Measurements of Central Magnetic Field Hysteresis Caused by Induced Screening Currents in Superconducting Coils Wound with (RE)BCO Coated Conductors

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Introduction

The design and construction of superconducting magnets for nuclear magnetic resonance (NMR) applications require suitable superconductors that are well characterized in terms of their physical behavior and performance. Especially, the (RE)BCO coated conductors, such as those based on $YBa_2Cu_3O_{7-\delta}$, are now being developed and commercialized. They show promise for the construction of such magnets, since they retain their superconducting state in magnetic fields above 100 T at low temperatures, whereas the niobium-based materials presently used cannot operate with a reasonable current density in fields that exceed 24 T or so. The (RE)BCO coated conductors support induced screening currents that generate hysteretic magnetic fields sufficient to distort the homogeneity of coils wound with such conductors. Thus, such fields cannot be neglected in magnet designs.

Experimental

Two magnets for different but related projects were constructed and tested, a layer-wound test coil (Platypus Short) for the HTS NMR magnet project, and a pancake-wound test magnet (Prototype 20-70) for the user 32 T magnet project. Both coils were wound with (RE)BCO coated conductors. As one of several tests, calibrated single-axis Hall sensors were positioned in the bores of these superconducting magnets to measure their central magnetic fields. The measurements revealed hysteresis generated by the screening currents induced in their conductors. This was done by comparison with the computed magnetic fields of superconducting magnets assumed to be wound with coated conductors that do not to support induced screening currents. Additional experimental details are published in another contemporaneous research report.

Discussion

As shown in the two figures, central magnetic field hysteresis and differences on the order of a percent or more continue to be measured, substantial for NMR applications. In the first figure, the operating current was cycled up and down to an increasing maximum with each cycle. In second figure, the operating current was cycled to the same maximum twice, the first cycle being that after cooling the magnet to 4.2 K initially. The arrows indicate the directions of the operating currents with respect to time of the corresponding loop edges.

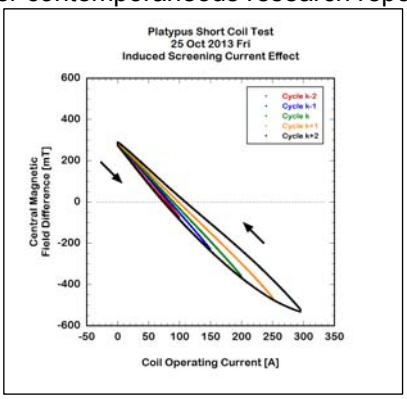

Fig. 1. Central magnetic field difference measurements of a layer-wound tape test coil reaching about 5.1 T self field at 300 A max.

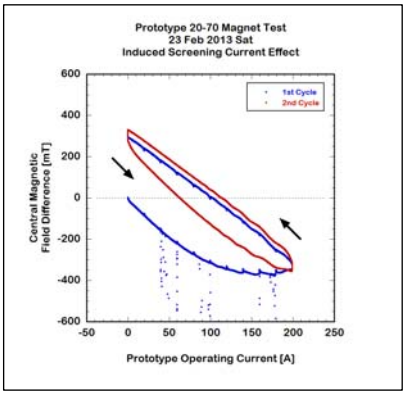

Fig. 2. Central magnetic field difference measurements of a pancake-wound tape test magnet reaching about 7.0 T self field at 200 A max.

Conclusions

By measurement and analysis of the induced screening current effects on the magnetic field, engineering design guidelines will be formulated for the winding of superconducting coils with (RE)BCO coated conductors. Considering the rapid development and commercialization of these conductors, and their imminent incorporation into high field magnets especially for NMR applications, the development of these engineering design guidelines will significantly advance the technology of these conductors in superconducting NMR coils wound with them. Important to active magnet projects, efforts to mathematically model these results are progressing [1, 2].

Acknowledgements

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References

[1] Hilton, D.K., *et al.,* Presentation 1PoAB-05, International Conference on Magnet Technology (MT-23), Boston, MA (July 2013).
[2] Hilton, D.K., *et al.,* Presentation 2JB-03, Applied Superconductivity Conference, Portland, OR (October 2012).