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Taguchi Analysis of tensile strength of Resistance Spot Welding weld

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Abstract: This research deals with an approach for optimizing the resistance spot welding (RSW). It is a process that is being used in industry for sheet joining purposes especially in the Automobile and Aerospace industry. The problems associated with RSW are tendency of alloying with the electrode resulting in increased tool wear, and subsequent deterioration of weld quality. The complicated behaviour of this process is analyzed to set the optimum parameters to get good quality weld. Furthermore, four important process parameters, namely welding current (WC), welding time (WT), materials and thickness are considered as the factors influencing the quality of the joints. The setting of welding parameters was determined using Taguchi experimental design method and L9 orthogonal array was chosen. The output parameter considered in this approach is the tensile strength of the weld.

Keywords: Resistance spot welding, Taguchi method, Tensile Strength, weld current.

I. INTRODUCTION

Resistance spot welding is performed by combining heat with pressure and time. Further to this, the process is carried on by using a current flow through the confrontation of the material so that it localizes heat in one spot. Although, much work has been done on RSW using different materials Darwishet. al.[1] proposed response surface methodology (RSM) for the influence of spot welding parameters on the strength of spot welded Aluminium sheets. Hefin Rowlands et. al. [2] presented the use of Taguchi's loss function analysis and RSM to a spot welding process in order to discover the key process parameters that influence the tensile strength of welded joints. Aslanlar [3] in his study has done the characterization ,understanding the effect of welding current and welding time on tensile shear strength and tensile peel strength of RSW of chromided micro-alloyed steel sheets having 0.8 mm thickness and galvanized chromided micro-alloyed steel sheets having 1.0 mm thickness. The optimum parameters are suggested to get appropriate Tensile strength. Mukhopadhya et. al. [4] have studied the effects of nugget diameter, mode of loading and alloy chemistry on the strength of spot welds in thin sheets of interstitial free steels. The results unambiguously infer that the strength values of spot welds remain same in a specific mode of loading, while the load-bearing capacity increases with increasing nugget size.

The strength of the spot weld has been found higher than that of the base metal with an interesting observation that the former bears a constant ratio with the latter. Ugur Esme [5] reported an investigation on the optimization and effect of welding parameters on the tensile shear strength of spot welded SAE 1010 steel sheet using Taguchi method. He investigated that increasing welding current and electrode force are prime factors controlling the weld strength. He concluded that Taguchi method can be effectively used for optimization of spot welding parameters. Thakur et. al. [6] presents an experimental investigation for optimization of Tensile Shear (T-S) strength of RSW for Galvanized steel by using Taguchi method. The experimental results confirmed the validity of used Taguchi method for enhancing welding performance and optimizing the welding parameter in RSW process. The confirmation test indicated that it is possible to increase tensile shear strength significantly. Floreaet. al. [7] worked on Resistance spot welding of 6061-T6 aluminum. Their study offers a novel research approach to compare weld quality for different welding conditions in order to achieve optimal end-product results. Quasi-static tensile tests were used to characterize the failure loads in specimens based upon these same process parameters. This study reveals that the welding process parameters have a great influence in the quality of the RSW joints. Profilo meter results clearly indicate that the larger the current, the deeper the weld imprints. It was found that the depth of the top part of the resistant spot welds varies linearly with respect to the applied electric current. Hamidinejad et. al. [8] RSW process of the galvanized interstitial free (IF) steel sheets and Galvanized bake hardenable (BH) steel sheets, has been modeled and optimized. The effects of welding parameters and their interactions on the tensile–shear strength were analyzed on the basis of the ANN model. Muhammad et. al. [9] deals with an approach for optimizing the weld zone developed by the resistance spot welding (RSW). This approach considers simultaneously the multiple quality characteristic (weld nugget and heat affected zone) using Multi-objective Taguchi Method (MTM).

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II. PROPOSED ALGORITHM

Based on literature survey and preliminary investigations, the following four parameters i.e. current (A), weld time (sec), thickness (mm) and material were chosen as input parameters. Table 1 shows different levels of these control parameters considered for welding operation. In the present work the performance of Resistance Spot Welding is measured by the tensile strength of the weld joint.

Table 1: Different level of the control parameters

INPUT PARAMETERS	SYMBOLS	LEVEL 1	LEVEL 2	LEVEL 3
CURRENT(A)	A	4000	5000	6000
WELD TIME(sec)	B	1	2	3
THICKNESS(mm)	C	0.65	0.80	1.26
MATERIAL	D	GS	MS	SS

In the present work Taguchi's parameter design approach is used to study the effect of process parameters on the various responses of the RSW process. For better weld joint higher tensile strength is always desired. Hence, tensile strength has been categorized as 'larger-the-better' type problem. The signal to noise ratio η (Vc) in this case has been calculated as follows:

$$\text{S/N ratio} = \eta\ (Vc) = -10 \log 10 \text{ (mean square reciprocal of tensile strength)} \qquad (1)$$

III. EXPERIMENT AND RESULT

On the basis of input factors and their levels, an orthogonal array (L9) consists of 9 experimental runs has been employed for modeling the RSW process. The 9 experiments were performed on Spot welding machine by KOKO TAWA. For each experimental run, the specified input parameter combination was set and the welding was done. The tensile strength for each work piece was measured using universal tensile testing machine is calculated.

Figure 1: Workpieces before welding, after welding and after tensile test

In the present study all the designs, plots and analysis have been carried out using Minitab statistical software. The experimental results for tensile strength with S/N values are given in Table 2.

Table 2: Set of experiments with their S/N ratio values.

Current(A)	Time(sec)	Thickness(gauge)	Material	Force (kgf)	SNRA1
4000	1.5	24	GS	324	50.2109
4000	2.0	22	MS	400	52.0412
4000	2.5	18	SS	510	54.1514
5000	1.5	22	SS	618	55.8198

5000	2.0	18	GS	490	53.8039
5000	2.5	24	MS	500	53.9794
6000	1.5	18	MS	451	53.0835
6000	2.0	24	SS	470	53.4420

Table 3: Response Table for Signal to Noise Ratios Larger is better

Level	Current	Time	Thickness	Material
1	52.13	53.04	53.68	52.66
2	54.53	53.10	53.94	53.03
3	53.50	53.03	53.54	54.47
Delta	2.40	0.99	1.40	1.81
Rank	1	4	3	2

IV. EFFECT ON TENSILE STRENGTH

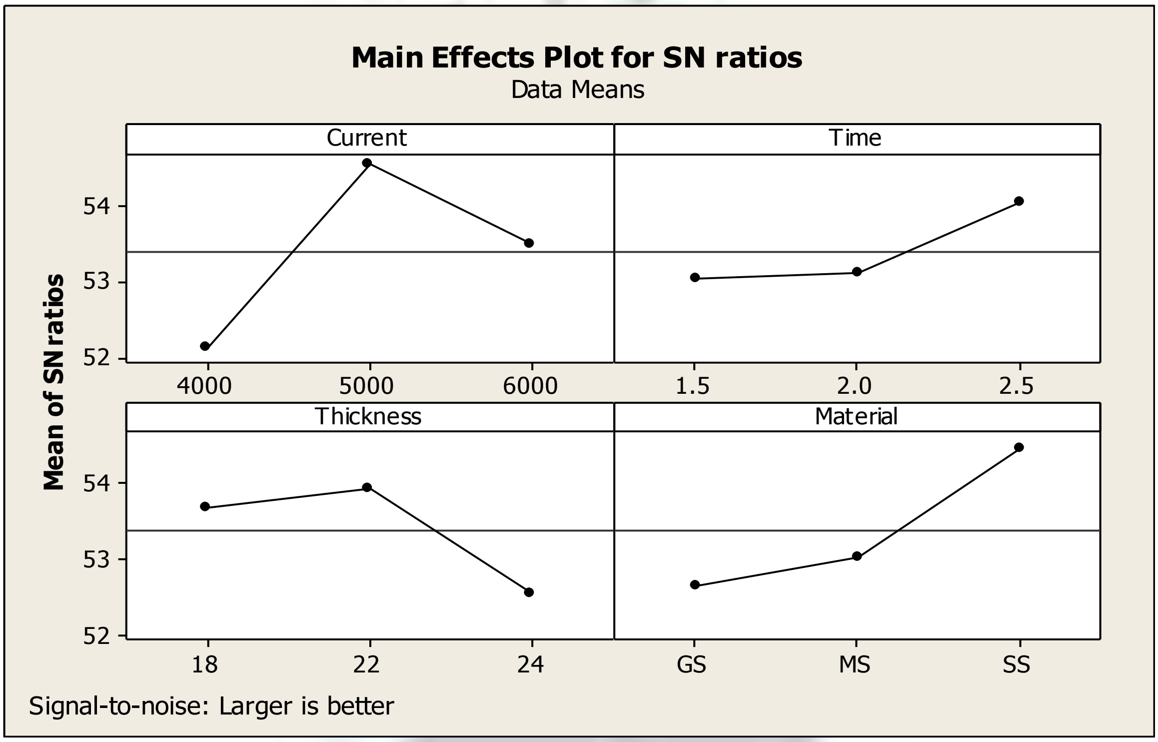

Figure 2: Main effect plots for S/N ratio (Tensile Strength) with current, time, thickness and material

Figure 2 shows the S/N ratio graph where the centre line is the value of the total mean of the S/N ratio. Basically, the larger the S/N ratio, the better is the quality characteristic for the tensile shear strength. The response of S/N ratio with respect to tensile strength indicates the welding current to be the most significant parameter that controls the weld tensile strength where's the holding time, thickness & Material are less significant in this regard.

Figure 2 shows variation of S/N ratio with respect to the welding current. As the current increases the weld strength also increases. But after a certain current value, strength reduces due to formation of crater due to high heat generated. In the plot maximum strength is at $A_{2.}$ after A_2 point the weld strength starts to decline with further increase in current.

Figure 2 shows variation of S/N ratio with respect to the weld time. With increase in weld time, the strength increases because the material will get proper time for the appropriate weld. Maximum strength is obtained at B_3.

Figure 2 shows variation of S/N ratio with respect to thickness. As the thickness is more the strength of the weld will be less because the penetration of heat through the pieces is not proper. As the thickness is reduced the strength of the weld is increased as the penetration of heat through the pieces is adequate but as we decrease the thickness further the strength will reduced because of deep indentation of welding electrodes in sheets due to high heat generation. Maximum strength is obtained at $C_{2.}$

Figure 2 shows maximum strength is obtained with Stainless Steel D_3, Mild steel has less strength as compared to Stainless Steel followed by Galvanized Steel having the lowest strength. The reason for highest value of weld strength of Stainless steel is the high electrical resistance. Also the reason for lowest weld strength of Galvanized Steel is due to the presence of zinc coating, though it is use to prevent corrosions, The low melting point of the zinc coating, compared to the fusion temperature of the steel sheet, causes the zinc to vaporize and the vaporization of the zinc can cause porosity in the weld and a general weakening of the expected weld strength.

Estimation of optimum response characteristics

The optimum value of characteristics is predicted at selected levels of significant parameters. The estimated mean of the response characteristics (tensile strength) can be computed as follows:

n_{opt} = Average performance + Contribution of significant factors at optimum levels

$= T + (A_2 - T) + (B_3 - T) + (C_2 - T) + (D_3 - T)$

$= A_2 + B_3 + C_2 + D_3 - 3T$

Where T = average results of S/N ratio for TS;

A_2 = S/N ratio value of current at 2^{nd} level,

B_3 = S/N ratio value for time at third level,

C_2 =is the S/N ratio value at second level of thickness

D_3 =is the S/N ratio value at third level of material.

Substituting the values from table 3 into the various terms of above equation,

$n_{opt} = (54.53) + (54.03) + (53.94) + (54.47) - 3 \times (53.38)$

$n_{opt} = 56.83$

$y^2_{opt} = \frac{1}{10^{\frac{-nopt}{10}}} = 481947.79$

$y_{opt} = 694.22$ kgf

Confirmation experiment was conducted at an optimal condition for observing accuracy of the developed Taguchi model. Based on the confirmation test results, it is found out that the developed model can be effectively used to obtain optimum the tensile strength of the weld in resistance spot welding.

CONCLUSION

Experiments are performed using Taguchi's design of experiment methodology. The effects of the process parameters viz. current, weld time , thickness and material were studied. The response of S/N ratio with respect to tensile strength indicates the welding current to be the most significant parameter that controls the weld tensile strength where's the weld time, material and thickness are comparatively less significant in this regard. Out of three materials selected, Stainless steel found to be best with Resistance Spot Welding.

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