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RESEARCH ARTICLE

Stray Currents near the Underpass Across the Railway Traction

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Abstract— ***This paper deals with modeling of stray currents under electrified railway traction. Our team is deals with this problem for many years [1,2]. Underpass is located under the tracks and crosses the track. Modeling was performed in order to determine how are concrete structures threatened by stray currents. Paper describes COMSOL program that was used for modeling. Progress of stray currents is determined by conductivities of the individual substructures which are under the rails and by conductivity of concrete, brick and insulation layers, which form underpass. Modelling shows how current flows around the concrete structure. The current reaches its maximum value in the space above the concrete construction of the underpass.***

Keywords— ***traction system, electrified railway traction, FEM, COMSOL, modeling***

Introduction

Our research group generates models of stray currents in concrete structures. Knowledge of the distribution of potentials and currents in them is important for reducing corrosion and the subsequent cracking of concrete structures. Geometric progressions currents in the substructure for the current distribution need not always necessary to know, but often enough to know what current flows in a given location, ie. to know how much is the potential gradient here.

The issue of solving the three-dimensional flow field has practical applications mostly in connection with the conductor, whose transverse dimensions are much smaller than the longitudinal dimensions. The solution is reduced in this case to one-dimensional problems, or is used for large current conductor in connection with the design of the individual ground or grounding systems. Models were performed mostly in 2D area or in areas with 2D to 3D with extrusion to space, exceptionally directly in 2D. In the cases solved here was not difference longitudinal dimensions (length rails) and transverse dimensions so large, we have not to use circuit models. Were used directly two- and three-dimensional models.

Modeling Rail traction is analytically difficult. The geometric shape of railway traction is irregular and transverse dimensions of the railway superstructure are much smaller than its longitudinal dimensions. Therefore, using numerical method based on Finite Element Method (FEM). FEM is suitable for such cases. FEM is adaptable and is widely used for solving both static and time-varying problems. FEM is very used to solve problems involving accumulated a leakage electromagnetic energy as well as on personal computers.

Process modeling system for the use of FEM starts with the definition of the physical model and identifying the required geometrical features of the model. These features include the shape (size), material properties (σ,ε,μ) and the power of the current system, ie. the density currents in conductors (sources) or the value of the excitation voltage and the shape of their course. Furthermore, this information must be converted into a physical model. Only features necessary for the desired partial analysis must be selected. So, just Neumann and Dirichlet boundary conditions the far enough are need to determine for electric rail traction. Furthermore, use of so-called infinite elements.

The geometric model has a number of redundant information that does not need to consider when we compile a mathematical model of a physical model. Particularly preferred is the use of the symmetry railway track. The mathematical model may not coincide with the physical model completely, but it may be the same with only a subset of its properties. In other examples from our practice - for example, we modeled only half the rails when calculating the internal inductance. Another example, for calculating the capacitance between the rails is considering the external surface of the rail because the permittivity of a good conductor is infinite.

The software used for the solution of currents

Currents near subway were computed using COMSOL Multiphysics with additional modules. Workflow for modeling jobs in COMSOL Multiphysics® can be described in a few basic steps. These steps are the main nodes of the tree modeling. The advantage of this approach is the clarity of steps and easy view of every detail of the model and the possibility of easy adaptation of the model.

Creating geometry

The geometry of studied model was created using CAD tools in a graphics editor COMSOL Multiphysics® in all cases. Geometric models for solving the task but may also be formed in the external CAD systems. For example, we solved this way the influence of electric currents on the cracks in the foundations of traction poles [3].

Determination boundary conditions

Boundary conditions and characteristics of areas in the model is an essential condition solving the task. Different parts of geometry, such as the areas, surfaces (in 3D), edges or points can be assigned to variables, expressions or functions that can be further used in the simulation. To enter materials subdomains exists a library of predefined materials. Generated model can contain multiple areas and each property can be assigned different backgrounds or material. To the prepared material library we added other materials such as various kinds of concrete.

Conductivity different areas of railway substructure most interested us. However, on the flow of stray currents affects soil moisture as well, in other words, the electrolyte. We used these values of the specific conductivity of materials:

Concrete (according to EN 62305 paragraph. 6.5.6.2.2.2) has a specific resistance of 200 Ωm, therefore, specific conductivity is 0,005 S/m.

Ground resistivity depends on its composition, can be moved within wide limits:

soil $\rho = 10^{-1} \div 10^{2}$ Ωm (conductivity $\sigma = 10^{-2} \div 10$ S/m)

clay $\rho = 10 \div 10^{2}$ Ωm (conductivity $\sigma = 0.1 \div 10^{-2}$ S/m)

sand $\rho = 0{,}1 \div 10^{5}$ Ωm (conductivity $\sigma = 10^{-2} \div 10^{-5}$ S/m), sand with an admixture of clay, 0,1 – 0,15 Ωkm,

ballast $\rho = 0{,}3 \div 10^{5}$ Ωm (conductivity $\sigma = 10^{-2} \div 10^{-5}$ S/m) - clean ballast 0,5 - 1 Ωkm, dirty ballast 0,3 - 0,5 Ωkm.

This specific resistance can be reduced from 1,5 to 2,5 times in the upper layers of irrigation and railway routes may increase 3-10 times during freezing.

However, a rigorous modeling value in the ground is far more complicated in practice, as a result of inhomogeneity soil composition. Inhomogeneous environment of a country often replaces individual homogeneous layers arranged with horizontal

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or vertical layering. Measured impedance of the soil is increased with depth of ground, the voltage drop is increased and the magnitude of the current in the ground is decreased when is increased the depth below the surface.

Resistivity rails are not taken into account. Its surface formed the boundary condition problem (the density of the current from the rail).

Meshing

The geometric model with defined boundary conditions is ready to generate mesh computing, in whose nodal points are calculated data. Mesh was generated in most of the tasks automatically. However, properties of the mesh can be affected by setting of various parameters in selected parts of the model. Several variants with different network elements may be combined in a single model.

Solvers

COMSOL Model Multiphysics® contains several types of solvers for linear and nonlinear calculation tasks, tasks in the frequency and time domains or tasks with the selected variable parameter. Direct and iterative solvers are available for solving systems of linear equations. Iterative solvers have available a number of preconditioners. In many cases, solutions no converge and we had to reconfigure the parameters of the model. There was also the case material (eg. Air in the underpass), selected from the library and we had materials to redefine manually.

Final Processing

Final Processing of the results can be accomplished in many ways. Multiphysics problems always contain a series of calculated variables that can be displayed in selected units simultaneously using color maps, isolines, isosurfaces, streamlines, arrows, particles or cuts. Each solution can be exported for further processing in simple text files. Of course it is generated export pictures and graphs. Processed model can be saved in Java or text M-file (MATLAB).

Modelling of the currents in the area of the underpass

The constructions of underpasses are prefabricated spatial components for engineering networks to build underground spaces used for walking, on transport, storage and leading of materials such as. cables, water, hot water and sewage pipes etc. Each component is structurally designed as a single entity rectangular section (Figure 1), which is self-supporting.

Concrete unit is established in the ground and surrounded by a permeable layer. On the unit are insulation and brick facing. One of the goals of modeling was also determining modeling methodology for detecting the current penetration through the insulation into the concrete unit and its eventual damage through by the stray currents. Conductivity and thickness of insulation can be in COMSOL change without major problems, like the other geometric dimensions and material parameters of the modeled objects.

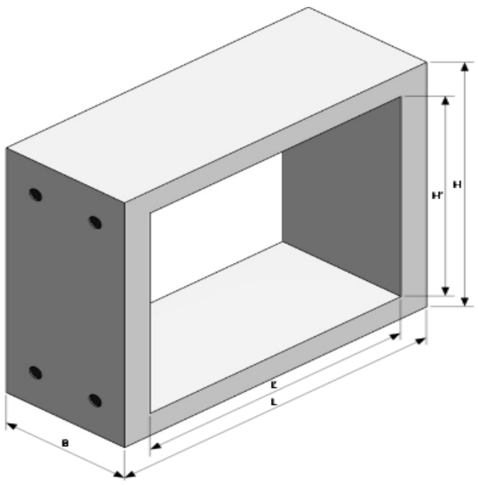

Fig. 1. The dimensions and parameters of the frame concrete structure of the underpass

TABLE I.

Designation SKA-KR	***B***	***H***	***H'***	***L***	***L'***	***Volume*** ***(m^2)***	***Weight*** ***(t)***
	(m)						
180/180	0,99	2,2	1,8	2,2	1,8	1,60	4
180/210	0,99	2,5	2,1	2,2	1,8	1,72	4,3
210/210	0,99	2,5	2,1	2,5	2,1	1,84	4,6
210/240	0,99	2,8	2,4	2,5	2,1	1,96	4,9
240/240	0,99	2,8	2,4	2,8	2,4	2,08	5,2
240/270	0,99	3,1	2,7	2,8	2,4	2,20	5,5

The arrangement of the underpass is shown in Figure 2 [4]. Figure 3 shows a geometric arrangement of COMSOL model. The problem was modeled as three-dimensional. Here is a view in the xy plane. In the xy plane was first design two-dimensional sectional view of solved area and it was further "extruded" to the three-dimensional region.

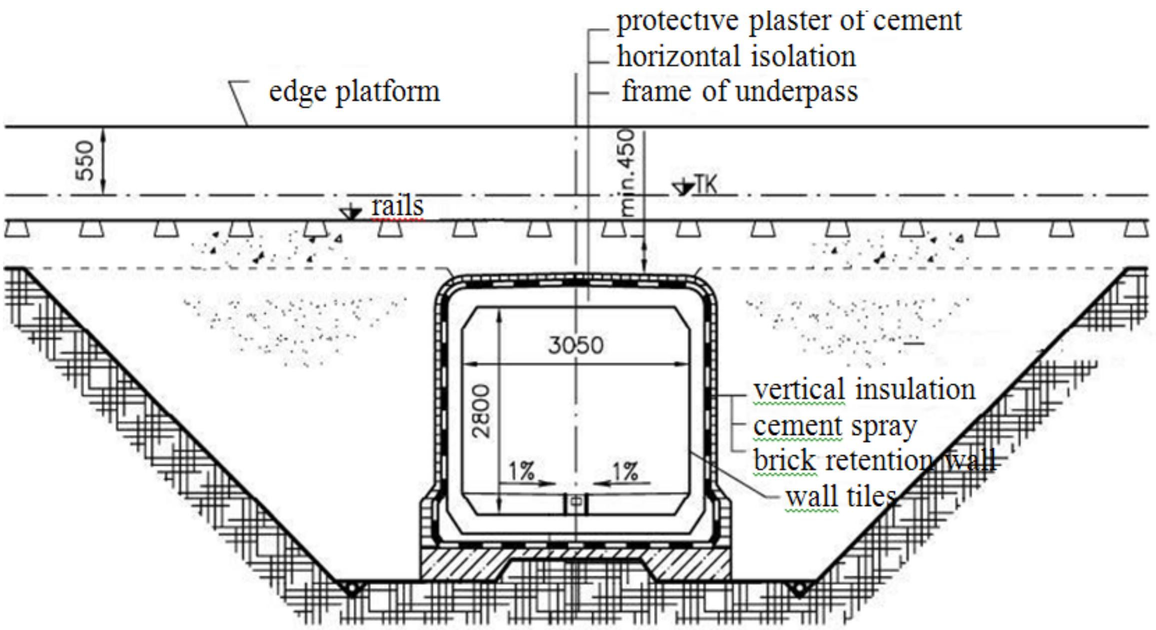

Fig. 2. Drawing of arrangement of the underpass

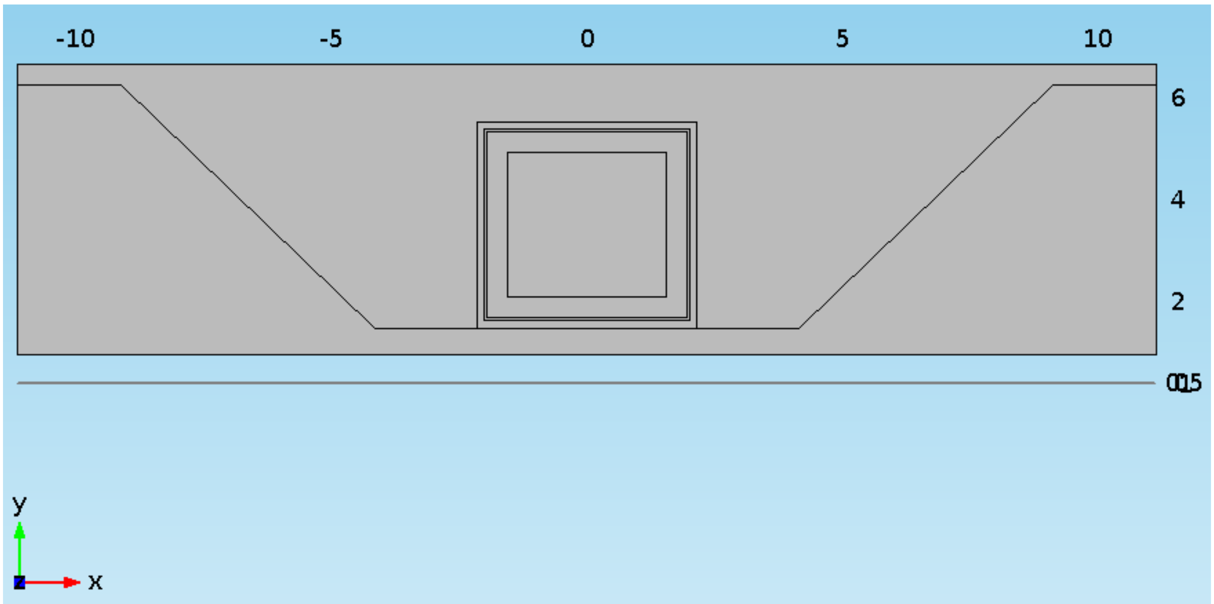

Fig. 3. Geometry model of the problem for the program COMSOL

Fig. 4.

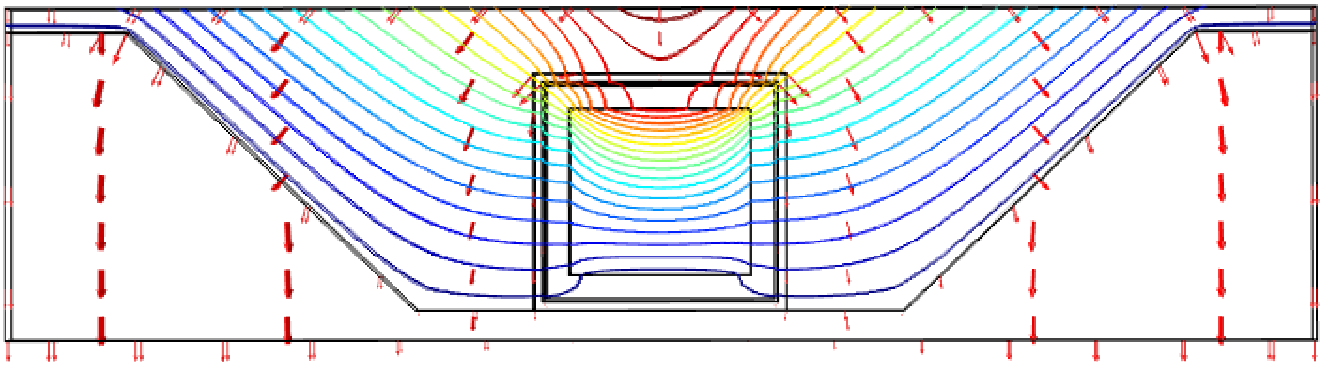

Fig. 5. Arrows of the vector current density and the equipotentials of electric potential

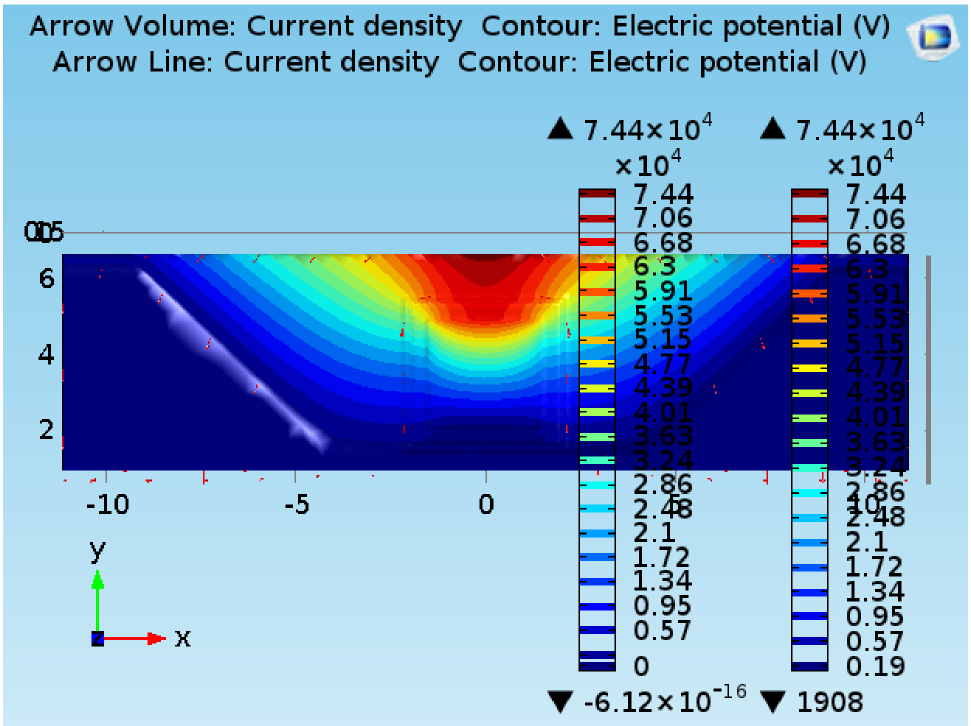

Fig. 6. Color-coded values of the current density and the potential

Making the calculations, the density of current flowing perpendicular to the surface of the rails of the ground was intended as a boundary condition,. The current density along the entire length of the rail is equal. The three-dimensional distribution of equidistant surfaces that actually correspond to the equipotential surfaces is shown in Figure 6.

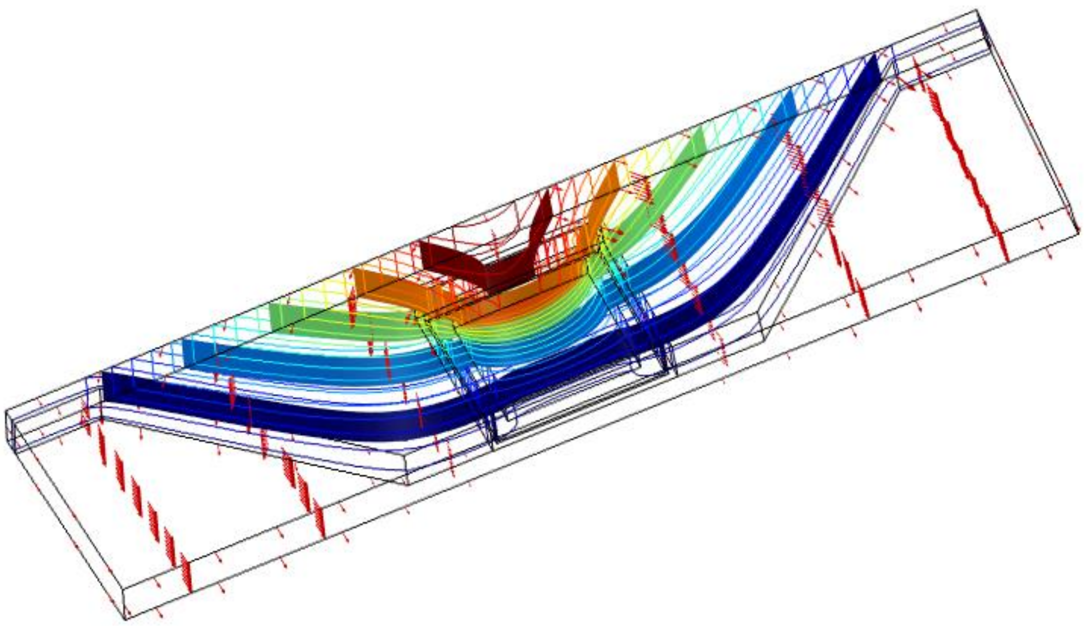

Fig. 7. 3D distribution of equipotential surfaces

Conclusion

Current flows around the underpass depending on the value of conductivity of ground and insulation. From Figure 3 it is clear that when selecting a very low specific conductivity of insulation 10^{-7} S/m, current, characterized here by arrows, does not flow through of the underpass sub region. From figure 3 and from Figure 4 it is clear that the current density in the space above the underpass increases. If there would have been sited imperfectly insulated pipe, there may be increased risk of corrosion of this pipe by means the electrical stray current.

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