IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X
PP. 86-91
www.iosrjournals.org

Experimental Investigation of Effect of Process Parameters on Tensile Strength In Resistance Spot Welding Process of HR E-34

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Abstract : *This paper presents an experimental study on the Tensile Strength of resistance spot welded HR E-34 grade material sheets. The sheet materials were joined by using resistance spot welding as a lap joint. Current, Weld cycle, pressure were selected as the input parameters .Tensile strength was selected as Output parameter for an experimental study. The experimental study was conducted under varying welding currents, weld cycle time and pressure for joining two sheets of 2.0 mm. The setting of welding parameters was determined using response surface methodology experimental design method and Box Behkan Design was chosen. The significant level of the welding parameters was further analyzed using analysis of variance (ANOVA). Furthermore, the first order model for predicting the Tensile Strength was developed by using Response Surface Methodology (RSM). In the analysis, it was observed that predicted and experimental results were in good agreement and the coefficient of determination was found to be 0.967 implies adequacy of derived model.*

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

I. Introduction

Spot welding is one of the most seasoned welding procedures. It's one type of resistance welding, which is a strategy for welding two or more metal sheets together without applying so as to utilize any filler material weight and warmth to the territory to be welded. Resistance spot welding is a broadly utilized joining procedure for manufacturing sheet metal gatherings, for example, automobiles, truck lodges, rail vehicles and home applications because of its points of interest in welding effectiveness and suitability for mechanization. It is an efficient joining process widely used for the fabrication of sheet metal assemblies. There are 3000-6000 spot welds in any car, which shows the level importance of the resistance spot welding. RSW has excellent techno-economic benefits such as low cost, high production rate and adaptability for automation which make it an attractive choice for auto-body assemblies, truck cabins, rail vehicles and home appliances.

II. Literature Review

The present paper review research work related to optimization of process parameter of Resistance Spot Welding Machine. The review presented in this section is on different techniques proposed and investigated by researchers resulting in the improvement in Nugget diameter and Weld Strength. Scrutiny of the published research work emphasized the need for such a review reporting all the available literature and suggesting the future direction for research. The present survey explores different methodologies and processes regarding the enhancement of responses like Nugget diameter and Tensile Strength. The Survey is given as:

Nizamettin Kahraman [1] 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 [2] has experimentally study effect of nucleus size on mechanical properties in electrical resistance spot welding of sheets used in automotive industry**.** M. Vural et.al. [3] have aimed to analyze the Effect of welding nugget diameter on the fatigue strength of the resistance spot welded joints of different steel sheets. L. Han et.al. [4] Concluded experimental Correlation Study of Mechanical Strength of Resistance Spot Welding of AA5754 Aluminium Alloy.

S.M. Hamidinejad et.al. [5] Carried out the modeling and process analysis of resistance spot welding on galvanized steel sheets used in car body manufacturing. Dawei Zhao et.al [6] demonstrated Process analysis and optimization for failure energy of spot welded titanium alloy. Seventeen tests were designed according to the three-level three-factor Box–Behnken experimental design and the mathematical model correlating the process parameters and the failure energy was established on the basis of response surface methodology (RSM) technique.

III. Design Of Experiments

In the present investigation, experiments were performed on the basis of the Design of Experiments (DOE) technique. Box-Behnken Design was employed for experimentation in order to improve reliability of result and to reduce the size of experimentation without loss of accuracy. The process parameter selected for the experimentation were Weld time, current, Electrode Force or Pressure and Tensile Strength as proposed response. The experiment has been carried out according to the run order provided in the experiment design matrix given in table. Also all the results obtained are systematically summarized .At the end of each run, setting for all three parameters were changed and reset for the next run. This was essential to introduce variability which is use by errors in experimental settings. Table 1 represents process parameters along with their various levels used in experimentation. 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.

Table 1: Input Parameter Ranges and Level

Parameters	**Low**	**Mid**	**High**
Weld cycle	8	10	12
Current	12	13.5	15
Pressure	4	4.5	5

3.1 Resistance Spot Welding Machine Set up

75 KVA Resistance spot welding machine is used for welding of specimens. Total thickness of material is 2 mm. Weld cycle, current, pressure are used for response like strength of weld. Following figure 3.1 shows Resistance spot welding machine set up in Samarth Engineers,C-104, MIDC Waluj, Aurangabad.

Figure 3.1: Resistance Spot welding Machine set up

3.2 Experimentation

There is shearing action take place at welded area if any tensile nature of load applied during destructive testing. These values are decided from Indian standard of Hot rolled steel. 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.

Formula for strength= Breaking Load/ Shearing Area=$P/2\pi Dt$

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

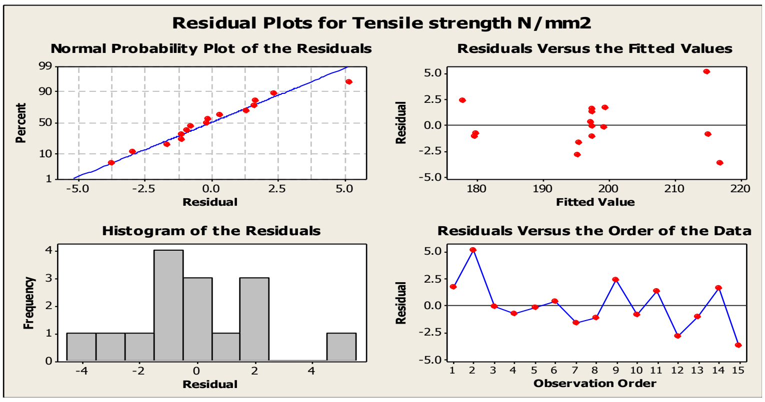
Figure 3.2: UTM Machine

IV. Results And Discussion

4.1 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 = 159.63 + 3.91 Weld Cycle - 6.59 Current + 19.5 Pressure



Graph 1: Residual Plots for Tensile Strength

4.2 Model adequacy test for 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 2: Pre ANOVA Model Summary Statics of Tensile Strength

Source	DF	**Contribution**	Adj SS	Adj MS	F-Value	P-Value
Model	3	96.72%	2028.1	676.019	108.06	0
Linear	3	96.72%	2028.1	676.019	108.06	0
Weld cycle	1	23.29%	488.44	488.438	78.08	0
Current	1	37.23%	780.64	780.639	124.79	0
Pressure	1	36.20%	758.98	758.98	121.33	0
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			

Table 3: ANOVA Model Summary Statics of Tensile Strength

The ANOVA and Fisher's statistical test (F-test) were performed to check the adequacy of the model as well as the significance of the individual parameters. Table 2 shows the pre ANOVA model summary statics of Tensile Strength. In the table 3 variance analysis results of the proposed model of Tensile Strength is presented. The values of 'P' for the terms of model are less than 0.05 (i.e. α=0.05, or 95 % confidence) indicates that the obtained model is considered to be statically significant. It is noted that MS of the model 676.02 is many times larger than MS of the residual (6.26) thus the computed F-value of the model (F=676.02 /6.26) of 108.06 implies that the model is significant. The other important coefficient is R^2 called as determination coefficient and is explained as the ratio of variability explained by the model to the total variability in the actual data and is used as a measure of degree of fit. Table 5 shows the “R-Squared (Adjust R^2)” and “predicted R-Squared (Pred. R^2)” statics. As R^2 approaches unity better the fit of experimental data and there exists less difference between the predicted and actual value of R^2. For the model value of R^2 is 0.967 implies that the model explains variations in the Tensile Strength to the extent of 96.7 % in the given experiment and thus the model is adequate to represent the process. Lower ‘S’ (Standard error of regression) value implies better prediction of the response. ‘S’ value of model is S = S = 2.50113 suggests that the model is significant. Thus the overall prediction capability of the model based on these criteria seems very satisfactory.

4.3 Analysis of Tensile Strength

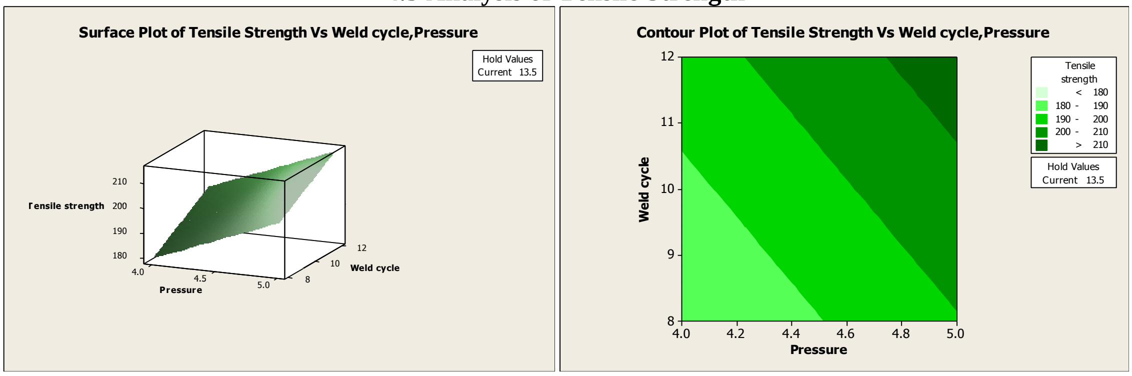


Fig 4.1: Surface and contour Plot showing Effect of Pressure and weld cycle on Tensile strength

Figure 4.3 shows the estimated response surface for the Tensile strength, according to design parameters of pressure and weld cycle, keeping current 13.5 KA constant. It shows that when pressure and weld cycle is increase the Tensile Strength tends to increase appreciably.

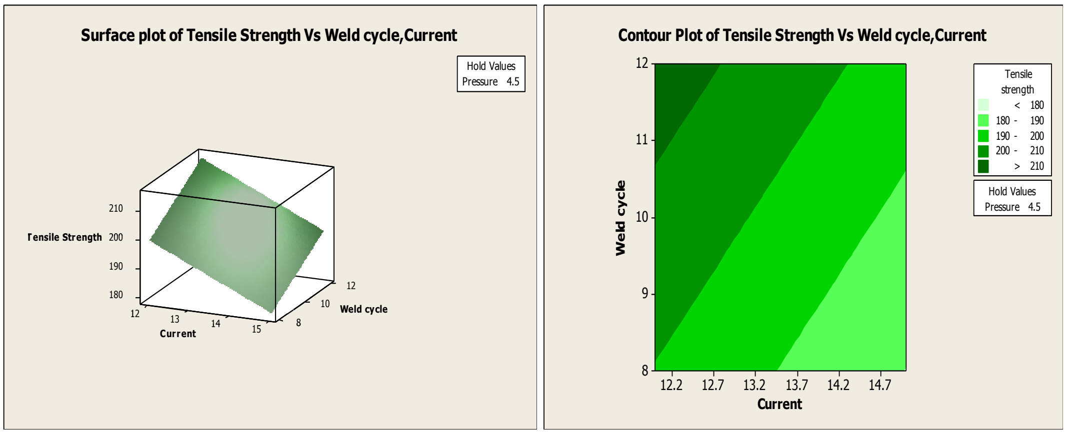
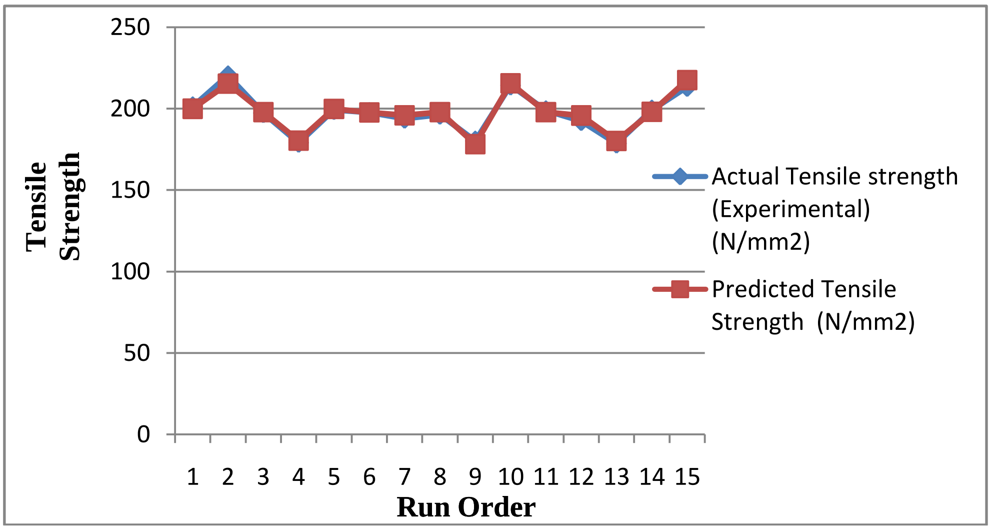


Fig 4.2: Surface and Contour Plot showing Effect of Current and weld cycle on Tensile strength

Figure 4.2 shows the estimated response surface for the Tensile strength, according to design parameters of current and weld cycle, keeping pressure 4.5 kg/cm^2 constant. It shows that when current is increased, the Tensile Strength tends to decrease appreciably.



Graph 2: Comparison of Measured and Predicted value for Tensile Strength

Predicted values of Tensile Strength of regression analysis are obtained using MINITAB17 SOFTWARE. These predicted values are compared with experimental values. . It is clear from the comparison that the values of Tensile Strength predicted by model are close to those recorded experimentally with a 95 % confidence level. Graph 2 shows comparison of measured and predicted values of Tensile Strength.

V. Conclusion

For the approach of investigation and optimization of response 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 results of ANOVA and coefficient of determination for Tensile Strength = 0.96 represent that the fitted regression models of the values of the responses are fairly fitted with the experimental values with a 95% confidence interval.
2) The results indicate that the input parameter significantly influenced their nugget size and strength of weld.
3) Experimental values Nugget Diameter and Tensile Strength can be satisfactorily predicted using residual.
4) The confirmation test performed for the optimum performance of the responses reveals that the negligible difference is present between actual and predicted values of responses.
5) Weld Current and Pressure are most significant factors and weld cycle is less significant in welding.
6) The Percentage contribution for Weld current, Pressure and weld cycle is found as 37.23%, 36.2% and 23.29% respectively.

Acknowledgements

An ack Authors would like to thank Mr. Pravin Dhokane, General Manager, Samarth Engineers Industries, C-104, MIDC Waluj, Aurangabad who have permitted to conduct this experimental work in their organization.

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