Recent Advances in the finite element analysis of resistance spot welding process – A review.

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Abstract

Finite element analysis is recently employed by many researchers to predict the influence of process parameters in the welding process. Many recent commercial finite element packages permit complex temperature dependent material flow analysis pertinent to welding process. Many researchers successfully simulated the welding process using finite element model. In this research work, the results of finite element simulation of resistance spot welding process of different materials, the difficulties faced and methodologies adopted to overcome the shortcomings are analyzed.

Keywords

Resistance spot welding; Finite element analysis, Numerical model, Temperature dependent analysis

Introduction:

Resistance spot welding process (RSW) is the most widely used resistance welding process[1-4]. It is an ancient welding process and has been used by the automotive industries since 1930. In the earlier days two hand held tongs were used which affected the quality of welds due to insufficient pressure. The recent spot welding machines are equipped with hydraulic or pneumatic electrode pressure set up. It is generally employed for lap joining of thin sheets of thickness upto 4 mm. Some of the applications of resistance spot welded stainless steel sheets are widely used in the food processing industries in the handling, production and packaging, Pharmaceutical Industries, Railways, Pulp & Paper Industries, Medical Applications, Nuclear Power Plants & Steel Plants, Architecture, building and construction, Automotive, Mining and Minerals, Seawater desalination plants, Pressure vessels, reactor tanks heat exchanger and, Shipbuilding industry.

Finite element analysis is numerical method to determine solutions for engineering problems. FEA provides solutions for complex structural, electrical and thermal engineering problems governed by the differential and integral equation. Hence it has been widely adopted in the civil, mechanical and aerospace engineering domains. FEA delivers the visualization of strength and stiffness at various locations and thermal profile of the analysis member. Thus it can be used to minimize the weight and cost of the structures by selecting a better design. Also FEA can be used to simulate a process and analyzing its effect on the process parameters. Hence the finite element analysis could be used to model resistance spot welding process as shown in figure 1.

Results and Discussion :

The first finite element model for resistance spot welding was done by Gould using a one dimensional model. Gould [5] developed a one dimensional finite element model to examine the nugget growth in the resistance spot welding process. Heat transfer in the radial direction was not included considered in the simulation. The nugget diameter predicted by the model is found to be higher than the actual diameter. The deviation signified the inability of a one dimensional model to predict the behaviour of resistance spot welding process.

E Feulvarch[6] compared two finite element models to establish electro thermal contact conditions in the resistance spot welding process. The first model was developed by joining elements face to face to obtain the necessary contact conditions. It assumed normal flux transfer between two elements as they were close to each other. The second model considered the relative displacements between the contact elements in establishing the contact conditions thus providing better results than the first model. However the model did not include mechanical contact area in the application of thermal contact conditions and it was selected arbitrarily.

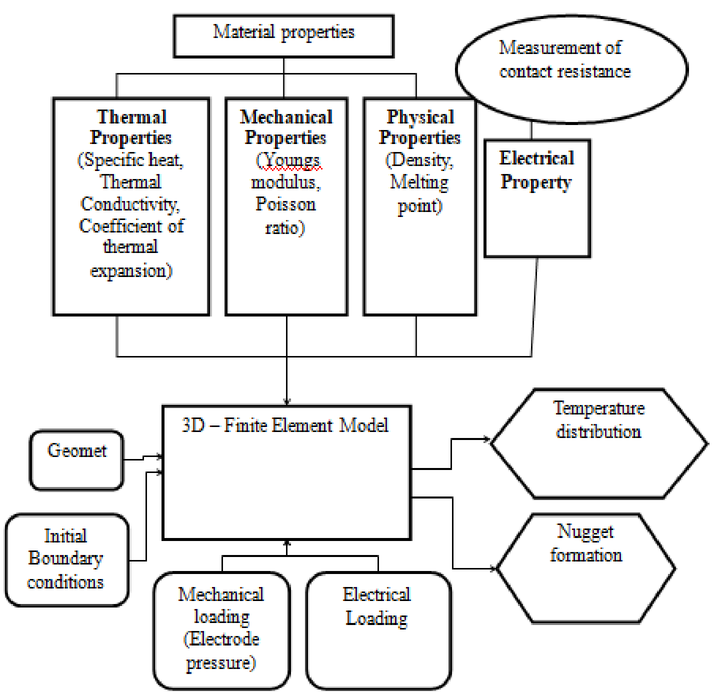

Figure 1 – Finite element modeling of resistance spot welding process

Bin wang et al [7] studied the effect of electrode wear on the nugget shape and size of the spot welding process. They considered two kinds of electrode wear namely Electrode pitting and electrode tip diameter enlargement for the study. A 2D Finite element model is created using ABAQUS software with different electrode tip morphology. Numerical results developed are compared with the experimental results by welding of DP590 dual phase steel under different electrode wear conditions. They concluded that elliptical nugget is obtained when the electrode is not subjected to wear. Two different shaped nuggets were observed under electrode wear conditions in the finite element analysis and verified by the experimental results. Glass section shaped nugget and hump section shaped nugget were formed under electrode pitting and electrode tip diameter enlargement condition respectively.

Zhigang Hou [8]et al investigated the resistance spot welding of mild steel using a finite element model. Two dimensional axisymmetrical model was developed using ANSYS software. Temperature dependent material properties were incorporated in the model and the mechanical behaviour of copper electrode and work piece are studied. They found that the higher contact pressure at the electrode work piece interface prevented the expulsion of molten stainless steel during welding. But at the same time the higher electrode pressure was found to increase the electrode wear.

Oscar Anderson et al [9] carried out the numerical analysis in the resistance spot welding of alloy steels. A 2D model was created using SYSWELD software to predict the nugget diameter. The numerical analysis results agreed with the experimental results. The mean absolute error observed in the prediction of nugget diameter was found to be 0.68 mm. The expulsion limits were found to be under estimated in the simulation with a mean absolute error of 1.1 kA.

H Eisazadeh et al [10] studied the resistance spot welding of AISI 1008 sheets using finite element analysis. A 2D model was created using ANSYS finite element software with temperature dependent material properties. Temperature distribution and nugget diameter was predicted using the ANSYS Software and compared with the experimental results. They concluded that the increase of welding current decreased the nugget growth rate but increased the nugget diameter till the expulsion of molten metal and more welding current was needed for the formation of weld nugget for larger plate thickness.

Long et al[11] studied the resistance spot welding of low carbon steel and high strength steel using ABAQUS software. Temperature dependent material properties were incorporated in the model to study the effect of holding time on mechanical performance. They found that holding time increased the fusion zone hardness upto 15 cycles. Beyond 15 cycles its effect on joint strength and hardness were not significant. They observed interfacial mode of failure when the holding time was 2 cycles and pull out type of failure when it was above 5 cycles.

Luo et al [12]studied analysed the variation in welding current and voltage in the secondary circuit to calculate the dynamic resistance in the resistance spot welding process. The dynamic resistance was used to predict the nugget growth and nugget quality. Based on the measurement of dynamic resistance, the nugget growth was analysed in three stages such as initial, growing and stable stage. They concluded that the process parameters significantly affected the nugget growth and dynamic resistance curves were more effective in the estimation of nugget growth.

Moshayedi et al[13] analysed the nugget growth of resistance spot welded austenitic stainless steel using a two dimensional finite element model. They found that welding time had less significant effect on expulsion that welding current. The predicted nugget diameter agreed with the experimental results and the deviation was found to be 13%. They concluded that the minimum welding current required for the formation of weld nugget in the austenitic stainless steel was 6 kA.

M. Eshragi et al[14] developed a two dimensional finite element model to study the resistance spot welding of DP600 dual-Phase steel. The effect of process parameters such as welding current, weld time, sheet thickness, electrode diameter and electrode pressure on the nugget radius, nugget thickness and Nugget volume were studied. It was found that the dominant factor that influences nugget diameter and nugget volume was welding current .The electrode pressure influenced only nugget thickness and its effect on the other responses were negligible. The temperature profile at various locations was analyzed. Actual nugget and the nugget developed by the model were compared and validated.

Hou and Kim [15] simulated the mechanical behavior of resistance spot welding process using a 2D axisymmetric model by considering temperature dependent material properties and displacement of work piece and copper electrodes. Stress and strain distributions in the weldment and electrode -workpiece interface were studied under the influence of temperature and electrode force. The maximum stress of 172 Mpa were observed in the copper electrode –mild steel workpiece interface and suggested that electrode displacement could be considered as a parameter for quality observations in resistance spot welding process.

Loulou and Bardon[16] developed a mathematical model with inverse heat transfer method to predict the thermal contact conductance in the resistance spot welding process. Thermocouples were used to measure the actual value and it was compared with the developed model. They concluded that the developed model was capable of predicting the early transient variations of conductance and heating stage needed more detailed investigation.

Conclusion:

Based on the recent research it is found several studies on temperature profile of the weld nugget based on finite element analysis is useful in understanding its influence on nugget growth. The practical method of temperature distribution profile of the weld nugget is more complicated as the heat transfer takes place simultaneously by conduction, convection and radiation. The practical measurement had its own limitation with respect to the range of the equipment and it is expensive as well as time consuming . The recent analysis softwares are capable of three dimensional modeling with temperature dependent material properties which delivers more accurate results.

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