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Sat-Af-Or2-06: A comprehensive framework for the mechanical analysis of Ultra High Field REBCO Solenoids

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The need for strong steady state magnetic fields, of 40 T and above, raises several new challenges in the design of superconducting magnets. Rare-earth barium copper oxide (REBCO) coated conductors (CCs) are nowadays the strongest candidates for this type of applications, yet the layered structure of these materials carries along the major mechanical challenges. Recent tests of ultra-high field (UHF) REBCO magnets have demonstrated the capabilities of these conductors of operating at fields up to 45.5 T, but they also evidenced some critical multi-scale dynamic effects, where crack patterns and delaminated areas in the REBCO phase influence the electrodynamics and quench behavior of the magnet.

In this contribution, we report on an encompassing multi-scale approach for the mechanical analyses of REBCO UHF solenoids; a paradigm that has been proposed in the context of the R&D studies for a 40+ T no/partial-insulation (NI/PI) solenoid for the Muon Collider. The goal of this approach is to estimate the stress/strain state inside a superconductor when employed for UHF applications. We investigate here the mechanical challenges based on material characterization campaigns and modeling efforts developed synergistically at coherent scales.

Initially, as a steppingstone, we focus on mechanical properties of REBCO layers'materials, presenting a measurement campaign at the micro-scale which provided with reliable constitutive laws for any further mechanical studies. We then address the issue of screening currents induced stresses/strains (SCIS) in connection with measurements of the delamination strength of REBCO CCs under Lorentz force. Finally, we move to examining the mechanical loads in the case of quenches in the windings. The evolution of the force density field and consequent stress fields are treated in a statistical manner, highlighting trends and extreme case scenarios.

In conclusion, for each of the mechanical load step mentioned above, we propose a set of design criteria to be used in the design of UHF solenoids.

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