Effect of Process Parameters on Resistance Welding

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***Abstract*— Resistance welding is the most widely used joining process in automobile industry. Several types of resistance welding are developed for certain applications such as localized welding and continuous welding for pressure-tight joints. The spot welding and seam welding are variants of resistance welding. This paper presents a review of effect of process parameters resistance spot welding and resistance seam welding. Particular attention is paid to the response variables and their variations according to input parameters. ANOVA and Taguchi method has proved to be very efficient tools for controlling and optimizing the effect of process parameters on response variables such as tensile strength, hardness, nugget diameter. Welding current is considered as most influential factor among all process parameters.**

***Index Terms*— Resistance spot welding; Resistance seam welding; Weld quality; Taguchi Method.**

I. INTRODUCTION

Metal joining process is considered as major manufacturing and fabrication process. Manufacturing industries' drive for cost reduction and productivity improvements have landed in the use of resistance welding for joining metal sheets predominantly. The need of localized joint, continuous joint developed resistance spot and resistance seam welding respectively. Major advantages of resistance welding are high working speed, suitability for automation and inclusion in high production lines with other fabrication operations. Resistance welding is most widely used in the sector of automobile industry where metal sheets are to be joined with high precision, high strength as well as quality.

II. RESISTANCE WELDING (RW) PROCESS

As name implicates, welding is carried out by using resistance heating phenomenon. Resistance spot welding is a process in which two faying surfaces are joined in one or more spots. The heat is generated by resistance to flow of electric current through workpiece. The workpiece is held together under simultaneous force by two electrodes. The surfaces in contact are heated by short-time pulse of low voltage-high amperage current to form a fused nugget of weld metal as shown in Fig. 1.

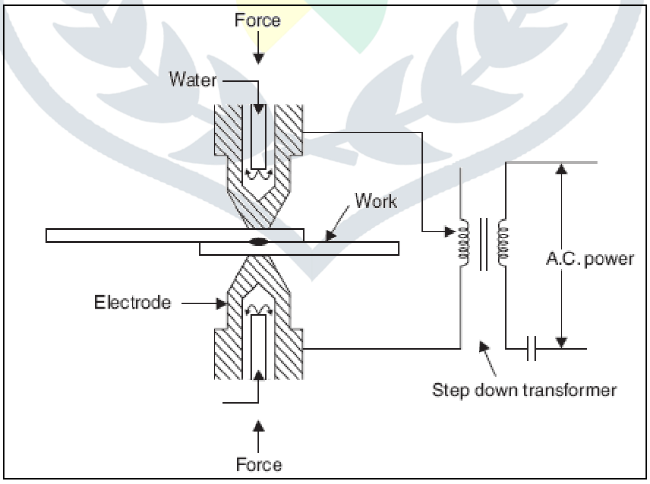

Fig.1. Working of resistance spot welding

The resistance seam welding also works in same manner, but only difference is that the continuous, a series of overlapping spot welds are given to produce leak-tight joint. As shown in Fig. 2, two rotating, circular electrodes are used for transmitting the current. Series of overlapping spot welds is carried out when electrode wheels advances in continuous or intermittently without retracting the electrodes or removing the electrode force [1].

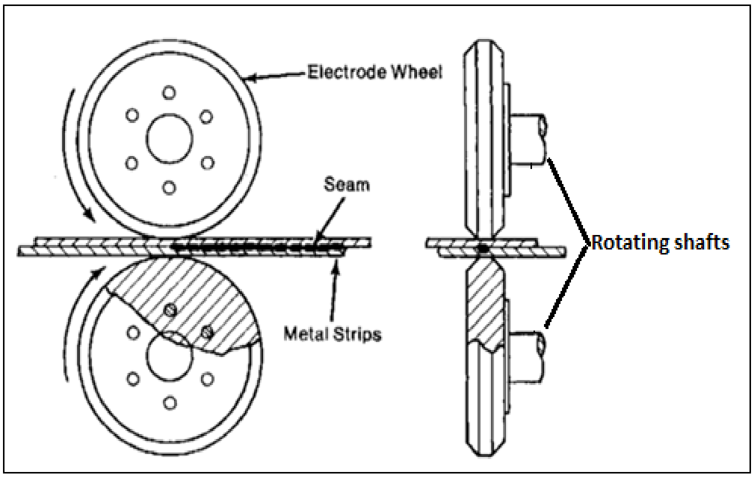

Fig.2. Working of resistance seam welding.

Heating principle:

There are three main parameters which affect the amount of heat generated in RW namely, welding current, contact resistance and weld time. In order to produce good quality weld the above parameters must be controlled properly. The amount of heat generated in this process is governed by the equation,

$$Q = I^2Rt \qquad \text{……... (Eq. 1)}$$

Where,
Q = Heat generated (J), I = Current (A),R = Resistance of the work piece (Ω), T = Time of current flow (Sec or Cycle).

III. PROCESS PARAMETERS

According to the Eq. 1, the parameters affecting the resistance welding process directly are welding current, resistance of material, time of current flow. As electrodes are squeezed on to the material, electrode force also comes into the picture. Fig. 3 shows the cause and effect diagram of process parameters affecting resistance welding process.

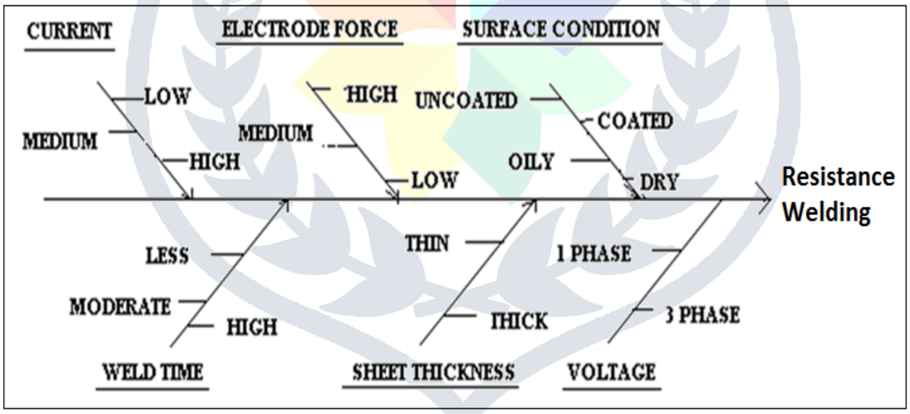

Fig.3. Cause and effect diagram

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Welding Current

Current controls the heat which generated according to the Eq. 1.This shows that the current has more influence on the amount of heat generated. Currents higher than for spot welding are used for seam welding because of the continuous shunting of the current through preceding welds. Low current causes minimum strength joint while current value in excess gives increase in nugget penetration and nugget overlap. Also, they can cause excessive indentation and burning of the weld.

Weld Time

The total heat developed is proportional to weld time. During a resistance welding operation, some minimum time is required to reach melting temperature at some suitable current density. The overall weld time governs the relative balance between the time available to make and to consolidate the weld. Heat and cool time are included in the welding time

Welding Force

As the force is increased, the contact resistance and the heat generated at the interface will decrease. The high spots are depressed and the actual metal-to-metal contact area is increased, thus decreasing the contact resistance. To increase the heat, amperage or weld time must be increased to compensate for the reduced resistance.

Welding Speed

Welding speed parameter is effective in seam welding. Electrode contact of electrode wheel depends on welding speed. The speed at which specimen should be welded depends on the parameters as: weld quality, design of workpiece, thickness and surface conditions of workpiece. Lower welding speed causes concentration of current at surface and hence causes surface burning. Rapid welding speed causes more reduction in weld strength, even with higher welding currents. As a result, optimum selection of electrode speeds is needed.

IV. LITERATURE REVIEW

Literature survey is done for welding variants; resistance spot welding and resistance seam welding. Process parameters and their influence of resistance welding can be analyzed by its impact on response variables. Effect of process parameters is evaluated under several quality measures such as tensile strength of joint, size-shape of welded joint, hardness of weld, microstructural changes and weld quality.

Resistance Spot Welding (RSW)

Ugur Esme [2] conducted experiments under varying electrode forces, welding currents, electrode diameters, and welding times. Material used was SAE 1010 and welding parameters were set and determined by using the Taguchi experimental design method. The analysis of variance (ANOVA) and analysis of signal-to-noise (S/N) ratio were used to optimize the process parameters. It proved that current and electrode force are most dominant process parameters in case of tensile strength of spot weld whereas electrode diameter and welding time were less effective factors. The results showed that welding current was about two times more important than the electrode force for controlling the tensile shear strength.

A.G. Thakur et al. [3] investigated Taguchi method for spot welding of galvanized steel. ANOVA and S/N ratio were the analysis techniques used. Welding current, time, electrode diameter and electrode force were the process parameters. ANOVA showed current (68.93%), welding time (18.66%) and electrode force (8.57%) were most influencing factors.

D.S. Sahota et al. [4] carried out a study of effect of parameters on resistance spot weld of Austenitic SS 316 material to study the significance of the process parameters i.e. current, electrode force and weld cycles, towards the percentage improvement in material hardness. They found that An increase in weld current, weld time and electrode force results in an increase in weld nugget diameter and width. An increase in current, weld time and electrode force results in an increase in electrode indentation.

Danial Kianersi et al. [5] studied resistance spot welding joints of AISI 316L austenitic stainless steel sheets. Effect of welding current at constant welding time was considered on the weld properties such as weld nugget size, tensile–shear load bearing capacity of welded materials, failure modes, failure energy, ductility, and microstructure of weld nuggets. Result obtained as tensile strength increases up to certain limit of current value and then decreases. In weld nugget region, grains were found to be elongated with columnar structure, parallel to the electrode compression. Micro hardness studies showed that hardness of weld nugget was lower in comparison to HAZ and base metal.

J.B. Shamsul et al. [6] researched on spot welding of austenitic stainless steel type 304. The relationship of nugget diameter and hardness distribution and welding current was investigated. They found out that increasing welding current gives large nugget diameter and welding current does not much affect the hardness distribution.

Kang Zhouand and Lilong Cai [7] tested effect of electrode force on resistance spot welding process. They employed the dynamic resistance profile to analyze the effect of the electrode force. Large force may decrease the overall dynamic resistance and increase the nugget growth at high speed.

Kamble V. A. [8] analyzed effect of process parameters on resistance spot welding shear strength using Taguchi method. They studied RSW process under varying welding current, welding time, electrode diameter and electrode force. From ANOVA, current and electrode force were the most dominating factors on welding process.

Ninshu Ma and Hidekazu Murakawa [9] investigated RSW process for three high strength steels by both experimental measurement and FEM simulation. The nugget sizes were determined experimentally and then compared with the simulated result. Simulation showed good conformance with experimental results.

Norasiah Muhammad et al. [10] developed an alternative optimization method for RSW using RSM and Taguchi method. Current, heat and hold time were the process parameters and nugget, HAZ were response variables studied. The contribution of parameters is welding current (73.91%), weld time (16.72%) and hold time (7.14%). The most effective parameter for the development of radius weld nugget and width of HAZ is the welding current.

Pradeep M. et al. [11] researched on process parameter optimization in resistance spot welding of dissimilar thickness low C steel. The process was optimized by Taguchi method and numerical model was developed for validation of experiments. They inferred that it can be inferred that weld time is the major factor in spot welding when compared with the welding current. The nugget geometry measured after peel test and predicted from numerical method were in good account with each other.

Shamsul Baharin Jamaludin et al. [12] investigated the effects of welding current and cycles on the galvanized steel sheets using spot welding. Tensile loading and peel tests were used to measure weld joint strength. The experiments showed that the value of tensile shear load was lower than tensile peel load. The strength of the joint increased with the increasing of welding current and welding cycle.

Thongchai Arunchai et al. [13] studied on optimization of RSW process using Artificial Neural Network on Aluminum 6061-T6. Aim was to investigate parameter prediction by the use of an artificial neural network (ANN) as a tool in finding the parameter optimization. Process parameter selected were welding current, electrode force, and welding time and electrical resistance of the aluminum alloy, which depends on the thickness of the material. Results obtained were in conformance with ANN process parameter prediction model.

Resistance Seam Welding (RSEW)

N.T. Williams et al. [14] investigated about the determination of the factors which influence weld formation at high welding speeds for both uncoated and coated steels. They concluded that the welding speed increases, the current required for weld formation also increases gradually. Low electrode force levels, interrupted current programs and steels with high resistivity limited the welding speed. The maximum welding speed which could be achieved in roller-spot welding was similar to that for continuous seam welding. It was experimentally showed that minimum indentation welds can be produced over a wide range of welding speeds and currents.

Robert Matteson [15] carried out a review on resistance seam welding. It discusses fundamentals of seam welding, such as applications, type of welded joints, metals welded etc. It also gives effect of electrode wheel geometry on the workpiece. Paper concludes that under given electrode conditions, increasing weld force improves the welding range for speed and helps control cracking.

M. D. Tumuluru et al. [16] investigated procedure development and practice considerations for seam welding. This paper elaborates seam welding of ferrous materials and nonferrous materials as Al, Cu, bronze etc. Parameters discussed are electrode force, welding speed, welding time and welding current. Their interaction effect is shown by the lobe diagrams against the given parameters and thickness of sheet. Peel test and tensile tests were carried out to evaluate mechanical strength of weld. The paper concludes that if the indentation is properly controlled, the welded joint will have a tensile strength of 80 to 100% of the parent metal.

Inoue Tomohiro et al. [17] investigated an electric resistance welding (ERW) line pipe technique with a high performance weld seam developed by JFE Steel. This new product is used in oil and gas line pipe in severe applications such as arctic regions. First, an analytical model of the ERW seam was constructed by finite element analysis. The effect of current, welding speed and heat distribution was evaluated. Improved seam mechanical properties were achieved by the development of this homogeneous heating technology.

Alireza Khosravi et al. [18] researched on weldability of electro galvanized versus galvanized interstitial free steel sheets by RSEW in an automotive fuel tank. It investigated effects of welding current and speed on microstructure and mechanical properties of the weld joint. The conclusions showed the decrease of nugget size and increase of joining zone thickness in each galvanized and electro galvanized sheet by raising welding current at low speeds. With the increase of welding speed keeping current constant, nugget size decreased and thickness of joining zone increased. Hardness grew from the base metal towards the center of the weld in both sheets. Therefore, the maximum hardness always was in the center of the weld. When compared, at equal speed, the electro galvanized sheet needed lower welding current in order to gain approximately equal strength to the galvanized sheet.

H Abdel-Aleem et al. [19] experimented on joining of Aluminum alloy 1050-5052 by RSEW and materials evaluation of joints. Process parameters were current and exhausting pressure while response variables were nugget shape, hardness and microstructure of weld. Paper concludes that at an identical welding current, nugget penetration increases with an increasing exhausting pressure. The hardness increases at the fusion boundary of 1050. The nugget hardness is much the same as the 5052 base metal hardness. The results obtained in tensile shear testing of joints suggest that fracture always occurs near the fusion boundary on the 1050 side and that the tensile strength therefore corresponds to that of 1050. 5052/ 5052 joints similarly have a tensile strength corresponding to that of 5052.

J. Saleem et al. [20] simulated 3 dimensional finite element analysis of seam welding process. In manual efforts the appropriate parameters settings for welding sheets of different thicknesses depends on trial and error methods. The paper proves that a three dimensional model with accurate material properties for the seam welding could prove to be a good tool for understanding the difference between applying different frequency/mode input signals and in checking their effect on the seam weld nugget growth.

VI. CONCLUSION

This paper has presented an overview focusing mainly on resistance welding process on sheet metals. It is one of the sustainable metals joining process which is significantly important in automotive, aerospace industries. On the basis of research findings reported in available literature reviewed and presented in this paper, the major observations learned are the following.

(i) The resistance welding process is highly dependent on its process parameters viz. welding current, electrode force, weld time and welding speed (in case seam welding).
(ii) Welding current is considered as most influential factor among all process parameters.
(iii) Materials with electric conductivity with different thickness can also be easily joined by resistance welding.
(iv) Difficult to weld materials like Aluminum are also weldable by resistance welding with high welding currents.
(v) ANOVA and Taguchi method has proved to be very efficient tools for controlling and optimizing the effect of process parameters on response variables such as tensile strength, hardness, nugget diameter.
(vi) It can also be numerically modeled with the use of Finite Element Analysis (FEA), Artificial Neural Network (ANN) etc.

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