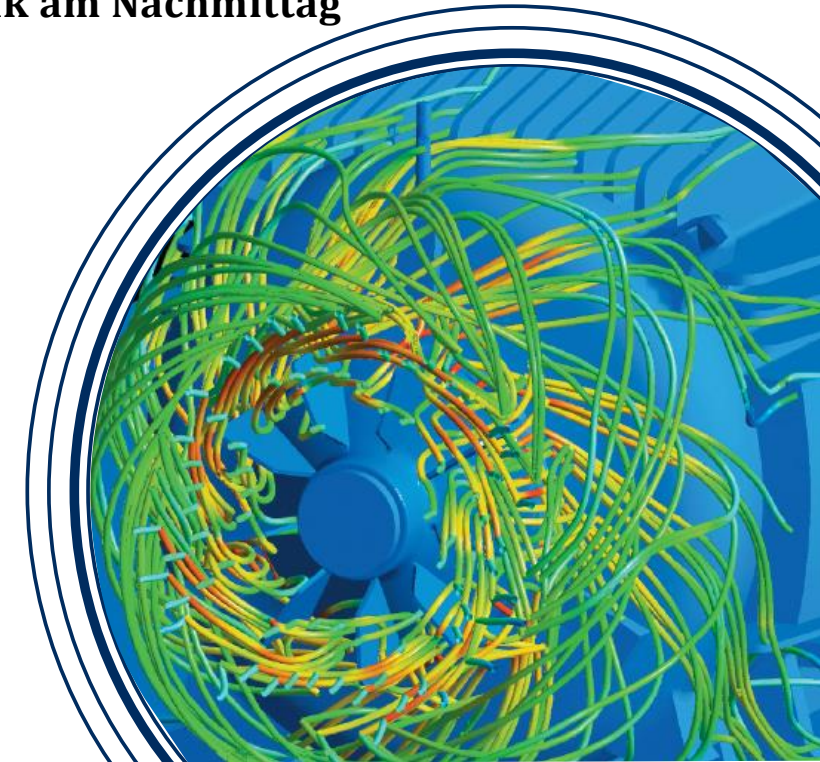
Coupled EM and CFD computation - advanced thermal management

CADFEM Technologietage 2021 – Elektromagnetik am Nachmittag

Lester Peña Gomez, CADFEM GmbH

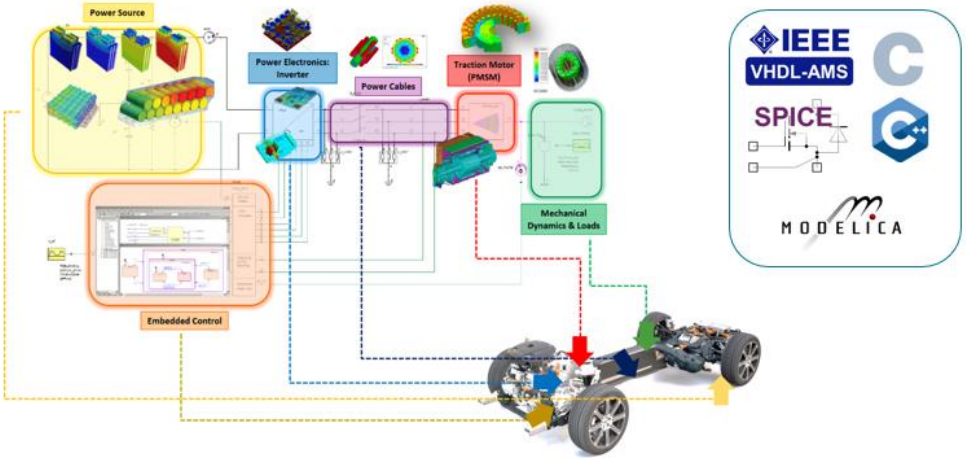
18.05.2021



CADFEM Ansys CERTIFIED ELITE CHANNEL PARTNER

Topics

- **ANSYS as virtual develop platform for E-Machines**
  - **Concept Design & Specification**
  - **Advance Magnetic Analysis**
  - **Thermal Management**

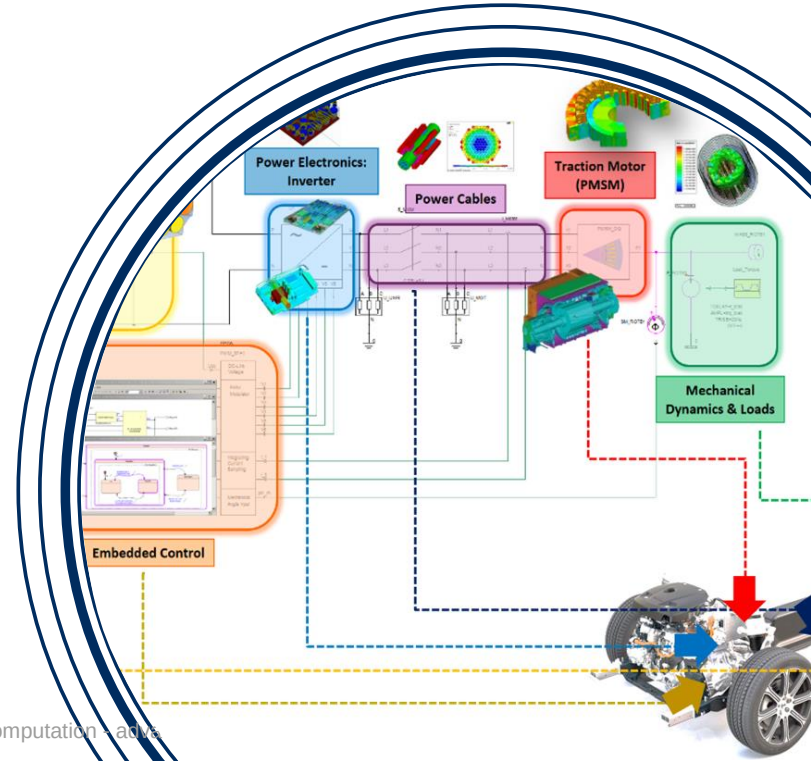


- **Model preparation for Advanced Magnetic Computation**

- **Model preparation for Advanced CFD (Fluent) Computation**

ANSYS as virtual develop platform for E-Machines

- Concept Design & Specification
- Advance Magnetic Analysis
- Thermal Management

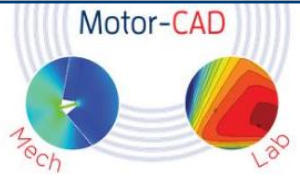


CADFEM Ansys CERTIFIED ELITE CHANNEL PARTNER

ANSYS as virtual develop platform for E-Machines

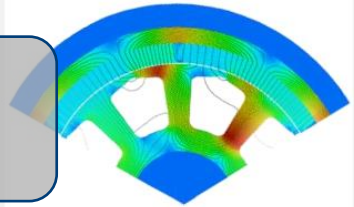
CADFEM

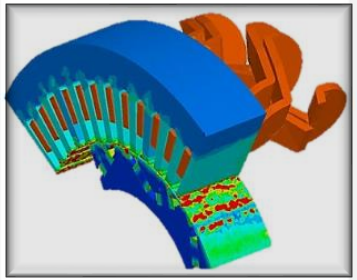
Motor-CAD
Rapid Multiphysics Electric Motor Design



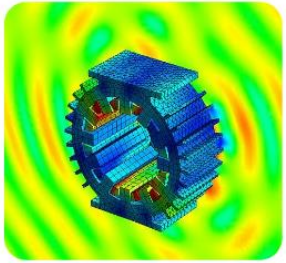
Iterative Design Space Exploration Toolkit

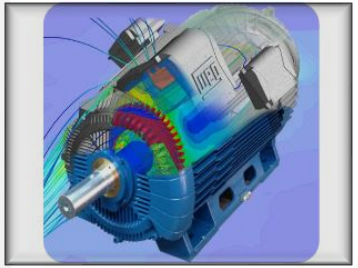
Maxwell 2D & 3D
Advanced Magnetics Modelling



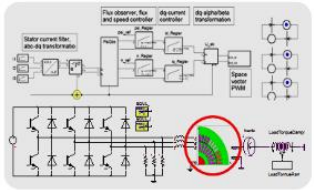


Mechanical & CFD
NVH, Cooling





System Validation
Control Logic, Software



Motor Design Limited

Concept Design

System Validation

3D Physical Validation

1) Multiphysics during the early design phase

2) Optimization to a given specification sheet

dynardo optiSLang®

Concept Design & Specification

CADFEM

Customer Goal

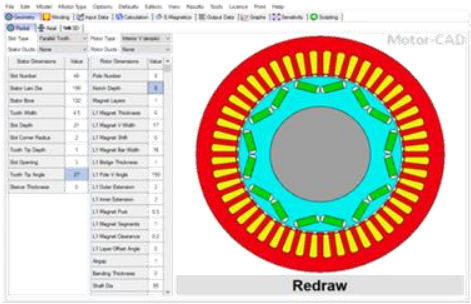
- Meet the **torque, power and packaging** requirements
- Ensure the Motor performance over the complete **operating envelop**

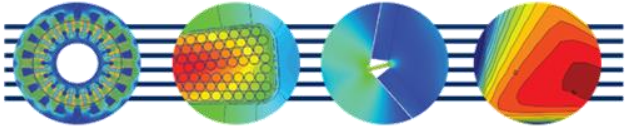
Solution

- **Speed:** Enable rapid electric machine sizing and design exploration
- **Usability:** Template based workflow customized for Traction motor development
- **Optimization:** Multidisciplinary / Multi objective optimization

Benefits

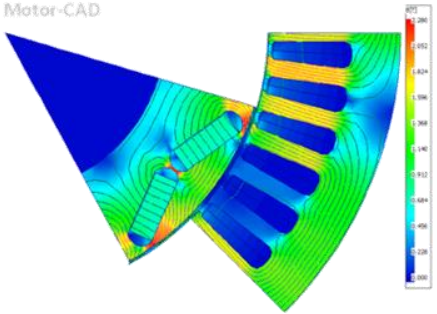
- **Front-load** the design decisions to compress the overall development cycle
- Evaluate the **electromagnetic & thermal performance** for a desire drive cycle
- Predict **concept feasibility** early in the development stage





EMag	Therm	Mech	Lab
Fast, template-based electromagnetic performance predictions.	Thermal performance predictions & advanced cooling system design.	Mechanical analysis of stress & displacement in rotors during operation.	Efficiency mapping & performance across a drive cycle.

Template based design for Multidiscipline



Rapid FEA Simulations for E Machines – Flux density plot

Multiphysics & Multi objective Optimization

Advanced Magnetic Analysis

CADFEM

Customer Goal

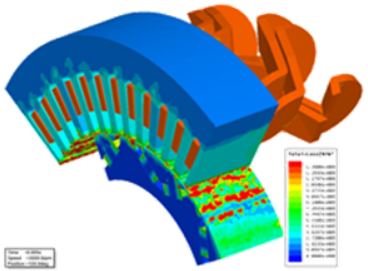
- Meet the **torque, power and packaging** requirements
- **Cost reduction** through optimum material utilization
- Ensure **robustness and fault tolerance**

Solution

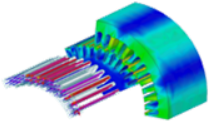
- **Accuracy:** Advance material modeling for accurate loss prediction
- **Advance Modeling:** Skewing, Magnetostriction, Vector hysteresis, Demagnetization etc.
- **Scalability:** High performance computing (HPC) for electromagnetic models

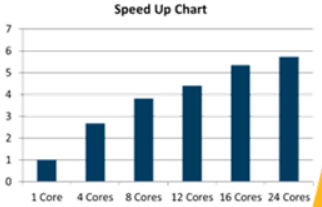
Benefits

- Verify the Electromagnetic **performance in greater details**
- Study different **material grades** and characteristics and perform trade off analysis
- Improve motor **robustness** by minimizing demagnetization

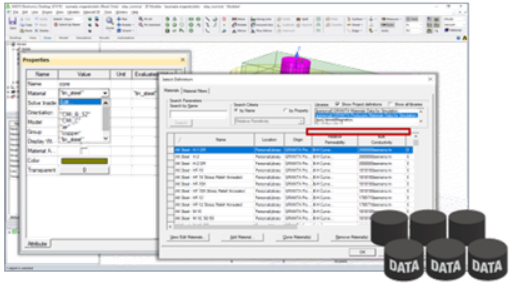


CAD Based Simulations with unique motor topologies





Scalable simulations through HPC



Reliable Material Data for Advance studies

"Speedup in Maxwell DSO on 32-Core High-Performance Compute Farm Doubles Traction Motor Design Productivity at General Motors"

Dr. Bradley Smith
General Motors Corporation

"Continuous Solutions used ANSYS Maxwell electromagnetic simulation software to reduce torque ripple by 90 percent and total noise by 50 percent in Switched Reluctance Motor"

Nir Vaks & Nyah Zarate
Continuous Solutions

Thermal Management

CADFEM

Customer Goal

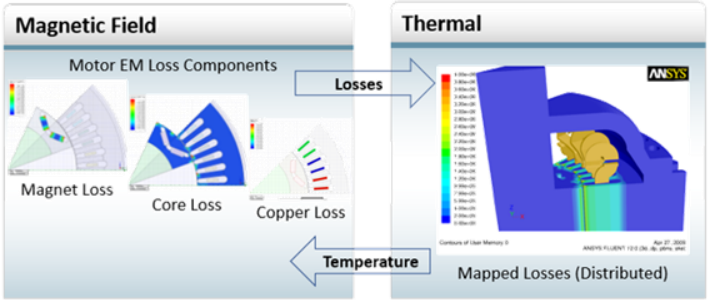
- **Optimum** cooling strategy
- Improve **thermal reliability and Motor life**
- **Minimize** package size

Solution

- **Seamless:** Electromagnetic and Thermal Physics coupling
- **Accurate:** Thermal Prediction for Air and Liquid cooling Including Oil Spray and Water Jackets
- **Fast Pre-processing**: Parameterize CAD with high-quality fast and robust meshing
- **Scalable:** High performance computing (HPC) for Thermal Simulations

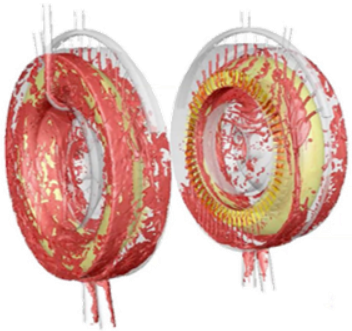
Benefits

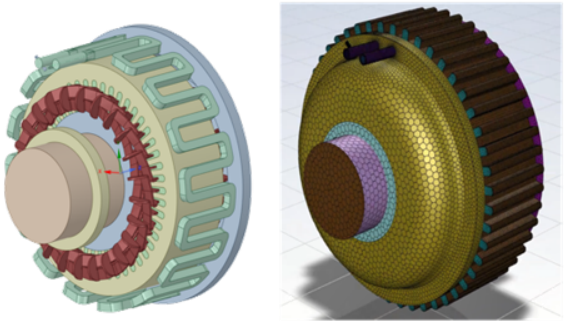
- Predict **temperature distribution** in critical components such as Windings, Magnets, Laminations
- Evaluate **electromagnetic and thermal interdependency**
- Improve design for **effective cooling**



Seamless Physics Coupling

Oil Spray Cooling





Fast Preprocessing

"Lucid engineers increased the power density and energy efficiency of the motor by 12 percent. The temperature predictions matched physical measurements within a 3 percent margin of error"

Lucid Motors

System Integration

Customer Goal

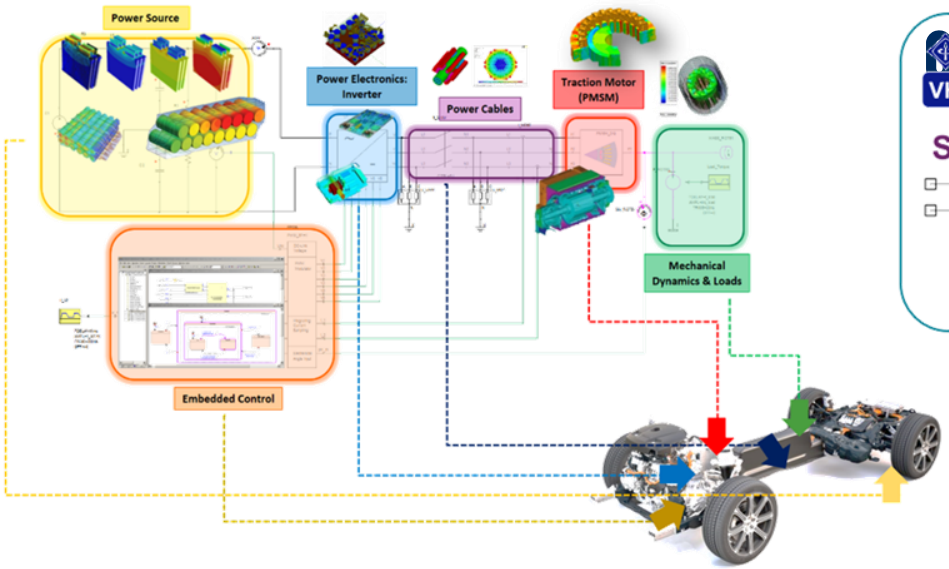
- **Validate** the system **before** any **hardware** is built
- **System level design trade-offs and optimization**
- Twin model for **offline computing** and edge/cloud deployment

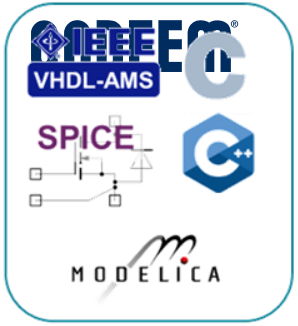
Solution

- **Complete workflow with integrated different model levels, domains and multiple physics**
- **Integration of** hardware systems with **control software**

Benefits

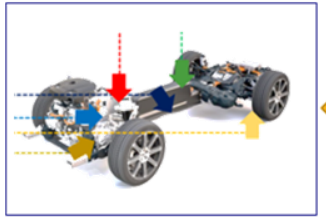
- **1000 times faster** with **high fidelity models** in the system
- 10 minutes for a virtual drive cycle test **(3 times faster than real time)**
- **Reduction of HiL costs** for software testing



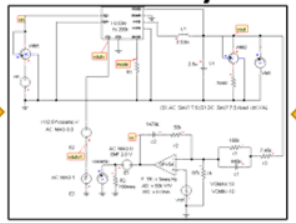


Integration of hardware systems with control software

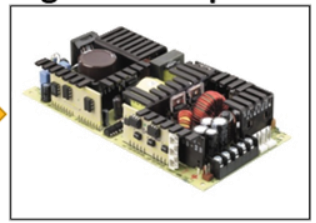
Powertrain system



Inverter subsystem

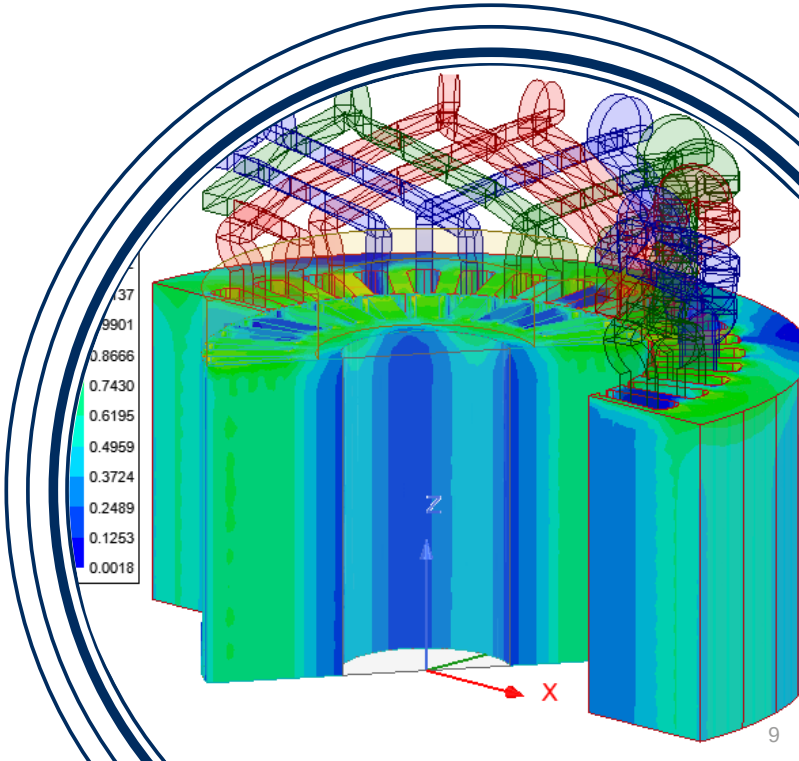


Magnetic component



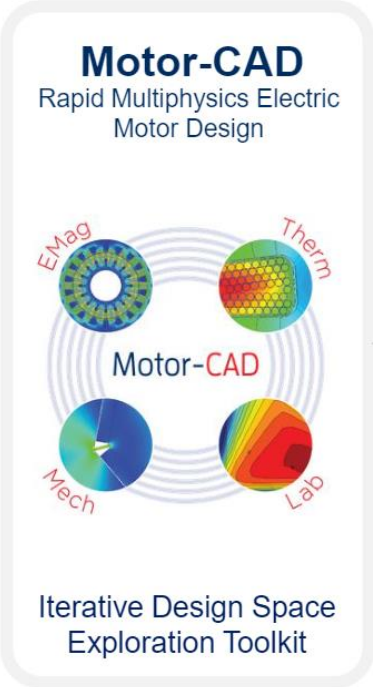
Libraries for subsystems and components

Model preparation for Advanced Magnetic Computation

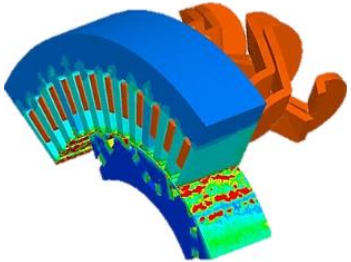


CADFEM Ansys CERTIFIED ELITE CHANNEL PARTNER

Model preparation for Advanced Magnetic Computation

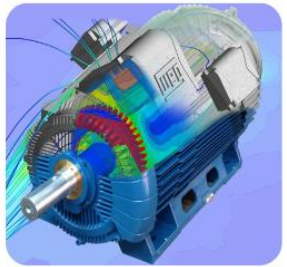


Advance Electromagnetic in 3D



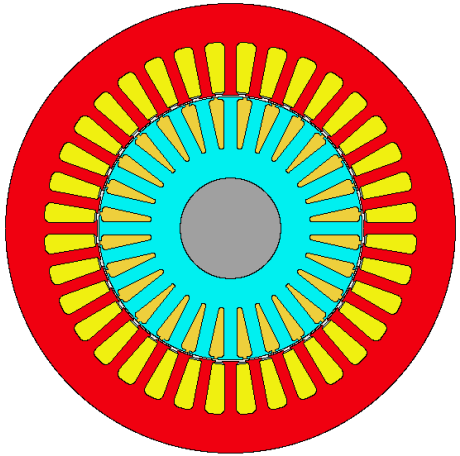
- *3D Maxwell Generation via VBS-File-Export from Motor-CAD EMag*
- *Material modelling and advanced Meshing for electrical machines in 3D*
- *Scalable simulations through HPC & Cloud Solution*

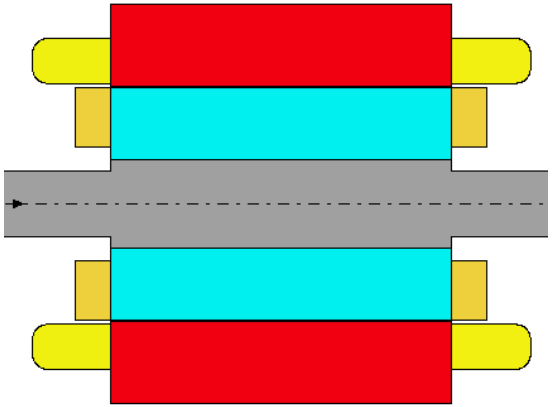
Advance CFD (Fluent)

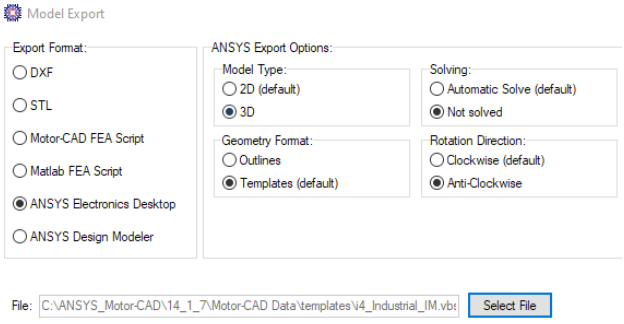


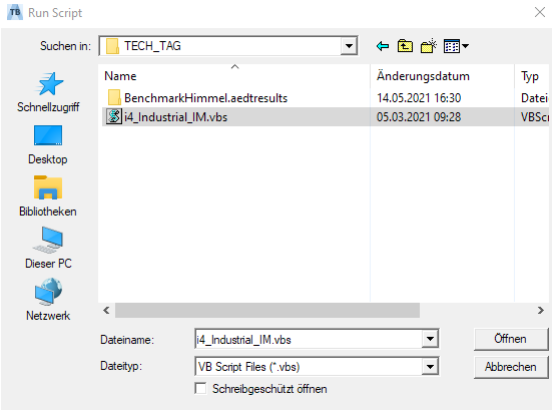
- *3D CAD Generation via Export js-File from Motor-CAD*
- *Watertight Geometry Meshing Workflow*
- *Scalable simulations through HPC & Cloud Solution*

Model preparation for Advanced Magnetic Computation

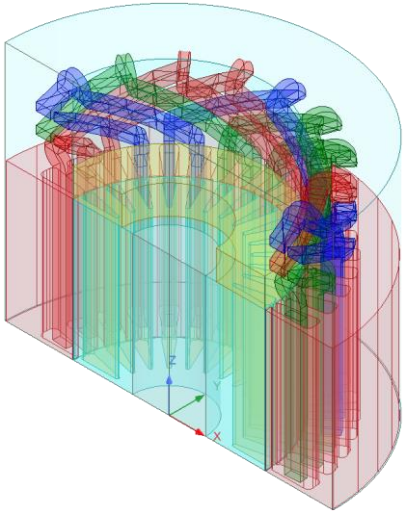








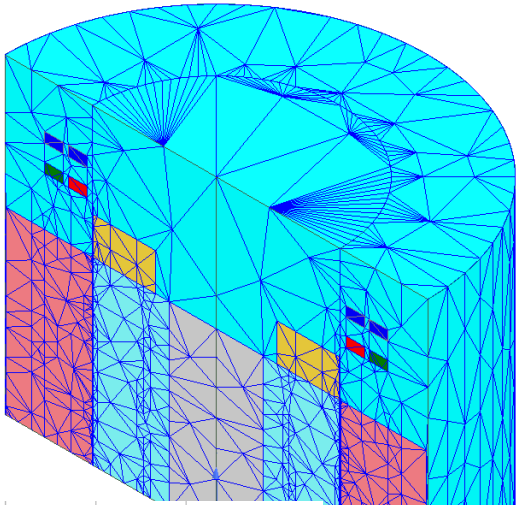
You can solve this model directly, or change it for better performance



Model preparation for Advanced Magnetic Computation

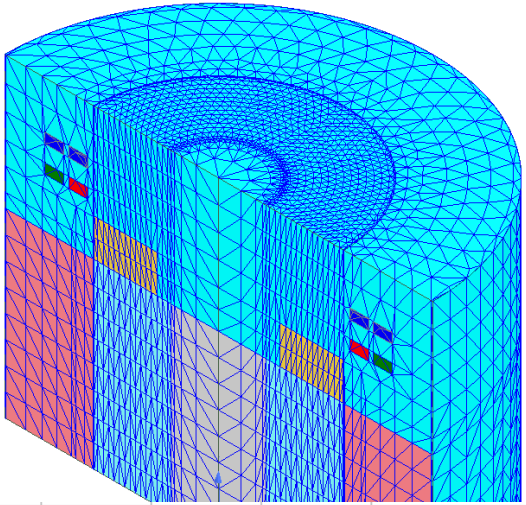
Advanced Meshing for Electrical Machine (3D)

TAU-Mesher without Clone



Mesh TAU4	00:00:34	00:00:44	568 M	465158 tetrahedra
Mesh Post(TAU)	00:00:36	00:00:36	568 M	124958 tetrahedra
Mesh Post	00:01:58	00:01:57	582 M	123615 tetrahedra
				Time: 05/14/2021 1
Total	00:03:08	00:03:17		Elapsed time : 00:03:

TAU-Mesher with Clone

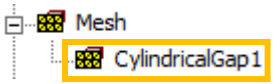


Mesh TAU4 (Clone)	00:00:13	00:00:17	270 M	183415 tetrahedra
Mesh Post	00:00:16	00:00:16	276 M	183381 tetrahedra
				Time: 05/14/2021 1
Total	00:00:29	00:00:33		Elapsed time : 00:00

Model preparation for Advanced Magnetic Computation

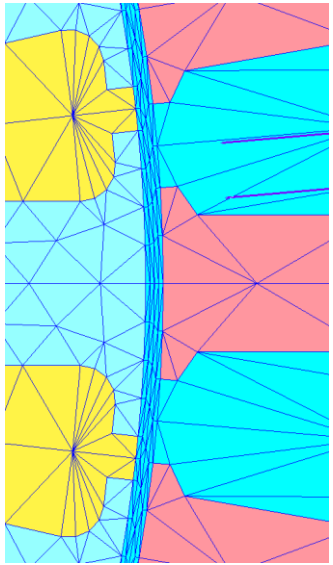
…when “Clone” is posible

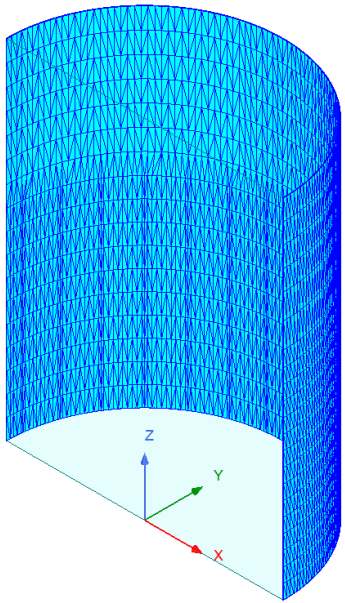
- Controlling the air gap mesh density in radial and circumferential direction

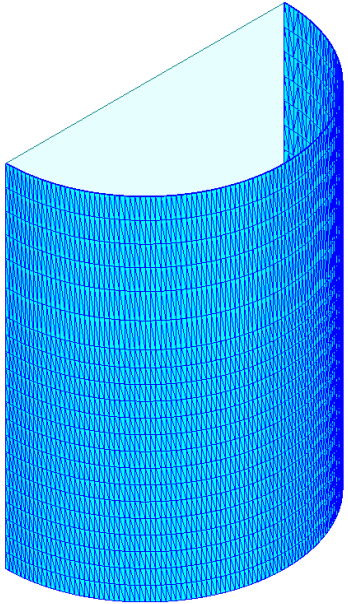


Properties

Name	Value	Unit	Evaluated Value
Name	CylindricalGap1		
Type	Cylindrical Gap Based		
Region	Inside Selection		
Clone Mesh	✔		
Band Mapping Angle	1.5	deg	1.5deg
Moving Side Layers	2		2
Static Side Layers	2		2



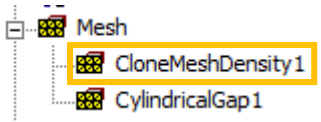




Model preparation for Advanced Magnetic Computation

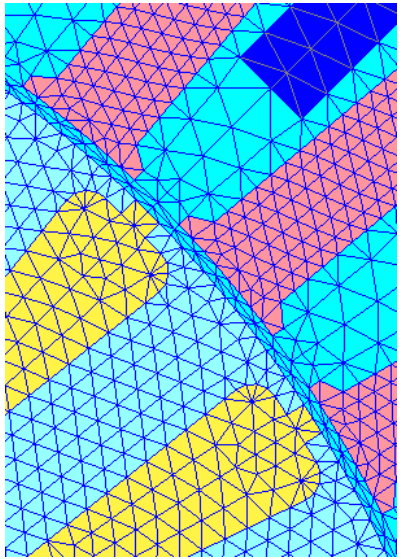
…when “Clone” is posible

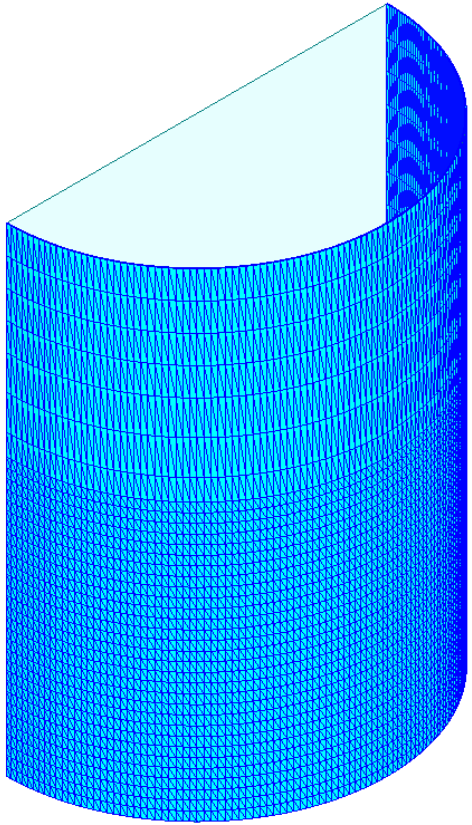
- Controlling the mesh density in radial and axial direction



Properties

Name	Value	Unit	Evaluated Value
Name	CloneMeshDensity1		
Type	CloneMeshDensity		
Region	Inside Selection		
Restrict Max Element Length	☑		
Max Element Length	0.75	mm	0.75mm
Restrict Layers Number	☑		
Number of layers	30		30

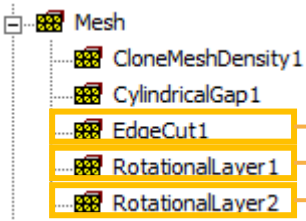




Model preparation for Advanced Magnetic Computation

…when “Clone” is posible

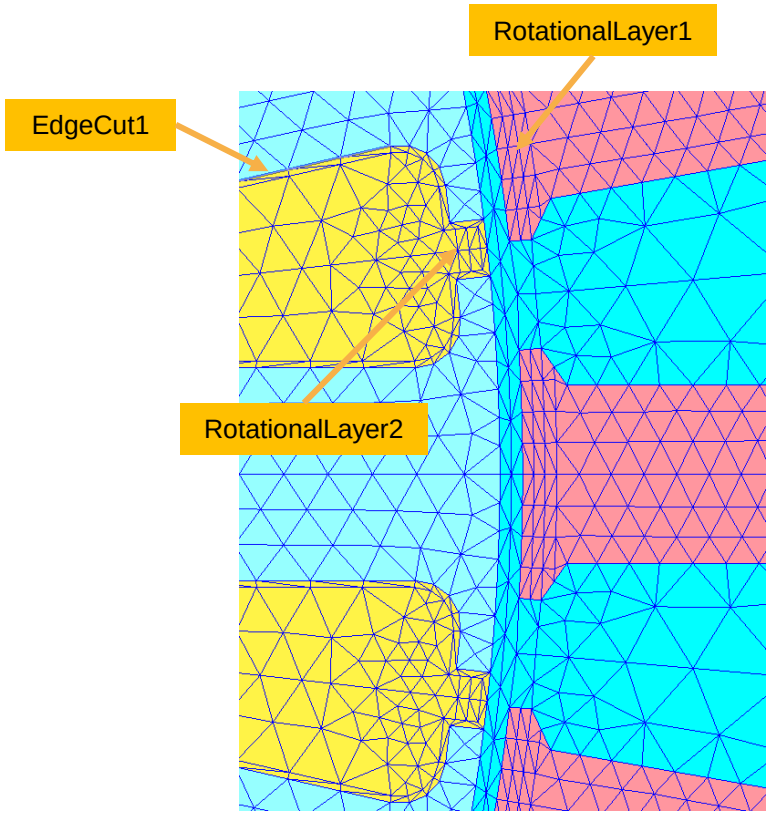
- Creating some Element-Mesh-Layers



Name	Value	Unit	Evaluated
Name	EdgeCut1		
Type	Edge Cut		
Region	Inside Selection		
Layer Thickness	0.15	mm	0.15mm

Name	Value	Unit	Evaluated
Name	RotationalLayer1		
Type	Rotational Layer		
Region	Inside Selection		
Total Layer Thickness	0.75	mm	0.75mm
Number of Layers	3		

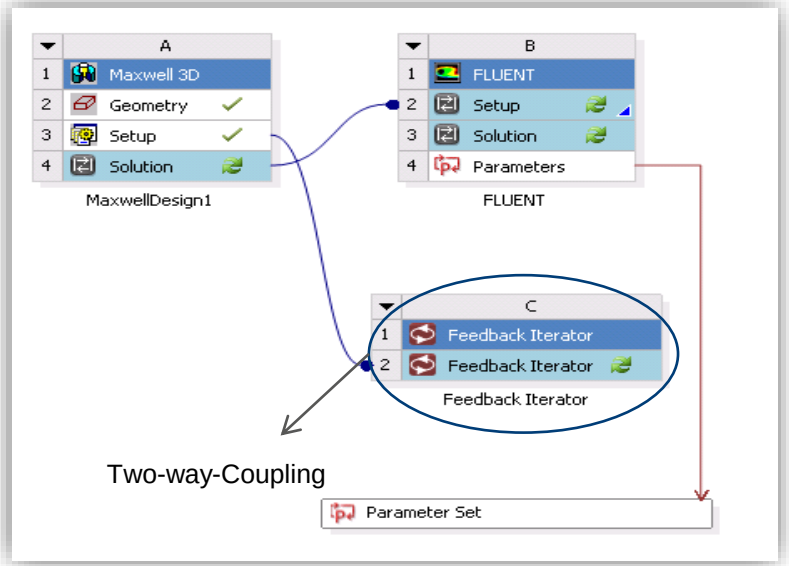
Name	Value	Unit	Evalua
Name	RotationalLayer2		
Type	Rotational Layer		
Region	Inside Selection		
Total Layer Thickness	1	mm	1mm
Number of Layers	2		



Model preparation for Advanced Magnetic Computation

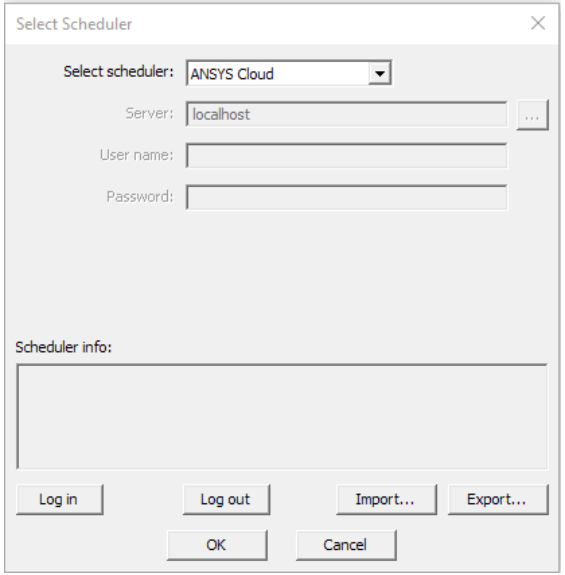
Material properties as a function of the temperature

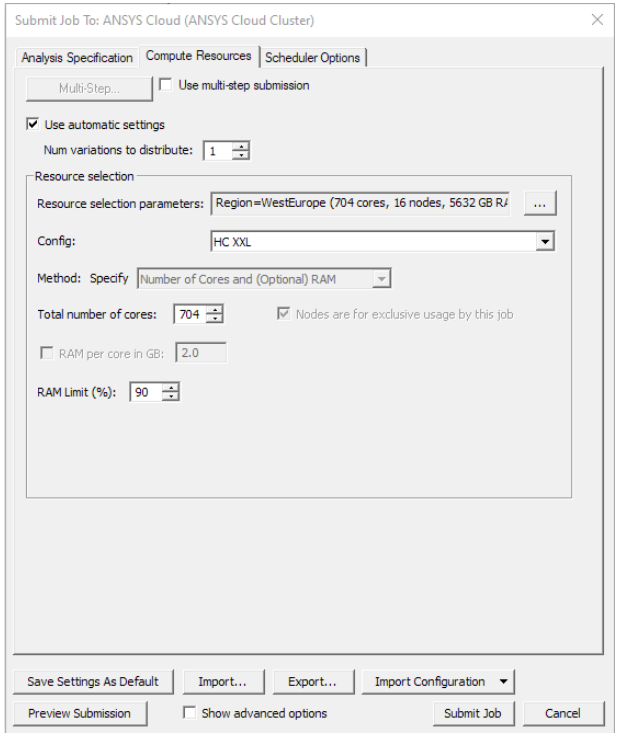
- Most of the Material properties can be defined with temperature dependencies.
- A global temperature per body can be also defined. In that case no coupling with a thermal/CFD solver is needed.
- Temperature distribution can be considered. In this case using a coupling with a CFD solver (Fluent).



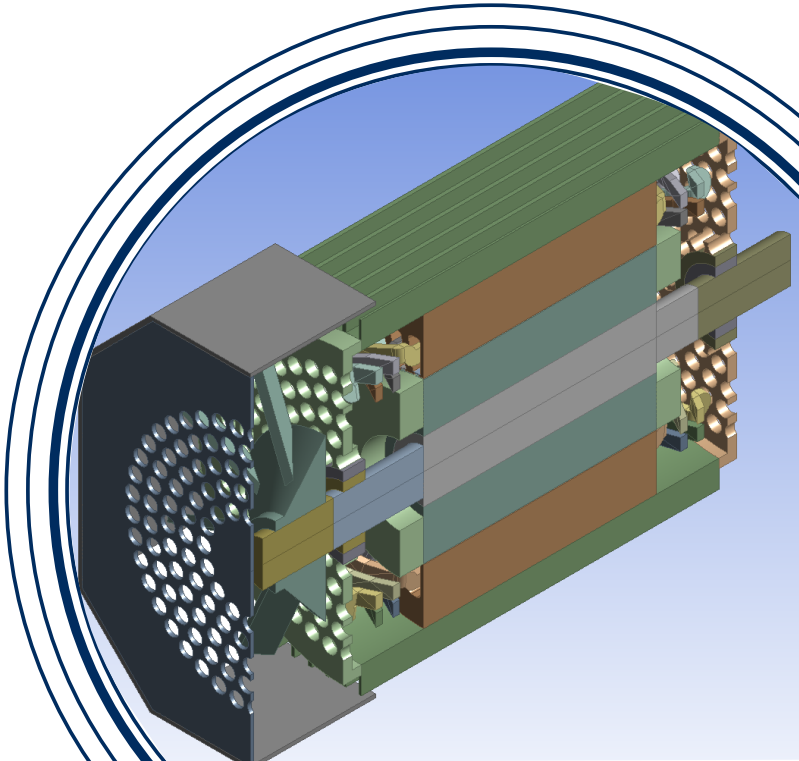
Model preparation for Advanced Magnetic Computation

- Where to solve such a Model?



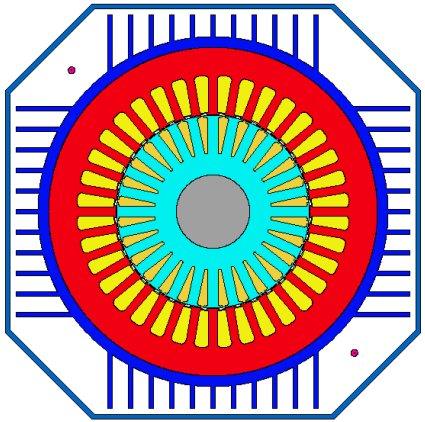


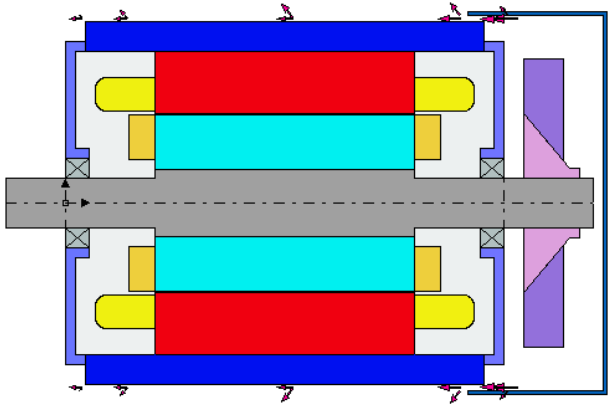
Model preparation for Advanced CFD (Fluent) Computation

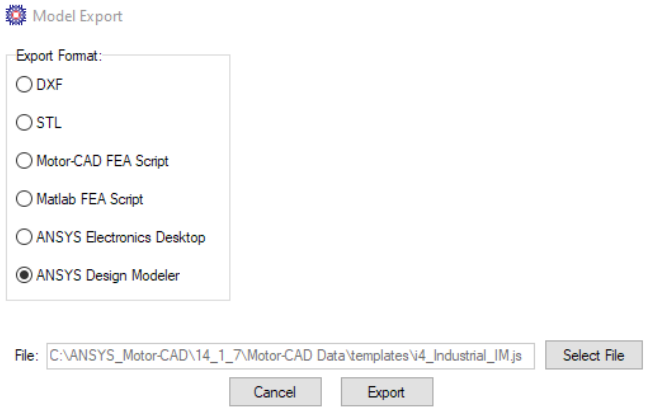


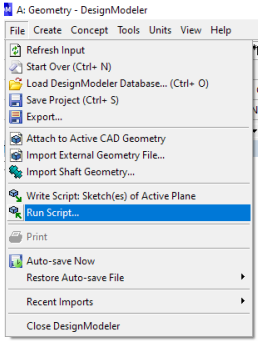
CADFEM® Ansys CERTIFIED ELITE CHANNEL PARTNER

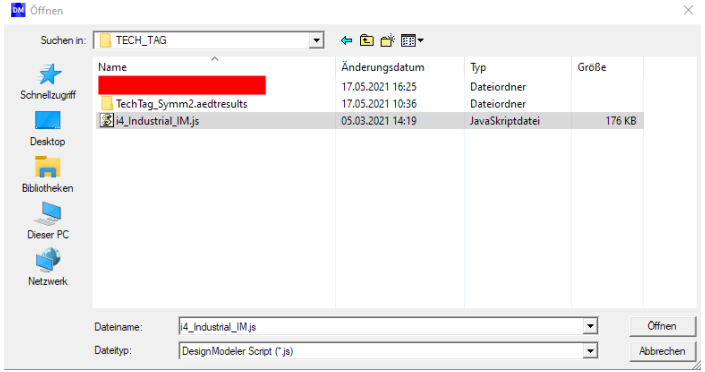
Model preparation for Advanced CFD (Fluent) Computation

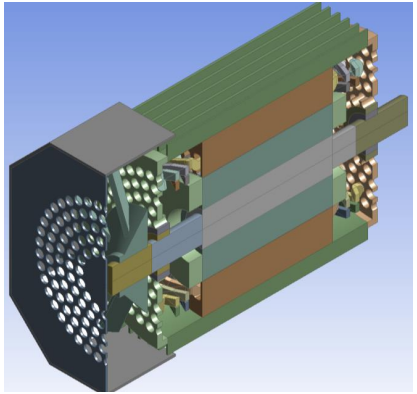








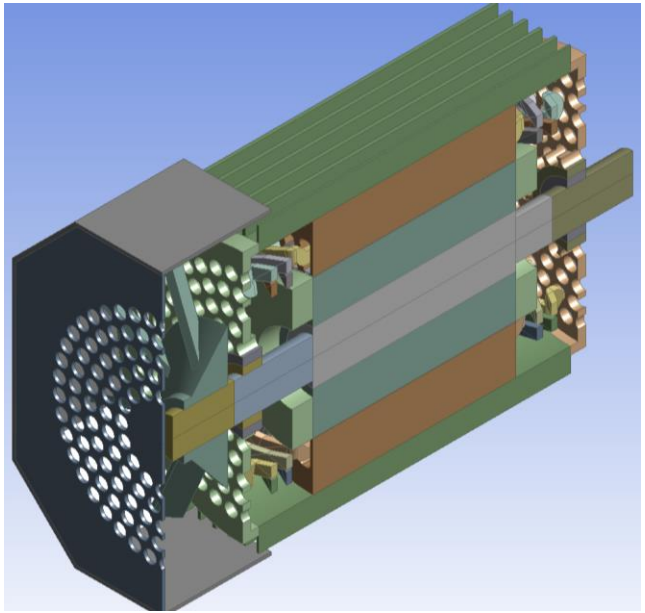


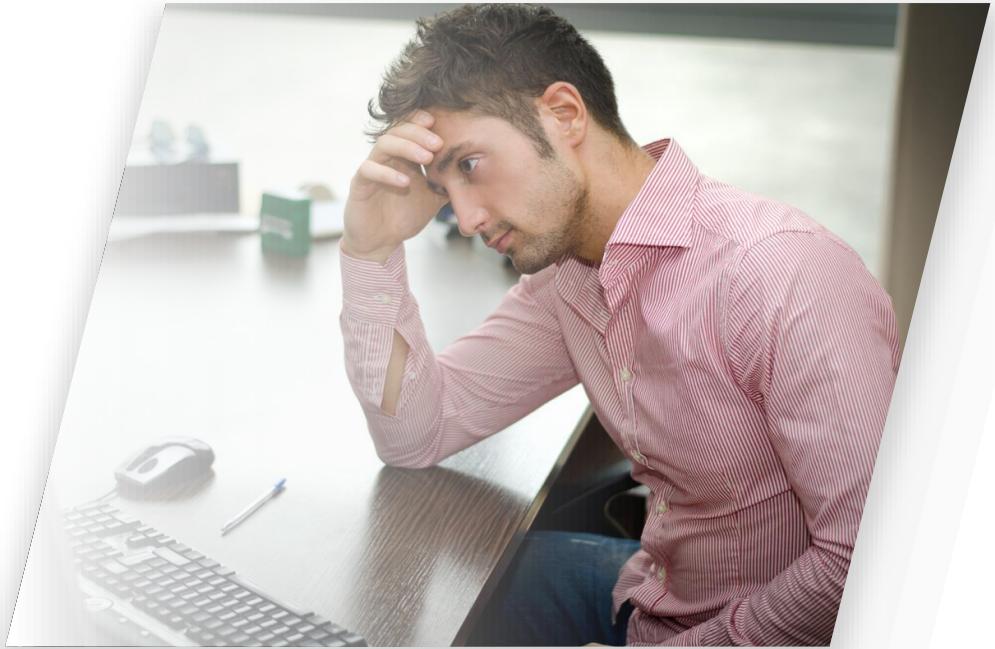


Model preparation for Advanced CFD (Fluent) Computation

CADFEM

How to mesh this model?



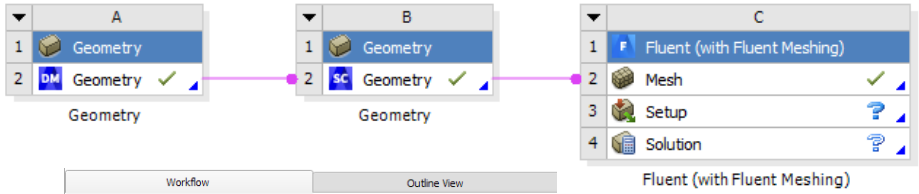


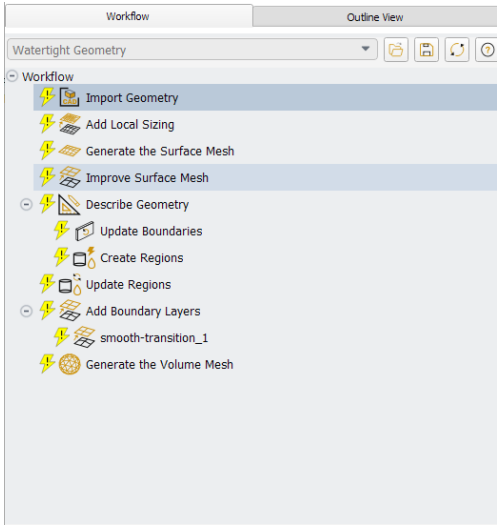
Model preparation for Advanced CFD (Fluent) Computation

Task-based workflow for watertight geometries

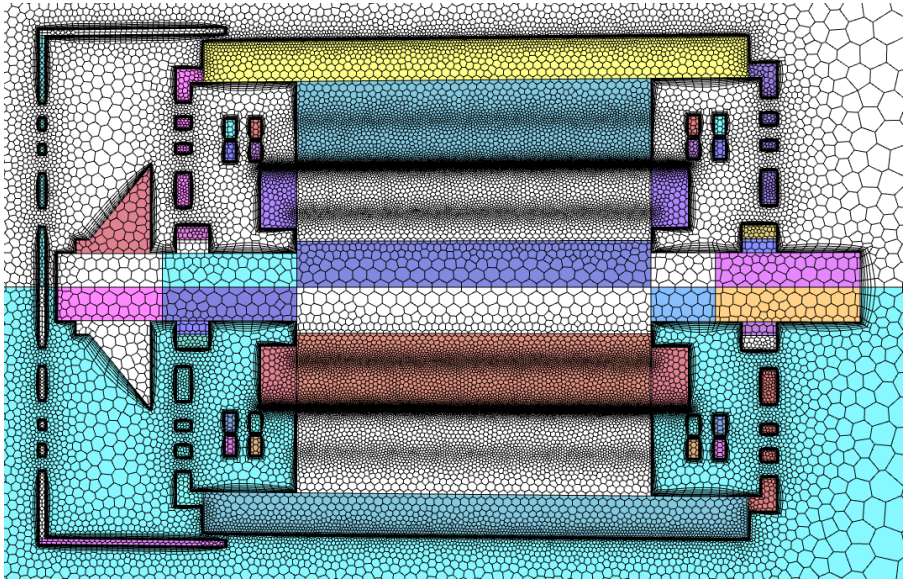
- ANSYS Fluent Watertight Geometry Workflow: 70% faster; 50% less hands-on time

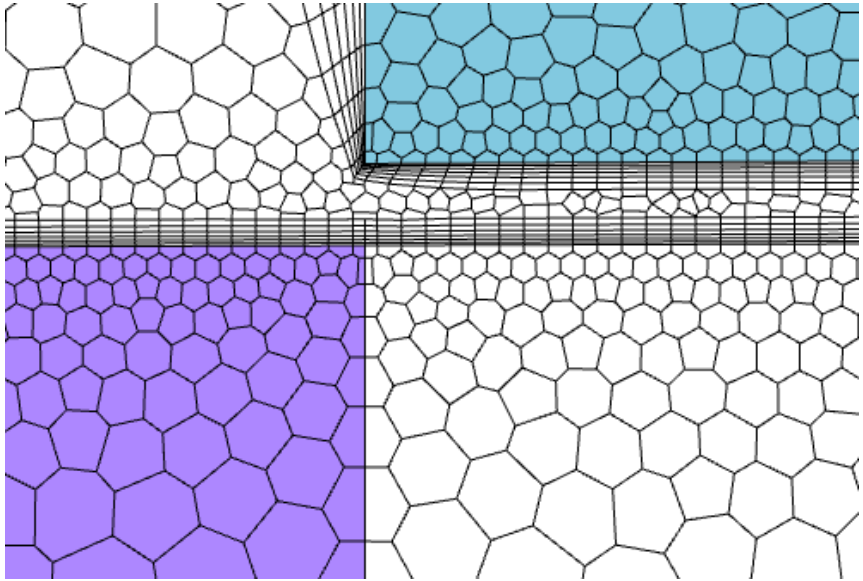
- Mosaic™ technology automatically combine disparate mashes with polyhedral elements for fast, accurate flow resolution



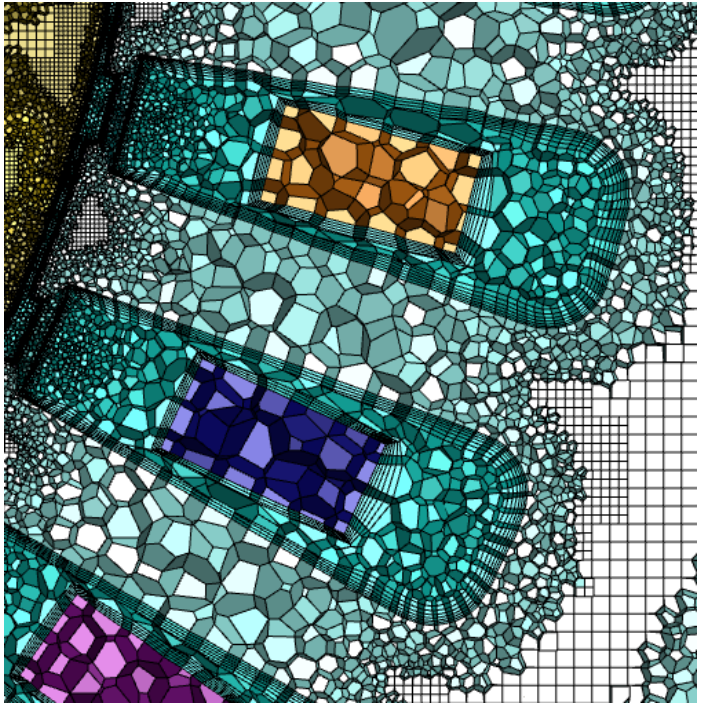


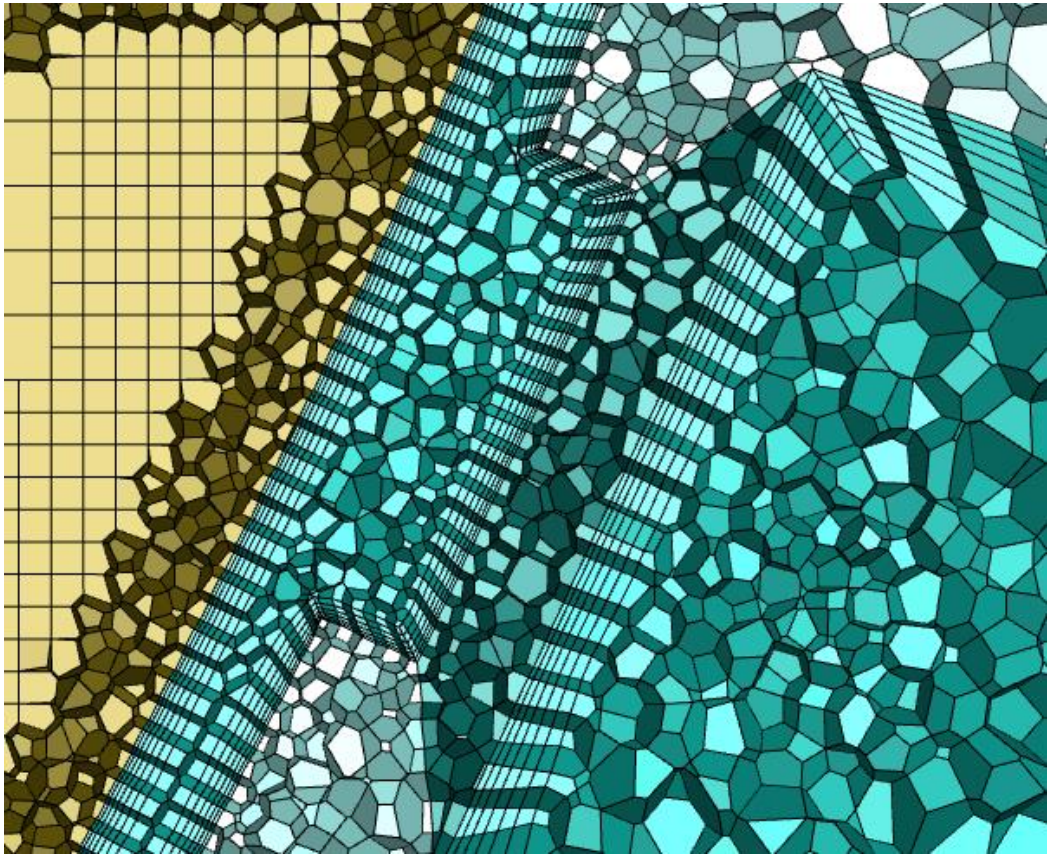
Model preparation for Advanced CFD (Fluent) Computation



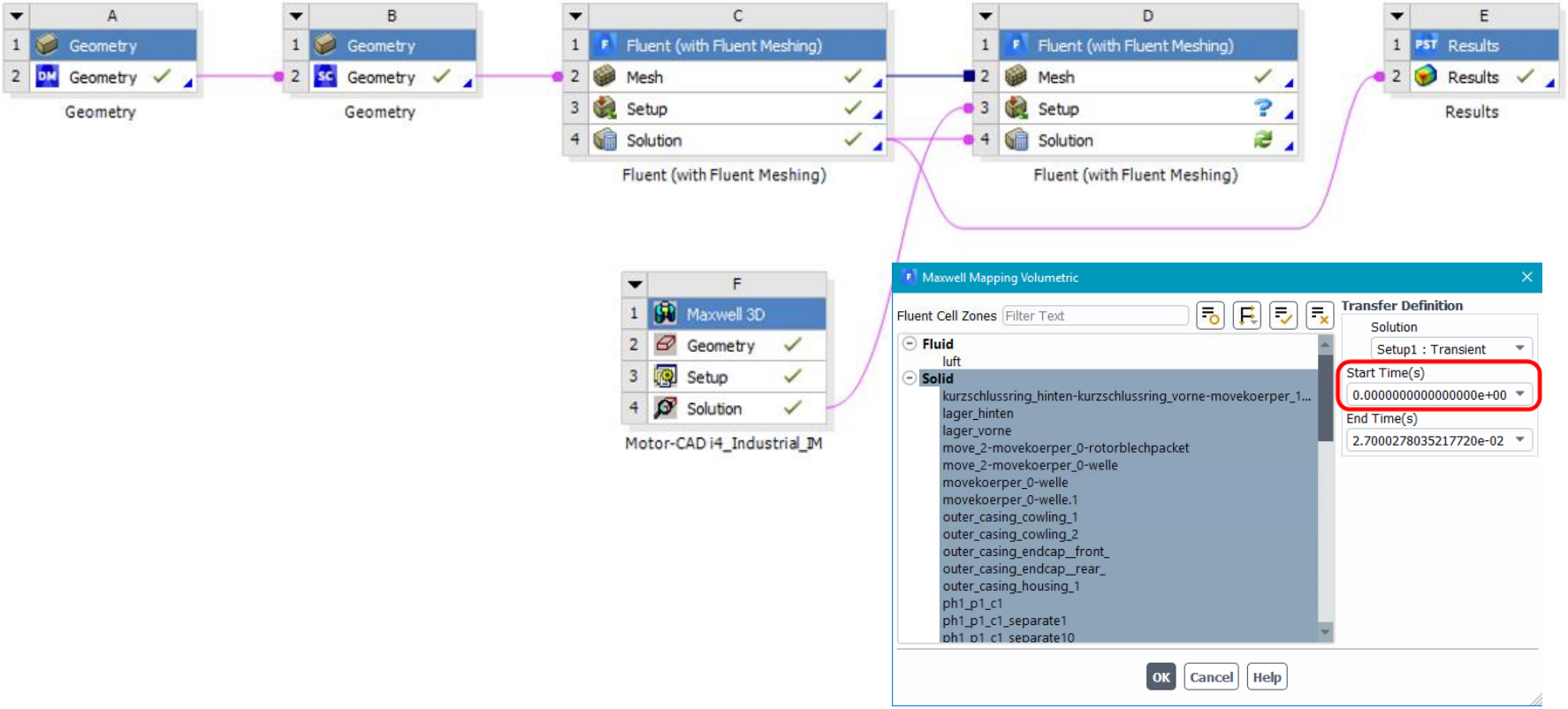


Model preparation for Advanced CFD (Fluent) Computation

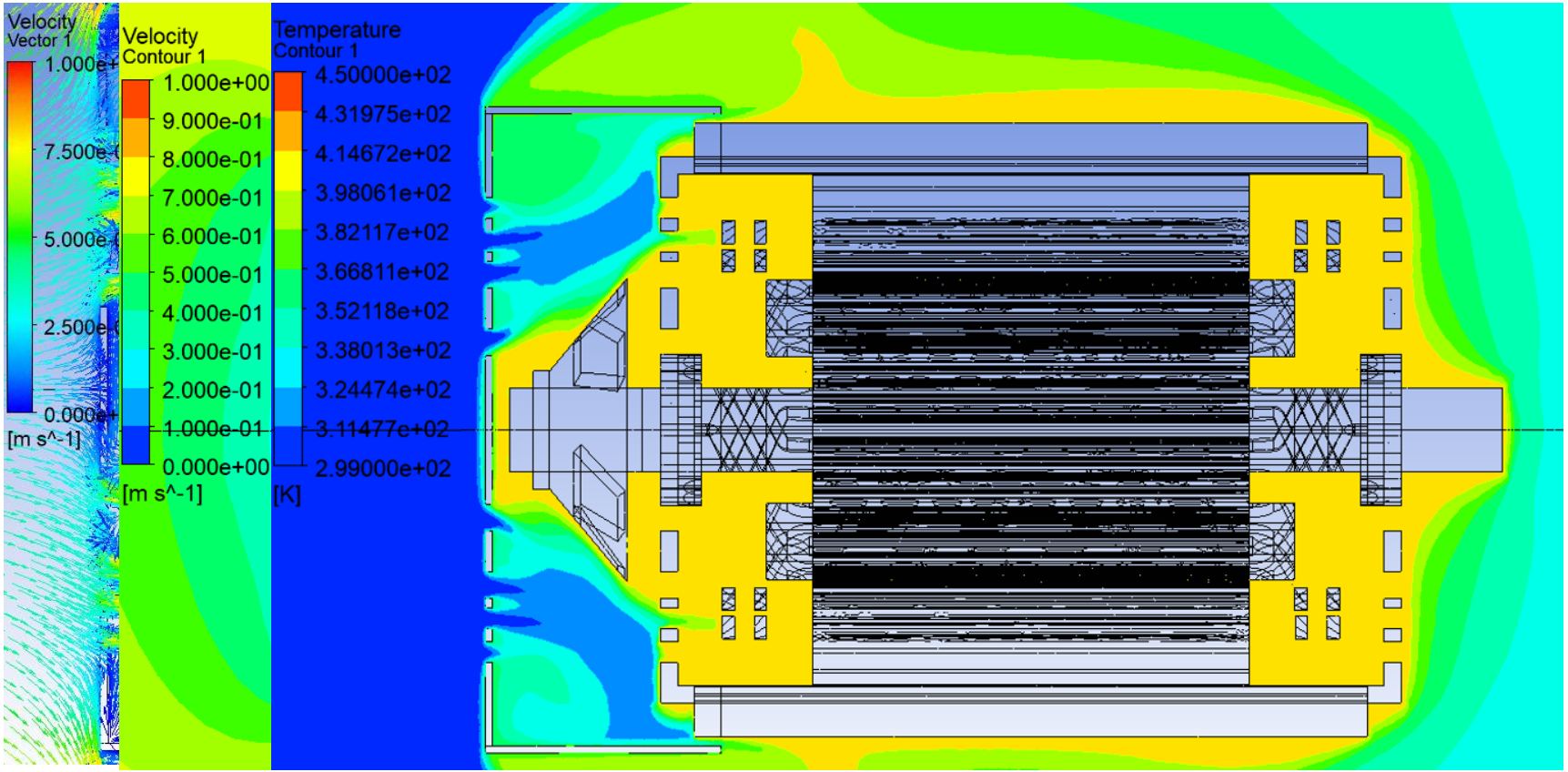




Coupling between Maxwell and Fluent



Postprocessing



Summary

- The first Motor ideas in Motor-CAD can been exported into Maxwell 3D for advanced magnetic calculations.
- Motor-CAD provide also an easy way to generate 3D Geometries for advance CFD calculations.
- Mesh settings in Maxwell 3D can help to create a regular mesh without extra manual work (rotational movement only).
- ANSYS Fluent Watertight Geometry Workflow provide a powerful tool for mesh generation with less hands-on time
- ANSYS Cloud support ANSYS Maxwell and ANSYS Fluent. Users can run large models on the cloud reducing the simulation time.

Nice Videos to watch

CADFEM

Cloud Computing from Electronics Desktop – YouTube

Ansys Cloud Demo with Fluent - YouTube

Fluent: Watertight Geometry Meshing Workflow – YouTube

Thermal Analysis of Induction Motor Using Maxwell & Fluent - Part 1 – YouTube

Thermal Analysis of Induction Motor Using Maxwell & Fluent Part 2 – YouTube