Generation of 25.7 T by LTS/REBCO Superconducting Magnets

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June 7, 2017 (HP125). Up to now, the highest magnetic field ever achieved with superconducting inserts is 40.2 T, obtained at the NHMFL, with a 9.2 T REBCO insert in a 31 T resistive magnet [1]. Although the cold bore size is only 14 mm in diameter, the achievement of this magnet really shows optimism in developing extremely high field REBCO inserts. As for all-superconducting magnets, the highest magnetic field so far is 27.6 T, obtained at RIKEN, with 10.5 T layer-wound Bi-2223/REBCO inserts in a 17.1 T LTS background magnet in January 2016 [2, 3]. In June 2015 at NHMFL, a prototype magnet for a 32 T/32 mm all superconducting user magnet program obtained a central field of 27 T, which was the highest field generated by all-superconducting magnets when it was tested [4, 5]. A 26.4 T all REBCO magnet was also developed at SuNAM in 2015 [6]. The REBCO magnet, which was non-insulated and wound with multi-width REBCO tapes, has generated the highest field by one single HTS magnet.

We, Institute of Electrical Engineering (IEE, CAS), have focused on extremely high field magnet for many years [7-10]. In our 25 T/32mm all superconducting magnet project, we designed a REBCO insert composed of 16 Double Pancake (DP) coils, to generate a 10-T central magnetic field in a 15 T/160 mm LTS background magnet. The inner diameter, outer diameter, and height of the insert are 32 mm, 104 mm, and 160 mm, respectively. The employed REBCO-coated conductor provided by SuNAM, with a cross section of 4.1 mm×0.15 mm, was strengthened by soldering a stainless steel layer on the conductor. While during the DP coils test, we found defects in one DP coil and excluded this DP coil from the insert assembly. After assembly, the height of the prototype insert was 150 mm. After soldering the DP-DP splice joints, the outer layer of the insert was reinforced with stainless steel tapes. Test at 77 K showed that the insert generated 1.62 T at a transport current of 32 A, self-field. Tests at 4.2 K showed that the insert successfully produced 11.2 T without the background field, and produced 9.0 T in the 15 T background field, i.e. a 24 T central field. During the tests we found 4 DP-DP splice joints showed obvious resistance increase, and 5 DP coils had different levels of premature quenches, most of which located on the top/bottom of the insert, where the much higher perpendicular fields left not enough operating margin for the conductors in those regions.

Based on these test results, we decided to employ double-wound method to reduce the current density on the top/bottom of insert, so as to improve the operating margin in those regions. We wound 10 new DP coils with SuperPower SCS4050 coated conductors, 4 of which were double-wound. During the new assembly, as shown in Fig.1, the 10 remaining SuNAM DP coils were placed in the center of the insert, and the double-wound SuperPower DP coils were placed at the top/bottom of the insert to increase the critical current in those regions, while the rest 6 single-wound SuperPower DP coils were symmetrically placed between the SuNAM DPs and the double-wound SuperPower DP coils. The outmost layers of the SuNAM DP coils were removed for soldering new DP-DP splice joints, so the outer diameter of REBCO insert decreased from 104 mm to 103 mm, while the height of insert increased from 150mm to 200 mm for adding 5 more DP coils. To keep the DP-DP splice joints from delamination, thicker stainless steel bindings were wound over the outmost layer of the insert. With these improvements, the REBCO insert successfully generated 10 T in the 15 T background field, which was the target field of our 25 T/32 mm superconducting magnet program. However, a gradual premature voltage appeared on several DPs when ramping from 25 T to 26 T, finally the REBCO insert quenched at a central field of 25.7 T, as shown in Fig.2.

The achievement of 25.7 T illuminates that the fabricated REBCO insert has met the requirements of the 25 T/32 mm superconducting magnet program, and that technical feasibility of REBCO insert has also been proved. Thicker overbanding to solve the delamination problem of the DP-DP splice joints and using double-wound DP coils to increase the safety margin at the top/bottom of the insert are effective in fabricating high field insert with high stability. Other measures such as continuous adjusting the current density in DP coils to improve the overall safety margin of the insert and improving the cooling conditions inside and around the insert where helium bubbles are trapped are also meaningful and still need more attention.

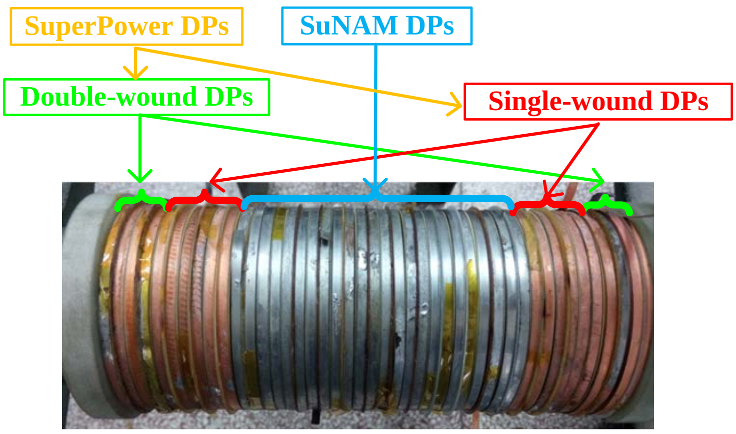

Fig.1. REBCO insert in assembly

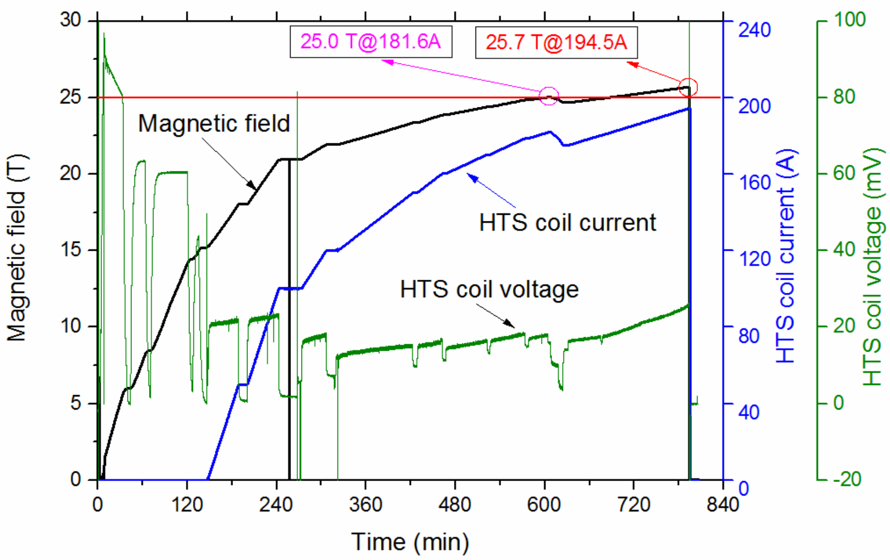

Fig.2. Test of the REBCO insert under 15 T background magnetic field at 4.2 K

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