Electric Powertrain Design Optimization: A Convex Surrogate Modeling Approach

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INTRODUCTION

In order to solve the joint **design and control problem** of electric powertrains, we need scalable models of the components.

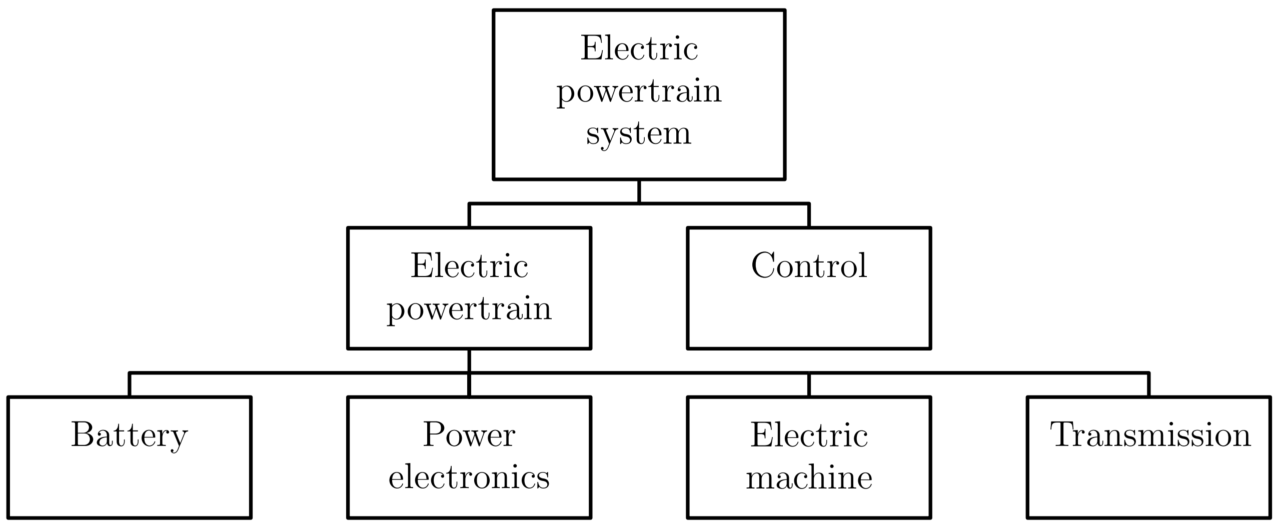

Fig. 1: Decomposition of the powertrain system.

However:

× Simplified low-fidelity **scalable models** are not precise enough (Fig. 2).

× **Accurate model** evaluations (FE, Fig. 3) are high-fidelity but computationally expensive and therefore not amenable to optimization.

Can we combine the strengths of these two levels of model fidelity into one model?

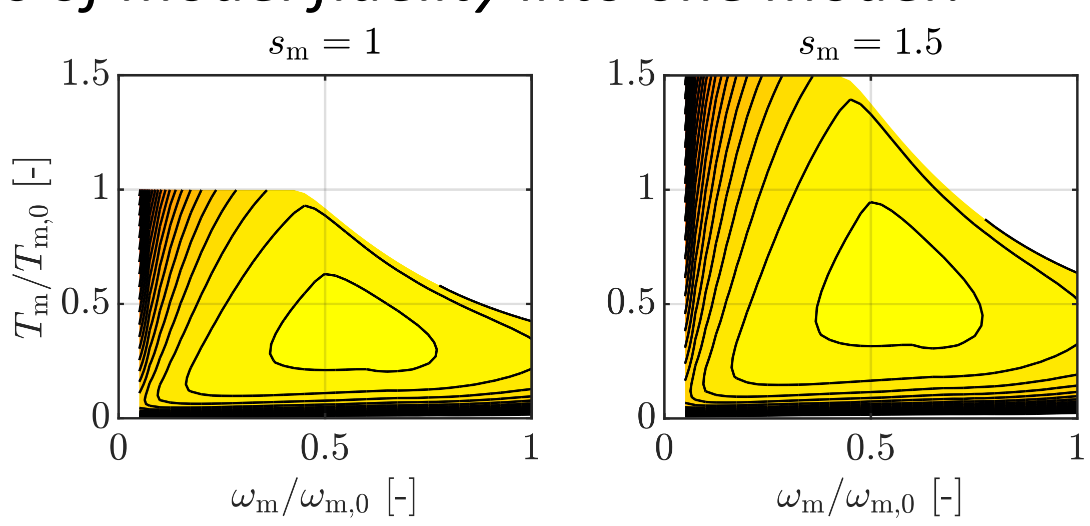

Fig. 2: Linear scaling of an electric motor.

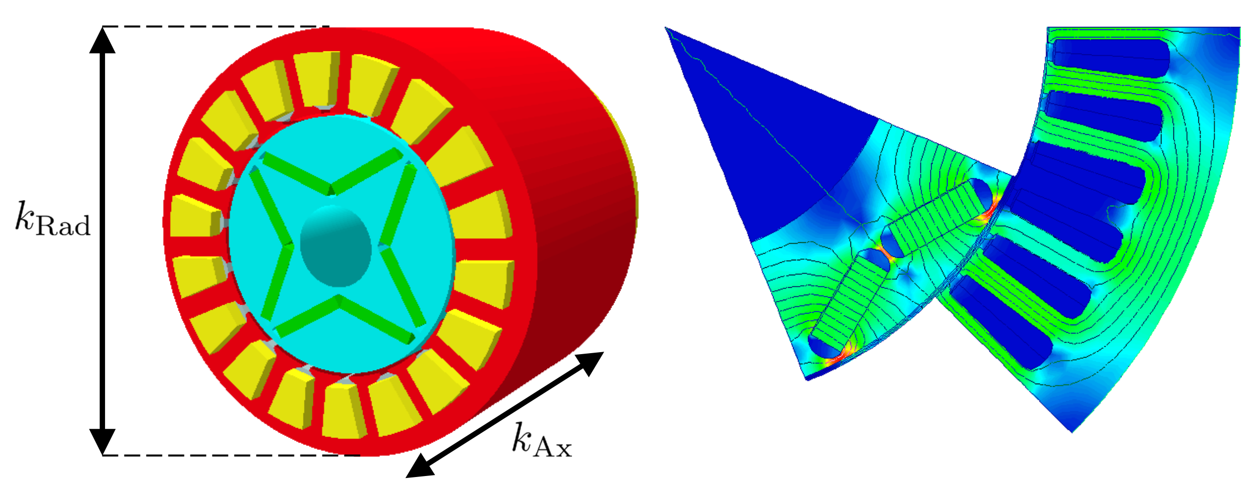

Fig. 3: The radial and axial scaling factors (k_{Rad} and k_{Ax}, respectively), illustrated on an optimized referent electric motor design, along with a FE magnetic flux density solution.

METHODS

1. We perform computationally-expensive and accurate simulations of a set of electric motors (EMs) by **scaling** them in **axial** (k_{Ax}) and **radial** (k_{Rad}) direction (Fig. 3).
2. Based on those samples, we derive convex surrogate models that predict the EM **limits** and the **losses** (Fig. 4) for the design space.
3. We include this surrogate model in a **vehicle powertrain model** to jointly solve the energy-optimal design and operation problem in a rapid and accurate fashion.

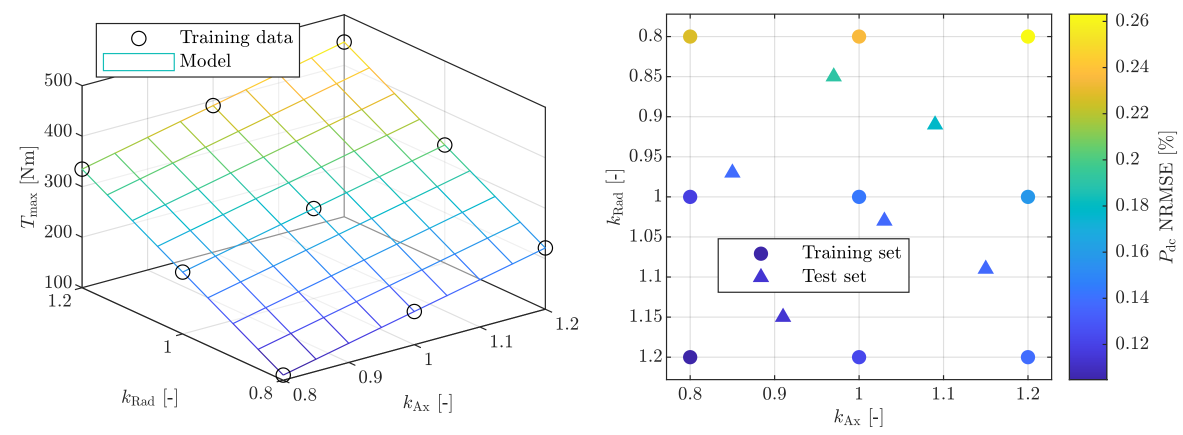

Fig. 4: The EM surrogate model limit predictions (left) and loss errors (right).

RESULTS

Owing to the preserved convex problem structure, our design and control solution is **guaranteed** to be **globally optimal** w.r.t. our models (Fig. 5), whilst being accurate.

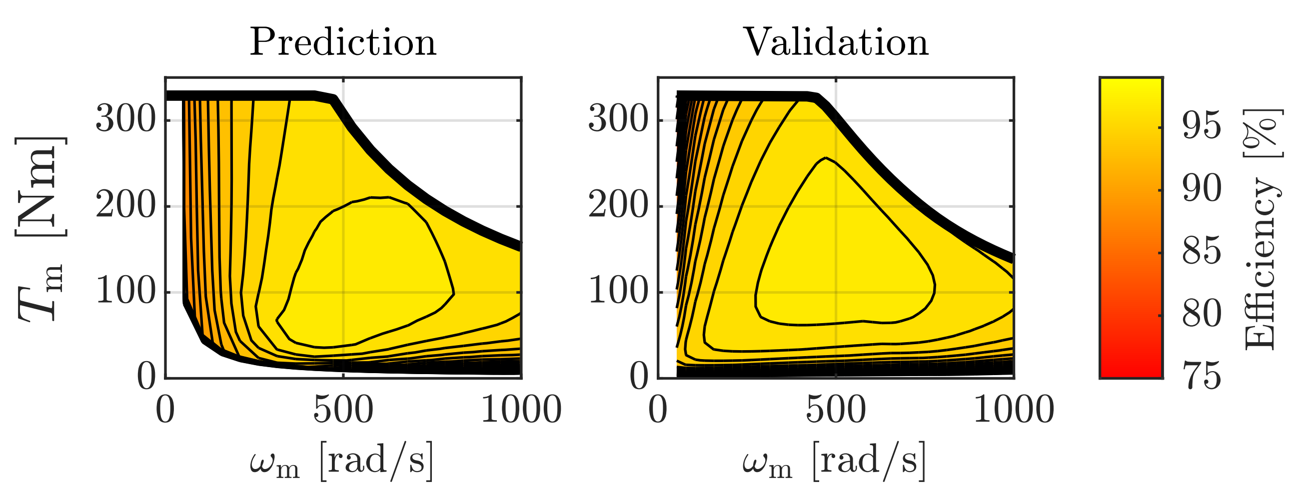

Fig. 5: Optimal predicted and validated EM map (with scaling factors $k_{\mathrm{Ax}} = 0.91$ and $k_{\mathrm{Rad}} = 1.15$).

OUTLOOK

Improve the quality of our surrogate model by iteratively taking more high-fidelity samples: trade-off between *exploration* and *exploitation*.