ABSTRACT

Level-set Based Shape Optimization of Surface-mounted Permanent Magnet Motor for Minimizing Torque Ripple

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One of the key performance of a surface-mounted permanent magnet(SPM) motor is producing a constant torque especially in an electric power steering(EPS) system where the torque fluctuation significantly affects the output characteristic of the system. More precisely, the SPM used in an EPS system requires a minimum torque ripple magnitude which could turn up the vibration of a steering handle and result in the deterioration of the vehicle performance. Since the EPS system designer demands such level of the torque ripple magnitude, the new design method should be proposed to achieve the design requirement.

Previous research shows that the magnitude of higher harmonics in the back

electromotive force(EMF) waveform and the cogging torque are the cause of the torque ripple and their magnitude can be mitigated by designing permanent magnet and state shoe shape. However, the material of the electric sheet has the nonlinear behavior due to the magnetic saturation phenomenon and the material nonlinearity can increase the magnitude of higher harmonics in the back EMF waveform even though it is designed sinusoidally without electric loading.

In this thesis, the level set based optimization method is applied to eliminate higher harmonics of back EMF waveform at load state and cogging torque at no-load state by designing the permanent magnet and the stator shoe. The ferromagnetic material and the permanent magnet are expressed by the level set function with Heaviside step function. The optimal configuration can be obtained by solving the level set equation. The normal velocity vector in the level set equation calculated by the adjoint variable method.

The optimization problem is proposed by two cases. Firstly, the unconstrained optimization problem is formulated by eliminating higher harmonics of the radial direction air gap flux density waveform at load state as the objective function. Secondly, the constrained optimization problem is formulated by eliminating higher harmonics of the back EMF waveform at load state as the objective function with the constraint of the maximum level of the cogging torque and the amount of material usage.

The proposed method is applied to design the 800 W 4-pole 6-slot SPM motor used in the EPS system. Both the optimization problem suggest the optimal configuration which can reduce higher harmonics of the back EMF waveform effectively, however, only the second optimization problem satisfy the design requirement. It is confirmed that the cogging torque constraint should be applied to reduce torque ripple.