The Investigation of Cogging Torque Reduction Technologies

Yong Chul Kim1, Ju Lee1

1. Hanyang University, 222. Wangsimni-ro, Seongdong-gu, Seoul, 40873, Korea

Background

Cogging Torque is essential torque component on permanent magnet motor having teeth and slots, and also this is an important characteristic of some applications which require precision position control and lower acoustic noise such as electric steering motor.

There had been investigated variety techniques to reduce cogging torque during several decades and most of them show common feature for some reduction of motor performance.

Objectives

- Fault tree analysis of cogging torque and correlation study between cogging torque and design parameters
- Sensitivity comparison for cogging torque and back emf constant according to design parameters
- Provide some guidance for selection of design parameters

Selection of Base Model

- Topology: Sihots 6poles Surface Permanent Magnet Motor
- Stator OD, ID and Stack: 85mm, 43mm and 15.5mm
- Winding: 1.4mm x 20turns, Parallel and Star Connection

Cogging Torque and Ke by Design Parameters

- The parameters of the stator core are strongly related with magnetic saturation effect because of its original function as the path of magnetic circuit. Three parameters (stator thickness, teeth width and teeth angle) as shown with green dot line in above graphs shows magnetic saturation effect when these have not enough dimensions. Therefore it is important to define the parameter as big as possible in order to avoid the magnetic saturation effects and lower cogging and higher Ke performance.
- Not found specific relationship between cogging and teeth depth.
- Smaller slot open is better for low cogging and higher Ke.

Sample Information

- Detail Dimension for Parameters
- Magnetic Flux Density Distribution of Study Model at 0A Condition

Conclusion

- For better motor design having lower cogging torque and higher Ke performance,
- At stator design aspect, the dimension of parameter for stator core is needed to consider the magnetic saturation effects for lower cogging and higher Ke. Hence, it could be better to be selected as big as possible except for slot open.
- At rotor design aspect, magnet width is needed as 0.92 ~ 0.94 pole ratio size. And others are needed to be chosen with optimum value because of trade off relationship between cogging and back emf constant.
- This paper is focused on the design stage, and it could provide some guidance for the selection of design parameters.
- Next plan is to study for cogging torque considering manufacturing process level which could make unbalance of a magnetic circuit or mechanical dimension.

Methods

- Selection of Study Parameters of Cogging Torque
- Study Parameters of Stator Core
- Study Parameters of Rotor Core and Magnet
- Selection of Base Model
- Definition of Analysis Range
- Sample Information
- Sample Detail

Results

- Selection of Study Parameters of Cogging Torque
- Table of Parameters
- Selection of Base Model
- Table of Parameters
- Magnetic Air Gap
- Sihots 6poles Surface Permanent Magnet Motor
- Stator OD, ID and Stack: 85mm, 43mm and 15.5mm
- Winding: 1.4mm x 20turns, Parallel and Star Connection
- Parameters: Rotor 3 stepped
- Stator Yoke Thickness: 4 mm
- Teeth Width: 8 mm
- Slot Open: 2 mm
- Teeth Depth: 1 mm
- Teeth Angle: 6.67 mdeg.
- Magnetic Air Gap: 0.9 mm
- Parameters: Star Yoke Thickness, Teeth Width, Slot Open, Teeth Depth, Teeth Angle, Magnetic Air Gap
- Selection of Base Model
- Table of Parameters
- Magnetic Air Gap
- Rotor and Magnet
- Stator Core
- Values
- Study Parameters
- Tensor
- Table of Parameters
- Motor Outline
- Study Parameters
- Tensor
- Table of Parameters
- Magnetic Flux Density Distribution of Study Model at 0A Condition

Sensitivity Comparison by Design Parameters

- Sensitivity of Cogging Torque
- Priority of Sensitivity for Cogging Torque
- Priority of Sensitivity for Back EMF Constant
- Sensitivity of Back EMF Constant
- Ke
- Priority of Sensitivity
- Three parameters (magnet width, magnet offset and teeth angle) needs to be selected more carefully with the optimal value because these are more sensitive for cogging and Ke performance compared to others.