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The modelling and analysis of the temperature in current guages and contact system

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***Abstract*—Contact assemblies of electric apparatuses belong to the most burdened elements of current circuits. They should be designed, made and exploited in order to acceptable restrictions to their technical parameters, resulting from adequate rules and standards, weren't crossed.**

***Keywords*—current guages, contact system, electric apparatus**

I. INTRODUCTION

Requirements established for large-power-transmission lines and pin arrangements are different than typical requirements for lines with little power load not only because they are "stricter", but new requirements result from the fact that constantly a size of designed devices grows and electrical power engineering systems, their extensiveness and the diversity appear. In currently existing conditions of the free competition, producers who want to stay at the market are forced to constant reducing the time of the development of the new production, lowering the price, raising functional advantages, fast reacting to changing requirements of customers and the adjustment to undergoing constant changes of the environment [1]. Adopting techniques of different kind of computer assisting engineering works, as well as developing appropriate procedures are the most effective way to coping with such a pressure and of algorithms carrying out design action. Issues concerning the heat flow, the temperature distribution and the current density are an object of the work in the contact system of the large-power-transmission line (fig. 1).

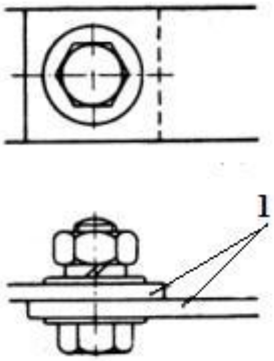

Fig. 1. Inseparable motionless contact system (1 – motionless joint).

II. PAPER SUBMISSION EXAMINATION OF THE IMPACT OF DIFFERENT SHAPES AND MATERIALS FOR THE TEMPERATURE DISTRIBUTION IN CONTACT SYSTEMS

In conditions of the normal work associated with long-term conducting working electricities, current with the intensity I flowing through the contact system is triggering the loss of the I2Rp power on his Rp resistance. The temperature of the place of the contact system is increased towards the operating temperature of the power rail. The value of this temperature is dependent on conditions of conveying the warmth from joints. Quantitative relations are pointed for the contact system spot, for remaining types of contact systems they constitute proximate information. The purpose of this work is to bring up issues of the selection of optimum parameters of the contact system, for which the energy transport would take place with the greatest efficiency. Analysis included at this work can contribute for better understanding of physical phenomena occurred in electric conductors. The tool which was used for the analysis was an ANSYS program. Amongst many systems of MES - ANSYS is a ranked leading program [2]. The software represents one of a few newest packages of using the finite element method, containing folded procedures facilitating the build of the geometric model and enabling to enter the description of the shape from the most popular systems CAD. ANSYS is a program equipped also with algorithms of the automatic discretization and extended modules of the graphical presentation of the model and results of calculations. In the program they implemented contact system like on picture 2.

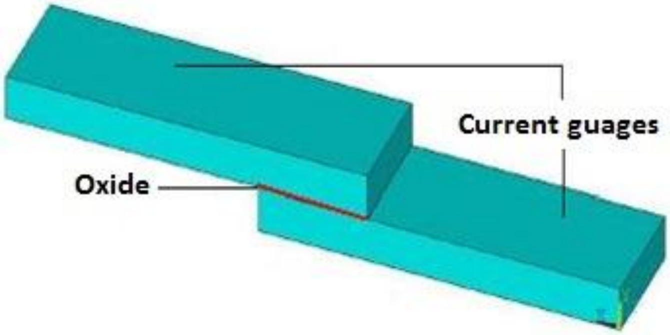

Fig. 2. Implemented contact system.

In the simulation the properties of materials shown in table 1were exploited.

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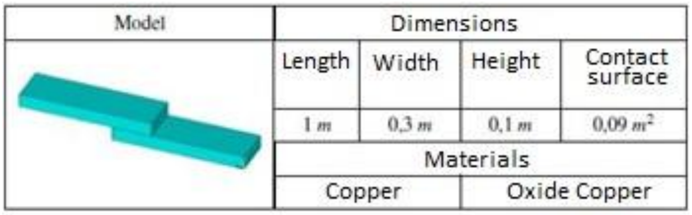
Table 1. Properties of copper exploited in the simulation.

Specificity	Copper	Oxide Copper	Aluminum	Oxide Aluminum
Density [$\frac{kg}{m^3}$]	8950	6000	2700	3950
Proper warm [$\frac{W}{m \cdot K}$]	384	0,698	205	40
Resistivity [$\Omega \cdot m$]	$1{,}72 \cdot 10^{-8}$	5	$2{,}65 \cdot 10^{-8}$	10^{14}
Permittivity [-]	0,999969	1,002991	1,000207	0,99995
Specific heat [$\frac{J}{kg \cdot K}$]	386	503	900	775
Emissivity [-]	0,05	0,65	0,02	0,2

While having a model prepared for calculations at its disposal, we should one by one inflict burdens. Current analysis regards thermal and electric issues, so it should be implemented. The study contains instructions to individual functions according to the real work in the program. Access paths of the function are in English. From main menu a Preferences bookmark was chosen and farther in options Thermal and Electric. Firstly, electric parameters were assigned. From main menu ANSYS, Preprocessor/Loads/DefineLoads/Apply/Electric/Boundary/Voltage/On Areas, lets to assign the electric potential. It was added as the voltage drop at the episode of power rail by determining the value in volts. So that there is a possibility of the exchange of the thermal energy a convection was put on an upper surface of the power-transmission lines [3]. The implementation of the burden will enable to experience the warmth to the centre where the power rail is, Preprocessor/ Loads/ DefineLoads/ Apply/ Thermal/ Convection/ OnAreas. After emphasizing an upper surfaces in the window you should describe the coefficient of the heat transfer VALI Film Coefficient (in the international system of units given in $\frac{W}{m^2 \cdot K}$) which value for air was assumed 20. Next in the same window VAL2I Bulk temperature was chosen, the value means the temperature of the centre in the Celsius degrees. For chosen analysis 40 degrees of Celsius were accepted. A copper contact system was analysed with the presence of the oxide of copper. In picture 3 model parameters have been shown.



Model	Dimensions			
	Length	Width	Height	Contact surface
	1 *m*	0,3 *m*	0,1 *m*	0,09 m^2
	Materials			
	Copper		Oxide Copper	

Fig. 3. Geometry and material data of the copper contact system.

Analysis was conducted according to described earlier assumptions. Under the influence of the flowing current, as a result of the generation of the Joule's warmth the contact system reached the higher temperature than the surrounding [4]. In the place of layer we can see the maximum value of the temperature. The disintegration of the current density and temperatures were shown in picture 4.

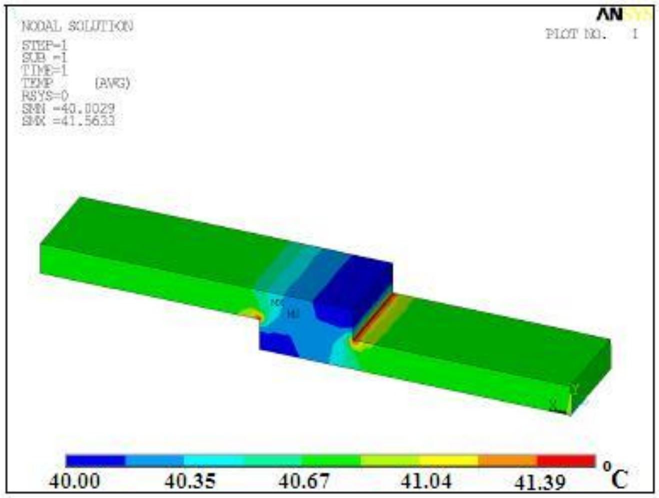


Fig. 4A. Temperature distribution in the copper contact system.

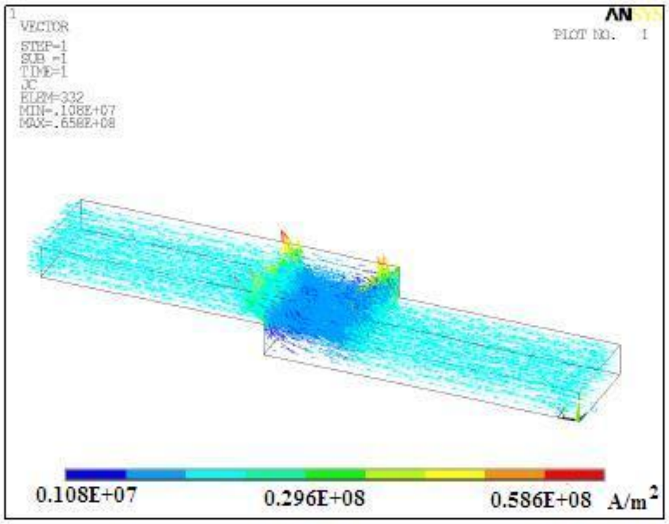
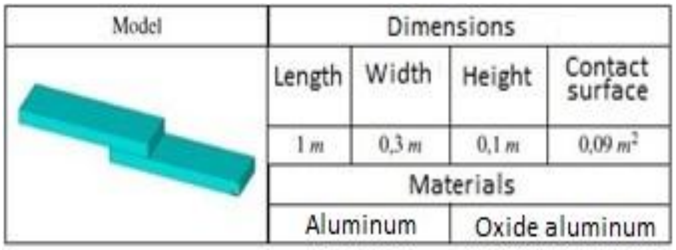


Fig. 4B. Disintegration of the current density in the copper contact system.

Results of the thermal-electric analysis of the copper contact system were used as a point of reference for further research. The model of the aluminum contact system has been shown in picture 5.



Model	Dimensions			
	Length	Width	Height	Contact surface
	1 *m*	0,3 *m*	0,1 *m*	0,09 m^2
	Materials			
	Aluminum		Oxide aluminum	

Fig. 5. Geometry and material data of the aluminum contact system.

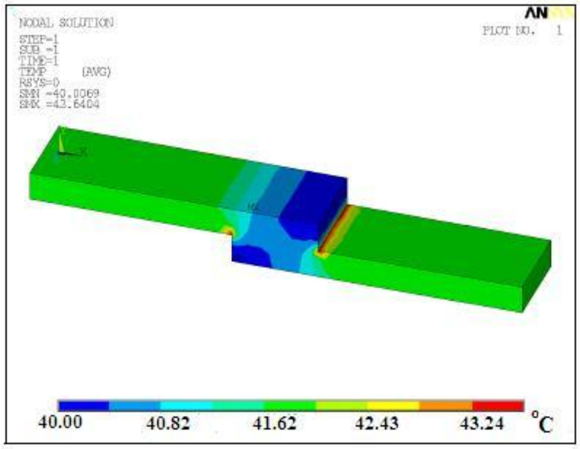


Fig. 5A. Temperature distribution in the aluminum contact system.

The aluminum contact system for the same conditions reached the higher temperature. It is caused by higher resistance of layers of the aluminum oxide [5]. Of course it should not be forgotten about the higher resistance of the metal towards to copper. On the temperature distribution we can see the value increased for it and not only on the connection, but also on the entire model. Invariably the area of the edge of the contact system is coolest and does not differ from the copper model with the same geometry. The current density is growing on edges of the contact system what means reducing the power-driven load capacity at keeping the same diameter towards the copper model (figure 5A i 5B).

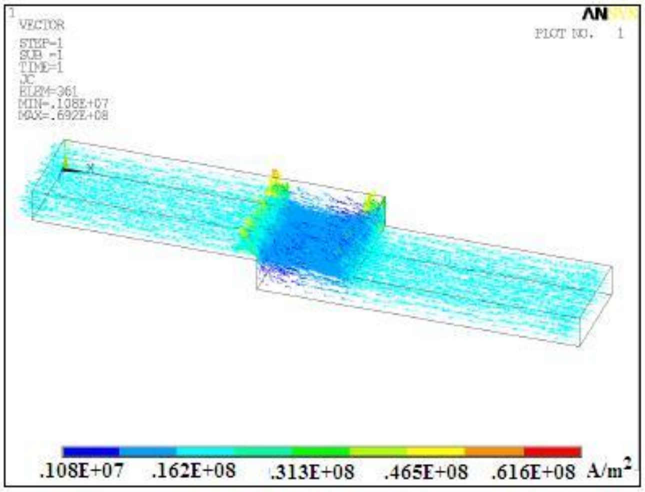


Fig. 5B. Disintegration of the current density in the aluminum contact system.

A sequence of analyses was carried out for different structures of the copper path along with the contact system:
- copper model with the height of tracks 0.05 m,
- copper model with the height of tracks 0.15 m,
- copper model with the width of tracks 0.45 m (a surface of the contact system also has been changed- 0.135 m2),
- copper model with the width of tracks 0.15 m (a surface of the contact system also has been changed- 0.045 m2),
- copper model with longer occurring of joints (a surface of the contact system has been changed- 0.135 m2),
- copper model with shorter occurring of joints (a surface of the contact system has been changed- 0.045 m2),
- copper model with cut edges of the contact system,
- copper model with longer occurring of joints, widths of tracks of 0.45 m and the height 0.05 m (a surface of the contact system also has been changed- 0.045 m2).

In order to depict examinations results were presented for the model with the contact system with the cut edges and changed geometry along with increased occurring of joints. On picture 6, 6a and, 6b the model parameters and analysis results have been shown.

Model	Dimensions			
	Length	Width	Height	Contact surface
	1 m	0,3 m	0,1 m	0,09 m^2
	Materials			
	Copper		Oxide Copper	

Fig. 6. Geometry and material data of the copper contact system with cut edges.

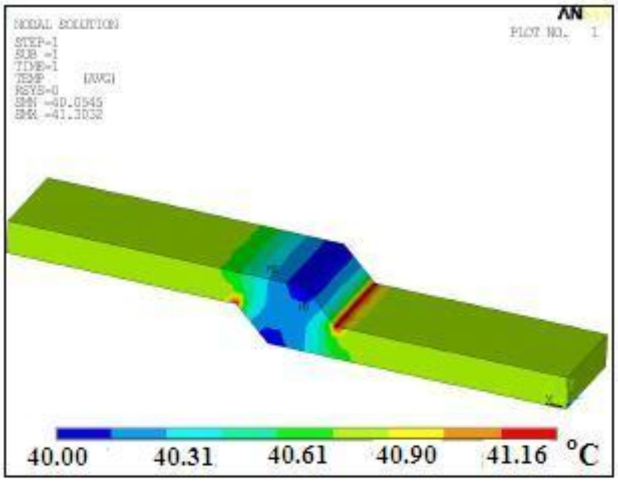


Fig. 6A. Temperature distribution in the copper contact system with cut edges.

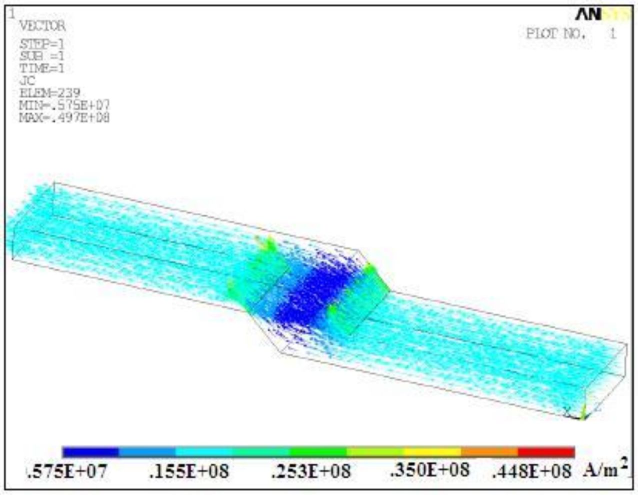


Fig. 6B. Disintegration of the current density in the copper contact system with cut edges.

The angle of chamfering was determined at 45^0. By cutting other geometrical parameters without the change of the surface of the convection additionally was enlarged. Removed geometry didn't participate in the flow of the electricity. A definitely more better heat flow turned out to be the effect. On picture 7, 7a and,7b model parameters have been shown (summary) and analysis results.

<table>
<tr><th>Model</th><th colspan="4">Dimensions</th></tr>
<tr><td rowspan="4"></td><td>Length</td><td>Width</td><td>Height</td><td>Contact surface</td></tr>
<tr><td>1 m</td><td>↑ 0,45 m</td><td>↓ 0,05 m</td><td>↑ 0,2025 m²</td></tr>
<tr><td colspan="4">Materials</td></tr>
<tr><td colspan="2">Copper</td><td colspan="2">Oxide Copper</td></tr>
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Fig. 7. Geometry and material data of the copper contact system with the increased surface of the contact system and cut edges.

The model according to expectations presents the low temperature and most even disintegration [6]. The wider power-driven transmission line contributed to a fall in temperature through the increased surface of the contact system and the convection. The longer bookmark of joints affected reducing the resistance of the passage and the more even syneresis of the electricity. Cutting the edge enlarged the convection additionally and had a positive effect on a syneresis of the warmth.

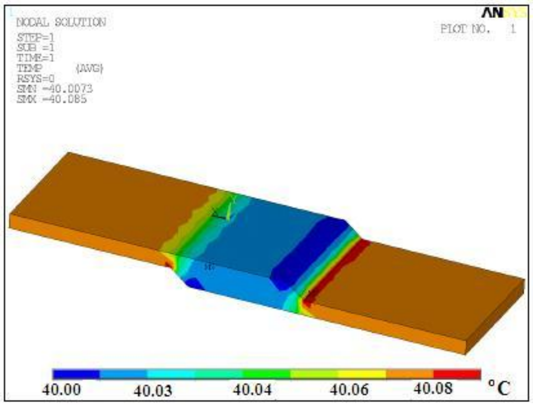


Fig. 7A. Temperature distribution in the copper contact system with the increased surface of the contact system and cut edges.

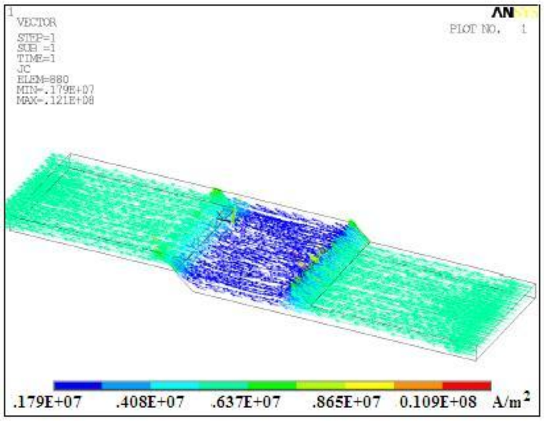
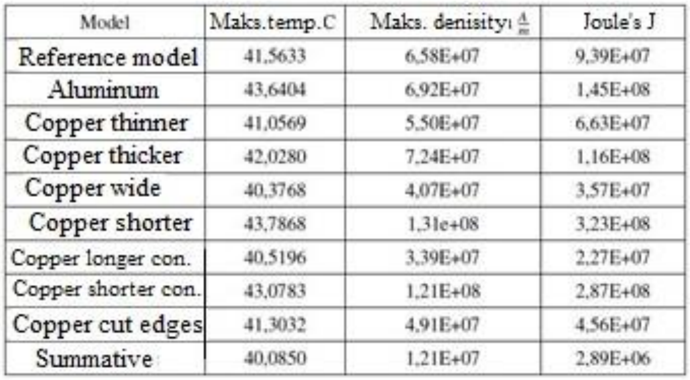


Fig. 7B. Disintegration of the current density in the copper contact system with the increased surface of the contact system and cut edges.

III. CONCLUSION

The author conducted the sequence of systematized simulations, which results were presented in table 2 and figures 8, 9.10.

Table 2. Numerical values of conducted analyses.



Model	Maks.temp.C	Maks. denisity: $\frac{A}{m}$	Joule's J
Reference model	41,5633	6,58E+07	9,39E+07
Aluminum	43,6404	6,92E+07	1,45E+08
Copper thinner	41,0569	5,50E+07	6,63E+07
Copper thicker	42,0280	7,24E+07	1,16E+08
Copper wide	40,3768	4,07E+07	3,57E+07
Copper shorter	43,7868	1,31e+08	3,23E+08
Copper longer con.	40,5196	3,39E+07	2,27E+07
Copper shorter con.	43,0783	1,21E+08	2,87E+08
Copper cut edges	41,3032	4,91E+07	4,56E+07
Summative	40,0850	1,21E+07	2,89E+06

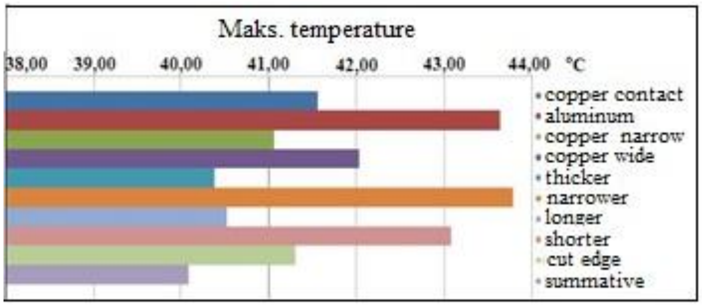


Fig. 8. Results of maximum temperatures of the contact system.

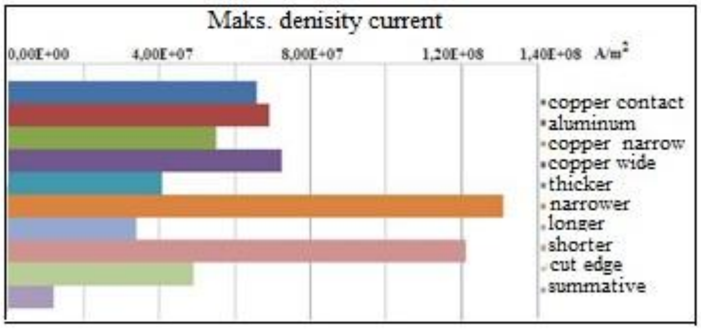


Fig. 9. Results of maximum densities of the current in the contact system.

Fig. 10. Results of maximal values of the Joule's warmth in the contact system.

At present arrangements of power rails are more and more often applied on account of their bigger load capacity and the possibility of the new system with using the same elements what decreases the costs very much. From the attention necessary for the lack of a detailed analysis of the temperature distribution at the large-power-transmission lines and contact systems, designers are forced to apply big engineering amendments. At the work there was described an approach for temperature analyses with using modern software tools. Softwares give the possibility to draw up the guidelines concerning the design of the large-power-transmission lines and contact systems with complicated shapes, configurations and used other than e.g. electric copper materials. An example can be type concatenation of copper lines of the tension up to 400 V, where current ratings in the scope from 1 kA to 6.3 kA are: 1, 1,25, 1,6, 2,0, 2,25, 2,50, 3,0, 3,6, 4,25, 4,4, 5,3 and 6,3kA. A question appears, how to select large-power-transmission lines and contact systems in cases of not classifying in type concatenation? Quoted analysis enables the instruction of proceedings to use the model in the situations like that. Presented results are an admission to the follow-up work of the author associated with the optimization of large-power-transmission lines and contact systems.

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IV. CONCLUSION

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

Łukasz Kolimas is a PhD Engineer, a Science officer in Warsaw University of Technology Decision of Power System Apparatus, Protection and Control. Personal economic activity related with professional technical counseling from 2007 to present. He was a PhD Student in Warsaw University of Technology, with a major in Electrical Engineering under the Electrical Apparatus Department from 2005-2006. He studied in Warsaw University of Technology (Power System and Robotics) and coordinated studios automation of drive form 2000-2005. He practiced in PGNiG (Polish Oil and Gas Company) from june 2002 – september 2002. He was a Conservator of elevator from june 2003 – september 2003 and a counselor on OSRAM Company from 2006 – 2008 before being engaged in a Personal economic activity in 2008.