Development and Research of Algorithm for Determining the BH Curve Using a Single Primary Measuring Converter Based on the Method of Full-Scale Model Tests

Danil Shaykhutdinov, Dmitriy Shurygin, Nikolay Gorbatenko, Valeriy Grechikhin,
Roman Leukhin, Igor Stetsenko, Roman Oganyan, Viacheslav Bondarenko and Vadim Leukhin
Department of Information and Measurement Systems and Technologies,
Platov South Russia State Polytechnic University (NPI), Novocherkassk, Russia

Abstract: This study presents the results of the development of the algorithm for determining the two coordinate BH magnetization curve of the material according to indications of one transmitter. The method of full-scale model tests is used to solve the problem. The algorithm is implemented as lua-script for FEMM 4.2 program. A program implemented in LabVIEW 2013 environment to control the process of determining the BH magnetization curve.

Key words: Method of full-scale model tests, flux-current characteristics, BH curve, magnetic, measurement

INTRODUCTION

Now a days magnetic materials are important components of most devices: transformers (Ovchinnikov, 2012), electric drives (Gorbatenko *et al.*, 2011, 2015a, b; Shayhutdinov *et al.*, 2015a), electromagnetic relays. Electrical devices in turn are important components of the various technical systems (Dubrov *et al.*, 2015a, b).

Methods and approaches to determine their status separately and as part of systems being actively developed (Lankin *et al.*, 2015; Shaykhutdinov *et al.*, 2013, 2015a-e).

Wide spread techniques based on computational and experimental approach, including the method of full-scale model tests (Bulgakov *et al.*, 2015; Shayhutdinov *et al.*, 2015b; Lankin *et al.*, 2015). The method of full-scale model tests involves the use of the experimental results as a model setting criteria and as the initial characteristics of the controlled object. An important problem is to minimize the number of primary devices used to implement the method of full-scale model tests.

The aim of this study is to develop a new algorithm for implementing the method of full-scale model tests. This algorithm should define two coordinate function BH characteristic of the material. The source of information should be a measure of the only one physical quantity the magnetic flux.

MATERIALS AND METHODS

The problem is solved by the using of the device for the control of electrical steel sheet, previously developed (Shaikhutdinov *et al.*, 2015; Shayhutdinov *et al.*, 2015c).

The result of operation of the device is the Weber-voltage characteristic of the magnetic system "magnetizing device-test sample". In the study the algorithm has been proposed in which the function is defined by the BH-characteristic varied by one coordinate the magnetic field H. Thus, the error in determining the characteristics of BH was reduced to 5%. A further reduction of the error causes difficulties due to the lack of a degree of convergence of the algorithm.

Greater efficiency showed an algorithm for determining of magnetic BH characteristics shown in Fig. 1. Software package FEMM 4.2 was chosen as the simulation environment. This package implements the most accurate of the currently existing finite element method. The algorithm (Fig. 1) as a lua-script for FEMM 4.2 environment was implemented. This lua-script controls the process of determining the magnetic characteristics. An algorithm (Fig. 1) became a piece of software for the PC. This PC is a part of information-measuring system for measuring the magnetic properties of electrical steel sheet. The software with the graphical programming language in LabVIEW 2013 environment was implemented.

The software provides a readout data of magnetic flus, electric current and the thickness of the test sample and lua-script definition of BH characteristics. The software executes lua-script with the given input data afterwards. The inverse problem of determining the magnetic characteristics of BH as measured magnetic flux interim results are displayed on the PC screen in the process of solving. An example of the results of the work of the information-measuring system for measuring the magnetic properties of electrical steel sheet is shown in Fig. 2.

Corresponding Author: Danil Shaykhutdinov, Department of Information and Measurement Systems and Technologies,
Platov South Russia State Polytechnic University (NPI), Novocherkassk, Russia

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                    ┌──────────┐
                    │  Begin   │
                    └──────────┘
                         │
        ╱───────────────────────────────────╲
       ╱ 1. Input data: a, c, l, wnk, N, delta, psi[N],╲
       ╲              I[N]                   ╱
        ╲───────────────────────────────────╱
                         │
       ┌───────────────────────────────────┐
       │ 2. Calculate cross-sectional area │
       │ of the test articles: S=a·c        │
       └───────────────────────────────────┘
                         │
       ┌───────────────────────────────────┐
       │ 3.Initialization of the model file │
       └───────────────────────────────────┘
                         │
       ┌───────────────────────────────────┐
       │ 4. The calculation of the initial │
       │ values: B=psi/S; H=I·wnk/l         │
       └───────────────────────────────────┘
                         │
       ⬡ 5. Repeat until {delta_rasch}/{psi}|max >delta ⬡
                         │
       ┌───────────────────────────────────┐
       │ 6. Data entry of dependence B (H) │
       │ as the product of the magnetic    │
       │ characteristics of the material   │
       └───────────────────────────────────┘
                         │
            ⬡ 7.  For k=1,N ⬡
                         │
            ┌────────────────────────┐
            │ 8. Set the current MC  │
            │ Ink=I[k]               │
            └────────────────────────┘
                         │
            ┌────────────────────────┐
            │ 9. Analysis of the     │
            │ model by means of Femm │
            │ program                │
            └────────────────────────┘
                         │
            ┌────────────────────────┐
            │ 10. Getting the value  │
            │ of psi_mod[k]          │
            └────────────────────────┘
                         │
            ┌────────────────────────┐
            │ 11. Calculation:       │
            │ delta_rasch[k]=        │
            │ =psi[k]-psi_mod[k]     │
            └────────────────────────┘
                         │
       ┌───────────────────────────────────┐
       │ 12. Finding the index of maximum  │
       │ of {delta_rasch} – ind_m           │
       └───────────────────────────────────┘
                         │
Yes ◇ 13. B(H)ind_m corresponds to the magnetic saturation? ◇ No
     │                              │
┌──────────────────────┐  ┌──────────────────────────┐
│ 14. The calculation  │  │ 15. The calculation of   │
│ of the new values    │  │ the new values           │
│ {B}={B}+{delta_rach}/S│  │ {H}={H}-{H}·{delta_rach}/(S·{B})│
└──────────────────────┘  └──────────────────────────┘
                         │
        ╱─────────────────────╲
       ╱ 16. Added B (H)       ╲
       ╲    in the file        ╱
        ╲─────────────────────╱
                         │
                    ┌──────────┐
                    │   End    │
                    └──────────┘
```
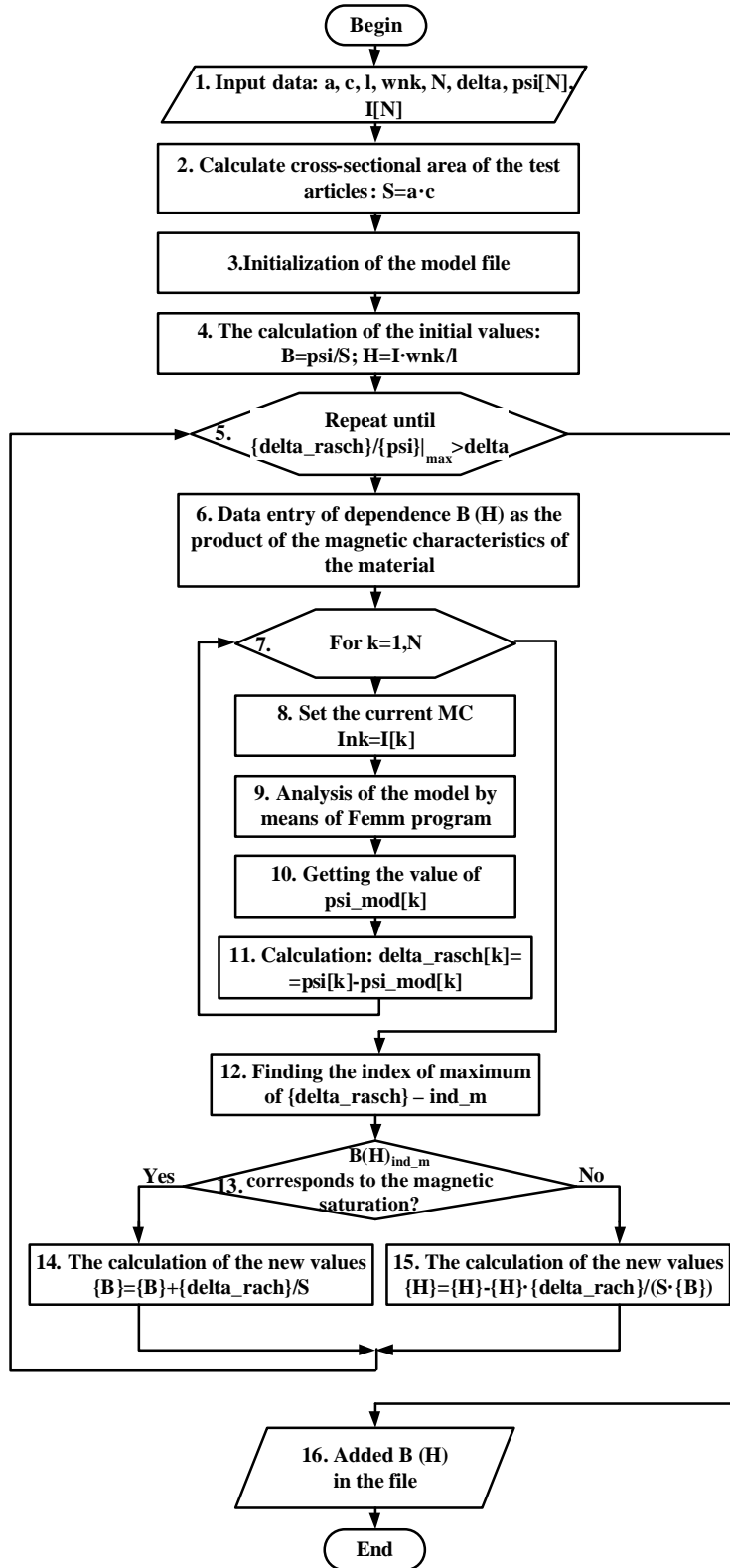
Fig. 1: The block diagram of algorithm for determining the BH curve using a single primary measuring converter based on the method of full-scale model tests
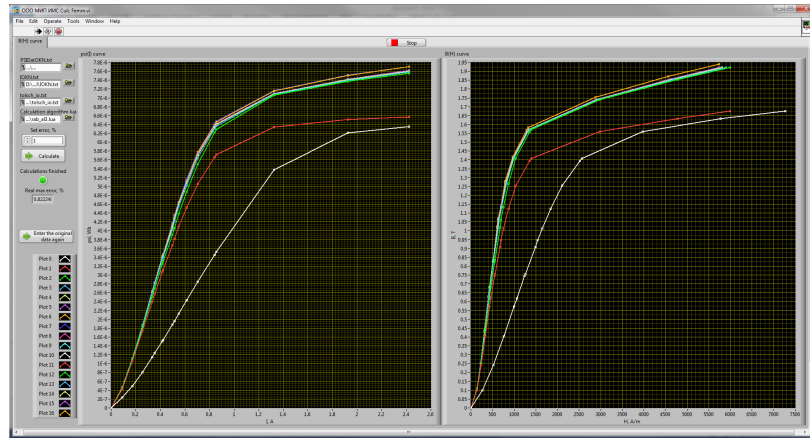
Fig. 2: An example of the implementation of the developed algorithm

RESULTS AND DISCUSSION

The algorithm for determining the 2 coordinate BH magnetization curve of the material according to indications of one transmitter is developed. The method of full-scale model tests is used to solve the problem. The algorithm is implemented as lua-script for FEMM 4.2 program. A program implemented in LabVIEW 2013 environment to control the process of determining the BH magnetization curve.

The developed algorithm for determining the BH curve using a single primary measuring converter based on the method of full-scale model tests provides a definition of magnetic characteristics with high level of the convergence and accuracy (error is no >3%).

Thus, it becomes possible to implement the algorithm in devices for measuring of magnetic characteristics of various ferromagnetic materials.

CONCLUSION

In the study developed and approved the algorithm and program for determining the magnetic characteristic based on computational and experimental approach. The algorithm is different from the others in that it is allow to configure an adequate model of testing object by using only one measurement parameter magnetic flux.

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REFERENCES

Bulgakov, A., D. Shaykhutdinov, N. Gorbatenko and S. Akhmedov, 2015. Application of full-scale experiments for structural study of high-rise buildings. Procedia Eng., 123: 94-100.

Dubrov, V.I., D.V. Shaykhutdinov and K.M. Shirokov, 2015a. Information-measuring system for the flow process hydraulic machines testing stand. Procedia Eng., 129: 184-190.

Dubrov, V.I., D.V. Shaykhutdinov, K.M. Shirokov, S.V. Akhmedov and N.I. Gorbatenko, 2015b. Information-measurement system for stend for testing hydraulic products. Proceedings of the 2015 International Siberian Conference on Control and Communications (SIBCON), May 21-23, 2015, IEEE, Omsk, Russia, ISBN: 978-1-4799-7102-2, pp: 1-3.

Gorbatenko, N.I., V.V. Grechikhin and D.V. Shaikhutdinov, 2015a. Measuring and actuating devices based on shape memory ferromagnets. Met. Sci. Heat Treat., 56: 609-613.

Gorbatenko N.I., A.M. Lankin, M.V. Lankin, D.V. Shayhutdinov, 2015b. Determination of weber-ampere characteristic for electrical devices based on the solution of harmonic balance inverse problem. Int. J. Appl. Eng. Res., 10: 6509-6519.

Gorbatenko, N., M. Lankin, D. Shaykhutdinov, K. Gazarov and A. Kolomiets, 2011. Electromagnetic induction system for testing ferromagnetic shape memory alloys. Proceedings of the 6th International Forum on Strategic Technology, Volume 1, August 22-24, 2011, Harbin, Heilongjiang, China, pp: 194-196.

Lankin, A.M., M.V. Lankin, V.V. Grechikhin and D.V. Shaikhutdinov, 2015. Determination of magnetic characteristics of alternative current electrotechnical devices using the method of full-scale-model tests. Res. J. Appl. Sci., 10: 690-695.

Ovchinnikov, I.A., 2012. Electromechanical and mechatronic systems. Crown-Print, Moscow, Russia, Pages: 400.

Shaikhutdinov, D.V., N.I. Gorbatenko and K.M. Shirokov, 2015. Facility for measuring magnetic parameters of articles from sheet electrical steel on the basis of national instruments technologies. Met. Sci. Heat Treat., 56: 618-620.

Shayhutdinov, D., N. Gorbatenko, V. Grechikhin, K. Shirokov and V. Dubrov, 2015a. Development of the computer-based stand for research of the voltage generation effect of the magnetic shape memory material. Res. J. Appl. Sci., 10: 170-172.

Shayhutdinov, D., N. Gorbatenko, G. Aleksanyan, V. Grechikhin and K. Shirokov *et al.*, 2015b. Development of a computer-based stand for testing algorithms of electrical impedance tomography. Res. J. Appl. Sci., 10: 173-175.

Shayhutdinov, D., A. Lankin, N. Narakidze, V. Grechikhin, K. Shirokov and N. Gorbatenko, 2015c. Complex predict fault diagnostics of electromagnetic actuators based on the principle component analyses. Res. J. Appl. Sci., 10: 555-557.

Shaykhutdinov, D.V., N.I. Gorbatenko, S.V. Akhmedov and R.I. Leukhin, 2015a. Device for control of magnetic properties of electrical steel for industrial production management system. International Siberian Conference on Control and Communications, May 21-23, 2015, Omsk, Russia, pp: 1-2.

Shaykhutdinov, D.V., R.I. Leukhin and K.M. Shirokov, 2015b. Automated stand for intelligent actuators regulators setup parameters. Procedia Eng., 129: 749-753.

Shaykhutdinov, D., A. Lankin, S. Janvarev, N. Gorbatenko and D. Schuchkin, 2015c. Application of tensor methodologies for the description of non-linear processes in electromagnetic drive. Res. J. Appl. Sci., 10: 798-800.

Shaykhutdinov, D., A. Lankin, S. Janvarev, N. Narakidze and R. Leukhin *et al.*, 2015d. Development multiprocessing mathematical model of electromagnetic AC drive. Res. J. Appl. Sci., 10: 812-814.

Shaykhutdinov, D., N. Gorbatenko, R. Leukhin, 2015e. Development of a computer-based stand for research of the methods of sensorless control of electromagnets DC. Res. J. Appl. Sci., 10: 845-847.

Shaykhutdinov, D.V., N.I. Gorbatentko, V. Akhmedov, M.V. Shaykhutdinova and K.M. Shirokov, 2013. Experimental and simulation tests of magnetic characteristics of electrical sheet steel. Life Sci. J., 10: 2698-2702.