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User Defined Elements in ANSYS for Multiphysics Modeling of Superconducting Magnets

The commercial finite element software ANSYS is widely used for mechanical, thermal, and magnetic modeling of superconducting magnets. This software includes the capability for users to create their own element type by writing the code which defines the element's properties and method by which the finite element matrices are generated. After compiling a custom ANSYS executable, all other aspects of the software (such as geometry generation, meshing, solving, and post-processing) are compatible with the user element. We report on the development of 2D and 3D user defined elements which extend the capability of ANSYS to now include the effects of interfilament coupling currents (IFCC), quench, and multivariable dependent material properties. Use of these elements with the ANSYS Multi-field solver is shown capable of simulating strongly coupled transient electromagnetic, thermal, and circuit behavior for superconducting magnets. A first benchmarking study is presented which shows close agreement between the new ANSYS elements and a COMSOL Multiphysics implementation developed at CERN for dump resistor and CLIQ based magnet protection of a Nb3Sn block dipole. Following this, the ANSYS elements are shown reproducing strong quench back behavior observed during the test of a Nb3Sn superconducting undulator prototype at Lawrence Berkeley National Laboratory. The agreement with other codes and to test data is a first demonstration ANSYS can simulate IFCC induced quench back behavior required for accurate modeling of many superconducting magnets.

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