Design, Simulation, and Prototyping of a Novel Hybrid-Excitation Flux-Switching Permanent Magnet Machine with Segmental Magnet for Electric Vehicle Applications

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I would like to dedicate this thesis to:

My loving family and especially

My Beautiful Angel,

My Mother.

Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this or any other university. This dissertation is my work and contains nothing about the outcome of work done in collaboration with others, except as specified in the text and acknowledgments.

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Abstract

Electrical drive (ED) systems are the fundamental components of many modern appliances and industrial systems. For best performance, various methods have been developed for the design optimization of EDs. Torque density and cost are the most critical and demanding criteria for automotive and aerospace applications. However, these objectives are conflicting, and so there should be a related trade-off region for them.

By placing the PMs on the stator side as in flux switching PM (FSPM) machines, we can manage their temperature rise more efficiently, and the risk of demagnetization decreases significantly. FSPM machines have attracted significant attention from researchers, particularly over the last decade, because of high torque density, low torque ripple, high efficiency, excellent thermal behavior, and ease of control. The magnet-less rotor structure of the FSPM machine is quite robust, cost-effective, and applicable at high speeds, unlike some other PM motors. Hybrid excitation machines are of attention due to the potential of combining the high-power density of PM machines with the flux-adjusting capability of wound field excitation machines. Magnet segmentation is a common technique in different PM machines, including the FSPM machine. The main aim of such a method is to reduce the eddy current loss in the PMs. By this method, the location and thickness of each segment can be optimized to have the best torque and cost performances. In other words, by the segmentation method, one can obtain more freedom in the design.

Although electromagnetic solution determines the torque performance of the machine for most portions, considering other issues is also crucial in practical situations. Thermal, mechanical, and vibration are the essential motor-related problems that one should assess for a reliable and safe operation. Temperature distribution and dynamics for all parts, appropriate cooling method, mechanical deformation and stress, and vibration noise are the most valuable outputs of this analysis. The result of the multi-physics analysis determines the final confirmation of the machine design.

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Chapter 1

Introduction