

# Electric Powertrain Design Optimization: A Convex Surrogate Modeling Approach

**Citation for published version (APA):**

Borsboom, O. J. T., Salazar, M., & Hofman, T. (2022). *Electric Powertrain Design Optimization: A Convex Surrogate Modeling Approach*. Poster session presented at 35th International Electric Vehicle Symposium and Exhibition (EVS35), Oslo, Norway.

**Document status and date:**

Published: 13/06/2022

**Document Version:**

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

**Please check the document version of this publication:**

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

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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.

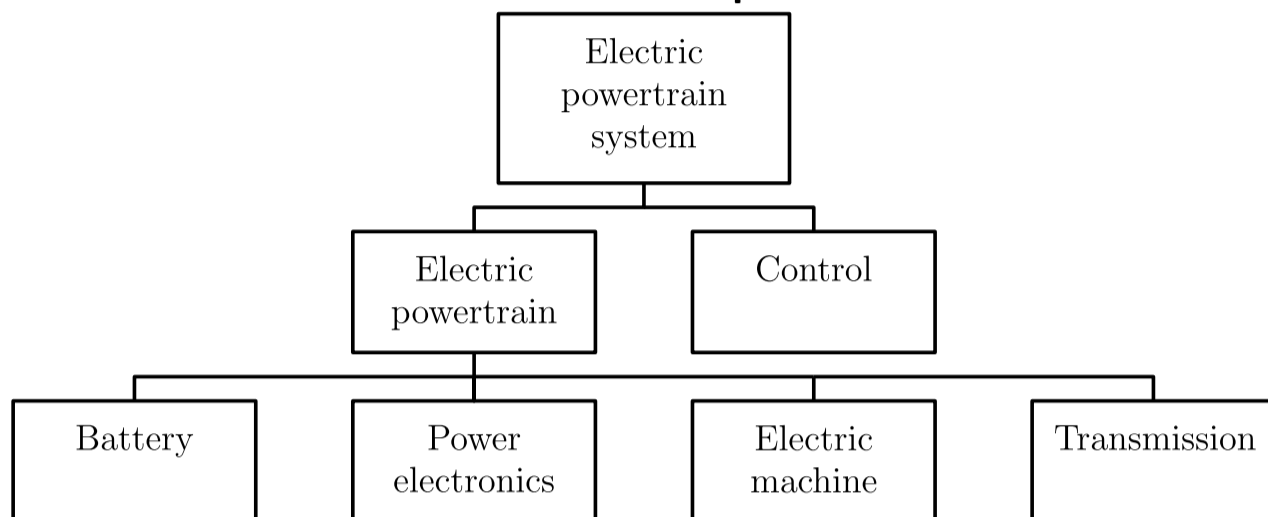


Fig. 1: Decomposition of the powertrain system.

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?*

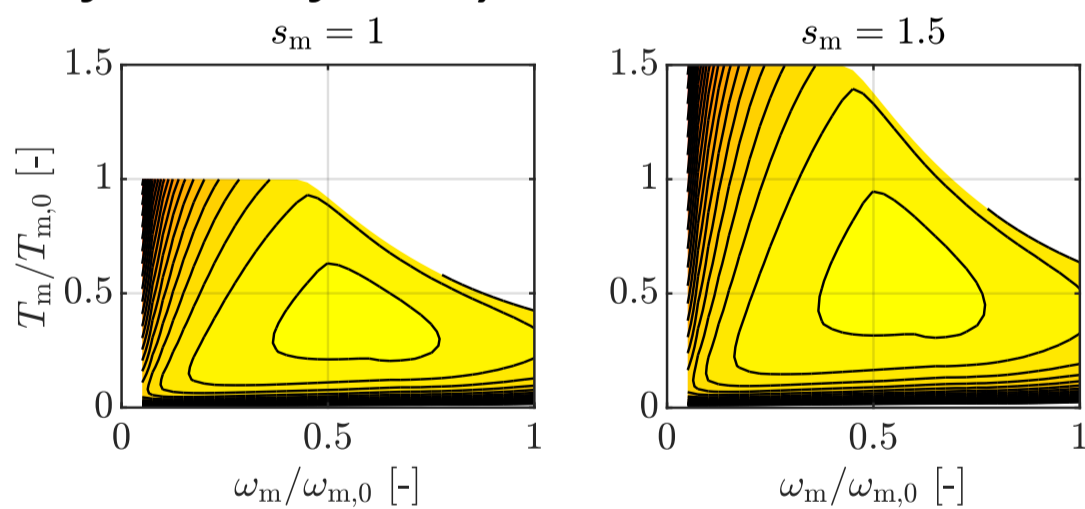


Fig. 2: Linear scaling of an electric motor.

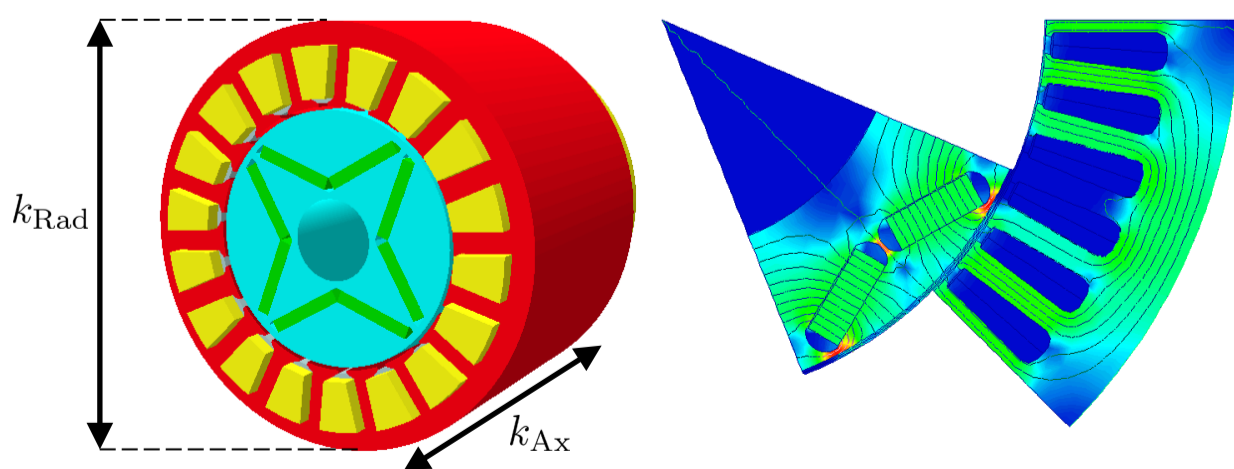


Fig. 3: The radial and axial scaling factors ( $k_{Rad}$  and  $k_{Ax}$ , respectively), illustrated on an optimized referent electric motor design, along with a FE magnetic flux density solution.

## 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.

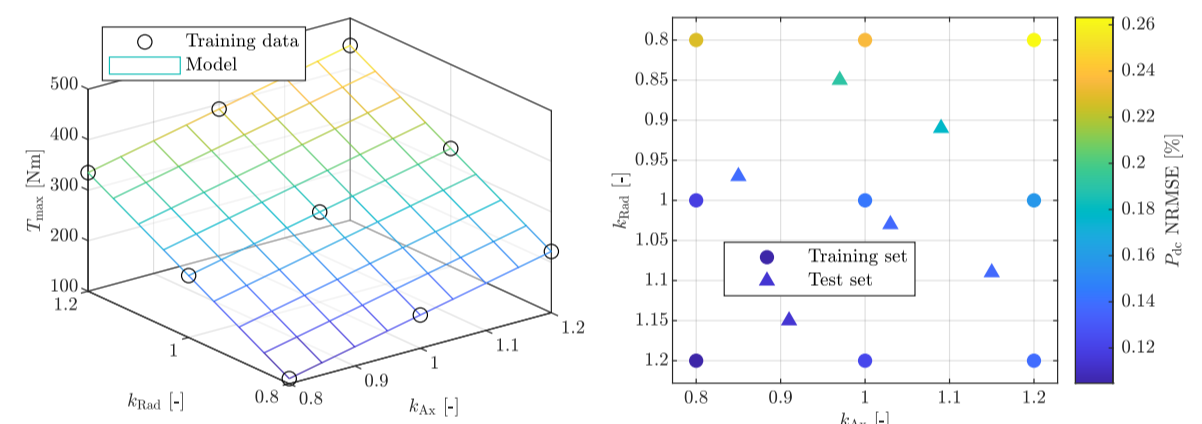


Fig. 4: The EM surrogate model limit predictions (left) and loss errors (right).

## 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.

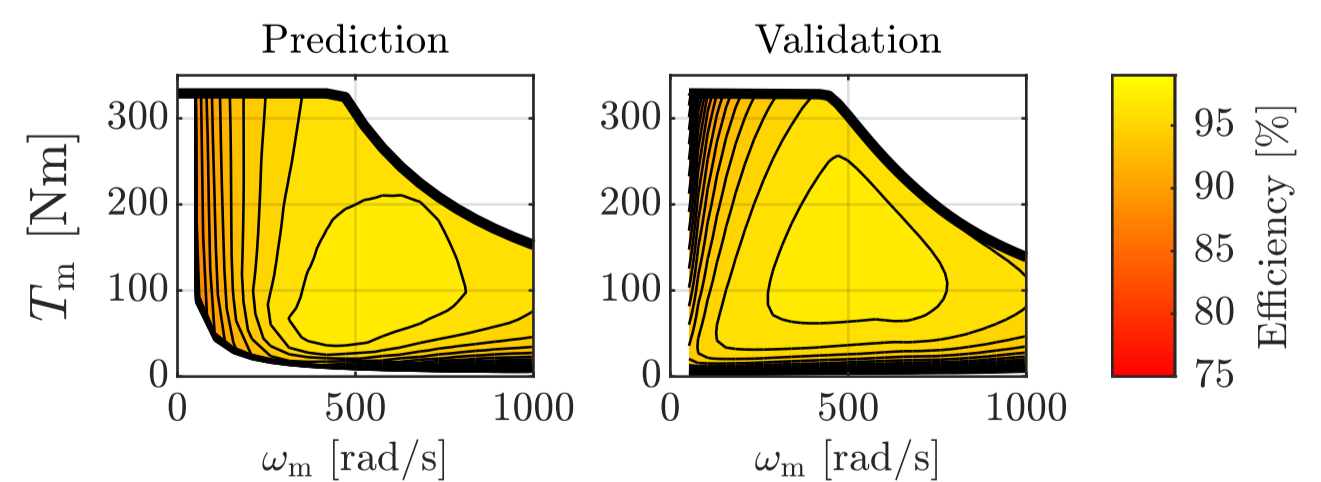


Fig. 5: Optimal predicted and validated EM map (with scaling factors  $k_{Ax} = 0.91$  and  $k_{Rad} = 1.15$ ).

## OUTLOOK

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