Modelling Quench Propagation: Strengths and Limitations of Commercial and Custom Software

B. Auchmann*, M. Maciejewski*, D. Paudel*, S. Rowan*, and A. Verweij*

* European Centre for Nuclear Research (CERN)
1211 Geneva 23, Switzerland
e-mail: bernhard.auchmann@cern.ch, web page: http://cern.ch

ABSTRACT

The simulation of quenches in superconducting magnets is a multiphysics problem of highest complexity. Operated at 1.9 K above absolute zero, the material properties of superconductors and superfluid helium vary by several orders of magnitude over a range of only 10 K. The resolution of a propagating front requires a sub-millimeter discretization for magnets that may be longer than 10 m. Transverse propagation below the lambda temperature is determined by the superfluid properties of helium, which enable efficient heat transport through microchannels of only 10 µm width. The heat transfer from metal to helium goes through different transfer and boiling regimes as a function of temperature, heat flux, and transferred energy. Electrical, magnetic, thermal, and hydrodynamic effects are intimately coupled, yet "live" on vastly different time and spatial scales.

In this context we study the strengths and limitations of different approaches to quench modelling. While the physical models [1-3] may be the same in all cases, it is an open debate whether the user should opt for commercial multiphysics software like ANSYS [4-5] or COMSOL [6-7], write customized models based on general-purpose network solvers like SPICE or [8] SABER [9-10], or implement the physics models and numerical solvers entirely in custom software, like the QP3 [11], THEA [12], and ROXIE [13] codes currently in use at our institute. Each approach has its own strengths and limitations, some related to performance, others to usability and maintainability, others again to the flexibility of material parameterizations. We attempt a systematic analysis of this topic, based on benchmark problems that are implemented with various tools.

REFERENCES

[1] P. Bauer. Stability of Superconducting Strands for Accelerator Magnets. PhD thesis, Technical University Vienna, 1996.

[2] G. Willering. Stability of Superconducting Rutherford Cables. PhD thesis, University of Twente Enschede, 2009.

[3] P. P. Granieri. Heat Transfer between the Superconducting Cables of the LHC Accelerator Magnets and the Superfluid Helium Bath. PhD thesis, EPFL, Lausanne, 2012.

[4] ANSYS Inc. Ansys 14.5. http://www.ansys.com, last checked Aug. 2013.

[5] S. Caspi, et al. Calculating quench propagation with ANSYS. IEEE Transactions On Applied Superconductivity, 13(2):1714–1717, June 2003.

[6] COMSOL Inc. COMSOL 4.2. http://www.comsol.com, last checked Aug. 2013.

[7] G. Volpini. Quench propagation in 1-d and 2-d models of high current superconductors. Proc. of the COMSOL Conference 2009 Milan, 2009.

[8] C. Williams. SPICE 3 User's Manual. http://newton.ex.ac.uk/teaching/CDHW/Electronics2/userguide/, last checked Aug. 2013.

[9] Synopsis Inc. Saber. http://www.synopsis.com, last checked Oct. 2014.

[10] A. Danner and F. Sonnemann. Review of quench simulations for the protection of LHC main dipole magnets. LHC ICP-Internal Note 00-199, CERN, October 1999.

[11] A. Verweij. QP3: Users Manual. CERN, 2008.

[12] L. Bottura. THEA. CryoSoft, 1.3 edition, 2003.

[13] S. Russenschuck. ROXIE 10.2. http://cern.ch/roxie. CERN, 2012.