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VIBRATION REDUCTION DESIGN OF PERMANENT MAGNET MOTOR USING MULTI PHASE LEVEL SET MODEL

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Since mechanical vibration is harmful to the robustness of an integration system and generates audible noise, which is a critical factor in human sensitivity, vibration reduction has become an important issue in motor design [1]. Many studies have noted that the main sources of motor vibration are fluctuation of the magnetic force and mechanical deformation of the motor structure [2]. Hence, several design techniques such as modification of the motor shape and pole-slot combination have been proposed to minimize them. Particularly in the surface-mounted permanent magnet (SPM) motor where the permanent magnet (PM) dominates the magnetic flux path, the shape change of the rotor is the key to vibration reduction [3]. Unfortunately, since the magnetic forces that cause the motor's vibration are essential to satisfy the output power, it is very difficult to design a low-vibration rotor shape by using previous approaches because they depend on experimental data and engineering intuition.

In this paper, an optimization method that incorporates localized geometrical change is introduced to get an innovative rotor design that guarantees a decrease in the motor vibration. The level set functions are employed to express the clear boundaries of the rotor and to calculate the magnetic properties of the PM and the ferromagnetic material (FM) [4]. The optimization problem is formulated to minimize the fluctuation of the magnetic forces, such as the local force on the stator (f_j) and the driving torque (T_j), which can cause mechanical deformation of the stator. The volume fraction constraints for each level set function are added to the problem formulation for limiting the material usage. The optimization is performed by solving the time evolutional equation that can lead to initial-independent results.

The proposed method is applied to the rotor design of an 8-pole 12-slot SPM motor. The initial design illustrated in Fig. 1 (a) is developed for the EPS system of which the important design target is vibration reduction. The design domain is the upper side of the rotor and the target torque is assigned to 3.2 Nm for maintaining the output power. Fig. 1 (b) shows the optimal distribution of each material and it is noted that the outer surface of the PM becomes an uneven shape for adjusting the path of the magnetic flux. The FM around the edge of the PM is eliminated to reduce the leakage flux and it is confirmed that these shapes of the PM and FM help to minimize the torque ripple (T_{ripple}) with maintaining the average torque (T_{avg}). The optimal rotor design provides a large decrease in both the torque ripple and fluctuation of the magnetic force ($\Delta f_{\text{peak to peak}}$) with only a slight loss of the output power, as summarized in Table 1.

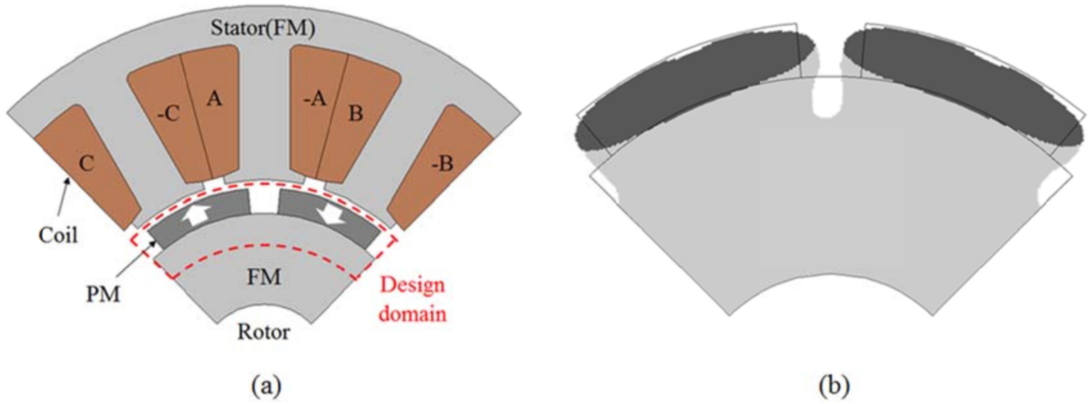

Fig. 1. Configuration of SPM motor: (a) design domain (b) optimal design

Table 1 Comparison between initial and optimal design

	T_{avg} [Nm]	T_{ripple} [%]	f_{avg} [N]	$\Delta f_{\text{peak to peak}}$ [N]
Initial design	3.18	3.79	2505.1	1969.0
Optimal design	3.16 (0.6% ↓)	0.38 (90.0% ↓)	2489.5 (0.6% ↓)	1562.0 (20.7% ↓)

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REFERENCES

[1] W. Cai, P. Pillay, J. Tang and A. M. Omekanda, Low-Vibration Design of Switched Reluctance Motors for Automotive Applications Using Modal analysis. *IEEE Trans. on Magn.*, Vol. **39**, pp. 971–977, 2003.

[2] H.-S. Ko and K.-J. Kim, Characterization of Noise and Vibration Sources in Interior Permanent-Magnet Brushless DC Motors. *IEEE Trans. on Magn.*, Vol. **40**, pp. 3482–3489, 2004.

[3] S. Chaithongsuk, N. Takorabet and F. Meibody-Tabar, On the Use of Pulse Width Modulation Method for the Elimination of Flux Density Harmonics in the Air-Gap of Surface PM Motor. *IEEE Trans. on Magn.*, Vol. **45**, pp. 1736–1739, 2009.

[4] S. Lim and S. Min, Design Optimization of Permanent Magnet Actuator Using Multi-Phase Level-Set Model. *IEEE Trans. on Magn.*, Vol. **48**, pp. 1641–1644, 2012.