Efficiency Analysis of Quench Protection Heaters for the NHMFL 32T All-Superconducting Magnet Insert

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Introduction

The design and development of a 32-T, 32-mm cold-bore all-superconducting magnet with high field REBCO inner coils is underway at the NHMFL. The two nested REBCO coils that just form the high field section (insert) are dry wind technology, with un-insulated conductor/tape and insulated steel co-wind reinforcement. The insert coils are assembled from multiple double-pancakes (modules). Active quench protection is planned using distributed protection heaters (Fig. 1) servicing to normalize quickly and uniformly the insert inner and outer coils in the event of quench. The heaters are positioned between the modules and are to be energized using lead-acid batteries. To ensure sufficient heat transfer between the heater disks and the coil windings, one aims for the coils to be flat to within 0.1 mm, which was achieved with the use of a winding guide [1].

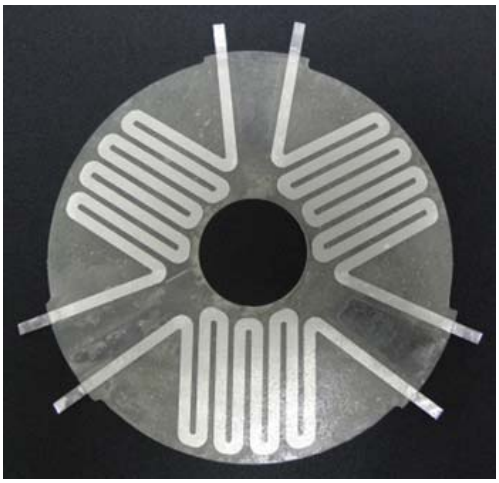

Fig. 1. A heater disk for the insert inner coil with three sub-elements (sandwiched between thin G-10 sheets) to be positioned between the double-pancakes (modules).

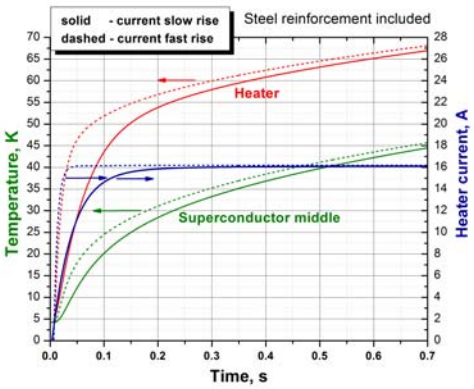

Fig. 2. Evolution of temperature of the heaters and heated coil winding for different scenarios of the heater energizing.

An analysis done in the course of heaters efficiency verification

In order to verify the heaters' efficiency, i.e., the capability of promptly and sufficiently heating the coils up when and if required, a comprehensive thermal transient 2D non-linear computer analysis was done, appropriately including the fine discrete structure of the coils and heaters and peculiarities of the heat transfer process from the heaters to the coils as well, e.g., the variable thermal contact resistance at the tape - steel reinforcement interface. A computer FORTRAN code was created to fulfill the task. In the course of computer simulation, the heater current and the current ramp rate values were varied in an effort to find the sufficient ones. In so doing, evolution of the heater and coil temperatures with time (Fig. 2) and the non-stationary heat input into the coil were monitored and analyzed in full to check the heater efficiency at a given scenario of the heater energizing. The obtained time-varying coil temperature distribution and non-stationary heat flux at the heater-coil winding interface provide confidence that the quench heaters can work fast enough.

Acknowledgement

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Reference

[1] Weijers, H.W., *et al*., presented at the 23rd Magnet Technology Conf., Boston, MA, July 2013