Thermomechanical Behavior Of High Temperature Superconductors In Test Configurations

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Abstract

Determining thermal stresses on High-Temperature Superconducting (HTS) tapes for applications to electrical grids such as superconducting fault current limiters (SFCL) and SMES (Superconducting Magnetic Energy Storage) has long been a challenge, both theoretically and experimentally.

The present work shows Structural Mechanics simulations predicting thermal stresses in test configurations due to thermomechanical constraints at 77 K under steady-state conditions. The whole complex structure of the tapes was considered, together with the different coefficients of thermal expansion, Young's moduli and thicknesses of the materials. Hooke's law was used as fundamental consitutive equation. Different boundary conditions such as Contact and Continuity between the layers of the tape and between the tape and the sample holders for the tapes were tested. Both linear and cylindrical geometries of the different sample holders were examined in 2D or 3D modeling.

Thanks to these COMSOL Multiphysics simulations, the thermal stress on the external surface of the tape and along the thickness of the tapes was evaluated. Suitable weighted averages of the stress were then calculated to provide a representative value for comparison with experimental data. The obtained result was compared to stresses worked out from strain gauge measurements of thermomechanical deformation on the external surface of the HTS tapes.

Stresses on tapes in cylindrical configuration are much more affected by different boundary conditions than in linear configuration. Although the average stresses on the tapes in these configurations are quite independent of the chosen weights, the stress values in both cases range from 70 MPa up to 700 MPa, where experimentally measurable. Although this range requires further future investigations, it represents a very suitable range in agreement with the maximum stress limits beyond which the HTS tapes undergo irreversible degradation of their electrical properties [1]. The computational results turned out to be comparable and showed good agreement with the experimental data, validating the modeling approach and the assumptions made.

New simulations in COMSOL Multiphysics with further evaluations of appropriate geometries, boundary conditions, and physical assumptions are planned for a better comparison with experimental results. These efforts aim to enhance model accuracy and support the design of HTS-based components for power grid integration.

Reference

[1] C. Barth et al., Electro-Mechanical Properties of REBCO Coated Conductors from various Industrial Manufacturers at 77 K, self-field and 4.2 K, 19 T, Supercond. Sci. Technol., vol. 28, no. 4, pp. 045011 (2015)
[2] H.-S. Shin et al., Evaluation of Irreversible Strain/Stress Limits for Ic Degradation in Practical REBCO CC Tapes Under Uniaxial Tension, EEE Trans. Appl. Supercond., vol. 28, no. 3, pp. 8241762 (2018)

Figures used in the abstract

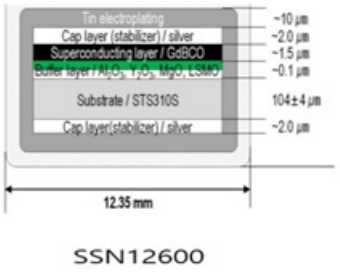

Figure 1 : Structure of one of the SuNAM HTS tapes studied (Figure not in scale).

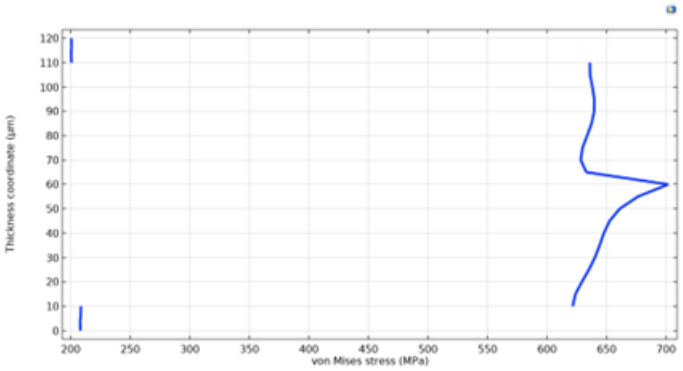

Figure 2 : Example of the thermal stress of the HTS tape as a function of the tape thickness.

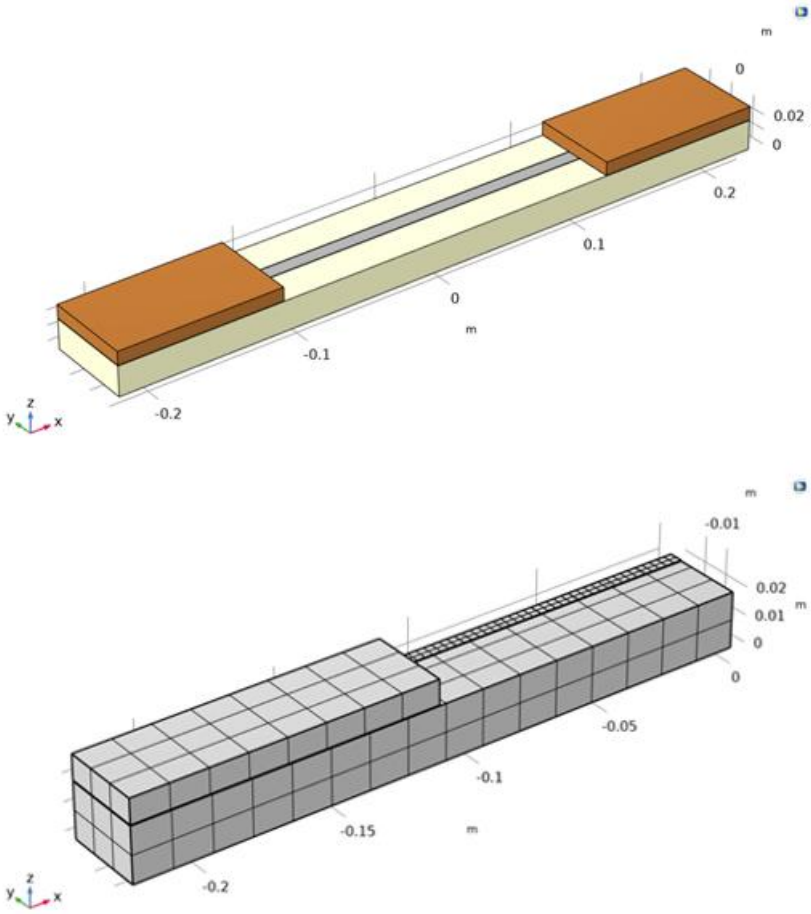

Figure 3 : Example of the geometry and mesh respectively used in COMSOL Multiphysics to simulate thermal stress of HTS tapes on a linear sample holder.