DETAILED ELECTROMAGNETIC AND THERMAL SIMULATION OF A TRACTION DRIVE ELECTRICAL MACHINE

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AGENDA

—Traton Group

—Traction Motor Overview

—HPC Performance

—Electromagnetic Analysis

—Thermal Workflow and Results

—Conclusions

GROUP

(87.5% owned by Volkswagen Group)

Strong brands under one roof

SCANIA

MAN

Caminhões Ônibus

INTERNATIONAL

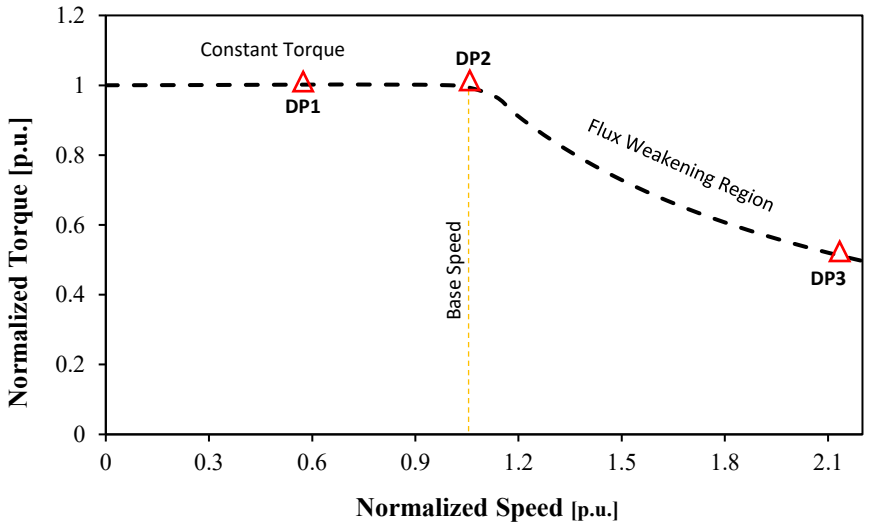
4	commercial vehicle brands	**26**	countries with production sites	**107,454**	active workforce

From brand alliance to integrated Group R&D

2015	2018	2021	2025	2025
Volkswagen Truck & Bus	TRATON Group	International acquired	TRATON Group R&D	Scania Rugao industrial hub

A double V-shaped interior permanent magnet machine (IPM) is considered for analysis.

- It has 10 rotor poles and 60 stator slots;
- Hairpin stator winding;
- Thin gauge NGO electrical steel is used for rotor and stator laminations;
- High temperature NdFeB magnets with axial segmentations;
- Skewed rotor with notches;





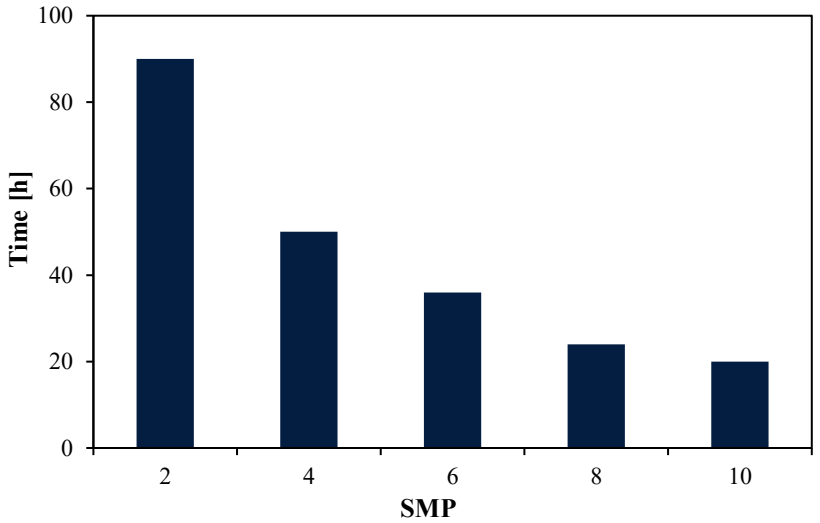
IPM double V-shaped motor

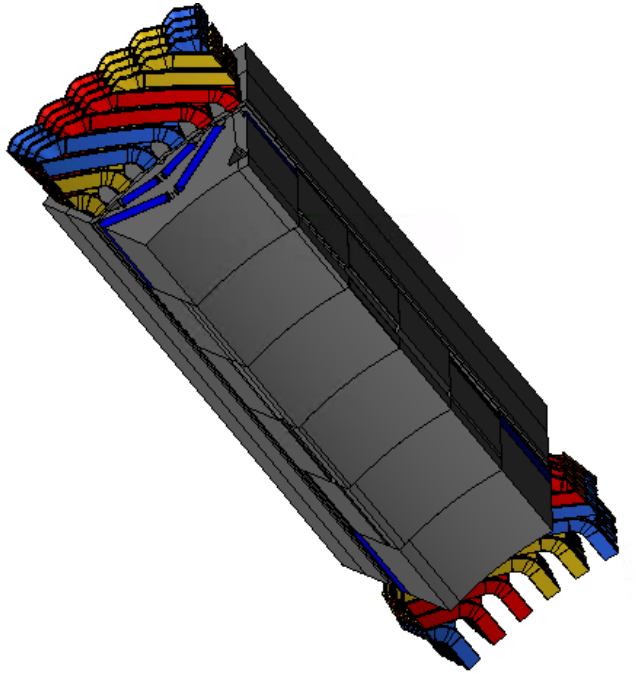
Note: Normalization: Power – continuous power | Torque – peak torque | Speed – base speed

DP1: Peak torque | DP2: Base speed | DP3: High speed

A one-pole 3D model including end windings is used to select practical solver settings for the detailed analysis.

- 74 steps per electric cycle;
- 5.7 million mesh elements;
- 2 → 6 SMP: 60% reduction in simulation time;
- Beyond 6 SMP: lower incremental benefit relative to resource usage;
- 128-core MPP run completed in about 3.5 h;
- 6 SMP selected as the baseline considering runtime and resource allocation for parallel operating-point calculations;

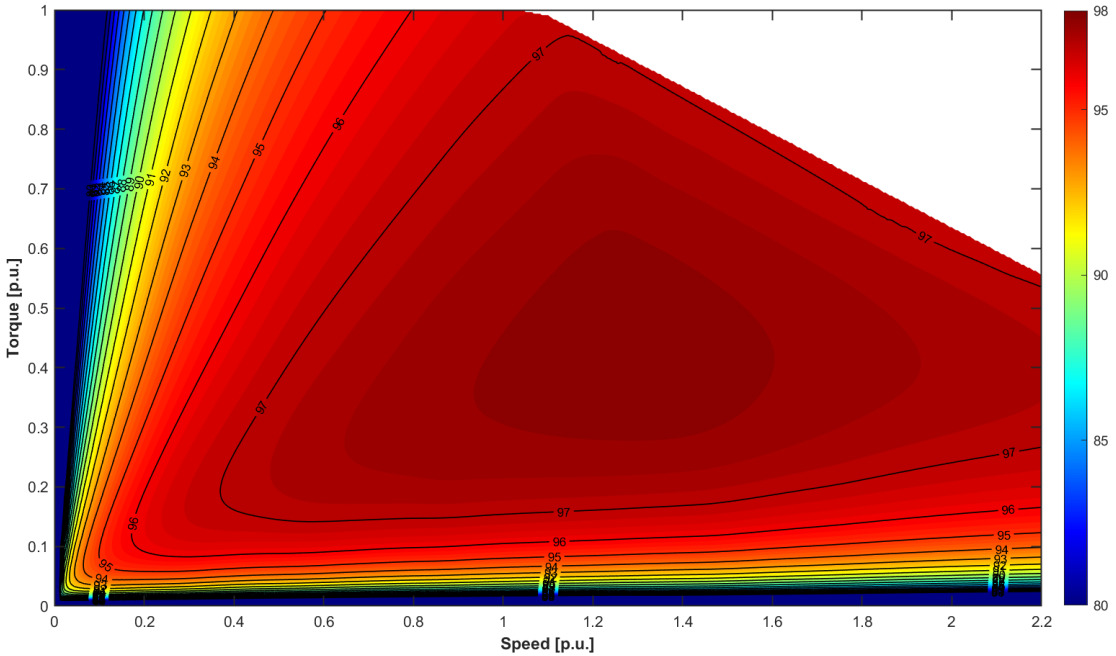




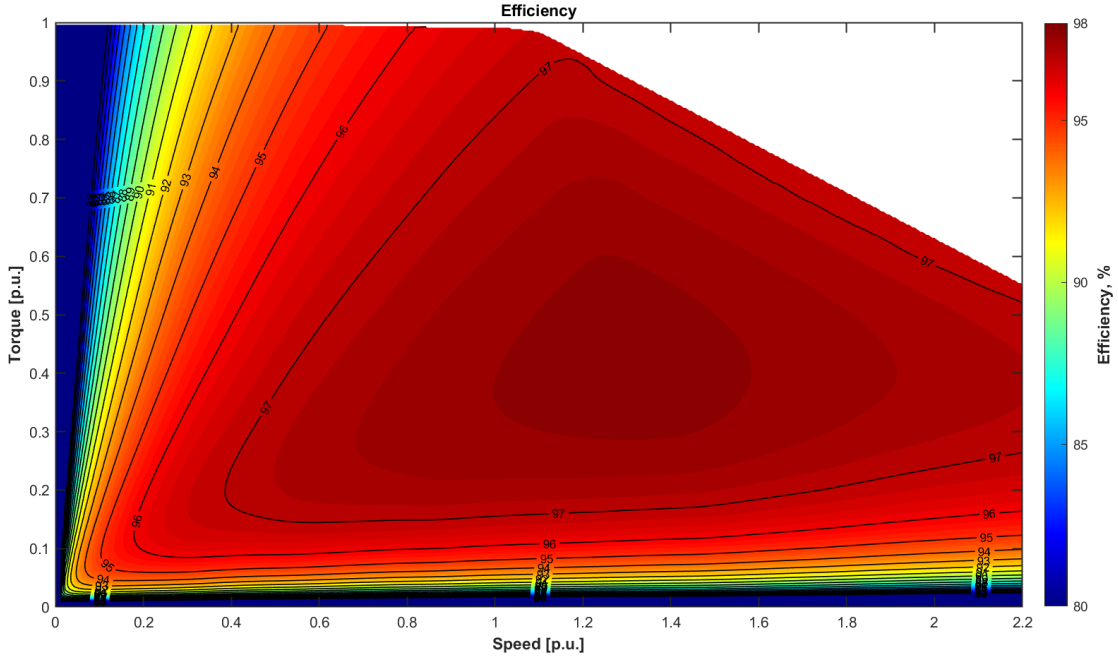
3D-IPM Motor

Speed-priority efficiency mapping is performed using 2D and 3D models.

- Simplified mesh in 3D model (3 million elements);
- 43 operating points across the torque-speed envelope;
- Thermal conditions: Winding 140 °C | Magnet 100 °C;
- Iron and DC copper losses included;
- Compensation factors;



2D Efficiency Map



3D Efficiency Map

Three representative duty points are selected from the speed-priority operating envelope for detailed 3D loss and thermal analysis.

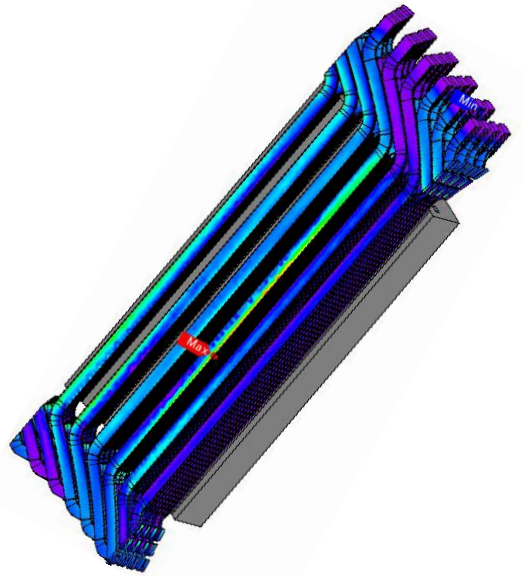
- Peak torque, base speed, and high speed points;
- Detailed AC and DC copper losses;
- Iron and magnet eddy-current losses;
- PWM induced additional losses;

Selected Duty Point Operating Conditions

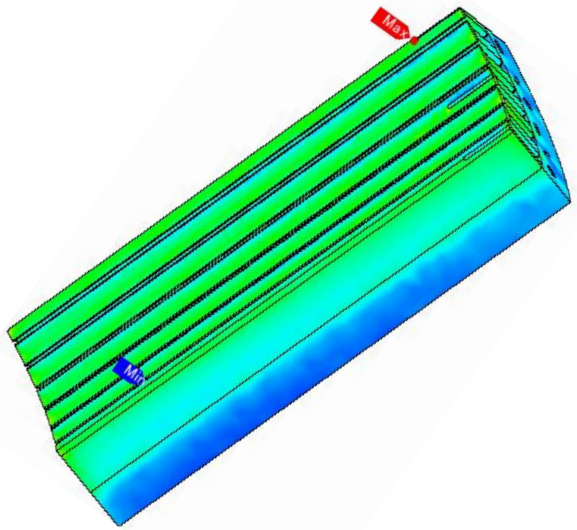
Duty Points	Normalized Torque	Normalized Speed	Normalized Power	Normalized Losses	Efficiency (%)
High Torque-DP1	1	0.59	0.55	0.6	95.9
Base Speed-DP2	0.99	1	0.92	0.73	96.8
High Speed-DP3	0.47	2.07	0.91	0.7	96.6

Loss characteristics vary across the operating envelope, highlighting the need for duty-point-specific thermal analysis.

Note: Normalization: Power – continuous power | Torque – peak torque | Speed – base speed | Total loss – maximum total motor loss



3D Winding Current Density



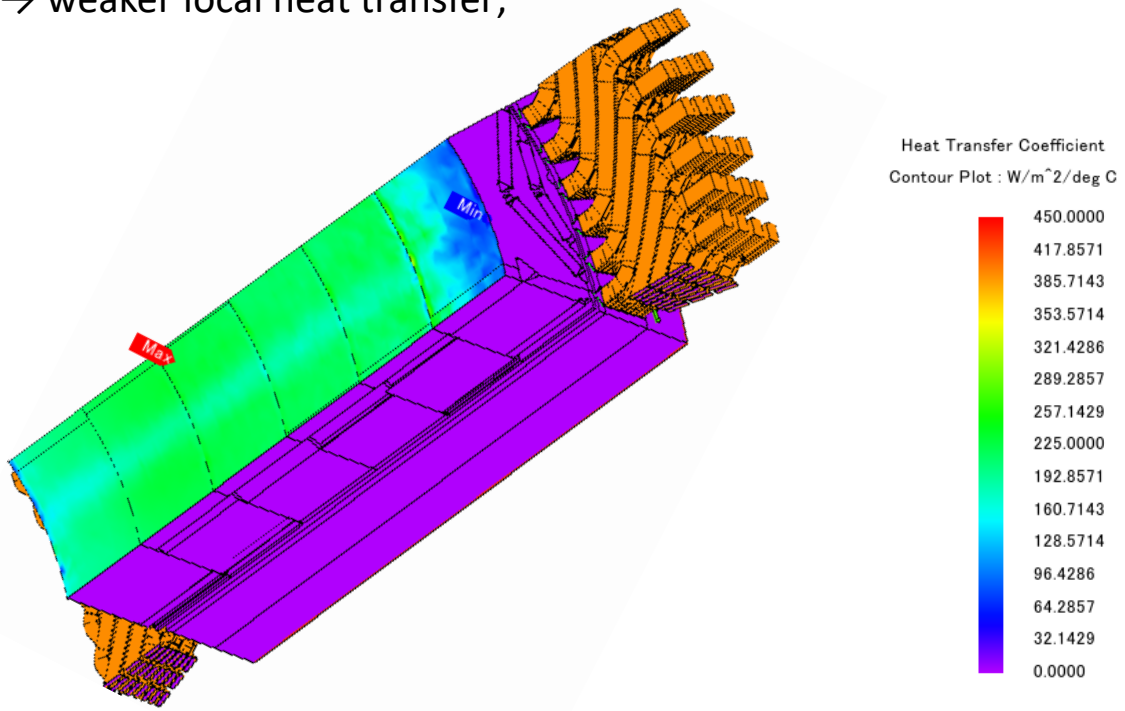
3D Stator Iron Loss Density

Detailed electromagnetic losses are provided to CFD as heat sources, and the resulting spatial HTC distribution is mapped to the JMAG thermal model.

— Spatially varying HTC applied to the corresponding motor surfaces;

— Higher HTC → stronger local heat transfer;

— Lower HTC → weaker local heat transfer;



3D HTC Distribution

JMAG Electromagnetic Analysis
— 3 selected duty points

↓

Loss distributions — Copper | Iron | Magnet

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CFD Thermal/Flow Analysis —
Losses + coolant/flow boundary conditions

↓

CFD-derived HTC (x,y,z,h), W/(m².K)

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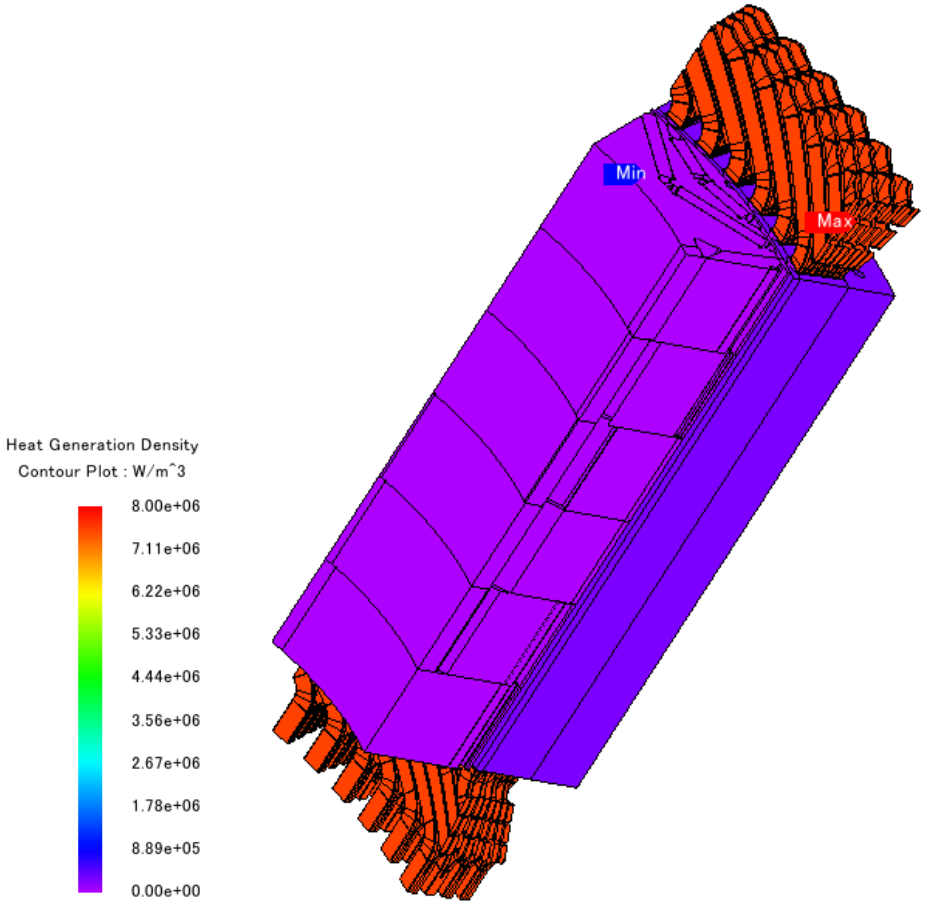
HTC mapping to JMAG

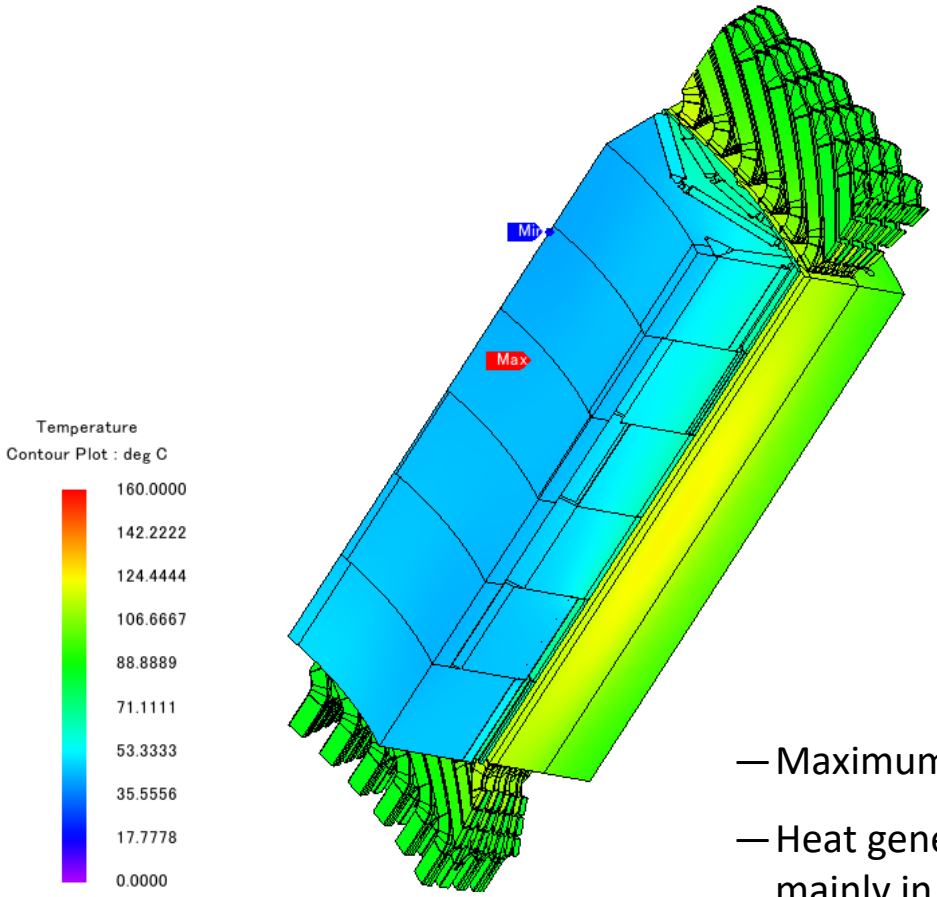
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JMAG Thermal Analysis

TRATON

The detailed loss distribution and CFD-derived HTC are used to predict the spatial temperature distribution and identify thermal hotspots.





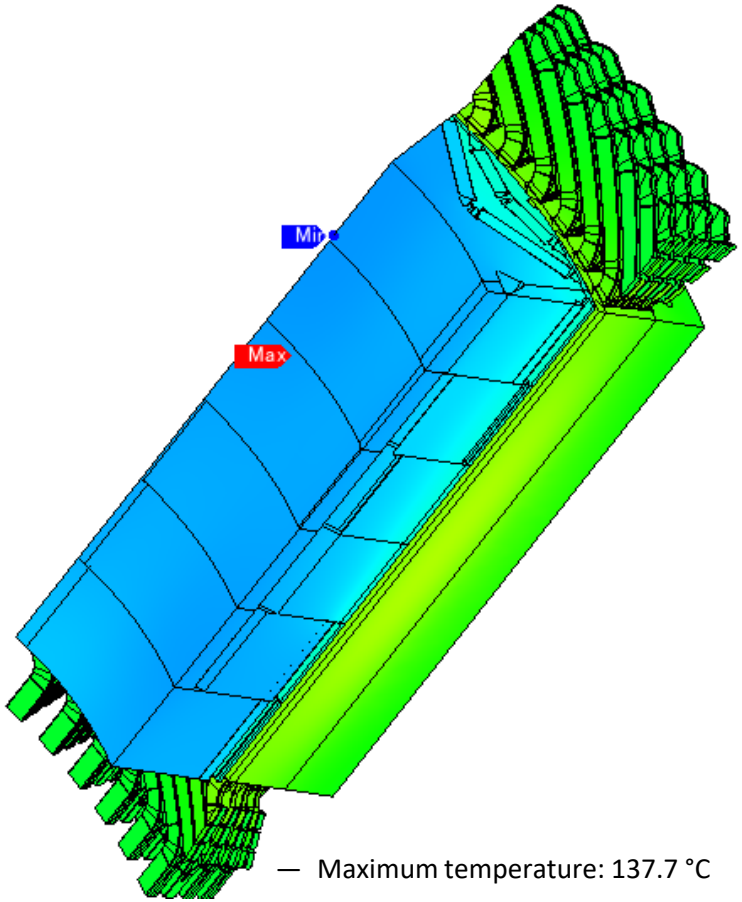
— Maximum temperature: 153.3 °C

— Heat generation is concentrated mainly in stator region

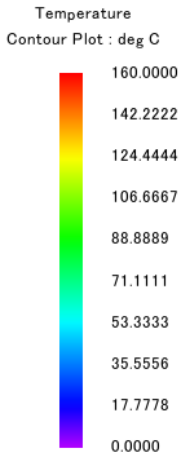
3D Steady State Heat Generation and Temperature Distribution-DP2

Thermal loading depends on the operating condition, with high-speed operation producing a higher peak temperature despite lower torque demand.

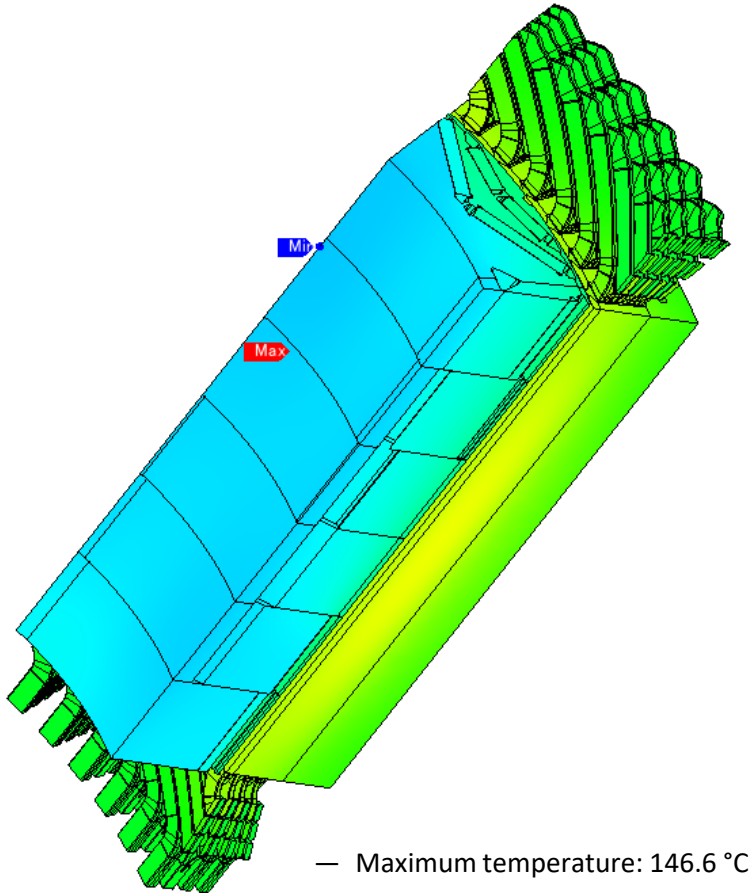
DP 1 Peak Torque



— Maximum temperature: 137.7 °C



DP 3 High Speed



— Maximum temperature: 146.6 °C

— Six SMP reduced the benchmark runtime from approximately 90 h to 36 h.

— The efficiency map identified three representative points for detailed 3D loss analysis.

— Operating-point-specific loss and HTC distributions determine the predicted thermal hotspots.

— A-sample correlation is required to establish predictive accuracy.

Thank you