Validation of the 3D Code SARUMAN in a Stability and Quench Experiment with the Superconducting Magnet SAFFO

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Experiments on stability and quench propagation were performed on a NbTi hollow conductor test module allowing heat conduction only between adjacent layers, while the turns in a layer are thermally insulated (2-D winding). The measurements performed over a wide range of operating conditions were used as the experimental database for the comparison with the results of the simulations done using the quench analysis code SARUMAN. In the paper the experimental results are compared with the predictions of a 2-D version of SARUMAN, which show that the simulation is able to reproduce the general features of the quench propagation experiments.

KEY WORDS: Quench propagation; stability; force-flow cooled superconductors.

1. INTRODUCTION

Design tools allowing a quantitative estimate of the stability margin and quench behaviour are required for a reliable design of large-scale forced-flow cooled superconducting magnets. One-dimensional approximations, assuming dominant propagation along the helium flow, may lead to over-dimensioning of the stabilizer and to the prediction of non-realistic catastrophic events.

The 3-D computed code, SARUMAN, has been developed to allow a safe and more efficient magnet design. A set of experiments have been performed at the Superconductivity Laboratory of Frascati using its force-flow facility, a Helium refrigerator and superconductor test-magnet SAFFO. The validation test in a 2-D winding geometry was dedicated to quantify the relevance of transverse heat conduction. A 2-D test module was designed and built, using some spare Nb-Ti SAFFO hollow conductors. The main scope of the experiment was to produce experimental data in a winding configuration such as to allow a transverse quench propagation through heat conduction between adjacent layers. Part of the activity was already reported in [6]. Here we give full details on the validation campaign.

2. THE EXPERIMENTAL APPARATUS

A schematic layout of the facility is shown in Fig. 1. The background magnet, SAFFO, is a pancake-wound solenoid. A square hollow conductor, formed by cabling and soft soldering 20 NbTi multifilamentary wires on a OFHC copper tube and schematically shown in Fig. 2, was used to wind the magnet. The SAFFO solenoid consists of 20 double pancakes, wet impregnated with epoxy resin.

The test module was designed to be non-inductive and to have a 2-D heat propagation, i.e. longitudinally in the direction of the coolant flow and radially among turns of adjacent layers, while turn-to-turn axial heat flow in the same layer was inhibited. The module was...
wound using the SAFFO conductor, in four layers (9 turns/layer). To achieve a low axial thermal resistance, the conductor was insulated by a 0.25 mm cotton tape and wet epoxy impregnated during winding. The main data of the SAFFO magnet and the SAFFO Insert Module (called in the following SIM) are listed in Table I. The module was installed in the 20 cm bore of the magnet, electrically and hydraulically in series with it.

Figure 3 shows schematically the SIM instrumentation. Pulsed heaters made of thin stainless steel strip were placed at the helium inlet on the outer layer (named V and VI, 1 m and 0.1 m length, 2.15 W and 1 W resistance, respectively), while two couples (I–III and II–IV, 0.5 m and 0.05 m length, 0.78–0.62 W and 0.88–0.52 W respectively) were located before and after the middle joint in the windings.