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Effect and Optimization of Various Control Parameters of Resistance Spot Welding : A Review

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***Abstract*:** Resistance spot welding is commonly used in sheet joining in the automotive industry, because it has the advantage which is high speed, high-production assembly lines and suitability for automation. The problems associated with RSW are tendency of alloying with the electrode. We here will perform experiment for optimizing of Tensile Shear (T-S) strength of RSW by using Taguchi method. Orthogonal arrays of Taguchi, the signal-to-noise (S/N) ratio, the optimal process parameter levels eill be found and analyze the effect of these parameters on tensile shear strength values.

Keywords-*Resistance Spot Welding , welding parameters, Taguchi Method , S/N Ratio, Optimization*

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1.Introduction:

Resistance spot welding (RSW) is a process in which contacting metal surfaces are joined by the heat obtained from resistance to electric current. Work-pieces are held together under pressure exerted by electrodes. Typically the sheets are in the 0.5 to 3 mm (0.020 to 0.118 in) thickness range. The process use two shaped copper alloy electrodes to concentrate welding current into a small "spot" and to simultaneously clamp the sheets together. Forcing a large current through the spot will melt the metal and form the weld.[1]

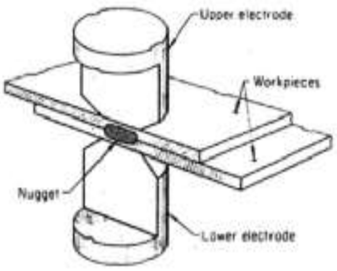


Fig1:Illustration of resistance spot welding

Electrically, metallic objects have some level of resistance to the flow of electrical current. This resistance will cause heat energy as electric current passes through the workpiece. The higher the capacity and duration of current, the higher the heat energy will be produced. This relationship can be expressed in the simple equation:

$Q=I^2RT$[2]

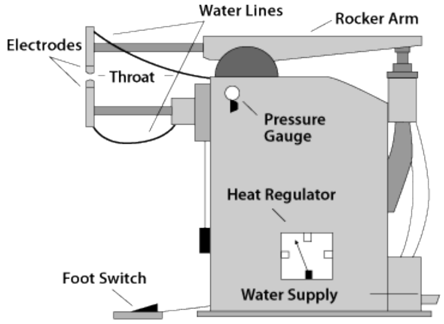
(1) Where Q is heat generated (J); I is welding current (A); R is resistance of the work piece(Ω); T is time of current flow (Sec).

2.Processing and equipment:

Spot welding involves three stages; the first of which involves the electrodes being brought to the surface of the metal and applying a slight amount of pressure. The current from the electrodes is then applied briefly after which the current is removed but the electrodes remain in place for the material to cool. Weld times range from 0.01 sec to 0.63 sec depending on the thickness of the metal, the electrode force and the diameter of the electrodes themselves.

The equipment used in the spot welding process consists of tool holders and electrodes. The tool holders function as a mechanism to hold the electrodes firmly in place and also support optional water hoses that cool the electrodes during welding. Tool holding methods include a paddle-type, light duty, universal, and regular offset. The electrodes generally are made of a low resistance alloy, usually copper, and are designed in many different shapes and sizes depending on the application needed.

The two materials being welded together are known as the workpieces and must conduct electricity. The width of the workpieces is limited by the throat length of the welding apparatus and ranges typically from 5 to 50 inches (13 to 130 cm). Workpiece thickness can range from 0.008 to 1.25 inches (0.20 to 32 mm).



(**Fig2**:Resistance spot welding machine)

After the current is removed from the workpiece, it is cooled via the coolant holes in the center of the electrodes. Both water and a brine solution may be used as coolants in spot welding mechanisms.[1]

3. Applications and Advantages

Applications:
Spot welding is typically used when welding particular types of sheet metal, welded wire mesh or wire mesh.The most common application of spot welding is in the automobile manufacturing industry, where it is used almost universally to weld the sheet metal to form a car. Spot welding is also used in the orthodontist's clinic.[1]

Advantages:
Spot welding is quick and easy. There is no need to use any fluxes or filler metal to create a join by spot welding, and there is no dangerous open flame.

Spot welding can be performed without any special skill.
Sheets as thin as 1/4 inch can be spot welded, and multiple sheets may be joined together at the same time.[1]

4 .Welding parameters:

The three main parameters in spot welding are current, contact resistance and weld time. In order to produce good quality weld the above parameters must be controlled properly.

4.1 Electrode force:

The purpose of the electrode force is to squeeze the metal sheets to be joined together. This requires a large electrode force because else the weld quality will not be good enough. However, the force must not be to large as it might cause other problems. When the electrode force is increased the heat energy will decrease. This means that the higher electrode force requires a higher weld current. When weld current becomes to high spatter will occur between electrodes and sheets. This will cause the electrodes to get stuck to the sheet.

4.2Weld time

Weld time is the time during which welding current is applied to the metal sheets. The weld time is measured and adjusted in cycles of line voltage as are all timing functions.
As the weld time is, more or less, related to what is required for the weld spot, it is difficult to give an exact value of the optimum weld time.

4.3Weld current

The weld current is the current in the welding circuit during the making of a weld. The amount of weld current is controlled by two things; first, the setting of the transformer tap switch determines the maximum amount of weld current available; second the percent of current control determines the percent of the [3]

5. Literature Review:

A. Process Parameter Optimization in Resistance Spot Welding of Dissimilar Thickness Materials.
(Pradeep M.,et al.)
This paper presents the welding process design and parameter optimization of RSW used in joining of low carbon steel sheet of thickness 0.8 mm and metal strips of cross section 10 x 5mmfor electrical motor applications. Taguchi method was used for optimization of parameters. The material used is low carbon steel sheet having chemical composition of (wt%) 0.101 C, 0.332 Mn, 0.011 S, 0.019 P, Fe . Copper Chromium alloy of 10mm diameter Electrode used was. Input parameters selected were welding current and weld time Optimum process parameters (current- 3.5kA and time- 10 cycles) were obtained from the Taguchi analysis and shear test results.
Experiment result showed that the weld quality was within acceptable interval. Further, numerical simulation of RSW process was carried out with selected weld parameters to quantify the temperature at faying surface and check for formation of appropriate nugget. The nugget geometry measured after peel test and predicted from numerical validation method were similar and in accordance with the standards[4].

B. OPTIMIZATION OF SPOT WELDING PROCESS PARAMETERS FOR MAXIMUM TENSILE STRENGTH .(Manoj Raut and Vishal Achwal)
This paper is based on an investigation of the effect and optimization of welding parameters on the tensile shear strength in the Resistance Spot Welding (RSW) process. The experiment was conducted under varying electrode forces, welding currents, and welding times. The values of welding parameters were determined by using the Taguchi experimental design of L18 Orthogonal array method. The combination of the optimum welding parameters have determined by using the analysis of Signal-to-Noise (S/N) ratio. For the experiment Mild steel sheets of thickness 0.8 mm and 1 mm are used.
The experimental results show that the welding parameters are the important factors for the strength of the welded joint. which may increase or decrease the strength of the welding joint so we can say that the combination of the suitable parameters is necessary for the maximum strength of the spot welded joint.[5]

C. OPTIMIZATION OF RESISTANCE SPOT WELDING PARAMETERS USING TAGUCHI METHOD.
(A.K. PANDEY, et al.)
This paper presents the optimization of various parameters of resistance spot welding. The experiments are carried under varying pressure, welding current, pressure, and welding time. In this investigation has been determined using Taguchi Method. Material used here is low carbon cold rolled 0.9 mm mild steel sheets (AISI 1008/ASTM A366) with the following composition carbon 0.08%; manganese 0.6%;phosphorus 0.35%; copper 0.2% ;sulphur 0.04% remaining iron.
The following conclusions were drawn:

1. The experimental results show that the right section of the input parameters are: medium current, medium pressure and high holding time.
2. 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 and pressure are comparatively less significant in this regard.
3. The contribution of welding current holding time and pressure towards tensile strength is 61%, 28.7%and 4% respectively as determined by the ANOVA method.
4. Optimum results have been found by taguchi method using medium current of 6.8 KA, medium pressure of 0.79KPa and high holding time of 5 seconds.[6]

D. APPLICATION OF TAGUCHI METHOD FOR THE OPTIMIZATION OF RESISTANCE SPOT WELDING PROCESS.
(Uğur Eşme)
This shows an investigation of the effect and optimization of welding parameters on the tensile shear strength in the resistance spot welding (RSW) process. The experimental studies were conducted under varying electrode forces, welding currents, electrode diameters, and welding times. Taguchi experimental design method was used for optimization. Here optimization of SAE 1010 steel sheets with different thicknesses is done.
The results showed that the tensile shear strength is increased by 2.03 and 1.20 times for 1 mm and 2 mm, respectively.
Therefore, the tensile shear strength is greatly improved by using the Taguchi metod.The results also showed that welding current was about two times more important than the electrode force for controlling the tensile shear strength.[7]

E. APPLICATION OF TAGUCHI METHOD FOR RESISTANCE SPOT WELDING OF GALVANIZED STEEL
(A. G. Thakur, T. E. Rao, et al.)
This paper represents an experimental investigation for optimization of Tensile Shear (T-S) strength of RSW for Galvanized steel by using Taguchi method. The experimental studies were carried out for varying welding current, welding time, electrode diameter and electrode force. Taguchi method was used to determine Strength to Noise(S/N ratio), Analysis of Variance (ANOVA) and F test value for determining most significant parameters affecting the spot weld performance.

Materials used was Galvanized steel sheet having chemical composition of (w_t %) 0.065 C, 0.095 Si, 0.017 Cr 0.032 Ni, 0.053 Cu, 0.404 M_n, 0.34 S_i, 0.017 S, 0.018 P, (balance) Fe .
The results indicated that it was possible to increase tensile shear strength significantly (13.43 %) by using the proposed statistical technique[8].

F. Optimization of the Welding Parameters in Resistance Spot Welding.
B.D.Gurav & S.D.Ambekar)
This paper represents the study on the optimization and the effect of the welding parameters (welding current, welding time, & electrode force) on the tensile shear strength of the resistance spot welded joints. The material used is CRCA (close rolled close annealing) steel sheets and thickness is 2mm thickness. Taguchi method was used to find the optimal process parameters levels and to analyze the effect of these parameters on tensile shear strength values The welding current was found to be the most effective factor in spot welding process. The contribution of welding current, weld time and electrode force towards tensile strength is 49.72%, 42.19%, and 7.85% respectively as determined by the ANOVA method.[9]

G. A Quality Improvement Approach For Resistance Spot Welding Using Multi-objective Taguchi Method And Response Surface Methodology.
(Norasiah Muhammad et al.)
The Taguchi experimental design method, Multi objective Taguchi Method (MTM) and response surface method (RSM) has been used to develop the response models and to optimize the multiple quality characteristics which are radius of weld nugget and width of HAZ. The parameters considered are welding current, weld and hold time for joining two sheets of 1.0 mm. Low carbon steel were used, for using Taguchi experimental design method and chosen L9 orthogonal array.
The test results to found out the developed model can be effectively used to predict the size of weld zone which can improve the welding quality and performance in RSW. Based on the results, the developed model can be effectively used to predict the size of weld zone which can improve the welding quality and performance in RSW.[10]

H. Application of Taguchi method for optimization of resistance spot welding of austenitic stainless steel AISI 301L.
(Mr. Niranjan Kumar Singh and Dr. Y. Vijayakumar)
This paper determines effect of process parameters initial measure of weld quality and tensile strength, nugget diameter and penetration. The welding parameters like welding current, weld cycle, hold time & cool cycle using quality tools, were selected Taguchi method was used for the parameters. Based on ANOVA method, the highly effective parameters on indentation are found as weld cycle, interaction between weld current & weld cycle and interaction between weld current, weld cycle & hold time whereas weld current, hold time and cool time were less effective factors.

The experimental results confirmed the validity of Taguchi method for optimizing the process parameter in resistance spot welding[11].
I. Optimization and modeling of spot welding parameters with simultaneous multiple response consideration using multi-objective Taguchi method and RSM .
(Norasiah Muhammad, et al.)

This paper shows a method to optimize process parameters of resistance spot welding (RSW). The optimization approach attempts to consider simultaneously the multiple

quality characteristics, namely weld nugget and heat affected zone (HAZ), using multi-objective Taguchi method (MTM). The plate of 1.5 mm was used under different welding current, weld time and hold time. The optimum welding parameters derived by Taguchi method.
The following conclusions can be drawn:
(1) Multiple characteristics such as radius of weld nugget and width of HAZ can be simultaneously considered using multi-objective Taguchi method. (2) The contribution of different control factors is welding current (73.91%), weld time (16.72%) and hold time (7.14%). The highle effective parameter was welding current. (3) The optimum parameters for nominal weld nugget and smaller HAZ size are: welding current at level 3 (6.0 kA), weld time at level 3 (14 cycles) and hold time at level 3 (4 cycles). (4) The developed linear response surface model for prediction radius of weld nugget and width of HAZ has been found well fitted.[12]

J, Application of Taguchi Method for Resistance Spot Welding of Stainless Steel-304 Grade
(Manjunath R. Rawal, Dr. K. H. Inamdar)
This paper performs experiment for the Tensile Shear (T-S) strength and Nugget diameter of resistance spot weld. Taguchi method was used for optimization. The material used was Stainless Steel (304). Welding current, Electrode force and Weld time were process parameters. Taguchi quality design concept of L27 orthogonal array was used to determine S/N Ratio, Analysis of Variance (ANOVA).The level of importance of welding parameters for T-S strength and Nugget Diameter are determined by ANOVA in Minitab 16 Software **.**

The following conclusions drawn were:
i. Welding current was found to be most significant parameter by the response of S/N ratio for tensile shear strength , while electrode force and weld time were less significant.
ii. The optimum results were obtained by Taguchi method for tensile shear strength and nugget diameter which were as Welding Current of 7 kA, Electrode force of 0.588 kN and weld time of 55 cycle.[13]

6.Conclusion:

The work presented here is an overview of recent works of Resistance Spot Welding process and future references. From above discussion it can be concluded that:

1. Resistance Spot welding process mainly depends on process parameters (e.g. welding current, weld time, electrode force).
2. Some research papers also concluded that there is increase in tensile strength with use of taguchi method.
3. Also some of the research papers concluded that current is the major factor to affect of the weld quality and weld strength by increasing/decreasing others parameters.
4. Experimental analysis have been carried out on dissimilar thickness of similar materials.

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