CONCEPTUAL DESIGN OF AN ALL-SUPERCONDUCTING 30 T SOLENOID USING WIRE-IN-CONDUIT CONDUCTORS

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Introduction

The next generation of high-field, high-homogeneity, all-superconducting magnet systems is expected to require high-temperature superconductors (HTS) at low temperatures to extend the central field capability beyond the 22 T to 23 T achievable with Nb₃Sn. Round HTS conductors have demonstrated impressive current densities at 4.2 K in background fields as high as 45 T [1], [2]. However, support of the Lorentz forces to limit strain degradation remains one of the primary challenges for employing HTS within the winding pack of a high field system. The NHMFL’s recent demonstration of 25 T, via combination of a 5 T HTS insert at 4.2 K inside a 20 T resistive magnet background field, employed the more typical stainless-steel-lamination reinforcement to HTS tape [3]. This work proposes a new conductor configuration (patent pending) consisting of a single wire inside a conduit, named wire-in-conduit (WIC), that is shown here to satisfy the structural requirements for a high-field magnet system. As a demonstration of the concept, a 30 T design is described using materials in a WIC configuration that achieves acceptable stress and critical-current levels for a superconducting magnet.

Results and Discussion

Examining a coil design strictly from the point of view of acceptable stress limits in the conduit and critical current margins in the superconductor at 1.8 K operation, a 30 T all-superconducting magnet was designed that employs 12 coils. The resultant mid-plane stresses for each of the coils is shown in Fig. 1. The six innermost coils use recently tested Bi-2212 round superconductor and Haynes 25 conduit. The next three coils used internal-tin Nb₃Sn superconductor and Haynes 242 conduit. The three outermost coils used NbTi superconductor and 316LN conduit. The allowable stress in the conduit was set at the minimum of 2/3 yield or 1/2 ultimate stress. The current density limit was set at 60% of the critical current for the HTS conductor and 90% of the critical current for the LTS conductors.

Conclusions

A conceptual design and stress analysis has demonstrated that an all superconducting, 30 T, wind-and-react magnet can be built with WIC conductors that will satisfy acceptable superconducting and structural design margins. Superconductor and conduit material pairs have been selected based on reported critical current measurements in Bi-2212 and internal tin Nb₃Sn round wires and based on reported mechanical property measurements of Haynes alloys. The Haynes alloys have been selected to provide high strength while maintaining compatibility with a wind-and-react coil fabrication process. Although this design demonstrates conceptual feasibility of a 30 T magnet, other issues must still be solved such as selection of helium environment, quench protection electrical network, conductor fabrication and heat treatment processing.

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References