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

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TRATON 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

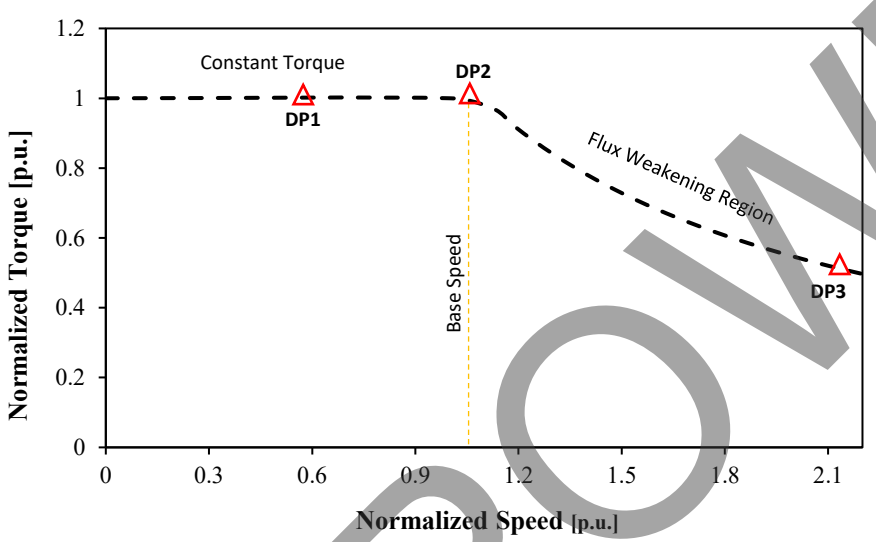
From brand alliance to integrated Group R&D

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

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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

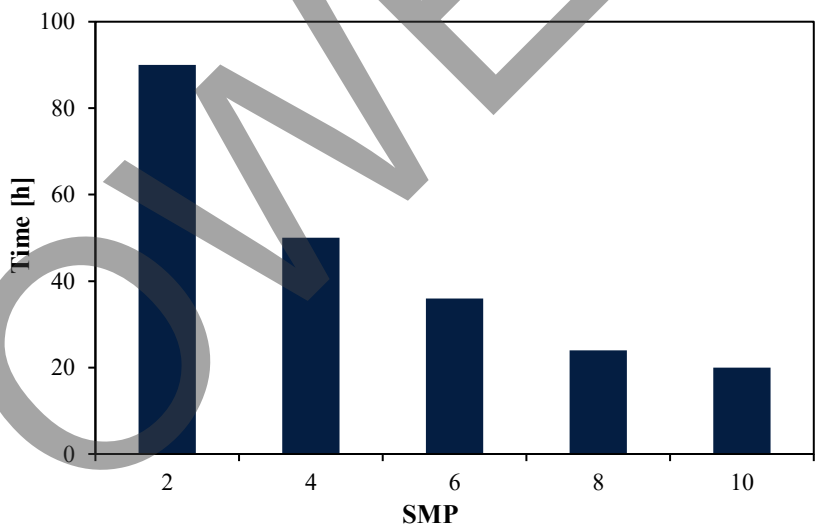
Note: Normalization: Power – continuous power | Torque – peak torque | Speed – base speed

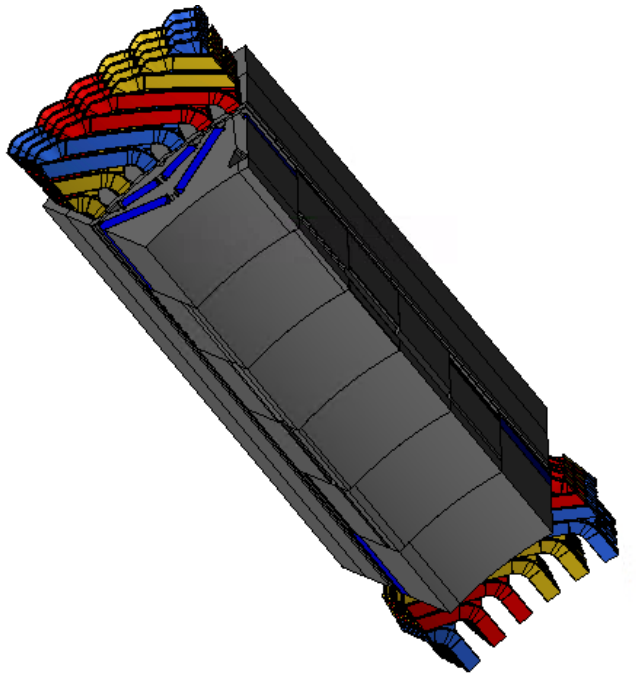
DP1: Peak torque | DP2: Base speed | DP3: High speed

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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;



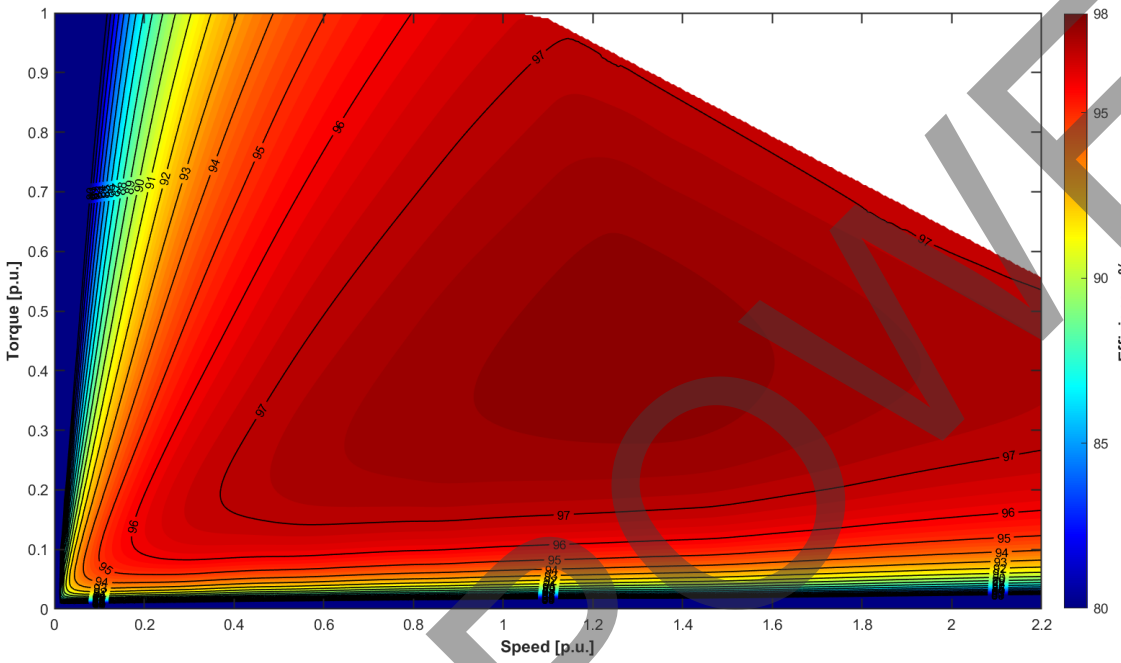


3D-IPM Motor

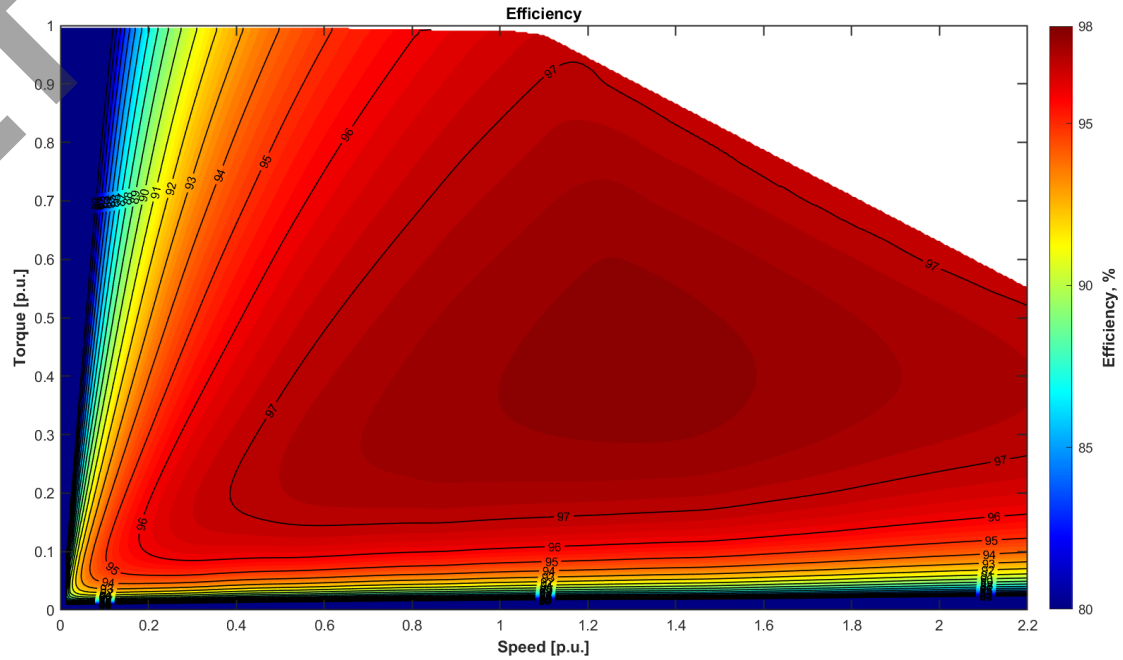
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Speed-priority efficiency mapping is performed using 2D and 3D models.

- 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

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

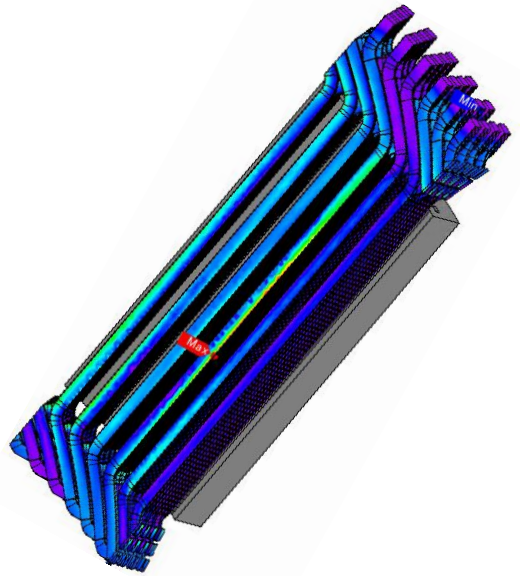
- Peak torque, base speed, and high speed points;
- Detailed AC and DC copper losses;
- Iron and magnet eddy-current losses;
- PWM induced additional losses;

Selected Duty Point Operating Conditions

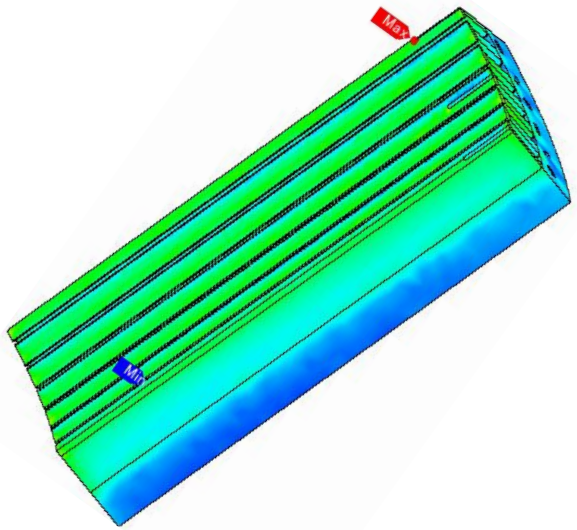
Duty Points	Normalized Torque	Normalized Speed	Normalized Power	Normalized Losses	Efficiency (%)
High Torque-DP1	1	0.59	0.55	0.6	95.9
Base Speed-DP2	0.99	1	0.92	0.73	96.8
High Speed-DP3	0.47	2.07	0.91	0.7	96.6

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

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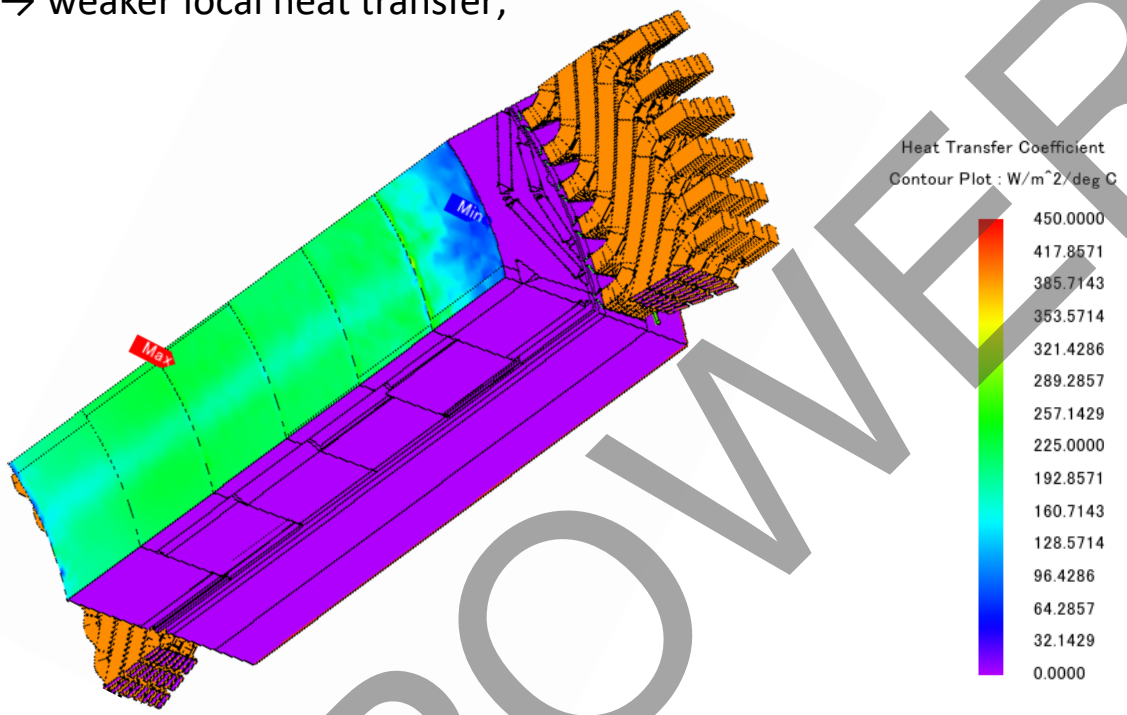
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Detailed electromagnetic losses are provided to CFD as heat sources, and the resulting spatial HTC distribution is mapped to the JMAG thermal model.

— 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

↓

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

↓

CFD-derived HTC (x,y,z,h), W/(m².K)

↓

HTC mapping to JMAG

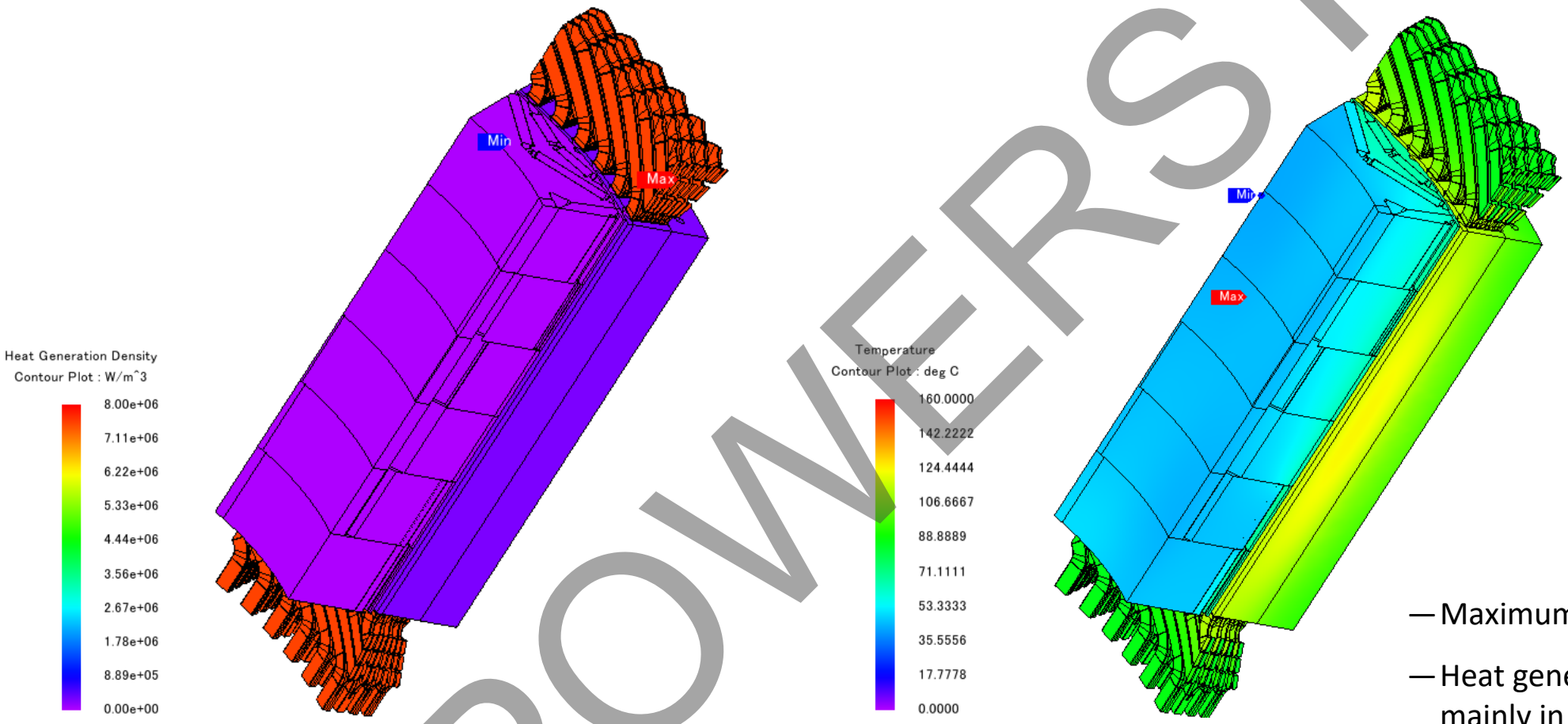
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JMAG Thermal Analysis

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



3D Steady State Heat Generation and Temperature Distribution-DP2

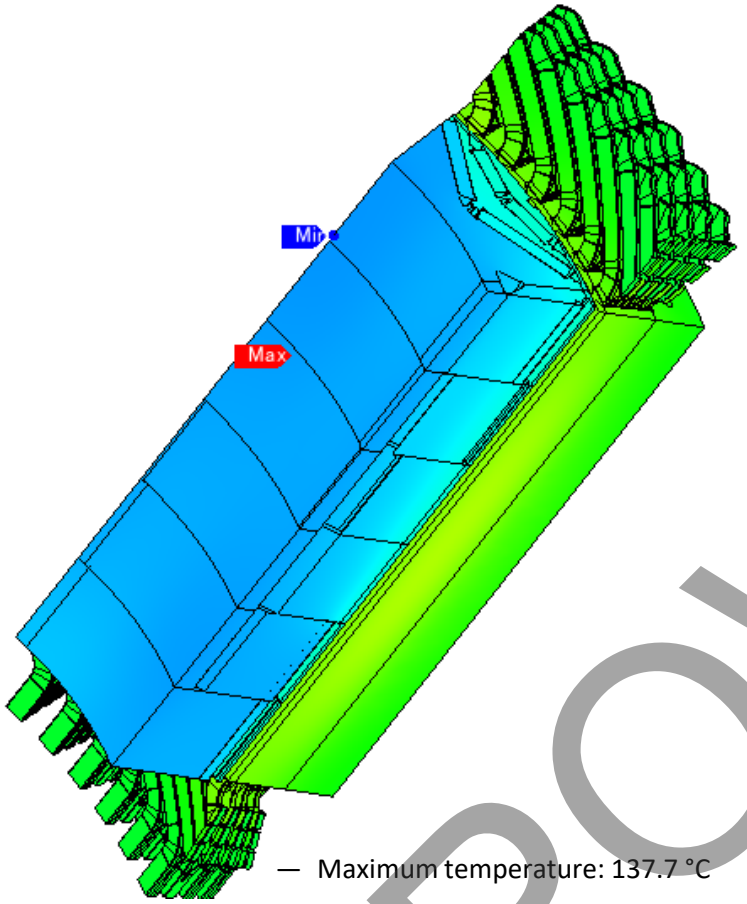
— Maximum temperature: 153.3 °C

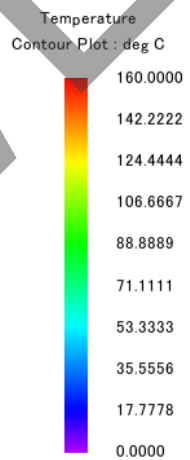
— Heat generation is concentrated mainly in stator region

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

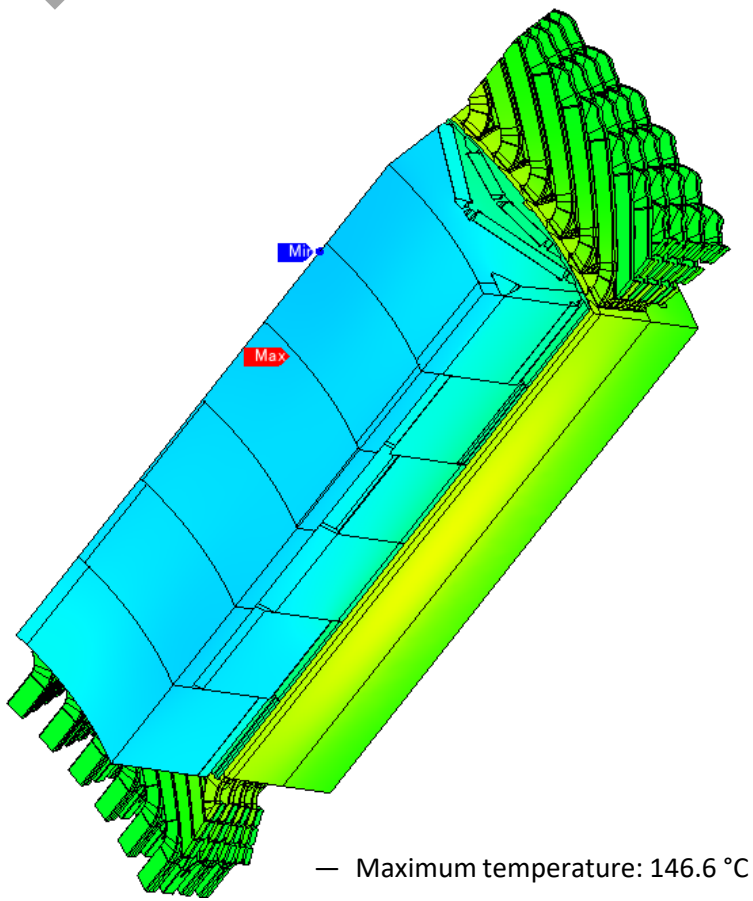
DP 1 Peak Torque





— Maximum temperature: 137.7 °C

DP 3 High Speed



— Maximum temperature: 146.6 °C

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— 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.

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Thank you

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