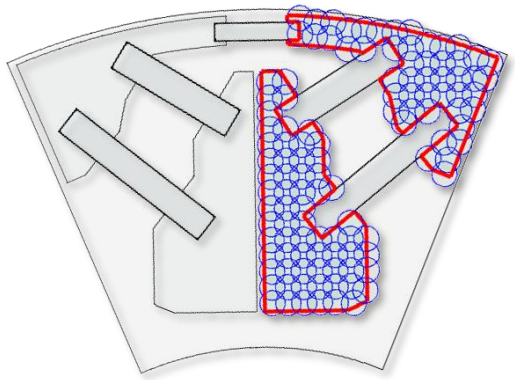
DAIMLER TRUCK

The Next Generation of Rotor Design

Topology Optimization Meets Air-Pocket Design



JMAG User Conference 2026 in Stuttgart
TT/XTA – Daniel Romanowski
30.09.2026

Agenda

01 **Motivation**

Why topology optimization for e-motor design?

02 **Air Pocket Optimization**

Design-space parametrization with Gaussian basis function

03 **Optimization Workflow**

JMAG workflow, HPC setup & computational effort

04 **Performance Comparison**

Base design vs. optimized design

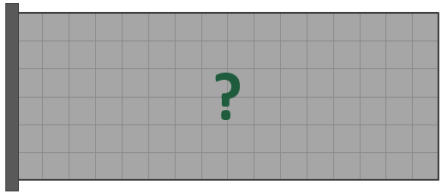
05 **Summary**

Key findings & next steps

What is Topology Optimization? – From Design Space to Optimized Structure

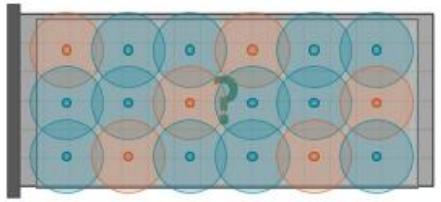
Transformation of a continuous material field into an optimized geometry

Design Region (FEM Mesh)



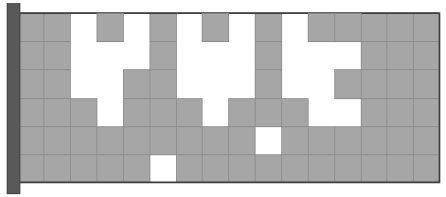
- Fully solid design domain
- Search space for optimization

Gaussian-Based Material Field



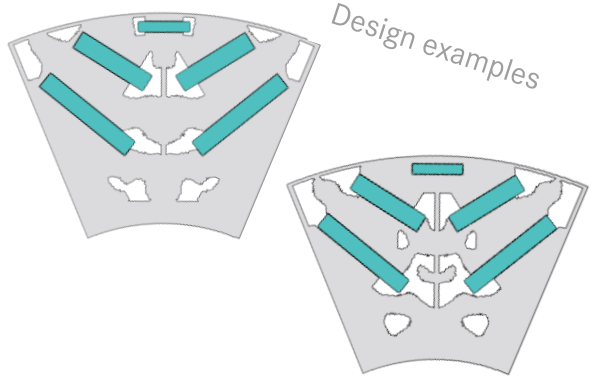
- Continuous material representation
- Defined by Gaussian basis function

Optimized Topology



- Material and air regions defined
- Optimized geometry generated

Optimized rotor design



- Air pockets generated by topology optimization

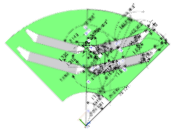
KEY TAKEAWAY

Topology optimization identifies an optimal material distribution within a predefined design space

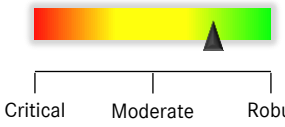
Why Topology Optimization for Rotor Design?

Parametric Design Process

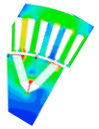
01 Geometry
- Moderate number of parameterized rotor variables
- Robust design for manufacturing



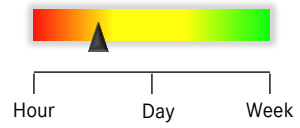
Solution quality



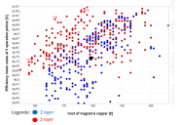
02 FEM Simulation ~ 1k Design's
- Manageable with small license pool



Computational time



03 Optimization
- First indication of trade-off designs

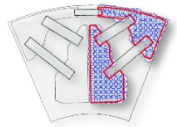


Selection Design on Pareto

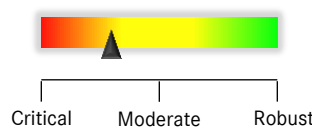


Topology Design Process

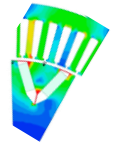
01 Mesh (Gaussian Circles)
- High number of free-form variables
- Simplified air pocket modeling



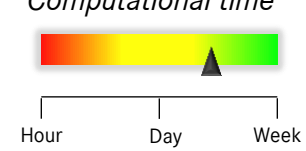
Solution quality



02 FEM Simulation ~ 30k Design's
- Higher number of design to evaluate
- Requires a larger license pool



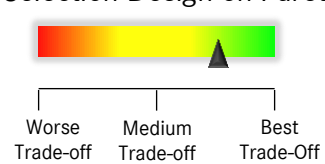
Computational time



03 Optimization
- Achieves convergence across multiple objectives



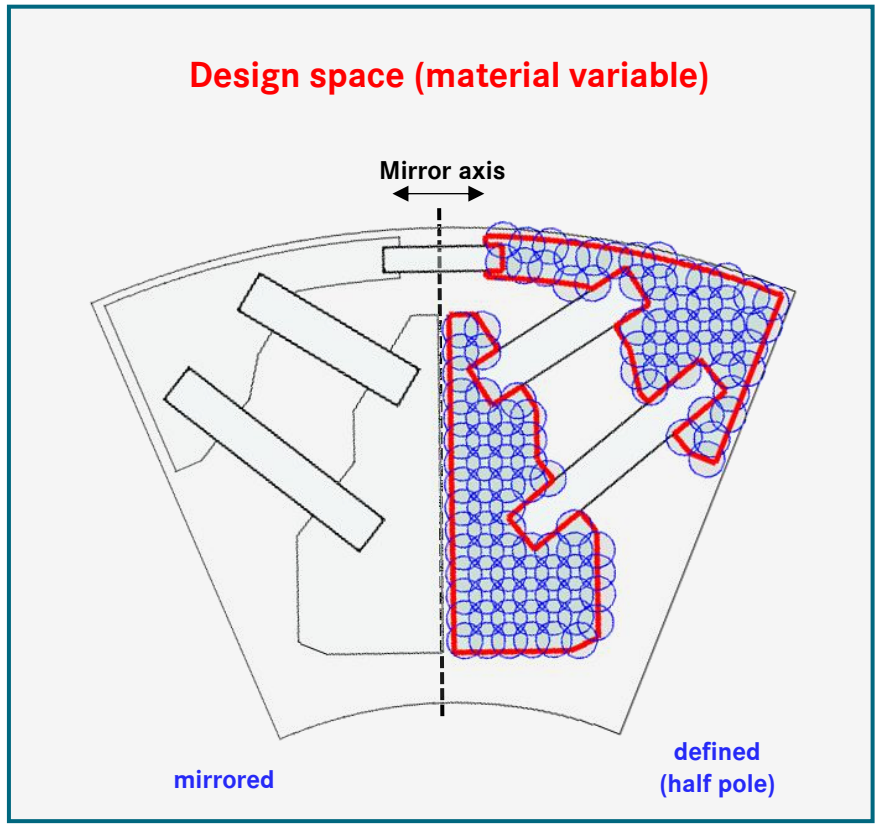
Selection Design on Pareto



KEY TAKEAWAY

Topology optimization expands the accessible design space beyond conventional parametrization

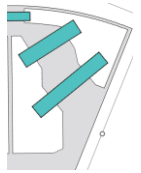
Air Pocket Optimization: Design Space Parametrization



Parametrization Process

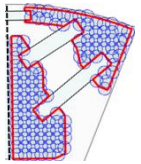
01 Define Design Space (white area)

- Defines the region where material can be assigned
- Only air and electrical sheet is selected in this study



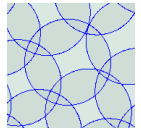
02 Place ~ 110 Gaussian Circles

- More circles → finer resolution of the air-pocket geometry
- More generations needed for the shape to converge



03 Balance Overlap (Half-Value Width)

- Recommended: circles overlap by approximately half their radius



04 Mirror via Symmetry

- Bases mirrored across the chosen symmetry edge



KEY TAKEAWAY

Gaussian basis functions remove predefined geometric constraints and enable free-form airpockets designs

Candidate Evaluation – Three Coupled JMAG Studies (1/2)

Workflow with Three Coupled Studies within a Single Analysis Group

01 Speed Priority

- Build up Efficiency map
- Torque point evaluation

Setup

- 25 OP | 5 x 5 grid | ½ el. Period | ~30k elements

02 Demagnetization

- Torque behavior before/after ASC
- Determine required coercive field strength

Setup

- 1 fixed OP for each design (no coupling to SP)

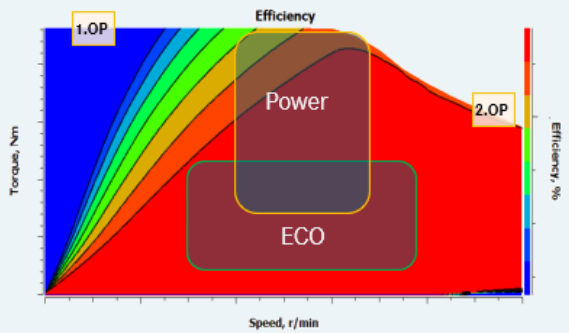
03 Mechanical Structure

- Mises stress & Displacement

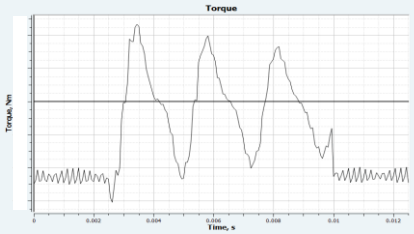
Setup

- 1 mechanical load case (overspeed)

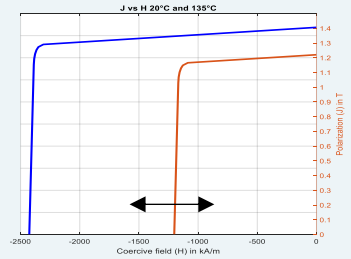
Efficiency map & Torque curve



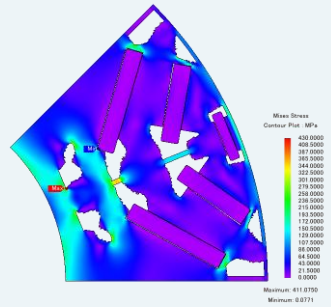
Torque before / after ASC



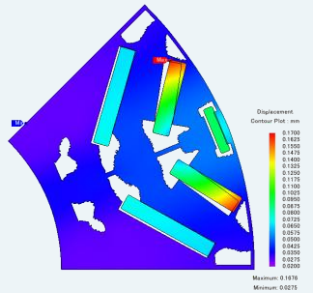
B/H-Curve for Magnet grade selection



Mises stress



Displacement



Design Example

Global Optimization & HPC Setup (2/2)

Optimization Setup

What is optimzed?

Objectives

- Maximum torque
- Minimum cost

Design Variables

- 110 Gaussian circles
- 3 x Br + 3 x Hcj = **116 variables**

Constraints

- Demagnetization limit
- Mises stress

Optimization run & HPC scale

How is it exceuted?

5 nodes x 32 cores	**PSL 200**	**200**	**~36k**	**~ 110h**
HPC SETUP	LICENSE SETUP	GENERATIONS	DESIGNS	OPTIMIZATION
Configuration	Parallel excution	optimization run	Candidate evaluations	Total time

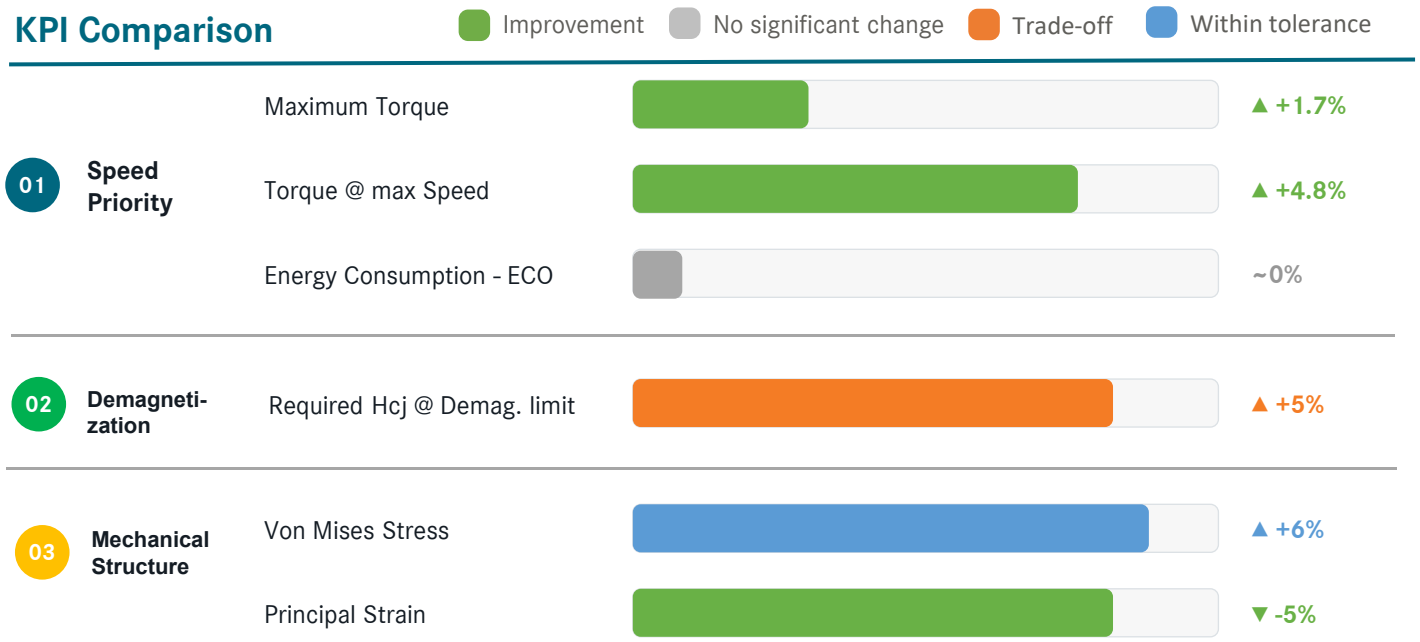
KEY TAKEAWAY

Coupled JMAG studies and PSL200 Setup on HPC enable ~36k candidate evaulations in ~110h.

KPI Comparison: Base Design vs. Optimized Design

Reference design (parametric geometry) = 100 % baseline. Absolute values and optimized geometry are not disclosed

KPI Comparison



Design Requirements – Status (Optimized Design)

Performance
Higher torque, especially at maximum speed

Demagnetization
Within allowable limit

Mechanical Integrity
Stresses and strains within allowable limits

Selection criterion
Displacement < 0.2mm, applied to all designs

KEY TAKEAWAY

+4.8% torque at maximum speed with ~0% change in energy consumption – all constraints satisfied

Summary

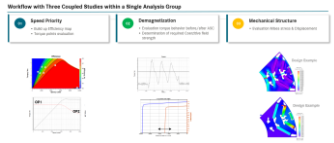
What have we achieved so far?

✓ **Efficient workflow:** Practical optimization times achieved using the PSL license

✓ **Speed-priority optimization:** Topology optimization enabled from JMAG v25.1 onward

✓ **Performance gain:** Optimized design achieves **+4.8% torque at maximum speed** while satisfying all constraints

✓ **Design insight:** Topology optimization reveals where conventional parametrization limits the accessible design space





What will we do next?

- **Investigate the influence of the number of Gaussian basis functions**
- **Explore HPC settings to further reduce optimization time**

