Volume : 2 | Issue : 11 | November 2013 • ISSN No 2277 - 8179

Research Paper

Analysis of Effect of Process Parameters on Resistance Spot Welding Shear Strength

Engineering

KEYWORDS : Resistance spot welding, Taguchi method, S/N ratio, tensile strength.

Kamble Vijay Ananda

Asst. Prof. in Mechanical Engineering in Textile and Engineering Institute Ichalkaranji 416115

ABSTRACT

Resistance spot welding is commonly used in the automotive industry. because it has the advantage which is high speed, high-production assembly lines and suitability for automation. The objective of this paper is to find out the influence of the various process parameters on the tensile shear strength of the resistance spot welded joints for low carbon steel. The problems associated with RSW are tendency of alloying with the electrode resulting in increased tool wear, and subsequent deterioration of weld quality. More current and time lead to expulsion and overheating of the electrode, affecting the weld quality and less value result in insufficient weld strength. The complicated behavior of this process must be analyzed to set the optimum parameters to get good quality weld. The experimental studies were conducted under varying welding current, welding time, electrode diameter and electrode force. By doing the analysis, an optimum parameter combination for the maximum tensile shear strength was obtained. The settings of the process parameters were determined by using Taguchi's experimental design method. Orthogonal arrays of Taguchi, the signal-to-noise (S/N) ratio, the analysis of variance (ANOVA) employed to find the optimal process parameter levels and to analyze the effect of these parameters on tensile shear strength values.

INTRODUCTION

Spot, seam and projection welding are three resistance welding processes in which coalescence of metal is produced at the faying surface by the heat generated at the joint by the contact resistance to the flow of electric current. Force is always applied before, during and after the application of current to prevent arcing at the faying surfaces and in some applications to forge the weld metal during post heating. The process is completed within a specified cycle time. Generally, melting occurs at the faying surface during welding. The Resistance Spot Welding (RSW) is getting significant importance in manufacturing car, bus and railway bodies etc. due to automatic and fast process. [7]

In resistance welding the heat is generated by the passage of an electric current through the resistance formed by them contact between two metal surfaces. In this, current density is so high that a local pool of molten metal is formed, joining the two parts. The current is often in the range 1 000-1 00 000 A, and the voltage in the range 1-30 V [7]

Different types of resistance welding are spot welding, seam welding, projection welding, resistance butt welding (upset welding), and flash welding.

Common properties:

- Generally fast, efficient and low polluting.
- No filler materials are required.
- Generally each machine can be used for one type of welding. [7]

Literature Review

Ugur Eşme has studied optimization of RSW process parameters for SAE 1010 steel using Taguchi method. He investigated that increasing welding current and electrode force are prime factors controlling the weld strength. D.S. Sahota, Ramandeep Singh, Rajesh Sharma, Harpreet Singh has studied the effect of parameters on resistance spot weld of ASS316 material. From his results it is clear that parameters significantly affect both the mean and the variation in the percentage improvement in Hardness values of the ASS316 material.

A.K. Pandey, M.I. Khan. K.M. Moeed investigation indicate the welding current to be the most significant parameter controlling the weld tensile strength as well as the nugget diameter for AISI-1008 steel sheets .Also they effectively use Taguchi method for optimization of spot welding parameters. Niranjan Kumar Singh and Dr. Y. Vijayakumar has presented an investigation on the optimization and effect of welding parameters on indentation of spot welded AISI 301L stainless steel. [4]

M. Vural et al. have done study on the fatigue strength of resistance spot welded galvanized steel sheets and AISI 304 sheets. The results show that galvanized steel sheet combination has the highest fatigue limit. The sheet combination which has minimum fatigue limit is galvanized-AISI 304 sheet combination. [5]

Resistance spot welding

Resistance welding is a thermo-electric process in which heat is generated at the interface of the parts to be joined by passing an electrical current through the parts for a precisely controlled time and under a controlled pressure (also called force). [2]

Working principle

Resistance welding is accomplished when current is caused to flow through electrode tips and the separate pieces of metal to be joined. The resistance of the base metal to electrical current flow causes localized heating in the joint, and the weld is made. [3]

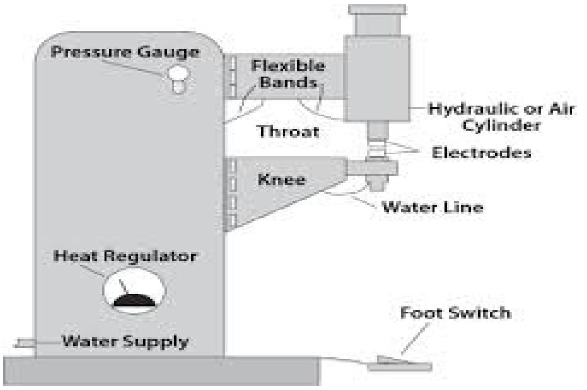

Fig.1 Spot welding machine

Heat Generation

A modification of Ohm's Law may be made when watts and heat are considered synonymous. When current is passed through a conductor the electrical resistance of the conductor to current flow will cause heat to be generated. The basic formula for heat generation may be stated:

$H = I^2R$

H = Heat

I^2 = Welding Current Squared

R = Resistance

The resistances are in series, and each point of resistance will retard current flow. The amount of resistance at the interface of the work pieces, depends on the heat–transfer capabilities of the material, the material's electrical resistance, and the combined thickness of the materials at the weld joint. It is at this part of the circuit that the nugget of the weld is formed. [3]

Materials for electrode and work piece

The physical metallurgy of the materials to be welded determines the application of the resistance welding process variables. In general there are two categories of metals to be welded: "Conductive" (such as aluminium, copper, silver and gold), and "Resistive" (steel, nickel, inconel, titanium, tungsten, molybdenum) with a third, small, middle ground category occupied primarily by brass. The "rule of opposites" applies to matching electrodes to workpieces to be welded. The general rule (with a few exceptions such as aluminium and beryllium copper) is to utilize conductive electrodes against resistive parts and resistive electrodes against conductive parts. By extension, when welding dissimilar materials, the upper and lower (or anode and cathode) electrodes must be of different materials to each other in order to apply the "rule of opposites." [2]

Factors in spot welding

The various factors in resistance spot welding-

A. Welding time
B. Pressure
C. Electrode Tips
D. Welding/ Electrode Force
E. Electrode Tip Size/ Electrode diameter

Welding time

Resistance spot welding depends on the resistance of the base metal and the amount of current flowing to produce the heat necessary to make the spot weld. Another important factor is time. In most cases several thousand amperes are used in making the spot weld. Such amperage values, flowing through a relatively high resistance, will create a lot of heat in a short time. With the addition of the time element, the formula is completed as follows:

$H = I^2*R*T*K$

H = Heat

I^2 = Current Squared

R = Resistance

T = Time

K = Heat Losses

Pressure

The effect of pressure on the resistance spot weld should be carefully considered. The primary purpose of pressure is to hold the parts to be welded in intimate contact at the joint interface. This action assures consistent electrical resistance and conductivity at the point of weld. [3]

Electrode Tips

Copper is the base metal normally used for resistance spot welding tongs and tips. The purpose of the electrode tips is to conduct the welding current to the work piece, to be the focal point of the pressure applied to the weld joint, and to conduct heat from the work surface. The tips must maintain their integrity of shape and characteristics of thermal and electrical conductivity under working conditions. Electrode tips are made of copper alloys and other materials. [8]

Welding/ Electrode Force

The pressure exerted by the tongs and the electrode tips on the work piece has a great effect on the amount of weld current that flows through the joint. The greater the pressure, the higher the welding current value will be, within the capacity of the resistance spot welding machine. Setting pressure is relatively easy. Normally, samples of material to be welded are placed between the electrode tips and checked for adequate pressure to make the weld.

Electrode Tip Size/ Electrode diameter

When you consider that it is through the electrode that the welding current is permitted to flow into the work piece, it is logical that the size of the electrode tip point controls the size of the resistance spot weld. Actually, the weld nugget diameter should be slightly less than the diameter of the electrode tip point. [3]

EXPERIMENTATION

Low carbon steel is extensively used for deep drawing of motor car bodies, motor cycle parts, and other domestic applications. Therefore, the present work was planned to optimize the resistance spot welding parameters of SAE 1010 steel sheets with different thicknesses. The specimens were prepared by cutting the workpieces material into the suitable dimensions and then cleaned and abraded to prevent high contact resistance which is created due to an oxide layer. In this study, copper was used as an electrode material and it was kept constant during the experiment.

Design of experiment

The process objective/output parameter was to maximize tensile shear strength which determines weld strength. Design parameters affecting the process are

- Welding current
- Weld time
- Electrode diameter
- Welding force

Number of levels- 3

Table 1 Process Parameters and Their Levels

Thickness Mm	Symbol	Process Parameter	Unit	Level 1	Level 2	Level 3
1 mm	A	Electrode Force	kN	1.5	2.9	3.5
	B	Welding Current	kA	6.2	8.2	10.8
	C	Electrode Diameter	mm	3.2	6.5	8.2
	D	Welding Time	cycle	10	14	18
2 mm	A	Electrode Force	kN	3.5	4.5	4.9
	B	Welding Current	kA	11	13.5	14.4
	C	Electrode Diameter	mm	8	9.5	11
	D	Welding Time	cycle	2	25	30

In complex manufacturing systems and nonlinear processes, the interaction effects of the process parameters become significant. However, in the present study, since orthogonal arrays do not test all variable combinations, the interaction effect of the welding parameters could not be taken into optimization process. As a result, the main effect of each welding parameter on the tensile strength response was merely taken.

Degree of freedom= [Number of factors*(number of levels -1)] + [Number of interactions* (Number of levels -1) ^2] +one for average

Degree of freedom= (4*2) +0+1=9

In this study, an L18 (34) orthogonal array which has 17 degrees of freedom was used. Eighteen experiments are required to study the entire welding parameter space when the L18 orthogonal array is used.

Table 2. Experimental Results for the Tensile Shear Strength

Experiment Number	Tensile shear strength per spot in kN	
	1 mm	2 mm
1	2	9
2	3	9.7
3	3.2	10.2
4	2.5	9
5	4	10.6
6	3.4	9.2
7	1.8	7.4
8	2.7	8.5
9	2.4	8.9
10	1.5	8.1
11	3.1	9.8
12	2.6	9.3
13	2	8.5
14	3.4	10.2
15	2.8	9.5
16	1.7	8.2
17	2.5	9.4
18	1.8	7.7

Overall Loss Function and its S/N ratio

Tensile shear strength of the welded structures belongs to the larger-the-better quality characteristics. The loss function of the larger-the-better quality characteristics can be expressed as

$$L_j = (1/n \;\; \sum_{\square=1}^{\square} 1/\square^{2} \sum_{\square=1}^{\square} 1/\square^{2})$$

$$\eta_j = -10 \log L_j$$

Where n is the number of tests, and yi the experimental value of the ith quality characteristic, Elk overall loss function, and η j is the S/N ratio. By applying Equations (1)–(2), the η corresponding to the overall loss function for each experiment of L18 was calculated and The effect of each welding process parameter on the S/N ratio at different levels can be separated out because the experimental design is orthogonal.

Figure 2. shows the S/N ratio graph where the dashed 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.

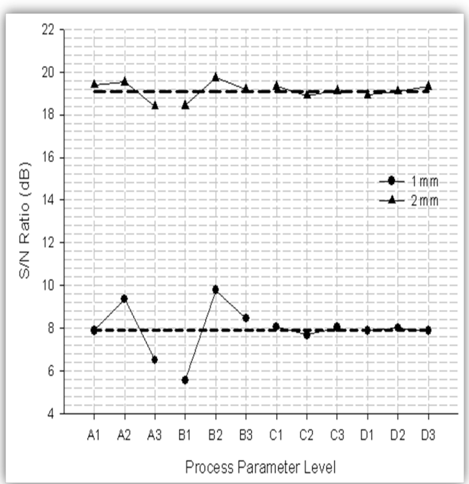

Figure 2. S/N ratio graph

Analysis of Variance (ANOVA)

Optimum combinations of the welding parameters can be found by using ANOVA.The results of ANOVA for the welding outputs are presented in Tables 3. and 4. Statistically, F-test provides a decision at some confidence level as to whether these estimates are significantly different. Larger F-value indicates that the variation of the process parameter makes a big change on the performance.

Table 3. Results of ANOVA for 1 mm Steel Sheet

Parameter	Process Parameters	Degree of Freedom	Sum of Square	Variance	F	Contribution percentage
A	Electrode force	2	2.25	1.12	6.77a	29.22
B	Welding current	2	4.45	2.22	13.38a	57.8
C	Electrode diameter	2	0.12	0.06	0.36	1.56
D	Welding time	2	0.054	0.02	0.16	0.7
Error		5	0.83	0.16		10.7
Total		13	7.7			100

Table 4 Results of ANOVA for 2 mm Steel Sheets

Parameter	Process Parameters	Degree of Freedom	Sum of Square	Variance	F	Contribution percentage
A	Electrode force	2	4.69	2.23	9.07a	35.42
B	Welding current	2	5.37	2.68	10.39a	40.56
C	Electrode diameter	2	0.48	0.24	0.93	3.62
D	Welding time	2	0.37	0.18	0.72	2.79
Error		9	2.33	0.26	-	17.60
Total		17	13.24	-	-	100

Confirmation Tests

In this study, after determining the optimum conditions and predicting the response under these conditions, a new experiment was designed and conducted with the optimum levels of the welding parameters.The final step is to predict and verify the improvement of the performance characteristic. The predicted S/N ratio η using the optimal levels of the welding parameters can be calculated as

$$\eta = \eta_m + \sum_{\square=\square}^{\square}(\eta_{\square} - \eta_{\square}) \sum_{\square=\square}^{\square}(\eta_{\square} - \eta_{\square})$$

Where η m is total mean of S/N ratio,

η is the mean of S/N ratio at the optimal level,

n is the number of main welding parameters that significantly affect the performance.

The results of experimental confirmation using optimal welding parameters and comparison of the predicted tensile shear strength with the actual tensile shear strength using the optimal welding parameters are shown in Table 4.

Table 4 Results of the Confirmation Experiment

Thickness		Initial process parameters	Optimal process parameters		Improvement in S/N ratio
			Prediction	Experiment	
1 mm	Level	A2B1C2D3	A2B2C1D2	A2B2C1D2	4.69
	Tensile shear strength (kN)	2.3	3.5	3.7	
	S/N (dB)	6.71	11.43	11.4	
2 mm	Level	A2B1C2D3	A2B2C1D3	A2B2C1D3	1.77
	Tensile shear strength (kN)	8.82	10.55	10.6	
	S/N (dB)	18.83	20.56	20.6	

CONCLUSIONS

An optimum parameter combination for the maximum tensile shear strength was obtained by using the analysis of signal-to-noise (S/N) ratio. The confirmation tests indicated that it is possible to increase tensile shear strength significantly by using the proposed statistical technique. The experimental results confirmed the validity of the used Taguchi method for enhancing the welding performance and optimizing the welding parameters in resistance spot welding operations.

REFERENCE

[1] Wikipedia-spot welding and Taguchi method | [2] Miyachi unitech, "Resistance welding fundamentals", 2013. | [3] Miller electric, "Handbook for resistance welding", 2012. | [4] B. D. Gurav,"Optimization of process parameters in welding", IJMET, 2013. | [5] Niranjan kumar singh, "Application of Taguchi method", iiste, Vol 3, No 10, 2012 | [6] A.G. Thakur, "Application of taguchi method to stainless steel", JSIR, Vol.69, sept.2013. | [7]] Dr. Caner "Welding metallurgy and technology", BATIGÜN. | [8] Uğur Eşme, "Application of taguchi method for spot welds", The Arabian Journal for Science and Engineering, Volume 34, 2009. | [9] Stephanie, "Design of experiment through taguchi method", 2008. |