# §20. Structural Design of the Remountable Magnet and Development of Joint Section of a High-temperature Superconducting Conductor

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Segmented high-temperature superconducting (HTS) magnets have been proposed for helical reactor, FFHR-d1.[1)-3)] The magnet is constructed by assembling short conductors or segments with resistive joints. HTS materials can allow the resistive joint because they have high thermal stability and achieve low electric power to run cryoplant. Objectives of this corroborative study are investigation of structure and cooling system for the segmented helical magnet, and development of mechanical joints of large-scale HTS conductors to be used for the magnet.

In this year, we fabricated two HTS conductor samples and their mechanical joints: 30-kA-class and 100-kA-class HTS conductors. The conductor samples were also tested at the test facility which can provide bias magnetic fields up to 9 T at NIFS. Fig. 1 shows a schematic illustration of the 100-kA-class HTS conductor, especially its joint section. The 30-kA-class HTS conductor has two rows and ten layers of GdBCO tapes (Fujikura Ltd., FYSC-SC10) whereas the 100-kA-class HTS conductor has three rows and fourteen layers of GdBCO tapes in the joint region, three rows and eighteen layers in the continuous region. The GdBCO tapes were embedded in oxygen-free copper (OFC) and type-316 stainless steel (SS316) jackets. The conductor samples were joined with the bridge-type mechanical lap joint (the mechanical bridge joint) to be one turn race track coil with no current lead. Current was induced when the bias magnetic field changed and attenuated when the field becomes constant. The current was evaluated with Rogowski coils and Hall probes. The time constant of current attenuation was used to obtain the joint resistance for the entire joint.

Fig. 2 shows an excitation test result for the 100-kA-class HTS conductor at 4.2 K where bias magnetic field at $x$=100 mm and $y$=0 mm shown in Fig. 1 varied from 3 T to 0.45 T. At the above condition, a maximum current of 118 kA was applied without quench at the joint section. Currents evaluated with the Hall probes count magnetic field generated by shielding current induced in HTS tape whereas Rogowski coils do not count this. In the same manner, we use mainly current evaluated by Rogowski coils to estimate joint resistance in this study. Achieved currents and joint resistance are 45 kA at 20 K, 6.1 T, 70 kA at 4.2 K, 1.2 T and ~4 nΩ in the 30-kA-class HTS conductor and 100 kA at 20 K, 5.3 T, 118 kA at 4.2 K, 0.45 T and ~4 nΩ in the 100-kA-class HTS conductor, respectively. Fig. 3 shows joint resistivity (product of joint resistance and joint area) as a function of joint pressure obtained in this study where the results in a fundamental test[4)] with the mechanical bridge joint having single and double layers of GdBCO tape. The joint resistivities obtained in the HTS conductor samples were comparable to that obtained in the fundamental test. We also noted that obtained joint resistivity is small enough to properly run the cryoplant of the reactor in the FFHR-d1.

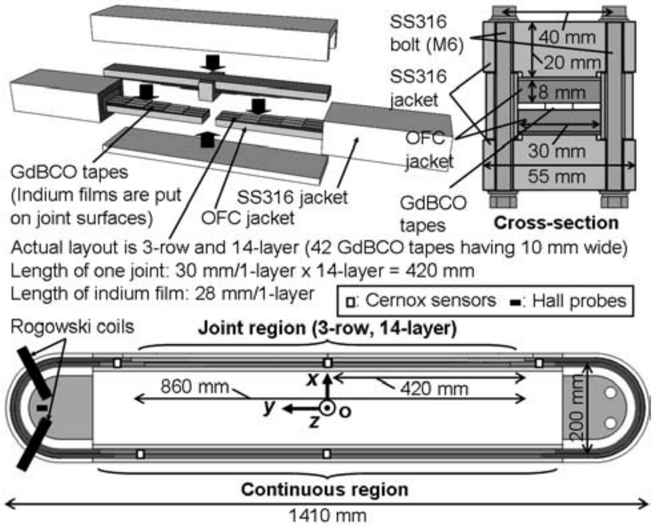


Fig. 1. Schematic of joint section in the 100-kA-class HTS conductor sample.

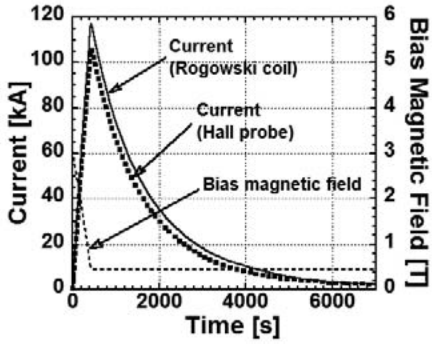


Fig. 2. A typical excitation test result for the 100-kA-class HTS conductor.

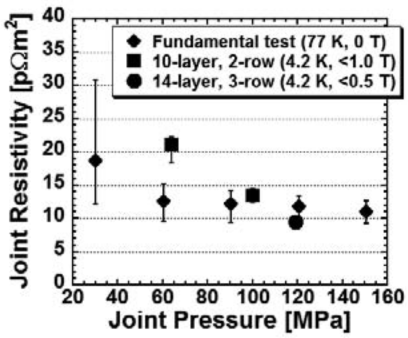


Fig. 3. Joint resistivity as a function of joint pressure.

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2) Yanagi, N. et al.: Fusion Sci. Technol. **60** (2001) 648.
3) Sagara, A. et al.: Fusion Eng. Des. **87** (2012) 594.
4) Kawai, K. et al.: IEEE Trans. Appl. Supercond., **23** (2013) 4801704.