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3-D MICRO-ANALYSIS OF ELECTRICAL CONTACT RESISTANCE FOR SPOT WELDING

Hiroyuki Kuramae[1], Tomoya Niho[2] and Tomoyoshi Horie[2]

[1] Osaka Institute of Technology, 5-16-1 Omiya, Asahi-ku, Osaka 535-8585 Japan,
kuramae@dim.oit.ac.jp, http://www.oit.ac.jp/dim/kuramae/
[2] Kyushu Institute of Technology, 680-4 Kawazu, Iizuka, Fukuoka 820-8502 Japan,
niho@mse.kyutech.ac.jp, horie@mse.kyutech.ac.jp, http://solid.mse.kyutech.ac.jp/

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Electrical contact resistance is an important property in the numerical simulations for resistance spot welding. Until now, some mathematical models of electrical multipoint contacts were developed. In the simple case, the Holm’s equation [1] was used for a large number of small equal spots distributed uniformly and densely over a circular area. Greenwood [2] expanded the Holm’s equation to a cluster of spots with various sizes and their distributions. Babu [3] proposed a useful model for spot welding simulation by introducing the asperity density η (m^{-2}), which is the number density of asperities in real contact, into the Greenwood’s model in order to eliminate parameters of the surface roughness as follow:

$$R_{\mathrm{CA}} = (\rho_1 + \rho_2)\left(\frac{1}{4}\sqrt{\frac{\pi\sigma_{\mathrm{YS}}}{\eta P}} + \frac{3\pi}{16\sqrt{\eta}}\right) , \tag{1}$$

where ρ_1 and ρ_2 are resistivity of materials. This model is expressed by only the contact pressure P and the yield stress σ_{YS} of material, however, the microscopic shape of the asperities and loading paths of contact pressure and temperature is not considered.

In this study, three-dimensional micro-analysis of electrical contact resistance is presented based on coupled finite element (FE) method among structure, electricity and temperature. A micro-FE model, which corresponds to the representative volume element (RVE), is constructed based on surface roughness measurement of a steel sheet using the laser microscope KEYENCE VK-9700. The measurement area was 1411×1058μm^2 with 0.689μm interval in-plane. A statistically similar RVE (SSRVE) was determined and sampled as 40×40μm^2 by comparing the frequency distribution of measured surface roughness as shown in Fig. 1. The SSRVE is equally divided into 20-node solid elements with the size of 2.756μm in-plane. On the side face of the SSRVE FE model, the periodic boundary condition is satisfied.

A rigid plate is contacted to the SSRVE FE model with contact pressure as shown in Fig. 2 (a). The temperature was set as shown in Fig. 2 (b). Three cases of different time history of contact pressure and temperature, which are sampled from an FE result of macroscopic spot welding simulation, are employed with the same initial and final values in order to verify the loading paths. In the Case 1, the largest contact pressure and abrupt increase of temperature are applied than the others because it is located directly below electrode.

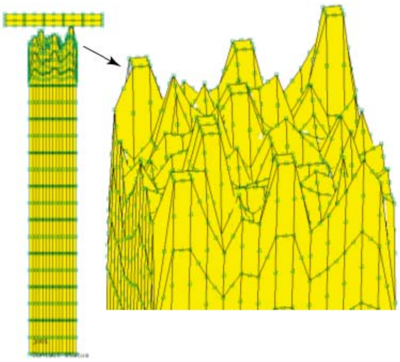
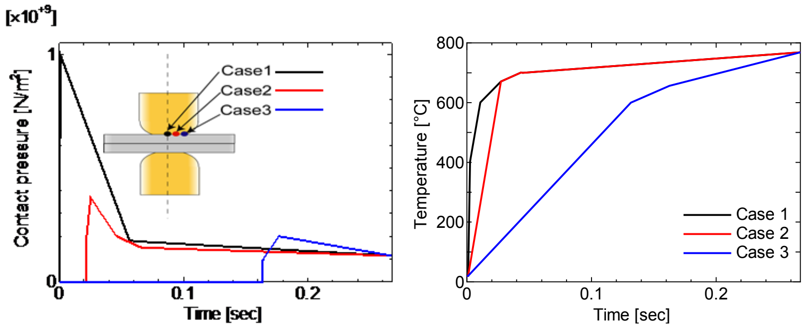
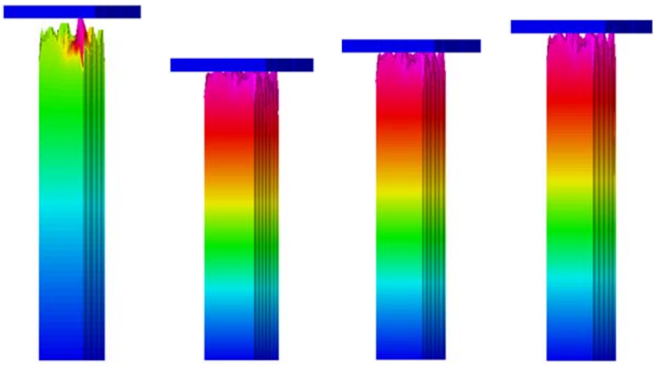


Fig. 1 SSRVE FE model of steel sheet



(a) Contact pressure (b) Temperature

Fig. 2 Time histories of contact pressure and temperature during spot welding



(a) Initial (b) Case 1 (c) Case 2 (d) Case 3

Fig. 3 Electrical potential distribution of the initial (a) and final deformed shape (b)–(d) of SSRVE FE model

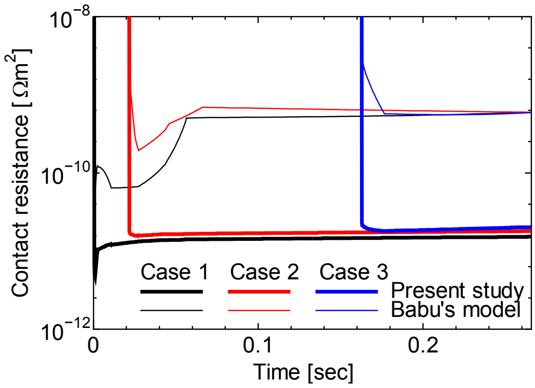


Fig. 4 Comparison of contact resistance between micro-FE results and Babu’s model

The coupled FE analysis was conducted by MSC/Marc 2012 combined with the original electric FE code based on ϕ-method, which called as a user subroutine from the Marc. The Marc analyzes elast-plasticity contact between the SSRVE FE model and the rigid plate, and the electric FE code computes the contact resistance of the deformed shape of the SSRVE. Temperature-dependent material properties such as yield stress, work hardening rate and resistivity are considered in the analysis.

Figure 3 shows the initial and final deformed shapes and electric potential distributions of SSRVE model. There are different shapes and contact status among Case 1, 2 and 3 due to different loading paths. Figure 4 shows the time history of contact resistance compared with Babu’s model by Eq. (1). In the FE results, the final contact resistance among three cases are different, however, the Babu’s results indicate same values because the loading paths of the contact pressure and temperature are not evaluated in the Babu’s model.

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