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Coupled mechanical-electrical identification of the contact resistance in the stranded electric power cable

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Analysis and modelling

ABSTRACT

Purpose: To analyse the phenomena in the stranded cable it is necessary to know how the contact resistance influenced the current repartition in the cable. The aims of our research are to find the dependence of the cable resistance on the design parameters.
Design/methodology/approach: When current passes from one wire to another, the crucial parameter is the resistance of the contact region. The paper presents a method by which this region can be identified and relevant resistance measured. Comprehensive simulations were conducted for different types of wires and cables to assess the influence of design parameters on the current distribution and uniformity.
Findings: The found in the course of the work was a method of identification of contact resistance and elaboration of parameters dependence.
Research limitations/implications: The future research will be focused on the taking into account the nonhomogenity of the contact area.
Practical implications: The presented method will by apply for the optimisation of design of the stranded electric power cable.
Originality/value: The novelty is in the way the contact region is identified where current passes from one filament to another. Original relationships have been proposed showing the dependence of the contact region resistance on the design parameters of the cable and mechanical stress.
Keywords: Contact resistance; Identification; Stranded cable; Contact resistance measurement; Design parameters

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1. Introduction

The principal parameter affecting the passing of current from one wire to another is the resistance of the contact interface. Existing experimental techniques fail to provide accurate values of such contact resistance. In this paper we suggest a series of simulations to establish the relationship between the current flow patterns and the geometry, design type, etc., under various conditions, including variable mechanical pressure on the cable parameters. These simulations have been performed using two commercial software packages: OPERA for electric current flow distributions and Abaqus for mechanical modelling. One of the challenges encountered was due to the fact that Abaqus - used to model mechanical deformation due to twisting or compression stress - provides deformed mesh, but not deformed geometry, whereas OPERA requires data input for solid geometry. It was therefore necessary to transform the deformed mesh into a solid geometry. Finally the Ansys environment has been used, that allowed for direct calculation of current flow applied to the deformed shape of the model. For each of the two selected geometries a series of simulations were first carried out using Abaqus to compute the geometrical deformations, and then the deformed meshes were converted into solid geometry models to provide input data for the OPERA software.

The force exerted on the wire strands results in both plastic and elastic deformation of the material. The deformations generated in the conductor result in a change in the contact area, in its electrical resistance. Localized compressive stresses on the surface in the contact areas of the different strands allow breaking the various layers of contamination due to oxidation and the manufacturing process of the driver to increase the real contact area, to ensure good distribution of current in the conductor.

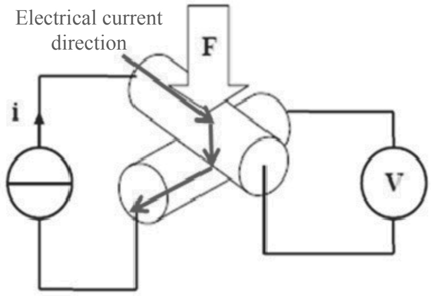
Generally, a surface is made of pikes and furrows materializing some roughness value. This roughness depends on the manufacturing process. Wire drawing and cold drawing of conductor produce a surface finish coefficient Ra that can vary from 0.4 to 3.2 microns. The Ra value greatly affects the electrical resistance of the contact. Indeed, the contact between two more or less rough solids takes place at certain points of the real surface.

In an electrical contact, the current lines are tightened to pass through the separated contact spots (Fig. 1). The constriction of the electrical current lines through the spots reduces the volume of material used for the electrical conduction and thereby increases the electrical resistance. The evolution of the compressive force produces plastic and elastic deformations of asperities that increase the contact area and reduce the electrical resistance. In addition to the surface roughness, certain easily oxidizable materials such as aluminium require a large compressive force to break the layer of alumina. To measure the electrical contact resistance between two crossed wires, we used the Kelvin method, as shown in Fig. 2. This method has the advantage of separating the injection current circuit from the potential circuit to eliminate the resistance of the conductor connection [2].

To find the correlation between contact resistance and the force applied on the crossing of two wires, we performed a series of measurements by changing the force applied to the intersection of the two wires. It can be observed that elastic deformation occurs when the applied force less than 19.8 N while plastic deformation occurs for forces beyond this value.

Finding out how the current passes from one conductor to another is possible only by computer simulation. In the first simulation a model was used where two cylindrical conductors, each of 30 cm length, intersect perpendicularly. The contact is considered to be ideal and made of copper. Next, the contact was replaced by a layer with variable resistivity where its value was adjusted up from that of the ideal contact, until it was consistent with the value obtained experimentally.

a) Kelvin measurement method



b) Experimental connection

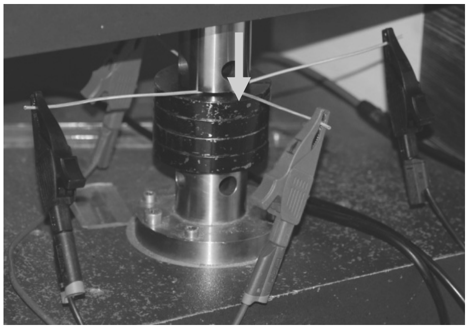


Fig. 1. Electrical contact resistance measurement - Kelvin method

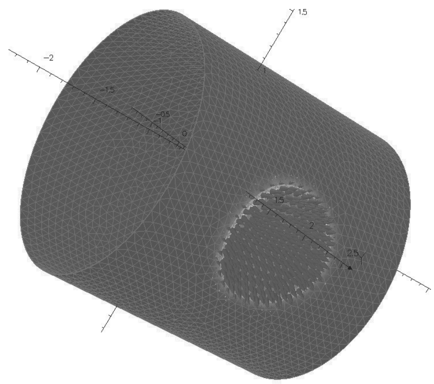


Fig. 2. Modulus of current density taking into account the resistance of transition layer

If the contact surface is assumed without resistance the current distribution in the contact zone is not homogeneous. The current flows mainly at the edges of the cavities. The current turns instead of going through the entire surface. Comparison of measurement and simulation of an ideal transition zone indicates the existence of transition layers of different conductivity than the conductivity of copper.

We performed a series of simulations by changing the depth and the resistance of the contact area. It was found that the current distribution is approximately uniform and the value of the resistance of the homogenized contact area depends on its depth.

The identified contact resistance was used in the simulation of the 1 + 6 cable for the different parameters of the cable. The simulation was compared with the measurement.

In the paper a series of simulations to establish the dependence of the current flow patterns on the geometry, design type, etc., under various conditions, including variable mechanical pressure was presented. These simulations have been performed using three commercial software packages: OPERA for electric current flow distributions and Abaqus for mechanical modelling and also in Ansys environment included both simulations. It has been shown that the voltage and current distribution in analysed device strongly depends on the forces and wires deformations.

References

[1] P. Lindholm, Numerical study of coated electrical contacts, Proceedings of the COMSOL Conference, Paris, 2010.

[2] P. Dular, J. Gyselinck, Modeling of 3-D stranded inductors with the magnetic vector potential formulation and spatially dependent turn voltages of reduced suport, IEEE Transaction on Magnetics 40/2 (2004) 1298-1301.

[3] M. Braunovic, V. Konchits, N. Myshkin, Fundalentals of electrical contacts, Taylor and Francis Group, LLC, 2006.

[4] M. Butta, P. Ripka, S. Atalay, F.E. Atalay, X.P. Li, Fluxgate effect in twisted magnetic wire, Journal of Magnetism and Magnetic Materials 320 (2008) 974-978.

[5] P.Y. Duvier, V. Mandrillon, J.P. Polizzi, K. Inal, Etude de la resistance electrique d’un contact Au/Au en function de la force appliqué, Proceedigs of the 19th Congrès Français de Mecanique, 2009 (in French).

[6] Y. Zeroukhi, K. Komeza, E. Napieralska-Juszczak, F. Morganti, G. Vegas, Improving the accuracy of the method of measuring the cable resistance exploiting current flow simulation, Proceeding of EPNC Conference, Pula, Croatia, 2012.