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Improvement of a numerical framework to systematically assess the temperature distribution in complex He II-cooled magnet geometries using open-source software

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In the context of the High Luminosity upgrade of the Large Hadron Collider (HL-LHC) at CERN, a numerical framework has been developed to systematically assess the temperature distribution in complex He II-cooled magnet geometries using open-source software. The precise knowledge of the magnet's thermal characteristics and heat extraction performance is essential in determining safe operating margins and validating the thermal design of impregnated accelerator coils.
First, a 1D heat transfer model of a coil section was developed using the Julia programming language. This tool facilitates intensive parametric studies, making use of a phenomenological model for estimation of helium content in the insulation and cable layers.
Secondly, a 2D multi-region solver based on conjugate heat transfer between a composite solid body and stagnant He II has been redeveloped in OpenFOAM, along with the required libraries for material properties. The model can handle complex geometries composed of different materials each with their temperature-dependent properties, and the interface between the solid bodies and the stagnant He II is mediated by a Kapitza-type interface contact resistance. The strategy of creating a model with only two regions –a composite solid and a He II region –in which the composite solid region can be divided into zones with distinct material properties, has allowed for a reduced usage of baffles and drastically improved the computation time when compared to earlier versions used during the design phase of the magnets [1].
Both tools have been validated with experimental data obtained from laboratory-scale experiments on impregnated coil samples, which are reported and discussed here.
Experimental measurements of impregnated Nb_3Sn coil samples in He II allowed also for the extraction of material properties, especially of composite structures such as the coil's insulation layers where literature data is either unavailable or inadequate.
Recently, a full cross-section of a He II-cooled magnet cold mass exposed to inhomogeneous collision-generated power densities was modelled using the 2D numerical tool [2]. Its potential as a robust, easily adaptable toolkit was demonstrated: it allows for parametric investigation of geometry, temperature, and heat deposition on geometries cooled by stagnant He II in a timely manner and attests to the consolidation work with respect to previous iterations [1] of the model.

[1] G. Bozza, Z. M. Malecha, R. van Weelderen, Cryogenics 80 3 (2016)
[2] P. Borges de Sousa et al., IEEE Trans. Appl. Supercond. (submitted, presented at ASC 2022)

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