A Review on Study and Analysis of Various Parameters Affecting Nugget Formation in Resistance Spot Welding Using FEM

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Abstract— Resistance spot welding is the most popular joining process in an automobile body assembly production lines. Today's automobiles typically contains approximately five thousand or more spot weld. Current spot welding technology relies on volume on empirical data's to set the working parameters. Often this data is no sufficient to ensure that a nugget of sufficient size is formed thus quality and strength depends on the optimum welding diameter of welding nugget. There are various parameters affecting the nugget size in RSW. In this paper the effect of weld time and weld current is studied on CRCA material by experiments and also by using the FEA model.

Key words: FEM Analysis, Nugget, Parameters, spot welding, Weld time, Weld current

I. INTRODUCTION

Welding is a fabrication or sculpture process that joins material, usually metal or thermoplastic by causing coalescence. This is often done by melting the work piece and adding a filler material to form a pool of molten material that cools to become a strong joint, with pressure sometimes used in conjunction with heat or by itself to produce the weld. Resistance spot welding was invented in 1877 by Elihu Thomson and has been widely used since then as a manufacturing process for joining sheet metal. Even though resistance spot welding is over 100 years old, the physics of the process has not been well understood; however, this has not hindered its industrial application for joining a large variety of metals. The automotive industry is the major user of this welding process, followed by the appliance industry. It is also used by many industries manufacturing a variety of products made of thin gauge metals. Spot is employed to join overlapping strips, sheets or plates of metal at small area the pieces are assembled and placed between two electrodes, which must possess high electrical and thermal conductivity and retain the required strength at high temperature so they are made of pure copper for a limited amount of service, and of alloys of copper of tungsten, or copper and chromium for continuous working.

The welding current of 4–20 kA is used for making a single weld. The welding current depends on the material to be welded and work piece thickness. This may be used to weld steel and other metal parts up to a total thickness of 12mm. Spot welding can be used for joining several metallic materials and sheets of different thicknesses together without large deformations. Spot welding allows large-scale production with a small number of employees and it can be easily automated.

II. SPOT WELDING CYCLE

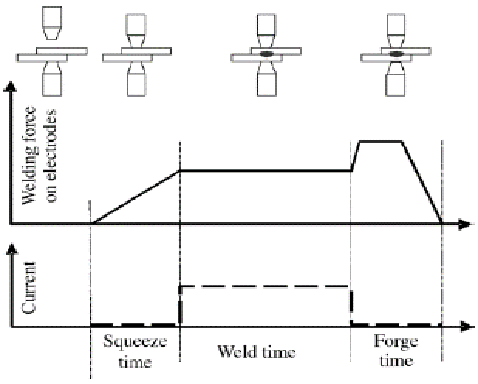

Fig. 1: Spot welding cycle

A. Squeeze Time:

It is the time required for the electrodes to align and clamp the two work piece together under them and provide the necessary electrical contact.

B. Wild Time:

It is the time of the current to flow through the work piece till they are heated to the welding temperature. It is controlled by electronic timer.

C. Hold Time:

It is the time when the pressure is to be maintaining on the molten metal without the electric current during this period the pieces are expected to be force welded.

D. Off Time:

It is the time during which the pressure on the electrode is taken off so that the plates can be positioned for the next spot.

III. NUGGET GENERATION

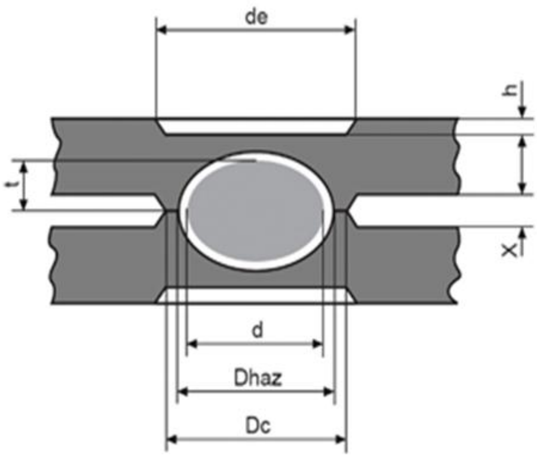

Fig. 2: Dimension of nugget

Where,

- d= nugget size
- h= Indentation
- t= nugget penetration
- X= gap between sheets
- Dc= diffusion joint area
- HAZ= heat affected zone

When a low voltage and high ampere electric current is passed between the electrodes. This electric current faces electrical resistance which produces heat which is greater at faying surface thus there more heat is produced. This is where the weld nugget forms

IV. PARAMETERS AFFECTING NUGGET

The determination of appropriate welding parameters for spot welding is a very complex issue. A small change of one parameter will affect all the other parameters.

A. Weld Current:

The weld current is used during welding is being made. 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 percentage of current control determines the percentage of the available current to be used for making the weld. Low percentage of current settings is not normally recommended because it might affect the quality of the weld. Proper welding current can be obtained with the percentage current set between seventy and ninety percent by adjust the tap switch.

The weld current should be kept as low as possible. When determining the current to be used, the current is gradually increased until weld spatter occurs between the metal sheets. This indicates that the correct weld current has been reached. Weld current also influences the value of nugget diameter. Different value of current, it will produce different dimension of the nugget diameter.

B. Weld 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. One cycle is 1/50 of a second in a 50 Hz power system. (When the weld time is taken from American literature, the number of cycles has to be reduced due to the higher frequency (60Hz) that is used in the USA.)

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. When welding sheets with a thickness greater than 2 mm it might be appropriate to divide the weld time into a number of impulses to avoid the heat energy to increase. This method will give good-looking spot welds but the strength of the weld might be poor.

By multiplying the thickness of the sheet by ten, a good target value for the weld time can be reached. When welding two sheets with the thickness 1 mm each, an appropriate weld time is 10 periods (50Hz).

C. Squeeze Force:

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

D. Hold Time:

Hold time is the time, after the welding and occurred when the electrodes are still applied to the sheet to chill the weld (time that pressure is maintained after weld is made.). Hold time is necessary to allow the weld nugget to solidify before releasing the welded parts, but it must not be too long as this may cause the heat in the weld spot to spread to the electrode and heat it. The electrode will then get more exposed to wear. Further, if the hold time is too long and the carbon content of the material is high (more than 0.1%), there is a risk the weld will become brittle.

E. Diameter Of The Electrode Contact Surface:

One general criterion of resistance spot-welding is that the weld shall have a nugget diameter of 5*t1/2, “t” being the thickness of the steel sheet. Thus, a spot weld made in two sheets, each 1 mm in thickness, would generate a nugget 5 mm in diameter according to the 5*t½-rule. Diameter of the electrode contact surface should be slightly larger than the nugget diameter. For example, spot welding two sheets of 1 mm thickness would require an electrode with a contact diameter of 6 mm. In practice, an electrode with a contact diameter of 6 mm is standard for sheet thickness of 0.5 to 1.25 mm. This contact diameter of 6 mm conforms to the ISO standard for new electrodes. The geometry and dimensions of the electrodes and work pieces are very important, since they influence the current density distribution and thus the results of resistance welding. The geometry of electrodes in spot welding controls the current density and the resulting size of the weld nugget.

V. LITERATURE REVIEW

H. A. Nied et al. [1] in this study an axisymmetric finite element mode of resistance spot welding was used for analyzing the squeeze and weld cycles to determine the electrical, thermal, and mechanical responses. Predictions of the tempera-true distribution, thermal expansion and associated stresses, and weld nugget geometry were obtained from this mod-el. Extensive resistance spot welding tests were conducted on Type 321 stainless steel sheets to validate the finite element model. Comparison of the analytic results to test data are presented and dis-cussed. Finite element modeling and analysis is a well-developed technique. Using this method, one can investigate weld nugget formation for a variety of materials to be joined and different electrode configurations. The use of an analytic tool by the process engineer provides him with another procedure to develop weld schedules before going onto the shop floor to conduct tests.

C. L. Tsai et al. [2] in this study the weld nugget in resistance spot welding of Type 347 stainless steel was found, using finite element methods, to initiate in a ring shape at a distance from the electrode center. The ring-like weld nugget expands inward and outward during the welding cycles. The welding current, electrode pressure and hold time affected the thermo-mechanical interactions of the welding process and changed the final nugget geometry. Also, when spot welding work-pieces of unequal thicknesses, it was found that the weld nugget formed mostly in the thicker work piece than in the thinner work piece, and when spot welding dissimilar materials, the weld nugget formed more in the work piece of lower thermal conductivity or higher electrical resistivity.

Z. Han et al. [3] by study of this paper spot welds were produced using a high-strength cold-rolled sheet steel 0.08-in. (1.9-mm) thick. The welding parameters were systematically varied to examine their effects on nugget formation, microstructure, and mechanical properties. Following welding, several spot welds were cross-sectioned and mechanically polished for metallographic examination. Other spot welds were submitted to shear tensile tests.

H. Zhigang et al. [4] here in this study a 2D axisymmetric Finite Element Method (FEM) model has been developed to analyze the transient thermal behaviors of Resistance Spot Welding (RSW) process. In this model, the temperature dependent material properties, phase change and convectional boundary conditions were taken account for the improvement of the calculated accuracy, but the determination of the contact resistance at the surface is moderately simplified in order to reduce the calculating time through the analysis.

Joseph Richard et al. [5] by study of this paper spot the work has as purpose to evaluate the nugget behavior and the distribution of temperature in a joint welded for Resistance spot welding. The methodology used for the evaluation had as characteristic the study through microscopy optics and numerical simulation for Finite Elements. For distribution of temperature of the welding in two distinct sets of metal sheets was adopted the increase method with Ansys Parametric Design Language (APDL) using commercial finite element code ANSYS. Galvanized sheet, with 0.6 and 1.2mm thicknesses, with 8 µm of coating, were used. The specimens were cut in the size of 38x125 mm according to the French standard NF A-87-001. An assessment was made by optical microscopy to validate this model to verify the geometry and dimensions of the nugget. The results obtained in predicting of size nugget were similar when comparing the assessment of numerical simulation and the measurements obtained by optical microscopy

Walther Jenis et al. [6] the objective of this project is to study the effect of welding nugget diameter on the tensile strength of the resistance spot welded joints. Using the tensile test method to analyze the selected size of the nugget diameter to determine the maximum load that can be applied before the specimen is rupture or tears apart. By doing the analysis, the suitable size of the nugget diameter can be determined. The materials used in this study are Aluminum and Mild Steel sheet metal and the selected nugget diameter used 4 mm, 5mm and 6 mm because it is varied in the industrial applications.

M. Rashid et al. [7] in this study the surface interaction at the FS interface during the RSW of AA5182 was studied experimentally and with FEA. Factors influencing the melting and nugget formation were identified and investigated

Rajanarender reddy pingili et al. [8] in this study, a 2-D finite element model has been developed to predict the transient thermal behavior of spot welding electrodes. The model included heat transfer analysis, electrical field analysis and phase change during melting or solidification and temperature dependent material properties, and also their inter-dependence. The contacts at faying surface and at electrode –work interface, with temperature dependent contact resistances were modeled. Three types of electrode shapes –flat, pointed and dome nose were analyzed. Temperature distribution on each electrode shape was obtained from the finite element analysis. Maximum temperature of 2876 ºC was observed in dome nose electrode in 0.2 seconds of welding time. Dome nose electrode requires a minimum weld time of all the other electrode shapes to get the required nugget size, resulting in the least power consumption. Nugget size was predicted for each electrode shape. Experimental results obtained were in good agreement with the finite element analysis results.

M Iyota et al. [9] this study examines the effect of the electrode force condition on the nugget diameter and residual stress in spot welded high-strength steel sheets. Numerical simulations of spot welding were performed to examine the nugget diameter and residual stress. The results indicate that adjusting the force profile changes the current density and stress state at the spot welds. Therefore, choosing an appropriate force profile extends the nugget diameter and reduces the residual stress.

Hamid Eisazadeh et al. [10] in this study, an incremental and coupled thermal-electromechanical finite element model is presented for predicting temperature distribution and spot nugget size in a spot welded steel joint. By providing the necessary information and boundary conditions, simulations were performed for three combined analysis during different stages of welding cycle. Experimental data and solutions of a one-dimensional model developed in a published article are also utilized for comparison. The results provide information on the development of the weld nugget and thus predict the welding quality prior to the actual welding process. The input parameters to the model can be adjusted to give different sizes of the weld nugget. As a result, optimum setting of the welding parameters for the desired quality and different materials of the work piece can be obtained through simulations, without performing large number of physical experiments. If the electric current flow exceeds the flow necessary for nugget growth, causes a rapid growth of nugget. The nugget growth rate decreases as the current flow increases but the nugget size raises until melt spattering occurs. Therefore, space between nuggets affects current flow which means that to eliminate the current shunting more space between nuggets is necessary. Increasing electric cycles remarkably raises the contact surface temperature so that the contact zone melts leading to a big nugget but no melt spattering occurs. In fact, increase of welding time gives equilibrium to the melt pool. Increase of load on the electrodes decreases the nugget size as it raises the contact surface area. If the plate thickness is increased, the current flow needed for the formation of appropriate weld nugget increases. Decreasing the plate thickness lowers the electrode diameter.

VI. CONCLUSION

Resistance spot welding is the most important process in an automobile fabrication. The strength of any spot welding component depends on the nugget formed in between the joining plate. There are various parameter affecting the nugget dimension. It can be predicted using Ansys software. Thus an optimal parameter should be selected to get its maximum strength.

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