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# *Analysis of Spot Welding Process Parameters by Using Response Surface Methodology for Zinc Coated Steel Sheet*

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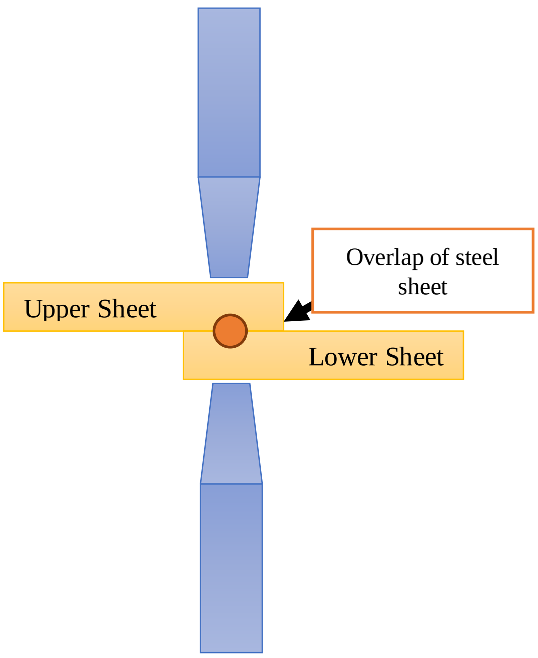
A B S T R A C T

Resistance Spot Welding (RSW) is used to joint sheet metal sheets up to 3.2 mm thickness. It may be similar and dissimilar steel sheet. Generally Resistance spot welding process is applying in the automobile and aerospace industry. Moreover, the process requires very less operator's skill. In this work, the systematic analysis of resistance spot welding of zinc coated steel sheet has been done by using the response surface methodology. The effect of input process parameters has been evaluate by using the response surface of nugget size and contour plots.

**Keywords:**RSW, Zinc coated steel sheet, contour plots, response surfaces plot

## 1 Introduction

Resistance Spot Welding (RSW) is used to joint sheet metal sheets up to 3.2 mm thickness. It may be similar and dissimilar steel sheet. Generally Resistance spot welding process is applying in the automobile and aerospace industry. Moreover, the process requires very less operator's skill. In RSW, the weld nugget is produced at the faying surface of metal sheets by the heat generated due to the electrical resistance offered by the metal sheets. The heat generated in the process is adequate to melt and fuse the faying surfaces. The total heat generation in the process increases with the increase in the welding current. The process is used in preference to mechanical fastening, such as riveting or screwing, when disassembly for maintenance is not required. It is much faster and more economical because separate fasteners are not needed for assembly.



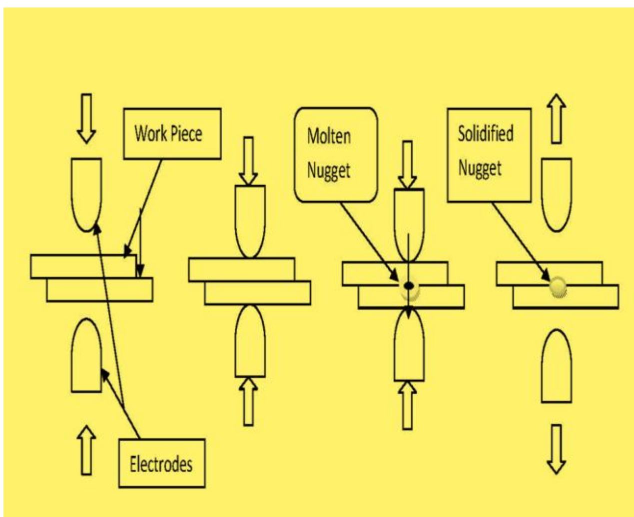




**Figure 1: Schematic diagram of RSW**

**Figure 2: Schematic diagram of resistance spot welding [2]**

Factorial designs are most capable to find out the effect of process parameters on the responses. By a factorial design, each complete trial or replicate of the experiment all possible combinations of the levels of the factors are investigated. For example, if there are a levels of factor A and b levels of factor B, each replicate contains all AB treatment combinations. When factors are arranged in a factorial design, they are often said to be crossed.

Boriwal L et al [1]. They investigated the optimized process parameters of the zinc coated steel sheet by using the full factorial design. They performed the pilot experiments to identify the range and levels of input process parameters. Welding current, weld time, and electrode pressure has been taken as a input process parameters and nugget size as response of it. Based on 3 level and 3 factor, total 27 combination of process parameters has been developed say design of experiments by using the Minitab 14 software.Mohammed B et al. [4] they combined the box bhenken design technique with the response surface methodology to optimization of the photo catalytic mıneralızatıon of C.I. basıc red 46 dye from aqueous solutıonXiaobing C et. al [5] they applied the response surface methodology and genetic algorithm to analyzed and optimized the resistance spot welded 5052 aluminum to Al-Si coated boron steel.Hanane C et. al.[6] They used Box-Behnken design in the response surface methodology (RSM) to analyze the modelization and optimization of Methyl Orange (MO) mineralization parameters. The process was carried out in the presence of lanthanum (La) doped mesoporous titanium dioxide (TiO2) by a simple impregnation method using various La doping amounts (0.5, 1.5 and 3 wt%).Koilraj M et al [6] Author's applied the Taguchi L16 orthogonal design of experiments to optimize the process parameter of friction stir welding process to join the dissimilar Al–Cu alloy AA2219-T87 and Al–Mg alloy AA5083-H321 plates.

## 2. Response Surface Methodology

Response surface methodology is a combination of mathematical and statistical techniques, which consists the experimental design for defining the range of the independent input variables, empirical mathematical model to explore an appropriate approximating relationship between responses and process variables, and the optimization of the response variables influenced by various process parameters. The effect of spot welding and weld bonding process parameters on the response i.e. tensile shear strength and peel strength were evaluated by mathematical model.In this research work, the range and level of input process parameters has been taken from the published article of Boriwal L. In that article authors were selected the welding current (kA), Weld cycle and electrode pressure (kg/cm2). They had create the full factorial design matrix for the experimentation of resistance spot welded join. Full factorial Design produce 3*3= 27 set of combination of input process parameters to produce the spot weld joints.

Table 1 Design matrix [1]

| StdOrder | Current (kA) | Weld Time | Pressure (kg/cm2) |
|---|---|---|---|
| 1 | 6 | 4 | 3 |
| 2 | 7.99 | 4 | 3 |
| 3 | 6 | 6 | 3 |
| 4 | 7.99 | 6 | 3 |
| 5 | 6 | 5 | 2 |
| 6 | 7.99 | 5 | 2 |
| 7 | 6 | 5 | 4 |
| 8 | 7.99 | 5 | 4 |
| 9 | 6.995 | 4 | 2 |
| 10 | 6.995 | 6 | 2 |
| 11 | 6.995 | 4 | 4 |
| 12 | 6.995 | 6 | 4 |
| 13 | 6.995 | 5 | 3 |
| 14 | 6.995 | 5 | 3 |
| 15 | 6.995 | 5 | 3 |

## 3. Design Analysis

Surface methodology is a collection of mathematical and statistical techniques, which consists of the experimental design for defining the range of the independent input variables, empirical mathematical model to explore an appropriate approximating relationship between the output responses and the input variables, and optimization methods for achieving the optimum values of the process parameters that produce the desirable responses

## 4. Results and Discussion

The response surface and contour plots play a very important role in the study of a response surface. They provide an effective way to visualize the relationship between responses and experiment levels of each variable and the type of interaction between two process parameters.

The states of the contour plots, elliptical or circular, demonstrate whether the common interaction between the process parameters are significant or not. Circular contour plot shows that the interaction between the equivalent parameters are negligible while elliptical contour plot shows that the interaction between the equivalent parameters is significant. The tri-dimensional response surface and two-dimensional contour plots are obtained through setting the one process parameter as constant value while remain two process parameters vary between the defined range.

Figure 3 shown the main effect plots for the nugget size of spot welded joints. It shown that welding current and weld time increases the nugget size and electrode pressure decreases the nugget size due to surface contact area improvement. Fig. 4 & Fig. 7 shows contour plots of nugget size of spot welded joint from the regression model at welding current 4 kA to 6.3 kA, weld time 4 cycles to 6 cycles at electrode pressure 3 kg/cm2. It is apparent that nugget size increases with higher welding current and weld time. This is due to increase of welding current with weld time up to its limit results in increasing of heat at faying surfaces and hence tensile shear strength increase. The maximum value of nugget size is achieved at 6.3 kA welding current and 6 cycle weld.

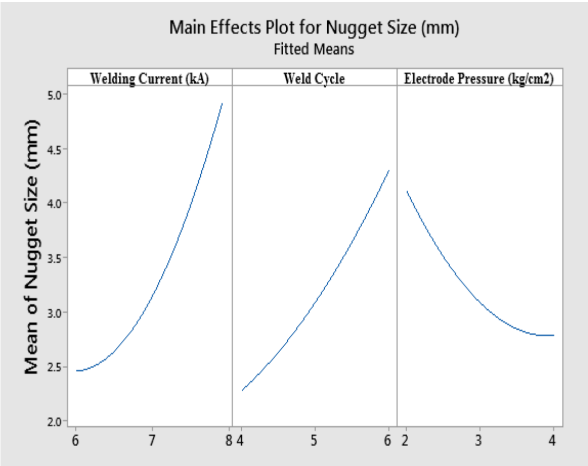



Figure 3 Main effect plots for Nugget Size of spot welded joints

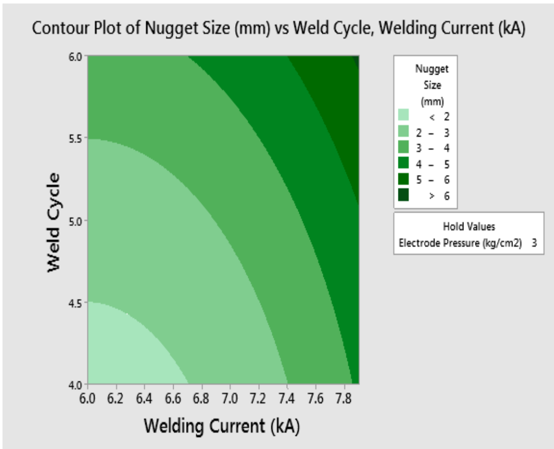



Figure 4 Contour plot with electrode pressure kept at 3 kg/cm2

Fig. 8 & Fig. 10 shows response plots of nugget size of spot welded joint from the regression model at welding current 4 kA to 6.3 kA, weld time 4 cycles to 6 cycles at electrode pressure 3 kg/cm2. It is apparent that nugget size increases with higher welding current and weld time. This is due to increase of welding current with weld time up to its limit results in increasing of heat at faying surfaces and hence tensile shear strength increase. The maximum value of nugget size is achieved at 6.3 kA welding current and 6 cycle weld time at 2 kg/cm2 electrode pressure.

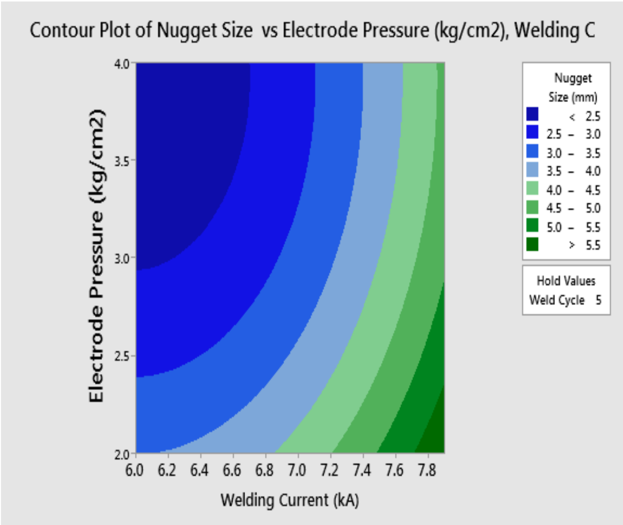



Figure 5 Contour with the weld time kept at 5 cycles

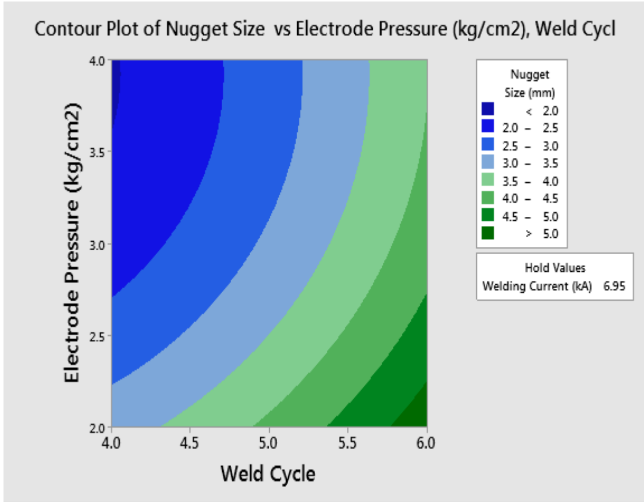



Figure 6Contour plot with the welding current at 6.95 kA

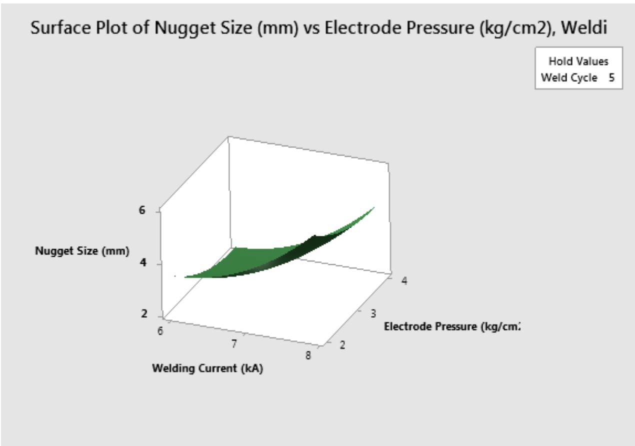



Figure 7Surface response plot with weld cycle at

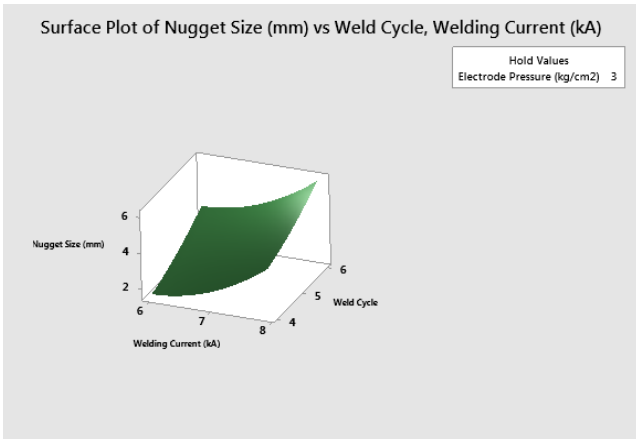



Figure 8Surface response plot with electrode pressure at 3 (kg/cm2)

## 5. Validation of developed model

The most important step to verify the developed model is confirmation test case experiments. The developed model is validated by confirmation test results.Predicted value was investigated by the regression equation and compared with the actual value (test case results). The percentage of error between the actual values and predicted values results show that the models developed are quite accurate as the percentage error between the estimated and the experimental values is small. Maximum 13.11 % error has been observed.

## 6. Conclusion

The response surface and contour plots play a very important role in the study of a response surface. They provide an effective way to visualize the relationship between responses and experiment levels of each variable.

- It is apparent that nugget size increases with higher welding current and weld time. This is due to increase of welding current with weld time up to its limit results in increasing of heat at faying surfaces and hence size increase.
- The maximum value of nugget size is achieved at 6.3 kA welding current and 6 cycle weld time at 2 kg/cm2 electrode pressure.
- The maximum value of nugget size is achieved at 6.3 kA welding current and 6 cycle weld time at 2 kg/cm2 electrode pressure.

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