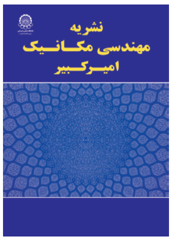

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A Coupled Finite Element Model to Study on Mechanical and Thermal Features of Resistance Spot Welding Process with Experimental Verification

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ABSTRACT: Resistance spot welding is a strong coupling process which involves electrical, thermal, and mechanical interactions. These make the whole welding procedure highly non-linear and difficult to model. In this paper, finite element analyzing tool, ANSYS, was used to simulate and model Resistance spot welding. In order to improve accuracy, material properties were defined temperature-dependent and phase transformation was taken into account in the simulation. The steel sheets in this study were AISI 1008 steel. The key parameters of the process including contact radius, contact pressure, and temperature distribution were investigated. Also, the development of weld nugget during the process was investigated and numerical calculations for nugget size showed good agreement with experimental results. This causes the weld nugget diameter abnormal variations and consequently reduces the weld strength. Therefore, the tip of the electrode should be dressed in this process. With these results, optimum settings for current, timing and pressure of the spot welding machine can be formulated for different materials to produce the desired welding quality. In addition to the magnitude of welding current, current shunting phenomenon affects the nugget size. In order to investigate the effect of electric current shunting, some tests were designed and simulated.

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1- Introduction

During the Resistance Spot Welding (RSW) process, deformation, stress, and strain will be generated and changed in the weldment due to the electrode force and Joule heating, and residual stress and strain will retain in the weldment after welding. These mechanical, thermal and electrical features have great influences on the properties of the welded joint, including the failure strength and fatigue life. Therefore, it is very important to understand the behaviour of stress, temperature history, and deformation during the RSW process. However, RSW process is a complex process in which coupled interactions exist between electrical, thermal, mechanical, metallurgical phenomena, and even surface behaviours.

Wang et al. [1] analyzed resistance spot welding of Al-steel by developing a fully coupled multi-physics simulation model. They calculated the Al-steel Intermetallic Compound (IMC) thickness, which is critical to weld strength, based on the thermal history at the Al-steel contact interface and the parabolic kinetics mode of growth. Pashazadeh et al. [2] modeled and optimized resistance spot welding process parameters using Neural Networks (NN) and Multi-Objective Genetic Algorithm (MOGA). Hamedi et al [3] optimized three important process parameters in the spot welding of the body components, namely welding current, welding time, and gun force. In this paper, finite element analyzing tool, ANSYS, was used for simulation and modeling of RSW. In order to improve accuracy, material properties were defined temperature-dependent, phase transformation was taken into account in the simulation. Also, Thermal Contact Conductivity (TCC) and Electrical Contact Conductivity (ECC) were considered temperature dependent.The key parameters of the process including contact area radius, contact pressure, and temperature distribution are investigated.

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2- Material Properties and Welding Conditions

The steel sheets in this study were AISI 1008 steel and the electrode was taken as copper. The thickness of the sheets was 0.7 mm. The larger diameter of the electrode was 13 mm, the smaller diameter 4.2 mm and the angle 150°). For an accurate representation of strong interactions between thermal, electrical, metallurgical and mechanical phenomena in the process, the model considers temperature-dependent material properties and thermal/electrical/mechanical contact interactions at all interfaces [4].
The welding parameters were used in this analysis: welding current, 50 Hz sine wave at the current of 7.5 kA; weld time, 16 cycles (0.32 s); electrode force, 2000 N; hold time, five cycles (0.1 s). Both the electrodes and the sheet material have well-defined values of electrical resistivity together with other material properties.

3- Numerical Model Development

After the theoretical analysis of the welding process, a numerical method was applied to solve this coupled problem. The electro-thermal-mechanical coupling of a spot welding is a complex phenomenon and depends on mechanical, electrical, thermal and metallurgical factors. The work in this study aims at developing a resistance spot welding process model that emphasizes on the nugget sizes and the thermal history of the fusion zone in the resistance spot welding conditions [5].

4- Experimental Work

The specimens were cut parallel to the rolling direction of the sheets. The surfaces of the specimens were cleaned using acetone, then washed and dried before welding a small circle was marked on the centre of the upper face of the specimens in order to help the accurate and consistent alignment of the electrode tip on the centre of the overlap area during welding, using a specially designed fixture.

5- Results and Discussion

These results include contact pressure and contact area radius at the electrode/sheet (E/S) and sheet/sheet (S/S) interfaces, thermal history of the process and nugget development. According to the results, it is clear that the radius of the connecting line increases, to except when the welding process is in the first stages, we see a decrease in the radius. Fig. 1 shows the pressure is in the middle area 171 MPa and at the edge is 97 MPa. As welding continues the pressure in the central region increases rapidly, which results in a rapid reduction of the radius connects.

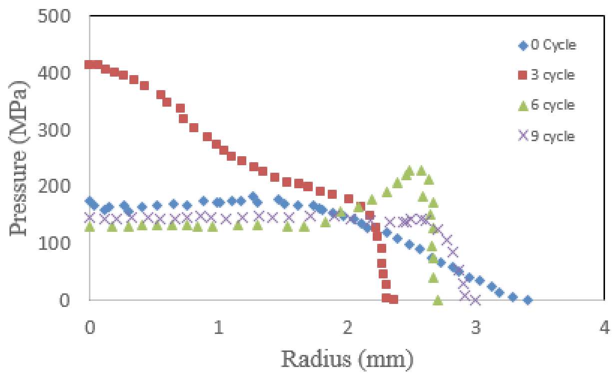

Fig. 1. Contact pressure variation at workpiece/workpiece interface

Fig. 2 shows the results of half the model obtained after analysis. The highest temperature during the RSW process is at the center of the connecting surfaces. Nuggets are elliptical, and as the temperature rises, the nugget begins to grow rapidly in both directions vertically and horizontally, and its original size at the end of the process after cooling is due to weld deformation, electrode pressure, and material distortion.

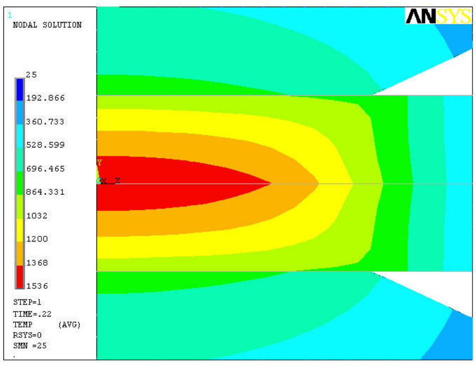

Fig. 2. Temperature profile and nugget growth temperature distributions at the time of nugget starting

The first test whilst space between nuggets is considered far away, therefore, the total current is forced to pass through the faying surface close to electrode tips. Consequently, the current density is more aggregated in this area and current shunting is not observed.

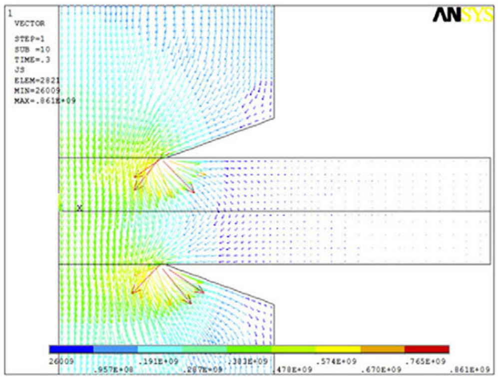

Fig. 3. Schematic of electric current flow. (Current shunting has not been considered).

6- Conclusion

In this study, finite element analyzing tool, ANSYS, was used to develop a 2D mathematical model to investigate the key parameters of the RSW process. The results highlight that:

- The initial contact radius at the faying surface interface is larger than the electrode tip radius, but after a short period of heating, the contact radius reduces sharply until it reaches its minimum value, and then until the end of welding the contact radius continually increases but at a relatively slower rate.
- The contact pressure at the faying surface was nearly constant during the welding cycles, except the earlier stages of the process.
- The contact pressure distributions at the E/S interface shows a stress concentration at the edge of the electrode, which leads to the wear of the electrode tip.
- In addition to the magnitude of welding current, current shunting phenomenon affects the nugget size. In order to investigate the effect of electric current shunting, some tests were designed and simulated.
- In the RSW process, the weld quality depends on the weld nugget size. Welding current, electrode force, Welding time parameters. They affect the dimensions of the nugget, so these parameters must be controlled.
- A good agreement has been found between the predicted and the measured data that verifies the validity of the employed model.
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7- References

[1] J. Wang, H.-P. Wang, F. Lu, B.E. Carlson, D.R. Sigler, Analysis of Al-steel resistance spot welding process by developing a fully coupled multi-physics simulation model, International Journal of Heat and Mass Transfer, 89 (2015) 1061-1072.

[2] H. Pashazadeh, Y. Gheisari, M. Hamedi, Statistical modeling and optimization of resistance spot welding process parameters using neural networks and multi-objective genetic algorithm, Journal of Intelligent Manufacturing, 27(3) (2016) 549-559.

[3] M. Hamedi, M. Shariatpanahi, A. Mansourzadeh, Optimizing spot welding parameters in a sheet metal assembly by neural networks and genetic algorithm, Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 221(7) (2007) 1175-1184.

[4] M. Fatehi, M. Kaviany, Adiabatic reverse combustion in a packed bed, Combustion and Flame, 99(1) (1994) 1-17.

[5] ANSYS. http://www.ansys.com.