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Optimization of process parameters for Resistance Spot Welding process of Austenitic SS304 using Response Surface Method – A Review

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Abstract:** Resistance Spot Welding (RSW) is widely utilized for joining purpose especially in automobile industry due to its robustness, speed, flexibility and low cost operation. It depends on the resistance of the base metal and the amount of current flowing to produce the heat necessary to make the spot weld. There are various process parameters (weld current, weld time, electrode force) which affect the weld nugget and its strength. So it is necessary to optimize the process parameters of resistance spot welding process. In the present study, different materials Galvenized Steel, CRCA Steel, Mild Steel, Stainless Steel is machined with resistance spot welding. The experimental studies have been conducted under varying pressure, current & time on quality characteristic, HAZ (Heat affected zone), & nugget geometry. The approach is based on Response Surface Method to optimize the Resistance spot welding process parameters for effective machining.
***Keywords:** Resistance Spot Welding, Response Surface Method, Austenitic SS304.*

I. INTRODUCTION

Spot welding is one form of resistance welding, which is a method of welding two or more metal sheets together without using any filler material by applying pressure and heat to the area to be welded. The process is used for joining sheet materials and uses shaped copper alloy electrodes to apply pressure and convey the electrical current through the work pieces. In all forms of resistance welding, the parts are locally heated. The material between the electrodes yields and is squeezed together. It then melts, destroying the interface between the parts. The current is switched off and the "nugget" of molten materials solidifies forming the joint. The principle of resistance welding is based on Joule heating. The work pieces are clamped between the electrodes by applying an electrode force, then an electric current passes through the top and bottom electrodes and heats the work pieces by Joule heating. When the temperature at the interface reaches the melting point of the material, a molten nugget begins to form and grow. When the welding current is switched off, this nugget will solidify to form a weld that joins the work pieces together. Figure 1.1 shows the general setup and procedure of the resistance spot welding with the two electrodes.

The process is used extensively for joining low and mild carbon steel sheet metal components for automobiles, cabinets, furniture and similar products. Stainless steel, aluminum and copper alloys are also spot welded commercially. Excessive heating in resistance welding results in metal expulsion during the welding operation. Since accurate method for selection of welding variables i.e. welding current, welding time and electrode force, thickness of sheet, electrode type, electrode tip diameter, gap in the electrodes, shape of electrode tip, electrode material etc. are lacking.

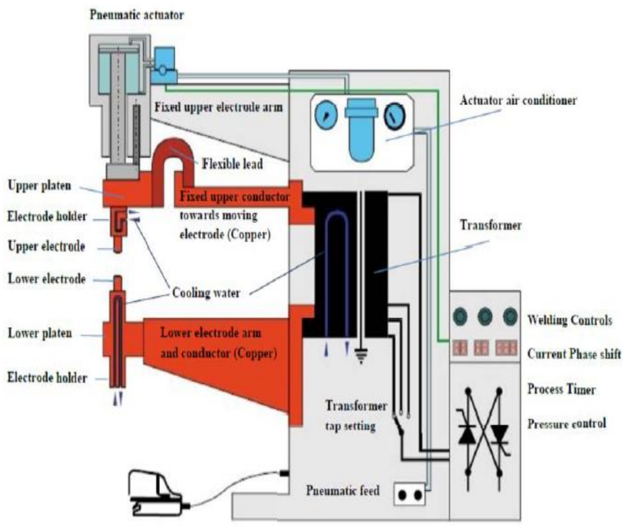

Fig. 1. General setup of Resistance Spot Welding

How its work?

There are various factors involves resistance spot welding process which are responsible for the quality of weld. Depending on the thickness and type of the metal, welding conditions such as weld current, weld time, electrode type and electrode force should be adjusted. Generally, a weld cycle can be divided into a number of stages in figure 1.2:

- Pre-squeeze stage (1 to 2)
- Squeeze stage (2 to 3)
- Weld stage (3 to 4)
- Hold stage (4 to 5)
- and Release stage (5 to 6)

In the Pre-squeeze stage, the moving electrode closes towards the work pieces, resulting in contact between the electrodes and work pieces. The velocity of the electrodes at this point of impact is very important considering that too high impact energy will results in excessive electrode wear.

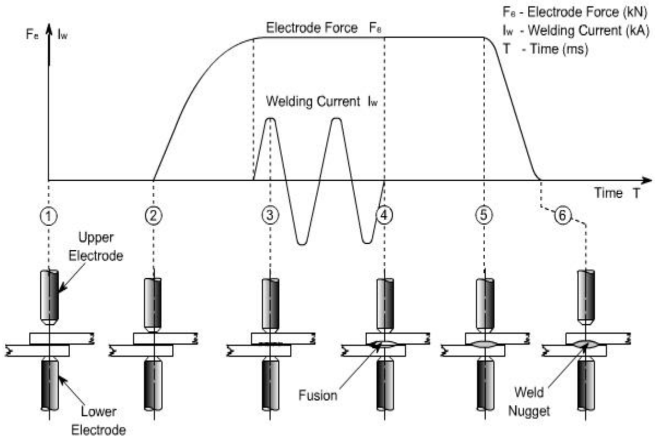

Figure 1.2 Welding Cycle of RSW process

In the squeeze stage, the electrodes are forced on the work piece surfaces by means of the force actuating system and this offers the possibility to deform the work piece to ensure sound contact between them. In the weld stage, while force remains on the work pieces, current will be flowing through the electrodes and the work piece, heating up every part in the secondary weld circuit proportional to the effective resistance present at each point. In the hold stage, the current is cut off and produced weld is allowed to solidify and cool down under maintain pressurizing force. After sufficient holding time, the electrodes release the work piece and the cycle is complete. The major advantages of the resistance welding processes over any other welding process is the feature that heat necessary for weld formation is generated at the exact location where the joints needs to appear. The possibility to highly reduce the time to complete a weld resulting in cycle times being competitive over other welding process. The another advantage is the absence of a molten weld pool penetrating from one side through a work piece, resulting in less aesthetical damage to the work piece surfaces.

1.1 Response Surface Methodology

Response surface methodology is a collection of statistical and mathematical methods that are useful for the modeling and analyzing engineering problems. In this technique, the main objective is to optimize the response surface that is influenced by various process parameters. Response surface methodology also quantifies the relationship between the controllable input parameters and the obtained response surfaces. The RSM (Response Surface Method) is important in designing, formulating, developing & analyzing new scientific studying and products. It is also efficient in the improvement of existing studies and products. The common applications of RSM are in Industrial, Biological & Clinical Science, Social Science, Food Science, and Physical & Engineering Science.

II. LITERATURE SURVEY

K. Pandey, M. I. Khan, K. M. Moeed. "Optimization of Resistance Spot Welding Parameters Using Taguchi Method". In this research they have been represents the optimization of various process parameters of resistance spot welding process. The material used is low carbon cold rolled 0.9mm mild steel sheets (AISI 1008/ASTM A366). For the experimental setup and investigation of varying process parameters (welding current, welding pressure, and welding time) to effect of the quality characteristic (tensile strength) using Taguchi Method. An experimental result shows that, S/N ratio to tensile strength indicates the welding current to be the most significant parameter that controls the weld tensile strength where the holding time and pressure are less. The contribution of Welding current, holding time and Pressure towards tensile strength is 61%, 28.7%, and 4% determined by the ANNOVA method. [1]

B.D.Gurav & S.D.Ambekar. "Optimization of the Welding Parameters in Resistance Spot Welding". On this paper to studied 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 for using CRCA (close rolled close annealing) steel sheets with 2mm thickness. For using orthogonal array of Taguchi method, the signal-to-noise ratio, the analysis of variance (ANNOVA) employed to find the optimal process parameters levels and to analyze the effect of these parameters on tensile shear strength values. At last for the experimental setup and results to show that the input parameters are high current, medium electrode force and high weld time. The welding current is 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. [2]

K Pandey, M. I. Khan, K. M. Moeed "Investigation of the Effect of Current on Tensile Strength and Nugget Diameter of Spot Welds Made On AISI-1008 Steel Sheets". In the present research, they had investigated that welding current is most effective parameter controlling the weld tensile strength as well as the nugget diameter. They used low carbon cold rolled 0.9mm mild steel sheets (AISI 1008/ASTM A366) which are good strength, corrosion or erosion resistance, ductility and toughness properties. By using of taguchi method, orthogonal array are selected. For the experimental results to show that the Signal to Noise(S/N) ratio to tensile strength and nugget diameter indicates the welding current to be most effective parameter that control the Tensile strength (hold time and pressure are less) and nugget diameter (pressure and weld time are less). [3]

Norasiah Muhammad and Yupiter HP Manurung. "Design parameters selection and Optimization of weld zone development in Resistance Spot Welding". They have been investigates the development of weld zone in Resistance Spot Welding. The work piece material used in this study was 1.21mm thick coated low carbon steel as the base metal. A general 2^4 factorial design augmented by 5 centre points was used to study the effect of factors namely weld current, weld time, electrode force and hold time on the development of weld zone. Optimization of the significant parameters affecting the development of weld zone obtained from the factorial design was carried out using CCD (Central Composite Design) in Response Surface Method. An experimental design was used to determine the effects of welding parameters (weld current, weld time, electrode force and hold time) on the development of the weld zone. On the results define that all the selected factors expect hold time affected the radius of weld nugget and HAZ (Heat Affected Zone) significantly and optimized using the Central Composite Design by RSM. A quadratic model of for radius of weld nugget and radius of HAZ were developed. The experimental results obtained under optimum operating conditions were compared with the predicted values and found to agree satisfactorily with each other. [4]

Norasiah Muhammad, Yupiter HP Manurung, Mohammad Hafidzi, Sunhaji Kiyai Abas, Ghalib Tham, M.Ridzwan Abd.Rahim "A Quality Improvement Approach For Resistance Spot Welding Using Multi-objective Taguchi Method And Response Surface Methodology". On this studied paper considers simultaneously the multiple quality characteristic (weld nugget and heat affected zone) using Multi-objective Taguchi Method (MTM). A Taguchi experimental design method, Multi objective Taguchi Method (MTM) and response surface method (RSM) approach 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. As the main objective of the manufacturing process is always to improve the overall quality of a product, it is necessary to optimize multiple quality characteristics simultaneously. The experimental study conducted under varying parameters (welding current, weld and hold time) for joining two sheets of 1.0 mm low carbon steel, for using Taguchi experimental design method and chosen L9 orthogonal array. The confirmation test results to find 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. [5]

Norasiah Muhammad, Yupiter H. P. Manurung, Roseleena Jaafar, Sunhaji Kiyai Abas, Ghalib Tham, Esa Haruman "Model Development For Quality Features Of Resistance Spot Welding Using Multi-objective Taguchi Method And Response Surface Methodology". The effect of parameters in Resistance Spot Welding (RSW) on the weld zone development was investigated using Taguchi Method. RSM was employed to develop the mathematical model for predicting the weld zone development. To validate the predicted model, experimental confirmation test was conducted for plate thickness of 1 and 1.5 mm (Low Carbon Steel). 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. ANNOVA technique has been employed to detect significant factors in multi-objective optimization for radius of weld nugget and width of HAZ. According to the analysis, it shows that weld current was statistically significant and the percentage contribution of different control factors on multiple quality characteristics (radius of weld nugget and width of HAZ). In RSW, welding current and contact surface have the greatest effect on the growth of weld nugget. The confirmation test results to find 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. [6]

Uğur Esme "Application of Taguchi Method for the Optimization of Resistance Spot Welding Process". He 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. He concluded that Taguchi method can be effectively used for optimization of spot welding parameters. He used SAE 1010 steel sheets material with different thicknesses. For the use of Taguchi method to determine the process parameters in the spot welding of SAE 1010 steel sheets. The L18 (34) Orthogonal array was chosen. In complex manufacturing systems and on linear processes, the interaction effects of the process parameters become significant. Since orthogonal arrays do not test all variable combinations, the interaction effect of the welding parameters could not be taken into optimization process. According to the analysis, the most effective parameters with respect to tensile shear strength is welding current, electrode force, electrode diameter, and welding time. The level of importance of the welding parameters on the tensile shear strength is determined by using ANOVA. Based on the ANOVA method, the highly effective parameters on tensile shear strength were found as welding current and electrode force, whereas electrode diameter and welding time were less effective factors. The results showed that welding current was about two times more important than the second ranking factor (electrode force) for controlling the tensile shear strength. An optimum parameter combination for the maximum tensile shear strength was obtained by using the analysis of signal-to-noise (S/N) ratio. 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 operation. [7]

A.G.Thakur, T.E.Rao, M.S.Mukhedkar, V.M.Nandedkar "Application of Taguchi method for Resistance Spot Welding of Galvenized Steel". They have studied an experimental investigation for optimization of Tensile Shear (T-S) strength of RSW for Galvenized steel using Taguchi method. RSW of galvanized steel is always difficult due to tendency of zinc coating alloying with electrode. The experimental studies were conducted under varying welding current, welding time, electrode diameter and electrode force. Taguchi quality design concepts of L27 orthogonal array has been 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. The S/N ratio is used to measure quality characteristic and it is also used to measure significant welding parameters. The main aim of ANOVA is to investigate the design parameters and to indicate which parameters are significantly affecting the output parameters. In the analysis, the sum of squares and variance are calculated. The level of importance of the welding parameters on the tensile shear strength is determined by using ANOVA. Based on the ANOVA method, the highly effective parameters on tensile shear strength were found as welding current and welding time, whereas electrode force and electrode diameter were less effective factors. The results showed that welding current was about two times more important than the second factor weld time for controlling the tensile shear strength. The experimental results confirmed the validity of used Taguchi method for enhancing welding performance and optimizing the welding parameter in RSW process. [8]

J.B. Shamsul and M.M. Hisyam "Study of Spot Welding of Austenitic Stainless Steel Type 304".On this study paper, austenitic stainless steel type 304 was welded by resistance spot welding. It was investigated the relationship between of the nugget diameter and welding current and also Hardness distribution along welding zone. They used Austenitic SS304 of 3mm thickness. The experimental results to shows, that the changes of the current, the nugget diameter were changed. So it is proven that the weld nugget increases with the increasing of welding current. Micro hardness testing was used to carried out on the cross section samples across the horizontal & vertical of the nugget the graphs were studied to show that the weld nuggets due to the varied welding current. Austenitic stainless steel AISI-304 is an extremely important commercial alloy due to its excellent corrosion resistance, high strength, good ductility and toughness. The results show that increasing welding current increased the nugget size. The nugget size does not influence the hardness distribution. In addition, increasing welding current does not increase the hardness distribution. [9]

Gyanendra Singh, Dheeraj Sagar, Rajeev Arora, Nishant Singh "Effect of weld current and time on hardness of spot weld". On this paper to study the impacts of weld current and weld time on the heat affected zone (HAZ) hardness of spot weld. Qualitative characteristic of spot welds have been assessed by measuring the hardness of Heat Affected Zone. They used Austenitic stainless steel grade 304, 304L, 304H. The austenitic structure also gives these grades excellent toughness, even down to cryogenic temperatures. For the experimental work, to improve the reliability of results that using on the basis of response surface methodology (RSM) technique. A central composite design with orthogonal blocking is chosen, for four variables and five levels. At last the results shown that Hardness of heat affected zone (HAZ) decreases with increase in weld current and weld time. The effect of weld current and weld time on weld nugget diameter, width of HAZ and degree of electrode indentation can also be examined. [10]

III. CONCLUSION AND DISCUSSION

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 is quick and easy process, no need to use any fluxes or filler metal to create a join and also there is no dangerous open flame.
2. Resistance Spot welding process mainly depends on process parameters (e.g. welding current, weld time, electrode force), material parameters (e.g. types, thickness).
3. The most of the parametric study has been done by considering the three process parameters such as weld time, applied force and squeeze time and weld quality has been evaluated with respect to the individual properties such as tensile shear strength, tensile peel strength etc.
4. The literature survey infers that there is a need to study the effects of all process parameters on the weld quality and weld strength in detail. At the 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.

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