High definition 3D finite element analysis of low temperature Rutherford cable

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In the perspective of simulating and managing the mechanical stresses within strain-sensitive superconductors such as Nb₃Sn, we are proposing a multiscale numerical approach for 3D simulation of Rutherford cables, up to the filament scale. It opens the way to the prediction of coil electromagnetic performance in 3D.

The cable mesh is built over a transposition pitch within a simplified cabling process model (pre-processor) [1]. Periodic boundary conditions allow to build longer cable meshes, that can be used for the 3D Finite Element mechanical calculation of the cable in service [2]. Both models (cabling and service) rely on a bi-metallic description of the strands. Several geometrical options for the modeling of the strand annular topology are used. The material behavior law of each component is obtained experimentally at the microstructure level [2]. Material properties are homogenized in 3D. Up to now, elastoplastic values at room temperature are used, without cycling.

Multiscale post-processing allows the inclusion of a high definition three-dimensional sub-modelling of the strand geometry, up to the superconducting filaments scale. Options for the description of the strand topology are compared on the basis of these models. The strain/stress map on the superconducting filaments can be used to compute the critical current degradation using existing scaling laws [4,5].

CONCLUSIONS

This multiscale approach has allowed us to bridge 3D mechanical models at the cable level to the estimation of strain/stress map on the superconducting filaments, which drives the cable current transport capability. In the future, after obtaining cryogenic material properties, the full loop will be cross-checked with experimental critical current measurements on a cable under transverse pressure [6].

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