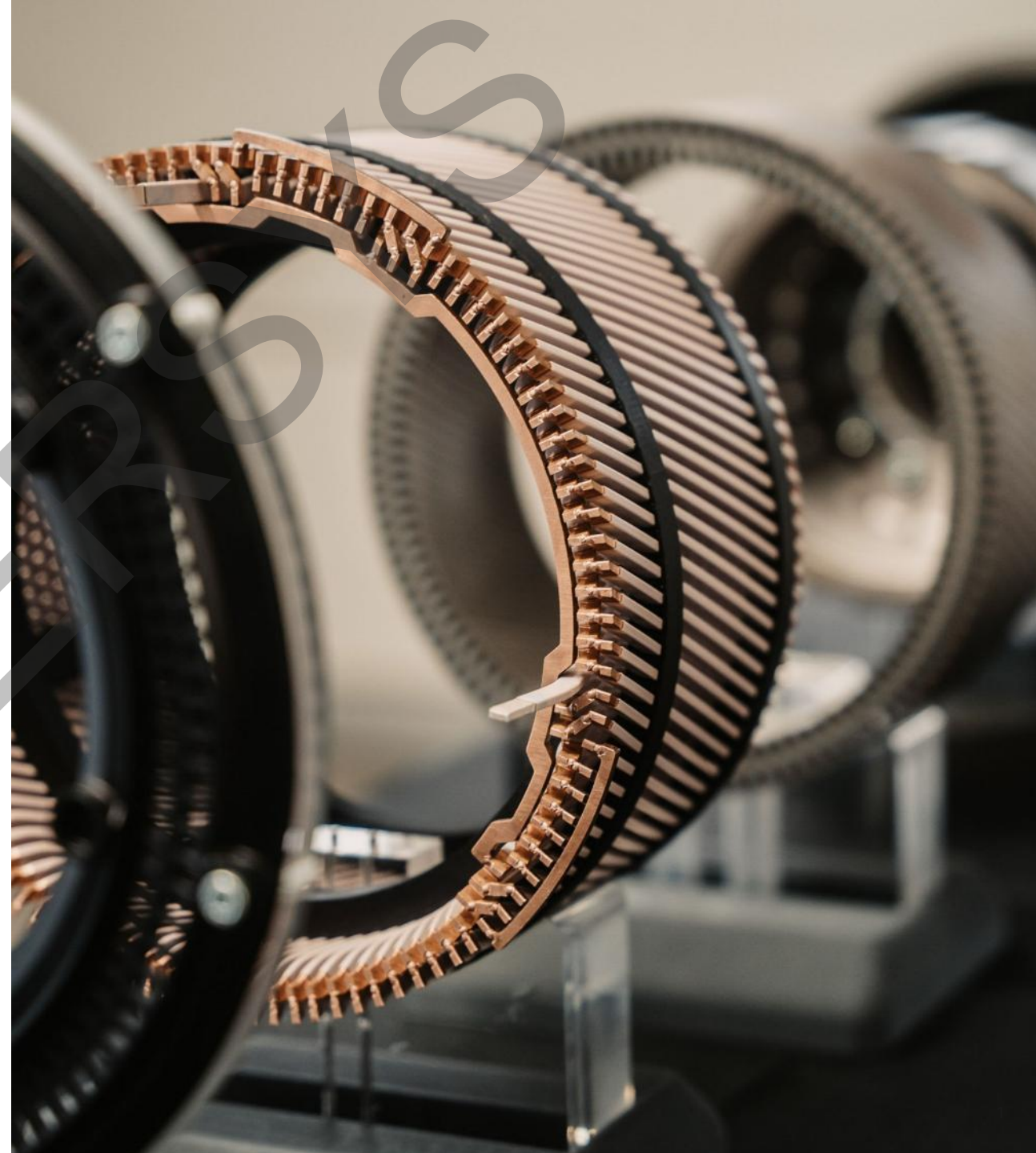


DeepDrive

3D Optimization of Dual-Rotor, Radial-Flux Electric Machines based on Surrogate Models

JMAG User Conference
September, 30th 2026

Dr.-Ing. Alexander Rosen



DeepDrive at a glance

Provider of category-leading electric drives

CUTTING EDGE-TECHNOLOGY AND HIGHEST SPEED OF EXECUTION

- Based in Munich, Germany, founded in 2021 by experts with leading roles in the **first large-scale Automotive projects with >3 million electric drive units**
- **Total investment of ~€50m** in R&D and validation, as well as state-of-the-art R&D and production facility for electric drives in **Munich, Germany** and **Shanghai, China**
- **Backed by top deep-tech investors** Leitmotif (VW), BMW i Ventures, Aumovio, the Bavarian State Fund and UVC Partners
- Validated category-leading motor and inverter technology with highest efficiency, torque-density and lowest cost
- First high-volume **Automotive SOPs** (+100k units p.a.) planned in 2028
- Utilization of **Automotive experience in design, validation, manufacturing and quality** to scale joint modules quickly



SENIOR EXPERTS



Peter Mertens
Ex CTO,
Audi and Volvo



Peter Hochholdinger
Ex Head of Production,
Tesla and Lucid



Jörg Grotendorst
Ex CTO,
Magna and ZF



Jens Wiese
Ex Head of Cooperations,
Volkswagen

SELECTED AWARDS



German
Innovation
Award
2024



Automotive

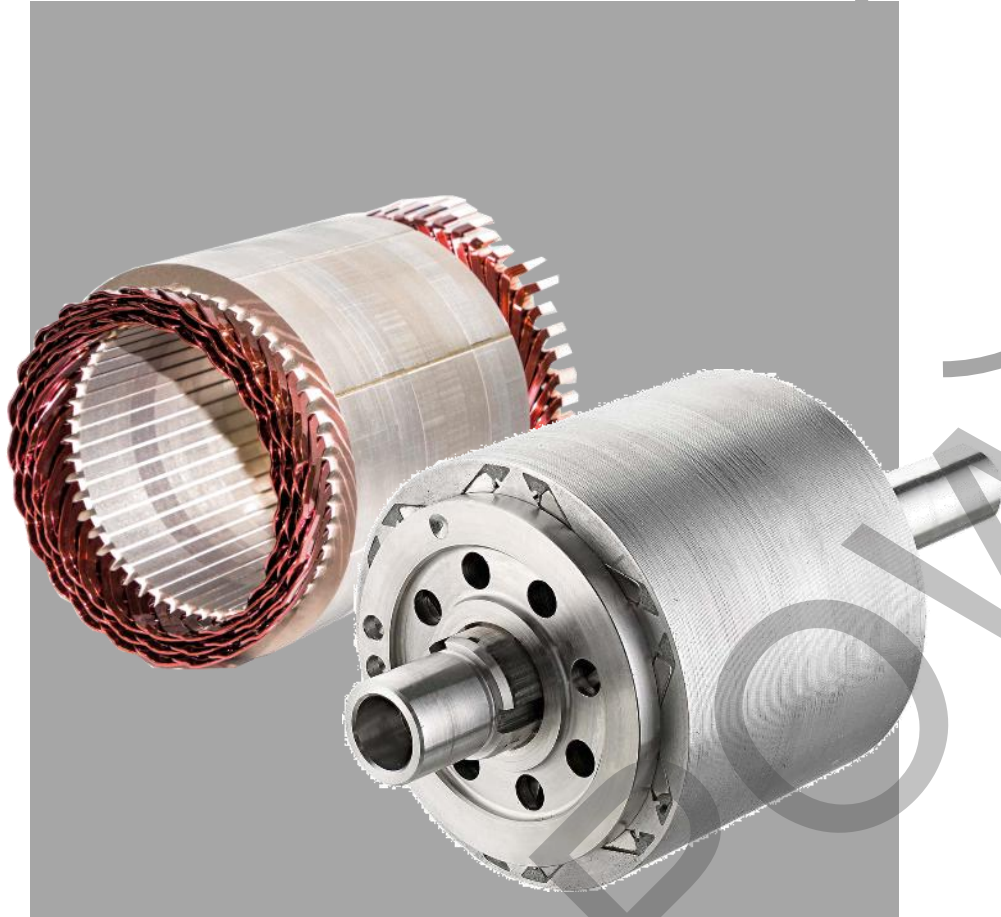
Advanced E-Motor
Technology Award
2024



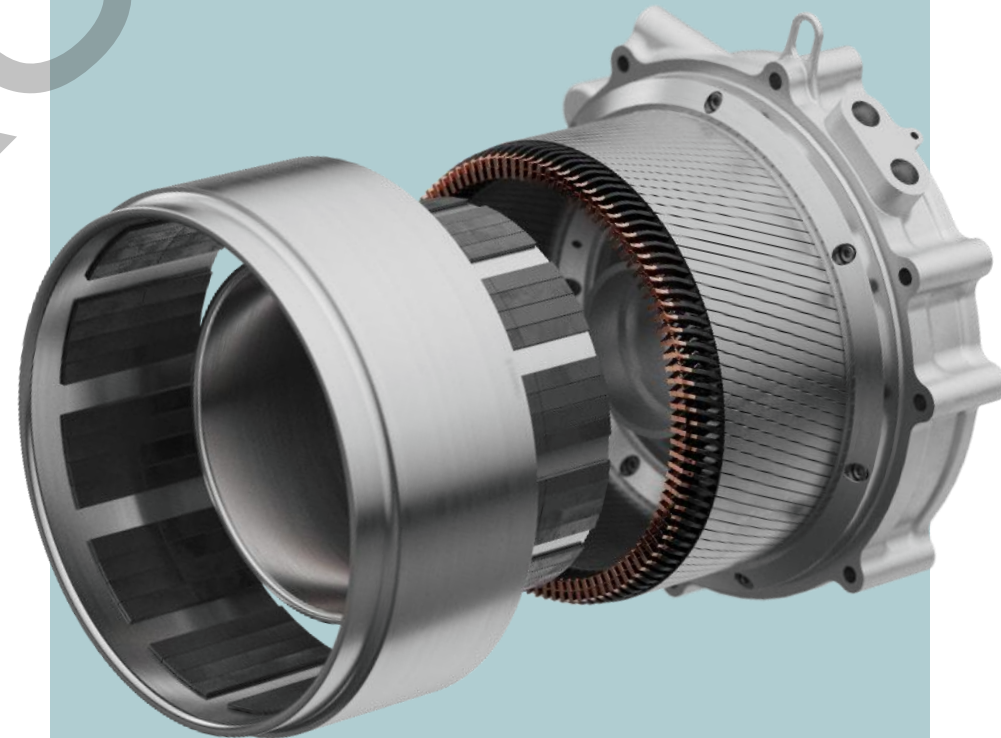
German
Founders
Award 2026

The DeepDrive Dual Rotor is redefining electric drive standards/ electric mobility

State of the Art in EVs today



DeepDrive Dual Rotor



The DeepDrive Dual Rotor is redefining electric drive standards/ electric mobility

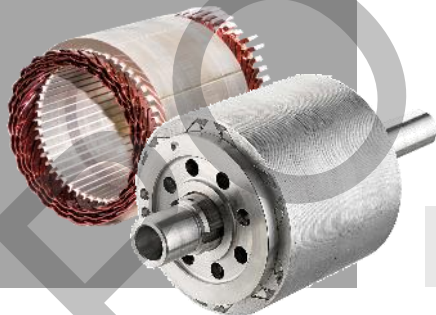
State of the Art in EVs today

Technological features:

- Radial flux PSM
- 2L SiC Inverter
- Hairpin winding with high complexity
- Full cut lamination stack
- Water + Oil cooling
- Parallel + coaxial gearboxes

Technology reaches limits of S-shape curve

- ~18 Wh/km total EDU losses in WLTP¹⁾
- ~92% WLTP cycle efficiency
- ~80 kg total EDU weight



¹⁾Vehicle data assumptions:
 $m=2000 \text{ kg}$, $cwxA=0.65\text{m}^2$, $\mu=0.008$

DeepDrive Dual Rotor

Technological features:

- Dual Rotor, Radial Flux PSM
- Multilevel SiC Inverter
- Easy + robust, self-supported winding
- Segmented lamination stack
- Water + Oil cooling
- Parallel + coaxial gearboxes

Dual-rotor technology shifts boundaries

- 16 Wh/km with potential to 10 Wh/km¹⁾
- >95% WLTP cycle efficiency
- <60 kg total EDU weight

20% BOM cost reduction



Breaking down the Dual Rotor, Radial Flux Technology

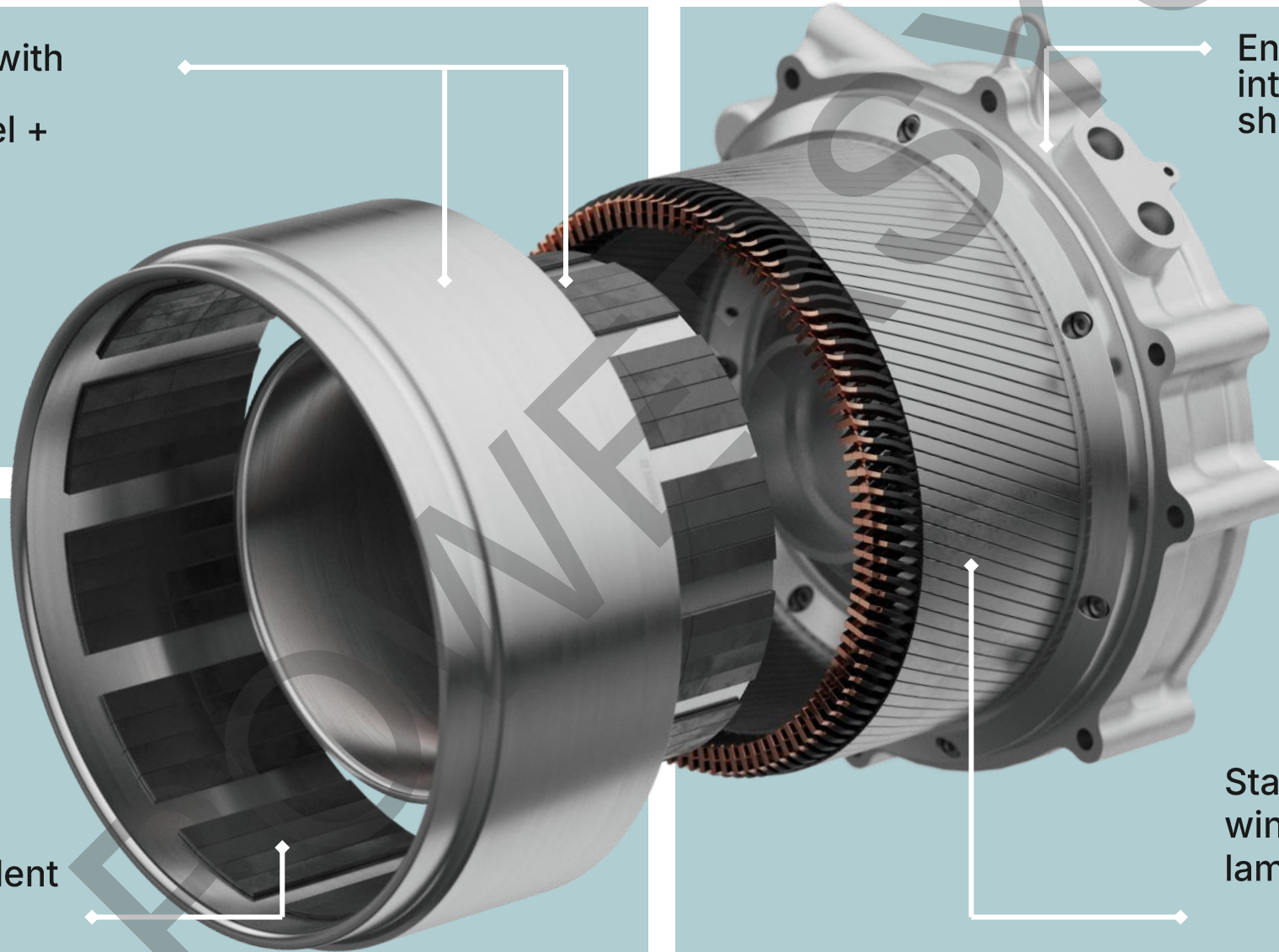


Inner + outer rotor with high-strength, low alloy structural steel + thin lamination ring

Endshield with integrated inverter and shared cooling channel

Surface mounted magnets with excellent utilisation

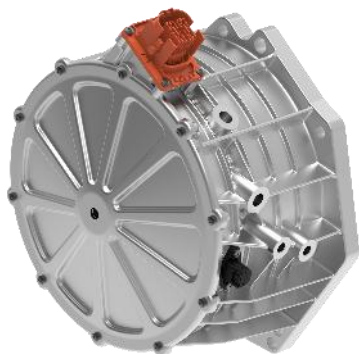
Stator with torsional stiff winding and segmented, lamination stack



Technology covers entire drive portfolio

AUTOMOTIVE

GENERATOR



- Highest **product-market fit**
- **Short-term high-volume opportunities** in pipeline
- **Compact solution** for gearless generators with **lowest material cost**

Performance validated ✓
Samples available ✓

IN-WHEEL-MOTOR



- Highest **product differentiation**
- **Direct drive** frees up space inside vehicle for passenger, battery, cargo
- **Range advantage** of >15% compared to Tesla M3

Performance validated ✓
Vehicles running ✓

CENTRAL DRIVE



- Highest **long-term market potential**
- **Best-in-class efficiency** (<15 Wh/km for C-segment vehicle)
- **Lowest BOM cost** with huge weight advantage – only 60kg

Performance validated ✓
Samples available ✓

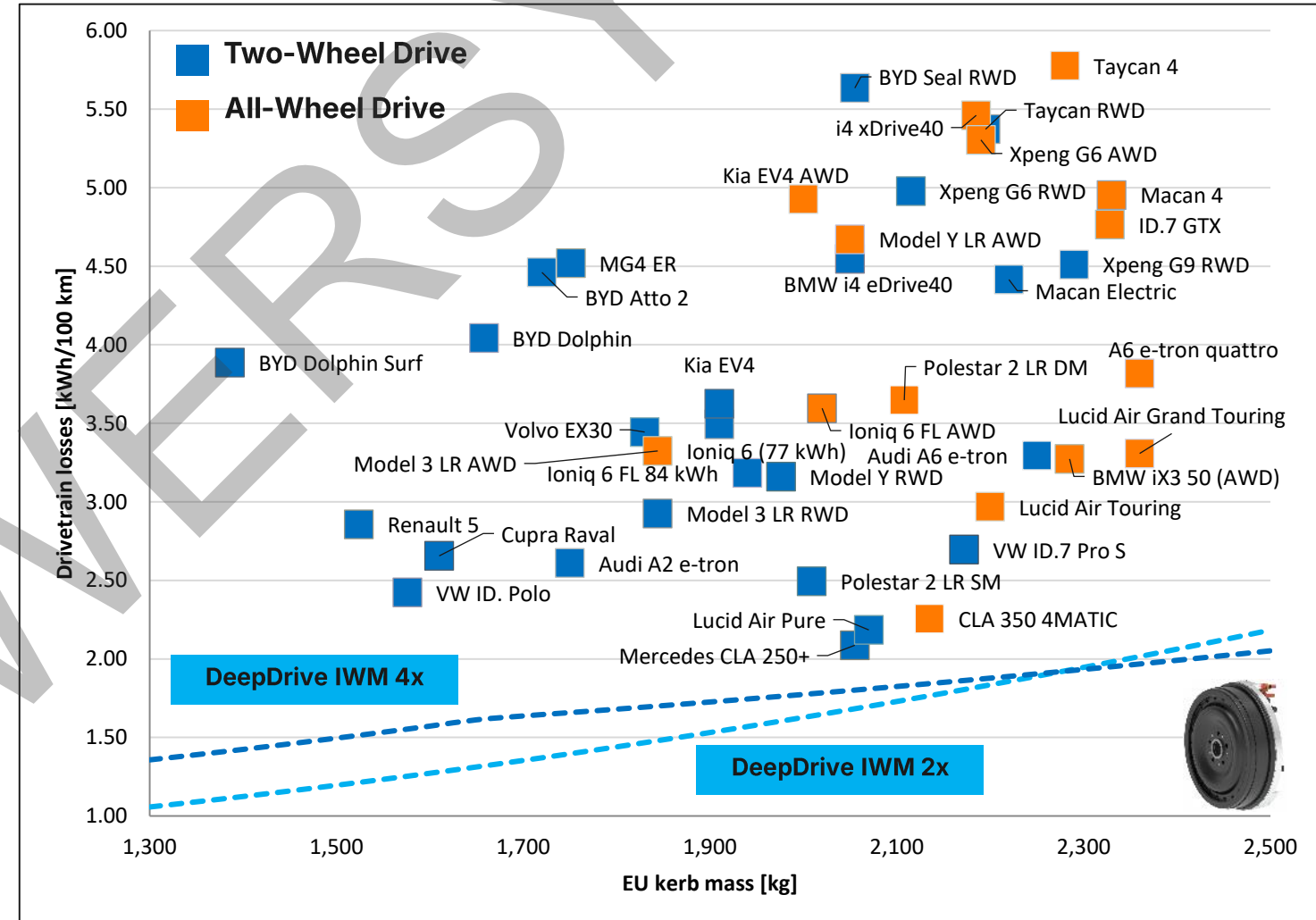
Why is efficiency still important?

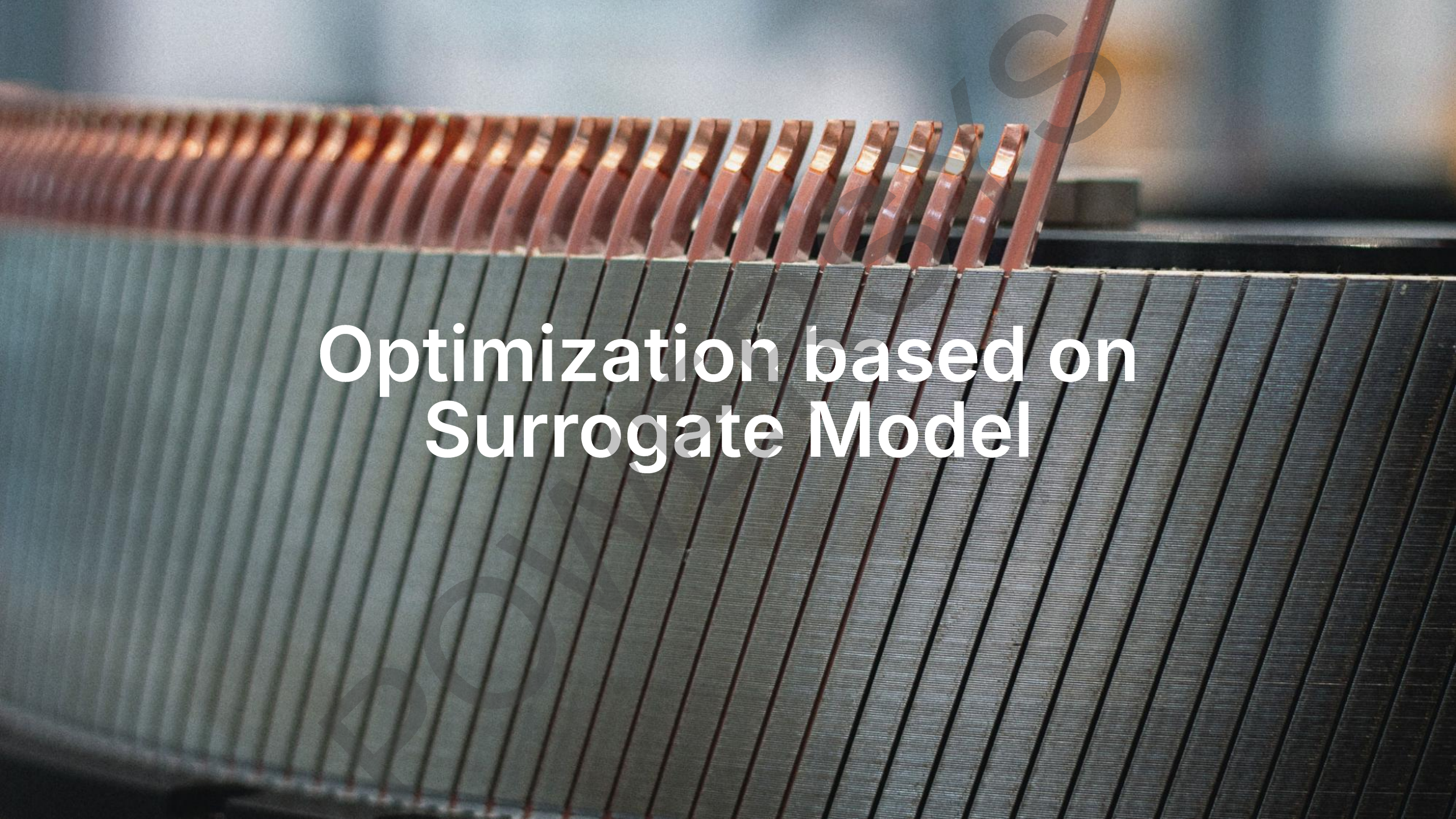
- Powertrain losses are still a significant contributor to energy consumption of electric vehicles
 - Average "real-world-efficiency" of driving resistance vs. energy consumption in WLTC is <70%
 - Examples:
 - Model 3 LR: 2.9 kWh/100km, 72%
 - ID2 Polo: 2.4 kWh/100km, 77%
 - CLA250+: 2.1 kWh/100km, 79%
 - XPeng G6: 5 kWh/100km, 66%
- The range-impact of EDU losses is still 30-40% in most EVs
- Real world driving in low temperatures and highway cycles further reduces efficiency

DeepDrive In-Wheel Motors are the most efficient powertrain in real-world use cases

Methodology: Bottom-up drivetrain losses from WLTP data
Input: WLTP TEL consumption, range, net battery capacity
Energy from battery: Net capacity ÷ range (fallback: 12 % charging loss)
Road load (WLTC 3b): Aero drag, tyre rolling resistance ($f_R = 6.0 \text{ N/kN}$), wheel bearings ($4 \times 0.8 \text{ Nm}$)
Auxiliaries: 250 W 12 V load, 0.2 kWh/100 km battery losses
Assumption: No friction braking, all deceleration recuperated
Drivetrain losses = energy from battery – road load – auxiliaries

Powertrain losses of current EVs:





Optimization based on Surrogate Model

The JMAG 3D FE model

Fully parametric transient model of one anti-periodic sector

197 h

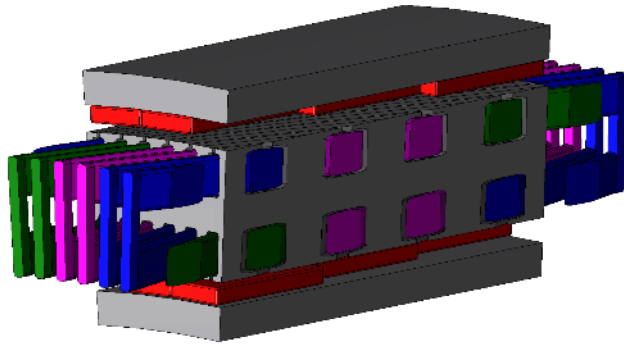
compute time

≈ 18 min

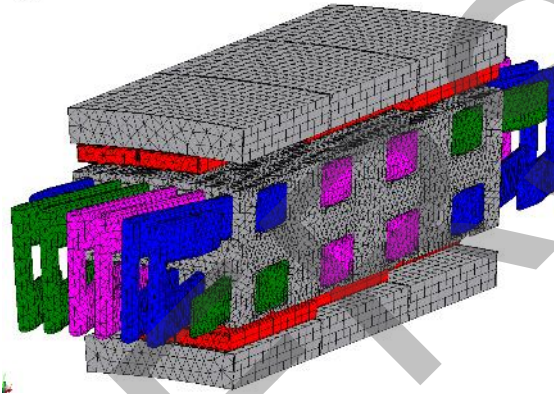
per design, 22 OP

≈ 50 s

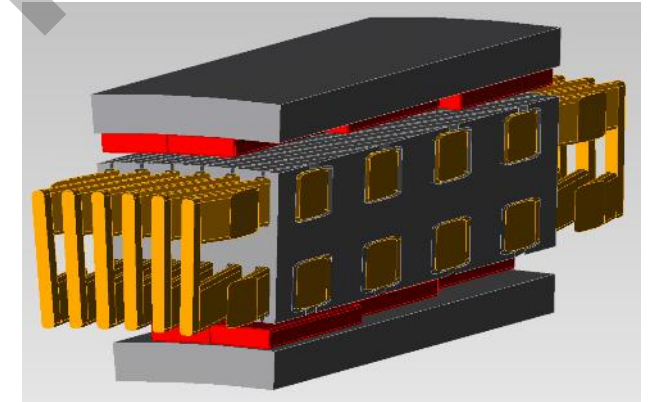
per case



Three phases, magnets in both rotors



Mesh of the model shown: ~432k elements



Parametric CAD model (JMAG CAD Editor)

Electromagnetic model

- FEM conductors: coil AC losses
- Eddy currents in winding and rotor back iron
- Anti-periodic symmetry condition
- Counter-skewed conductors
- Counter-skewed rotors, 3 magnet slices

Mesh and time stepping

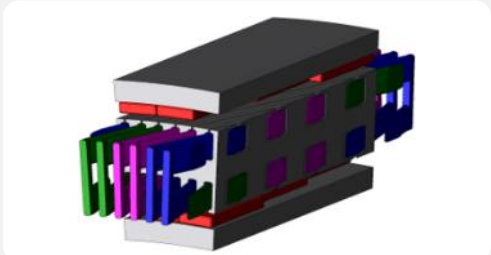
- Extruded mesh in the rotors
- Free, non-extruded mesh in the stator
- 320k–400k elements per design
- 31 time steps: 16 to settle the eddy currents, 15 evaluated in steady state
- 22 operating points per design

Study, HPC and licence

- 641 designs × 22 OP = 14 102 cases
- One partition, 6 nodes, each:
 - 2 × EPYC 9354: 64 cores, 3.25 GHz
 - 768 GB DDR5-4800, InfiniBand HDR100
- JMAG PSL200: TR 3D transient solver, LS iron loss, PP pre/post

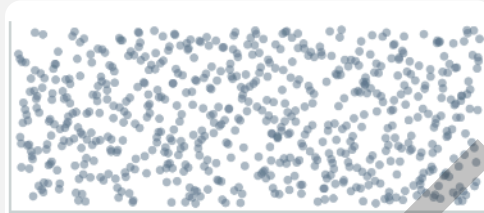
Method: From 3D FE Model to Surrogate Model

STEP 1 JMAG 3D model



- Double rotor, $q = 2$, incl. end windings
- ψ , torque, ripple and losses at 1 and 1000 rpm
- Br 1.4 T at 20 °C, copper at 80 °C

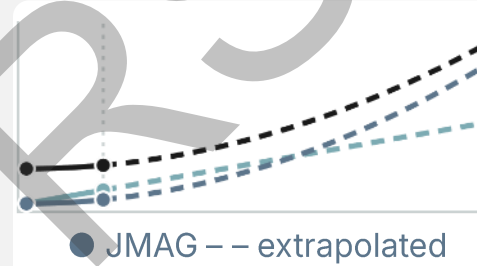
STEP 2 Design space sampling



x: lFe 60–80 mm · y: hCu 5–8 mm

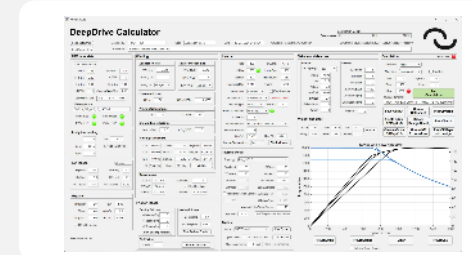
- 641 designs, 10 free parameters
- p, lFe, conductor, yoke, magnet, tubes, skew
- $r_{2,a} = 207.1$ mm fixed; $r_{2,i}$, bMag and $r_{3,a}$ follow

STEP 3 Speed extrapolation



- Hysteresis $\propto n$, eddy currents $\propto n^2$
- Copper: DC from 1 rpm, AC = $P(1000) - P(DC)$, $\propto n^2$
- Id/Iq map up to 6000 rpm, read-back ≤ 0.3 %

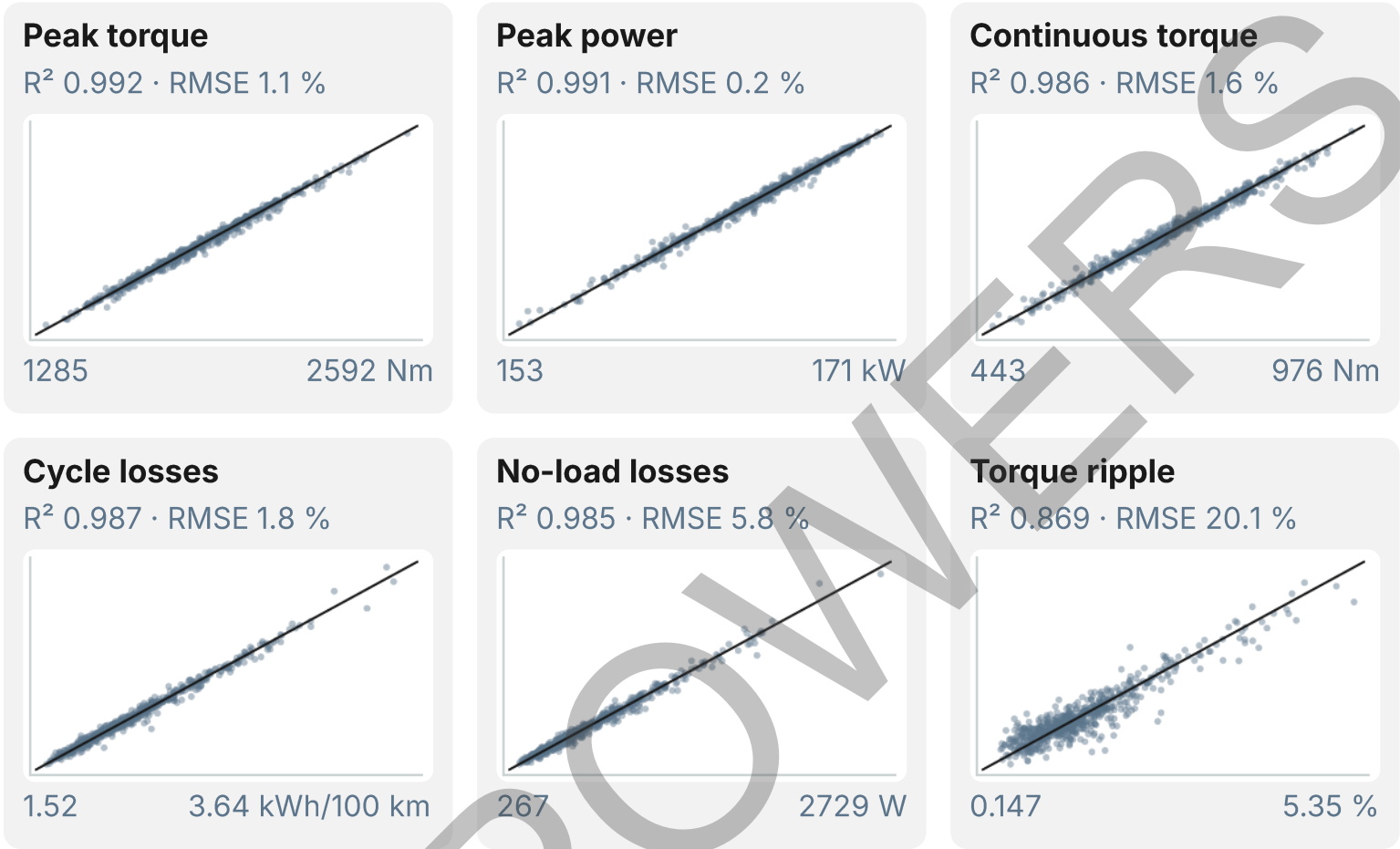
STEP 4 DeepDrive Calculator



- CalcEM with the DDC template: 19 KPIs per design
- 3D end winding off, DDC end winding 15/12 mm on
- PWM and UHF losses scaled from RM025

OUTPUT 641 designs $\times$ 19 KPIs $\rightarrow$ Gaussian-process surrogate (cross-validated $R^2 \geq 0.985$ for the main KPIs) $\rightarrow$ NSGA-II trade-off fronts

Surrogate quality: predicted vs. calculated KPIs



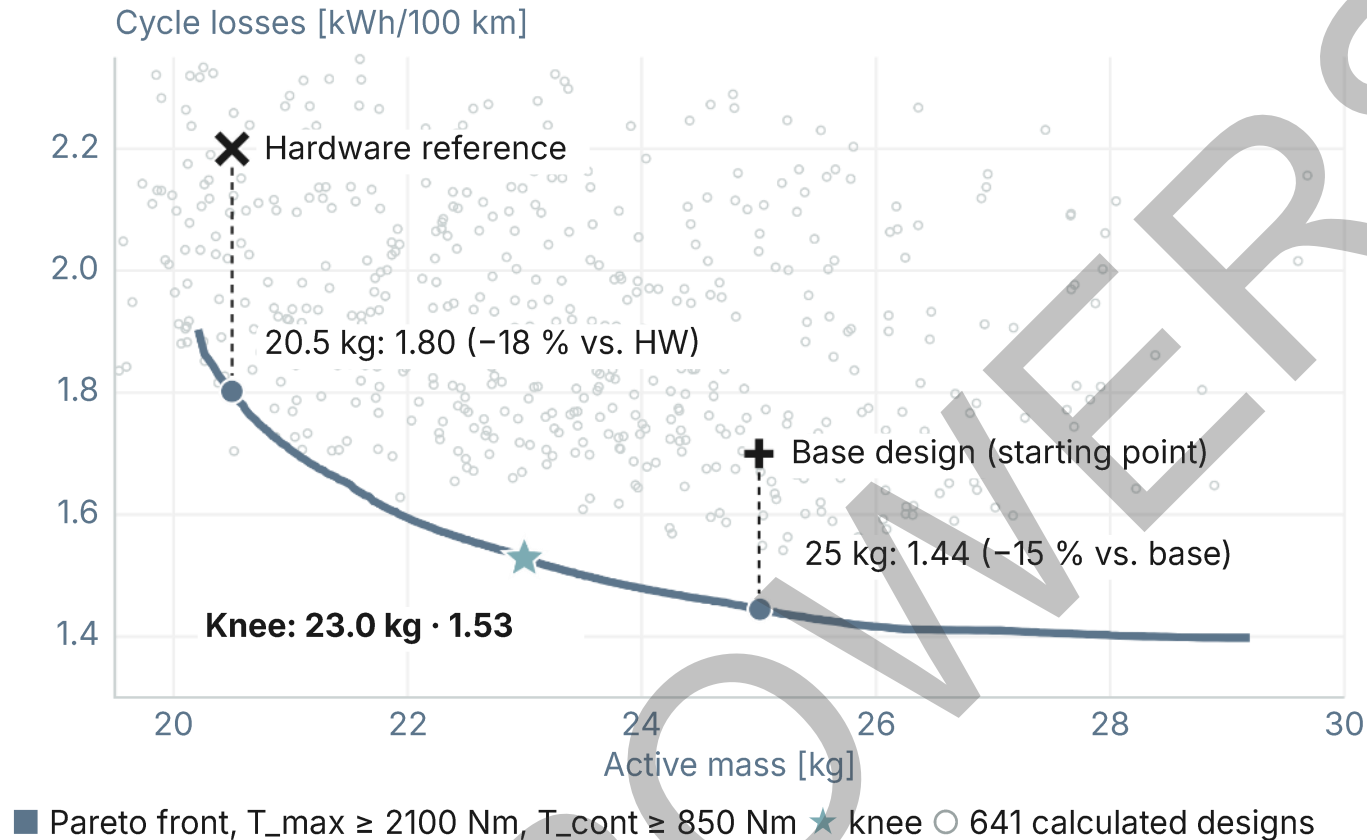
Accuracy of all 19 KPIs

KPI	CV R²	RMSE
Peak torque	0.992	1.1 %
Peak power	0.991	0.2 %
Continuous torque	0.986	1.6 %
Cycle losses	0.987	1.8 %
Cycle efficiency	0.987	0.2 %
No-load losses	0.985	5.8 %
Loss constant	0.989	2.3 %
Losses at T_max	1.000	< 0.1 %
Masses	1.000	< 0.1 %
Torque ripple (6)	0.57–0.87	20–41 %

90 % band holds; checked to distance 0.77, final fronts at 0.59–0.63.

Optimisation results: cycle losses vs. active mass

Minimise cycle losses and active mass · on the 90 % band: $T_{\max} \geq 2100$ Nm, $T_{\text{cont}} \geq 850$ Nm, Pk2Pk ripple ≤ 2.5 %, $P_{\max} \geq 150$ kW



Candidates vs. the references

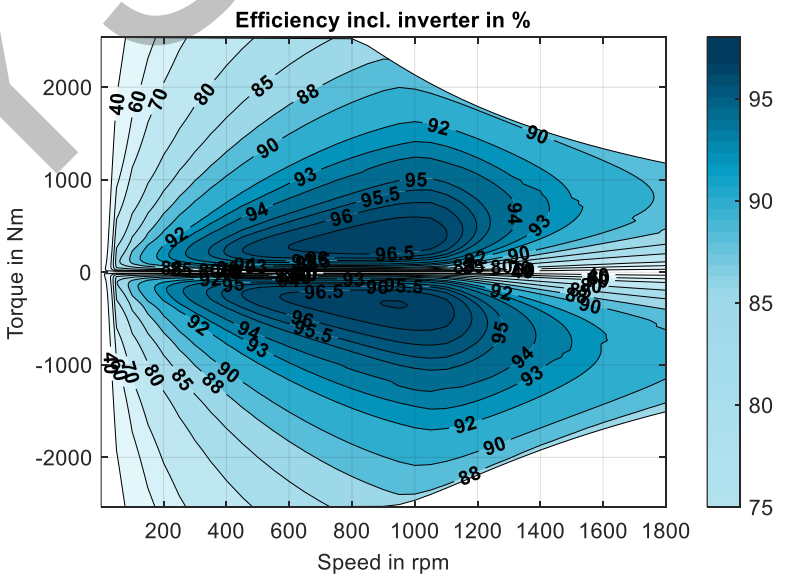
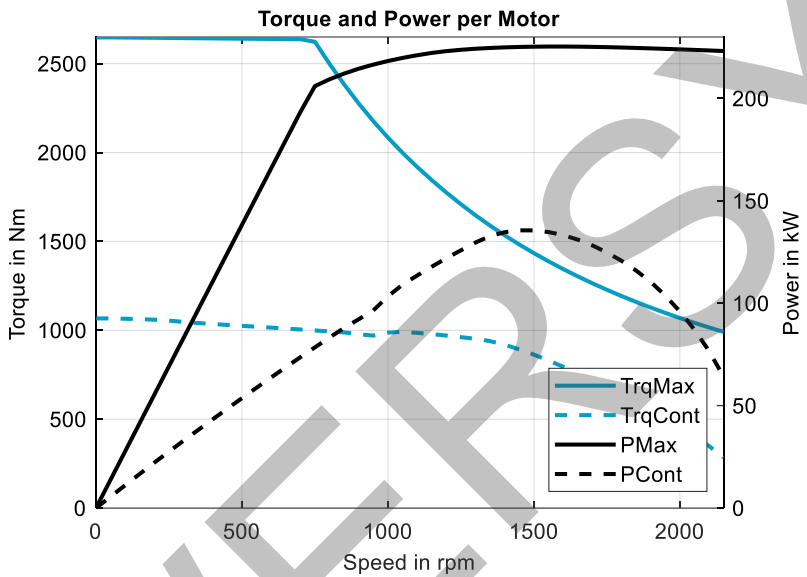
Design	Mass	Cycle	$T_{\max}$	T_{cont}
Knee	23.0	1.53	2137	875
20.5 kg variant	20.5	1.80	2150	879
25 kg variant	25.0	1.44	2155	876
Base design	25.0	1.70	2200	900
Hardware ref.	20.5	2.20	1900	650

Mass in kg, cycle losses in kWh/100 km, torques in Nm

At the hardware reference's mass: 18 % lower cycle losses, 13 % more peak and 35 % more continuous torque.

At the base design's mass: 15 % lower cycle losses, but 2 % less peak torque (the 2100 Nm limit).

In Wheel Motor IW2600 – DeepDrive Gen2



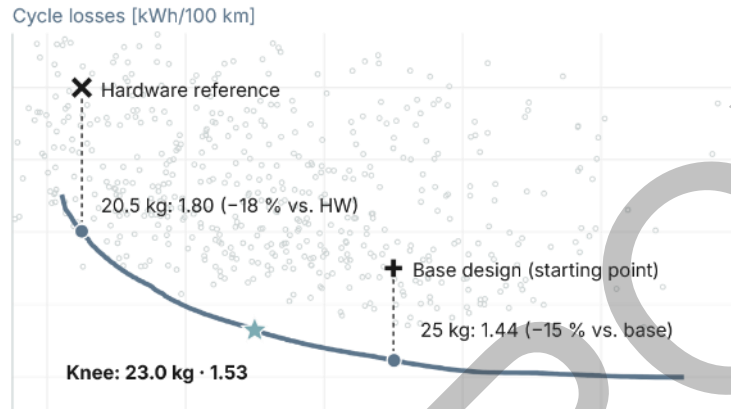
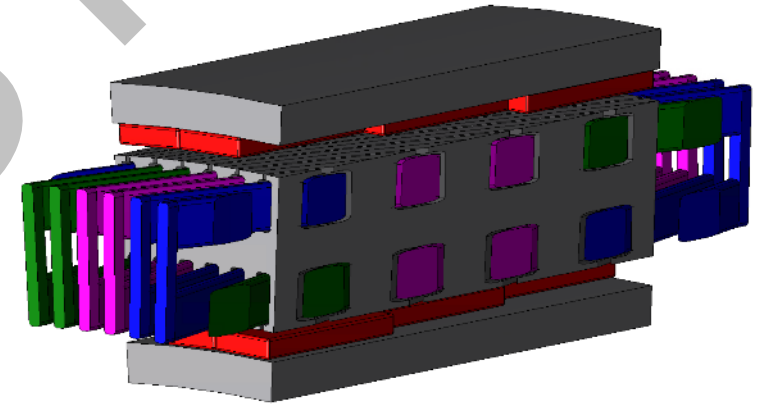
Name	DeepDrive 19"
Torque Peak Cont.	2600 Nm 1000 Nm
Torque Peak Cont.	220 kW 120 kW
DC voltage	600-1000 Vdc
Coolant temperature	60°C
Coolant flow rate	8 l/min
Max. Speed	>2200 rpm (>260 km/h)
Diameter active part	430 mm (19" Rim)
Weight IWM incl. inverter*	38 kg
System weight incl. brake	46 kg

- Plug & Play system for 19" rims with integrated SiC inverter
- **Worlds most efficient EV powertrain**
 - Integrated Brake system
- Lowest BOM cost, competitive to conventional EDU

Conclusion + Outlook

Conclusion

- Dual Rotor Technology requires 3D Simulation to cover all relevant effects like Torque-ripple, losses etc.
- 3D Optimization based on surrogate models offers an efficient and accurate approach for design optimization
- Significant cost savings or efficiency improvements can be achieved
- Subsequent multi-target optimization allows very fast adaption of designs to customer requirements



Next Steps

- Include PWM harmonic losses in full 3D model (currently covered by simplified 2D approach)
- Extend model parameter space to improve accuracy and extend validity of model
- Transfer approach to new applications
- Validate optimized model in IWM Gen 2 hardware



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