Zielkonflikte in der E-Maschinenentwicklung elegant lösen

Guillermo Zschaeck & Bernhard Scharinger

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Agenda

- Zielkonflikte in der Entwicklung von Elektroantrieben erkennen
- Lösungsansätze mit Motorsolve und HEEDS identifizieren
- Live Demo und Vorstellung des Workflows
- Zusammenfassung und Q&A

Guillermo Zschaeck

Senior Application Engineer, HEEDS Technical Team

- Customer support & training
- Support pre-sales/sales activities
- Support product management, development & marketing of HEEDS

Experience & Education

- 2016-2019 Siemens CT eAircraft, Thermal Management
- 2011-2016 ANSYS, Senior Consultant (CFD)
- 2007-2011 ANSYS, Application Engineer (CFD)

- 2005 MSc Chemical Engineering, Uni Erlangen, Germany
- 2000 BSc Chemical Engineering, Uni Caracas, Venezuela

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Bernhard Scharinger

Portfolio Developer, Simulation & Testing Solutions

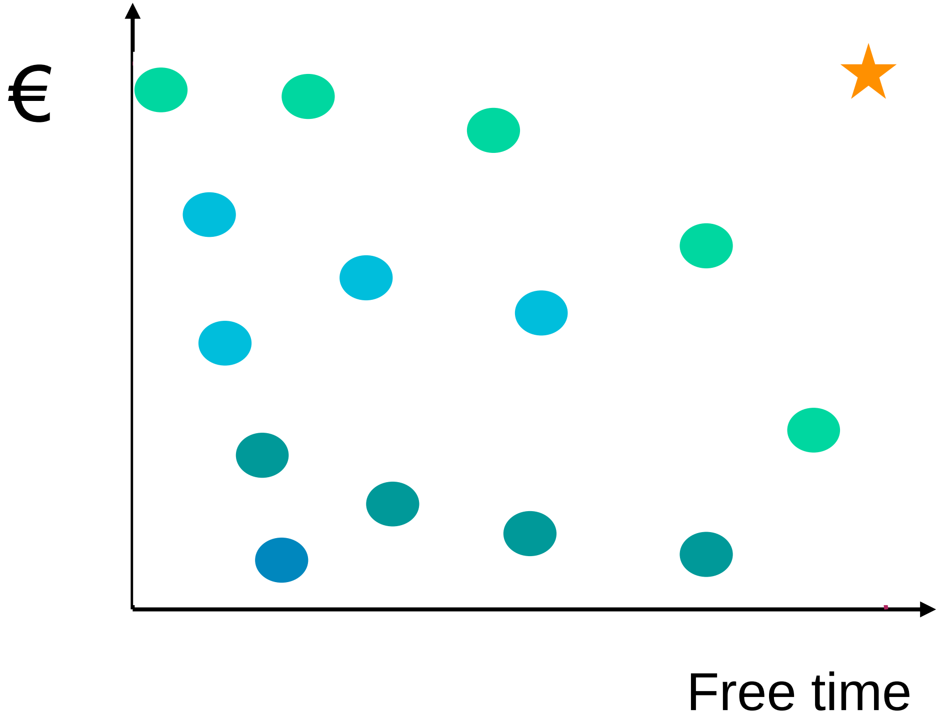
- Technical sales support
- Business Planning
- Marketing Initiatives

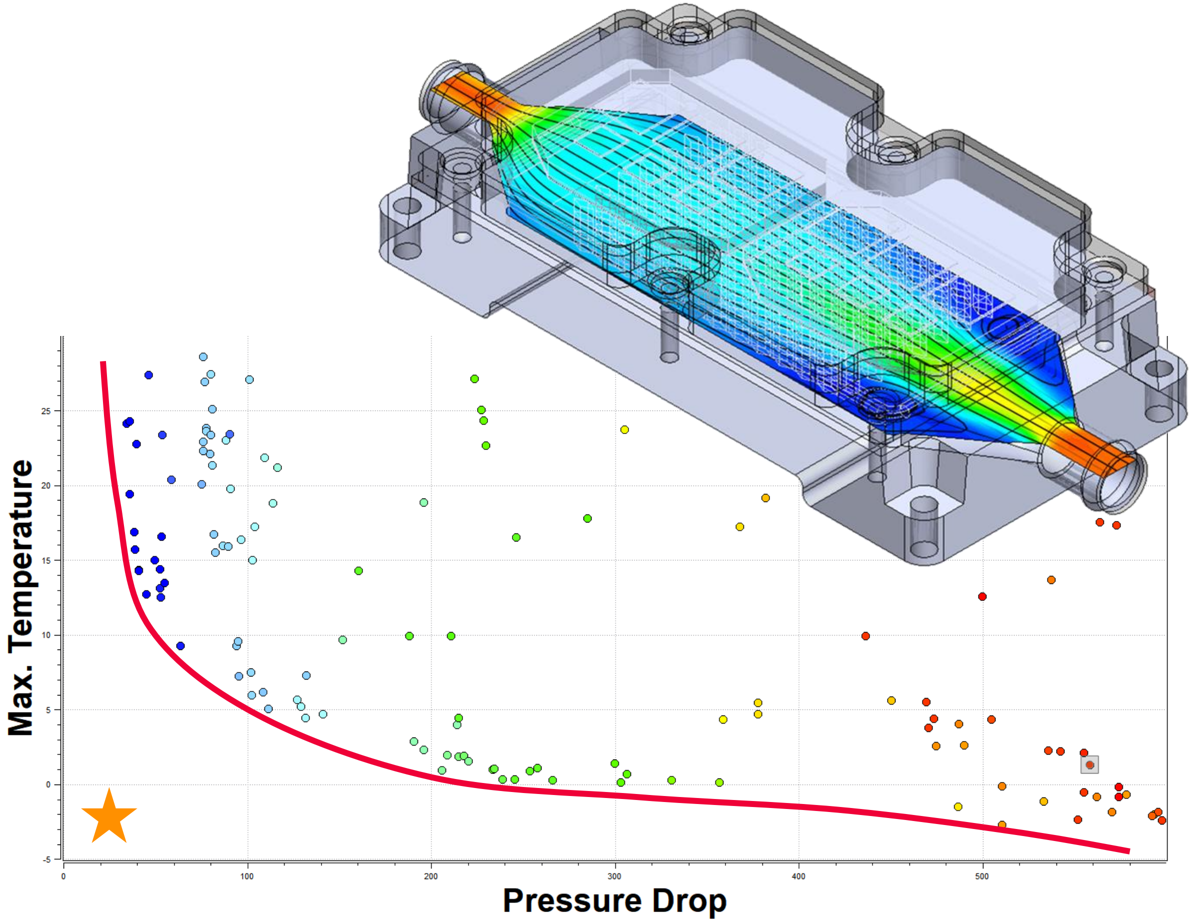
Experience & Education

- 2017-2019 Siemens DISW Presales Simcenter 3D
- 2014-2016 WINTERSTEIGER, Simulation Engineer
- 2009-2014 ZKW Group, Simulation Engineer

- 2008 DI(FH) Material Engineering, Wels, Austria
- 2002 HTL für Maschinenbau, Wels, Austria

What is a target conflict?



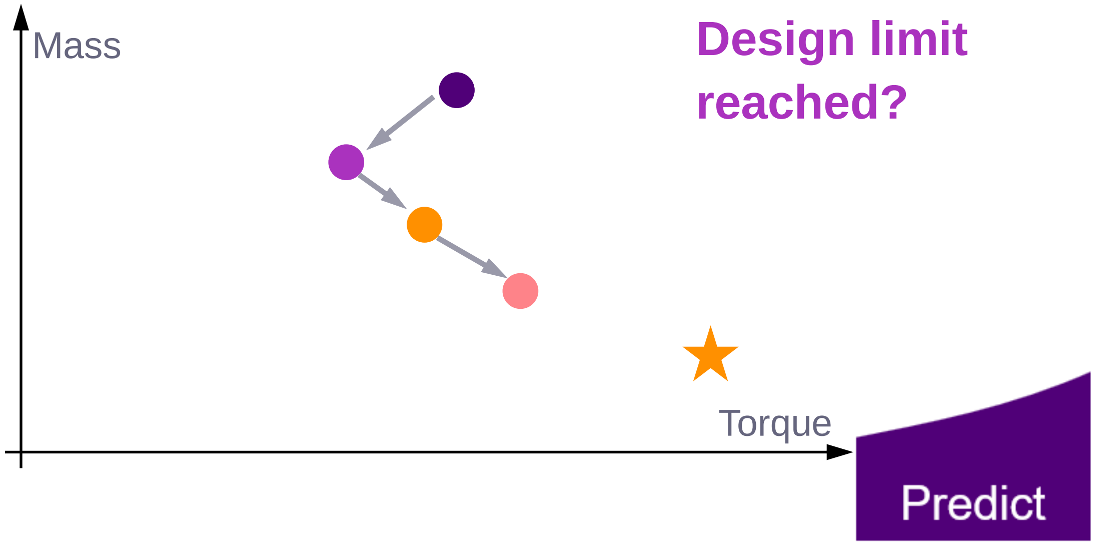


Simulation versus Design Space Exploration

Manual Simulation

Based on experience

- Step-by-step, trial & error approach

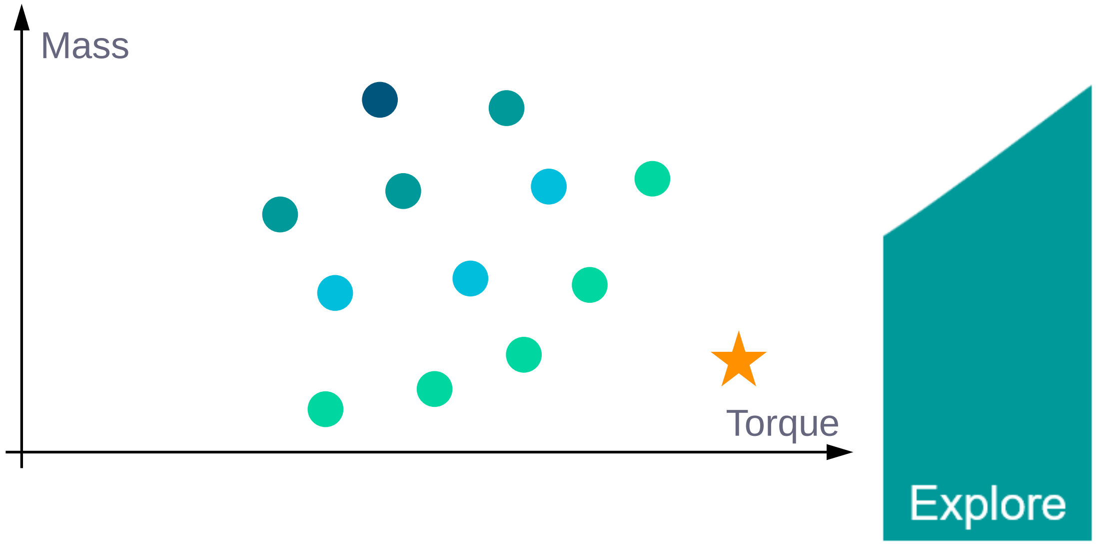


Possible for a few parameters
Time-consuming, requires experience

Alternative Method

HEEDS – Focus on objectives

- Targeted parameter modifications



For large number of parameters
No needs for special optimization knowledge

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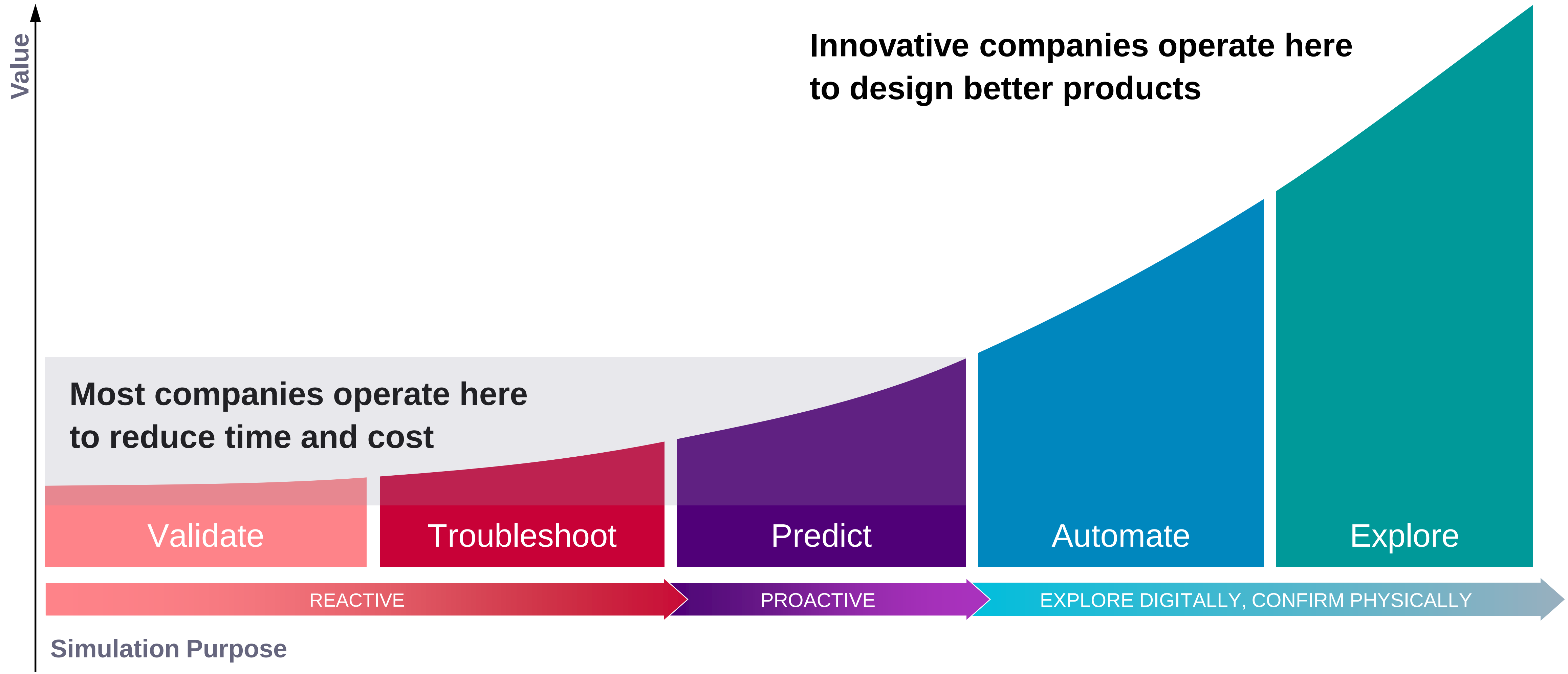
Simulation Strategy for Innovation



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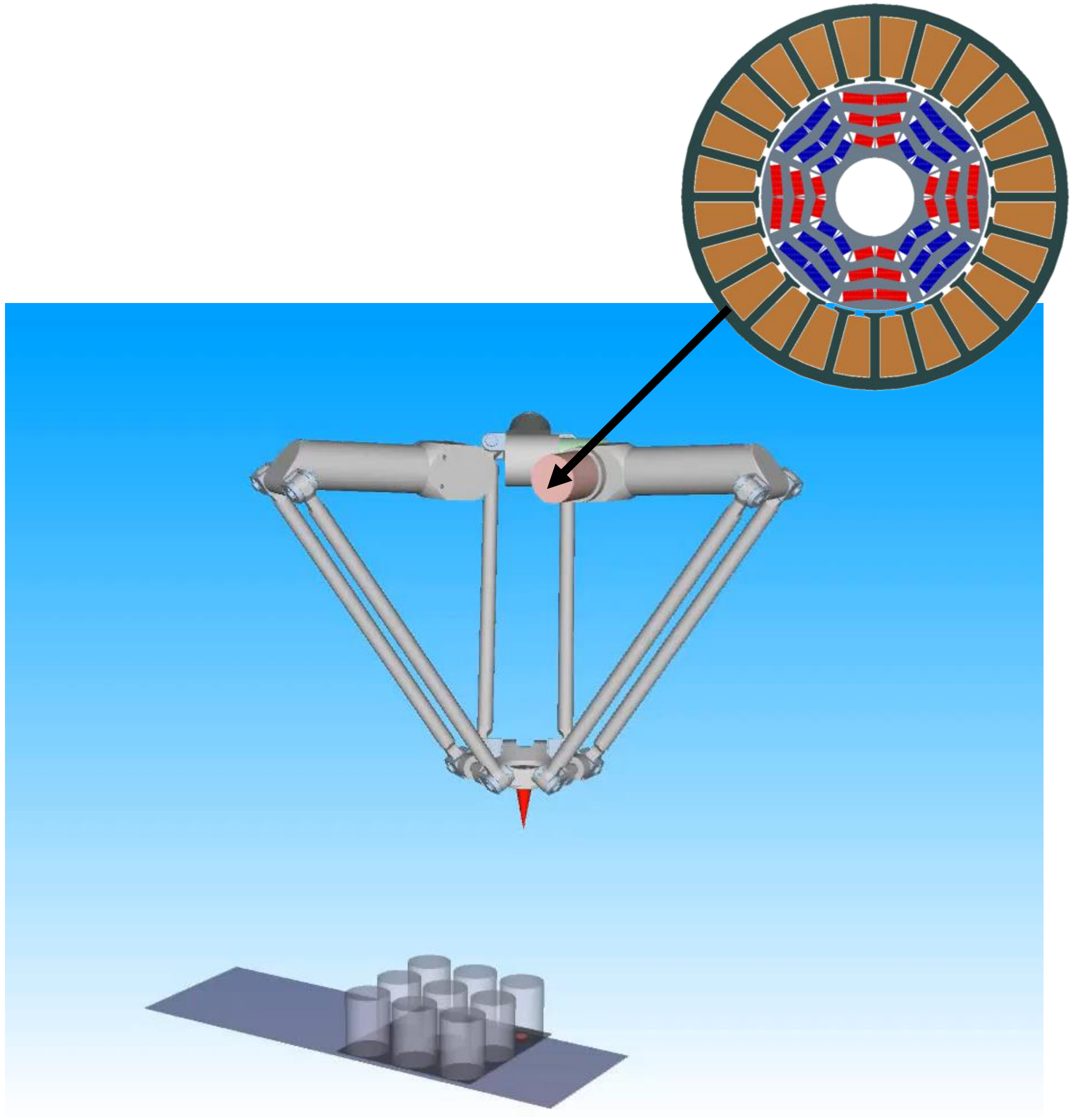
Case Study: eMotor for Robotic Arm

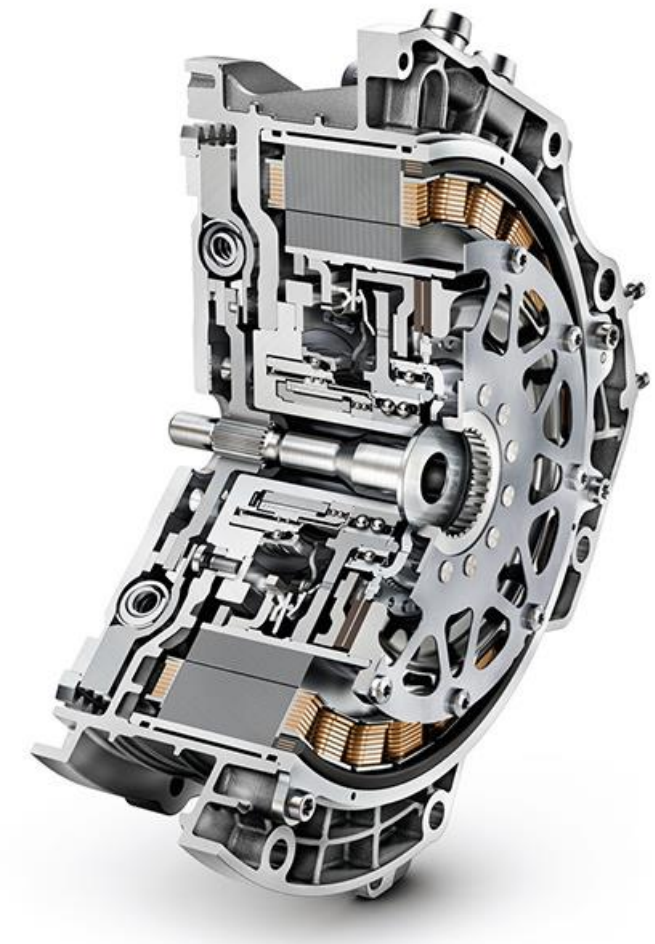
- Robotic arms are widely used in industry automation

- Improve eMotor performance
  - Maximize torque
  - Minimize mass of permanent magnets
  - Minimize torque ripple

- Change 22x geometric parameters
- External diameter & length are fixed



Modern Electric Motors Engineering Challenges



Operational Excellence

- Maximize power density and efficiency in a **wide speed range**
- Guarantee a robust and reliable operation
- Low Noise and Vibration (**NVH**), reduce torque ripple

Cost Reduction

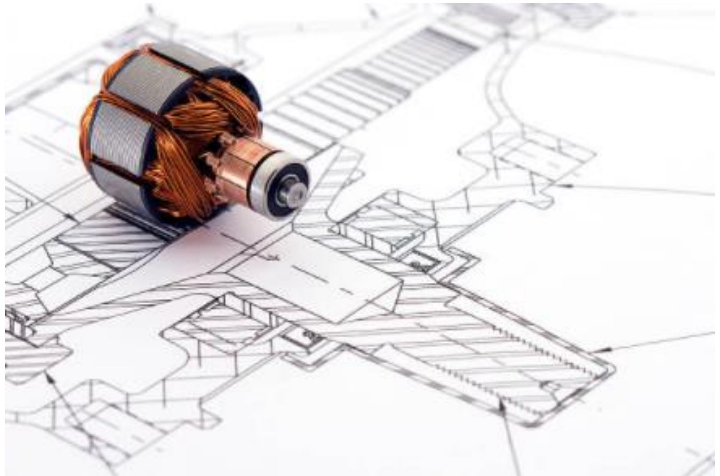
- Reduce rare earth material usage
- **Seamless collaboration** among emag, thermal, structure and acoustics engineers

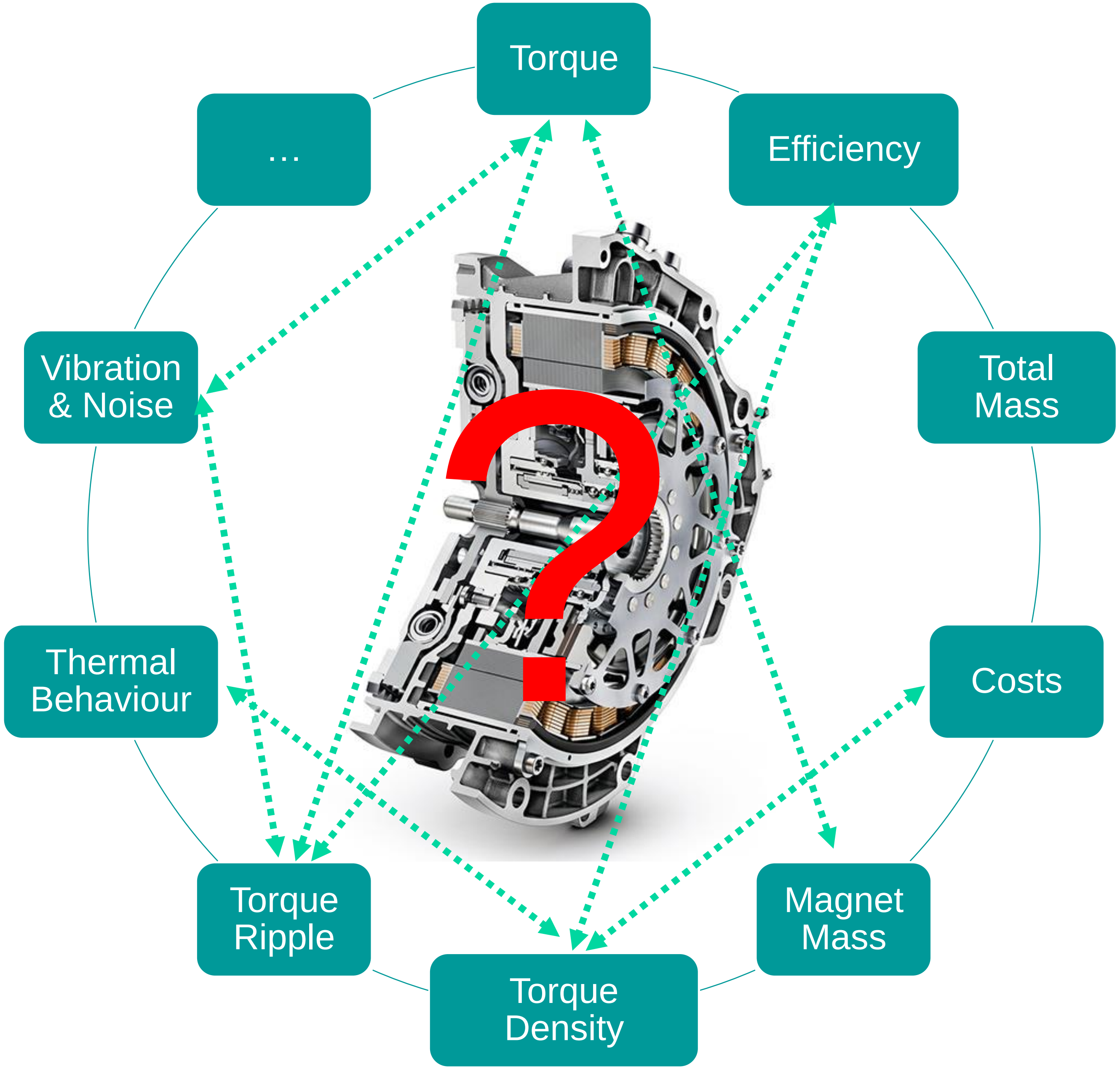
Innovation

- Improve **integration with system**
- Accelerate product development with **digital twin framework**

Objectives & Trade-Offs

- Some trade-offs are known for each discipline
- As complexity increases, trade-offs must be „discovered“

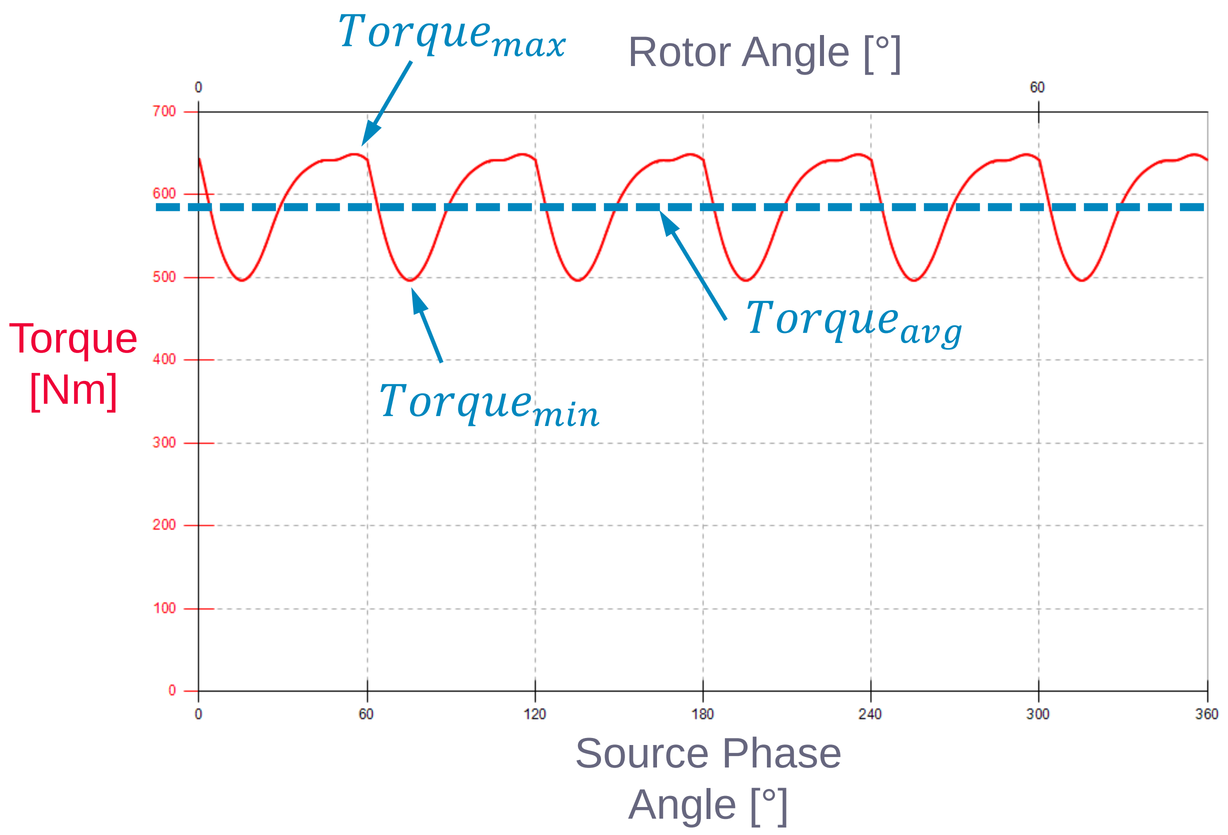




Electric Motor Terminology
Torque Ripple

Torque Ripple is one of the main cause of vibration & acoustic noise in e-motors

$$Torque\ Ripple = \frac{Torque_{max} - Torque_{min}}{Torque_{ave}}$$



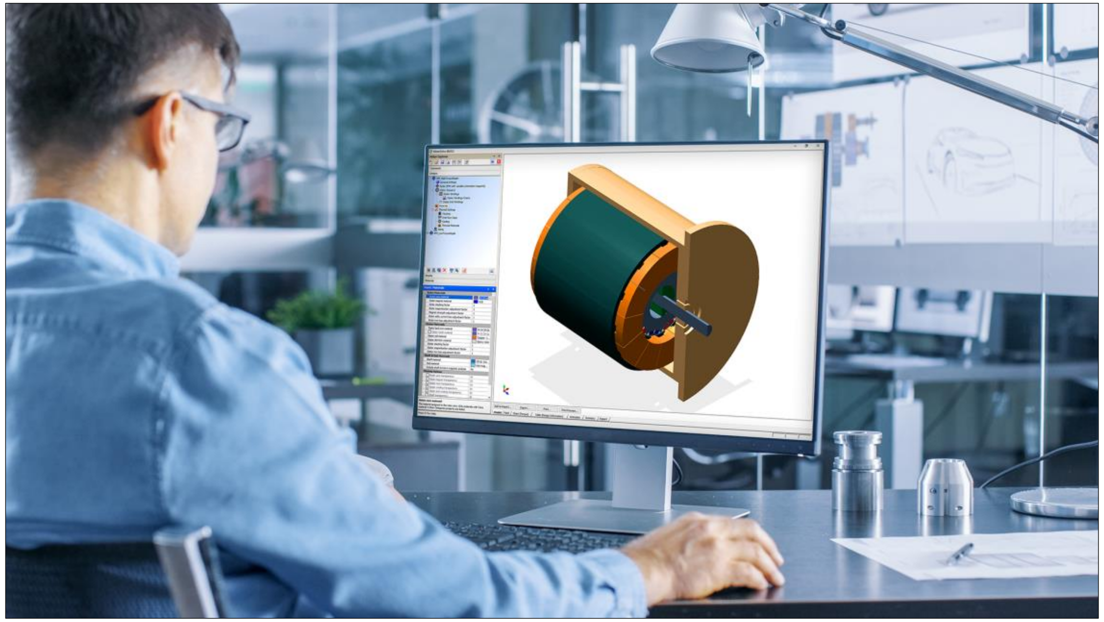
Simcenter Motorsolve
Simulation Software

Software to design and analyze electrical machines

- Permanent magnets, induction, synchronous, brush-commutated

User-friendly interface and handling

- Flexible templates for practically any motor
- Pre- & Post-processing environment
- Automation capabilities



HEEDS
Design Exploration Software

HEEDS automates and accelerates the exploration of a large design space

Useful for detailed component design as well as complex, multi-disciplinary system simulations

Driving Innovation

- Until now simulation was used for single evaluations of a design
- Now you specify goals and requirements for a design
- HEEDS searches for possible solutions in the design space

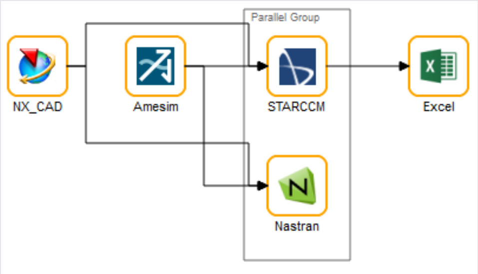
Discover Better Designs, *Faster!*

HEEDS Key Technologies

Engineer

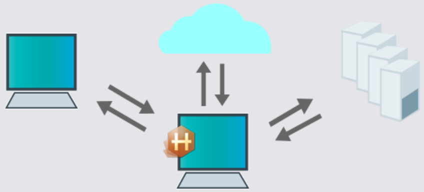
Workflow Management

Automates data sharing in desired workflows



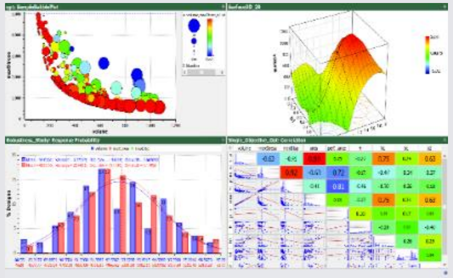
Distributed Execution

Manages various compute resources (Linux, Windows, Cloud)



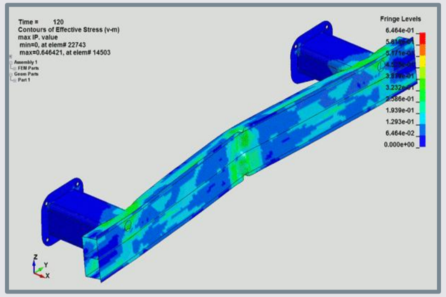
Insight & Discovery

Post-processing images, tables, 2-D, 3-D plots, and more!



Efficient Search

Discovers better designs, *faster!*



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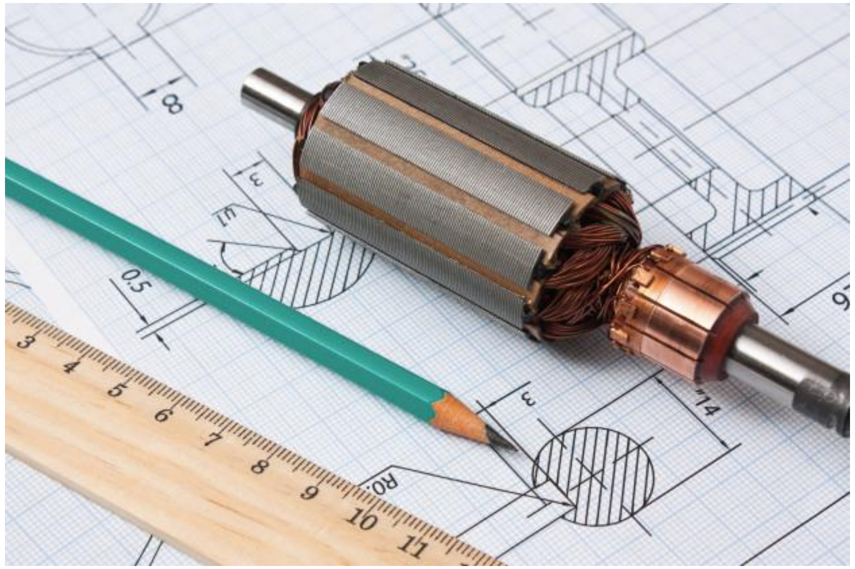
Case Study
HEEDS and Simcenter Motorsolve

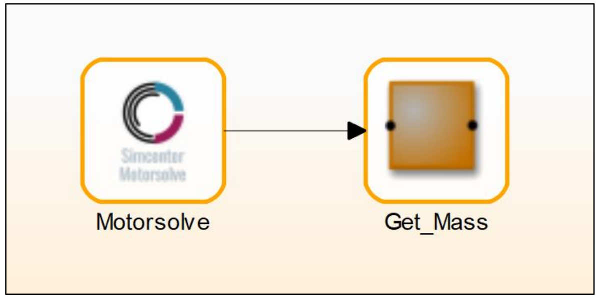
Challenge
- Maximize torque
- Minimize torque ripple
- Minimize magnet's mass

2D-FEM Simulation
- Brushless DC (BLDC) with Interior Permanent Magnets (IPM)

Design variables
- 22 design variables

Tools
- Simcenter Motorsolve
- HEEDS





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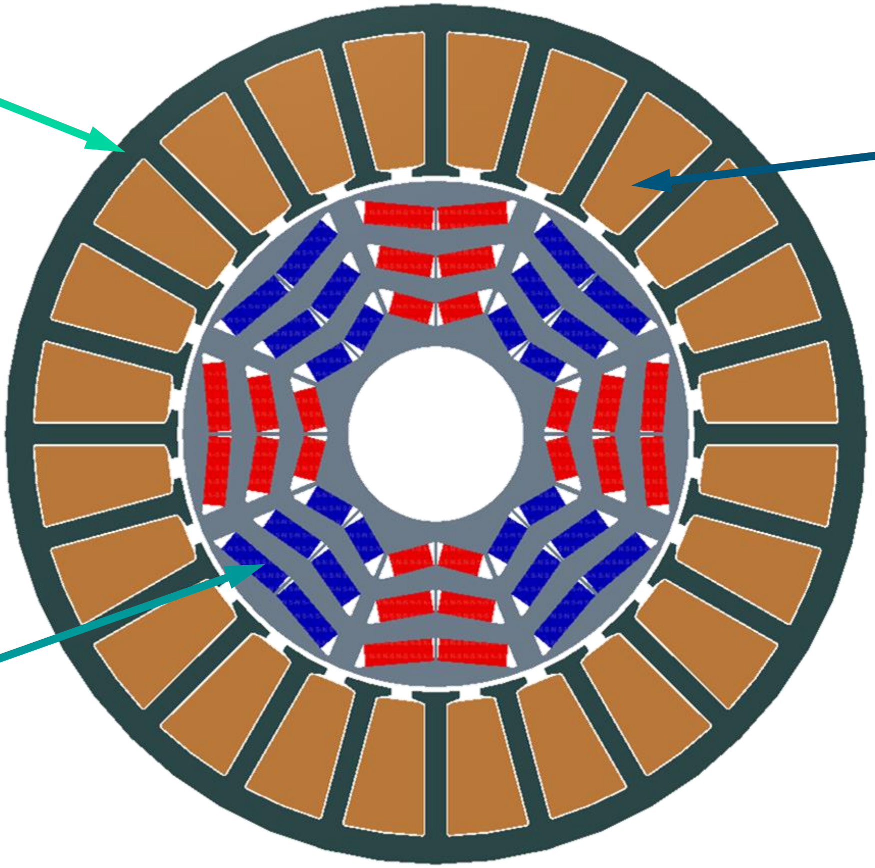
Design Variables Overview
Simcenter Motorsolve

General settings
- Advance Angle

Stator
- Slot depth
- Slot opening width
- Tooth tip thickness
- Tooth width

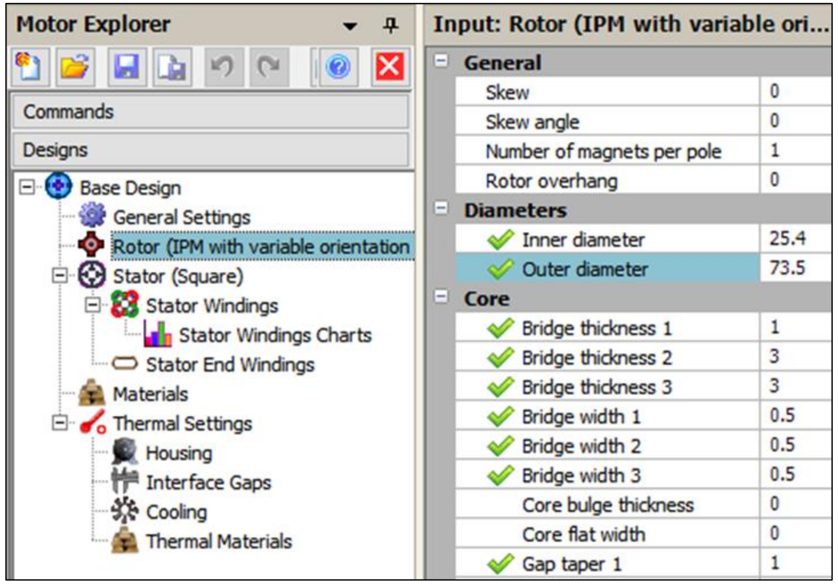


Rotor
- Inner diameter
- Outer diameter
- Magnet width x3
- Magnet thickness x3
- Magnet orientation x3
- Bridge thickness x3
- Web thickness x3

Model Modification & Automated Simulation

- The direct interface between HEEDS and Simcenter Motorsolve allows a simple model modification and automated simulation

Simcenter Motorsolve



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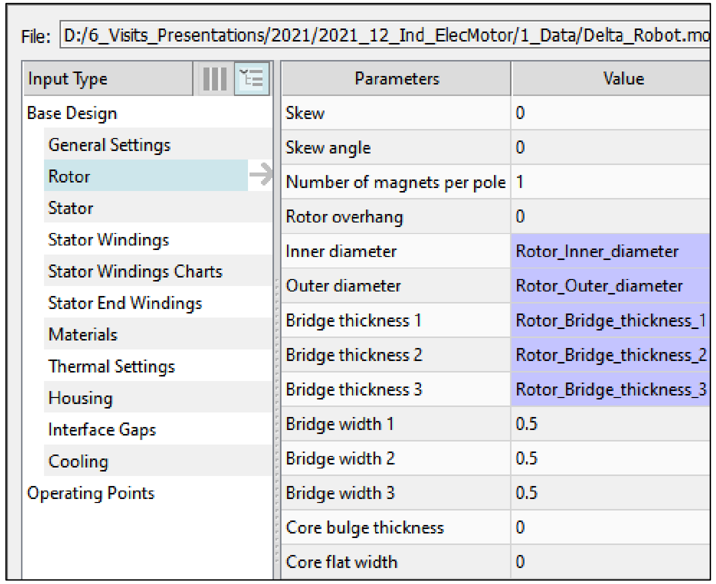

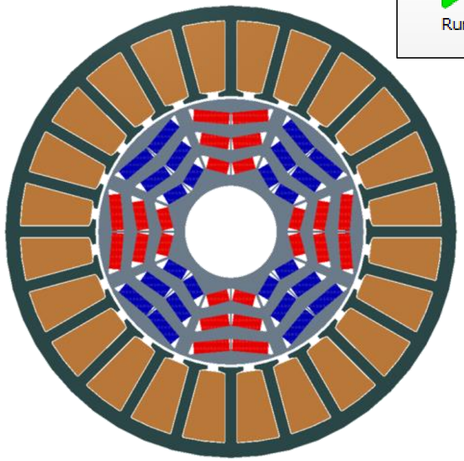

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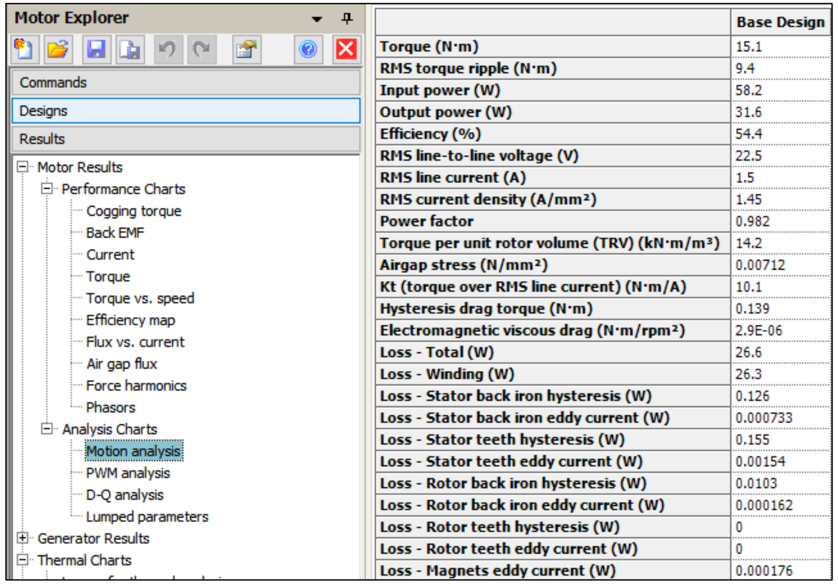
Extraction of Simulation Results

- HEEDS extracts available simulation results from Simcenter Motorsolve
- Data is transfer to subsequent tools in the workflow

Simcenter Motorsolve



	Base Design
Torque (N·m)	15.1
RMS torque ripple (N·m)	9.4
Input power (W)	58.2
Output power (W)	31.6
Efficiency (%)	54.4
RMS line-to-line voltage (V)	22.5
RMS line current (A)	1.5
RMS current density (A/mm²)	1.45
Power factor	0.982
Torque per unit rotor volume (TRV) (kN·m/m³)	14.2
Airgap stress (N/mm²)	0.00712
Kt (torque over RMS line current) (N·m/A)	10.1
Hysteresis drag torque (N·m)	0.139
Electromagnetic viscous drag (N·m/rpm²)	2.9E-06
Loss - Total (W)	26.6
Loss - Winding (W)	26.3
Loss - Stator back iron hysteresis (W)	0.126
Loss - Stator back iron eddy current (W)	0.000733
Loss - Stator teeth hysteresis (W)	0.155
Loss - Stator teeth eddy current (W)	0.00154
Loss - Rotor back iron hysteresis (W)	0.0103
Loss - Rotor back iron eddy current (W)	0.000162
Loss - Rotor teeth hysteresis (W)	0
Loss - Rotor teeth eddy current (W)	0
Loss - Magnets eddy current (W)	0.000176

Simcenter Motorsolve

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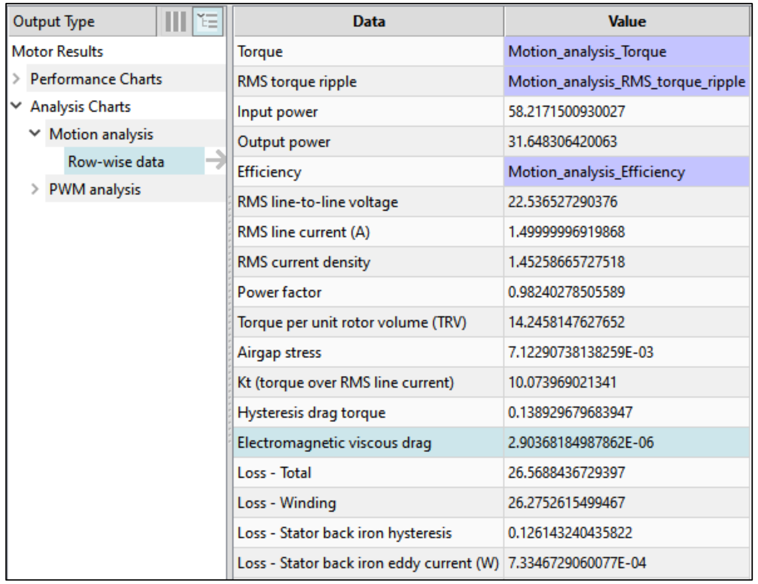
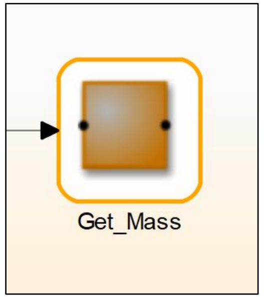
Portal

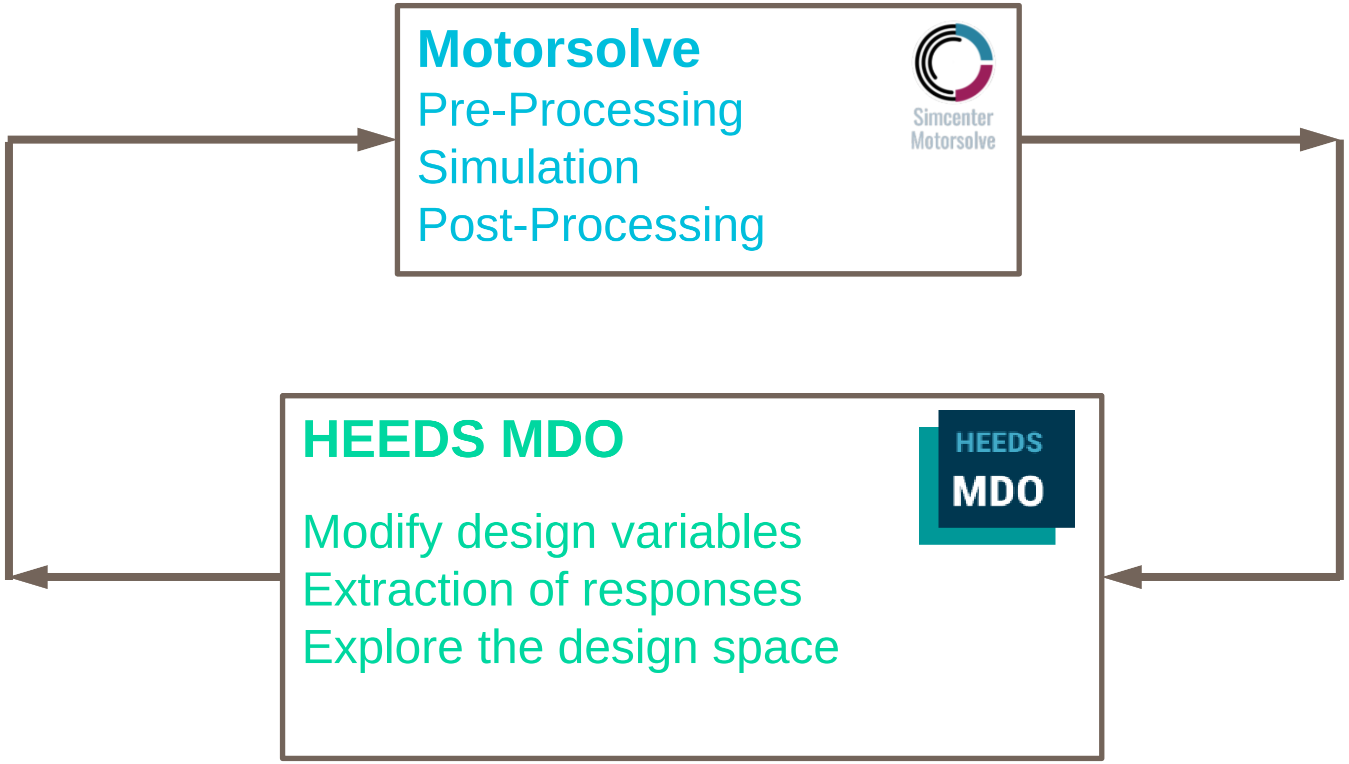
HEEDS MDO



Data	Value
Torque	Motion_analysis_Torque
RMS torque ripple	Motion_analysis_RMS_torque_ripple
Input power	58.2171500930027
Output power	31.648306420063
Efficiency	Motion_analysis_Efficiency
RMS line-to-line voltage	22.536527290376
RMS line current (A)	1.49999996919868
RMS current density	1.45258665727518
Power factor	0.98240278505589
Torque per unit rotor volume (TRV)	14.2458147627652
Airgap stress	7.12290738138259E-03
Kt (torque over RMS line current)	10.073969021341
Hysteresis drag torque	0.138929679683947
Electromagnetic viscous drag	2.90368184987862E-06
Loss - Total	26.5688436729397
Loss - Winding	26.2752615499467
Loss - Stator back iron hysteresis	0.126143240435822
Loss - Stator back iron eddy current (W)	7.3346729060077E-04

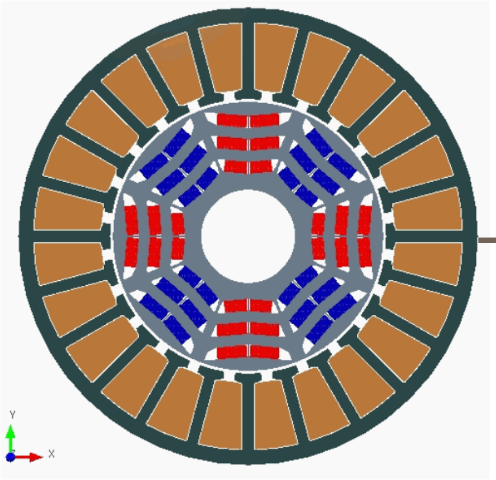


Process Automation
HEEDS



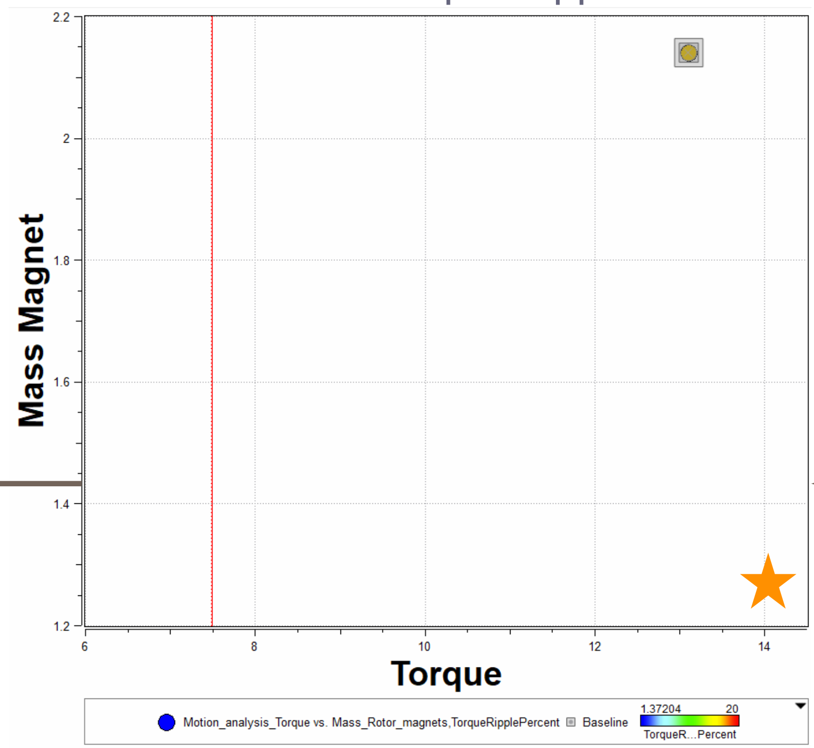
Efficient Design Space Exploration

Simcenter Motorsolve

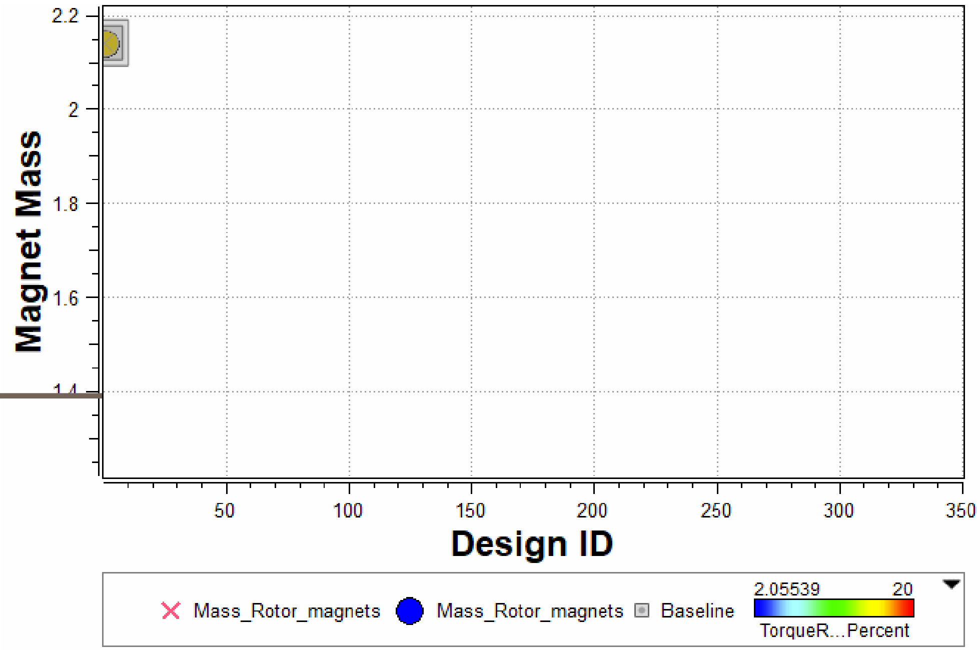


Simcenter Motorsolve

Maximize Torque
Minimize Mass
Minimize Torque Ripple



Search design space

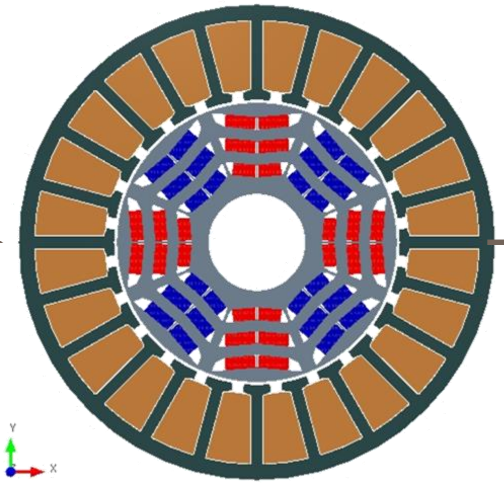


HEEDS MDO

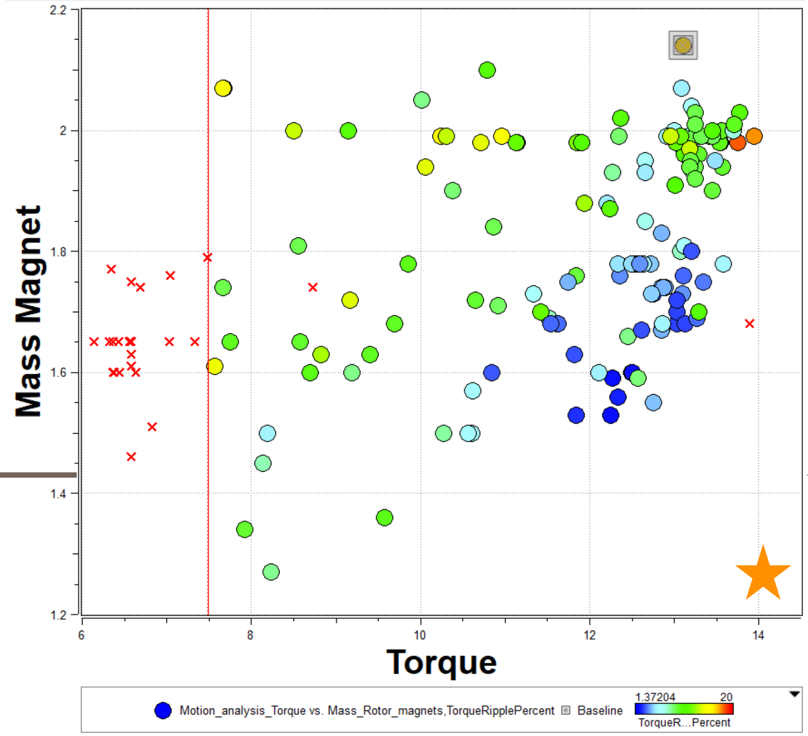
HEEDS MDO

Efficient Design Space Exploration

Simcenter Motorsolve



Maximize Torque
Minimize Mass
Minimize Torque Ripple



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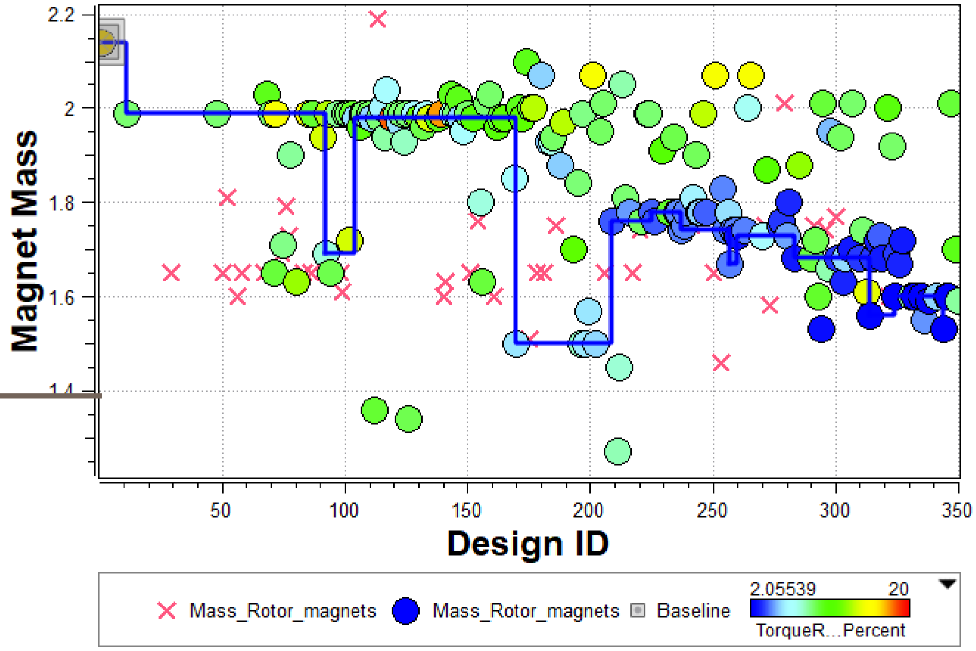

HEEDS MDO

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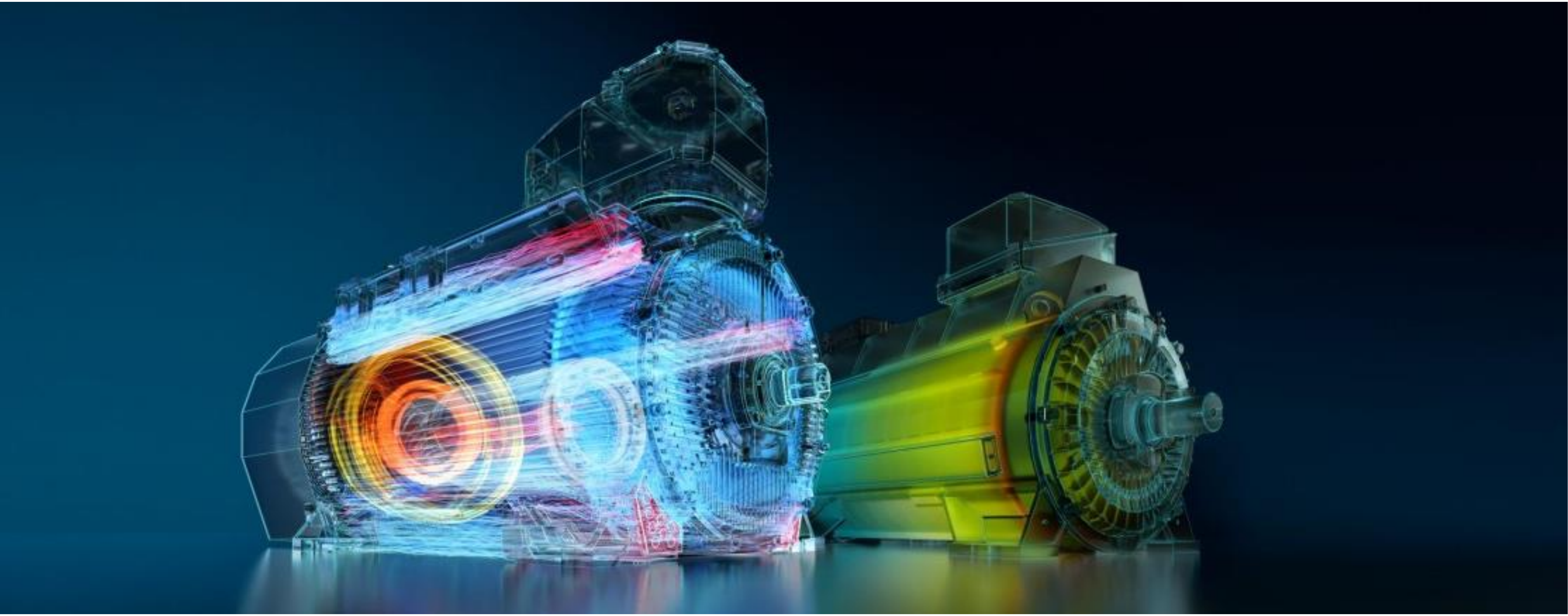
HEEDS Demonstration



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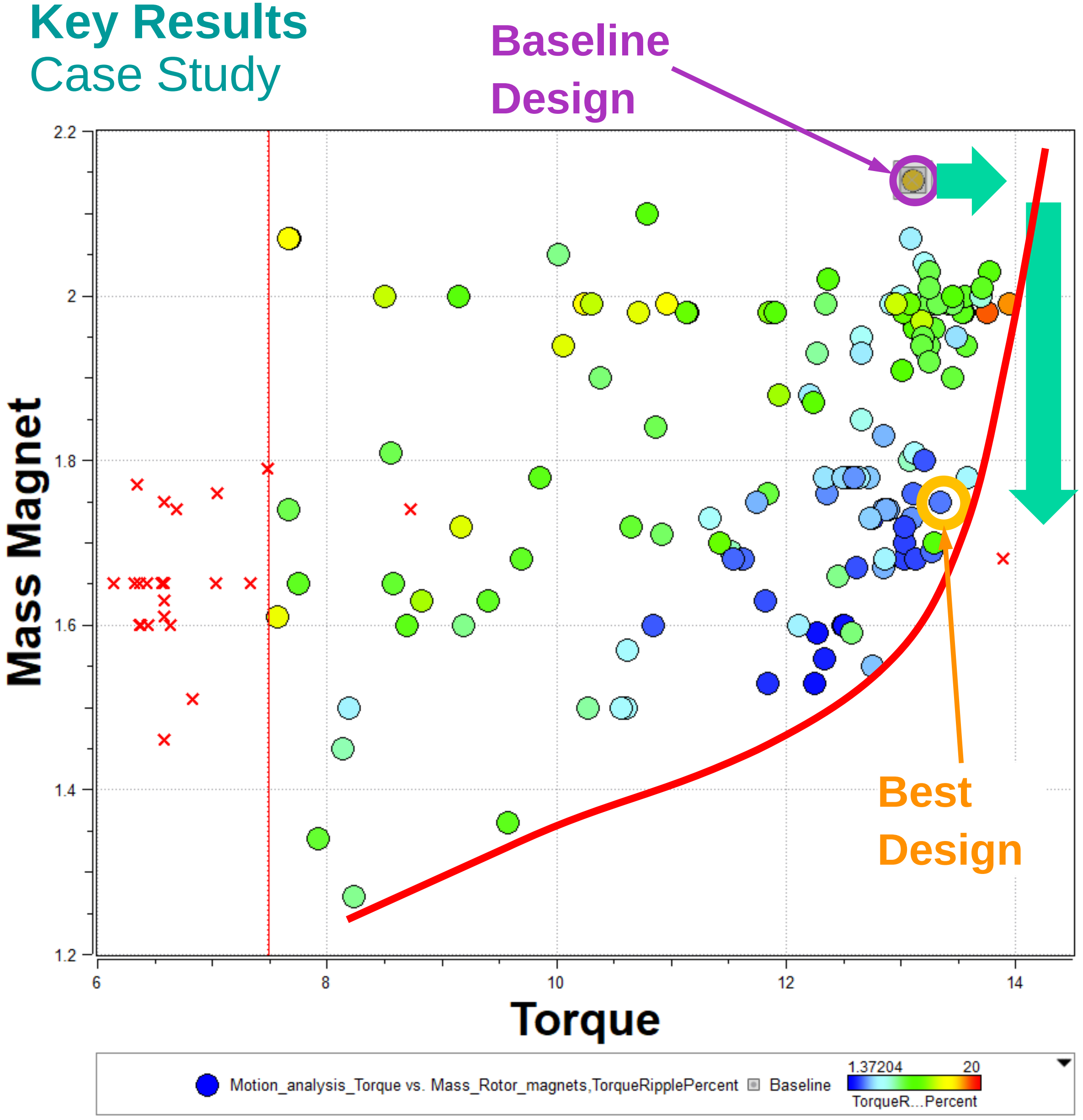
Key Results
Case Study



Design Exploration

- Searched 350 design evaluations
- Fulfilled requirements for torque and torque ripple
- Maximized torque
- Minimized mass and torque ripple ratio

Design Improvements

- Best vs baseline design
  - Improved torque by 4%
  - Improved mass by 18%
  - Improved torque ripple ratio by 78%

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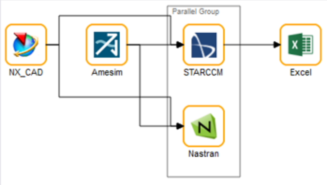
Summary

- Discussed challenges in e-motor design
- Introduced HEEDS & Simcenter Motorsolve
- HEEDS‘ portals to CAE tools
- Demonstrated HEEDS capabilities for multi-objective optimization

Workflow Management

Automates data sharing in desired workflows



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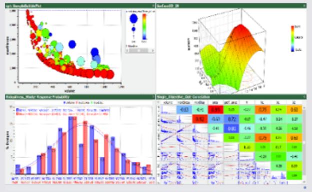
Insight & Discovery

Post-processing images, tables, 2-D, 3-D plots, and more!



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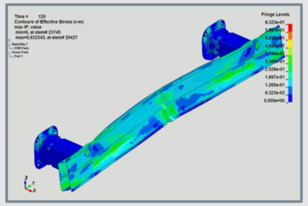
Discovers better designs, *faster!*



Discover Better Designs, *Faster*

Q & A