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Quasi-3D Magneto-Thermal Quench Simulation of Superconducting Magnets

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Superconducting magnets are employed in accelerators to achieve higher magnetic fields to attain a higher particle-beam deflection. However, superconductivity, i.e. the complete absence of electrical resistivity, is lost upon exceeding a critical temperature leading to the quench phenomenon. Then, the affected magnet regions shift to normal-conducting state and begin to heat up. In the worst case, this can lead to a thermal runaway and extensive damage to the magnet.

Numerical simulations play a crucial role for understanding and predicting quench phenomena. However, the simulation of superconducting accelerator magnets imposes both a geometrical and physical multi-scale problem leading to unreasonably high computational times if tackled with conventional three-dimensional (3D) finite-element (FE) methods.

This work presents an alternative approach, in which a two-dimensional FE method on the transversal magnet cross-section is combined with one-dimensional orthogonal polynomials in the longitudinal direction. The result is a quasi-3D (Q3D) method with hybrid shape functions, which proves to have superior efficiency compared to the conventional 3D FE method while delivering accurate results with much less computational effort. The method is employed to carry out a magneto-thermal coupled simulation on a superconducting magnet component.

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