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TOPOLOGY DESIGN OPTIMIZATION OF SWITCHED RELUCTANCE MOTORS FOR THE DESIRED TORQUE PROFILE

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ABSTRACT

Switched reluctance motors (SRMs) have gained in popularity over recent years due to a number of advantages they offer. First, their rugged structure is simple and robust, and the manufacturing cost is low. Second, they have a high torque/weight ratio and high efficiency. Third, their operation is reliable even at very high speeds. Therefore, SRMs have been considered as a potential candidate for electric vehicles (EVs) and hybrid electric vehicles (HEVs).

Over the past several years, there have been vigorous research activities in electromagnetic design optimization for the high performance of SRMs [1]-[4]. The operational performance of SRMs is highly dependent on the geometries of the stator and the rotor. The sizes and shapes of SRMs have been modified using various design parameters including air-gap length, rotor pole arc length, and stator pole arc length. However, size and shape optimizations have less design possibility than topology optimization, because the geometric and topological configurations are fixed in the size and shape design approaches. In this paper, we consider a topological design approach to obtain the optimal rotor shape for high-performance SRMs with the minimum amount of material.

Topology optimization is aimed at finding the optimal layout of a structure by distributing a given amount of material. The technique was first introduced by Bendsøe and Kikuchi [5], and it has been successfully applied to various engineering fields including electromagnetics. Dyck and Lowther [6] have led the application of the topology optimization technique for electromagnetic devices. Topology optimization of SRMs have been reported by Byun and Hahn [7] and by Yoo [8]. Byun and Hahn focused on the design of a rotor that would produce the desired magnetic energy profile, as opposed to producing the desired torque profile. Yoo considered the vibration caused by magnetic forces as a design objective for a single, specific rotor angle to design the topology of the stator.

We propose the design method of finding the optimal rotor shape that will allow control of the torque profile during rotation at a steady angular velocity. Since we apply the topology optimization technique, the design variable is the material density in each finite element. In order to achieve 0-1 design in topology optimization, the density convergence function is added to the objective function as a penalization function. The penalty weightings are controlled adaptively by the reciprocal value of the difference between the matched torque and the target torque. In addition, we also consider the

voltage on-off angles as design variables. Here, we employ sequential linear programming (SLP) for optimization. Taking advantage of the explicit expression of the torque profile by using a Fourier series, the sensitivity analysis is derived.

The performance analysis process for the torque calculation of SRMs is as follows. First, the electromagnetic finite element method is used to calculate the inductances at several rotor angles. Those inductance values are interpolated using the Fourier series to obtain the explicit analytical representation of inductance with respect to time. By differentiating the inductance with respect to time, the torque profile is calculated by the global virtual work method [9]. It is assumed that magnetic permeability is independent of magnetic flux density, i.e., the SRM model is linear. It should be noted that the proposed design method using a Fourier series may be extended easily to the case of a non-linear, unsteady SRM model.

The proposed design method is applied to a 6/4 type SRM, i.e., the SRM has six stator poles and four rotor poles. The sensitivity filtering method is used to insure the mesh-independency of optimized designs. Numerical results show that the differences between the optimized torque and the desired torque are less than 10%. The weight of the SRM is reduced by as much as 30%.

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