Pressure and weld cycle on Tensile strength

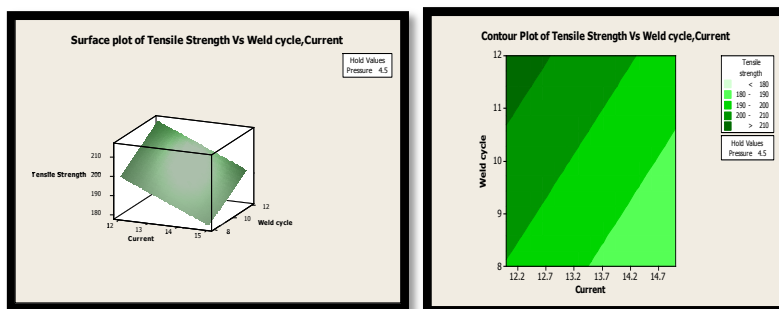
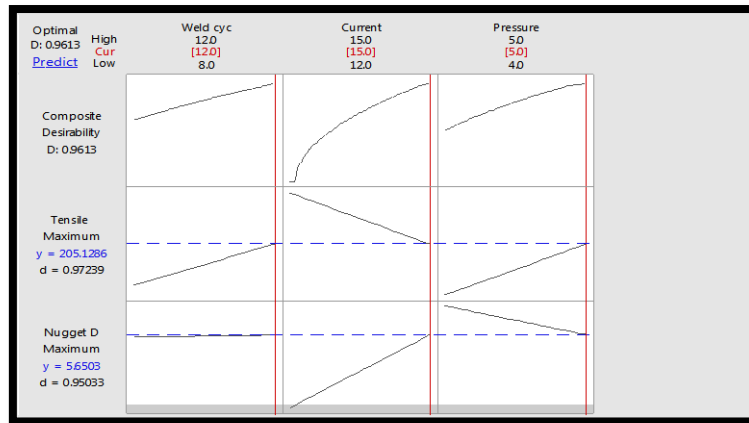


Fig.4: Surface Plot showing Effect of Current and weld cycle on Tensile strength

V. CONFIRMATION TEST

Confirmation test is performed in order to verify the difference between optimized values predicted by RSM’s D-optimization Method and the values obtained through conducting experiment by using parameters level setting for optimal performance of both the responses. Table 6 shows the results obtained through experimentation and prediction by model, also prediction error in terms of % is calculated. It is observed that experimentally obtained values are in close proximity with predicted values of both the responses.



Graph 2: Optimization Plot for Nugget Diameter and Tensile Strength

Table 6: Result of the Confirmation Experiment

Sr.No.	Actual Factors			Nugget Dia.		Pred. Error %	Tensile Strength		Pred. Error %
				(mm)			(N/mm ²)		
	Weld cycle	Current	Pressure	Predicted	Actual		Predicted	Actual	
1	12	15	5	5.65	5.68	0.53	205.12	206.62	0.73

The feasible solution obtained accepted for production trail run. Trail done on successive product lot and survey done regarding qualitative issues of weld obtained by resistance spot welding.

VI. CONCLUSIONS

For the approach of investigation and optimization of responses like Nugget Diameter and Tensile Strength in the Resistance Spot Welding process of Hot Rolled E-34 material .The generated empirical models yield to the following conclusions:

- 1) The outcomes of Analysis of variance and coefficient of determination for Nugget Diameter = 0.95 and for Tensile Strength = 0.96 represent that the fitted regression models is moderately determine the responses.
- 2) Optimum results have been found by using response surface method for tensile strength and nugget diameter are at weld cycle of 12 cycles, current of 15 KA, and pressure of 5 kg/cm²,so by using this combination of input parameter we can reduce various types of defects and error produce during Resistance spot welding operation.
- 3) Rationalization of machining parameters is done for the responses in the resistance Spot Welding machine process of Hot Rolled E-34 material. Since by using proper combinations of input parameter values we can overcome various defects in welding and process is improved.
- 4) The Percentage contribution of Weld strength and Nugget diameter for Weld current, Pressure and weld cycle is found as 37.23%, 36.2%, 23.29% and 82.62%, 12.82%, 0.08% respectively.

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