Analysis of Eddy Current Losses in End Winding Encapsulations of High Speed PMSM

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e+a Elektromaschinen und Antriebe AG is a Swiss company specialized in the design and manufacture of tailored, high-performance rotating electrical machines for a wide range of demanding applications. This research project focuses on the modeling, simulation and optimization of eddy current losses that are induced in the end winding encapsulations (ALKA™) of permanent magnet synchronous machines (PMSM) by implementing 3-dimensional finite element analysis (FEA).

Introduction

Resin impregnation and aluminum encapsulations of the end windings (ALKA™) provides increased performance due to improved cooling, while ensuring excellent winding protection and insulation. On the other hand, aluminium encapsulations are prone to eddy currents caused by magnetic flux leakage at the machine edges, reducing the efficiency and leading to considerable heating in certain specific cases. The development of custom motors requires efficient and reproducible design and simulation capabilities. For this purpose, e+a Elektromaschinen und Antriebe AG has developed extensive experience in dimensioning its components using analytical approachs and finite element analysis (FEA). To address this specific problem, a 3-dimensional transient simulation solution is required and has to be integrated to the company's in house development tool. This Master's thesis therefore focuses on the development of an automated FEA simulation workflow to allow the subsequent analysis and optimization of eddy current losses using 3-dimensional models.

Goals

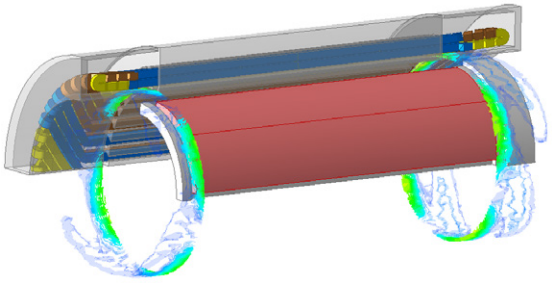
- Developing a software interface to enable a seamless and automated transfer of geometry data and operating point between the e+a in house development tool and a FEA software capable of 3-dimensional and transient simulations.
- Based on the previously developed simulation tool, a refinement of the simulation models has to be performed to match as closely as possible the laboratory measurements. Once an accurate and reliable model is obtained, the simulation tool can be used for advanced analysis of eddy current losses induced in the end winding encapsulations.
- Depending on the outcomes of the previous calculations, a range of solutions are analyzed and proposed with the aim of optimizing machine performances, providing improvement concepts for potential future implementations.

Method

Transient and 3-dimensional simulations are performed using the electromagnetic simulation software Ansys Maxwell. The interface for automatic generation of simulation models and the integration with the company's development workflow is programmed in Python, and takes advantage of the open-source library PyAEDT. Several measurements have been carried out on the test bench to check simulation results against reality, and to compare and improve the model's accuracy. Thanks to the first part of the project, the extended simulation capabilities now enable the analysis of multiple cases to better understand the sources of eddy current losses in end winding encapsulations, and to identify potential improvements.

Results

The development of the Python interface enabled full integration of Ansys Maxwell software into the company's development workflow, extending the transient simulation capabilities to 3-dimensional problems. This enabled the generation of multiple models and the refinement of parameters until reliable and accurate results were obtained, which could then be compared with test bench measurements. The eddy currents induced in the encapsulations were analyzed in detail to better understand their causes, and an example of the results is shown in the figure below. Finally, several solutions have been proposed and successfully tested in simulation, showing significant reductions in eddy current losses.



Simulation result of induced eddy currents in the end winding encapsulations of a permanent magnet synchronous machine

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