CONTRIBUTION REGARDING THE DRIVING CURRENTS DISTRIBUTION IN SOLID MEDIUMS USING FERROFLUID DISPLAY DEVICE

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***Abstract* – The paper presents an experimental method to visualize the driving currents distribution using a ferrofluids display device. The method is based on the magnetic field provided by the driving current witch flows through a conductive plane plate. The importance of this paper is justified by the great number of situations in witch, due to the arbitrary shape of some inhomogeneous conductors, the value of stationary current is not the same in each point of the conductor cross section. The experimental method using ferrofluids, can be applied for stationary and non stationary steady state. The images obtained for those two conditions show the difference between the values of the conductive pattern resistance for direct or alternative current. In order to confirm the experimental results, the current flowed conductive plane plate was analyzed using a FEM's based soft–FLUX2D. The FEM method also allowed calculus of numerical values for driving current density in each point of the plate, the electrical potential or the conductive pattern resistance value.**

Keywords: *ferofluids**,** magnetic field spectrum, conductive pattern resistance, driving current density.*

1. INTRODUCTION

There are quite numerous practical situations in which due to the arbitrary shape of some inhomogeneous conductors, the value of stationary current is not the same in each point of the conductor cross section. For the mentioned situation, because of the irregularity of current distribution, the electric resistance of the conductive pattern can not be directly determined. A first step in evaluating the real shape of a magnetic field is to find the appropriate experimental method.

The classic experimental methods consist of using magneto-active powders, sometimes in association with the thermal effect of driving current [3]. The paper presents the possibility to visualize the spectrum of a magnetic field created by a current flow through a plate, using a ferrofluid board.

The advantage of the experimental methods is that they can be used for arbitrary field structures. They supply information about spatial distribution of the field and about the field gradient, but can not provide information about the absolute values of characteristic field quantities.

Taking into account the results obtained for stationary and non-stationary steady state, and in order to eliminate the disadvantage already mentioned, the practical situations were also studied using a FEM based soft, FLUX2D.

2. THE FERROFLUID DISPLAY DEVICE

For the development of the experimental method it was used a ferrofluidic screen consisting in a great number of capillary tubes, partially filled with a magnetic liquid. The magnetic liquid consist in a basic liquid, witch can be water, and ultra fine magnetic particles. This magnetic powder can be electrolytic obtained, as is shown in figure 1. In a cylindrical glass container filled with water are put the two electrodes. They are made of OL 37. In the exterior of the container, parallel with the electrodes is placed a

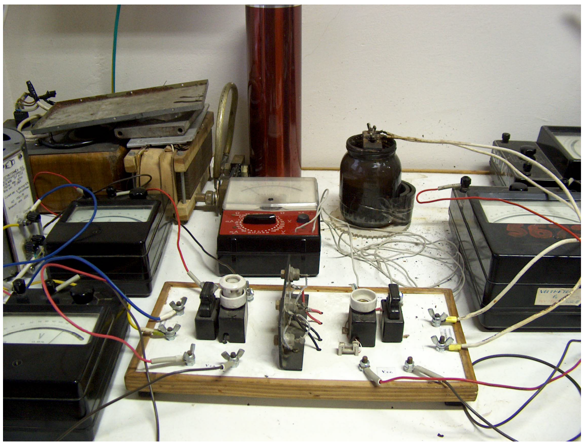


Figure 1: The electrolytic preparation of magnetic powder

permanent magnet, witch collect the magnetic particles.

The dimension of the magnetic powder particles depends on the current strength in the circuit. The smaller the current strength value, the finest the magnetic particles dimension generated. The magnetic powder obtained is then dried in an oven and then supplementary fractionated.

The capillary tubes, parallel grouped, are closed seal between two plane parallel transparent nonmagnetic faces. The obtained assemble can be used as a magnetic board, in order to visualize magnetic field spectrum.
When in front of one face of the board is placed a permanent magnet, the magnetic field will action upon the magnetic particles of the fluid from the capillaries, and because the dark color of those particles on the board face will appear the shape described with the permanent magnet. On this principle, when the magnetic field in vicinity of the board is stronger, the force witch action upon the ferromagnetic particles contained in the capillaries is stronger, so in those zones, the board becomes darker. When the magnetic field is not so strong, less ferromagnetic particles will enter under magnetic field influence, so the color of the board will be pale.

3. EXPERIMENTAL RESULTS

The paper presents the images obtained on the ferrofluid board when it is tightly closed to a conductive rectangular plate connected to a power supply through two terminals placed on the opposite sides of the plate. Because the injection of the current takes place only in a fraction of plate section side, the driving current density is not the same in different cross-sections of the plate, so the magnetic field distribution created by those current is non-uniform.
The plate, having a whole marking with the ferrofluid display device, was pressed between two ferromagnetic shields, using a hydraulic holding device, as is shown in figure 2.

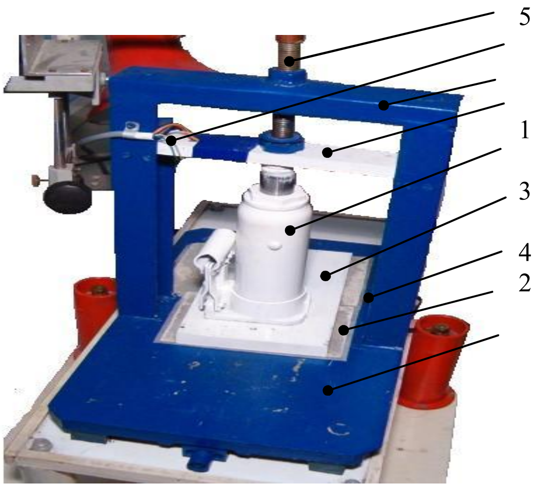
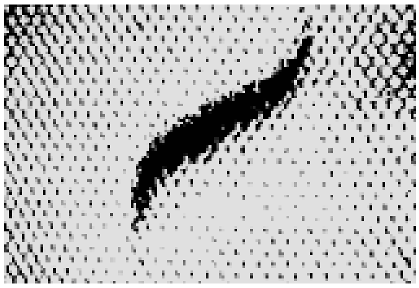
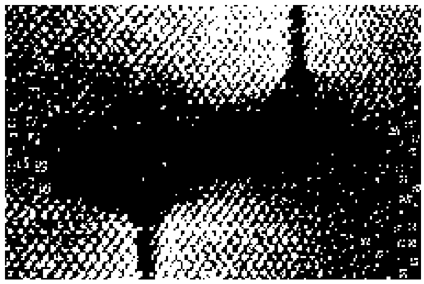


Figure 2: The ferrofluid board assembling device

The fixing hydraulic device 1, press the ferrofluid board 2, and the conductive plate tight between the ferromagnetic shields 3 and 4. The pressing force is fit using the adjustment screw 5. This ferrofluid board assembling device is necessary to minimized all the air interstitials between the conductive plate and the ferromagnetic shields. Thus, the magnetic field lines created by the driving current are forced to close only through ferromagnetic mediums.
The experimental method using ferrofluids, was applied for stationary and non stationary steady state.
The plate was first connected to a ac power supply. In order to obtain an important current strength, the plate was connected to the secondary winding of a welding transformer. The dc current impulse was obtained discharging of a capacitor bank on the primary winding of the same transformer.
The images obtained for those two conditions, for a rectangular plate connected through two equal



a.



b.

Figure 3: Current density spectrum on the ferrofluid device: a. a.c., b. d.c.

eccentrically tapping, are presented in figure 3a and 3b.
Although the plate was the same, it is easily observed that the images are quite different. The different strength recording zones suggest that the driving current density has not the same value in every point of the conductive path. Both pictures put in evidence that the driving current path is not a straight line between the two connected terminals. On both sides of the imaginary line joining the middle of the connecting terminals there are dispersion zones. They look different for stationary or non-stationary steady state. According to the distance growth to the imaginary line, the driving current density through the plate diminishes, similar with the magnetic field strength created by this current. As result, the ferrofluid board color varies from black to pale grey.
Comparing the images for stationary and non stationary steady state it can be observed the larger

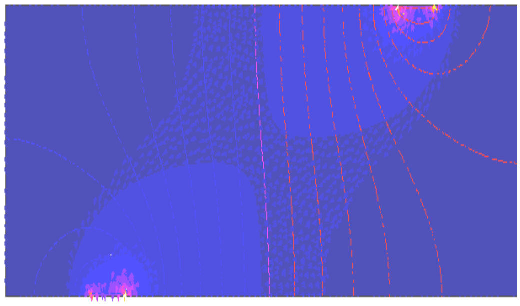
dispersion zone when the plate is connected to a d.c. power supply. When the plate was connected to an a.c. power supply the conduction zone between the tapping is narrow and fine outlined.
The different shape of the dispersion zones for the stationary and non stationary steady state can be explained by the difference between the values of the conductive pattern resistance for direct or alternative current. An important conductive pattern resistance value forced the driving current lines to flow through a narrow zone. That happens when the plate is connected to a c.a. power supply, and the conductive pattern resistance value is more important then if the plate is connected to dc. The great majority of current density lines flow inside or close to the central conductive zone.
When the capacitor bank discharges to the plate terminals, for a short time, the plate steady state is stationary, so the conductive pattern resistance of the same plate has a smaller value. It involves more important driving current lines dispersion, fact put in evidence by the triangular shape dispersion zone formed on each terminal.
The ca spectrum is also influenced by the non-stationary steady state electromagnetic field diffusion effects in solid mediums. Inside the ferromagnetic shields that hold together the ferrofluid board and the plate induced eddy-currents create a demagnetizing reaction field, witch affect the system magnetic field value.

4. FLUX 2D MODEL

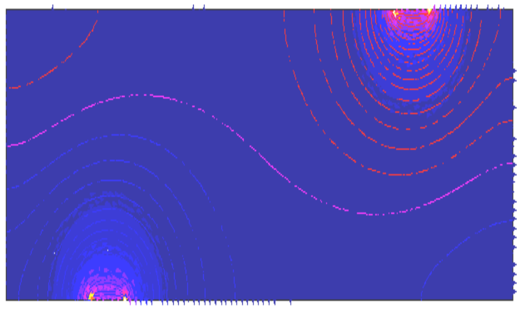
In order to confirm the validity of the experimental results it was used FLUX2D software to simulate the distribution of the driving currents in a rectangular plate having the same shape and dimension like those used in experiment. The simulations were realized for stationary and non stationary steady state.
Taking into account the local form of magnetic circuit law for immobile mediums and stationary or quasi-stationary working conditions:

$$\boldsymbol{curl}\ \vec{H} = \vec{\boldsymbol{J}} \tag{1}$$

It is evident that the current density lines are orthogonal to those of the magnetic field force lines. This means that magnetic field lines spectrum will be the same with equipotentials of the electric field. The current flow problem can be then also study as a magnetic one.
The current flow distribution in the plate is a plane-parallel problem and it is solved in planar rectangular coordinate system. It is assumed that neither geometric shape nor material proprieties nor field sources vary in the plane of the model. The geometric configuration is defined in concordance with the planar conductive plate used for the experimental method.
The field sources consist of surface electric currents distributed on the width of the terminals and they are described by electric current density. Both at the outward and at the inner boundaries of the sheet, where no field is calculated, it was to defined Dirichlet type boundary conditions. This type of boundary conditions defines normal component of the density vector. It was considered A=0 along the outward boundary, to keep flux from crossing these boundaries.
The images presented in figures 4a and 4b are obtained using FLUX2D and represent the equipotential lines when the plate is connected to a dc and an ac power supply.



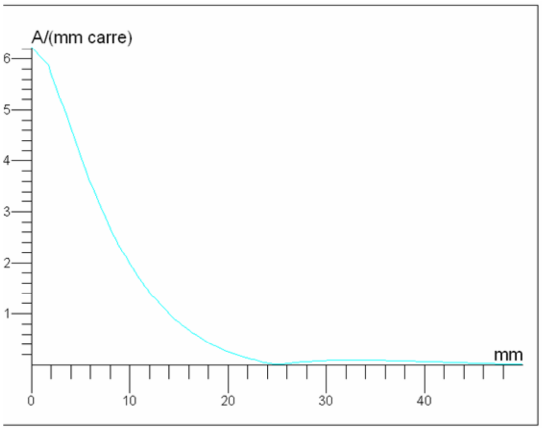
a.



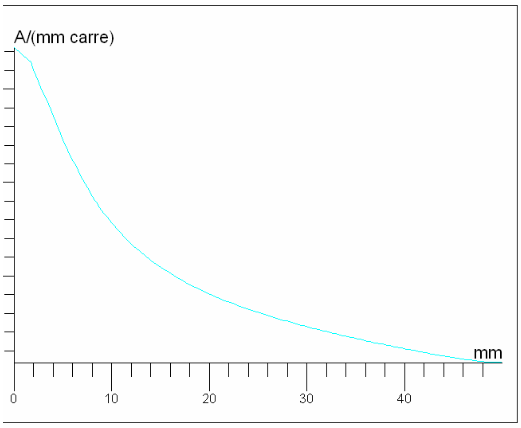
b.

Figure 4 Simulation of current distribution in the rectangular plate in non-stationary and stationary steady state

The driving current lines are in each point orthogonal to those equipotentials. So because the equipotentials in figure 4a middle zone are quasi parallel it is obvious that the driving current lines will be crowded and quasi parallel near the imaginary line jointed the two current injection zone centers. When the plate is connected to a ac power supply, equipotentials are deformed circles centered in the current injection points. In this case, the driving current lines will be radial, diverging from those circles. This means a more important dispersion of driving current lines, as shows the experiment.
For better understanding the different distribution of driving currents in the rectangular plate for stationary and non stationary steady state, based on the simulation values, there were represented the current density strength along the same line, normally situated on the faces the terminals are placed, and at the same distance from the terminal extremity.
As it is obvious, along the imaginary line starting orthogonally through one terminal, the driving



a



b.

Figure 5: Driving current density variation along a transversal orthogonal line between the plate

current density diminish faster for non-stationary steady state plate (figure 5a) and slowly for stationary steady state (figure 5b), when we already establish the dispersion zones are larger.

5. CONCLUSIONS

The advantage of experimental methods is that they can be used for complex field structures, difficult to be solved analytically. The experimental method does not need to know anything about the problem definition but also it does not determine any field values.

The similarity between experimental method and the simulated one give credibility to the first one.

The images obtained for stationary and non-stationary steady state using experimental methods and modeling approach are similar. They put in evidence the different current propagation for ac and dc working system in connection with the different electric conductive pattern resistance values.

The experiment represents also an easy way to put in evidence the driving current spectrum; the spectrum shape can be explained by the stationary and non-stationary electric resistance values.

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