3D Simulation of Transient Effects in Accelerator Magnets

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Cooperation DESY - TEMF

current research topics
- eigenvalue calculations
- resistive wakefield calculations
- photo-emission studies

brainstorm on further cooperation topics
- new cavity structures
- simulation of multipacting
- simulation of wakefield acceleration
- simulation of transient effects in accelerator magnets
Accelerator magnets

- complicated geometries + production tolerances
- 3D effects (fringing, eddy currents)
- multi-physics (cryogenics, deformation)
- multi-scale models (windings, laminations)
- transients (e.g. remanence)
- materials ...
Materials

- ferromagnetic materials (nonlinear, hysteretic, magnetostriction)
- superconducting materials (thermal & magnetic stability, persistent currents)
- composites (homogenisation)
- windings (homogenisation)
- uncertainties
Discretisation in space

differential equation: \[ \nabla \times (\nabla \times \vec{A}) + \sigma \frac{\partial \vec{A}}{\partial t} = \vec{J}_s \]

spatial discretisation
edge finite elements (curl-conforming)

\[ \vec{A} \approx \vec{A}_{\text{FE}} = \sum_j \vec{a}_j \vec{w}_j \]

semi-discrete system:

\[ K_\nu \vec{a} + M_\sigma \frac{d\vec{a}}{dt} = \vec{j}_s \]

temporal discretisation
Runge-Kutta

discrete system:

\[ (K_\nu + \alpha M_\sigma) \vec{a}_{k+1} = \text{RHS} \]
GSI SIS100 magnet

eddy-current losses over one cycle for different stacking factors $\gamma_{pk}$

S. Koch, J. Trommler, T. Weiland, TU Darmstadt
Computation effort

solution of $110 \times 4 = 440$ linear systems of equations

- $7.3 \text{ h} @ 72 \text{ CPUs}$
- $4.4 \text{ h} @ 132 \text{ CPUs}$

$W_j^{tv,(0)}$

$W_j^{tv,(1)}$

+ 2 per face

S. Koch, J. Trommler, T. Weiland, TU Darmstadt, 2009
Stern-Gerlach magnet

field homogeneity (original geometry)

field homogeneity (optimised geometry)

B. Masschaele, H. De Gersem (KU Leuven)
A. Pels, J. Corno, Z. Bontinck, S. Schöps, (TU Darmstadt)
Magnet simulation @ TEMF

Competence
• 3D transient FE solvers
• material models
• accurate post-processing (multipoles)
• uncertainty quantification and sensitivity analysis

Cooperation
• S-DALINAC magnets
• GSI magnets
• cooperation with CERN on the modelling of quench propagation