Preliminary Analysis of Central Magnetic Field Hysteresis from Induced Screening Currents in Superconducting Coils Wound with (RE)BCO Coated Conductors

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Introduction

The (RE)BCO coated conductors now being developed and commercialized, such as those based on $YBa_2Cu_3O_{7-\delta}$, are very anisotropic and support significant induced screening currents that generate magnetic fields with hysteresis and drift sufficient to distort the homogeneity of coils wound with such conductors. These effects cannot be ignored in the design of superconducting magnets for nuclear magnetic resonance (NMR) applications, and must be predictable to be controlled, by compensation or shimming, for example. The (RE)BCO coated conductors 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.

Experimental

Three magnets for different but related projects were constructed and tested, a layer-wound tape test coil (Platypus Short) for the HTS NMR magnet project, and two pancake-wound tape test magnets (Prototype 20-70 and Prototype 82-116) for the user 32 T magnet project. Their 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 support induced screening currents. Additional experimental details are published in other research reports.

Discussion

Shown in the first figure is an example of a central axial magnetic field loop of the layer-wound test coil indicating the terms in the expression used for the percent hysteresis. Only the fifth of five counter clockwise cycles is visible. The unlabeled arrows indicate the directions of the operating currents of the loop edges. Shown in the second figure is the percent hysteresis for the three different magnets mentioned above. The percent reduction of their central axial magnetic field maxima are shown also, a substantial concern in NMR applications.

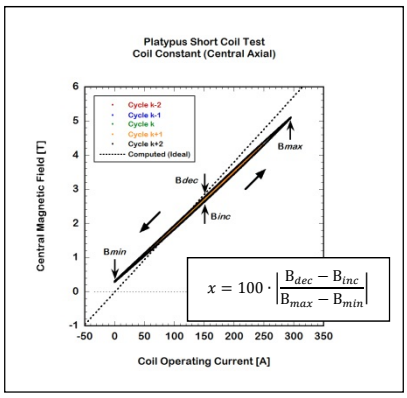

Fig. 1. Example central axial magnetic field loop of a layer-wound tape test coil indicating the terms in the expression for percent hysteresis.

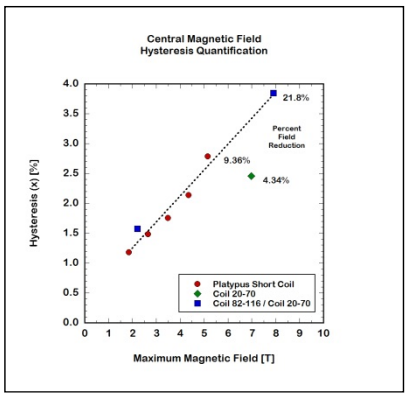

Fig. 2. The percent hysteresis versus maximum magnetic field for three different magnets, showing the percent reduction of their maxima also.

Summary

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

This work is funded by the National Science Foundation (Award No. DMR-1157490), the State of Florida, and the U.S. Department of Energy.

References

[1] Hilton, D.K., *et al.,* Presentation 2LPo2G-06:169, Applied Superconductivity Conference, Charlotte, NC (2014).
[2] Hilton, D.K., *et al.,* Presentation 1PoAB-05, International Conference on Magnet Technology, Boston, MA (2013).