EXPERIMENTAL VALIDATION OF NUMERICAL RESULTS CORESPONDING TO CATENARY CONTACT WIRE TEMPERATURE

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Abstract – **In this paper are presented the numerical 2D, 3D and experimental results obtained for catenary contact wire heating in alternative current. 2D numerical simulations were made in QuickField Professional and 3D in ProEngineer. We made numerical simulation not considering the resistivity variation with temperature. For 2D numerical determination of temperature values in alternative current we solved a coupled problem magnetic – thermal field. The source term necessary for 3D problem was obtained by solving a magnetic 2D problem. It was calculating the relative error by comparing numerical 2D, 3D and experimental results. The paper present also experimental results obtained by heating contact wire in alternative current. We use a contact wire type TF 100, 100 mm^2 section, coresponding to Romanian Railways catenary. For contact wire temperature determination were considered different values coresponding to electrical current (201 A, 250 A, 301 A, 350 A, 403 A, A.C.). Analysing the results we can observed that it is a small error in case of 3D numerical results comparative with 2D. The error increase with electrical current values increasing. Until to 301 A electrical current values, the errors were smalls (mean value 2,39 % in case of 2D and 1,91% in case of 3D).**

Keywords: *numerical simulation, 3D, 2D, thermal regin, catenary contact wire*

1. INTRODUCTION

The pantograph - catenaries system is still today the most reliable form of collecting electric energy for the train, when high speed operational conditions are considered.

This system should ideally operate with relatively low contact forces and no contact loss should be observed, so that the power is constant.

A thermal analysis of this system could help maintenance operations revealing, for example, overheating of the pantograph strip and contact wire.

On the intensive traffic lines, the tension draw and also the heating limits of the contact line wire must be verified.

The verification computations must take into account the line overloading and the time thermal constant [1].

On the main lines, in Romania are use catenary's suspensions with a copper contact wire 100 mm^2 section (TF-100) and suspension cable from OL-Zn 70 mm^2 section or OL-Cu cable 70 mm^2 sections [4].

Today, in many countries is extended the utilization of contact line wire on copper with 0,1% Ag, for a 760 amperes current, substituting the contact line wire with cadmium, for working security and environment protection reasons.

In some countries which has a development program to made high speed lines, 300-350 km/h, is extended the contact wire coil with 0,3-0,7% magnesium, 120 mm^2 section.

In this paper are presented the nunerical 2D, 3D and experimental results obtained for catenary contact wire heating in alternative current.

2D numerical simulation were made in QuickField Professional and 3D in ProEngineer.

For 2D numerical determination of temperature values in alternative current we solved a coupled problem magnetic – thermal field.

The source term necessary for 3D problem was obtained by solving a magnetic 2D problem.

It was calculating the relative error by comparing nunerical 2D, 3D and experimental results.

2. 2D NUMERICAL SIMULATION OF CATENARY CONTACT WIRE

2D numerical simulation for catenary contact wire stationary thermal regime was made in QuickField Professional [13] using the model presented in figure1.

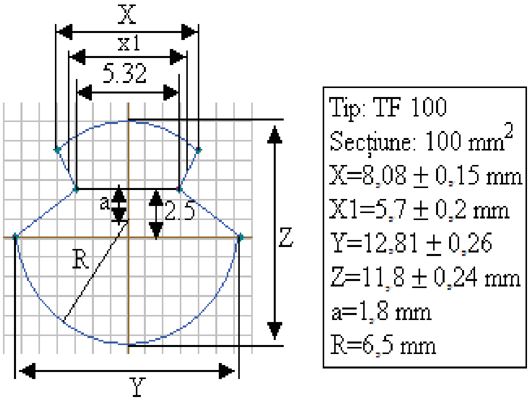

Figure 1: Contact wire type TF 100.

Analysis domain and boundary conditions are presented in figure 2 [2].

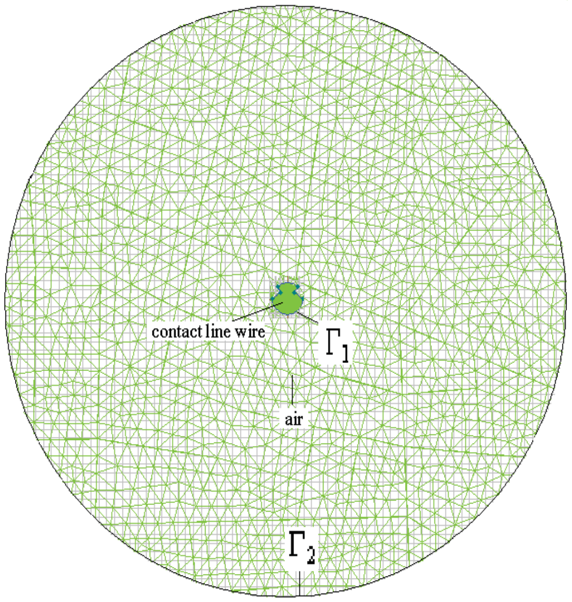

Figure 2: Analysis domain and boundary conditions for 2D.

The boundary condition for magnetic model is A =0 on Γ_2 and for thermal model is of convection type (α, T_0) on Γ_1.

We have solved a magnetic and thermal field coupled problem for determination the stabilized temperature value for alternative current.

The used mathematical model has two components, electromagnetic model and thermal model, both coupled through the source term (Joule specific loose) [2]:

$$S(\theta) = \rho(\theta) \cdot J^2(x, y) \qquad (1)$$

The electromagnetic model is governed by equation [2]:

$$\frac{\partial}{\partial x}\left(\frac{1}{\mu} \cdot \frac{\partial A}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{1}{\mu} \cdot \frac{\partial A}{\partial y}\right) - j \cdot \omega \cdot \sigma(\theta) \cdot A = -J \qquad (2)$$

where :

σ - electric conductivity;
μ - magnetic permeability;
A- magnetic potential vector;
j- imaginary unity;
ω- pulsation;
J - current density.

The temperature distribution in the analysis domain is given by the thermal conduction equation in steady state [2]:

$$\frac{\partial}{\partial x}\left(\lambda \frac{\partial \theta}{\partial x}\right) + \frac{\partial}{\partial y}\left(\lambda \frac{\partial \theta}{\partial y}\right) + S = 0 \qquad (3)$$

where:

θ– temperature;
λ – thermal conductivity ;
S - source term.

By solving a magnetic problem we obtained the current density distributions in contact line wire for 201 A, 301A (figure 3 and 4).

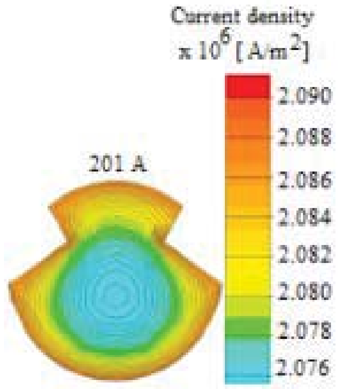

Figure 3: Current density distribution for 201 A

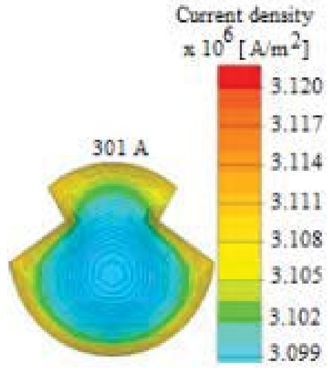

Figure 4: Current density distribution for 301 A

For determination the stabilized temperature value in alternative current we have solved a magnetic and thermal field coupled problem.
We introduced the source term in thermal problem and then we obtained the temperature values.

In figures 5 is shown temperatures values for 201 A, (ambient temperature $\theta_0 = 22{,}3$ °C), AC current [2].

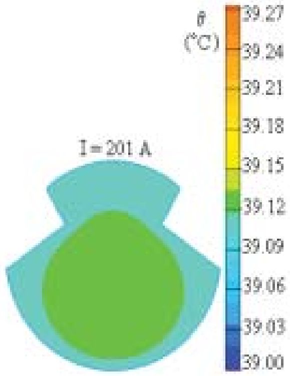

Figure 5: Temperature distribution for 201 A, alternative current, 2D.

For 301 A ambient temperature $\theta_0 = 23{,}6$ °C and the results are presented in figure 6.

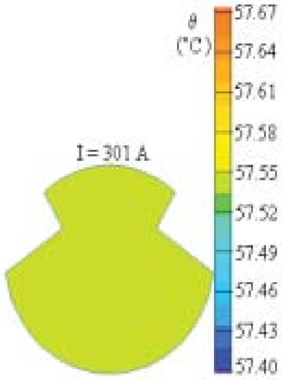

Figure 6: Temperature distribution for 301 A, alternative current, 2D.

3. 3D NUMERICAL SIMULATION OF CATENARY CONTACT WIRE

3D numerical simulation for stationary thermal regime study coresponding to catenary contact wire was made using Pro/ENGINEER Wildfire 4.0 – Promechanica [13].

The obtained numerical results in 3D were compared with 2D and experimental results. Then we calculated realtive error.

Analysis domain and boundary conditions are presented in figure 7.

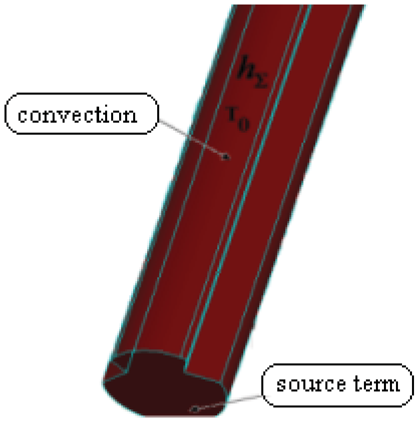

Figure 7: Analysis domain and boundary conditions for 3D.

For source term we used rhe results obtained by solving a 2D magnetic field problem in QuickField Professional 5.4 (figure 8 and 9).

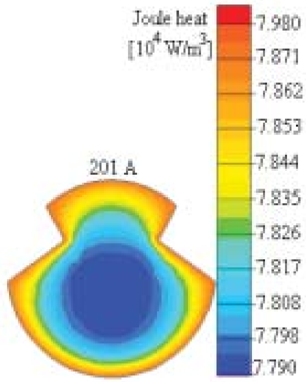

Figure 8: Source term distribution in contact wire for 201 A.

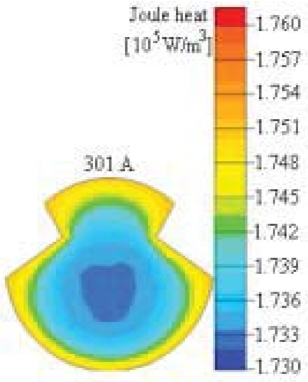

Figure 9: Source term distribution in contact wire for 301 A.

Using source term values obtained in Quickfield we determined catenary contact wire temperature for 201 A alternative current (figure 10).

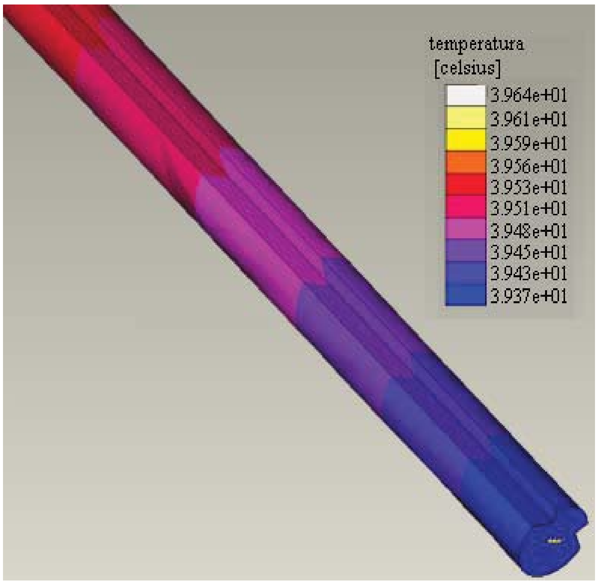

Figure 10: Temperature distribution for 201 A, alternative current, 3D.

Using the same algorithm we obtained catenary contact wire temperature values for 301A, alternative current.

Catenary contact wire temperature for 301 A alternative current is presented in figure 11.

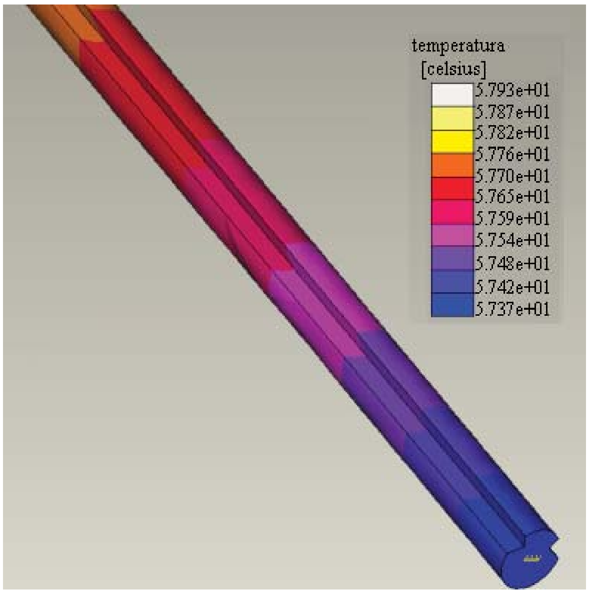

Figure 11: Temperature distribution for 301 A, alternative current, 3D.

4. EXPERIMENTAL RESULTS

For determining catenary contact wire temperature experimentally we use the configuration presented in figure 12 [6].

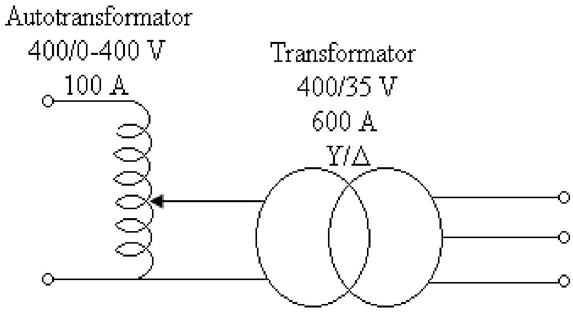

Figure 12: Configuration for experimentally temperature determination, alternative current.

In table 1 are presented the experimental results obtained for contact wire heating in alternative current. We used different altenative current values.

I [A]	θa [°C]	θs [°C]	Δθ [°C]
201	22,3	39,2	16,9
250	25,9	52,6	26,7
301	23,6	59	35,4
350	25,9	75,9	50
403	22,1	84	61,9

Table 1: Experimetal results for contact wire heating in alternative current.

In table 1 are used the next notation:

- θs – temperature stabilisation;
- θa – ambient temperature;
- Δθ - over temperature (Δθ = θs - θa).

Figure 13 presented catenaries' contact wire temperature time variation.

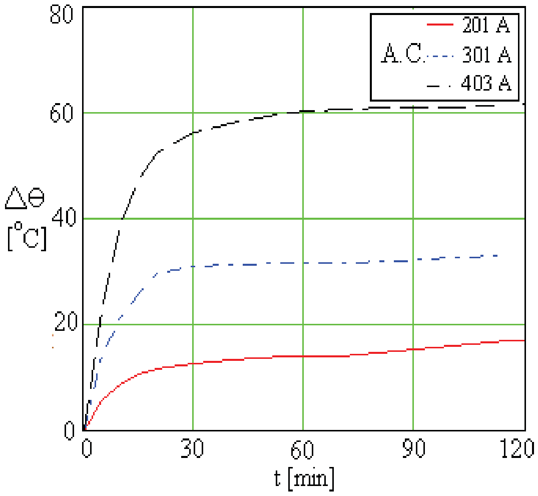

Figure 13: Catenary's contact wire temperature time variation

Using temperature values obtained for contact wire heating numerical 2D, 3D and experimental we calculate realtive error (table 2).

I [A]	θs [°C] 2D	θs [°C] 3D	θs [°C] Experi-mental	Error [%] 2D-Experi-mental	Error [%] 3D-Experi-mental
201	39,1	39,6	39,2	-0,255	1,02
250	50,3	51,1	52,6	-4,373	-2,852
301	57,5	57,9	59	-2,542	-1,864
350	67,4	69	75,9	-11,199	-9,091
403	74,2	76	84	-11,667	-9,524

Table 2: Relative error estimation.

5. CONCLUSION

Analyzing the presented results we can conclude that:

- Is a small error in case of 3D numerical simulation comparative with 2D;
- We made the 2D numerical simulation not considering the resistivity variation with temperature;
- In future the numerical model must take into account the resistivity variation with temperature;
- The error increase with electrical current values increasing;
- Until to 301 A electrical current values, the errors were smalls (mean value 2,39 % in case of 2D and 1,91% in case of 3D).

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