Modular Software Development for Quench Analysis of Accelerator Magnets

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$\Rightarrow$ Convenient usage of different tools is a common problem

Example 1

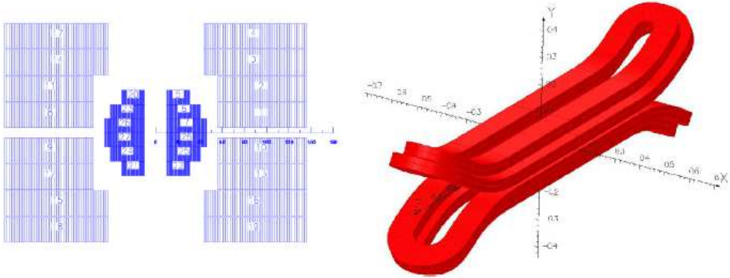

Figure: Early LTS-HTS dipole magnet design

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$\Rightarrow$ Everything could be handled with one software including multiple modules!

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- From these starting points we decided that our software, will be based on open source (C++) FEM platform GMSH[1].
  - There had been development project for GMSH going on for years in TUT, which was a tremendous help at the start.

[1] C. Geuzaine and J.-F. Remacle, Gmsh: a Three-Dimensional Finite Element Mesh Generator with Built-in Pre- and Post-processing Facilities, Int. J. Numer. Meth. Engng, vol. 79, pp. 1309-1331, 2009.

Example 2

The following equations are necessary when constructing a finite element method based software:

$$\nabla \cdot \lambda(T)\nabla T + Q(T, \mathbf{B}) = C(T)\frac{\partial T}{\partial t}, \tag{1}$$

$$T \approx \sum_{i=1}^{n} T_i \varphi_i \simeq [T_1 \ldots T_n]^T = \mathbf{T}, \tag{2}$$

$$S(T)\mathbf{T} + b(T) = M(T)\frac{\partial \mathbf{T}}{\partial t}, \tag{3}$$

$$S_{ij} = \int_\Omega \langle \nabla\varphi_i, \lambda(T)\nabla\varphi_j \rangle. \tag{4}$$

- Element iterators and DoF managers were available from previous development.

⇒ GMSH natural choice as the platform for our software!

Structure of the software: Heat diffusion equation solver

In our software we analyze quench by solving the heat diffusion equation (1) within the coil volume

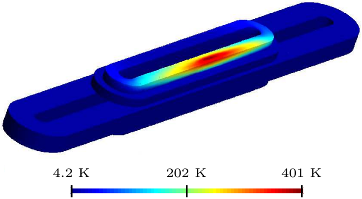

Figure: Example computation of temperature distribution after the quench.

Structure of the software: Magnetostatic solver

Magnetic field distribution is needed as an input for the quench solving module, thus, we have to solve the magnetostatic problem:

$$\nabla \times \frac{1}{\mu} \nabla \times \mathbf{A} = J. \tag{5}$$

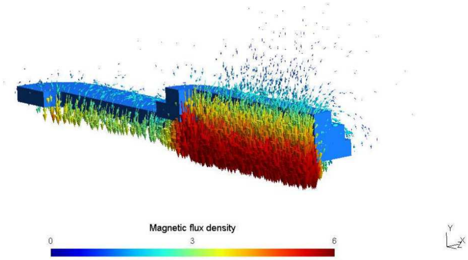

Figure: Magnetic field distribution for HTS insert.

Structure of the software: Flow of the software

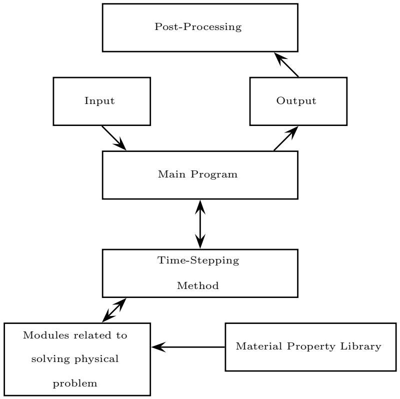

Figure: Block diagram of the computational model

Case study and results: YBCO insert magnet

- Quench simulation for a small insert magnet was scrutinized
- Modular approach was utilized
- CERN coordinated European project for R&D of HTS accelerator magnets:
  - our task is quench simulations

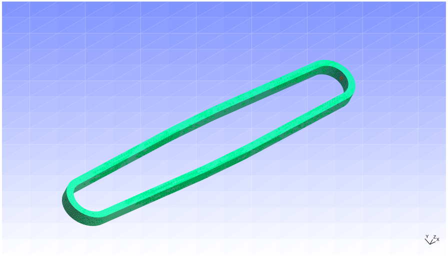

Figure: Investigated magnet.

Case study and results: YBCO insert magnet

- Complicated geometries can also be utilized

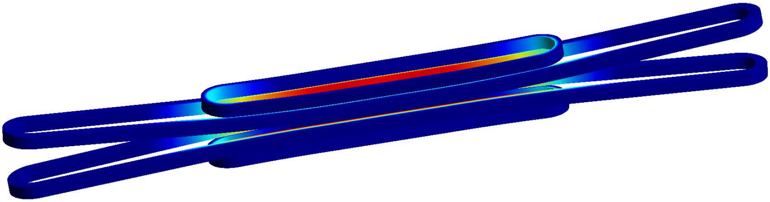

Figure: Advanced model of the insert magnet.

Case study and results: YBCO insert magnet

- Even this is possible!

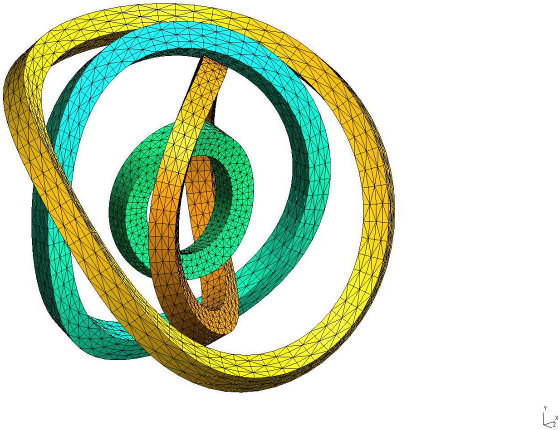

Figure: Only computing power is a limiting factor.

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- Utility and performance improvements for the software.

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Thank you