NUMERICAL MODELING OF THE MAGNETIC FIELD DISTRIBUTION IN SINGLE-PHASE SINGLE-CORE TRANSFORMER

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Abstract. An electromagnetic model of single-phase single-core transformer is made and a numerical simulation of the electromagnetic field is performed. The distribution of the magnetic induction in the transformer's core and in the surrounding space is obtained. A comparative analysis of the obtained electromagnetic values with the computed parameters by a chain model is carried out. The investigation enables the determination of the magnetic flux dissipated in the surrounding space outside the transformer that generates the electromagnetic interference.

Keywords: electromagnetic interference, numerical modelling, , magnetic induction, transformer.

INTRODUCTION

The purpose of the study is the distribution of the magnetic field of a single-phase single-core transformer.

The low power transformer P = 250VA with primary voltage $U_1 = 220V$ and secondary voltage $U_2 = 72V$ is investigated. The transformer's magnet is made of 0.35 mm thick silicon steel sheets. The primary winding is made of a circular copper conductor of diameter $d_1 = 1.0\ mm$ and with $W_1 = 289$ turns. The secondary winding is made of a circular copper conductor of diameter $d_2 = 1.62\ mm$ d_2 = 1.62 mm and with $W_2 = 104$ turns.

Numerical modeling using the finite element method is performed. The schema of the transformer in Figure 1 is shown.

THEORETICAL STATEMENT

The electromagnetic field in the transformer is described with a Poisson‘ equation [1]

(1) $$rot\frac{1}{\mu}\nabla\times\left(rot\vec{A}_\mu\right)+\gamma\frac{\partial\vec{A}}{\partial t}=\vec{J}\ ,$$

where: $\vec{A}_\mu$ is the magnetic vector– potential;

$\vec{J}$ is the current density vector;

μ is the magnetic permeability;

γ is the specific electrical conductivity.

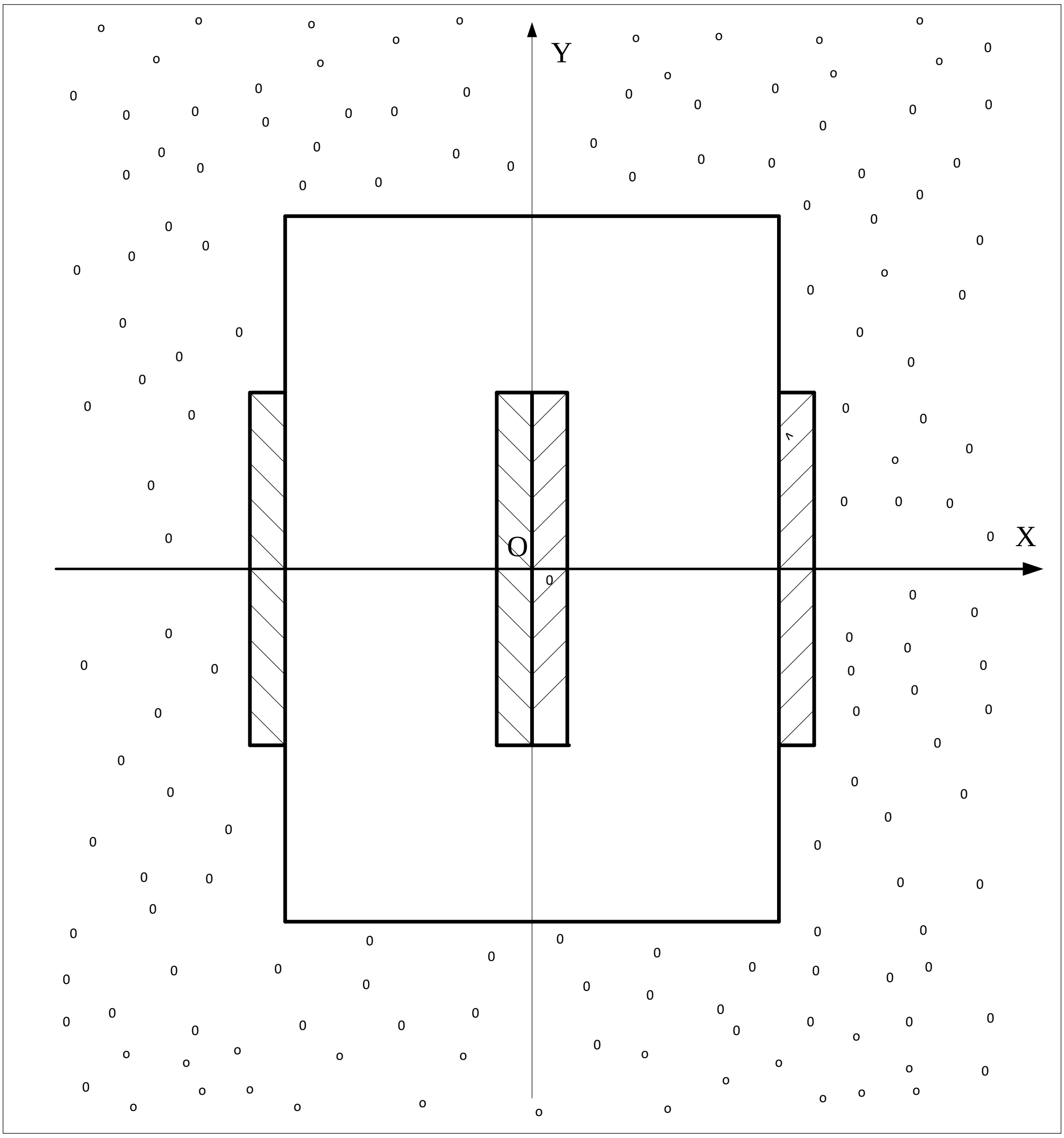

Figure 1. The schema of the investigated transformer

The current density is non-zero only in the cross-section of the winding.

The current in the primary winding is

(2) $$i_1(t) = i_{1m} \sin \omega t ,$$

where: i_{1m} is the amplitude, and ω is the angular frequency of the current in the primary winding. The primary coil is connected to a sinusoidal voltage source with a frequency f = 50 Hz.

The current density in the primary winding J_1 is

(3) $$J_1 = \frac{N_1}{S_1} i_{1m} \sin \omega t ,$$

where: N_1 is the number of turns of the primary winding

S_1 is the cross-section of the primary winding

The current density in the secondary winding is

(4) $$J_2 = \frac{N_2}{S_2} i_2(t),$$

where: N_2 is the number of turns of the secondary winding

S_2 is the cross-sectional area of the secondary winding

$i_2(t)$ is the current through the secondary winding.

The magnetic field in the transformer is flat-parallel, magnetostatic in a non-homogeneous environment and therefore the task as a two-dimensional one can be solved.

The all area of the study is divided into two parts - an area of the magnet core and the windings, where the magnetic field is concentrated and an area of the air, where the magnetic field is scattered.

Due to the symmetry of the transformer design, only half of the transformer can be tested.

The magnetic vector-potential has the component only on the z-axis- A_z, since the current density through the windings is in the z-axis direction- J_z Jz.

In this case, the equation describing the distribution of the magnetic field is [2]

(5) $$\frac{\partial}{\partial x}\left(\frac{1}{\mu}\frac{\partial A_\mu}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{1}{\mu}\frac{\partial A_\mu}{\partial y}\right) = -J_z$$

NUMERICAL MODELING

Numerical modeling is done using the finite element method FEM. The ANSYS software package is used [3, 4].

The distribution of the magnetic induction in the transformer magnet in case of magnetic shielding is shown in Fig. 2, but vector of the magnetic flux lines - in Fig. 3, respectively.

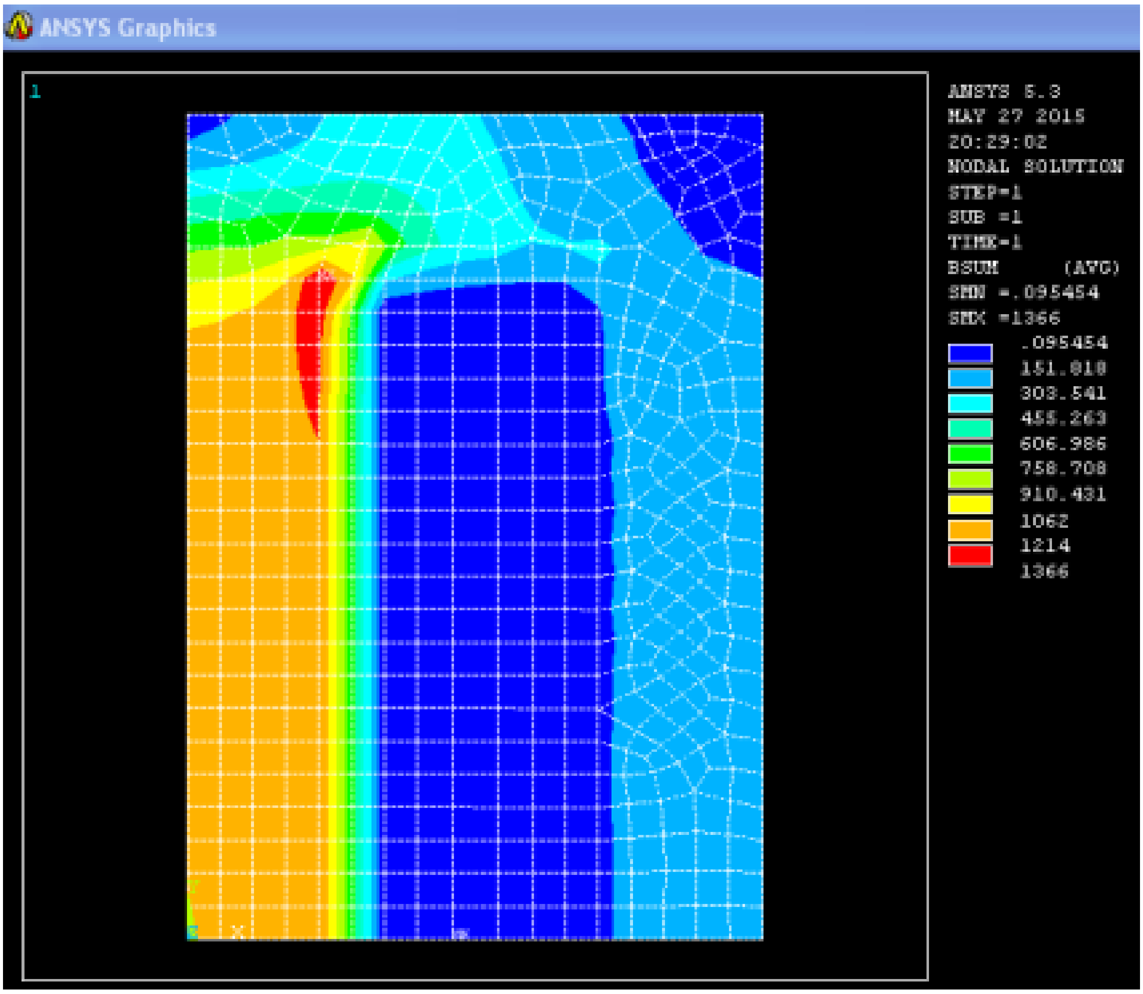

Figure 2. Distribution on magnetic induction in magnetic core.

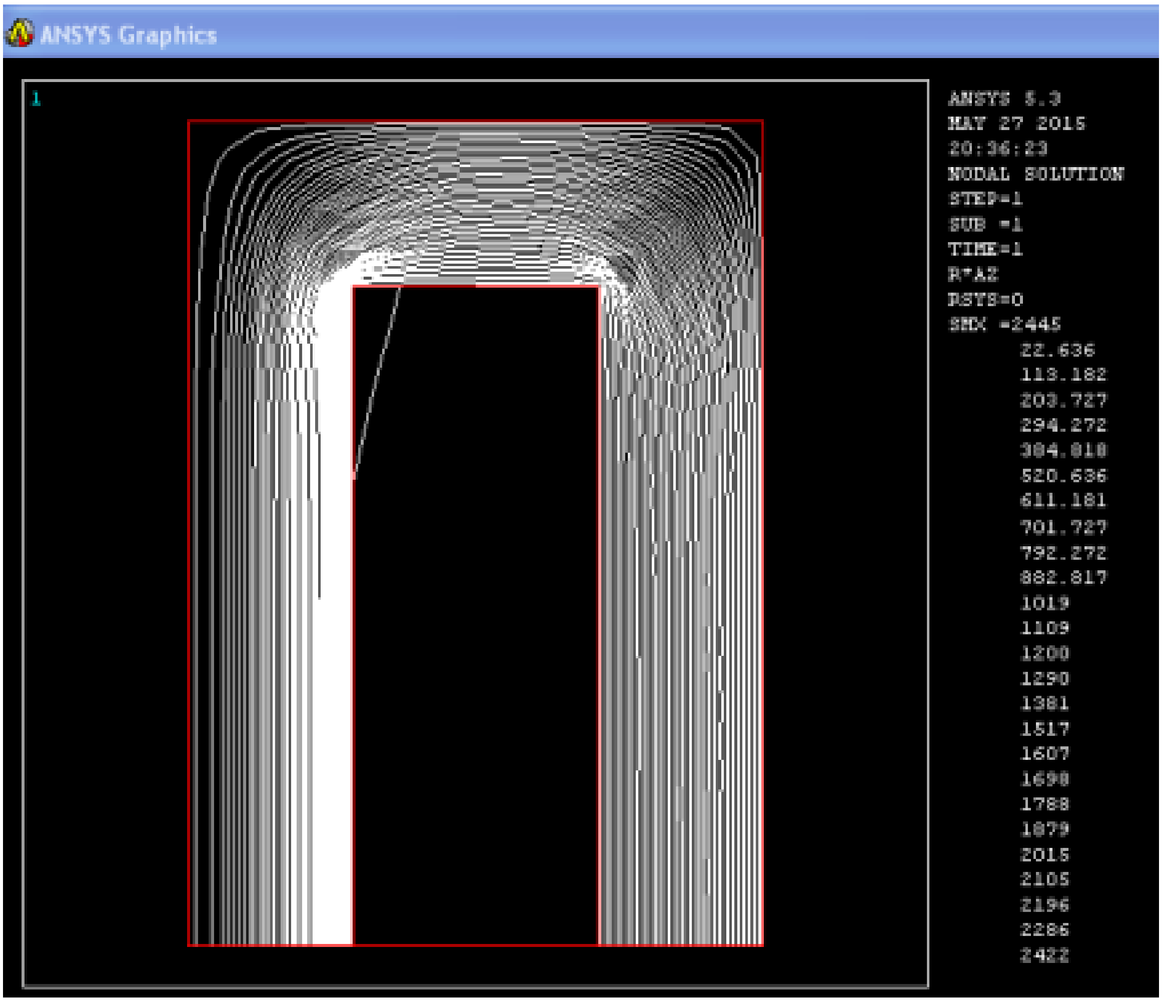

Figure 3. Distribution magnetic flux lines in magnetic core.

CONCLUSIONS

An electromagnetic model of single-phase single-core transformer is made and a numerical simulation of the electromagnetic field is performed. The distribution of the magnetic induction in the transformer's core and in the surrounding space is obtained.

The investigation enables the determination of the magnetic flux dissipated in the surrounding space outside the transformer that generates the electromagnetic interference.

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