Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 50(3) (2018) 185-188
DOI: 10.22060/mej.2017.11619.5163

Shunting Effect in Resistance Spot Welded Joints of Aluminum Alloys

M. Jafari Vardanjani, A. Araee*

Department of Mechanical Engineering, University of Tehran, Tehran, Iran

ABSTRACT: Shunting effect occurs in RSW when the electrical current passes through previous spot welds. Value of this current depends mostly on distance, number, and size of previous spot welds. This will cause some dimensional and metallurgical changes in welding nugget as well as heat affected zone (HAZ). In this study, shunting effect of RSW is considered in a finite element analysis (FEA) model and the results are compared to experiments performed on aluminum alloy 2219. Weld spacing together with welding current and time are considered to discover the effect of shunting current in the final quality of nugget. A three factor experiment design has been performed to find the significance of factors and interactive effects, as well as FEA model verification. Electrothermal and mechanical interactions are considered in the FEA model. Experimental and numerical solutions have yielded comparable similar results in terms of welding nugget properties. Asymmetry in electrical potential, temperature, and stress distribution and geometry of shunted nugget are predicted and verified directly or indirectly. Intense effect of shunting current on nugget height, asymmetric growth of heat affected zone (HAZ) toward previous welding nugget, as well as concentration of alloying elements along grain boundaries are also discovered.

Review History:

Received: 7 June 2016
Revised: 2 October 2016
Accepted: 25 December 2016
Available Online: 5 January 2017

Keywords:

Resistance spot welding
Shunting
Finite element analysis
Experiment

1- Introduction

Few studies can be found on shunting effect; however, most of Resistance Spot Welded (RSW) applications encounter with multiple spots. Intermittent spots change the mechanical and metallurgical quality of a new spot due to thermal-electrical alternations caused by the shunting current; and the current passing via the previous spot(s). This proves the necessity shunting effect analysis to optimize the adjustable parameters and compensate undesirable consequences.

Oldest experimental study of shunting effect is performed by Hard et al. [1]. They introduced a method for shunting path detection. Next studies considered the effect of sheet dimensions, welding distance, electrode geometry, material, and electrode force to find the minimum required distance to reduce shunting effect [2]. Howe and Wang et al. [3] tested several types of steels and discovered the dominant effect of distance and surface conditions in shunting intensity. In the simplified 3D electrothermal FEM by Chang [2], voltage and temperature distributions were predicted for a shunted nugget. In the theoretical model developed by Li et al. [4], a minimum required distance was obtained, however, it was mainly based on several geometrical and mathematical simplifications.

Finite Element Analyses (FEA) models to analyze RSW process are not readily usable to consider shunting effect; however, there are several RSW finite element analyses study about the simulation of thermal and electrical distribution, prediction of the electrical and thermal contact properties and contact radius (Shen et al. [5]), growth of nugget and thermal deformations, and electrical-thermal-mechanical analysis. Although most of these studies have included thermal, electrical and mechanical aspects of the RSW process, the asymmetry of shunting configuration due to the existence of shunting nugget, prohibits the use of 1D or 2D axisymmetric models.

In this paper, the shunting effect in RSW is considered by the use of FEM and the results are compared with experiments on AA2219. The influence of welding distance, current and time are investigated to consider shunting effect in the final quality of the nugget.

2- Methodology

Electrical and thermal equations used in FEM include Quasi-Laplace equation of electrical potential (ϕ) (Eq. (1)), and energy conservation principle [2] (Eq. (2)), respectively:

$$\frac{\partial}{\partial x}\left[\frac{1}{\rho}.\frac{\partial\phi}{\partial x}\right]+\frac{\partial}{\partial y}\left[\frac{1}{\rho}.\frac{\partial\phi}{\partial y}\right]+\frac{\partial}{\partial z}\left[\frac{1}{\rho}.\frac{\partial\phi}{\partial z}\right]=0 \quad (1)$$

where ρ is the bulk electrical resistivity.

$$D\,c.\frac{\partial T}{\partial t}=\frac{\partial}{\partial x}\left[k.\frac{\partial T}{\partial x}\right]+\frac{\partial}{\partial y}\left[k.\frac{\partial T}{\partial y}\right]+\frac{\partial}{\partial z}\left[k.\frac{\partial T}{\partial z}\right]+\frac{1}{\rho}\nabla\phi.\nabla\phi \quad (2)$$

where D is mass density, c is specific heat capacity, k is thermal conductivity coefficient, T is temperature, and ϕ is voltage. To simplify the calculation process, the previous nugget is defined as a cylindrical connection between the two sheets and the diameter is specified according to the dimensions of an experimental nugget, obtained using average welding parameters in single spot welding. Elastic-plastic material is specified as the type of material for AA2219 in the model.

Weldability tests, the design of experiment (DOE), model verification, and finding the significance of factors form

Corresponding author, E-mail: alaraee@ut.ac.ir

the main phases of experiments. Principles of coupons preparation, inspection of results, as well as preheating and welding parameters were excerpted from military and welding handbooks. 12 kA and 4 cycles were chosen for preheating, while off time was 2 cycles. Squeeze and holding force were 2 and 3.2 kN, respectively. Initial range of welding current, time, and force were 22-26 kA, 2-10 cycles, and 2.5-3.2 kN, respectively. Electrode was chosen as dome type according to the previous study [6].

3- Results and Discussion

Fig.1 shows the effect of welding distance on nugget diameter. Increasing welding current has increased nugget diameter while the interactive effect of welding current and distance is observed as the larger current has reduced distance effect on nugget diameter growth. The main reason could be the adequacy of applied welding current to produce maximum weld nugget diameter according to the contacting area; in this circumstance, increasing distance cannot have any significant effect on the reduction of shunting effect.

Micrographs and SEM images were also considered to check the microstructure of shunted nuggets and Heat Affected Zone (HAZ) . Comparison of images showed the reduction of nugget size (especially in thickness) while HAZ increased toward the previous spot due to shunting effect. This means a larger part of the thermal energy is used for generating HAZ rather than a nugget.

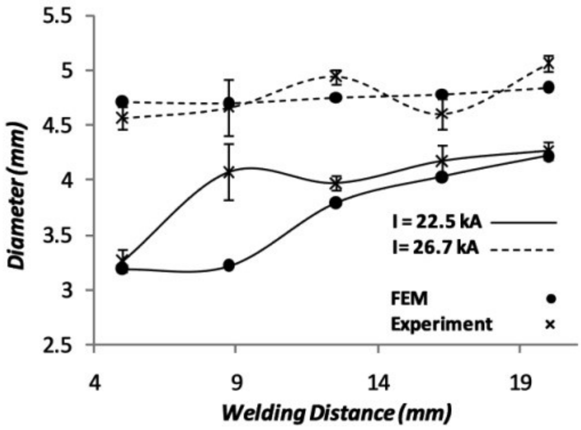

Fig. 1. Diameter-distance diagram for experimental and numerical results for 22, 5 and 26,7 kA welding current, and 4 cycles welding time.

The most important result drawn from SEM images is about the segregation of alloying elements along grain boundaries which is severe in HAZ. Segregation is increased by increasing welding distance as seen in Fig.2. White areas indicate the concentration of alloying elements. The significance of concentration for 5 mm welding distance is more than 20 mm. It could be interpreted as the negative effect of shunting current on HAZ. In fact, the shunting current has increased the nonuniformity of distribution of elements over HAZ. The main reason can be the rise of heat in HAZ acquired by the shunting current which did not melt the HAZ, but altered the microstructure in a negative way.

4- Conclusions

Shunting effect in resistance spot welding of 1 mm AA2219 sheets was considered experimentally and numerically using a FEM for two spots. The following conclusions are drawn by investigation of results.

- Distance effect was clearly observable on nugget size for experimental and numerical results. The main reason is the reduction of shunting current by increasing distance.
- HAZ asymmetry was observed in micrographs for shorter distances, while it developed mostly toward the previous spot due to shunting effect.
- SEM images indicated the effect of shunting current on segregation and concentration of alloying elements along the boundaries of grains, particularly on HAZ domain.

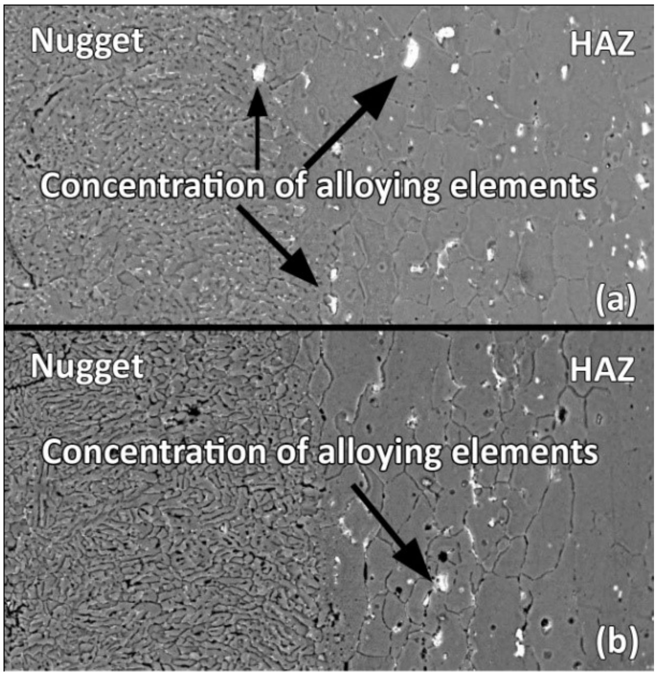

Fig. 2. SEM photo for the nugget section made by 25.3 kA welding current, 6 cycles welding time, and (a) 5, (b) 20 mm welding distance, with 500x magnification.

References

[1] A. Hard, „Preliminary test of spot weld shunting in 24ST Alclad", *Welding Journal*, 27(6) (1948) 491-495.

[2] H. Chang, H. Cho, A study on the shunt effect in resistance spot welding, *Welding Journal*, 69(8) (1990) 308-316.

[3] B. Wang, M. Lou, Q. Shen, Y. Li, H. Zhang, „Shunting effect in resistance spot welding steels—part 1: experimental study", *Welding Journal*, 92(6) (2013) 182s-189s.

[4] Y. Li, B. Wang, Q. Shen, M. Lou, H. Zhang, „Shunting effect in resistance spot welding steels—part 2: theoretical analysis", *Welding Journal*, 92(8) (2013) 231s-238s.

[5] J. Saleem, A. Majid, K. Bertilsson, T. Carlberg, M. Nazar Ul Islam, Nugget formation during resistance

spot welding using finite element model, in: World Academy of Science, *Engineering and Technology: An International Journal of Science, Engineering and Technology*, 2012.

Please cite this article using:

M. Jafari Vardanjani, A. Araee, Shunting Effect in Resistance Spot Welded Joints of Aluminum Alloys, *Amirkabir J. Mech. Eng.*, 50(3) (2018) 561-576.

DOI: 10.22060/mej.2017.11619.5163