Development of a Modular Toolkit for the Design and Optimization of Electric Machines

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Abstract

Introduction and Motivation

Nowadays global competition is characterized by high innovation speed as well as short development and product life cycles. Especially the field of electric machines is marked by rising expectations regarding efficiency, power density and production costs. In order to keep development times as low as possible and realize optimization loops in workable periods, effective design approaches are necessary.

With the intention of further accelerating the design process and to be able to react promptly to current trends with regard to new designs, an automated model generation is essential. Furthermore, the automation of the entire design methodology is expedient.

For this reason, a design toolkit is developed, which covers the entire range from analytical predictions for reducing the parameter space to electromagnetic FEM simulations and optimizations with AI algorithms. The toolkit also offers the option of adding further modules to the design methodology, such as an NVH module, as the topic of NVH is currently becoming increasingly important in the design of electrical machines.

This paper is focused on the development of a modular toolkit for calculating novel electric machine designs.

Applied Method

The Machine Design Toolkit shown in Figure 1 is developed for the universal, flexible and automated design and calculation of electric machines. The toolkit is developed in Python using object-oriented programming. It has a modular structure and consists of several components that are self-contained and executable and can also be used outside the design workflow.

In general, the design process of electrical machines must be seen in a multi-physical context, as electrical drive systems combine electromagnetics, mechanics and power electronics. However, this paper will focus on the electromagnetic domain.

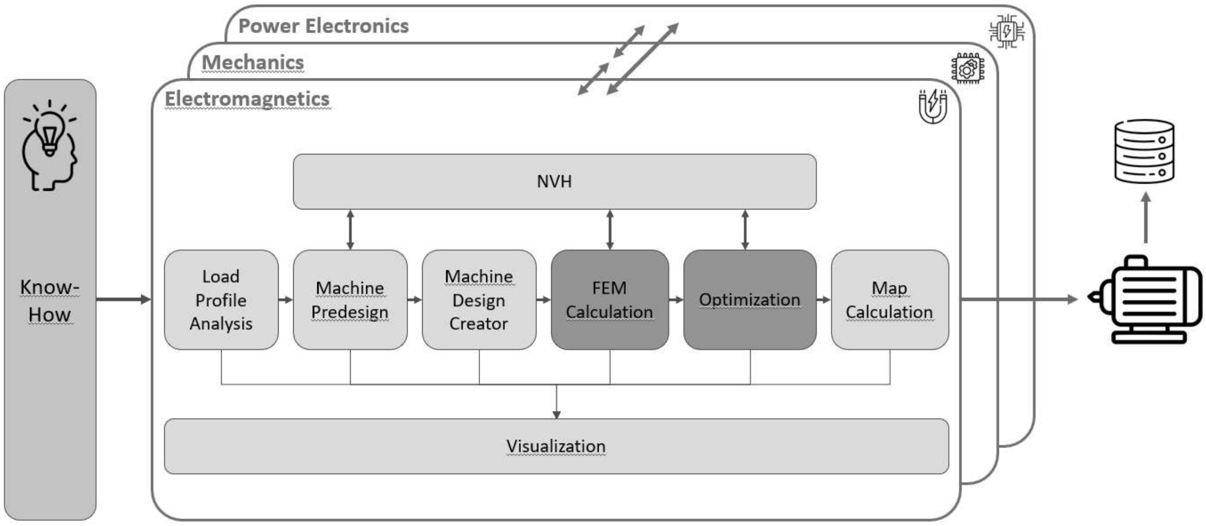

Figure 1: Calculation workflow of the Electric Machine Design Toolkit

The basis of every machine design is the know-how of the calculation engineer. Unfortunately, this knowledge is subject to strong fluctuations and the wealth of experience needs to be safeguarded. For this purpose, the toolkit collects characteristic data of current electric machines and reference values for the design in databases.

Based on the expert knowledge, the necessary steps for designing an electrical machine with the toolkit are then taken, which can be divided in Load Profile Analysis, Machine Predesign, Machine Design Creator, FEM Calculation, Optimization and Map Calculation. In addition, there is also the option of qualitatively examining the NVH behavior at an early design stage and looking at it in more detail at an advanced stage. The results of each design step can also be displayed graphically using a universal visualization tool.

The special features of the toolkit include not only the consideration of a large number of stator and rotor geometries for permanent magnet synchronous machines (PMSM), but also the possibility of using different FEM calculation programs. It is currently possible to investigate the magnetic behavior both in the freely available FEM software FEMM and in the commercial FEM software Ansys Maxwell.

The optimization is carried out with the Ansys OptiSLang software, which offers state-of-the-art optimization algorithms including AI to perform parametric design studies and better understand the design process of electric machines.

An export of the design parameters including results to a machine database, which provides the basis for the training of neural networks, follows the design process.

Results and Conclusion

With the help of the toolkit, a calculation chain has been created that can be adapted and expanded as required in order to consider the latest trends in the design of electrical machines in the shortest possible time. The automatic FEM model generation enables the creation of parameterized simulation models in just a few seconds. By using different FEM calculation programs, the overall time for the design process can be further reduced. This enables concept studies via FEM calculation to be carried out in the shortest possible time.

The integration of a powerful optimization tool into the workflow provides a deep insight into the relevance of each geometry parameter and also offers numerous optimization options.

In the following, it is planned to implement further stator and rotor geometries and to further advance the coupling of the individual domains. Furthermore, the design of electric machines using AI is to be investigated. The basis for this is the machine database, which contains the design parameters and results of each machine design. The calculated machine data can be used as training data for neural networks.

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