§27. Experiments of 30 kA-Class High-Temperature Superconductor Samples

Yanagi, N., Natsume, K., Hamaguchi, S., Noguchi, H., Tamura, H., Mito, T., Sagara, A.,
Terazaki, Y. (Grad. Univ. Advanced Studies),
Ito, S., Kawai, K., Seino, Y., Hashizume, H. (Tohoku Univ.)

The conceptual design studies for the helical fusion demo reactor FFHR-d1 are being intensively promoted.[1] In the present design, the helical coils have the major radius 15.6 m and generate the toroidal magnetic field 4.7 T to achieve 3 GW fusion power. The stored magnetic energy reaches 160 GJ and a 100-kA conductor is required to be used at the maximum magnetic field of 13 T. The high-temperature superconductor (HTS) seems feasible as a counter option to the low-temperature superconductor (LTS) considering the rapid progress of the wire production technology of HTS. In our design for the 100-kA class HTS conductor, we use YBCO tapes simply stacked in a copper and stainless-steel jacket and cooled indirectly. An attractive proposal using HTS is that the segmented fabrication of the huge and continuously wound helical coils be possible.[2] The present idea is to connect conductor segments with each half helical pitch using a bridge-type lap joint [3] formed either by soldering [4] or by mechanically connecting [5].

We started the HTS conductor development from a10 kA-class in 2005. In 2012, we fabricated a 30 kA-class conductor sample (Fig. 1) using the latest GdBCO tapes (Fujikura Ltd. FYSC-SC10, critical current >600 A at 77 K, self-field). The HTS tapes were simply stacked by 10 layers and 2 rows in a copper jacket. The outer stainless-steel jacket secured the mechanical rigidity and it was thermally insulated by a FRP jacket. A bridge-type mechanical lap joint developed at Tohoku Univ. was applied and the sample formed a short-circuit with a race-track shape.

The experiments were conducted two times. In the first experiment, the sample current was successfully induced by changing the bias magnetic field and the critical current of 45 kA was observed at 20 K and 6 T, however, the decay time constant of the induced current, ~90 s, was much shorter than the expected value of 550 s. This was due to the unexpectedly high joint resistance in one of the two joint locations. The sample quenched when the current exceeded 50 kA from the joint due to the high joule heating. The HTS tapes were replaced by new ones with an improved joint and the second experiment was carried out. This time the decay time constant was prolonged to be ~340 s, as shown in Fig. 2. The maximum current reached 70 kA at 4 K, 1 T. Stable excitations of >20 min. were also performed.

In our next step, the number of HTS tapes will be increased so that the rated current of 100 kA will be reached at 20 K and >6 T to meet the requirement for the helical coils of FFHR-d1.

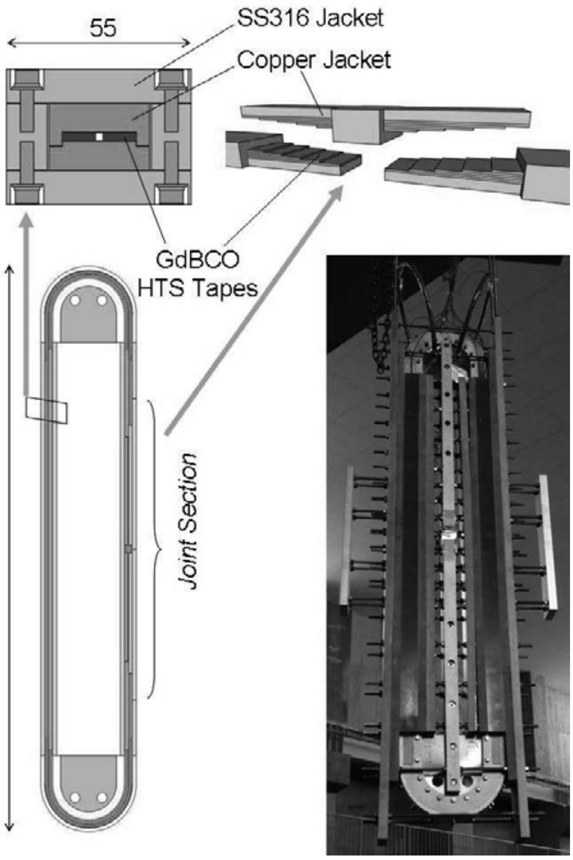

Fig. 1. The 30-kA class HTS conductor sample: a cross-sectional image of the conductor, the entire configuration with a racetrack shaped one-turn loop and a joint, the actual photo in the first experiment.

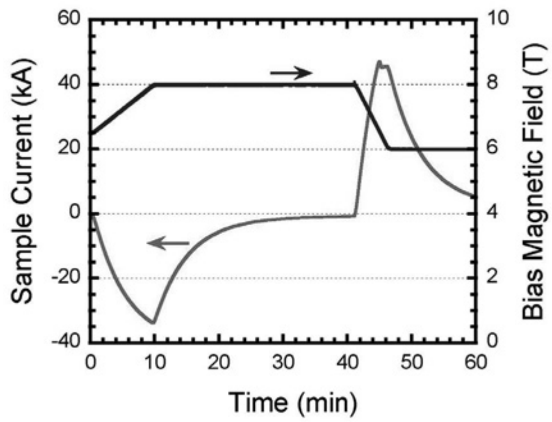

Fig. 2. Waveforms of the sample current and bias magnetic field during the second test at temperature 20 K.

1) Sagara, A. et al.: Fusion Eng. and Des. **87** (2012) 594.
2) Hashizume, H. et al.: Fusion Eng. Des. **63** (2002) 449.
3) Yanagi, N. et al.: Fusion Sci. Tech. **60** (2011) 648.
4) Terazaki, Y. et al.: Plasma Fusion Res. **7** (2012) 2405027.
5) Ito, S. et al.: IEEE Trans. Appl. Supercond. **22** (2012) 6400204.