Introducing openCFS

Coreform Webinar, January 13, 2022

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Content

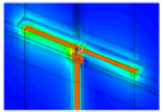
1. Introduction
2. openCFS
3. Case study of a current research project
4. Future developments in openCFS
5. Use of coreform cubit and openCFS for teaching and research

Our institute - IGTE

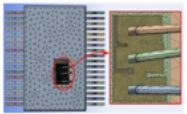
Institute of Fundamentals and Theory in Electrical Engineering, TU Graz, Graz, Austria

- Founded in 1950 at TU Graz
- Current head since 2020: Prof. Manfred Kaltenbacher
- Four research groups

Full wave FEM simulation of an unbalanced feed dipole antenna



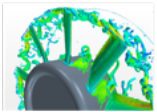
High-Frequency Electromagnetic Fields



Simulations of power semiconductors

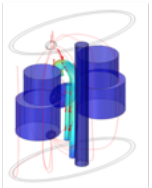
Multiphysical Modeling and Simulation

Aeroacoustics and Vibroacoustics



Sound sources of an axial fan

Optimization and Inverse Problems

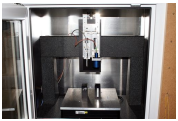


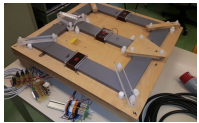
Simulation model of a human thorax for the identification of an aortic dissection

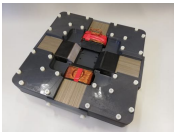
Multiphysical Modeling and Simulation Group (MMS)

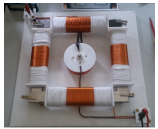
MMS Group

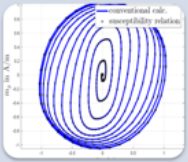
- PostDoc: Klaus Roppert
- Currently 2 PhD-, 3 MSc- and 1 BSc student
- Diverse set of topics, all connected via openCFS

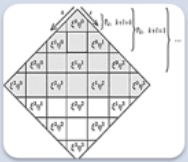












EM Material Modeling

- Network hysteresis
- Efficient Vectorhysteresis in FEM
- Measurements (RSST, Epstein, transformer benchmark, 3D Hall probe)
- ...

Computational Electromagnetics

- Development of EM field formulations
- Low frequency approximations
- Darwin approximation
- Efficient global excitation in FEM
- ...

openCFS Software Development

- Algebraic multigrid (AMG)
- Nonlinear solution strategies
- Non-conforming interfaces
- Sliding interfaces
- Higher order elements
- Edge elements
- ...

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Introduction to openCFS

Beginning
- Project “CAPA” started around 1985
- 1993 joined by Prof. Kaltenbacher

Continuous Development
- Continuously developed by PhD students of Prof. Kaltenbacher
- Renamed to “CFS++” (Coupled Field Simulations in C++)

Restructuring
- Introduced highly OOP paradigms
- Increased flexibility significantly
- Ensured future existence and further development

Open Source
- openCFS launched in 2021 under MIT license
- Three development universities: TU Graz (Austria), TU Wien (Austria), FAU Erlangen Nuremberg (Germany)

New in 2021

- Commercial support via EnSimTech UG
  `https://www.ensimtech.com/`
- Developed on gitlab.com
  `https://gitlab.com/openCFS/cfs`
- openCFS homepage
  `https://opencfs.org/`
- User documentation
  `https://opencfs.gitlab.io/userdocu/`

openCFS

openCFS - Capabilities Overview

- Acoustics
- Electrostatics
- Mechanics
- Magnetics
- Piezo
- Thermal
- Magneto-mechanics
- Vibroacoustics
- Piezo-Acoustics
- Magneto-mechanic-Acoustics
- Thermo-mechanics
- Static Analysis
- Transient Analysis
- Harmonic Analysis
- Multi-Harmonic Analysis
- Eigenfrequency Analysis
- Nonconforming Grid
- Model Order Reduction
- Structural Optimization

Simulation workflow

Preprocessing

- openCFS can read *cdb, gmsh, ensight, gmv, hdf5*
- Most of the time, coreform cubit's cdb interface is used
- Teaching: only coreform cubit

openCFS

- xml-based input (GUI in future releases)
- openCFS execution via terminal or script (python, bash, matlab, ...)
- Output writer supports *hdf5, txt, csv*

Postprocessing

- Field results via *hdf5* and Paraview
- Single value results via *txt*

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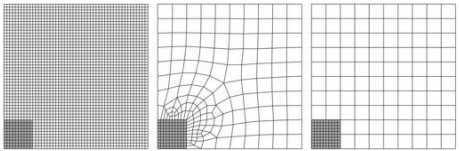
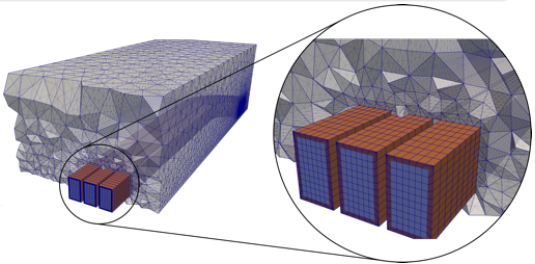
Non-conforming interfaces

Why NC interfaces?

- Easier preprocessing for localized solution agglomerations
- No need to handle elements in transition zone
- Coupling of different element types
- Relative motion between domains

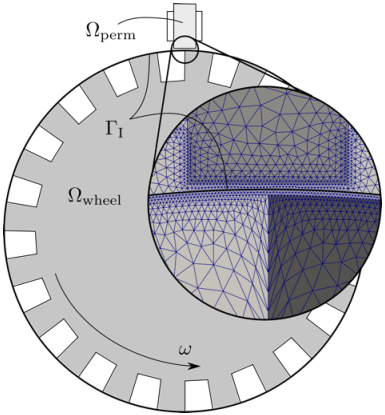




Non-conforming interfaces - gearwheel sensor

Simulation

- Eddy current problem (magneto quasistatic)
- Nedelec edge elements
- Nitsche non-conforming interfaces
- Rotating mesh



Video

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Future developments in openCFS

- Exodus-reader for better data exchange with coreform cubit
- Graphical user interface
- Improving the user-documentation for teaching
- Developer manual for lowering the entry barrier of contributing

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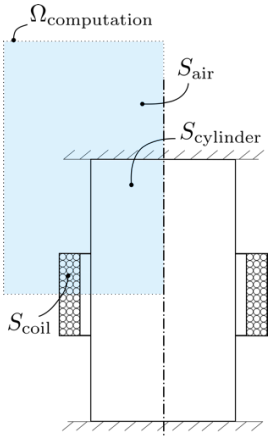
Demonstration example: Heating of a steel rod

- Steel cylinder is heated by an alternating current in the coil
- How fine do we need to discretize the skin-region?
- What's the temperature distribution in the rod?
- Observe the mechanical deformations of the rod

Goal: Coupled magnetic-thermal-mechanic PDE



Use of coreform cubit and openCFS for teaching

Teaching: Multiphyical Simulation I & II courses

1. Introduce coreform cubit's GUI
2. Draw the attention to the journal editor
3. Not every command must be memorized: GUI shows the correct journal command
4. Introduce variables in the journal file
5. Introduce terminal calls with variables
   `coreform_cubit -batch -nographics -nojournal variable1=1.45 journalfilename.jou`
6. Perform simple parameter studies by controlling `coreform_cubit` calls with python
7. Advanced: use coreform cubit's python API for more control of the meshing procedure

Questions?

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