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Modeling and Analysis of Magnetic Flux and Static Performance of Synchronous Motors with Electromagnetic Excitation using ANSYS MAXWELL

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ABSTRACT: The creation of new compounds and alloys based on rare earth materials expands the production of electric machines with electromagnetic excitation every year. Due to such advantages, high energy performance of magnetoelectric machines are widely used in many branches of technology. Currently, these machines are actively used to create a valve drive. One of the main tasks in the design of a synchronous motor is the study of electromagnetic and electrical processes in a magnetoelectric machine. The paper considers various methods for calculating the magnetic field of an electric machine. A description of domestic and foreign software products based on the finite element method is provided. A study of the operation of synchronous motors on a compressor unit used in the Syrdarya TPP was conducted. Modeling of a synchronous motor in the ANSYS software environment using Maxwell 2D and Simplorer applications.

KEYWORDS: ANSYS Maxwell, synchronous motor, analysis of electrical machine characteristics, calculation of electrical machines with electromagnetic excitation.

I. INTRODUCTION

In the last decade, special software packages for calculating electromagnetic field parameters have become increasingly popular. One of the most powerful tools for solving this problem is the Maxwell program from Ansys.

ANSYS Maxwell is a leading 2D and 3D electromagnetic field simulation software used to study and design 2D and 3D models, sensors, transformers, motors, and other electromechanical and electrical devices for a variety of applications. It is based on the Finite Element Method (FEM) and accurately calculates harmonic as well as static electric and electromagnetic fields and transients in field problems.[1,2]

Today, in the market conditions, the issues of cost-effectiveness and speed of processing of variants of solutions in the electromechanical industry are acute, that is, it is necessary to quickly and with minimal costs analyze various electromechanical systems [1-13]. At the same time, manual calculation using known methods [2-3] is labor-intensive and time-consuming. The purpose of this article is to acquaint the reader with modern methods of analysismagnetic flux and static characteristics of synchronous motors with electromagnetic excitationusing the example of the software package for electromagnetic calculations ANSYS Maxwell [4-14].

A typical application of this software package can be the automated calculation of electrical machines with given characteristics [5-15], for example, the calculation of an electricengine for compressor unit [6,7]. Initially, three variants of electric machines were proposed for consideration: an asynchronous motor and two permanent magnet brushless motors with radial magnetic flux and axial magnetic flux. Due to strength conditions and large losses in the rotor, the asynchronous motor was excluded [8-9]. An electric machine with an axial gap [10] was also left as a backup option due to its high labor intensity, uniqueness, difficulty of balancing and, as a result, high cost; however, it should be noted that, when making appropriate technical decisions, the axial machine is competitive. A synchronous motor with electromagnetic excitation was chosen as the main option due to its high technology, simple design, proven production method, and insignificant effect of the anchor reaction [11-21].

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II. SIGNIFICANCE OF THE SYSTEM

Thus, the task of designing a synchronous motor with electromagnetic excitation was set. To study the possibility of accelerating the calculation while simultaneously increasing the accuracy of calculations and, accordingly, improving the quality of the design, modern software was used - in this case, the ANSYS Maxwell software package [15-21].

This software suite is designed to simulate electromagnetic fields when designing and studying models of motors, sensors, transformers, and other electrical and electromechanical devices for various applications. ANSYS Maxwell is built on the basic Maxwell equations and uses the Finite Element Method (FEM) for calculations, which allows you to calculate electromagnetic and electrical fields, as well as transient processes in field problems.

III. LITERATURE SURVEY

The software package contains a large library of templates of known electrical machines. In these templates it is enough to enter the basic geometricdimensions, materials to be used, and using these initial data to calculate the characteristics of the electrical machine under study. It is possible to calculate and analyze at three different levels:

-accelerated analysis using substitution circuits;

-calculation by the finite element method in a two-dimensional problem statement;

-calculation by the finite element method in a three-dimensional problem statement.

At the last two levels, there is the possibility of solving a magnetostatic problem, a dynamic problem, there is the possibility of connecting an electrical circuit of the system, as shown in Figure 1, which means there is the possibility of analyzing the operation of an electric machine when connecting semiconductor technology, various loads, etc.

Considering the shortcomings, the primary task is the electromagnetic analysis of the engine, which can be successfully performed using the capabilities of the RMXprt add-on. ANSYS. RMxprt is a program that accelerates the process of optimization and design of rotating electric machines. It uses the equivalent magnetic circuit method to calculate the operating characteristics of the machine and the classical analytical theory of electric machines, which allows you to analyze the model much faster and give a result [3-20].

IV. METHODOLOGY

In addition, it is possible to view various oscillograms, as shown in Figure 2, see the magnitude of induction, the picture of the paths of the closure of the flow lines of force, as shown in Figure 3, calculate magnetic, electrical losses, as well as losses caused by the generation of eddy currents in the magnetically conductive parts of the system.

To check the quality of the calculation performed by the software package, a test calculation of a synchronous motor with electromagnetic excitation was carried out using known methods [2-3]. During the test, the magnetic circuit and losses in the electric machine were calculated, and the operating characteristics and oscillograms of voltages and currents of the idealized system were constructed. During the test, the magnetic circuit and losses in the electric machine were calculated, the operating characteristics and oscillograms of voltages and currents of the idealized system were constructed. For clarity, the calculation results are summarized in Table 1.

V. EXPERIMENTAL RESULTS

The issue of studying the magnetic field of electric machines is often complicated by the task of accurately describing the geometry of the magnetic system. In the Maxwell software environment, as part of the RMXprt library, there is the ability to accurately describe the features of the tooth zone geometry and calculate the current, EMF and electromagnetic torque curves taking into account the harmonic components (Fig. 1). When describing the geometry of the magnetic system, there is the ability to support computer-aided design systems, i.e. the model can be made in any CAD application, for example, in SolidWorks.

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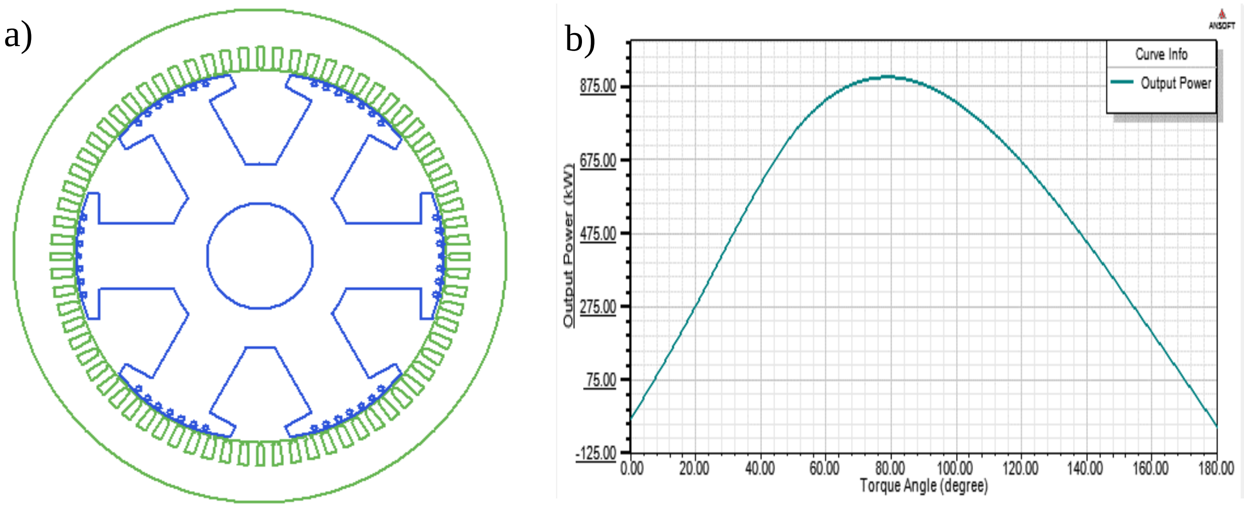

Fig.1. Model of a synchronous motor with electromagnetic excitation: a) view of the stator and rotor, b) Output power

Next, to calculate the motor, the properties of the materials of all solid objects in the magnetic system were determined. During the theoretical studies, it was found that the incorrect selection of materials distorts the picture of the electromagnetic field, which naturally affects the calculation results. The result of our work was the study of the following characteristics of synchronous motors with electromagnetic excitation: power consumption, efficiency, nominal slip, torque, speed and data on the electrical state of the rotor and stator windings (Fig. 2).

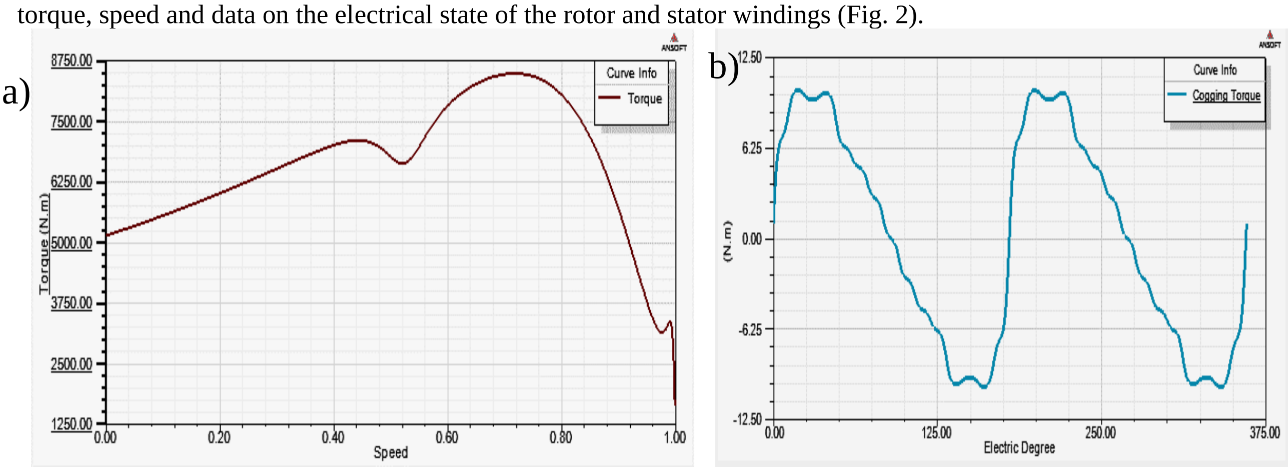

Fig.2. Results of modeling in ANSYS MAXWELL: a) Moment acting on the damper conductor [N·m], b) cogging torque

By analyzing the influence of the geometric characteristics of the electric motor on its external static characteristics, the most efficient design options for the tooth zone were determined from the standpoint of reducing electromagnetic torque pulsations. The following tooth zone parameters were changed: tooth height and width, number of turns in the groove, groove shape, and properties of the rotor magnetic circuit materials. The figure below shows a picture of the rotor electromagnetic field.

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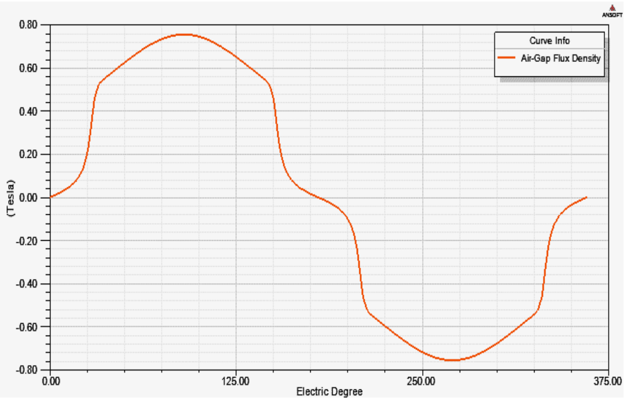
a)


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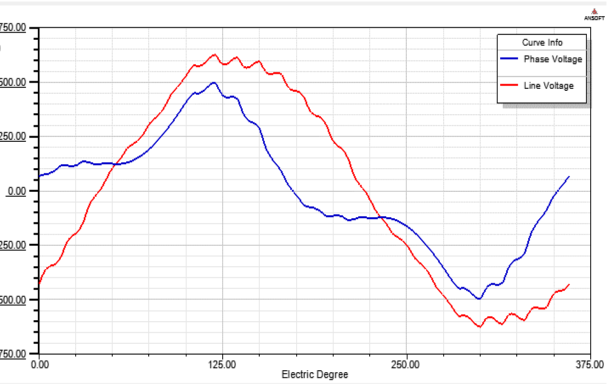
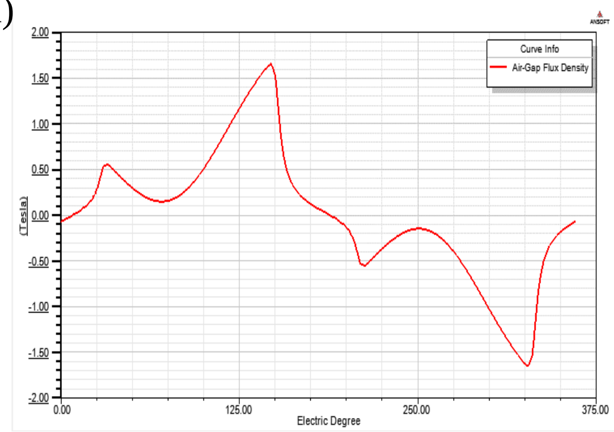


Fig.3. Magnetic flux in the air gap: a) Flux density in the air gap, b) voltage in line and phase

Table 1. Comparison of calculation results performed manually and using ANSYS Maxwell

Parameter being compared	ANSYS Maxwell	Manually
Air gap induction, [Tl]	1.51661	1,5013
Nominal phase current, [A]	776.536	778.25
Nominal moment, [N·m]	5137.54	5142.69
Magnetic losses, [W]	6484.32	6845.1
Electrical losses, [W]	22751.8	22720,2

a)


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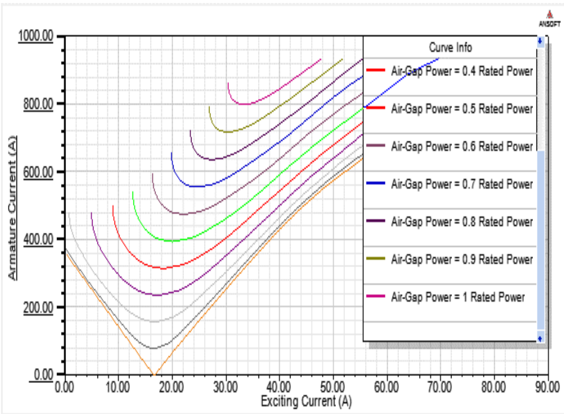

Fig.4. Magnetic flux in the air gap a), U-shaped characteristic of the engine b)

All manual calculations fully confirmed the results of calculations using the Maxwell program. It should be noted that Maxwell provides some additional features that are not available in manual calculations, such as voltage surges and current jumps, eddy current losses and electromagnetic torque pulsations.

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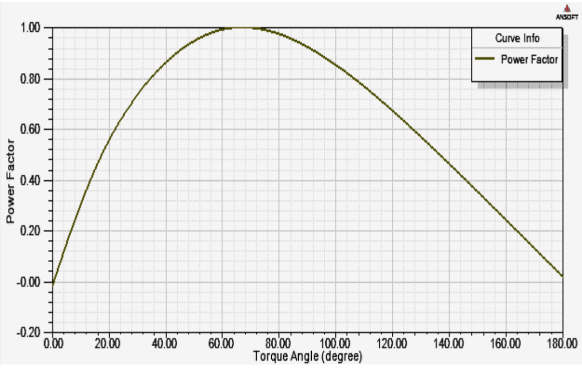
a)



b)

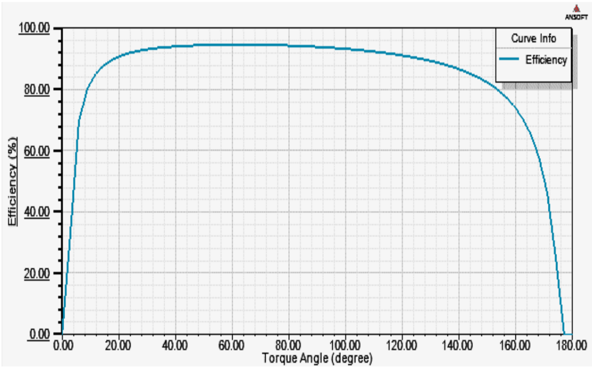


Fig.5. Engine energy indicators: a) power factor, b) efficiency factor

From the analysis of the graphs in Figures 5.a, b, we see that when the torque angle reaches 700 degrees, the engine power factor and efficiency factor reach their maximum value.

VI. CONCLUSION AND FUTURE WORK

In general, the use of RMXprt has reduced the time of studying the operating modes of a synchronous reluctance electric motor in terms of automated data processing. In cases where it is necessary to move from an analytical to a more accurate solution for a detailed examination of the processes occurring inside the machine, ANSYS RMxprt allows you to move from a virtual model to a two-dimensional or three-dimensional field model in ANSYS Maxwell 2D/3D.

Based on the design and analysis results, an engine was manufactured and tested, the parameters of which fully correspond to the calculated data.

Analyzing the results of the work done on calculating the electric machine, the following conclusions can be made:

-the accuracy of calculations of electrical machines in the ANSYS Maxwell software package is not inferior to the accuracy of calculations using traditional calculation methods;

-to perform an initial estimate calculation of an electromechanical system and determine the main dimensions, it is advisable to use simplified estimate design methods;

-To analyze and check calculations and perform optimization, modern software should be used, which will improve the accuracy of calculations and speed up the receipt of practical results.

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