A HIGH FIELD, HIGH TEMPERATURE SUPERCONDUCTING DIPOLE WITH DESIGN OPTIMIZED FOR FUSION AND HEP RESEARCH

R. Gupta, M. Anerella, P. Joshi, M. Kumar, F. Kurian, M. Palmer, P. Joshi, J. Schmalzle, and V. Teotia
Brookhaven National Laboratory, Upton, NY 11973

CONCEPT SUMMARY

We take a bottom-up objective approach to develop a new high field (20T@20K) magnet made with High Temperature Superconducting (HTS) cables for a variable temperature user test facility in a range of 4 K to 80 K. The ability to test HTS cables and related technologies is critical for compact fusion energy devices. No such magnet and facility currently exists in the United States, and none appears to be on horizon for user operation within the next five years. This proposal, which will be designed and executed in coordination with the fusion industry, could make the proposed facility available within about three years after the start of funding due to the inherent simplicity in the proposed design and construction. Besides employing HTS cable already developed for fusion, the proposed design approach departs in several significant ways from the current cosine theta dipole designs operating at 2K or 4 K for testing fusion cables at higher temperatures (such as at 20 K). In the proposed approach, the required aperture, stored energy and forces in the magnet will be much smaller than in other designs with no anti-cryostat needed to deal with the temperature gradients between the sample and the coil. It relies on a configuration where the magnet will operate at the same temperature as the test sample.

INNOVATION AND IMPACT

High field magnets built with the High Temperature Superconductors (HTS) offer transformative possibilities for future fusion energy systems. Most HTS Fusion cables are high current cables consisting of several HTS tapes and require a large bending diameter (~50 cm) to minimize degradation. A critical element of the proposed test stand will be the ability to test key technological components in an environment as that closely approximates the actual working environment. A high field magnet test facility to provide testing of high current cable allowing a test temperature of 20 K or so, has been identified as a key need. Moreover, building such a magnet and test facility has been considered as a major technical challenge requiring tens of millions of dollars and over a five year of effort to make such a facility available for users.

The proposed design differs substantially from other dipole magnet designs for cable test facilities that have been built or are in the design stage. The proposed approach offers notable advantages, such as: (a) a large reduction in magnet aperture since the test cable and magnet coil will operate at the same temperature with no additional cryostat required to house the cable; (b) an efficient and compact structure for testing fusion cables requiring large bend radii; (c) a configuration that allows characterization of both straight and bent cable, and (d) flexible adjustment of coil spacing to enable tests with either higher field or higher aperture; and (e) a simple racetrack coil design, with a geometry that is inherently suitable for dealing with the large Lorentz forces associated with such high fields.

The magnet design is based on the common coil dipole [1] geometry (Fig. 1) which allows use of fusion cables with a large bend radius. It uses the same high current fusion cables (such as the VIPER, etc.) that are being developed for fusion facilities and therefore should be readily available for building such a magnet. The common coil design was initially developed for the high energy collider dipoles. However, based on recent operational experience with the common coil dipole DCC017 [2] at BNL, this approach has been found to be well suited for a low-cost, rapid-turn-around facility [3] for testing fusion cables and other related magnet technologies. Furthermore, the field uniformity requirements for testing HTS fusion cables and insert coils can be readily met with this coil configuration.

The mechanical structure is a critical part of high field magnet designs. A key advantage of the common coil geometry is that the coils move as a unit without putting high strains or stresses on the conductor. This also allows the structure to be easily segmented for stress management. For instance, the common coil Nb_3Sn dipole that was previously built and tested at BNL had a design that allowed for over 200-micron displacement during operation versus the typical 25-50 microns for high field dipoles. This mechanical structure concept leverages the common coil geometry to insert (Fig. 1 left) or sandwich (Fig. 1 middle) a U-shape Fusion HTS cable with a large bending radius and assemble it into a bolted structure between the two coil halves. Recent work carried out under USMDP program shows that a relatively simple mechanical structure can provide the required stress-management.

The common coil magnet geometry is a modular geometry which allows intermediate test for lower field or smaller aperture demonstrator magnet with fewer coils. One can use these coils in building higher fields and larger aperture magnets.

We will engage fusion industry partners to participate in the design and construction of this magnet, particularly the one providing the HTS cable for this magnet. As such the development of this magnet and the cable used in the magnet will directly benefit from (and provide benefit to) the fusion industry for their magnet development program.

The magnet, while serving an important and unique need for user facility capability, will also be an important demonstration of several aspects of the HTS magnet technology that are relevant for high temperature magnet development for fusion and high energy physics applications.

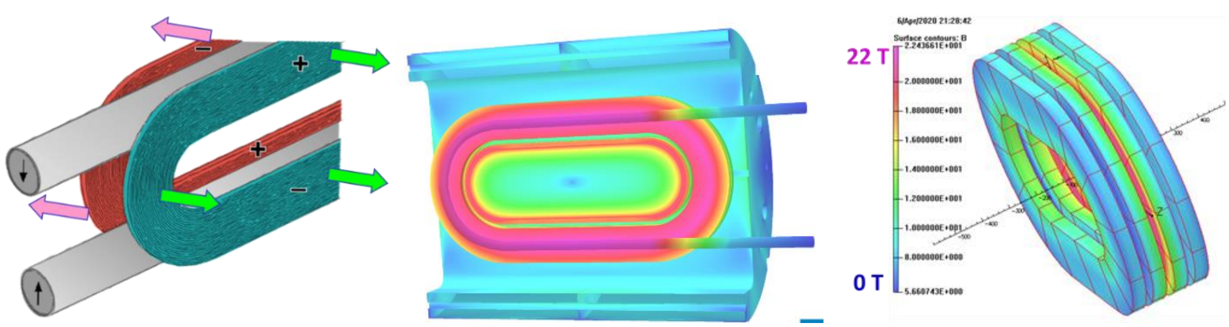

Fig. 1. Left: Common coil concept consisting a set of simple racetrack coils invented for high energy collider dipoles with the direction of field with black arrows and the direction of major forces with pink and green arrows, Middle: Cutaway view of the dipole with a large part of fusion test cable in the high field region, Right: A magnetic model of 30 mm bore, 22 T dipole with the field superimposed over a set of HTS coils.

REFERENCES

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