An integrated Workflow for the Simulation-Driven Development of Electric Motors and Generators

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New challenges in the development of electric drive systems

- Application specific requirements getting more restricted
- Faster response times to customer inquiries and shorter development times
- Different motor designs available and more competitors on the market
- System performance map required during tendering stage
- ...

Simulation-Driven Product Development

Concept & Design

Simulation

Virtual Prototype

Prototype

Parametric Design Optimization

Design Analysis
Simulation Depth

- Analytical Approach
- FEM Simulation
- Coupled Analysis
- Behaviour Models
- Fatigue & Lifetime

More Details

Multiphysics

System
Simulation Requirements

Preliminary Design

- Electro-magnetic
- Drive Circular
- Thermal

Component Development

- Electromagnetic
- Electronic
- Multiphysics
- Thermal
- Structural

System Engineering

- ROM
- C/C++
- FMU
- Model
- ...


**Objectives**

- Investigation of the possibilities
- Fast evaluation of different designs
- Coupled preliminary electromagnetic and thermal analysis
- Fast evaluation of performance maps and duty circles
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Requirements
• Software to evaluate fast and accurate electromagnetic and thermal behaviour
• Capability for preliminary optimization and sensitivity analysis
• Automated workflows for data exchange
Motor-CAD Software

- **EMag**: A fast 2D finite element module for accurate electromagnetic and electrical performance predictions.
- **Therm**: Combines a lumped circuit and finite element thermal calculation for optimising the cooling system of a machine.
- **Lab**: Provides efficiency mapping and duty cycle / drive cycle transient outputs within minutes.

*Written by motor design experts in the language of the motor designers so very easy to use.*
How to use Motor-CAD

- Extensive range of parameterised templates
  - Design Variables, Winding Type, Cooling Type, ...
- Simple input masks in the form of tables
  - Geometry, Winding, Materials, ...
- Automatic setup for different simulation tasks
  - Steady-State & Transient Thermal Analysis
  - Performance Tests: Single Operating Point, Open Circuit, On Load, Transient, ...
- Fast and accurate solver technique
  - Fastest FEA electromagnetic solver (assembly code)
  - FEA thermal solver for windings
- Coupled Analyses
  - Easy switching between electromagnetic and thermal setup
- Enhanced capabilities
  - Scripting, Smart loss calculation algorithms, Manufacturing data built into models
- All in one GUI
Simulation time less then a minute

Simulation time few seconds

Simulation time few minutes
Automation of Workflow and Optimisation

- Graphical programming, based on templates, wizard-based derivatives
- Post-Processing: visualization, main info at a glance, investigation when needed
- State-of-the-art sensitivity analysis + MOP + Robust Design Optimization

**fully automatic**

- pre-calculation
- optimize: slots, poles, winding
- optimize: peak torque + thermal
- optimize: multiple load cases / map
- optimize: NVH, 3D, losses

- Investigative research → gain insight & understanding
- Establish workflows → benefit from your (codified) competence
- Integrated Workflows → optiSLang connects
Objectives

- Detail analyses of the electric drive
- Investigation of transient or three dimensional effects on the electromagnetic behaviour
- Coupled and uncoupled structural, thermal and power electronics simulations
- Generating deeper physical understanding and there dependence on the electric drive system
- Acoustics simulations (NVH)
Objectives

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Requirements

- High-end simulation tools for the different physical domains
- Easy coupling between the results from different domains (Simulation Platform)
- Sensitivity and robustness analysis over different tools and many parameters
- Workflow automation and file data handling
MAXWELL
• Electromagnetic Fields
• Induced Voltage
• Induction Matrix
• Forces & Torques
• Losses

CFD
• Heat transfer Coefficient
• Temperature Distribution
• Flow Characteristics

Twin Builder
• Control Parameters
• System Behaviour
• Power Electronics

WORKBENCH
• Simple Exchange of Data
• Connecting by Drag and Drop
• All Physics Domain in one GUI
• Coupled Optimisation

MECHANICAL
• Stress, Stiffness and Deformation
• Eigenmode
• Temperature Distribution
Electronic-Electromagnetic Coupling

- Influences of power electronics
  - Sinus vs. PWM excitation
  - Additional Losses

- Control loops
  - Optimization
Why coupling?

- Without considering demag
- Considering demag but no temperature impact
- Considering demag and temperature dependence
The losses obtained by EM-Simulation are used as realistic loads.

- **Thermal analysis without fluid dynamics**
  - Conduction, diffusion, advection, convection and radiation
  - Special elements for advection
  - Solves faster due to smaller project size
  - Convection has to be defined by boundary condition
  - Thermal Heat Coefficients has to be taken from literature

- **Thermal analysis with fluid dynamics**
  - Solves for heat transfer coefficient
  - Higher accuracy for fluid problems
  - Setting up of the model is more complex
Automated load transfer from magnetic field analysis
- Uncoupled or Coupled Simulations
- Static Simulation
  - Stresses (E-Steel, Housing)
  - Deformation
  - Resonance Frequencies
- Dynamic Simulation
  - Harmonic response based on magnetic forces
- Transfer of transient magnetic loads to frequency domain by DFT
Workflow:

External computation of excitation loads

Electromagnetic Analysis

DFT

Excitation Loads

谐波振动分析

Harmoic Vibration Analysis

振荡，ERP，瀑布图

Oscillation, ERP, Waterfall Plot

ANSYS Mechanical with Electric Drive Acoustics inside ANSYS

E.D.A. inside ANSYS
Objectives

• Analysis and optimization of a system without extensive coupled FEM simulation
• Generating accurate behavior models from the component analysis
• Implementation of third party behavior models
• Fast evaluation of performance maps and duty circles on a system level
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Requirements

• Physical based system simulator with the possibility to generate State Space Model, Reduced Order Models, MOP, …
• Implementation of 3rd party models
• Optimization, sensitivity and robustness analyses
Twin Builder (Simplorer)

- Reduced Order Model Creation
- System Model Interoperability
- Co-simulation with 3D Physics
- Embedded Software Integration
- Multi-Domain Model Libraries
- Language-Based Modeling

Industry Standards for System Modeling
Thousand of Built-in Component Models
Interfaces with all ANSYS 3D Physics
ANSYS SCADE and More
3rd Party System Modeling Tools
Model Reduction in ANSYS Mechanical with CADFEM MOR-ACT
Summary - Workflow Overview

Preliminary Design

- Workflow Handling, Optimization, Sensitivity and MOP

Component Development

- ANSYS
- MAXWELL (Electromagnetic)
- CFD (Thermal)
- WORKBENCH (Multi Physics)
- MECHANICAL (Structural)

System Engineering

- ANSYS
- TWIN BUILDER (Power Electronics)

- CAD Data
- Material Data
Summary

- An integrated workflow for the simulation-driven development of electric motors was presented.

- The importance of an compact and fast simulation tool chain for the preliminary design phase was highlighted.

- Easy coupling of different physical domains is important to get realistic loads and accurate results.

- The development process have to be accompanied by optimization and sensitivity studies.

- Parts of the workflow was already implementation in the development process from our customers.
Simulation macht vieles möglich
Gemeinsam holen wir das Beste heraus