Generation of 32.35T with an All-superconducting Magnet at IEECAS

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(HP140, STH60). High field superconducting magnets are of vital importance for researches in condensed matter physics, NMR spectrometers, and MRI machines. By far the highest magnetic field ever achieved with superconducting magnets is known as 32 T, obtained at NHMFL with a 17.1 T REBCO insert in a 15T low-temperature superconducting (LTS) background magnet [1], and the second-highest is 27.6 T, obtained at RIKEN with a 10.4 T Bi2223/REBCO insert in a 17.2 T LTS background magnet [2].

Using high-temperature superconducting (HTS) insert magnet technology, Prof. WANG Qiuliang's group from the Institute of Electrical Engineering (IEECAS) has successively achieved all-superconducting magnets with a central field up to 25.7 T [3] and 27.2 T [4]. Based on the research foundation, we tried to build a 30T all-superconducting magnet for the **Synergetic Extreme Condition User Facility** (**SECUF**), which is designed to be China's premier user facility providing expertise, instrumentation, and infrastructure for investigating matter science under extreme physical conditions.

The current 30 T all-superconducting magnet project is based on a 15T/Φ160mm LTS magnet. For the 15T HTS insert, it consists of two non-insulated (NI) coils, named HTS1 and HTS2. The HTS1, composed of 24 Double-Pancakes (DP)s, has inner and outer diameters of 43 mm and 108 mm, respectively, and a height of 198 mm. While for HTS2, with 32 DPs, the inner diameter, outer diameter and height are 128 mm, 150 mm and 324 mm respectively. The current grading method was used to increase the safety margin. The designed highest engineering current density is 330A/mm^{2}and the peak hoop stress is around 500 MPa, all locating in HTS1. Overbonding and axial preloading devices are also employed to protect the DP-DP splice joints, which are easily damaged due to the large hoop stresses. Since the thickness of the employed conductor is not the same as the designed value, the actual turns are slightly larger than the designed value. In this case, the peak hoop stress in the REBCO insert will be around 515 MPa, and the peak current density will increase to 334.6 A/mm^2 when the central field is 30 T. Fig.1. shows the REBCO insert after assembly.

The REBCO insert was then tested in a 15 T LTS magnet in liquid helium bath. First, the REBCO was excited to generate a central field of 12 T to check whether the test system was normal and then was discharged as shown in Fig.1. Later excitation of the LTS magnet showed that the direction of the generated magnetic field was in the negative direction of the magnetic field generated by HTS insert. Hence the current direction of the LTS magnet was inversed. When the central field reached 30 T, the terminal voltage of the REBO insert was quite low, which indicated the insert was quite stable and had much operation margin to go. Then the current of the REBCO insert was excited to 155 A and maintained for half an hour, the central magnetic field finally reached 32.35T. Since the test took too much time and rapid excitation speed resulted in large consumption of liquid helium, the REBCO insert was then discharged in case of running out of liquid helium, as shown in Fig.1. During the excitation process, the maximum current density in the REBCO insert reached 378.2 A/mm², and the peak hoop stress increased up to 610 MPa, which located in the innermost layer of HTS1. No quench happened during the test, which showed the REBCO insert functions well under such a high magnetic field and hoop stress.

The achieved 32.35 T central field by the all-superconducting magnet is currently the highest magnetic field ever achieved by all-superconducting magnets. With a clear bore of Φ35mm, the all-superconducting magnet can be directly used as an NMR user magnet.

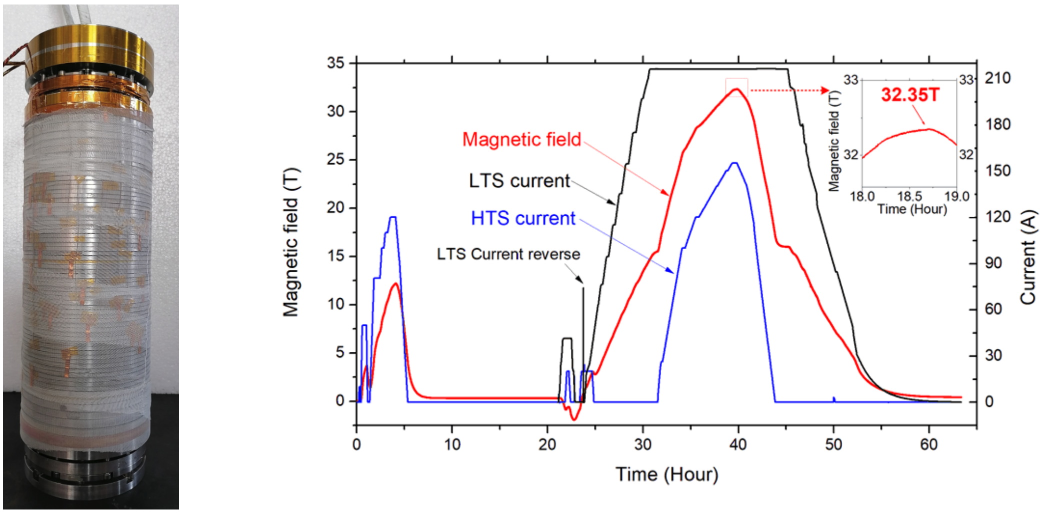

Fig.1. The REBCO insert (left) and the excitation process at 4.2 K (right). During the excitation process, the current direction of the LTS magnet was changed one time as shown in the figure, since the direction of the magnetic field generated by the LTS magnet was against the direction of the magnetic field generated by the HTS insert.

References

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