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Structural Modeling of HTS VIPER Cable for High-Field Magnet Applications

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A structural model has been developed for the VIPER cable, which is based on the Twisted Stacked-Tape Cable (TSTC) design and has four slots each containing 50 REBCO HTS tapes. Each slot contains a TSTC and the entire void space is filled with solder. The four slots are arranged around a central cooling channel. It is developed by Commonwealth Fusion Systems (CFS) in collaboration with the Plasma Science and Fusion Center (PSFC-MIT) [1]. The VIPER cable was designed for use in the Central Solenoid and Poloidal Field coils of the SPARC tokamak experiment. During the manufacturing and the operation of the magnets, the cable will experience including bending to the shape of the coil, cool down, and cyclic transverse compressive Lorentz loading. Understanding the stresses generated in the HTS tape-stacks during these conditions is crucial for characterizing the cable's performance and optimizing its design.

In this work, structural finite element analysis is used to simulate the stresses incurred within the tape-stacks of the VIPER cable under the following conditions: as the cable is (1) bent to the 1 m diameter specified for the central solenoid, (2) cooled down to its operating temperature (10 K), and (3) subjected to a transverse Lorentz load during operation. The simulations are used to investigate the mechanical effects of the solder impregnation onto the tape stacks during bending and cool down. In addition, results obtained in this work shed light on the early-stage critical current degradation observed experimentally in the VIPER cable during the first 10 cycles of Lorentz loading (400 kN/m) [1]. The numerical modeling provides important information on the strain state of the tape-stacks and insights on the optimization of future configurations.

[1] Hartwig, Zachary S., et al. "VIPER: an industrially scalable high-current high-temperature superconductor cable." Superconductor Science and Technology 33.11 (2020): 11LT01.

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