A Compact Test Bed for Critical Current Evaluation on High Temperature Superconducting Tape Samples

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Background
The motivation to develop a compact test bed for critical current evaluation of HTS tape samples is from the need of verifying the critical performances of delivered HTS wires for development of HTS insert coils in our high field magnet project. For the HTS coil designers, critical current performances at perpendicular magnetic field condition are usually taken as an important consideration. This is because the critical current in perpendicular magnetic field is the crucial parameter to determine the final performance HTS coils.

Objectives
The objective of developing this compact test bed should meet requirements: (1) Easy operation and exclusive to liquid helium involvement, only liquid nitrogen used as HTS sample coolant; (2) Adjustable transverse magnetic field from zero to 3.5T, horizontal magnetic field direction; (3) Removable sample holder, convenient to change HTS sample; (4) Batch sample tests for every cryogenic experiment; (5) Changeable angles between the tape surface and magnetic field direction; (6) Conduction cooling magnet system.

Structure and Composition
The designed test bed is integrated with a superconducting magnet system and an insert dewar. The superconducting magnet system consists of a split NbTi superconducting magnet, thermal shielding and cryostat as well as a GM cryocooler. The system is provided to HTS samples at the magnet center. The HTS sample holder is inserted to liquid nitrogen in the insert dewar.

Split Superconducting Magnet
The superconducting magnet of the test bed is designed as a split coil structure. The magnet is integrated with two coaxial split NbTi coils. The split gap between coils is 90 mm. Each split coil is wound onto a Cu former. The transverse clear bore is made before the coil windings are integrated. Diameter of the clear bore is 80mm.

To improve thermal conduction between the cold head and coil windings, two flanges made from high thermal conductivity material are used to fix the split coils.

Cryogenics
Cryogenics of the test bed includes cooling of two parts: the magnet cooling and the HTS sample. The magnet is water cooled by a 2-stage GM cryocooler and the HTS sample is of bath cooling with liquid nitrogen. Thermal analysis is performed for the superconducting magnet system. The thermal load of first stage is 23W, including radiation from vacuum vessel, conduction from shielding support and current lead. The load of the second stage is 0.8W.

Insert Dewar and Sample Holder
The insert dewar is functioned as the liquid nitrogen vessel. HTS sample holder is designed with a holder support bar is directly inserted to the liquid nitrogen bath.

Magnetic Field and Protection
The four coils are electrically connected in series and powered by a single power supply. Total inductance of the magnet is 14.5H. The magnet center field constant is 444.16 G/K. When the magnet is charged to a current of 78.8A, the horizontal magnetic field at the magnet center is 3.5T while maximum magnetic field in the coil winding is 5.7 T.

The total magnetic energy storage is 44.4J when the magnet is operated at the maximum current. The passive protection scheme is adopted with cold diode and resistors.

Field Quality Analysis
The magnetic field in the magnet center area is designed as applied transverse field for HTS sample test. Field mapping is performed to verify the uniformity. It shows that a field homogeneity of 95% can be met inside a cylinder volume of Ω0=50mm×50mm within a maximum perpendicular magnetic field of 3.5T, when the magnet is energized with the designed operating current of 78.8A.

Magnet Test
The superconducting magnet system has been installed and tested. It takes 45 hours to cool down to a temperature of 4.4K from room temperature, driven by a GM cryocooler with a second stage cooling power of 1.4 W (4.4K). The vacuum in the cryostat is 4.7×10⁻⁵ Pa and the temperature on the shielding is 42K without liquid nitrogen in the insert dewar.

The magnet is charged with a power supply. One quench is happened at a current of 72A. After this training, the nominated current of 78.8A is reached, corresponding a center magnetic field of 3.5T.

Now, the magnet system is ready for HTS sample test.