Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 129 (2015) 408 – 414

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Industrial Engineering

The Comparative Analysis of Permanent Magnet Electric Machines with Integer and Fractional Number of Slots per Pole and Phase

Gandzha S.A.[a], Sogrin A.I.[a]*, Kiessh I.E.[a]

[a]*State South Ural State University, 76, Lenin Avenue, Chelyabinsk, 454080, Russian Federation*

Abstract

The comparison of permanent magnet motors with integer and fractional number of slots per pole and phase was made. The torque developed by the motor and the torque ripples level were chosen as the major criterions. The comparison was made according to the results of equations of numerical calculation of magnetic field in active motors volumes using the finite element analysis. The recommendations on the choice of the most suitable option are given.

Peer-review under responsibility of the organizing committee of the International Conference on Industrial Engineering (ICIE-2015)

Keywords: Permanent magnet motor; Torque ripples; Cogging torque; Fractional-slot winding; Finite element analysis

1. Introduction

The brushless permanent magnet DC motors are being developed fast over the years. Nowadays we can see a new intensive turn of their development. It is connected with the appearance and commercial exploitation of powerful and comparatively cheap high-coercive magnets, the development of power electronics.

By nature an electric machine is a quite conservative drive part which is upgrading slower than electronic components and program control logic. Nevertheless, optimization of this unit is very important as it is the motor which determines to a great extent energetic data and weight-size parameters of the drive on the whole.

* Corresponding author. Tel.: +7-351-267-9057; fax: +7-351-267-9172.
E-mail address: sogrinai@susu.ac.ru

Peer-review under responsibility of the organizing committee of the International Conference on Industrial Engineering (ICIE-2015)
doi:10.1016/j.proeng.2015.12.137

One of the last tendencies is application of the electric machines with fractional numbers of slots per pole and phase [1]. If a few decades ago such solutions were used for low power devices then now quite powerful motor electric drives appear with similar machines [2,3,4,5].

It should be noted that analysis and synthesis theory of conversion devices to be observed is behind of practice requirements that is connected with complication of electromagnetic processes in the machines with fractional numbers of slots per pole and phase. In the academic circles we can observe active disputes concerning effectiveness of such machines. This article is directed to partial settlement of these disputes. The analysis was carried out with the help of modern program means of finite element analysis of electromechanic and electromagnetic devices ANSYS Maxwell.

2. Task description

The primary objective of this work is research of winding distribution influence on the value and ripples of electromagnetic torque of the permanent magnet motor.

The electric motor DB-72 (variant 1) was chosen as a subject of research which is designed for usage in the respiratory medical device. The passport specifications are given in table 1. The number of motor stator slots is18, the number of poles of the inductor is 20. Then, the motor is made with fractional number of slots per pole and phase q=3/10. The motor has a converse construction: the armature is located inside, the rotating induction coil — outside.

Table 1. Nominal data of the motor DB-72

Parameter	Value
nominal power, (W)	25
DC nominal voltage, (V)	24
nominal speed, (rpm)	1000
nominal current, (A)	2.5
nominal torque, (Nm)	0.25
number of phases	3
phase connection scheme	Y

The specially designed motor with integer number of slots per pole and phase having the equal dimensions with the base motor was accepted as an alternative variant (variant 2). The inductor of the alternative motor is the same as the base model. The stator has the number of slots per pole and phase q=1. At that the number of machine slots turned out to be equal:

$$z = 2p \cdot m \cdot q = 20 \cdot 3 \cdot 1 = 60,$$

where p — poles pair number, m — phase number of the armature winding. Note that value q=1 turned out to be the most possible on design considerations for given sizes and polarity of the machine: slots number increase crushes the stator teeth dimensions unacceptably.

For comparison accuracy the number of phases ampere-turns of motors to be observed was accepted equal (180 turns in the phase, phases currents — nominal, according to the nominal data of the base motor). The total areas of slots and teeth of motors to be observed are equal accordingly.

3. Design models

The designing of magnetic field in active motors volumes was carried out according to the finite element analysis in 3D task description. It allowed to take into account a possible stator slot skewing while analysis. The developed models of the motors consider the properties nonlinearity of ferromagnetic materials, alternation of electromagnetic