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Computation of electromechanical characteristic of salient poles synchronous motor with damper based on FEM

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Abstract

This paper deals with analysis of the magnetic field by using FEM and numerical computation of the electromechanical characteristics of salient synchronous motor with damper. The knowledge of electromechanical characteristics is very important in performance analysis of electrical machines, in general. In this paper it is presented a methodology for numerical calculation of electromechanical quantities, starting with the determination of the magnetic field distribution based on FEM.

Keywords: Electromechanical characteristic; Finite element method; Salient poles synchronous motor with damper; Magnetic field distribution; Magnetic coenergy; Electromagnetic torque

1. Introduction

The finite element method (FEM) in the recent years has been found as a very attractive method in the design and analysis of various types of electromechanical devices. For complex configurations as those in electrical machines, the finite element method is powerful numerical method for solution of electromagnetic field problems. By the application of this method in the whole discredited domain of the machine under consideration, an important contribution to the magnetic field computation could be done. An optimal designing of electrical machines requires the accurate calculation of the magnetic field distribution in the different cross-sections. This enables an accurate determination both the electromagnetic and electromechanical characteristics of the motor. The accuracy of the electromechanical quantities computations in a great rate is dependent on the precision of calculations of electromagnetic field distribution in the electrical machine [2,3].

The finite element method is very efficient for an electromagnetic field solution [4–8]. In the paper it will be applied on the salient poles synchronous motor with damper (SPSMD). By using this method almost all the necessary electric and magnetic quantities are determined for this type of electrical machine. In this paper it is presented the methodology of using the FEM for computation of electromechanical characteristics.

2. Geometrical model and mathematical model

For applied calculation of electrical machines, it is necessary appropriate geometrical CAD model of the machine and mathematical model.

CAD model of the machine is an essential basis for implementation of geometrical structure of the motor into the FEM calculation. By precise determination of all coordinates of the structure, the 3D CAD model is created as shown in Fig. 1:

The calculation of the magnetic field distribution in the SPSMD is started from the system of the Maxwell's equations, by which it is described the magnetic field in closed and bounded systems. After the magnetic vector potential $\boldsymbol{A}$, with the characteristic:

$$\boldsymbol{B} = \mathrm{rot}\boldsymbol{A} \tag{1}$$

as an auxiliary quantity is introduced, and knowing that

$$\mathrm{div}\boldsymbol{B} = 0 \tag{2}$$

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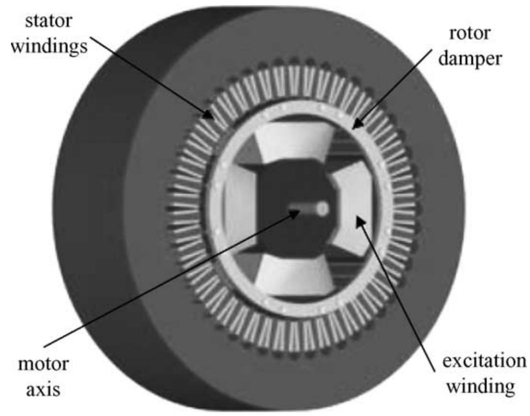

Fig. 1. 3D CAD model of SPSMD.

the distribution of the magnetic field is expressed by the following non-linear differential equation known as Poisson's equation:

$$\mathrm{rot}(\nu(B)\,\mathrm{rot}\boldsymbol{A}) = -J \tag{3}$$

where ν is the magnetic reluctivity in function of magnetic flux density $\boldsymbol{B}$ ($\nu = f(\boldsymbol{B})$).

In the special case, when there are no current sources in the domain under consideration, the right-hand side term turns to zero, and the equation is recognized as Laplace's.

3. FEM application

Appropriate algorithm is used for calculation of all relevant characteristics of electrical machines. The proposed algorithm is applied on the salient poles synchronous motor with damper (SPSMD), with rated data: 2.5 kW, 240 V, 1500 rpm, and delta stator winding connection [1]. The SPSMD is heterogeneous, non-linear domain with particular B–H characteristics of magnetic core in stator and rotor, and with prescribed boundary conditions. Therefore, Eq. (3) in developed form, is the variable coefficient type, and it is going to be solved by the numerical methods only. To realize this task, it is necessary the proper geometrical CAD and mathematical modeling of the motor to be carried out. Therefore, the geometrical cross-section of the motor is created from the CAD model, and is presented in Fig. 2.

At the beginning of the FEM calculations, it is requested to generate a correspondent mesh of finite elements. The algorithm of the software application that is used for FEM calculation generates finite element mesh. The mesh must be dense enough for precise calculation and also optimal for not consuming a lot of the computational time.

After several attempts for optimal finite element mesh, the most appropriate mesh is generated. This mesh provides calculation with high precision and at reasonable computational time.

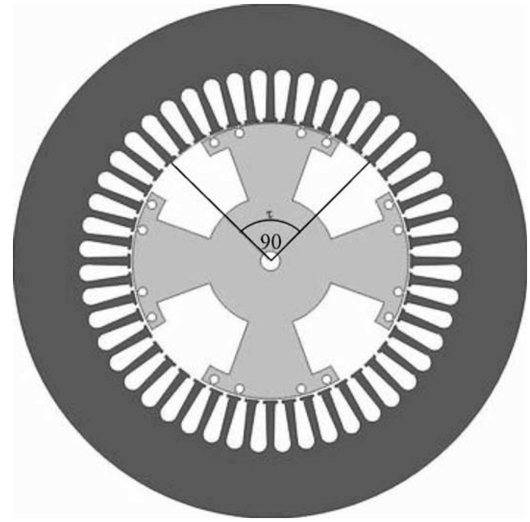

Fig. 2. Cross-section of SPSMD.

In this case, the most convenient mesh type is chosen to be triangular, with 8195 nodes and 16,344 finite elements, and is presented in Fig. 3.

The calculations are carried out as magneto static case, at arbitrary rotor position. Magnetic field distribution is shown on three characteristical cases:

- when only the rotor winding is excited (the excitation winding) with nominal excitation current;
- when only the stator winding is exited (armature winding) with nominal armature current;
- when the both stator and rotor winding are excited with nominal currents.

The rotor excitation winding is performed as concentrated and placed over the pole body. The rated excitation current is 5.5 A dc.

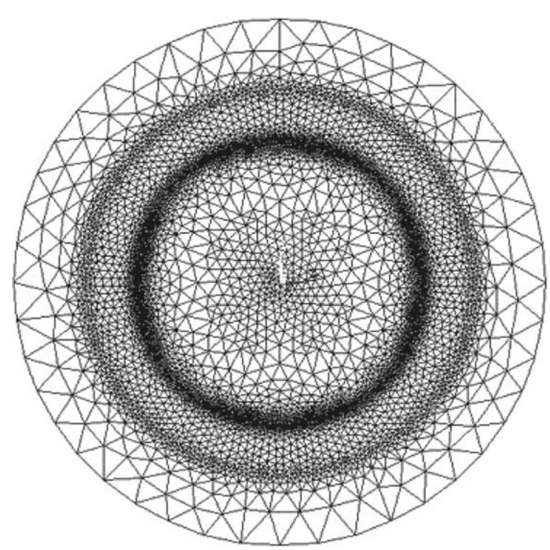

Fig. 3. Finite elements mesh.