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# Experimental Investigation of Tensile Shear Strength on Resistance Spot Welding of Stainless Steel AISI 304-Mild Steel 2062

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## Abstract

*Resistance spot welding is one of the solid-state welding processes and simplest of all Resistance welding. A typical automobile requires 2000-5000 spot welds. In the manuscript, Stainless steel AISI304 and Mild steel 2062 were lap welded by using Resistance spot welding. The influence of various Resistance spot welding process parameters and their levels are considered, i.e. Weld power, Electrode force, Weld time, hold time, Diameter of electrode contact surface on welds were studied for responses parameter of Tensile shear strength. The selection of the process parameters and their levels were determined by conducting the pilot Experiment and literature review. Taguchi's Orthogonal arrays (L18), signal-to-noise ratio and Analysis of variance (ANOVA) are used to find the optimal process parameter levels and to analyze the effect of the selected process parameters on the tensile shear strength of weld metals. The Confirmation test is conducted with an optimal level of selected parameters to validity the Taguchi's Optimization method and optimize the input process parameters and output response factor*

***Keywords-****Resistance spot welding, Stainless steel–Mild steel, Tensile shear strength test, Orthogonal arrays L18, Signal-to-Noise ratio, Analysis of Variance, Taguchi Optimization Method.*

## I. INTRODUCTION

Resistance spot welding is the simplest & commonly used resistance welding process. Spot welding is widely used for fabricating sheet-metal products. Atypical automobile requires 2000-5000 spot welds heat generated in resistance welding is given by following the major advantages include the fact that they don't require consumable electrodes, shielding gases, or flux [4]. The general expression for heat generation is

$H = I^2RT$

Where,

H is heat generated

I is current in ampere

R is resistance of area being welded

T is time for the flow of current.

In resistance spot welding, the tips of two electrodes contact the surfaces of the lap joint of two sheet metals, and resistance heating produces a spot weld. In the work, how the process parameters i.e. weld power, electrode force, weld time, hold time and diameter of electrode contact surface of resistance spot welding processes affect the dissimilar weld metal of stainless steel and mild steel and also find which parameters have significant effect the response factor i.e. tensile shear strength of weld joint. Also find the optimal level of parameter suitable for the dissimilar weld joint of resistance spot welding process. The results obtained are



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useful for parameters setting for design a resistance spot welding machine suitable for dissimilar weld materials when mass production is needed. Manoj Raut and Vishal Achwal [9] investigates the effect and optimization of welding parameters on the tensile shear strength in the RSW process by varying electrodes, welding currents and welding times. Their results showed that it is possible to increase the tensile shear strength of the joint by the combination of the suitable welding parameters, the validity of the Taguchi method was checked for enhancing the welding performance and optimizing the welding parameters. Nagsen [5] investigates the development of weld zone in resistance spot welding (RSW) which focuses on weld nuggets and strength 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. BaluNaik [6] conducts under varying Resistance spot welding parameters such as electrode force, welding current and welding time to establish their influence on spot weld quality. The quality characteristics are shear tensile strength and direct tensile strength of the spot-welded joint has been considered. K. Mathi [7] worked ERSW is applied in dissimilar materials (Stainless steel –Mild steel) and an attempt has been made to investigate the influence of process parameters such as welding current, welding time and electrode force. The welded joints were subjected to tensile test and hardness test. Thus, the effect of parameters on weld quality was characterized. M.Ishak [8] focused on an investigation of mechanical and material properties, and the optimization of mechanical properties in resistance spot welding methods in lap configurations between AISI 301 stainless steel and AISI 1020 carbon steel .J.Pasupathy, V.Ravisankar[10] presents the influence of welding parameters like welding current, welding speed on strength of low carbon steel on AA1050 material during welding.

## II. Material Selection

Based on various aspects of stainless steel AISI 304 and Mild steel 2062 have concluded to weld the dissimilar metals on resistance spot welding method to enhance its strength of weldments by appropriate varying the level of selected process parameters .Stainless steel (304) is composed of chromium, nickel, and manganese in iron. It is excellent corrosion resistance because of chromium content it forms the passivation layer when it is exposed to the atmosphere. Stainless steel 304 is most ductile of all stainless steel and hence can be formed easily. Mild Steel (2062) is tough, ductile malleable and good tensile strength but poor corrosion resistance. The Industry frequently uses mild steel, because of its ductility, malleability & Excellent weldability and low cost when compared to Stainless steel (304) Process parameters and its levels are selected based on the pilot runs and literature review.

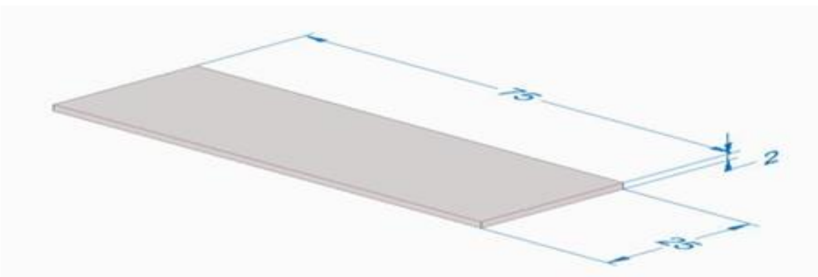


Figure 1. Dimensions of materials in mm



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**TABLE I Specify Parameters and its Units**

| S.NO | PARAMETERS | UNITS |
|---|---|---|
| A | Weld power | W |
| B | Electrode force | Kgf |
| C | Weld time | Secs |
| D | Hold time | Secs |
| E | Diameter of electrode contact surface | Mm |

TABLE II Levels of Process Parameters

| Process Parameters | | | | | | |
|---|---|---|---|---|---|---|
| **S.NO** | **Parameters** | **A** | **B** | **C** | **D** | **E** |
| 1 | Level 1 | 55 | 3 | 2 | 1 | 6 |
| 2 | Level 2 | 60 | 3.5 | 3 | 2 | 7 |
| 3 | Level 3 | - | 4 | 4 | 3 | 8 |

## III. RESULT AND DISCUSSIONS

### A. *Signal to Noise ratio*

Signal means output or response factor and Noise means negative effect on response factor. In general, the 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.

| $L_{18}$ | A | B | C | D | E | Mean tensile shear strength | SN Ratio |
|---|---|---|---|---|---|---|---|
| **1** | 55 | 3.0 | 2 | 1 | 6 | 13.53 | 22.6260 |
| **2** | 55 | 3.0 | 3 | 2 | 7 | 12.94 | 22.2387 |
| **3** | 55 | 3.0 | 4 | 3 | 8 | 13.38 | 22.5291 |
| **4** | 55 | 3.5 | 2 | 1 | 7 | 12.38 | 22.8544 |
| **5** | 55 | 3.5 | 3 | 2 | 8 | 12.42 | 21.8824 |
| **6** | 55 | 3.5 | 4 | 3 | 6 | 14.68 | 23.3345 |
| **7** | 55 | 4.0 | 2 | 2 | 6 | 9.24 | 19.3134 |
| **8** | 55 | 4.0 | 3 | 3 | 7 | 12.60 | 22.0074 |
| **9** | 55 | 4.0 | 4 | 1 | 8 | 13.88 | 22.8478 |
| **10** | 60 | 3.0 | 2 | 3 | 8 | 14.38 | 23.1552 |
| **11** | 60 | 3.0 | 3 | 1 | 6 | 15.64 | 23.8847 |
| **12** | 60 | 3.0 | 4 | 2 | 7 | 16.46 | 24.3286 |
| **13** | 60 | 3.5 | 2 | 2 | 8 | 14.66 | 23.3227 |
| **14** | 60 | 3.5 | 3 | 3 | 6 | 16.80 | 24.5062 |
| **15** | 60 | 3.5 | 4 | 1 | 7 | 15.80 | 23.9731 |
| **16** | 60 | 4.0 | 2 | 3 | 7 | 14.20 | 23.0458 |
| **17** | 60 | 4.0 | 3 | 1 | 8 | 14.62 | 23.2989 |
| **18** | 60 | 4.0 | 4 | 2 | 6 | 15.90 | 24.0279 |

**TABLE III Experimental Run**



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From this according to the output variable, the appropriate ratio is selected. To maximize the tensile shear strength i.e. output response factor then the Large is better SN Ratio is selected.

larger is better

S/N = -10 log 1/n ( $\Sigma$ 1/y2)

Where,

y= measured value in a run

n= no of observations

The goal was to produce high tensile strength spot welds. Higher values represent better strength of the resistance spot weld joint. Therefore, higher– is – better quality characteristic S/N ratio was implemented.

**TABLE IV Mean Strength of S/N Ratio**

| **Level** | **A** | **B** | **C** | D | **E** |
|---|---|---|---|---|---|
| **1** | 12.78 | 14.39 | 13.07 | 14.31 | **14.30** |
| **2** | **15.38** | **14.46** | 14.17 | 13.60 | 14.06 |
| **3** | | 13.41 | **15.02** | **14.34** | 13.89 |
| **Delta** | 2.60 | 1.05 | 1.95 | 0.74 | 0.41 |
| **Rank** | 1 | 3 | 2 | 4 | 5 |

From the table [4] of the S/N ratio, larger is better of the tensile shear strength. The optimum level is

- Weld power -60W
- Electrode force -3.5Kgf
- Weld time - 4secs
- Hold time – 3secs
- Diameter of electrode contact surface-6mm

The mean tensile shear strength of different levels of the parameters is summarized in the above table. The objective of the experiment is to find the optimal settings for the parameters such that the tensile shear strength is maximized. So, larger is better characteristic is used for the tensile shear strength and the corresponding optimal settings of the parameters are highlighted in bold font in the table. The optimal level of the parameters is A2 - B2 - C3- D3 -E1.

Prediction of tensile shear strength

Total of tensile shear strength = 760.53

Grand mean of tensile shear strength = 14.083

T = Total number of observations

T = 253.51 / 18 = 14.083

Predicted tensile shear strength = A2 + B2 +C3-+D3 +E1-4T

=15.38+14.46+15.02+14.34+14.30– 4*14.083 = 17.168 KN

Half-width of confidence interval d = (Fα (1., df of error) MSS error/n eff)0.5

Effective sample size n eff = N / (1+ Total df) N eff = 18 / (1+1+2+2+2+2) = 1.8

From the F table α=0.05, (1,8) = 5.32 d = (5.32*0.5418 / 1.8)0.5 = 1.265

Therefore, confidence interval of the predicted mean = 17.168 ± 1.265 = 15.90 KN to 18.43 KN.



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*B. ANOVA*

Analysis of variance is a statistical-based decision-making tool is used to find the significant factors affecting the response factors also find the amount of contribution of selected welding parameters to the response factors. In this work the welding parameters like Weld power, Electrode force, Weld time, Hold time and the diameter of the electrode contact surface have significantly affect the weld quality and its contribution to the tensile shear strength of the weld is found by statistically there is a tool called F-test, named after FISHER to see which parameters have a significant effect on the output characteristics.

**TABLE V Analysis of Variance**

| Source | DF | Seq SS | Adj MS | F-Value | P-Value | Remarks |
|---|---|---|---|---|---|---|
| **A** | 1 | 12.3495 | 12.3495 | 22.79 | 0.001 | Significant |
| **B** | 2 | 2.0331 | 1.0166 | 1.88 | 0.215 | Significant |
| **C** | 2 | 5.0167 | 2.5083 | 4.63 | 0.046 | Significant |
| **D** | 2 | 1.2987 | 0.6493 | 1.20 | 0.351 | Significant |
| **E** | 2 | 0.0367 | 0.0184 | 0.03 | 0.967 | Pooled |
| **Error** | 8 | 4.3342 | 0.5418 | | | |

Weld power contributes 49.56% is most significantly affect the response parameter. The second parameter which the effect the response factor is weld time is contribution is 20% and the electrode force and hold time contributes 8.11% and 5.18% respectively. The least Significant/Insignificant effecting parameter is the diameter of the electrode contact surface within the confidence level of 95%

*C. Confirmation Test*

After conducting the experimental runs. The result of tensile shear strength of dissimilar weld stainless steel – mild steel as shown below in Table [7]. Each combination of L18 Orthogonal array conducts randomly and repeat each experiment three times to find out the optimal combinations of the input parameters and calculate the best value of the response factors. The optimal condition of Input welding parameters was coincided with the experiments in L18. If it isn't then the confirmation experiment was carried out by setting the parameters at their optimal Level A2 - B2 - C3- D3 -E1 for three replications.

TABLE VI Conformation Test Result

| | **Initial Weld Parameters** | **Prediction optimal welding parameters** | **Confirmation Experiment** |
|---|---|---|---|
| **Level** | A2B1C3D2E2 | A2B2C3D3E1 | A2B2C3D3E1 |
| **Tensile Strength (KN)** | 16.80 | 15.90-18.43 | 16.89 |

The mean of the tensile shear strength of replication is 16.89 KN which is within the confidence interval of 95%.

## IV. CONCLUSION

This paper has described the use of Taguchi's orthogonal array and ANOVA, S/N ratio for analyzing the Tensile shear strength of dissimilar metal stainless steel AISI 304-mild steel 2062 of resistance spot welding by using Minitab software.

- Taguchi method is used to find the optimum electrical resistance spot welding parameter. The following conclusions is drawn is the optimal welding condition is the weld power 60W (A2),



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Electrode Force 3.5kgf(B2), weld time is 4s(C3), Hold time is 3s(D3) and Diameter of electrode contact surface is 6mm (E1).

- From the ANOVA is found that the welding power is the most significant parameter affecting the response factor. S/N Ratio is used to predict the LARGER IS BETTER Tensile shear strength.
- Confirmation test was conducted with these optimal level of selected process parameters to output responses factor tensile shear strength is 16.89 KN, its confirms the predicted mean shear strength 15.90KN to 18.43KN and also indicated the validity of the present optimization procedure by using Taguchi methodology.

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