Homogenization Strategies for Modeling Stacks of Insulated HTS Coils with the H-Phi Formulation

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The simulation of large-scale high-temperature superconducting (HTS) magnets is a computational challenge due to the multiple spatial scales involved, from the size of the magnet to the detailed turn-to-turn geometry. To reduce the computational cost associated with finite-element simulations of insulated HTS coils, several homogenization strategies can be considered. In this talk, we discuss two such strategies that can be developed with the h-ϕ formulation and compare their performance to detailed models and state-of-the-art homogenization methods [1].

The first strategy consists in combining the detailed resolution of analyzed tapes while the remaining non-analyzed tapes are homogenized as bulk conductors [2,3]. We discuss more specifically the simultaneous multi-scale (SMS) method [3], which we extend to include the h-ϕ thin-shell (TS) formulation [4], by collapsing the analyzed tapes into surfaces in order to simplify the mesh generation and increase the computational efficiency. The principle of the proposed h-ϕ TS-SMS method is illustrated in Fig. 1. The second homogenization strategy consists in representing the turn voltages as a continuous polynomial interpolation in an homogenized bulk conductor. This leads to the h-ϕ foil-winding (FW) formulation, that we recently proposed for scenarios requiring an accurate computation of voltage drops [5]. The method, illustrated in Fig. 2, enables the description of realistic induced current distributions while directly computing the voltage drop required, e.g., for quench detection.

The two methods are implemented in the open-source GetDP software [6] (code will be made available) and match reference results obtained with detailed models of the turn-to-turn geometry, however with a significant reduction of the size of the numerical problem. By applying these methods to the 2-D simulation of pancake stacks, we show the gain in computational time and highlight the particular efficiency of the h-ϕ FW method, which makes it a promising candidate for the 3-D simulation of large-scale insulated HTS coils.

Figures

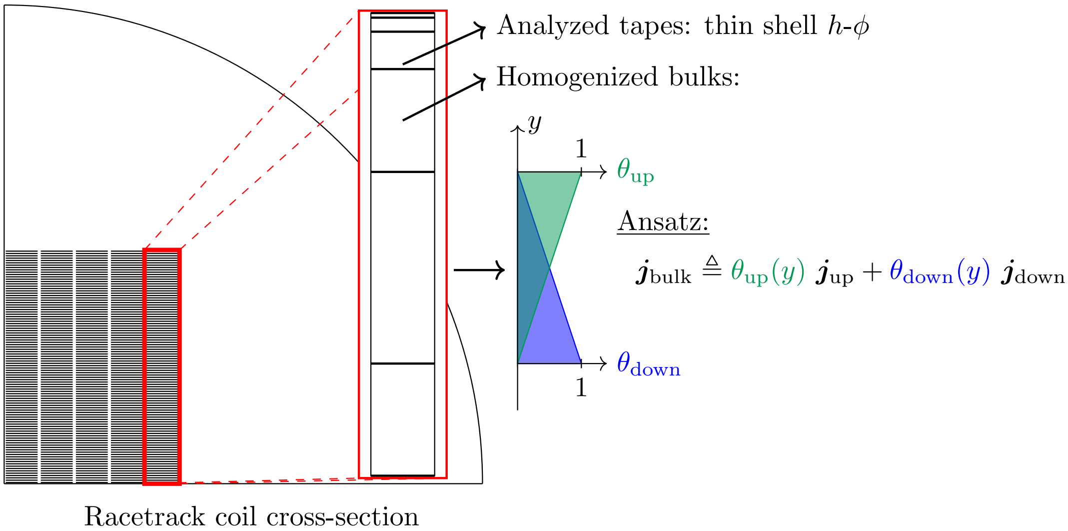

Figure 1: Principle of the h-ϕ TS-SMS method applied to stacks of pancake coils. The focus on the outermost pancake highlights that non-analyzed tapes are merged into homogenized bulks, in which the current density is interpolated from neighbouring analyzed tapes.

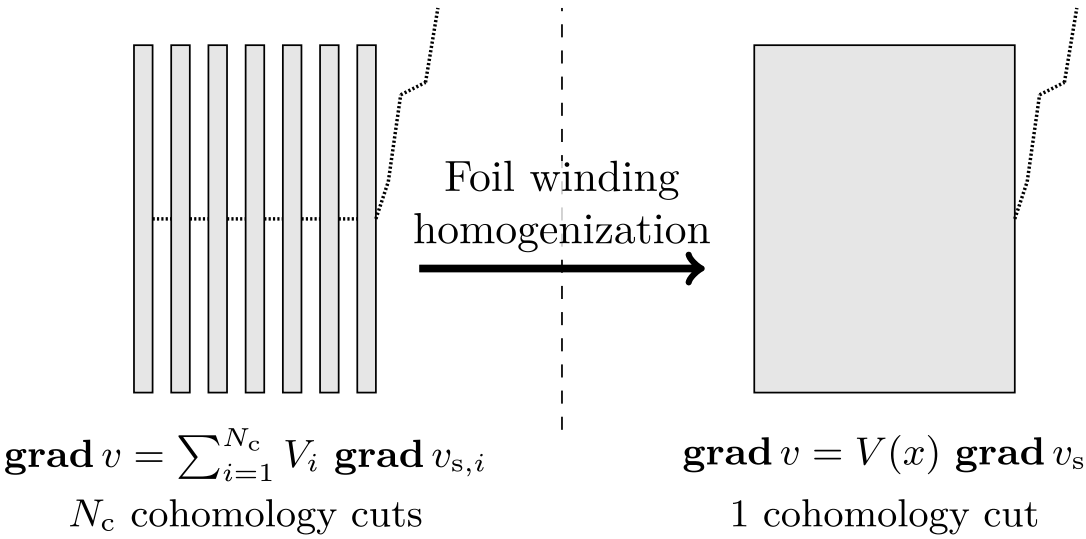

Figure 2: Principle of the h-ϕ FW method applied to a single pancake. The discrete voltage distribution is replaced by a continuous voltage distribution, which enables the use of a single cohomology cut, greatly simplifying the simulation setup.

References

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