SDU
Faculty of Engineering

PhD Defence

by

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Title:

Design and test of Next Generation High Power Density Motors

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Abstract

The work presented investigates the characteristics of high-power density motors, primarily evaluated by their power-to-mass ratio (specific power) at velocity regimes below those of high-speed machines (under 10.000 [rpm]).

A comprehensive review of the foundational principles for electric motor design is included, describing the mathematical framework provided by Maxwell's equations and the properties of the multiple materials involved.

A literature review was conducted, examining numerous published articles on the topic. Many studies have explored the advantages of using an axial flux topology over a radial flux topology to enhance power density.

Based on the analysis of both topologies and the experience gained during this research, the axial flux motor is identified as having the highest power density. This is attributed to the geometrical characteristics of the axial flux topology, which allows for the suppression of the back iron (or yokes) and the integration of an additional air gap. This configuration generates additional torque while maintaining a nearly constant motor mass.

Axial flux motors require 3D finite element analysis (FEA) to evaluate their performance, which involves significant computation times for a single solution. Given that optimization steps necessitate numerous iterations, the computational cost can be substantial.

To minimize computation times, an analogy between radial and axial flux motors is employed, involving analogous parametric definitions and boundary conditions from electromagnetic and thermal domains. This analogy represents the 3D axial flux motor as a 2D radial flux analogous model. The 2D radial flux model is iterated and optimized to achieve characteristics leading to higher power density. The optimized 2D model is then converted into its 3D analogous model for further evaluation and optimization.

Once the design is optimized and validated, it is used to define a machine prototype for construction.

Key characteristics, such as electromagnetic performance, mechanical fit and integrity, thermal conductivity, and losses were considered in the development of the prototype parts. The relevant processes for designing and developing these parts (such as stator, rotors, and housing) are described in detail in chapters 10, 11, and 12.

Following the assembly of parts, the prototype was electrically and mechanically connected to a test bench for testing. The results obtained from this stage are included and described in Chapter 13.

The construction steps for the prototype were mainly conducted within the faculty. Parts that could not be produced in-house, such as the construction and magnetization of sintered hard magnetic material, were outsourced.