# Complex of programs for studying magnetic fields of magnetostriction level converters

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**Abstract**. They provided the description of a complex of programs developed by the authors that implements an effective numerical method to calculate the magnetic fields of magnetostrictive level converters (MLC) of the applied type. Mathematical modeling of the MLC was carried out with its help. For this purpose, it is proposed to obtain a mathematical model of magnetic fields MLG of an overhead or submerged type on a type on ultrasonic waves of torsion by means of a numerical solution of integral equations. This generalizes the solution of the problem for any computational domain and provides a minimal approximation error. A method is also given to increase the efficiency of the calculation by using more complex schemes of difference approximation. The results can be used to optimize the designs of existing applied MLCs. We can conclude that the continuous dependences of the strength of the magnetic field of a permanent magnet on the width of the non-magnetic wall of the reservoir obtained with the help of the developed software package "Applied MLC" provide an opportunity to choose its minimum required value. **Keywords:** magnetostrictive level transducers, software for mathematical modeling.

## 1 Introduction

At present, various mathematical software packages of domestic and foreign firms are known [1, 2], which allow to solve many modeling problems. Usually, such software products are focused on solving the problems from a specific subject area (ELCUT, Littlemag, etc.), but there are also universal tools that provide ample opportunities for the mathematical modeling of various processes, which include a large number of built-in functions (ANSYS, MATLAB, etc.).

The known systems have a number of disadvantages that make it difficult to use them for modeling the magnetic fields of an applied MLC [2]. In this regard, the authors have developed a software package in the Borland Delphi environment, which makes it possible to facilitate significantly the calculation of the main parameters of such MLCs.

## 2 Materials and Methods

Let's consider an applied MLC, the design diagram of which is shown on Figure 1.

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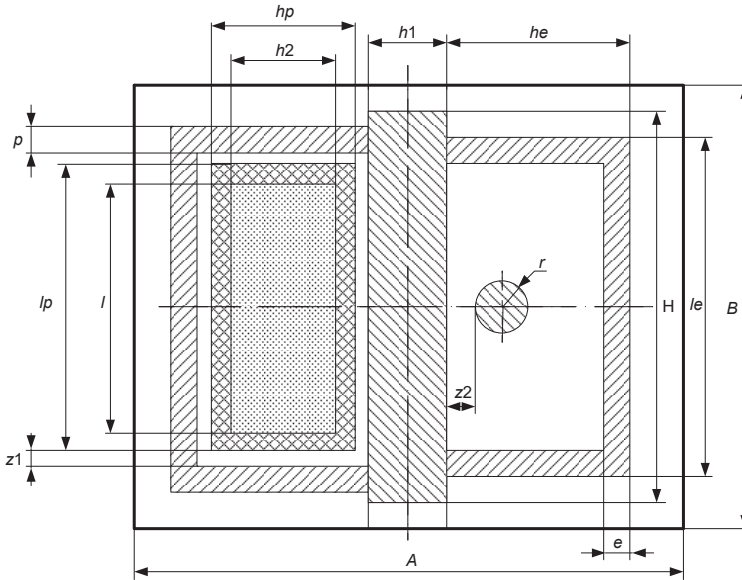
**Fig. 1**. Design scheme of the applied MLC (cross section).

Figure 1 shows that the following parameters must be set for a complete description of an applied MLC design: length and width of the computational domain (A, B), nonmagnetic wall (h1, H), float body (lp, hp), permanent magnet (l, h2), acoustic duct shield (le, he), the thickness of the float guiding groove (p) and acoustic duct shield (e), the size of the gaps between the float and the guiding groove (z1), between the acoustic duct and the nonmagnetic wall (z2), as well as the radius of the axial section of the acoustic duct (r).

The problem of finding the optimal width H of the nonmagnetic wall arises, at which the strength H of the magnetic field of a permanent magnet will be sufficient to form an ultrasonic wave (USW) of torsion in a sound conduit medium made of magnetostrictive material with the required acoustic energy [2].

After the modeling of the magnetic field of an applied MLC in the ELCUT environment, a picture of its field lines and various integral characteristics (tension, induction, potential, etc.) was obtained. However, it is not possible to track accurately the influence of its design parameter on the field characteristics using this system, since it does not provide the means for finding continuous field characteristics depending on the change in the computational domain geometry [2].

In general case, the algorithm for solving such a problem can be represented by the following scheme (Figure 2).
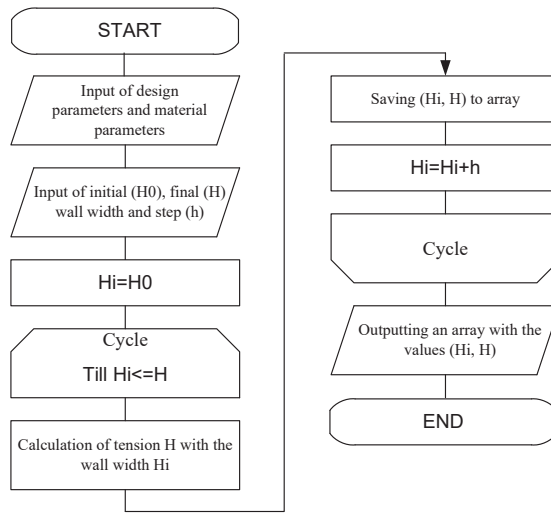
**Fig. 2**. Generalized diagram of the algorithm for the problem solution.

It is proposed to calculate the strength H of the magnetic field of the applied MLC at each step of the cycle based on the solution of the Maxwell equations for the electromagnetic field [3]:

$$\begin{cases} \operatorname{rot}\overline{H} = \overline{j} + \dfrac{\partial \overline{D}}{\partial t}; \\[2ex] \operatorname{rot}\overline{E} = -\dfrac{\partial \overline{B}}{\partial t}; \\[2ex] \operatorname{div}\overline{D} = \rho; \\[1ex] \operatorname{div}\overline{B} = 0. \end{cases} \tag{1}$$

It is known that by the grid method the system (1) can be reduced to a system of finite-difference equations of the form [3] written for each grid node by the balance method:

$$A_1 k_1 + A_2 k_2 + A_3 k_3 + A_4 k_4 - A_0 \left(k_1 + k_2 + k_3 + k_4\right) = -j_i, \tag{2}$$

Where $k_1 = \dfrac{v_4 + v_1}{2}$, $k_2 = \dfrac{v_1 + v_2}{2}$, $k_3 = \dfrac{v_2 + v_3}{2}$, $k_4 = \dfrac{v_3 + v_4}{2}$, $A_i -$ the desired values of the magnetic potentials at the nodes, $v_i = \dfrac{1}{\mu_i}$ – the value inverse to the magnetic permeability of the i-th grid node, $j_i$ – the conduction current of the i-th grid node.
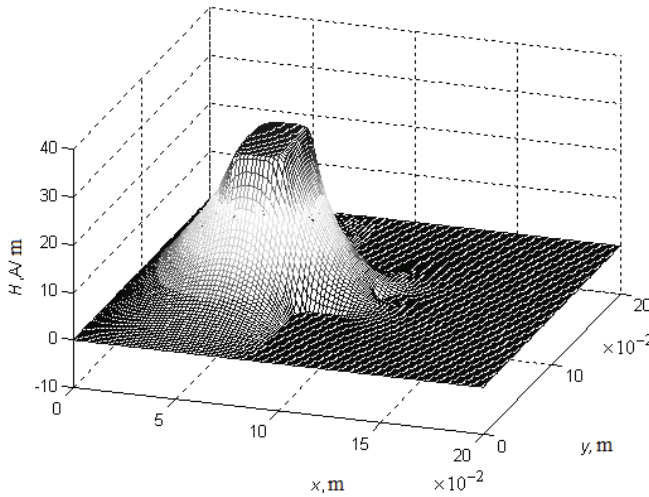
## 3 Results

Thus, the system of equations of the form (2) is algebraic and can be solved by numerical methods, with any degree of accuracy. As a numerical method for this system solution, the

upper relaxation method was chosen, characterized by a high convergence rate and simplicity of the iterative scheme [3].

The input data for the software package will be the dimensions of an applied MLC (Figure 1), the properties of the materials used, the initial H0 and the final H values of the non-magnetic wall width, the step h of its changes and a number of other parameters necessary for calculating the parameters, such as the mesh size, accuracy, and boundary conditions.

Taking into account all the above, the software package "Applied MLC" was developed in the MS Visual Studio 2019 environment.

Figure 3 demonstrates the results of the magnetic field modeling of an applied MLC type at fixed values of the design parameters using the developed software package.



**Fig. 3**. The dependence of the magnetic field strength H of the applied MLC on the coordinates x, y.

## 4 Discussion

Besides, this approach will expand the solved problem scope and simulate magnetic fields in space. Figure 4 shows the results of MLC magnetic field modeling over the entire space of its working area.
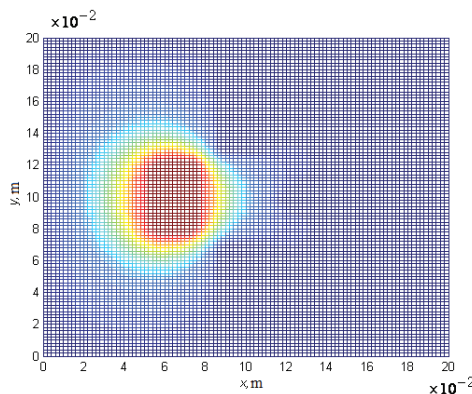


**Fig. 4**. Magnetic field strength of the MLC in the computational domain space.

Recent results make it possible to assess the adequacy of the obtained models of magnetic fields by the proposed method. To do this, you can use existing software products designed for the study of magnetic fields, for example, ELCUT. The reliability of the data obtained by them has been proven.

So, a solution was found for a similar computational domain of MLG (Figure 5), specified in the ELCUT environment, the graphical representation of which is shown on Figure 6.
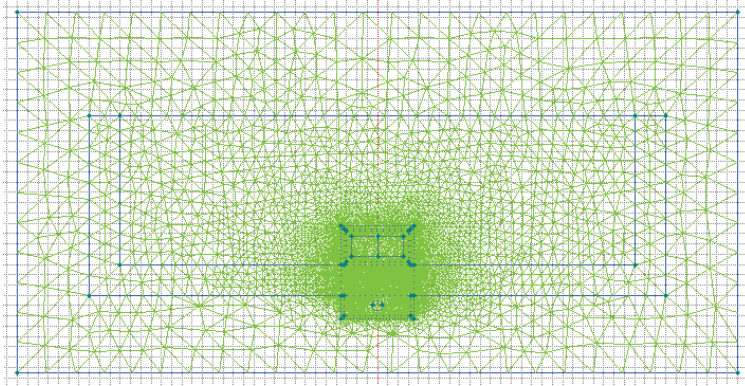


**Fig. 5**. Computational domain of the MLC in the ELCUT system.
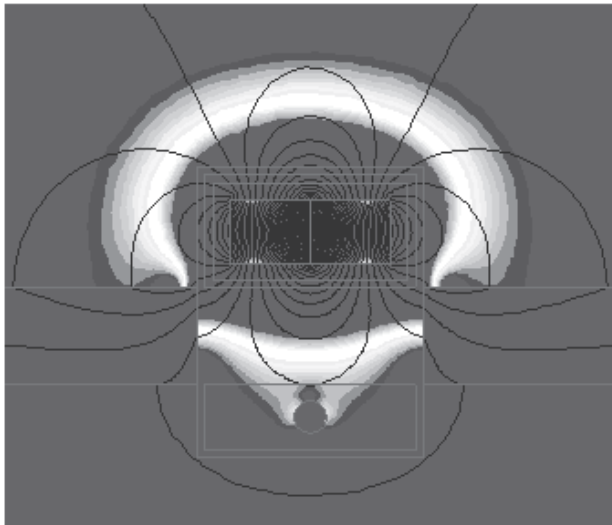


**Fig. 6**. Results of MLC magnetic field modeling in the ELCUT system.

It is also important to take into account the influence of the edge and surface effect during modeling by introducing appropriate coefficients when processing the obtained data.

Figure 7 shows the graph of the magnetic field strength H of a permanent magnet the applied MLC dependence on the width H of the non-magnetic wall of the tank with a controlled environment, obtained using the software package "Applied MLC".
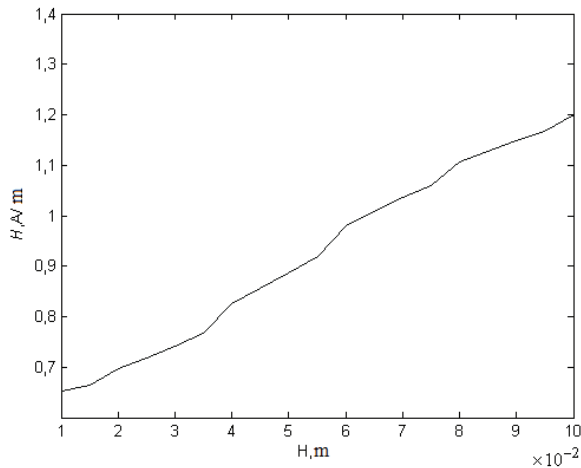
**Fig. 7**. Dependence of the strength H of the magnetic field of a constant magnet on the width H of the non-magnetic wall.

It should be noted that the presented software package can be improved to obtain other continuous dependences of the magnetic field strength H of the applied MLC on various design parameters at any point of the computational domain. For this, it is necessary to supplement it with event procedures that implement an algorithm similar to the algorithm in Figure 2 following the outlined methodology, where another constructive parameter of interest is selected as a variable.

## 5 Conclusions

Thus, we can conclude that the continuous dependences of the strength H of the magnetic field of a permanent magnet on the width H of the non-magnetic wall of the reservoir obtained with the help of the developed software package "Applied MLC" provide an opportunity to choose its minimum required value. This increases the accuracy of the applied MLC and reduces the cost of their manufacture.

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