A Study on Acoustic Noise Reduction in Brushless DC Interior Permanent Magnet Motor with Concentrated Windings

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Abstract— A study on magnetic force is more important than other factors, because acoustic noise of motors is mainly affected by vibration of structure. Especially, harmonics of normal force are associated with resonant frequency of structure. Therefore, although cogging torque and torque fluctuation influenced by tangential force are important factors in output characteristic, the normal force is more important for the acoustic noise. This paper deals with magnetic design to reduce the harmonics of normal force by using Response Surface Methodology (RSM), and then the relationship with acoustic noise, cogging torque, torque ripple, and the harmonics of normal force is illustrated by experiment and simulation.

I. INTRODUCTION

Concentrated winding types of Brushless DC (BLDC) Interior Permanent Magnet (IPM) motors have more advantages such as short end turns, low copper loss, and effective high-volume automated manufacturing than distributed winding types [1]. However, back electromotive force (BEMF) and current have many harmonics, because flux in concentrated winding types concentrates on stator pole. In addition, cogging torque and torque fluctuation are relatively high compared with distributed winding types.

In noise sources, the magnetic noise is generated by vibration of the core due to the magnetic forces, which consist of tangential and normal force, in the air-gap. Although several kinds of paper focus on the reduction of cogging torque and torque fluctuation generated by tangential force to reduce acoustic noise [2]-[3], the harmonics of normal force, which is relative to resonant frequency of stator, are more important factors in electric machines of high power density such as IPM motor [4].

Therefore, this paper deals with magnetic design to reduce the harmonics of normal force by using Response Surface Methodology (RSM), and then the results of acoustic noise, cogging torque, torque ripple, and the harmonics of normal force are valuated by experiment and simulation.

II. THEORY

Tangential and normal force are calculated by Maxwell's tensor and Equivalent Magnetizing Current (EMC) method [5], respectively, and normal force is applied to objective function of RSM for reducing acoustic noise. The objective function is expressed as

$$H = 10\log\sum 10^{\frac{F_2}{10}} \qquad (1)$$

where, F_2 is the harmonics of normal force which takes account of A-weighting in frequency weighting curves.

III. RESULTS AND DISCUSSIONS

Fig. 1 shows the comparison of characteristics concerning cogging torque, torque fluctuation, and the value of objective function. The cogging torque and torque fluctuation of Improved model (M2) are higher than that of Prototype model (M1), while the value of objective function is lower.

Fig. 2 shows the result of noise experiment measured by 1/3 Octave band. Total Sound Pressure Level (SPL) of M2 is less than that of M1.

The detail explanation concerning the results of design and noise experiment will be dealt with extended paper.

IV. REFERENCES

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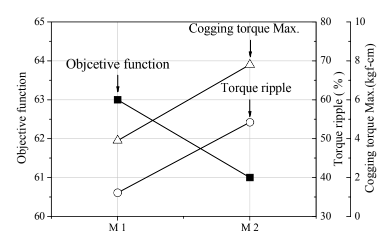

Fig. 1. The comparison of characteristics.

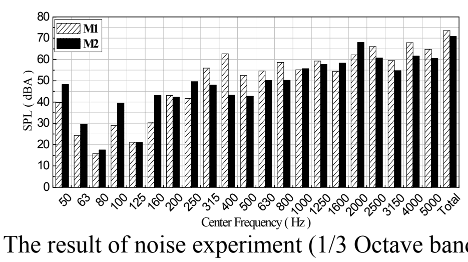

Fig. 2. The result of noise experiment (1/3 Octave band).

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