§16. Fabrication of REBCO Coil and Application for Fusion Plasma Experimental Device Mini-RT

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In 2003, an HTS coil fabricated from BSCCO was fabricated as the internal floating coil of the plasma experimental device Mini-RT, which has been extensively used in high beta plasma experiments. The decay time constant of the persistent current in this coil was 20–30 hours, which was considerably shorter than expected, and possibly due to some defects during the fabrication process. During 10 years of operation, the current decay of the persistent current has gradually fallen to ~2.7 h. Such deterioration is problematic for plasma experiments, where a constant magnetic field is preferable.

The performance of REBCO tapes has advanced sufficiently for us to consider replacing the BSCCO coil with a new REBCO coil in the Mini-RT device. We employed the REBCO tape of 4.3 mm wide. As for the countermeasure on the quench, a 0.1 mm-thick copper laminate was attached, and the coil was electrically insulated by a polyimide sheet. The final thickness of the REBCO tape was 0.27–0.28 mm. The total current of the newly fabricated REBCO coil resulted in 55.2 kA. If a few meters of the REBCO tape would be transited into the normal conducting state at the quench, the temperature of the REBCO tape should not exceed 200 K. Thus, to improve the heat dispersion at hot spots, an aluminum sheet was inserted between the winding pack and the coil frame. A persistent current switch was fabricated from the REBCO tape, and several improvements were introduced. As a uniform heating source, a stainless steel sheet was wound together with the REBCO tape. In addition, the cooling system was reinforced by an additional cooling channel. The size of the PCS was determined from its role as a heat sink for the stored magnetic energy during the demagnetization phase. The REBCO tapes were joined by a wrap-joint soldered at the copper laminate sides. Based on R&D results, the joint length was decided to be 30 mm.

Using the PCS and an external power supply, the current of the main coil was excited, and a persistent current was established, as shown in Fig. 1[1]. Under operation at 25 K, the decay time of the persistent current was improved to 320 h. The corresponding resistance was 125 nΩ, which is comparable with the total resistance of the seven joint sections in the persistent current circuit. The decay time was observed to be prolonged with decreasing operation temperature, as shown in Fig. 2. Based on these observations, we infer that the decay constant of the persistent current is attributable to joint resistance, and that the REBCO tape was not seriously degraded during the fabrication and cooling process.

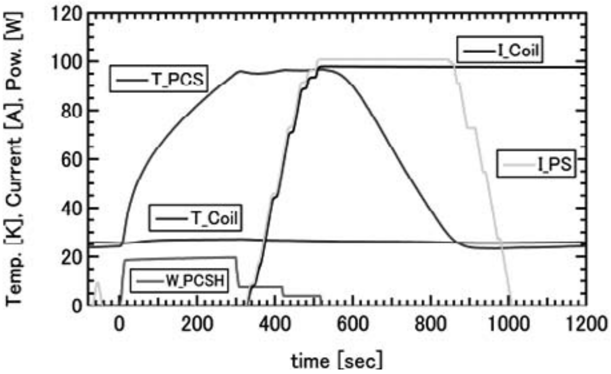

Fig. 1 Excitation experiment of the REBCO coil.

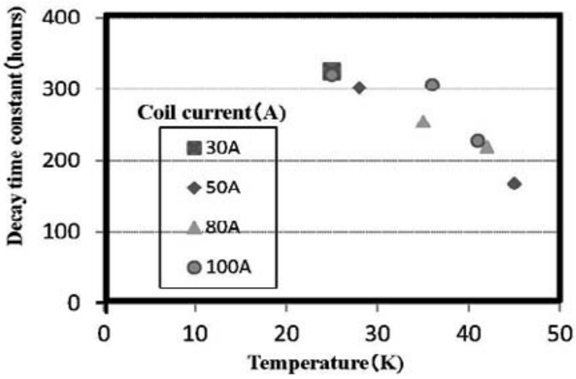

Fig. 2 Decay time constant of the persistent current for various coil currents as a function of the coil temperature.

Immediately following plasma experiments, the main coil must be demagnetized. Demagnetization of the Mini-RT coil was achieved via the PCS, which was designed to safely consume the stored magnetic energy of the main coil. As shown in Fig. 3, the PCS heater was switched on, and the temperature gradually increased. When the PCS temperature reached the critical temperature of the REBCO tape (~85 K), the persistent current was decayed by the emergent PCS resistance. The time constant of the persistent current decay was around 7–8 s, and the induced voltage across the circuit was at most 0.4 V.

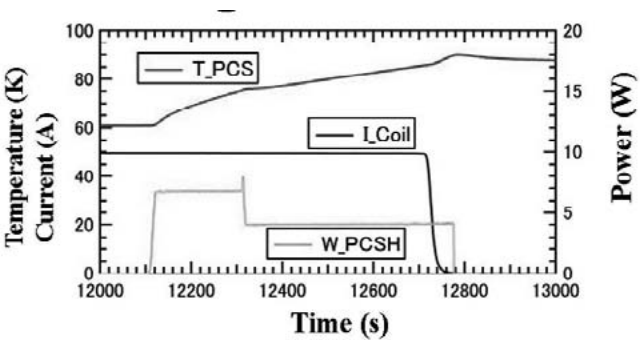

Fig. 3 Temporal behaviors of the coil parameters during the demagnetization phase.

[1] Y. Ogawa, et al., Plasma and Fusion Research: Regular Articles Volume 9, 1405014 (2014).