DRD TECHNOLOGY

# Fast, Efficient Solutions for Motor Design

Duncan Staggs – Senior Applications Engineer

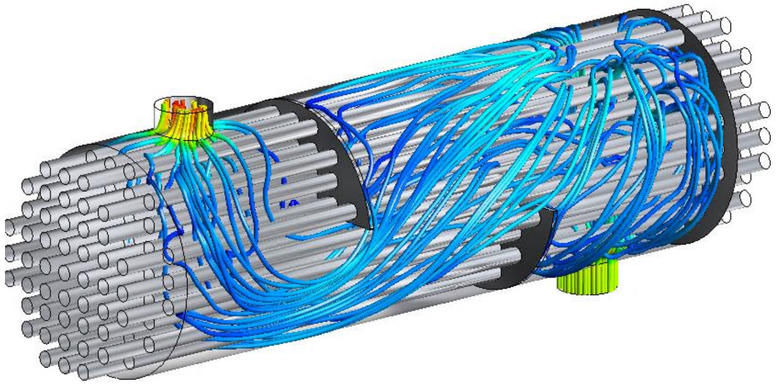
DRD

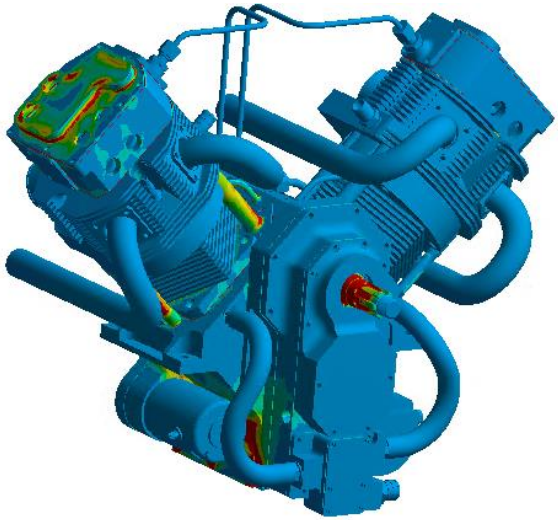
# Agenda

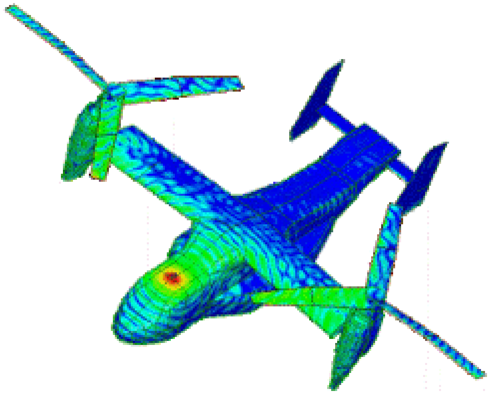
- Introduction to DRD
- Designing an E-Machine: Challenges & Needs
- End-to-End Workflows for Design, Analysis & Validation
- Using Ansys Motor-CAD for Rapid E-Machine Design
- Using Ansys Tools for Design, Analysis & Validation
- Questions

# Mission Statement

DRD Technology helps engineering teams accelerate product development. With in-house expertise spanning the entire range of physics, we ensure customers succeed when using Ansys simulation tools for virtual prototyping and design verification.







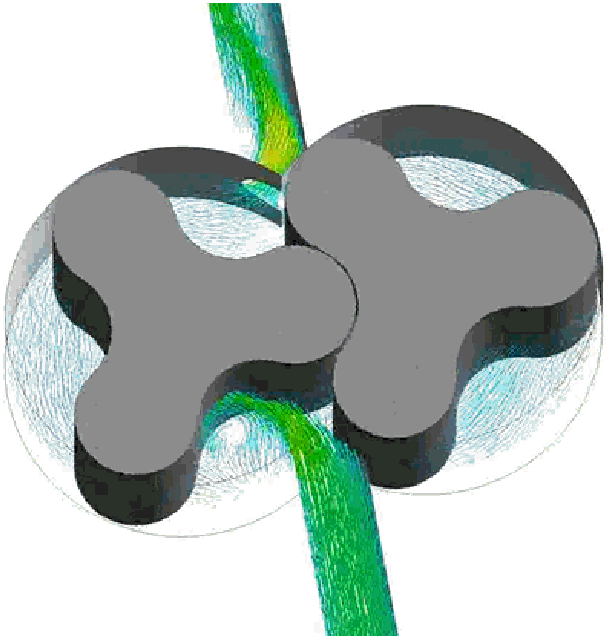
Ansys

CERTIFIED ELITE CHANNEL PARTNER

# DRD History

Since 1980, DRD Technology has been focused on engineering simulation.

In 1984, DRD became an Ansys Channel Partner.



Lobe pump

*I've been working with DRD for 29 years. Working with your team has been one of the more enjoyable parts of my career. You have always been ready to help in any way.*

- Rick Kunc

Sr. Research & Development Engineer

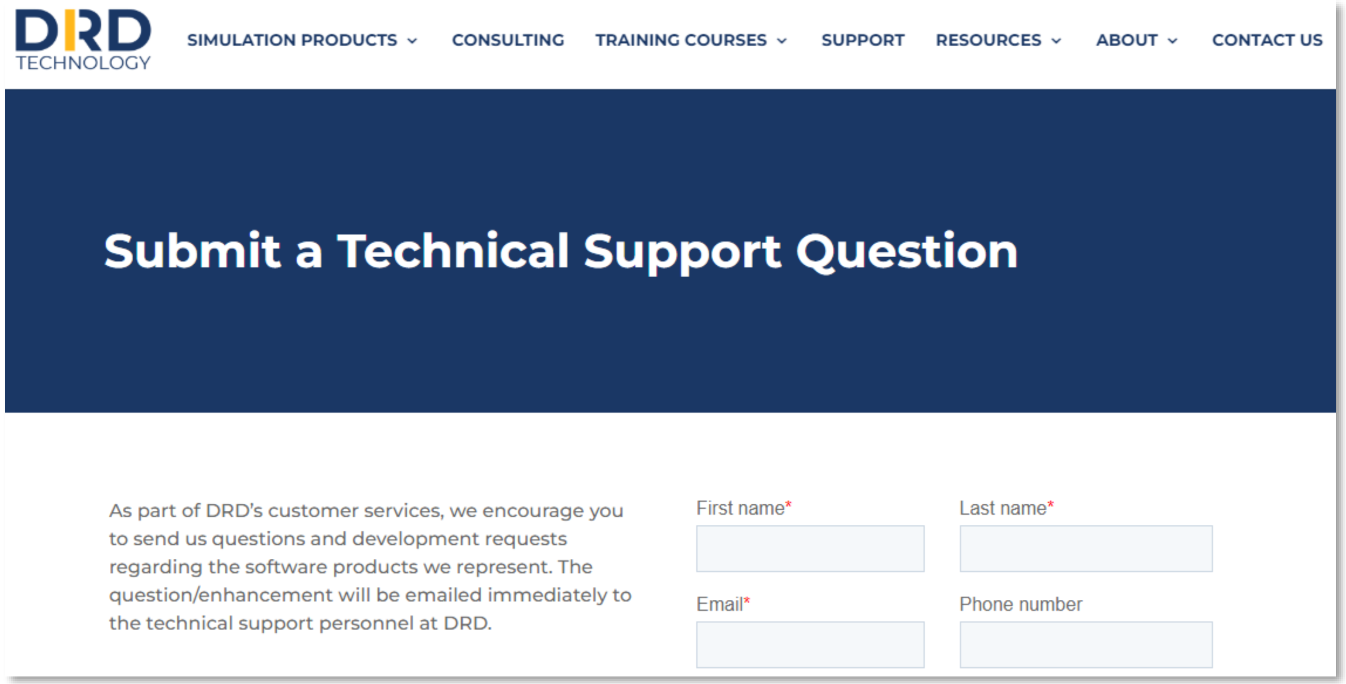
SOLVAY
asking more from chemistry®

Ansys
CERTIFIED ELITE CHANNEL PARTNER

# Technical Support Contact Coordinates

**Support:**
**(918) 743-3013 x1**
**support@drd.com**

**Or through our website at**
**www.drd.com**



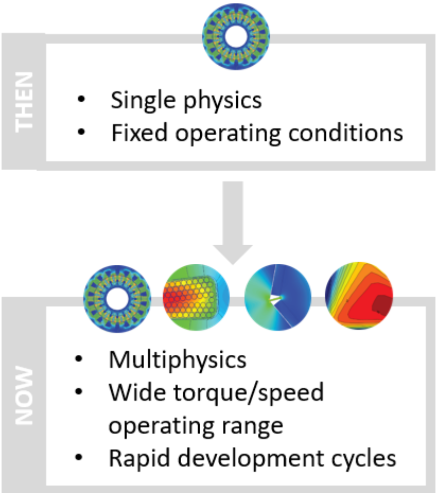

*For more than five years, I have worked closely with DRD Technology to execute tactical and strategic initiatives here at EaglePicher due to our unprecedented growth. We've been very happy with DRD and will continue to work with them as our business partner for using Ansys tools effectively and efficiently.*

- *Doug Austin*

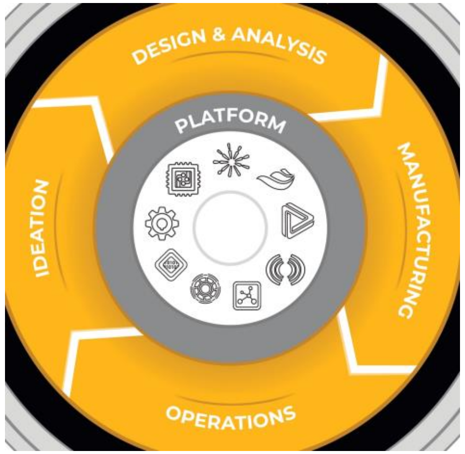
*Director of Research and Development*

EaglePicher™ Technologies, LLC

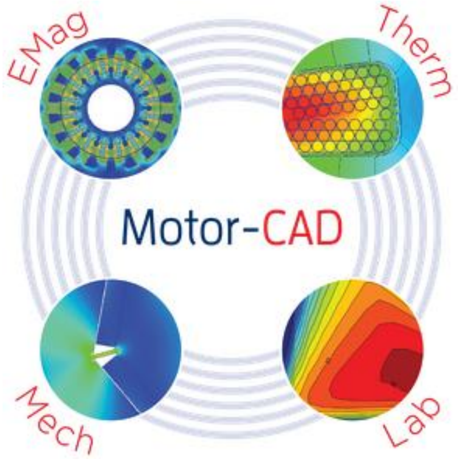
# Ansys Motor-CAD



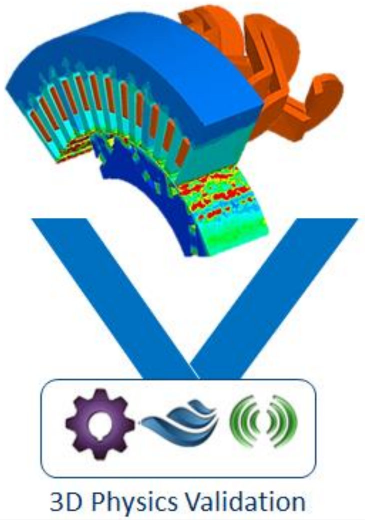

Designing an E-Machine: Challenges & Needs




End-to-End Workflows for Design, Analysis & Validation




Using Ansys Motor-CAD for Rapid E-Machine Design



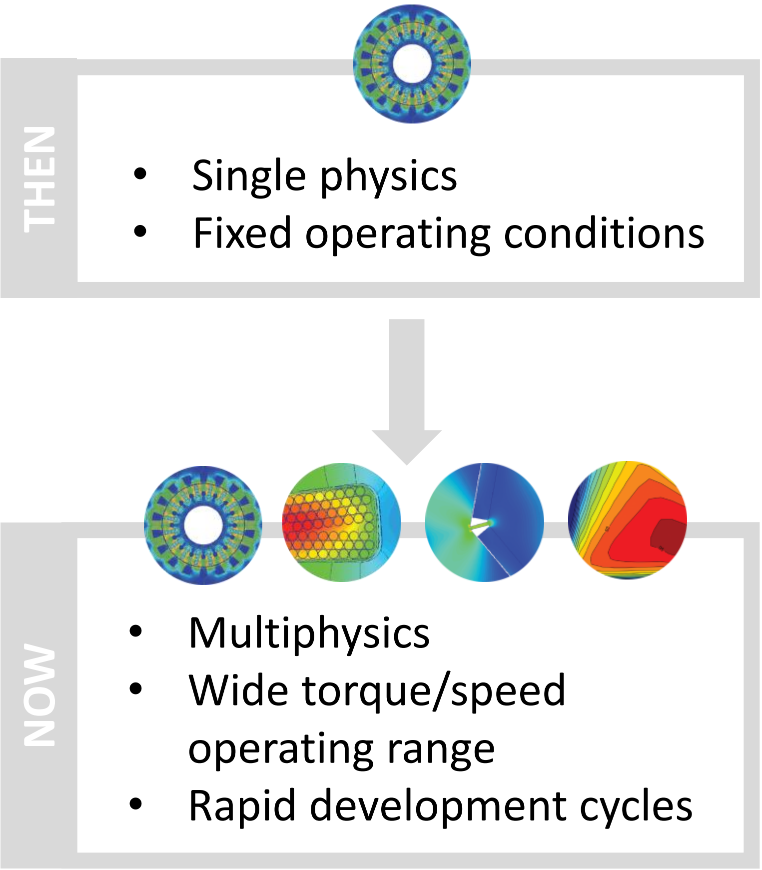

Using Ansys Tools for Design, Analysis & Validation

# E-Machines: The challenges

- In the past, electric machine design has been seen as only an electromagnetic problem
- Fast-moving field – design approaches have had to evolve to keep up

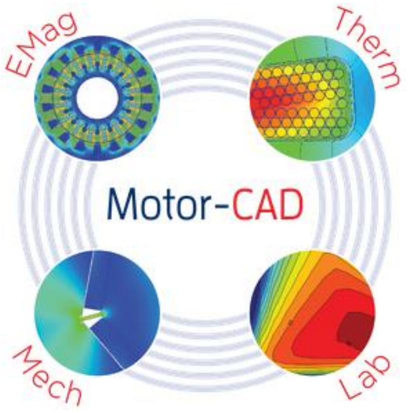
**Designing E-Machines at the cutting edge**

- Evolving performance requirements demand electric machine designs that operate at the electromagnetic, electrical, thermal and mechanical limits
- Usually over a wide torque/speed operating range
- Increasing competition requires shorter development cycles, with a strong focus on achieving highly optimised designs



# E-Machines: The need for rapid design & exploration

**Electric Machine Design Tool**



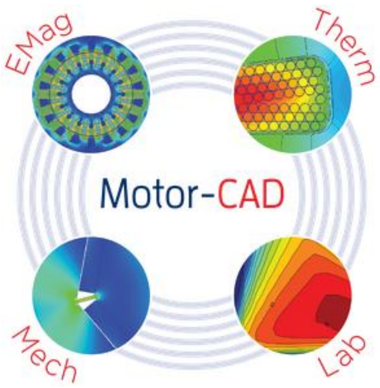

**Rapid multiphysics design tool** providing analysis across the full torque/speed operating range

**Enables:**

- Comprehensive design space exploration
- Better design and topology decisions
- More optimised designs
- Complete multiphysics evaluation of design candidates against the full specification
- Reduced risk of costly problems in the later development stages

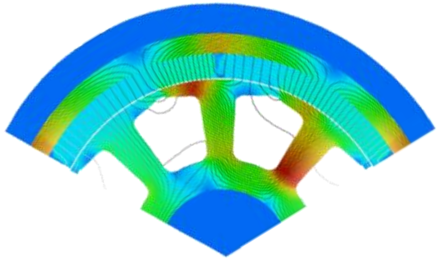
# End-to-End Workflow with Motor-CAD and Ansys tools

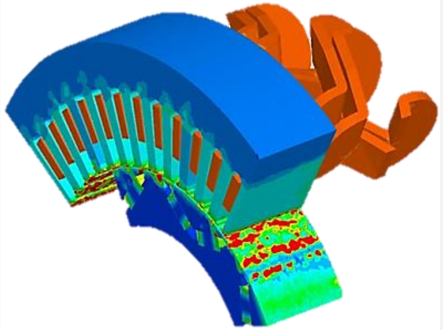
## Motor-CAD
Rapid Multiphysics Electric Motor Design



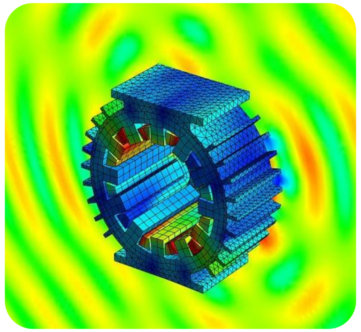

Iterative Design Space Exploration Toolkit

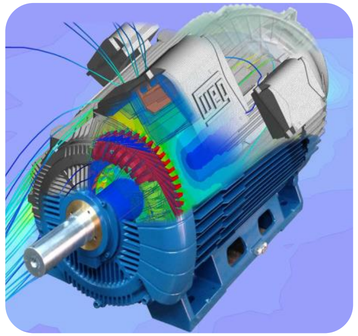
## Maxwell 2D & 3D
Advanced Magnetics Modelling



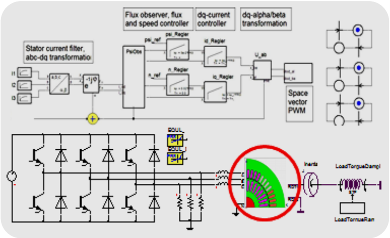


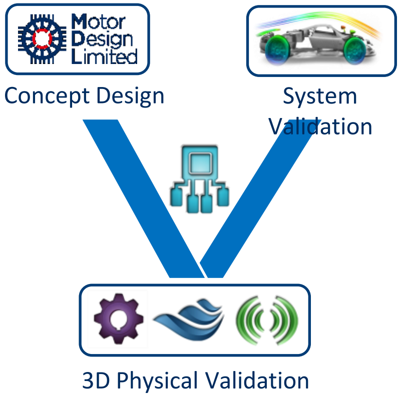
## Mechanical & CFD
NVH, Cooling





## System Validation
Control Logic, Software

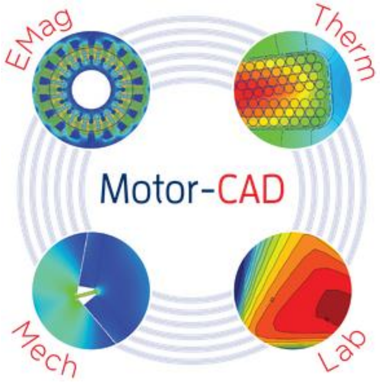





DESIGN → ANALYSIS → OPERATION

# End-to-End Workflow with Motor-CAD and Ansys tools

## Motor-CAD
Rapid Multiphysics Electric Motor Design




Iterative Design Space Exploration Toolkit

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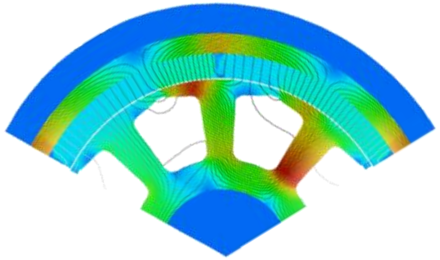

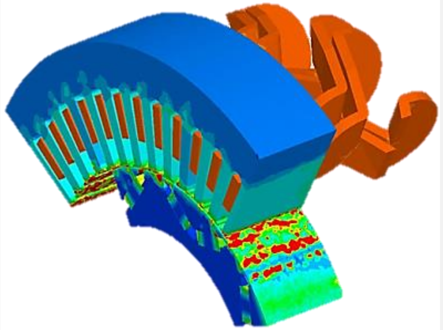

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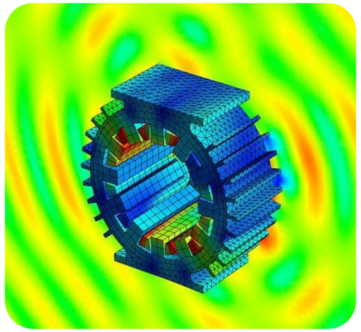

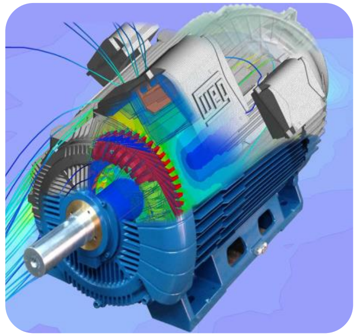

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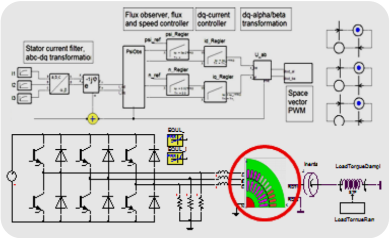
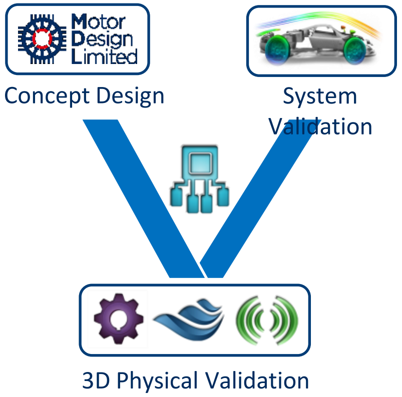
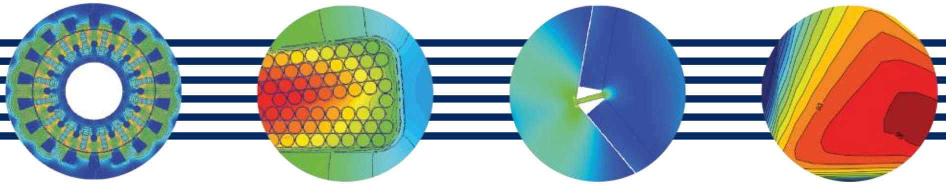





DESIGN → ANALYSIS → OPERATION

# Motor-CAD

MOTOR DESIGN SOFTWARE BY MOTOR DESIGN ENGINEERS



- Ansys Motor-CAD is the market leading tool dedicated to the design and analysis of electric motors
- Enables rapid and accurate electromagnetic, thermal and mechanical analysis of an electric machine across the full operating envelope
- Designed and developed in close collaboration with expert electric machine designers
- Embedded engineering expertise

**EMag**
Fast, template-based electromagnetic performance predictions.

**Therm**
Thermal performance predictions & advanced cooling system design.

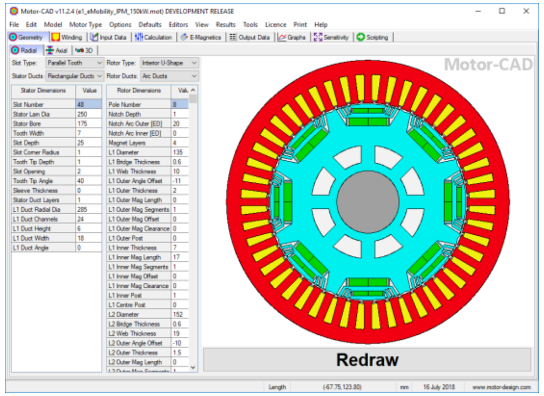
**Mech**
Mechanical analysis of stress & displacement in rotors during operation.

**Lab**
Efficiency mapping & performance across a drive cycle.

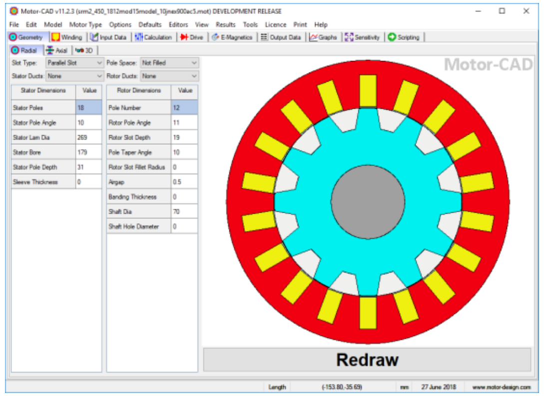
**Quickly** and **iteratively** evaluate motor topologies and concepts to produce designs that are **optimized for size, performance and efficiency**.

# Ansys Motor-CAD: Motor design types and templates

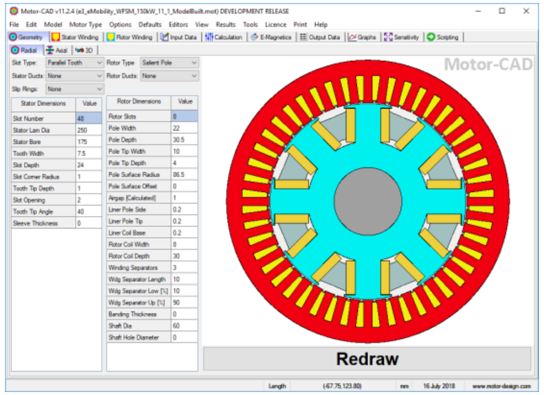
- Covers all typical types of radial flux rotating electric machines
- Motor Types:
  - Brushless permanent magnet (inner & outer rotor)
  - Induction
  - Synchronous reluctance
  - Switched reluctance
  - Synchronous wound field
  - Permanent magnet DC
  - Single phase induction
- Extensive range of parametrised templates & geometries



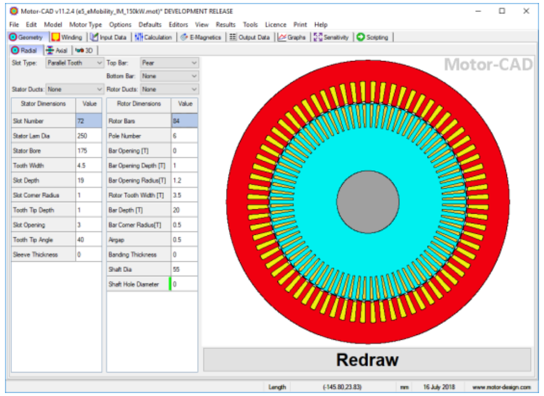

Interior PM machine design




Switched reluctance machine design




Synchronous wound field machine design

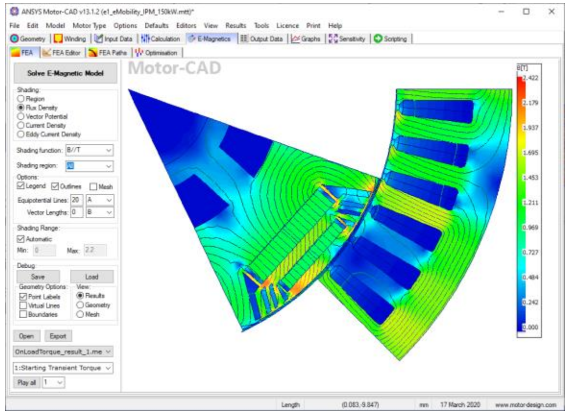



Induction machine design

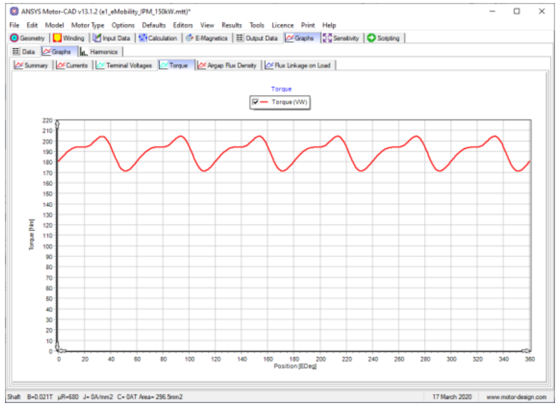
Ansys

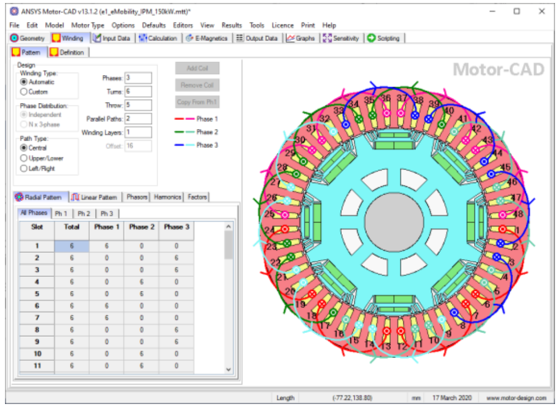
# Ansys Motor-CAD: Electromagnetic

- Calculates torque, power, losses, voltages, currents, inductances, flux linkages and forces
- Automated winding and slot cross-section editor
- Designs can be input and calculated in minutes allowing lots of iteration and full exploration of the design space - ensures optimal design decisions

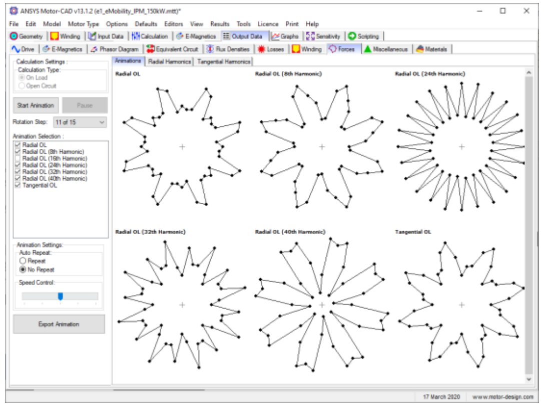


2D FEA Solver


Torque Ripple Waveform

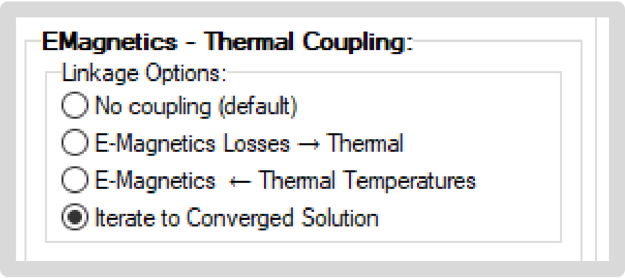


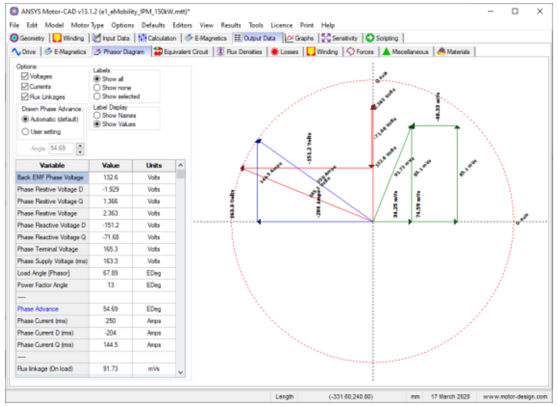
Radial winding pattern


Electromagnetic forces

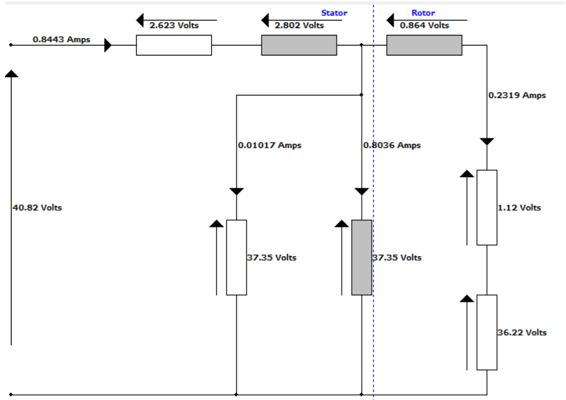
# Ansys Motor-CAD: Electromagnetic

- Combined 2D finite element and analytical modelling approach
- Calculates electrical & electromagnetic performance
- Coupled solution with the thermal model
- Automatically set-up calculations for different performance tests



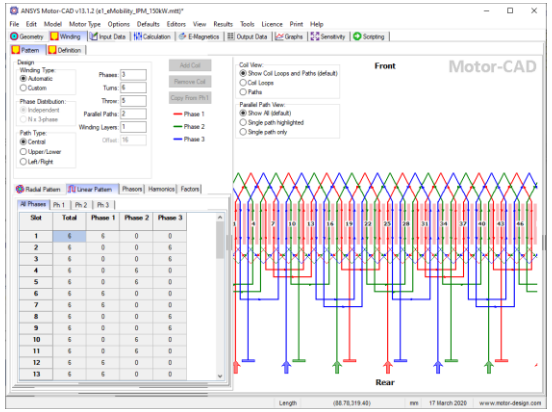



Phasor Diagram




Induction machine equivalent circuit

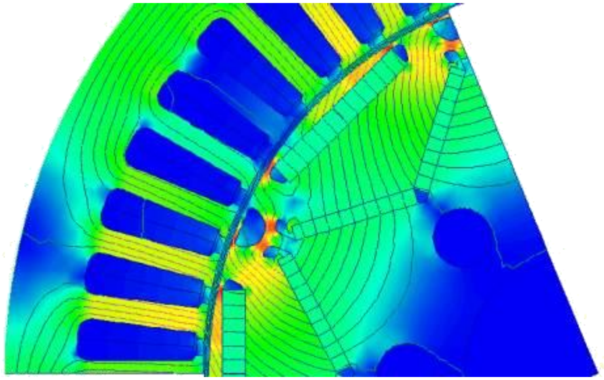
Fourier analysis of the voltage waveform



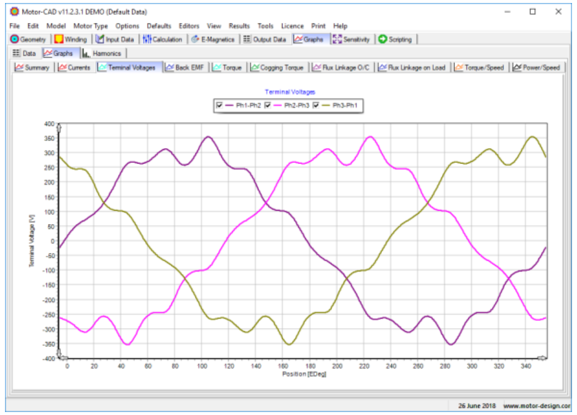
Linear winding layout

# Ansys Motor-CAD: Electromagnetic

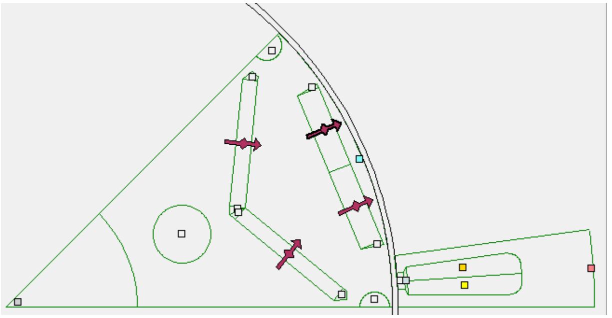
- Embedded 2D transient FEA solver
- Meshing, boundary conditions automatically set-up
- Advanced calculations such eddy current in magnets, induction machine rotor bars & AC winding losses
- DXF import, scriptable geometries, custom current waveforms, multi-slice skew
- Enables engineers to account for complex electromagnetic effects early in the design process



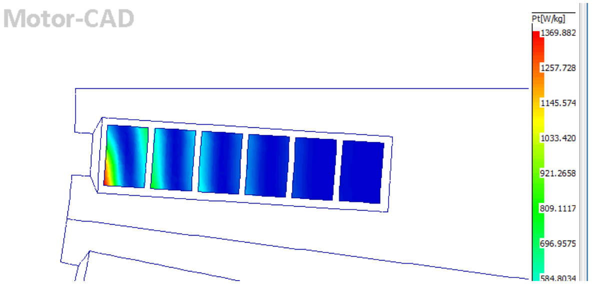
Flux density plot from FEA solver



Calculated voltage waveform



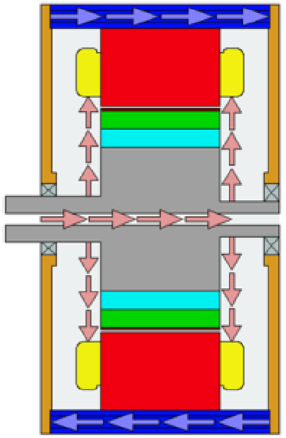
FEA geometry and region editor



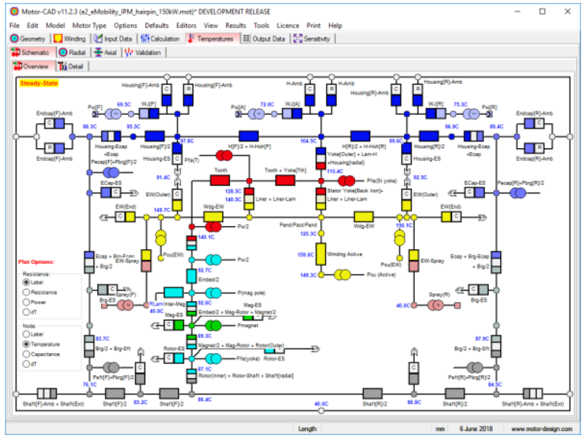

AC loss in a hairpin winding

# Ansys Motor-CAD: Thermal

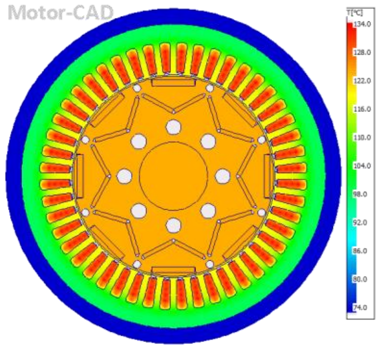
- Calculates temperature of the motor components in steady-state and transient operating conditions
- Enables accurate modelling of thermal behaviour within seconds of calculation
- Enables understanding of main heat transfer paths and opportunities to significantly improve output
- Allows iteration and full exploration of the design space



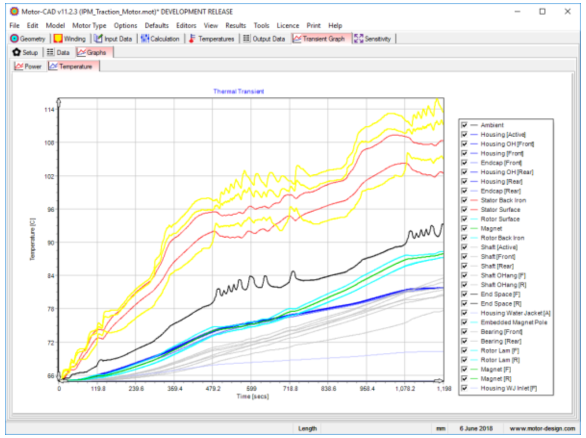
Visualisation of oil spray cooling



Thermal network



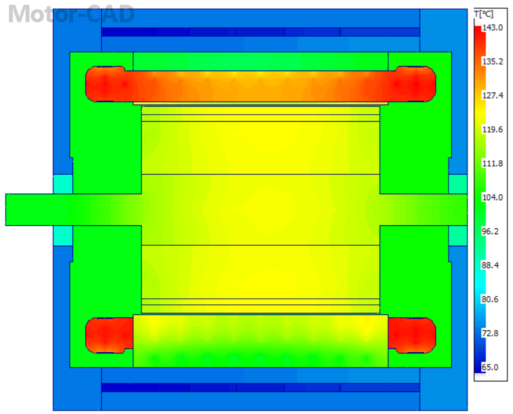

Radial temperature distribution



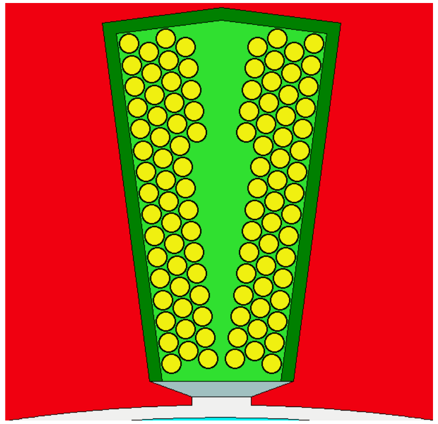
Thermal transient solution

# Ansys Motor-CAD: Thermal

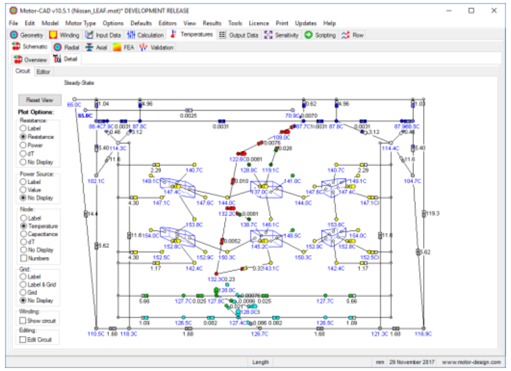
- Thermal and flow network generated automatically
- 3D network includes radial & axial heat transfer
- Detailed visualisation and calculation of the slot cross section
- CFD, FEA and empirical correlations behind all calculations



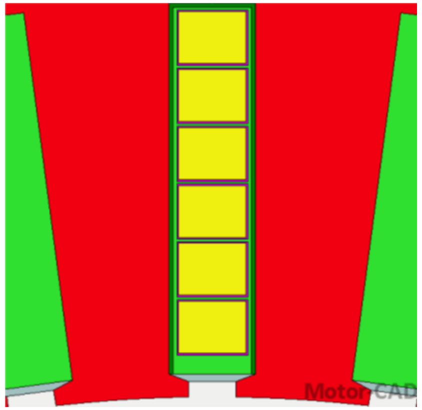

Cross-Section Showing Axial Temperatures



Slot cross section for a concentrated winding



Thermal Resistance Network

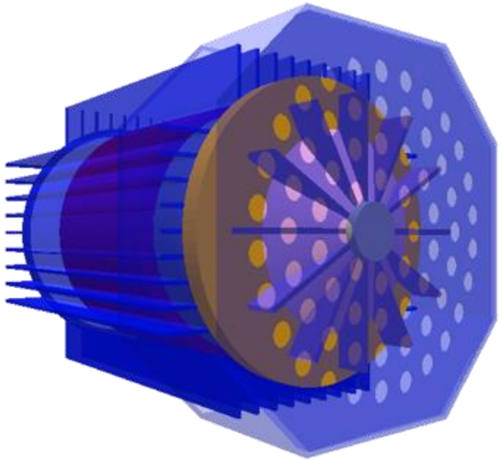



Slot cross section for hairpin winding

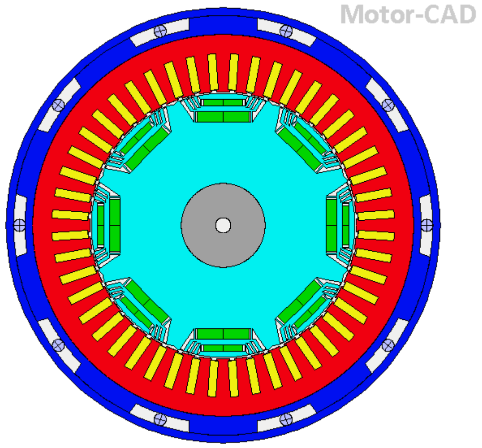
# Ansys Motor-CAD: Thermal – Cooling types

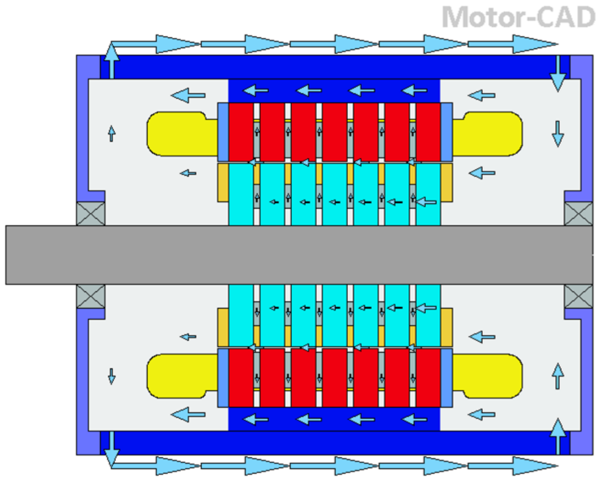
- TENV: Totally enclosed non-ventilated
  - Natural convection from housing
- TEFC: Totally enclosed fan cooled
  - Forced convection from housing
- Through Ventilation
- TE with Internal Circulating Air
  - Internal air circulating path
  - Water jacket as heat exchanger
- Open end-shield cooling
- Water Jackets
  - Axial or circumferential
- Submersible cooling
- Wet Rotor & Wet Stator cooling
- Spray Cooling
  - e.g. Oil spray cooing of end windings
- Direct conductor cooling
  - e.g. Slot ducts with oil

Fan cooled machine with cowling



Water jacket with axial channels




Through ventilation with radial ducts

# Ansys Motor-CAD: Thermal – Manufacturing data

- Thermal modelling of electric machine can be challenging as thermal behaviour is significantly affected by manufacturing aspects
- Examples of manufacturing uncertainties that affect temperature rise:
  - Goodness of effective interface between stator and housing
  - How well the winding is impregnated or potted.
- Experience is built into the software to assist users in selecting appropriate values

Equivalent interface gap that is useful for non heat transfer specialist

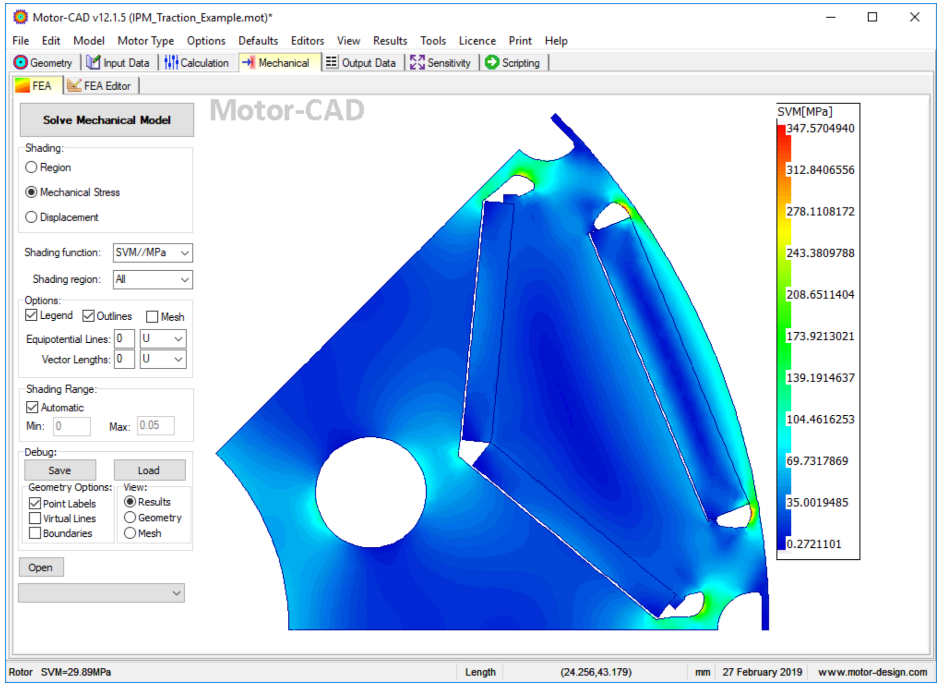
Example of guidance given to set stator lamination to housing interface thermal resistance

Interface resistance and conductance data that is suitable for thermal experts

| Component | Gap | Interface Material | Thermal Conductivity | Details | Resistance @T=100.0℃ | Conductance @T=100.0℃ |
|---|---|---|---|---|---|---|
| Units | mm | | W/m/℃ | | m2.C/W | W/m2/C |
| Stator Lam - Housing | 0.01 | Air (Motor-CAD model) | 0.03171 | Lamination-Metal - Good surface Contact | 0.0003153 | 3172 |
| Housing - OHang [F] | 0 | Air (Motor-CAD model) | 0.03171 | No Gap - Perfect surface Contact | 0 | 1E09 |
| Housing - OHang [R] | 0 | Air (Motor-CAD model) | 0.03171 | No Gap - Perfect surface Contact | 0 | 1E09 |
| Housing - Endcap [F] | 0.005 | Air (Motor-CAD model) | 0.03171 | Metal-Metal - Average surface Contact | 0.0001577 | 6341 |
| Housing - Endcap [R] | 0.005 | Air (Motor-CAD model) | 0.03171 | Metal-Metal - Average surface Contact | 0.0001577 | 6341 |

# Ansys Motor-CAD: Mechanical – Stress analysis for rotors

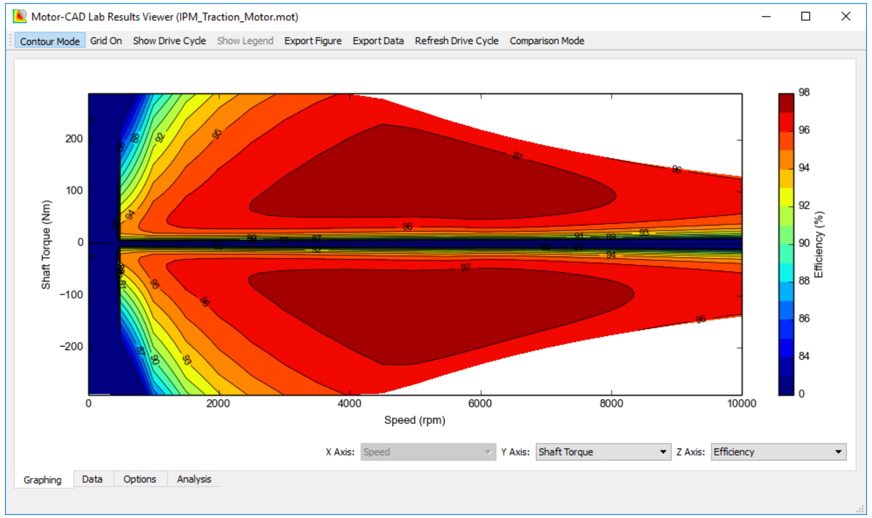
- FE solution based
- Very fast – solves within a couple of seconds
- Template or DXF import options available
- Enables engineers to consider Magnetic and Mechanical performance trade-off in design optimisation



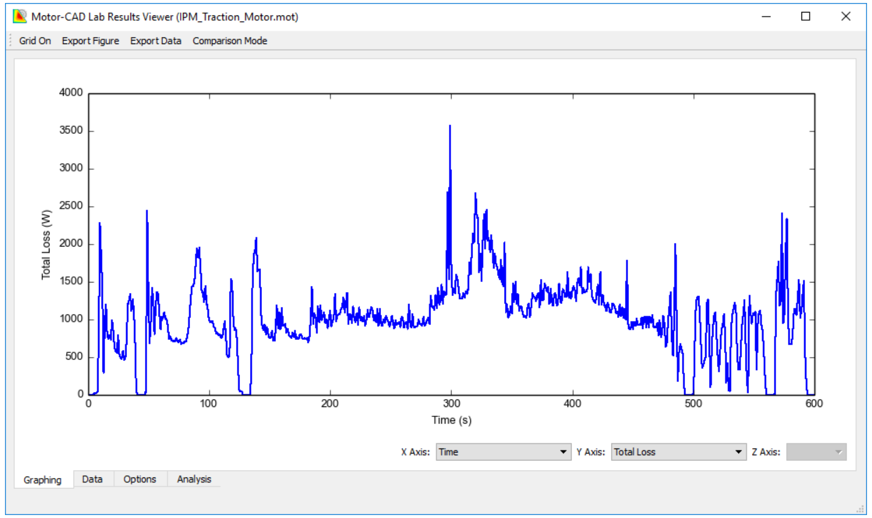

Von Mises Stress in IPM rotor at maximum speed

# Ansys Motor-CAD: Lab – Virtual testing laboratory

- Efficiency & loss maps
- Peak torque/speed curves
- Continuous torque/speed curves
- Duty cycle analysis
- Open & short circuit tests
- Automatically applies maximum torque/amp control strategies to replicate performance of machine with inverter
- Essential calculations for designing and analysing inverter driven machines with range of operating conditions



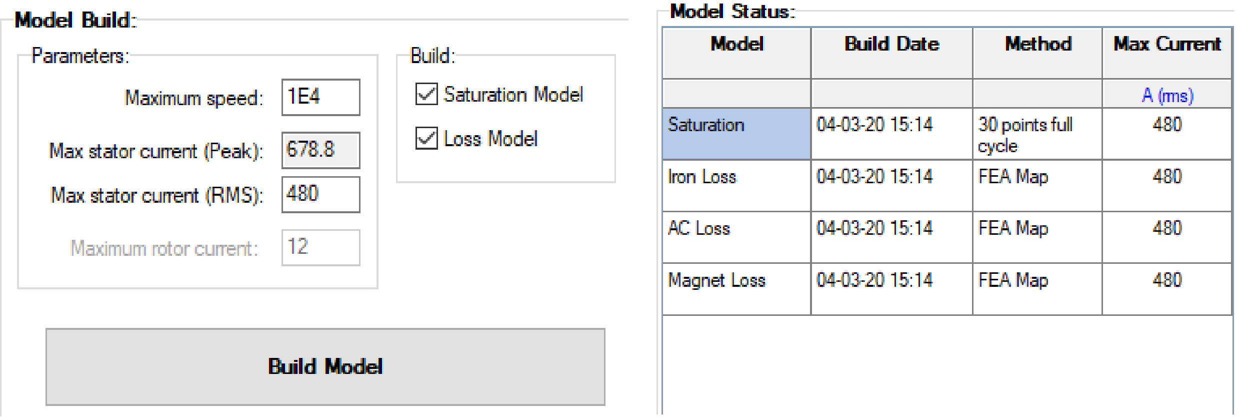

Calculated efficiency map in motoring and generating region



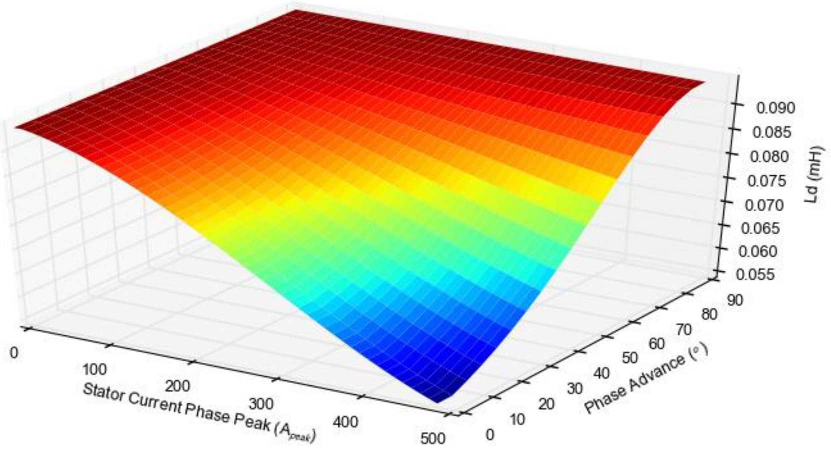

Calculated losses over time for a duty cycle

# Ansys Motor-CAD: Lab – Efficiency map & drive cycle modelling

- To generate the map and cycle data, thousands of operating points must be calculated
- We use the FEA and analytical EMag solvers to build inductance and loss maps of the machine design
- Couples with the thermal solver to predict combined EMag and thermal behaviour
- All calculations efficiency maps, duty cycles etc. can be calculated in minutes, and hence used during an iterative design process




Model build interface in Motor-CAD Lab

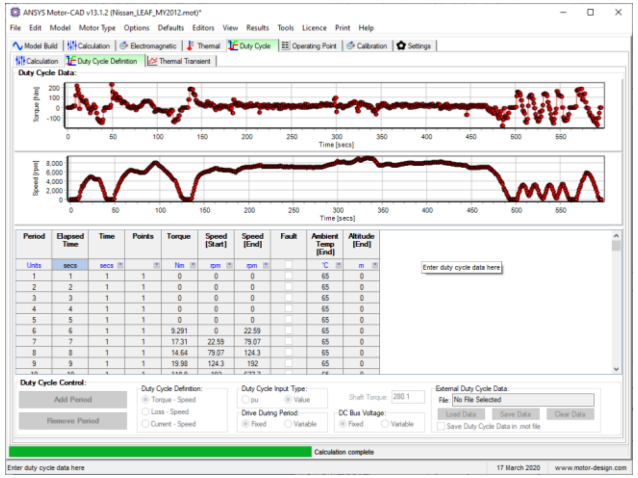



Response surface of d-axis inductance vs current magnitude and angle, calculated using the FEA solver

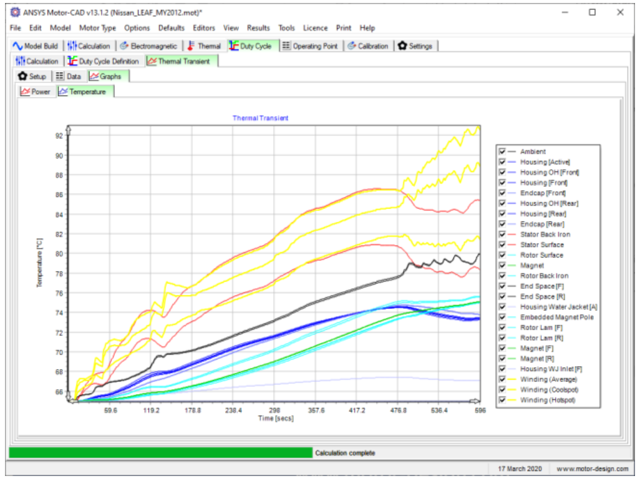
# Ansys Motor-CAD: Lab – Drive cycle analysis

- Losses, efficiency and energy usage can be calculated across any duty cycle
- The behaviour of the machine is solved with the thermal model to give temperature rise against time.
- The variation of losses and magnet flux (torque/amp) with temperature is accounted for
- This enables engineers to design a machine with minimum size/cost and optimise the design for maximum cycle efficiency

Motor/Generator: Time vs Torque vs Speed



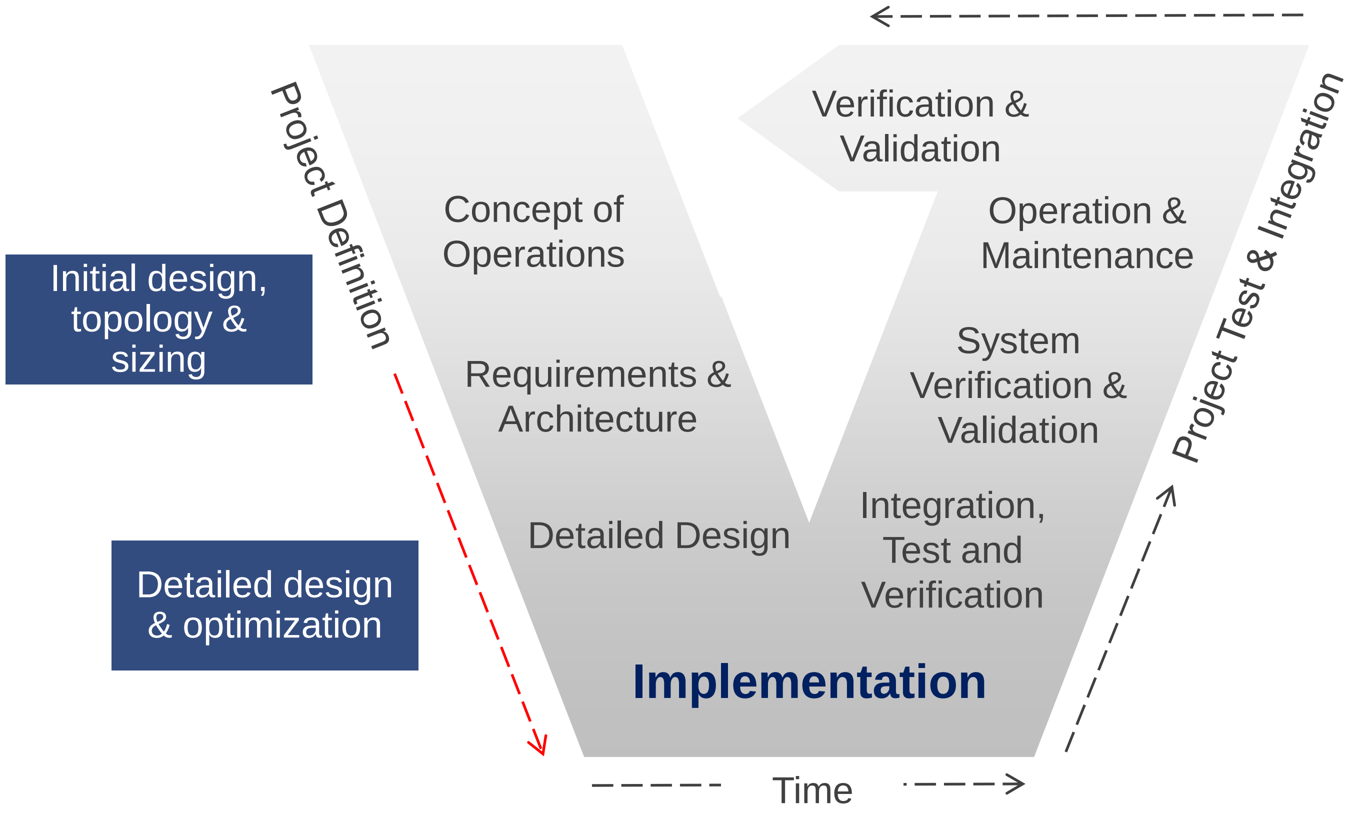
Motor/Generator: Temperature Vs Time



**Co-solved electromagnetic and thermal behaviour over cycle**

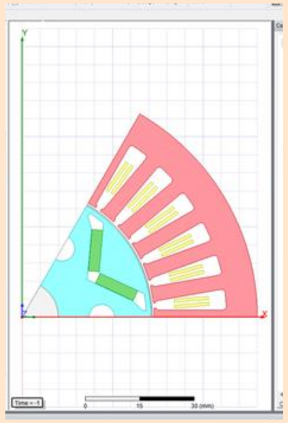
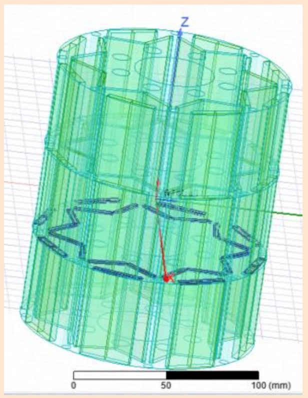
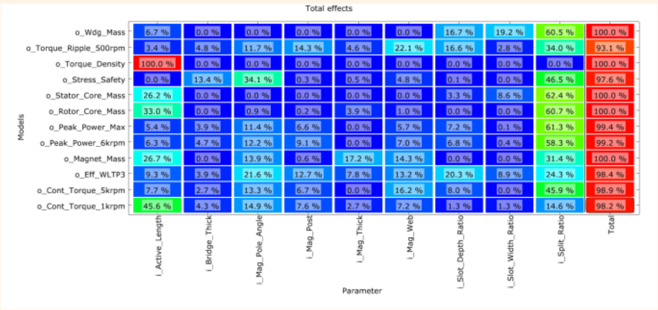
# Ansys Motor-CAD: Summary – Usage in development lifecycle

- Motor-CAD is primarily used by electric machine designers
- It is particularly useful for initial design, topology selection, sizing, analysis and optimisation across the full operating envelope
- It is typically used alongside 3D FEA and CFD tools for more detailed analysis in the latter stages of design




**Engineering product development lifecycle**

# Two example toolchains: Motor-CAD + other Ansys tools

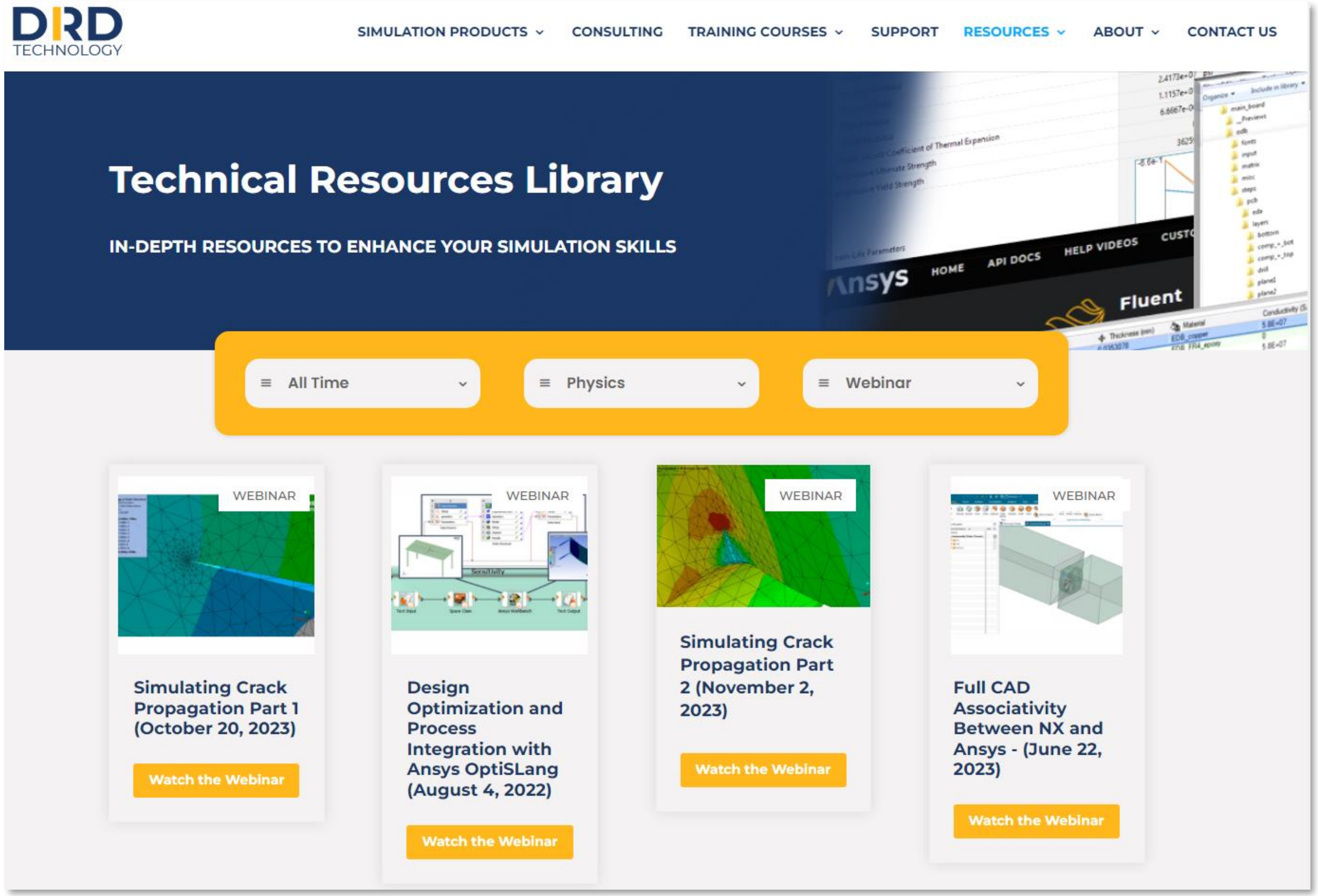
| Workflow | Coupling | Description | |
|---|---|---|---|
| Seamless model transfer for advanced electromagnetic analysis | Motor-CAD → Maxwell 2D/3D | • Export to ANSYS Maxwell machine geometries defined using templates or outlines.<br>• Transfers geometry, material properties, winding pattern, excitations, symmetry and boundary conditions. |   |
| Coupling for multiphysics design space exploration, optimisation and robust design | Motor-CAD ←→ OptiSLang | • Design candidates evaluated against full design specification<br>• Multiphysics, multi-objective optimisation |  |

# Electric machine design and development: Ansys motor design platform

- Electric machine design requires rapid, accurate, multiphysics analysis that facilitates full design space exploration
- Ansys Motor-CAD fulfils these requirements, enabling comprehensive analysis from an early design stage ensuring correct design decisions and resulting in better electric machine designs
- Designs developed in Motor-CAD can then be seamlessly transferred into the rest of the Ansys toolchain for detailed multiphysics design and validation, using comprehensive 3D numerical simulation.

# Ansys Expert Mail List

Request to be added by sending a note to support@drd.com



# Questions

Thanks for your time