§28. Critical Current Measurement of 30 kA Class HTS Conductor Samples

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Design activities on the helical-type fusion DEMO reactor, FFHR-d1, are progressing at NIFS[1]. The helical coils of FFHR-d1 have the major radius of 15.6 m and 100 kA current-capacity is required for the winding conductors under the maximum magnetic field of ~13 T. An indirectly-cooled high-temperature superconducting (HTS) conductor has been proposed as one of the conductor options for the FFHR-d1 magnet[2,3]. Although the HTS still has no practical accomplishments to be applied to large-scale fusion devices, it is expected to be an alternative to low-temperature superconductors (LTS) due to a number of potential advantages. For example, magnets of fusion reactors using HTS conductors will have high cryogenic stability and low refrigeration power at elevated temperature operations (>20 K). Furthermore, it is possible that helical coils of large-diameter and complex-shape be wound by joining half-pitch segmented conductors. This "segmented-fabrication" method can shorten the construction time. Although the joule heat dissipation is generated from joints between segmented conductors when the magnet is excited, it is well accepted by the large refrigeration capacity of the FFHR-d1 reactor designed primarily for the LTS conductor option.

A 30 kA class HTS conductor sample has been fabricated using 20 GdBCO tapes (critical current: ~600 A at 77 K, self field) simply stacked in a stabilizing copper (OFC) jacket. The copper jacket was then installed in a rigid stainless-steel jacket assembled by using bolts. The conductor sample formed a one-turn short circuit with a race-track shape having two straight sections. One of the straight sections (A) had no joint, whereas the other side (B) had a bridge-type mechanical lap joint. These straight sections were surrounded by FRP jackets for thermal insulation. The sample had no current-feeders and the current was induced by changing the background magnetic field generated by the 9 T split coils in the cryostat. Rogowski coils and Hall probes were used for measuring the transport current of the sample.

Figure 1 shows the critical currents measured at various temperatures and bias magnetic fields (perpendicular to the *c*-axis of the GdBCO tape). The critical current of 45 kA was measured at 6.5 T when the straight section (A) was kept at 20 K using heaters. The result is being examined by numerical simulation considering the current and the magnetic field distribution among the tapes self-consistently.

Figure 2 shows the waveforms of the sample current and bias magnetic field when > 30 kA was excited for >20 minutes. The sample current was continuously induced by keeping the field ramp rate at constant after the current reached the critical current. We consider that the cooling of the sample was larger than the heat generation in this excitation. The sample current increased by the increase of the critical current of the conductor as the bias magnetic field decreased. The numerical analysis to simulate this observation will be our future work.

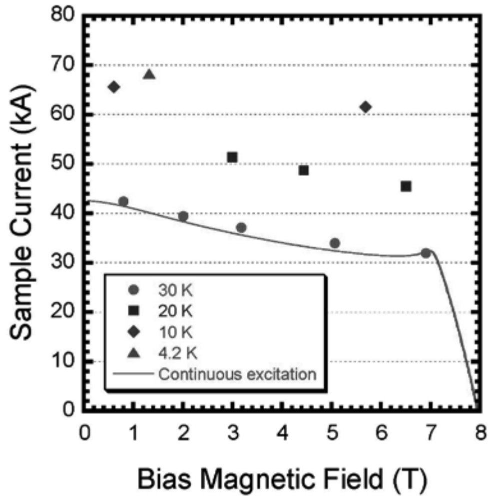

Fig.1 Critical currents of the HTS conductor sample measured at various temperatures as a function of the bias magnetic field (perpendicular to the *c*-axis of the GdBCO tape). The current observed in the continuous excitation in Fig. 2 is also plotted.

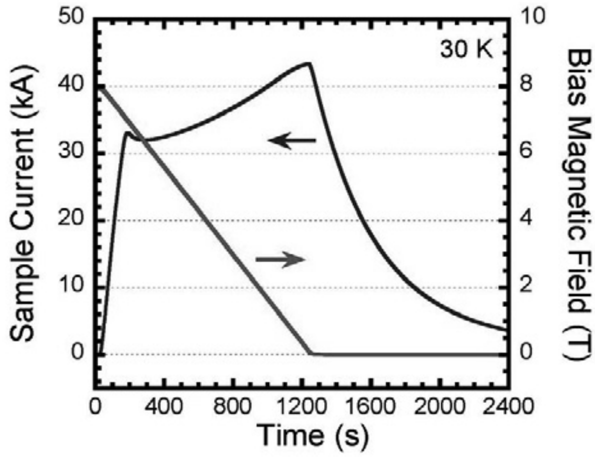

Fig.2 Temporal evolutions of the current of the HTS conductor sample and the bias magnetic field observed in the continuous excitation.

[1] A. Sagara et al., Fus. Eng. and Des. **87** (2012) 594.
[2] N. Yanagi et al., Fusion Sci. Tech. **60** (2011) 648.
[3] Y. Terazaki et al., Plasma Fus. Res. **7** (2012) 2405027.