

INVESTIGATION OF THE MAGNETIC FIELD IN THE VICINITY OF AC AN ELECTRICAL RAILWAY WITH SUPPORT OF EXCEL

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Abstract: This contribution deals with the calculation of the magnetic field in the vicinity of an AC electric railway. We focused on an AC 25 kV; 50Hz power-supply system. The calculation procedures are based on the numerical solution of the Helmholtz equation. The method of finite differences in EXCEL is used in the computation. The results are compared with FE method.

Key words: Magnetic harmonic fields, Helmholtz equation, EXCEL VBA

INTRODUCTION

Computation of the magnetic harmonic fields is a very important technical issue. We find it in solving of many problems: induction heating of electric conductive materials with eventual subsequent hardening, modeling work of the pumps of melt metals, problems of levitation of stiff bodies, levitating melting etc.

These calculations are generally performed using mostly of professional programs e.g. ANSYS, MARC, QUICKFIELD and FEMLAB. These are of course costly and always not easily available. Mastering some of them is often very difficult. It is necessary to study a lot of material to master the use of these programs.

Many of these programs are based on mathematically complex method of finite elements (FEM), which is for students in the first phases of studies hardly managed. We think indeed, that in this phase of studies the students should have a possibility to get familiar with the formulation, calculation and subsequently visualization of these physical problems.

That is why we decided to submit this article of an application of EXCEL for the solution of aforementioned problems. The purpose of the present contribution is to show, how EXCEL can be of use in this particular case, and how much accuracy can be attained in case of computation of time-variable electromagnetic fields.

1 FORMULATION OF TASK

The present contribution deals with problems of the electromagnetic field in the vicinity of a traction line characterized by Fig. 1.

Traction line consists of:

carrying wire 1	current I_1
trolley wire 2	current I_2
rails 3	current I_3

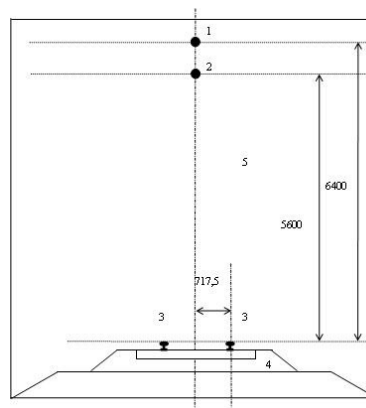


Fig.1: One-rail line

All system is powered by alternate current with frequency $f = 50$ Hz and is situated in dry air 5 with zero electric conductivity. Electrified railway rails 3 are deposited with base 4 with non-zero electric conductivity. Our intention is to calculate the magnetic field above and inside the wagon (2.5 m high over the level of rails). The ecological aspect of this type of electric traction should be reviewed. It is necessary to formulate the appropriate differential equations and solve them by means of a suitable numerical method, to achieve this objective.

2 MATHEMATICAL MODEL OF TASK AND HIS SUBSEQUENT COMPUTER REALIZATION

2.1 Continuous mathematical model problems

Magnetic harmonic fields are described [1] by means of the Helmholtz equation for the using phasor \underline{A} of the magnetic vector potential A , which is commonly given by relation

$$\underline{A} = x_0 \underline{A}_x + y_0 \underline{A}_y + z_0 \underline{A}_z.$$

In the x,y co-ordinate system only $A_z(x,y)$ component is non-null. In the following, for simplicity we put $A_z = A$, respectively $A_z = A$. In this plane co-ordinate system Helmholtz equation is written as

$$\frac{\partial^2 \underline{A}}{\partial x^2} + \frac{\partial^2 \underline{A}}{\partial y^2} - j\omega\gamma\mu_0 \underline{A} = -\mu_0 \underline{J}_{ext} \quad (1)$$

The phasor of the vector magnetic potential has real and imaginary component. Unambiguousness of the solution is guaranteed in this case by means of boundary conductions of type:

$$- \underline{A} = \underline{0} \quad \dots \text{field line on fictitious boundary } \Gamma_\infty$$

$$- \frac{\partial \underline{A}}{\partial n} = \underline{0} \quad \dots \text{symmetry of electromagnetic field in}$$

plane of symmetry of the wagon

2.2 Computer solving of defined task

The continuous mathematical model is firstly discretized. The method of finite differences was used in our case. For more details see e.g. [2], [3]. The finite differences method transforms the continuous mathematical model into a well known five-point scheme. Solution is obtained by "scanning" all nodes iteratively. Detailed description of this algorithm is in [3].

3 ILLUSTRATIVE EXAMPLE

3.1 Definition of task

Determine the electromagnetic field in the vicinity of a traction line, whose geometry is depicted in Fig.1. The values of flowing currents are (see paragraph 1):

$$I_1 = 10 \text{ A, current of feeder 1}$$

$$I_2 = 90 \text{ A, current thru trolley line 2}$$

$$I_3 = 50 \text{ A, current thru rails 3.}$$

Permeability and conductivity of all media present are also given.

3.2 Results of computing and discussion

Two results follow from solving the example:

▼ Electromagnetic field is in our case localized in the surrounding of trolley wire and rails see Fig. 2. As there is no human presence in this region, ecological impact is insignificant in this case.

▼ The variation of the magnetic flux density at a horizontal level 2.5 m over the rails (i.e. in the location of sitting travelers within the wagon) is in Fig. 3. From there one can see, that strongest field is in a plane of symmetry

in the centre of wagon (under trolley and feeder line) and rapidly falls in the space outside of the rails ($L > 0.4$ m). At the same time values of magnetic flux density are very low. Reference level for magnetic flux density B is cited in [4]. In conformity with this standard reference level for continuous exposition is $500 \cdot 10^{-6}$ T for employees and $100 \cdot 10^{-6}$ T for other persons.

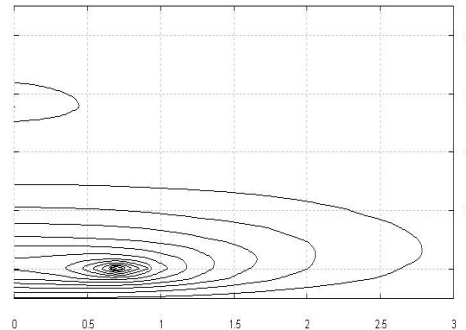


Fig. 2: Detail of field lines

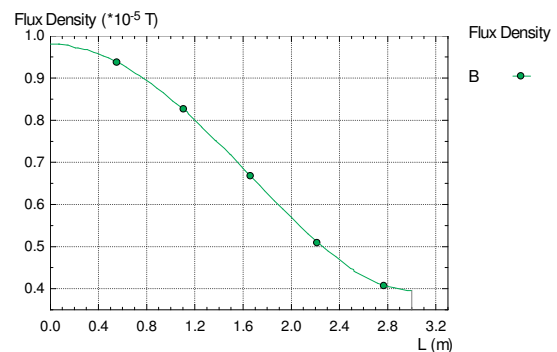


Fig. 3: Magnetic flux density in wagon, at high 2.5 m height

4 CONCLUSIONS

The performed computations showed the pertinence of the proposed algorithm for calculation of electromagnetic fields in the case, that cross-section of conductors can be neglected (the so called incommensurable problems). Computations of this type can be extended on three phase problems, e.g. on calculation electromagnetic fields in surroundings power lines, on problems in three core cables etc.

5 REFERENCES

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