Analysis and Measurement of Induced Screening Current Effects on the Magnetic Field of Superconducting Coils Layer-Wound with (RE)BCO Coated Conductors

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Introduction

The (RE)BCO coated conductors, such as those based on $YBa_2Cu_3O_{7-\delta}$, are now being developed and commercialized. Particularly, they show potential for the construction of high field magnets, since they retain their superconducting state in magnetic fields up to ~100 T at low temperatures, whereas the materials presently used to construct superconducting magnets, Nb-Ti and Nb_3Sn, cannot operate with a reasonable current density in fields that exceed about 24 T. Construction of superconducting magnets for nuclear magnetic resonance (NMR) applications requires suitable conductors that are well characterized in terms of their physical behavior and performance. Especially the wide-tape (RE)BCO coated conductors support induced screening currents that cannot be neglected in magnet designs. Such currents generate magnetic fields sufficient to distort the homogeneity of coils wound with such conductors.

Experimental

We constructed a rotating probe with precision multi-axis Hall sensors for the bore of a layer-would REBCO superconducting coil in order to map its full 3D magnetic field. The sensors in the rotator follow helical pathways within the coil bore. The measurements of its magnetic field revealed distortions generated by the screening current induced in its conductor, whose magnitude was assessed by comparison with the computed magnetic field of a normal metal layer-wound that does not support an induced screening current. Experimental details are presented in a second research report by Dalban-Canassy.

Discussion

Since the sheet current density in (RE)BCO coated conductors is not constant due to the induced screening currents, the theoretical distribution developed by Brandt and Indenbom [1] is used for the computation of the screening currents. Magnetic field differences on the order of a percent or more, substantial with respect to NMR applications, are predicted and were found, a result supported boy others work too [**Figure 1(a, b)**].

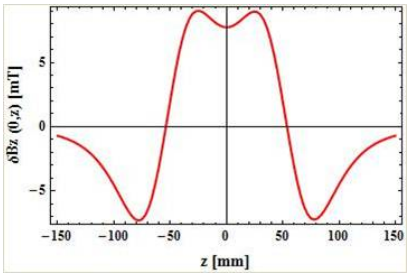

Figure 1(a). Magnetic field difference *computations* of a YBCO-123 tape layer-wound coil at 990 mT [2].

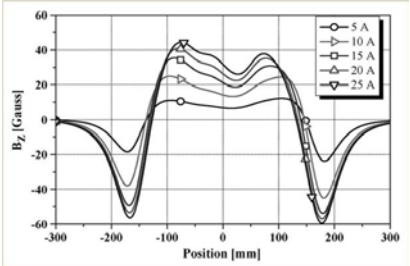

Figure 1(b). Remnant magnetic field *measurements* of a BSCCO-2223 tape double-pancake coil [3].

Summary

By analysis and measurement 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. This methodology is being incorporated into analysis of further REBCO coils being tested for the 32 T project and for NMR prototypes.

Acknowledgements

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References

[1] Brandt, E.H., Indenbom, M., "Type-II Superconductor Strip with Current in a Perpendicular Magnetic Field", *Phys. Rev. B*, **48**, 12893-12906 (1993).

[2] Hilton, D.K., et al., "Determination of Induced Screening Current Effects on Magnetic Field Homogeneity of Layer-Wound (RE)BCO Coils: Measurement, Analysis, and Progress", Presentation 2JB-03, Applied Superconductivity Conference, Portland, Oregon (7-12 October 2012).

[3] Ahn, M.C., et al., "Spatial and Temporal Variations of a Screening Current Induced Magnetic Field in a Double-Pancake HTS Insert of an LTS / HTS NMR Magnet", *IEEE Trans. Appl. Supercond.*, **19**, 2269-2272 (2009), Fig. 3.