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Interaction of EM and Other Fields with Applications

Development of micro brushless DC motor model based on project design calculation using Ansys Maxwell RMxprt

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Abstract* — The theoretical basis of Ansys Maxwell RMxprt software and modeling methods are considered. A method of project design calculation of a micro brushless direct current (BLDC) motor using Ansys Maxwell RMxprt software was developed for a manufactured motor with known overall dimensions and some passport data (rated voltage, rated speed, rated current, rated torque, rated power) of arbitrary power for the purpose of further parameterization of the BLDC motor model from the MATLAB Simulink library. This will allow the development of new models of micro electric drives and the synthesis of efficient micro BLDC control systems, which can improve their performance, accuracy and speed of operation. The calculation was carried out on the example of a specific Sinotech model BY35BL30 BLDC micromotor using Ansys Maxwell RMxprt software in accordance with the developed micro BLDC project design calculation methodology. The results obtained by the project design calculation using Ansys Maxwell RMxprt software coincide with the known original passport data of the manufactured BLDC micromotor with a small error of up to 5%. A comparative analysis of the results allows us to conclude about their high degree of coincidence. The use of this approach provides all the necessary parameters for the parameterization of the BLDC motor model from the MATLAB Simulink library. Research has been carried out of the micro BLDC model in the Ansys Maxwell RMxprt software were carried out based on the data obtained during the project design calculation. Thus, the proposed approach has confirmed its workability and the assumption that it can be used for further research on electric drives based on BLDC.

Keywords* — micro BLDC, mathematical model, project design calculation, Ansys Maxwell RMxprt

I. INTRODUCTION

The main component of various technical device is the electric drive, which drives the executive mechanism with the specified parameters of the motion tachogram [1]. A special place is occupied by microelectric drives - electric drives are built on the basis of micromotors with a power of up to several tens of watts. Microelectric drives (MED) are used in various devices, such as 3D printers, 3D scanners, drones, household appliances, hand tools, medical equipment, printing industry, etc. [2]. The main part of such MED is a microelectric motor (MEM), with a power of up to several tens of watts. The use of classic direct current collector electric motors in MED is quite problematic due to the presence of the collector and permanent magnets.

Especially the presence of permanent magnets in DC micro motors causes the operation problem of the MEM at low speeds, unstable operation during start-up and braking. One of the ways to get rid of these specified disadvantages is the use of brushless direct current electric micromotors with permanent magnet excitation [2].

A BLDC motors have relatively small dimensions and light weight, produces significant torque, and also provide high rotation speed that can reach tens of thousands of rpm. However, the most significant advantage of BLDC compared to collector PM DC motors is their specific power per unit volume. The collector of the micromotor physically cannot transmit much power.

For a successful simulation of the MED, for example in MATLAB Simulink software, a mathematical model of the MEM with relevant parameters is usually necessary, such as: rated voltage, rated speed, rated current, rated torque, rated power, stator phase resistance *Rs* (Ω), armature inductance *Ls* (H), flux linkage, voltage constant, torque constant, moment of inertia.

For the application case of standard series brushless micromotors, some data such as rated voltage, power and speed in particular can be obtained from the data plate. This is not enough for research and modeling. In some cases, it is necessary to design a new MEM to ensure technological process requirements. Therefore, the task of calculating all parameters of the micromotor is relevant.

The parameters determination and calculation for the design and manufacture of MEM is a rather complex, time-consuming and resource-consuming task. It is necessary to additionally calculate such parameters as: stator phase resistance *Rs* (Ω), armature inductance *Ls* (H), flux linkage, voltage constant, torque constant, moment of inertia.

Currently, there are many specialized scientific and applied software packages for calculating the parameters of electric motors. For example, Ansys, various developments in MathCad and algorithmic programming languages.

In this work, the Ansys Maxwell RMxprt software [3] was used for the BLDC micromotor project design calculation. RMxprt is a template-based electrical machine design tool that provides fast analytical calculations of machine performance and generation of 2-D and 3-D geometry for detailed finite element calculations in ANSYS Maxwell.

Using RMxprt, it is possible to model and analyze such as electrical machines: three-phase and single-phase asynchronous motors, three-phase synchronous machines, brushless DC motors with permanent magnets, universal motors, etc.

Therefore, it is necessary to determine the methodology for calculating the parameters of the MEM, in particular micro BLDC, for the further use of these parameters for mathematical and computer MED modeling in general.

II. LITERATURE REVIEW

To create and research the processes of mathematical models of the MEM, it is necessary to calculate the MEM parameters. This can be done in two ways: in manual mode based on the analytical dependence of parameters or with the help of special software. For example, article [4] presents the calculation of alternating current single-phase collector motor parameters as a result of project design calculation based on the fundamental theory for calculating the motor design in the range from tens of watts to several kilowatts. As a result, a mathematical model of such motor was developed in the MATLAB Simulink software.

The model is built on the basis of motor and thyristor models using real parameters and with a real voltage regulation scheme. As can be seen from this article [4], the project design calculation process includes the calculation of a many number of analytical formulas in manual mode. That requires a lot of time and there is also a question of calculations accuracy. Therefore, there is an actual need to automate and optimize the calculation process by using special software packages, such as Ansys Maxwell RMxprt.

In the article [5] in MATLAB Simulink, a model of a single-phase collector motor with alternating current supply and voltage regulation based on the results of the project design calculation was developed and researched. For modeling purposes, the authors [5] obtained all the necessary motor parameters for mathematical models. This model is built on the basis of existing universal motor and thyristor models in the MATLAB Simscape library using data obtained during the project design calculation and real passport data of the thyristor. The authors of [5] carried out research of the mechanical characteristics of an AC motor with voltage regulation using one or two thyristors for different thyristor ignition angle. It is of scientific interest to carry out a similar mathematical modeling for the micro BLDC application option.

In the article [6], a model of an electric drive based on a single-phase collector motor (SPCM) with inverter supply model was built. Previously, the calculation of the washing machine motor was carried out and the main formulas of the design and construction calculation of the main parameters of the SPCM alternating current of arbitrary power were analyzed. However, there is an interest in using, for example, the Ansys Maxwell RMxprt software for automating the calculation of the MEM parameters and creating the corresponding micro BLDC model.

The article [7] uses the ANSYS Electromagnetics and RMxprt software to determine the parameters of synchronous machines with permanent magnets: parameters of windings, losses, motor performance. First, in the article defines all the necessary parameters of a synchronous motor with permanent magnets for performing calculations in RMxprt. Obtained transient characteristics in ANSYS Simplorer software by exporting the servo motor object from RMxprt to ANSYS Electro-magnetics Simplorer work environment. The results obtained by the authors in [7] confirm the correctness of the chosen strategy for determining the micro BLDC parameters. However, it is preferable to use the MATLAB/Simulink software for computer simulation, given the large built-in library

In the article [8], the design and research of a brushless direct current motor with excitation from permanent magnets during use in a direct drive is carried out. The motor model was developed using Ansys Maxwell software. In particular, the magnetic system of such a BLDC motor was calculated and analyzed. The results of modeling in the Ansys Maxwell software showed that the operating characteristics of the stator of the prototype fully meet the requirements of the electric vehicle. This use of the Ansys Maxwell software for the design and research of the executive motor confirms the correctness of the strategic decision of the authors of this article to study the problem of determining the micro BLDC parameters.

In the article [9] it is provides an example of the design and development of an asynchronous motor, starting with the creation of a 3D model in the SolidWorks software and obtaining the necessary parameters of the motor geometry. Based on these data, an asynchronous motor was designed in the software Ansys Electronic Suite - Maxwell RMxprt. As a result, the electrical parameters of the motor were calculated using the analytical dependences of the classical theory of electric machines and the method of the equivalent magnetic circuit of Ansys Electronic Suite - Maxwell RMxprt. The results obtained by the authors [9] demonstrate a modern scientific approach to the design of electric machines in general and confirm the need for project design calculation of micro BLDC using the Ansys Electronic Suite - Maxwell RMxprt software.

III. PROBLEM STATEMENT

The main objective of this research is to carry out a project design calculation and to research the micro BLDC motor model in the Ansys Maxwell RMxprt software for an already manufactured motor with known overall dimensions and some passport data (rated voltage, rated speed, rated current, rated torque, rated power). Check the possibility of using the micro BLDC motor parameters obtained in the Ansys Maxwell RMxprt software to parameterize the BLDC motor model from the MATLAB Simulink library. Also to concludeabout the possibility of its further use for the research of micro-drives built on the basis of a BLDC motor. To compare the results obtained during the project design calculation in the Ansys Maxwell RMxprt software with the known original passport data of the manufactured micromotor and to conclude about the coincidence of the obtained results and the prospects for further application of this approach.

The research result is the development of conclusions and recommendations about the possibility of further application of the proposed approach of using Ansys Maxwell RMxprt to create micro BLDC motor models based on the project data of the project design calculation and their further modeling using one or another software.

The main tasks of this paper are as follows:

- to consider the theoretical foundations of the Ansys Maxwell RMxprt software and applied modeling methods;

- to develop a methodology for the project design calculation of a micro BLDC motor in the Ansys Maxwell RMxprt software for an already manufactured motor with known overall dimensions and some passport data (rated voltage, rated speed, rated current, rated torque, rated power) of arbitrary power and perform such a calculation on the example of a specific motor;

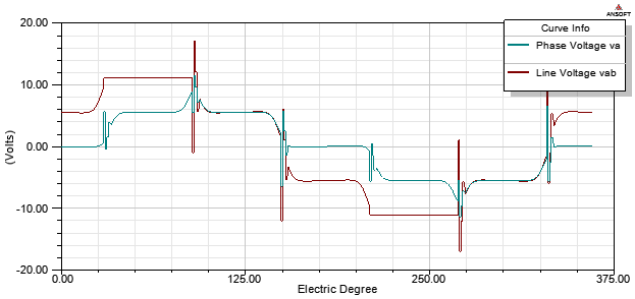

Рис.15. Winding voltages under load micro BLDC in RMxprt

In fig. 12-15 shows only a part of the obtained results of the designed micro BLDC in RMxprt. Further, based on the obtained results, it is possible to proceed to the development and research of electric drive models based on BLDC in MATLAB Simulink.

VII. Conclusions

1 The theoretical foundations of the Ansys Maxwell RMxprt software and modeling methods are considered. A method of project design calculation of a micro BLDC motor in the Ansys Maxwell RMxprt software has been developed for an already manufactured motor with known overall dimensions and some passport data (rated voltage, rated speed, rated current, rated torque, rated power) of arbitrary power.

2. The calculation was carried out on the example of a specific Sinotech model BY35BL30 BLDC micromotor in the Ansys Maxwell RMxprt software in accordance with the developed micro BLDC project design calculation methodology.

3 The results obtained by the design calculation in the Ansys Maxwell RMxprt software coincide with the known original passport data of the manufactured micro BLDC with a small error of up to 5%. A comparative analysis of the results allows us to make a conclusion about their high degree of coincidence. Thus, the application of this approach provides all the necessary parameters for the parameterization of the BLDC motor model from the MATLAB Simulink library.

4. The researches of the micro motor model were carried out in the Ansys Maxwell RMxprt software based on the data obtained during the project design calculation. Thus, the proposed approach has confirmed its workability and the assumption that it can be used for further research on electric drives based on BLDC micro motor.

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