Analysis of Mechanical and Mechanoelectrical Coupling Behaviors of Cubic and Tetragonal Phase Nb3Sn Superconducting Crystals at Cryogenic Temperatures (Postprint)

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Abstract

The electromechanical coupling effects in Nb3Sn superconducting phase transitions exert adverse effects on the electromagnetic performance metrics and safe operation of superconducting magnet systems. Given that Nb3Sn possesses two crystallographic phases—cubic and tetragonal—mechanical models for Nb3Sn cubic-phase, tetragonal-phase, and mixed-phase crystals have been developed, as well as an electromechanical coupling response model incorporating strain-induced critical temperature degradation and strain-dependent normal-state resistivity variation. The results indicate that while phase structure leads to differences in the elastic properties of single crystals, the local stress state in Nb3Sn polycrystals with different phase structures under hydrostatic pressure is independent of phase structure and is determined solely by grain morphology and orientation. Owing to the fundamentally consistent evolution of the electronic density of states at the Fermi surface under external loading for different phase structures, the strain-induced critical temperature degradation shows no dependence on phase structure. For the normal-state resistivity variation in mixed-phase Nb3Sn, the T^2 dependence derived from the electron-electron scattering assumption can be used to describe the behavior below the martensitic transformation temperature; above this temperature, the transformation from tetragonal to cubic phase requires consideration of electron-phonon coupling contributions to normal-state resistivity, and the extended Woodard-Cody resistivity model can be used to describe the strain effect on macroscopic resistivity. These results improve the understanding of critical performance degradation mechanisms across different phases.

Full Text

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