Numerical Study of the Temperature Distribution into a Contact Spot

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The present study deals with the numerical simulation of the electro-thermal properties of a contact spot. By resolving the Poisson equation we determine the current distribution inside different shapes of contact. These current distributions lead us to estimate the time evolution of the contact spot temperature due to the Joule effect and due to the constriction of current lines related to the shape of the contact spot.

Keywords: Electro-thermal properties, electrical contact resistance, multi-contacts interface.

1. Introduction

Contact between rough surfaces is realized by tiny contact spots where their number, distribution, shapes or size, i.e. their geometrical properties, depend from the roughness, the used materials, and the stress applied on the contact interface. Many studies describing the multi-contact interfaces state under stresses are currently used in many ways and are based on Holm's work [1].
In the present work, we focus on the electro-thermal properties of the contact spots according to their geometrical properties. Electric current can be used as a probe of the contact state but it has an influence on the temperature which itself has a consequence on the mechanical evolution of the spot during time (creep phenomenon) [2, 3].

2. Methods

In order to determine the current lines into the spot, we resolve first the Poisson equation of the electrical potential V using a 2D finite-difference method (FDM):

$$\Delta V(\vec{r}) = 0 \qquad (1)$$

Yielding:

$$\frac{V_j^{i+1} - 2V_j^i + V_j^{i-1}}{h_x^2} + \frac{V_{j+1}^i - 2V_j^i + V_{j-1}^i}{h_y^2} = 0 \qquad (2)$$

Figure 1 gives the distribution of V, its equipotentials and its associated current lines for a cylindrical contact. In this situation the spot area is therefore circular, permitting us to compare our results to those from Holm's theory.
From this first computation, we resolve then the heat equation using the same method to determine the temperature T inside the spot:

$$\frac{\partial T(\vec{r},t)}{\partial t} - D\Delta T(\vec{r},t) = \vec{J}(\vec{r},t).\vec{E}(\vec{r},t) \qquad (3)$$

Since $\vec{E}(\vec{r},t) = \rho\big(T(\vec{r},t)\big).\vec{J}(\vec{r},t)$ and $\rho\big(T(\vec{r},t)\big) = \rho_0\big(1 + \alpha(T(\vec{r},t) - T_0)\big)$, it yields:

$$\frac{T_{i,j}^{\tau+1} - T_{i,j}^{\tau}}{h_\tau} - D\Delta T_{i,j}^{\tau} = f\big(T_{i,j}^{\tau}\big) \qquad (4)$$

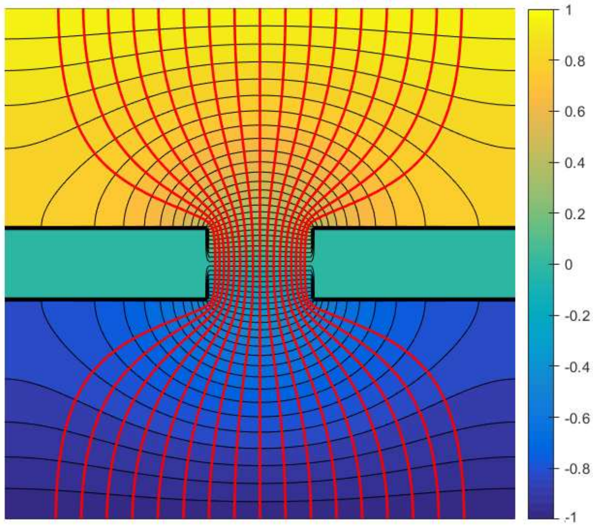

Figure 1: Current lines (red) and equipotential (black) for a cylindrical contact (arbitrary units).

3. Results and discussion

As we can see on the figure 1, currents lines are not homogeneous into the contact. This result, previously determined by Holm, shows that the heating process from Joule effect is mainly on the side part of the contact. So, by resolving the heat equation we are able to predict the influence of the current flow on the contact electrical resistance. This point leads to a more precise description of the electrical properties of contact spots which is required to improve the electrical description of multi-contact interfaces.
Furthermore, the evolution of the electrical resistance during time due to heating is a first clue to determine precisely the contact temperature which can be very difficult to access by common methods.

4. References

[1] Holm, R., "Electric Contacts - Theory and Applications", 4th Edition, Springer, 1967. ISBN 978-3-662-06688-1
[2] Zhai, C., Hanaor, D., Proust, G., and Gan, Y., "Stress-Dependent Electrical Contact Resistance at Fractal Rough Surfaces", J. of Eng. Mech. 143, 3, 2017.
[3] Bowden, F. P., and Williamson, J. P. B., "Electrical conduction in solids I. Influence of the passage of current on the contact between solids", Proc. R. Soc. Lond. A2461-12, 1958.