

§26. Experiment and Analysis of the Critical Current of a 100-kA Class HTS Conductor Sample

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A 100 kA-class conductor is required to be used for the LHD-type helical fusion reactor, FFHR-d1, and the high-temperature superconducting (HTS) conductor is proposed as one of the options¹⁾. Using HTS, the reactor can be economically operated at an elevated operating temperature, e.g. 20 K. High cryogenic stability of the conductor is also obtained due to the increased heat capacity of metals equivalent to that of helium at 4 K. In addition, it is proposed that the fusion magnet can be constructed by connecting conductor segments²⁾ (or coil segments³⁾). An HTS conductor having a 100 kA nominal current at 20 K, 12 T has been proposed and designed²⁾. Development of such a conductor suitable for the helical fusion reactor is our final goal. We successfully fabricated and tested 30-kA class HTS conductors in FY2012^{4, 5, 6)}

A 100-kA class conductor sample was fabricated in FY2013 using GdBCO tapes (critical current: ~600 A at 77 K, self-field) simply stacked in a stabilizing copper 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 54 GdBCO tapes and no joint, whereas the other side (B) had 42 tapes and a bridge-type mechanical lap joint⁷⁾. These straight sections were surrounded by FRP jackets for a 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 waveforms of the 100-kA conductor sample current and the bias magnetic field produced by the 9-T split coils. The maximum current of 118 kA was attained in the sample at the temperature of 4.2 K and magnetic field of 0.45 T.

A numerical analysis for examining the critical current of the 100-kA conductor sample was performed. In the calculation, the bundle of GdBCO tapes is regarded as one conductor, which is divided into current elements. The overall transport current of the sample was increased step by step, starting from a uniform current distribution. If the transport current of any element exceeds the critical current of that element which was obtained from the critical current characteristics of the GdBCO tape evaluated by a percolation model, the transport current is reduced to the critical current and the difference is equally distributed to other elements where the transport current is still lower than the critical

current. This process is iterated, by developing a non-uniform current distribution, until the transport currents of all the elements reach the critical current. Then, the critical current of the conductor sample is defined as the summation of the transport currents of all the elements, and the iteration is finished. Figure 2 shows the distributions of the calculated magnetic field and critical current density when the sample reached the critical current at 4.2 K, 0.45 T. The critical current of the sample is dominantly determined by the perpendicular component (perpendicular to the tape surface) of the self-field at lower bias magnetic field. We consider that the sample was not deteriorated because the calculated critical current of 119 kA is higher than the measured value of 118 kA.

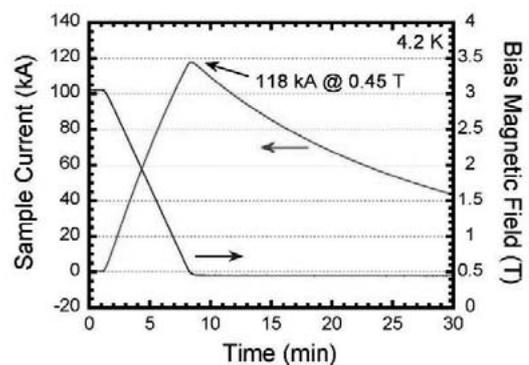


Fig.1 Temporal evaluations of the current of the 100-kA HTS conductor sample and the bias magnetic field of the 9-T split coils.

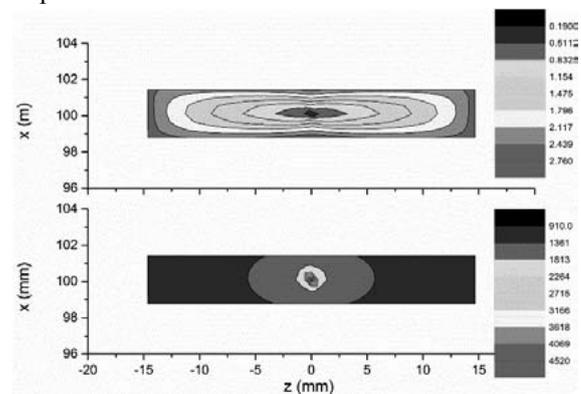


Fig.2 Calculated distributions of the magnetic field and critical current density in the 100-kA conductor sample at 4.2 K, 0.45 T.

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