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Energizing behaviors of A No-insulation and Layer-wound REBCO Coil in high magnetic field

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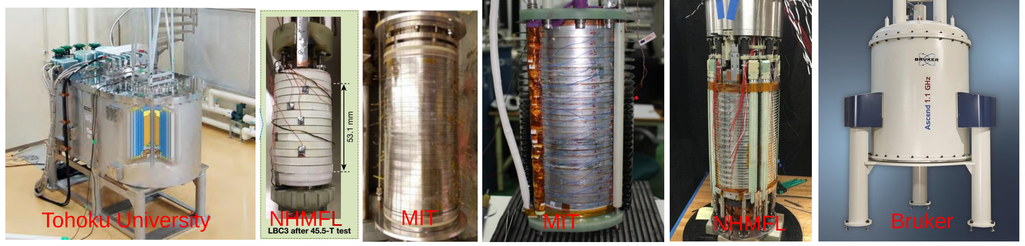
MT 26 International Conference on Magnet Technology
Vancouver, Canada | 2019

1. Background

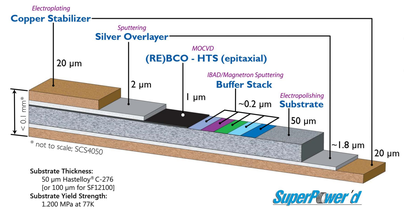
To study the fabrication technology and performance of REBCO coil, a no-insulation and layer-wound REBCO coil using SuperPower SCS4050 coated conductor was designed, fabricated and tested under a background magnetic field of 31.5 T in order to develop the basic coil fabrication technique and to understand the high field performance.



2. REBCO Coil design

The REBCO coil was wound by means of the no-insulation and layer-wound technique。

The average critical current of 38 m long conductor at 77 K and self-field was measured to be 131 A。



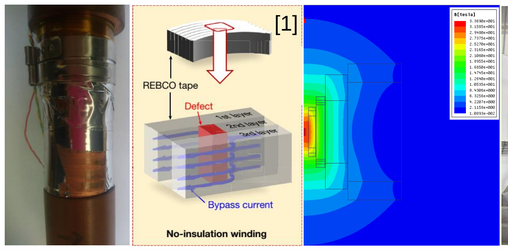


Table. Parameters of the no-insulation layer-wound REBCO coil

Parameters	unit	Value
REBCO conductor		Superpower SCS4050
Conductor width	mm	4
Conductor thickness	mm	0.1
Cu stabilizer thickness	mm	0.04
Inner diameter	mm	15
Outer diameter	mm	29
Height	mm	38
Total number of turns		427
Length of the conductor	m	37
Self-inductance	mH	1.43
Magnet constant	mT/A	16.5
Winding tension of the coil	T	25

3. Coil test results at 77 K and 4.2 K

➢ **The REBCO coil was tested at 77 K in liquid nitrogen bath and self-field excitation**

Fig. Coil voltage, central field, power supply current evolution with time when the REBCO coil was charged and discharged.

Fig. Magnet constant, measured at different operation current at 77 K, self-field.

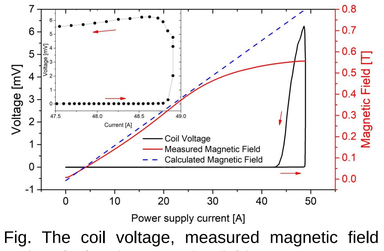


Fig. The coil voltage, measured magnetic field and calculated magnetic field versus current characteristic at 77 K in the self-field.

screening currents effect and current leaking

- Critical current :48.5 A
- Central field: 0.55 T
- highly nonlinear and irreversible behavior in the range from 48.5 A to 44.1 A
- magnet constants rose firstly from 13.1 mT/A at 5 A to 15.7 mT/A at 25.1 A, dropped to 11.5 mT/A at 48 A.

➢ **the REBCO coil was also tested at 4.2 K in liquid helium bath in self-field excitation**

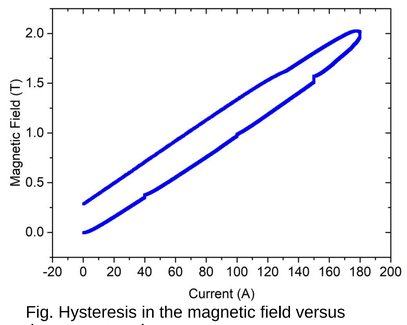


Fig. Hysteresis in the magnetic field versus the power supply current.

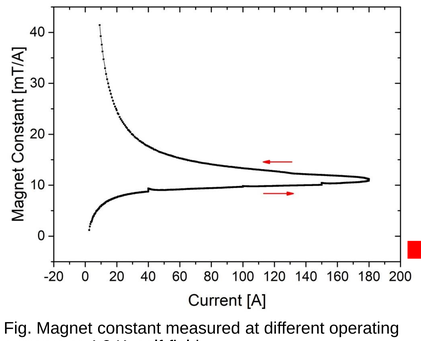


Fig. Magnet constant measured at different operating currents at 4.2 K, self-field.

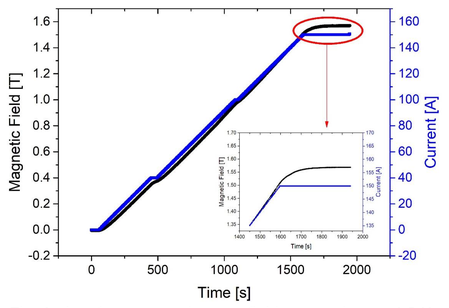


Fig. A plot of current and center field versus time at 4.2 K when the REBCO coil was charged up to 150 A at ramping rate of 0.1 A/s.

- Another main drawback of the no-insulation technique is a charging delay time: 345 s
- Current : 180 A, Central field: 2 T
- Remanent magnetic field: 193 mT
- The magnet constants ramped up with the power supply current.
- The screening currents more than the current leaking.

➢ **the REBCO coil was tested at 4.2 K in a background field of up to 31.5 T generated by a resistive magnet system at the CHFML**

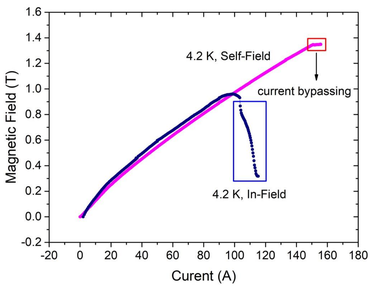


Fig. The magnetic field versus current at 4.2 K, in-field and self-field.

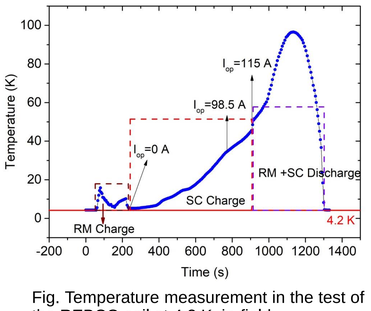
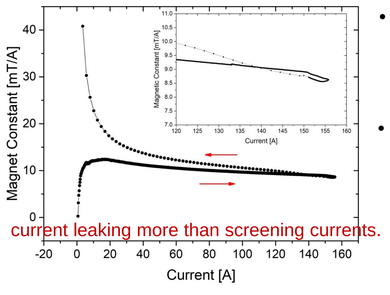


Fig. Temperature measurement in the test of the REBCO coil at 4.2 K, in-field.



current leaking more than screening currents.

Fig. Magnet constant, measured at different operating current at 4.2 K, self-field.

- The central magnetic field reached its peak of 1 T when current rise up to 98.5 A, then started to decrease rapidly.
- The temperature increased to 15.8 K at the beginning of the resistive magnet charging, the temperature dropped to 5.1 K after the magnetic field rose to 31.5 T. when the REBCO coil began to charge, the temperature increased irreversibly.

4.Damages inside the coil

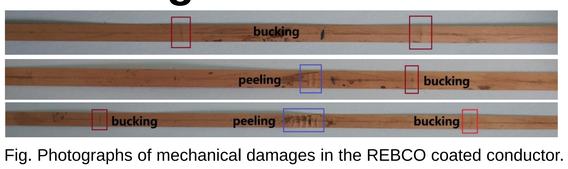
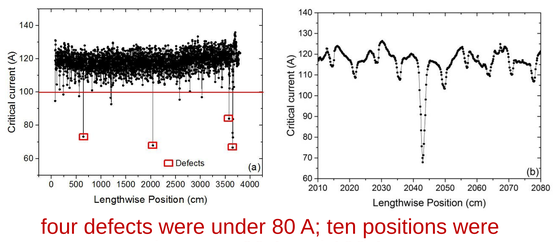
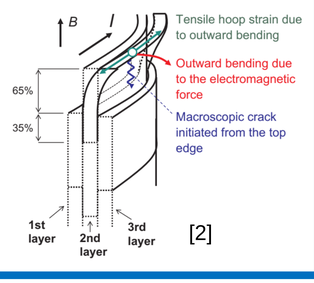


Fig. Photographs of mechanical damages in the REBCO coated conductor.

two types of major mechanical damages were found: peeling and bucking



four defects were under 80 A; ten positions were between 90 A and 100 A



[2]

5. Conclusion

We developed a no-insulation and layer-wound REBCO coil without epoxy impregnation using REBCO coated conductor. The REBCO coil was charged up to 180 A which produced 2.0 T magnetic field at 4.2 K in liquid helium in self-field condition and was also tested in a background field of 31.5 T and reached a magnetic field for operation of the REBCO coil of 32.5 T. The electromagnetic and no-insulation behaviors that include charging delay and non-linear magnet constant of the REBCO coil were investigated.

[1] Seungyong Hahn, et al., *Naturevolume 570, pages496–499 (2019)* [2] T. Matsuda, et al., *Cryogenics 90 (2018) 47–51*