# Influence of Constructive Parameters on the Cogging Torque in PMSMs

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**Abstract.** The influence of constructive parameters on the cogging torque of two permanent magnet synchronous motor with single and fractional slot winding is analyzed in this work. The number of stator slots is fixed and the parameters modified in both types of motor are: a) slot opening width, b) rotor pole radius, and c) magnets thickness. The simulation of the motors behaviour is done by the use of finite elements. The torque is calculated using the virtual work method. The results of both types of machines are compared and discussed.

**Keywords. -** Cogging torque, finite element, permanent magnet synchronous motors, virtual work.

## 1. Introduction

One of the main problems presented by permanent magnet synchronous motors (PMSMs) is the torque ripple being the cause of noise, vibration, speed variation and problems in control devices [1]. One of the main causes of torque ripple is the cogging torque. Cogging torque is the result of interaction (magnetic attraction) between the magnetic flux from the magnets and stator geometry producing a variable reluctance with angular position of the rotor. This torque does not contribute to net torque of the machine and is manifested by the tendency of the rotor to align in a number of positions. Several researchers [1] - [4] have proposed various methods to reduce cogging torque (using a fractional number of slots per pole, skewing of magnets or stator slots, displacing and shaping the magnets, introducing auxiliary slots or teeth, etc. ..).

The use of a fractional number of slots per pole reduces the amplitude of cogging torque; this reduction is achieved by increasing the number of torque cycles since each slot is located in a different angular position with respect to the magnets [5].

The main purpose of this paper is to analyze the influence on cogging torque of: a) slot opening width, b) rotor pole radius, and c) magnets thickness, in two 36 stator slot PMSMs with 12- and 10-poles, representing single and fractional slot winding respectively.

## 2. Development

*A) Number of periods of cogging torque*

Its number of periods during rotation of one slot pitch *(N)*, can be determined by the following expression [2], [6]:

$$N = \frac{2p}{GCD(2p,Q)} \tag{1}$$

where *GCD* is the maximum common divisor between number of poles (*2p*) and slot number (*Q*). A way to influence in the cogging torque of a machine is to find a relationship between *Q* and *2p* producing a high number of cycles, this means a decrease in the peak-to-peak value of the cogging torque.

*B) Virtual work*

The global torque developed by a rotating electric machine can be calculated from the magnetic co-energy and its partial derivative with respect to the angular displacement of the rotor [7].

$$T = \frac{\partial W_c}{\partial \theta} \tag{2}$$

where $\theta$ is the rotor angular displacement.

## 3. Analyzed motors

The analyzed machines in this study are of the embedded magnets type, both in the same power and external dimensions, the only difference being the number of rotor poles (12 and 10). Fig. 1 shows the distribution of magnetic flux density, for a fixed rotor position, of one analyzed motor.

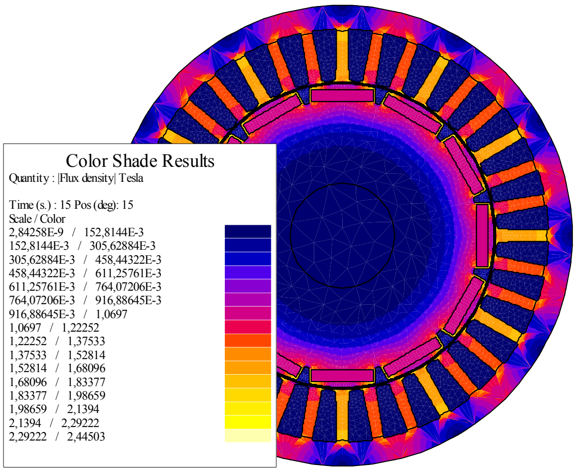
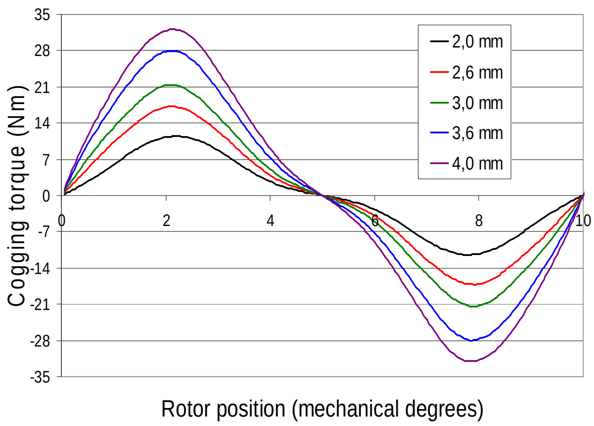


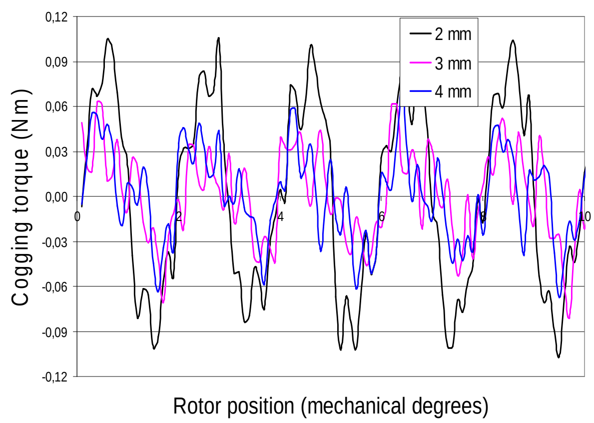

Fig. 1. Magnetic flux density (12 pole machine).

## 4. Results

The finite element technique is used for the computation of the machine behaviour. A nonlineal field analysis is carried out for the magnetic flux density calculation. The model used is two-dimensional. Cogging torque is calculated by simulating the machine behaviour on no-laod for different rotor positions. For each rotor position model mesh is automatically recalculated. Fig. 2 shows, for the two analyzed machines, the cogging torque as a function of rotor position for different slot opening widths.




a) 12-pole motor




b) 10-pole motor

Fig. 2. Cogging torque as a function of the slot opening width.

The final work, in addition to shown results, presents the corresponding of other constructive parameters, such as pole radius and magnets thickness.

## 5. Conclusions

Torque values calculated on fractional slot winding machine are much smaller than those calculated on the single slot winding machine, justifying the use of fractional slots-per-pole number as an effective method for reducing cogging torque in this type of machines.

Performance of constructive parameters as a method to reduce cogging torque is much higher on machines with a integer number of slots per pole, where evolution of cogging torque with the studied parameter is more predictable. The studies showed important differences between the values of maximum torque calculated. For the case of the fractional slot winding machine the results show a less predictable relationship between cogging torque and the studied parameters. Only when the polar radius is modified its evolution is similar to that of the 12-pole machine

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