A Survey on RSW Coupled Analysis Using Weld Nugget for Temperature Distribution

[1]Bodlapati S S Charan, [2]Maredi Akshay Kumar Reddy
[1,2]Dept. of ME, Chaitanyabharathi institute of technology Gandipet, Hyderabad, India

Abstract
Resistance Spot Welding is being used in the industry for sheet joining process especially in the automobile and aerospace industry. The complicated behavior of this process must be analyzed to set the optimum parameters to get the optimum weld quality. This paper presents the FEA simulation of the RSW process. It requires modeling of complex interactions between electrical, thermal, metallurgical and mechanical phenomena. A 2D ax symmetric FEM model has been developed to analyse the transient thermal behaviors of process using ANSYS software and coupled structural thermoelectric analysis is performed by using advanced coupled field element PLANE223 to simulate the thermal characteristics of RSW process. The objectives of this analysis are to understand physics of the process and to develop a predictive tool reducing the number of experiments for the optimization of welding parameters.

Keywords
RSW, Coupled Analysis, weld nugget, Temperature distribution

I. Introduction

Resistance welding is the most commonly used method for joining steel sheets. An electro conductive contact surface is created between the work pieces by pressing them together. Water-cooled electrodes made of alloyed copper are used in resistance welding. Electrodes convey a pressing force to the joint and direct the welding current to the joint in an appropriate manner. After welding, the electrodes rapidlycool down the welded joint. Resistance spot welding is a complex process in which coupled interactions exist between electrical, thermal, mechanical, metallurgical phenomena and even surface behaviors. In the recent years, finite element method has provided a powerful tool in studying these interactions and many related works have been carried out on the FEM modelling of RSW. Nied developed the first FEA model for RSW process, investigated the effect of the geometry of electrode onwork piece and predicted the deformation and stresses as a function of temperature. Furthermore, many researchers developed more sophisticated FEA models that considered temperature dependent material properties, contact status, phase changing and coupled field effects into the simulation of RSW. To solve the coupled problem, iterative solution procedure is an often adopted method. Initially the stress field and contact status are obtained from the thermal mechanical analysis and then the temperature field is obtained from the fully coupled thermal electrical analysis based on the contact area at the electrodeworkpiece interface and faying surface. The calculated temperature field is then passed back to the thermal structural analysis to update the stress field and contact status. The objective of this paper is to develop a multicoupled method to analyse the thermal and mechanical behaviors of RSW process, reduce the computing time with the minimum loss of accuracy and get more adequate information of the process.

A. Spot Welding Cycle

Fig. 1 shows the spot welding process. The RSW process consists of four stages as follows; a) Squeeze cycle time during which the upper electrode is brought in contact with the sheets and a force is exerted at the region that needs to be welded. b) Weld cycle time during which current is turned on and resistance to current flow at the sheet interface produces a nugget. c) Hold cycle – time during which the current is turned off and the fully grown nugget is allowed to cool and solidify slowly under constant pressure. D) Off cycle time during which the electrode is raised from the welded sheets. Water-cooled electrodes made of alloyed copper are used in resistance welding. After welding, the electrodes rapidly cool down the welded joint. The 3 main welding parameters are: a) current b) force and c) weld time. All these parameters need to be controlled effectively in order to produce a good quality weld.

II. Related Work

A. Finite Element Analysis

1. FEA Model and Mesh

FEA model of RSW process is shown in fig. 3 and 4, which is ax symmetric about y axis since only half portion of the complete model is analyzed. The x axis is the contact surface of the two sheets called as faying surface. The model is meshed using three elements; PLANE223, CONTA172 AND TARGE169. The element PLANE223 with structural thermoelectric capabilities has eight nodes with up to four degrees of freedom per node. It has UX, UY, TEMP and VOLT degrees of freedom. The other elements are contact elements consisting of contact pair of CONTA172 and TARGE169. Contact occurs when the element surface penetrates one of the target segment elements (TARGE169) on a specified target surface. Any translational or rotational displacement, forces, moments, temperature, voltage and magnetic potential can be imposed on the target segment element [6-7].

2. Material Models and Welding Conditions

Temperature varying properties are considered for copper electrode and mild steel sheets.The properties assigned are thermal conductivity, resistivity, Young's modulus, coefficient ofthermal expansion, yield stress, specific heat and contact resistivity. These temperature dependent properties are assigned in the range of 21ºC to 1204ºC [4]. In modeling RSWprocess with the complicated thermoelectric behavior, several physical phenomena must be considered. It is of great importance to define the parameters correctly to obtain correct results. Since electric current has great influence on the quality of RSW process, the input current in this simulation is 50 Hz sine wave AC current of 10 kA, applied for 200 Mrs. The current is imposed as an electric load on the top surface of upper electrode. To simulate the cooling process of the welding, the hold time is taken as 60 ms. a force of 3000 N is appliedon the upper electrode which is equivalent to the pneumatic pressure applied on the sheets. The most important property in the simulation of RSW process is the contact resistivity offaying surface. To simplify the problem, the contact resistivity is considered as a function of temperature.

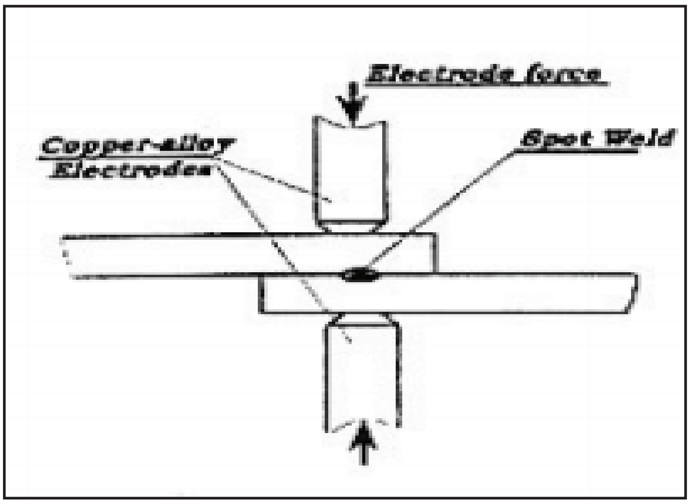

Fig. 1: Spot Welding Process

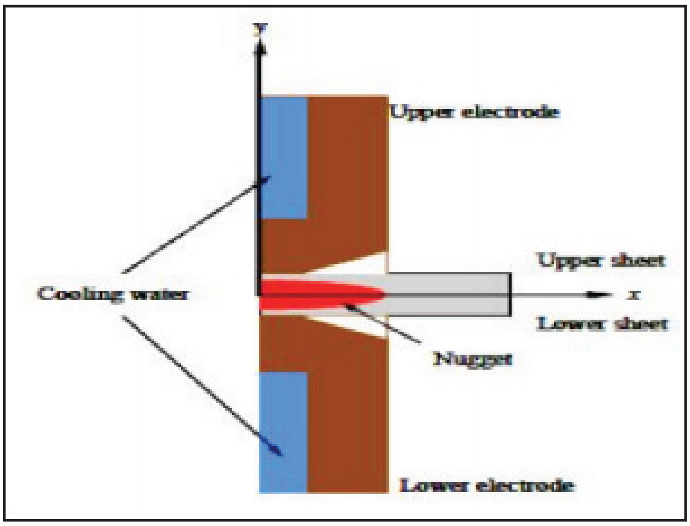

Fig. 2: FEA Model of RSW Process.

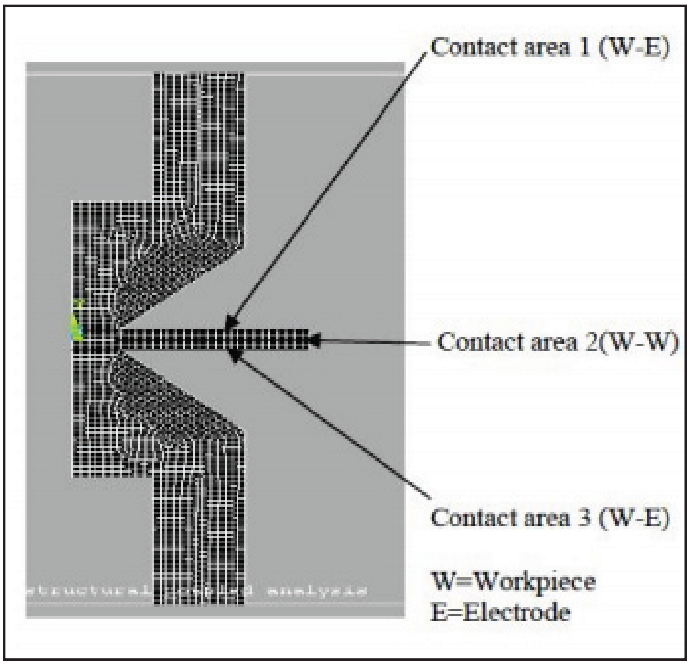

Fig. 3: Mesh of the FEA Model.

3. Boundary conditions

Fig. 4 shows the boundary conditions imposed for the analysis. The upper face of top electrode and lower face of bottom electrode are constrained in x and y directions. A voltage difference is applied across the top face of upper electrode and bottom face of lower electrode. The convection coefficient of air (21 W/m2 ºC) is applied on faces of electrode and sheet which are open to environment. The convection coefficient of water (300 W/m 2 ºC) is applied on the inner faces of electrodes which are in contact with the circulating cooling water with initial temperature of 10ºC [5].

III. Experimental Result

The FEM model is employed to simulate the RSW process in order to quantitatively understand the effects of the process parameters on temperature distribution and the nugget size at different cycles. The stress and strain fields in the weldment during the RSW process are very complex due to the combination of temperature and electrode force. At the squeeze stage, the electrodes and work pieces are deformed nder the application of the load.

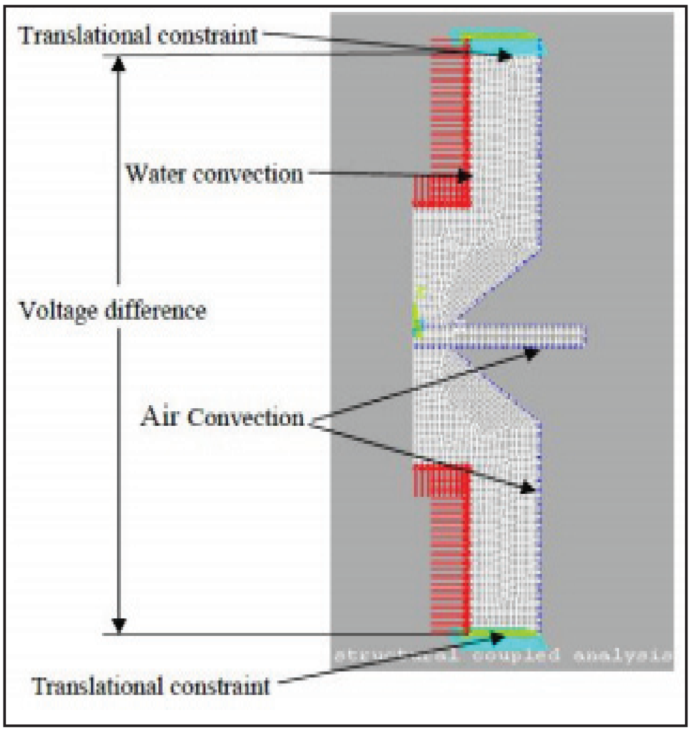

Fig. 4: Boundary Conditions

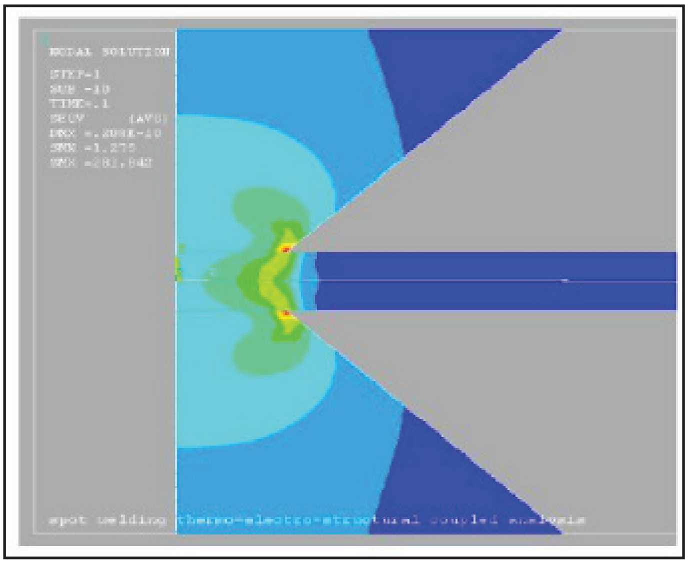

Fig. 5: Distribution of Von Mises Stress During Squeeze Stage

Fig. 5 shows the Von Mises stress distribution after the squeezing stage. The maximumstress (281 MPa.) occurs at the edge of the contact surface between the electrode and the work piece. The contact pressure on the WE interface is fairly uniformly in the majorityaround the axis and in the domain near the electrode edge, there is severe stress concentration. The welding residual stress is produced in welded joint as a result of plastic deformationcaused by nonuniform thermal expansion and contraction due to non-uniform temperaturedistribution in the welding process. The deformation at the end of hold step is extremely large than that of the squeeze step. This means much deformation is produced in the RSW processdue to the thermal expansion. Fig 6 shows the temperature profile and nugget growth at the time when nugget start to form. At the start of the welding process, the temperature at the center of faying surface increases very fast. The highest temperature remains at the center ofthe faying surface throughout the whole welding process. Melting first occur at the fayingsurface and then expand to the material near it. Due to the resistance offered to the flow ofcurrent at the faying surfaces, Joule heat is generated at this surfaces which is greater than the heat generated at other points on the weld surfaces. The nugget is formed in the 10th cycle ofthe welding process assuming 1530ºC as the melting point of mild steel. The spot nugget region appears as red in color. The weld nugget is close to the elliptical shape. The highest temperature always remains in the middle of the workpiece and the temperature away form the faying surface decreases due to transfer of heat by convection of air and cooling water. By changing the welding conditions, the temperature profile could be varied which in turnchanges the nugget size i.e. the welding quality. During the holding time in which the current is set to zero, convection and squeezing forces are onlyexternal loads in the thermomechanical model. The final nugget size is obtained at the end of holding time because there is some deformation in the weldingzone whenthe well-meant cools due to the electrode pressure and material shrinkage. As the electric current ceases at 0.3 s, the well-meant starts tocool down. In a veryshort time, the temperature of the nugget center decreases. The temperatureat the center of electrodeworkpiece interface decreasesmore slowlybut continuously. Fi. 7 shows the temperature distribution at the end of the hold period i.e. afterthe weld current is switched off.

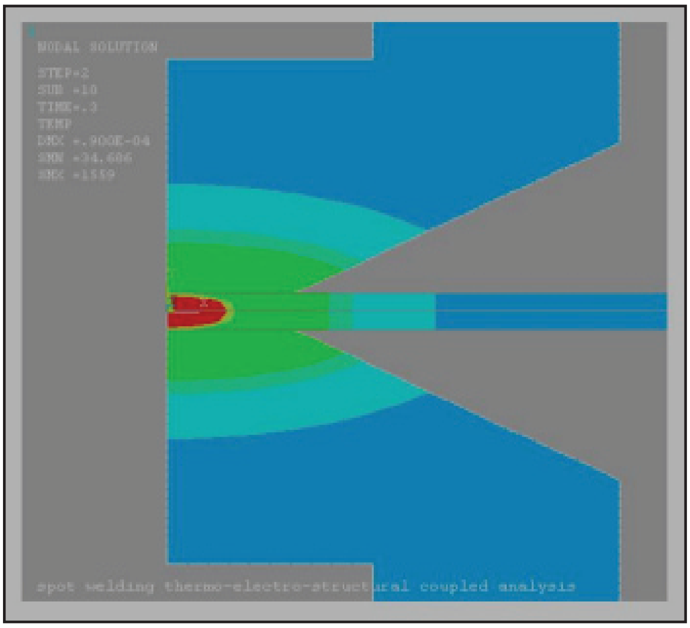

Fig. 6: Temperature distribution at the time nugget started to form.

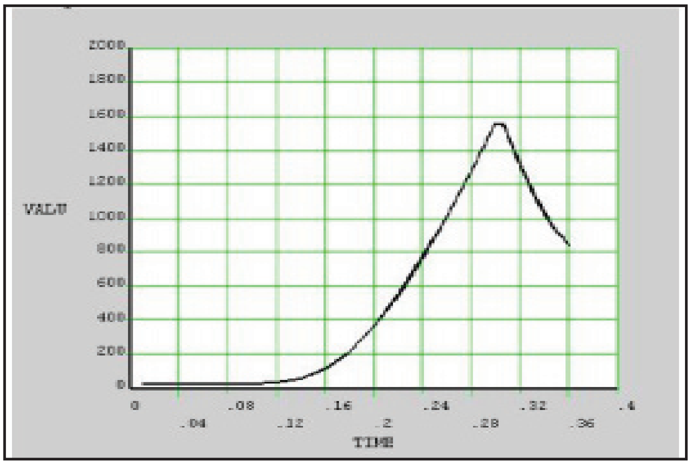

Fig. 8: Temperature Variation Along the Faying Surface

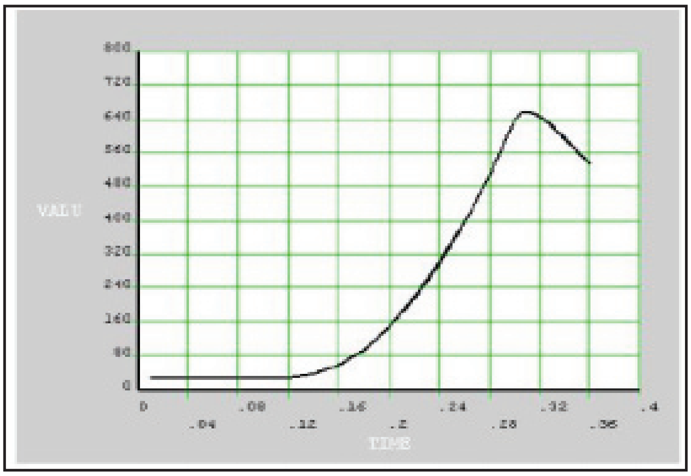

Fig. 9: Temperature Variation along the Workpiece Electrode Interface.

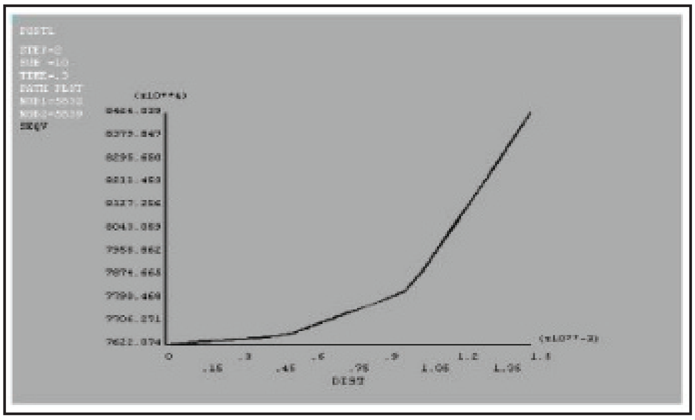

Fig. 10: Distribution of Von Mises Stresses Along the Faying Surface

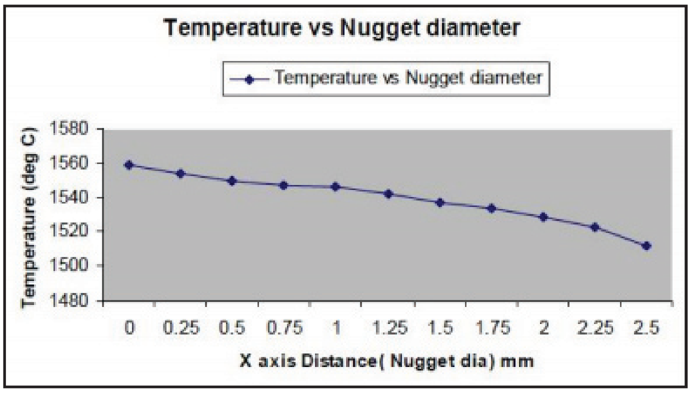

Fig. 11: Variation of Nugget Diameter With Temperature

The size ofthe weldnugget decreases slightly as compared to the size at the end of weld cycle. This is because the heat generation is stopped due to switching off the weld current. Also there is convective heat transfer from the heated surfaces of the sheets and the electrodes. Figure 8shows the temperature variation along the contactsurfaces ofthe two mild steel sheets i.e. Faying surface. In the first stage of the process, since only force is applied on the surfaces, there is no heat generation and hence the temperature remains constant. After the current is passed through the electrodes, there is generation of heat due to Joule effect and the temperature at the contact surfaces starts increasing. The temperature keeps on increasing till the time current flows through the electrodes. The maximum temperature of 1559 ºC is obtained at the end of 10 th weld cycle. After this time, the current is switched off and there is decrease in temperature due to loss of heat by convection of air andcooling water. At the end of hold period, the temperature reached is 842ºC. Figure 9 shows the variation of temperature along the workpiecesheet interface. The nugget size obtained is 2.75 mm. Fig. 10 shows the distribution of Von mises stress along the faying surface andFigure shows the variation of nugget diameter with temperature.

IV. Conclusion

A multicoupled structural thermoelectric analysis is carried out on the RSW process. This multicoupled method can efficiently provide sufficient details of RSW process and increase the quality monitoring and process control of RSW. Due to the combination of temperature and electrode force, the stress and strain fields are very complex in the element. During the welding cycles there is compressive stress in the contact area of faying surface, which is helpful for good metallurgical structure, forming a condensed weld nugget. Through the thermal histories and temperature distributions obtained from this analysis, the geometry and dimensions of the nugget can be calculated.

References

[1] Dikmen, S.Ü., Aksel, M., Yiğit, S.,“A Study of the Effects of tall Buildings on the Pedestrian WindComfort in Istanbul”, CENG’10: 6th International Symposium on Civil and Environmental Engineering, Lefke,Kıbrıs, 2010.
[2] Dikmen, S.Ü., Yiğit, S., Aksel, M.,“Effects of Wind in the Construction Activities at Highrise Buildings”, 2011a.
[3] Sixth International Conference on Construction in the 21st Century (CITC-VI) “Construction Challenges in theNew Decade” July 5-7 2011, Kuala Lumpur, Malaysia.
[4] Dikmen, S.Ü., Yiğit, S., Aksel, M., Sönmez, M., Şener, B.,“ YüksekYapıÇalışmalarındaBirVerimlilikFaktörü: Rüzgar”, İMO 6. İnşaatYönetimiKongresi, 25 – 27 Kasım, Bursa, 2011b.
[5] Dikmen, S.Ü., Yiğit, S., Aksel, M., Sönmez, M., Şener, B.,“ YüksekYapıÇalışmalarındaBirVerimlilikFaktörü: Rüzgar”, NWSA – Engineering Sciences, Vol. 7, No.1, pp. 84 – 95, 2012.
[6] Kolarevic, B., Klinger, K.,"Manufacturing Material Effects: Rethinking Design and Making inArchitecture, Routledge, NY, 2008.
[7] Kolarevic, B., Malkavi, A.,"Performative Architecture: Beyond Instrumentality", Spon Press, NY andLondon, 2005.
[8] Kolarevic, B.,"Architecture in the Digital Age: Design and Manufacturing", Spon Press, NY and London, 2003.