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M2Po2B-06: A 3D/2D mixed-dimensional structural model and electro-mechanical phenomenological model for REBCO coated conductors

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As typical REBCO conductors contain laminated high-aspect-ratio (HAR) thin films, such as the silver, REBCO, and buffer layers, effective modeling is a significant challenge. In this study, the three-dimensional/two-dimensional (3D/2D) mixed-dimensional modeling method is adopted to build a novel elastic-plastic structural mechanics model, which realizes the entire simulation of fabrication and cooling processes and subsequently under tensile loading with multi-step modeling. Based on the cohesive zone model (CZM) and 3D/2D mixed-dimensional modeling methodology, the delamination model is further generated. The models include all the major constituent layers of a typical REBCO conductor. Furthermore, a phenomenological model of the internal strain in the REBCO films dependence of critical current (Ic) was developed based on Ekin power-law formula and Weibull distribution function for analyzing the electromechanical properties of REBCO CC tapes under different deformation modes. Simulation results show that the 3D/2D mixed-dimensional model performs simulations with much higher computational efficiency than the full-3D counterpart while maintaining sufficient accuracy. Multi-step modeling is an effective method for elastic-plastic stress and strain analyses of REBCO conductors during the fabrication and cooling processes and under tensile loads. The 3D/2D mixed-dimensional elastic-plastic delamination FE model based on CZM can be used to study the delamination behaviors in REBCO conductors. The phenomenological model was experimentally verified to be effective in Ic degradation behavior prediction under different deformation modes. The 3D/2D mixed-dimensional method models any number of laminated HAR thin layers in a composite as stacked 2D surfaces, thus, resolving the thickness-dependent meshing and computational problems in modeling such composites with full 3D FE approaches. With a set of appropriate model parameters determined by experimental data for Ic under uniaxial tensile deformation, the proposed model can effectively predict Ic degradation behavior including reversible and irreversible processes in different deformation modes.

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