ABSTRACT

Level-set Based Design Optimization Using Phase-field Model in Magnetic Field

Sunghoon Lim

(Directed by Professor Seungjae Min, Ph. D.)

Department of Automotive Engineering

Graduate School

Hanyang University

Magnetic devices which are widely used for various industrial applications use magnetic fields to produce mechanical motion. Since the magnetic performance is quite sensitive to the distribution of magnetic material, extensive research on design optimization of magnetic device has been performed. Design for maximizing the magnetic performance through few parameters has been evolved into various changes of the optimal shape since the introduction of topology optimization in magnetic fields. Recently, a level-set based topology optimization method has been successfully applied to the magnetic problem due to the clear boundary expressions. However, since the level-set function is updated by solving the so-called Hamilton-Jacobi equation, the setting of the initial level-set distribution strongly affects the resulting optimal

configurations. Also, optimal configurations may include highly complex geometrical structures that are inappropriate for manufacturing standpoint.

This dissertation proposes a new level-set based optimization method for design of magnetic device, which can adjust the geometrical complexity of optimal configurations by introducing an interface free energy based on the concept of the phase-field model.

For the magnetostatic analysis, relative reluctivity and remanent flux density are defined by a level-set function to represent the distribution of magnetic material. The optimization problems are formulated to maximize the magnetic performance and simplify the complexity of boundaries, constrained with the volume of magnetic material. Furthermore, to make the design optimization method more practical, the multi-phase level-set model is introduced in problem formulation to deal with a whole component consists of permanent magnet, ferromagnetic material and air. The update scheme is developed based on time evolutional equation that provides the optimal variation to level-set function and the sensitivities are obtained using the adjoint variable method which can reduce the computational time.

Several design examples are presented, such as the C-core actuator design for maximize magnetic force, the low torque ripple stator design of IPM motor and the design of permanent magnet actuator with consideration for two driving conditions, to demonstrate the effectiveness of the presented method and optimal designs satisfied with both the magnetic performance and manufacturability are proposed.