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Analysis of the Torque of a Permanent Magnetic Synchronous Motor with Single Tooth Coils

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Abstract— *This paper deals with synchronous motors (alternators) with permanent magnets on the rotor and with the stator winding in the design with so-called single-tooth coils. The basic ones are summarized her. Knowledge of the design of these machines, their advantages and disadvantages. Furthermore, problems related to the possible design of basic parameters, such as the context, are briefly outlined between the number of grooves on the stator and the number of magnets on the rotor, the width of the magnets.*

Keywords— *Permanent magnetic, Synchronous motor, tooth coils.*

I. Introduction

Recently, machines with permanent magnet excitation are increasingly used. These machines Vs to a classical wound rotor, they show a higher magnetic flux at smaller dimensions, thus enabling to achieve better characteristics (higher torque) of the given machines while simultaneously reducing the dimensions. The so-called single-tooth coils eliminate some of the problems associated with the production of classic windings, in particular due to the elimination of long winding faces. So they are coils with groove pitch 1 (first and second side the coils lie in the adjacent groove). In the event of the design of these machines, but in general any electric machine, we often come across the problem of correctly choosing a whole range of different parameters, factors, etc. For common designs of electrical machines, these coefficients and factors are quite precisely determined from the values obtained in practice, but for the relatively new layout of the machines they are not more precisely defined. At it is therefore advantageous to use some modern computing tools to examine the given parameters. In current technical practice, the numerical method of finite elements is the most widespread and used. A number of calculation programs, such as Ansys, Opera, FEMM, and others, work on the basis of this method. The Ansys 7.1 program was used to perform the analysis of the mentioned machine, as it is one from the best known and highest quality commercial programs of this kind. Another program used is the FEMM 4.0 program, which belongs to the category of freely available (version 4.0 and older) and user and of course also with simpler computing options, the author of which is David Meeker.

II. Basic Principle Arrangements

The basis of the structural arrangement is a permanent magnet attached in a suitable way (most often glued) to the rotor made of solid material, mostly steel. This magnet is oriented in the radial direction and interacts with the magnetic field induced by the passage of current through the coil (in individual pairs of stator slots). Mostly these machines are made as three-phase, powered by sinusoidal current from frequency converters. In order to assess the accuracy of individual programs, it is of course necessary to verify the calculation by measurement. For this purpose, a model of the given machine was assembled, the resulting moment of which was then determined individual programs. The basis of the model is a stator bundle with 36 grooves, on the teeth of which there is 18 coils wound. The interconnection of the individual coils can be seen from Fig. 2.1. It is located on the rotor (with alternating polarity 34) magnets.

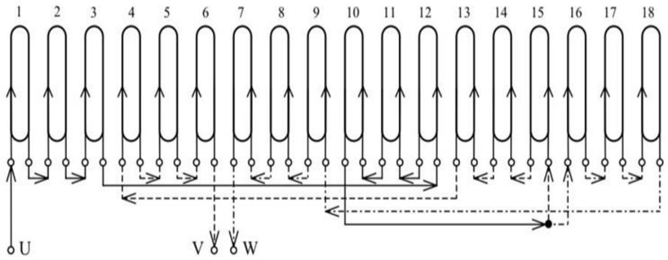

Fig 2.1. Stator coil connection diagram. (The arrows show the directions of the currents at the moment in time when IU = max and therefore IV = IW = -IU/2).

III. Numerical Model of the Given Machine

To calculate the moment acting on the rotor of the machine, it is necessary to determine the values of magnetic induction in

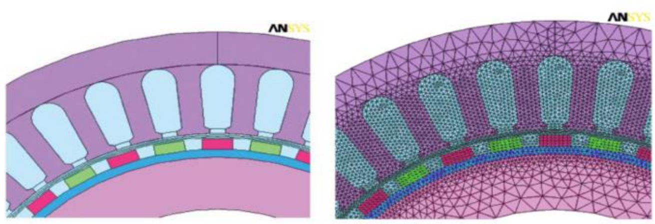

Fig. 3.1 a) Section from the machine model in the Ansys program.
b) Section covered by the finite element mesh

A system of equations is then compiled for individual nodes of the resulting network, which is solved by one of the available solvers (in version Ansys 7.1, it is possible to choose from a total of 12 solver modifications). In the FEMM program, creating a machine model is easier for the user, using lines and so-called marks, which they define which material properties are to be used for the given area enclosed by lines (see Fig.3.2.a). This model is then covered with a mesh of finite elements, just like

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in the Ansys program (Fig. 3.2.b). However, it can only be triangular (with three nodes), instead of the large number of different elements available (elements) in Ansys. A single solver can be used to solve the assembled system of equations (modification of conjugate gradients). So that the calculations are usable, for example, for design or optimization of a given machine, it is necessary for these numerical models to be created fully parametrically. Both programs used allow this. The Ansys program using the so-called macro model, which is essentially a written sequence of commands, and the FEMM program using Lua script, which is a general scripting language based on in the C programming language.

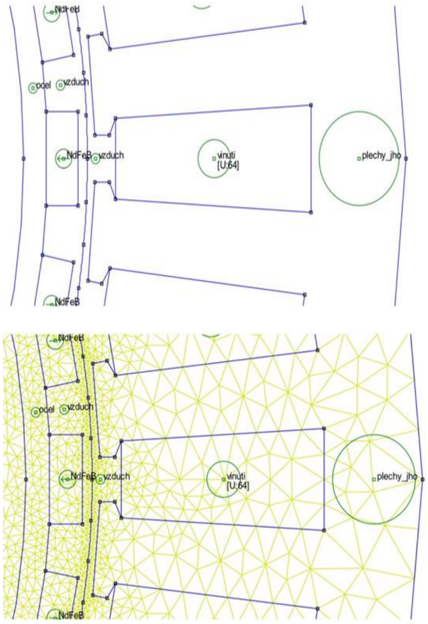

Fig.3.2.section from the machine model in the FEMM program
b) Section covered by the finite element mesh.

One of the decisive factors for choosing the program used is not only the accuracy of the results, but also speed of individual calculations. In Tab.1. Individual parameters and respective times are listed needed to calculate the torque of the given machine. These calculations were performed on a computer server with 2 Intel Xeon 800MHz processors and 768MB RIMM memory.

TABLE 1. Necessary times for individual steps of numerical analysis

	Number of nodes Network	Number of houses elements	Creation geometry	Creation KP network	The solution systems	Calculation results	Total time on 1 calculation
Ansys	16893	33606	9s	18s	1m 22s	7s	1m 56s
FEMM	16971	33796	6s	3s	1m 14s	6s	1m 29s

IV. Evaluation Of Results

Using both programs, a number of calculations were performed to compare the accuracy of the solution, primarily the distribution of magnetic induction in individual parts of the machine was calculated (see Fig.4.1.) and then the moment acting on the rotor of this machine was calculated

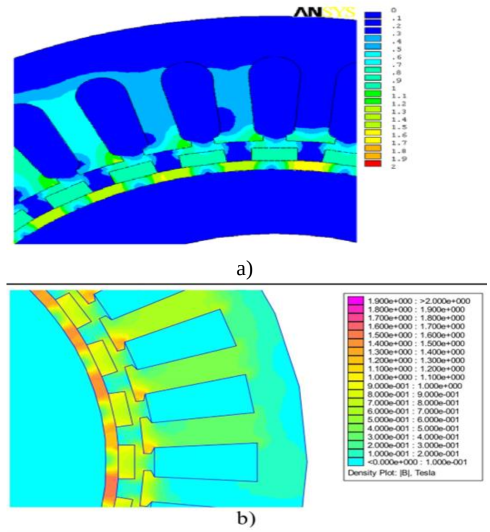

Fig. 4.1. a) Distribution of magnetic induction in the part of the machine determined by calculation in the Ansys program.
b) Distribution of magnetic induction in the same part of the machine determined by FEMM calculation.

The Ansys program allows directly calculating the moment in a 2D task using the virtual work method and using the Maxwell stress tensor. The results of these calculations are shown in Fig. 4.2.a-b, where they are the dependences of the torque on the angle of rotation of the rotor for different sizes of the stator current are plotted.

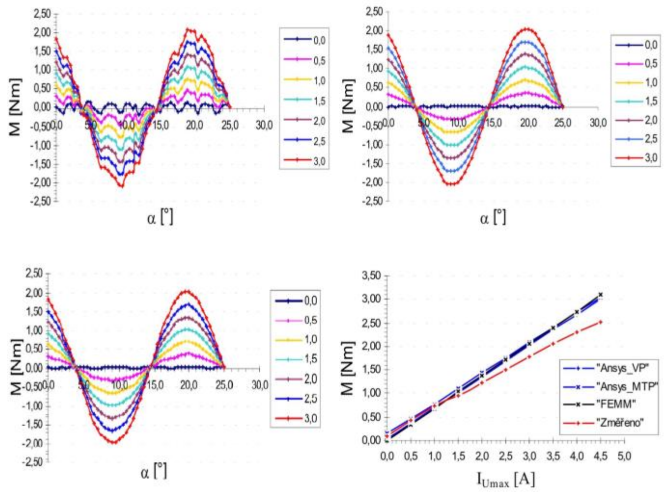

Fig. 4.2. The course of the moment depending on the angle of rotation and the size of I_U max calculated using
a) Ansys – Maxwell stress tensor (MTP),
b) Ansys – virtual work (VP),
c) FEMM – Maxwell stress tensor
. d) Magnitude of the maximum torque value depending on I_{MAX}.

Using the FEMM program, it is also possible to calculate the resulting moment using the Maxwell tensor tension. The moments determined in this way are plotted in Fig. 4.2.c. Last but not least was for control of the correctness of individual numerical analyses carried out measurement of the so-called static moment on made by machine. These measured values are plotted in Fig. 4.2.d.

V. Conclusion

From the courses of the calculated and measured moment (Fig. 4.2.d) it is evident that both programs used they provide almost identical, relatively accurate and therefore usable results in practice. As the most accurate se the moment waveform results appear to be determined using Ansys and Maxwell's method of the tension tensor (Fig. 4.2.a), as this course also affects the so-called stepping (ripple) moment caused by permanent magnets. Simple determination of which of the used programs is more suitable for the given numerical analysis is not possible. It is always necessary to evaluate their individual advantages and disadvantages, like: Ansys provides more accurate results, more options and above all 3D analysis, FEMM is the opposite less demanding on computing time, has a relatively simpler control, and the indisputable advantage is that it is free availability of this program.

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