§17. Cryogenic Stability of LTS/HTS Hybrid Conductors

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Large current capacity together with high current density is supposed to be achieved by solid composite-type superconductors if they are extra-stabilized with low resistive metals, such as pure aluminum. However, it was found with the aluminum-stabilized superconductor used for the helical coils of the Large Helical Device (LHD) that both the cold-end recovery current and minimum propagation current were lower than the expected values. These are due to the enhancement of the magnetoresistivity of aluminum-copper composites by the generation of Hall currents and by long magnetic diffusion time constant in the pure aluminum [1]. If these problems with composite-type superconductors can be solved, the current capacity will be further improved, and this type of conductors may still be applied for the future superconducting coils. We consider that high-temperature superconducting (HTS) wires can be used as stabilizers since they have effectively zero resistivity as long as the transport current is lower than the critical current. Thus, HTS wires can be regarded as ideal stabilizers for the so-called LHS/HTS hybrid conductors.

In order to develop LTS/HTS hybrid conductors, we started with the combination of NbTi/Cu and Bi-2223/Ag wires [2]. Figure 1 shows the cross-sectional views of the two types of fabricated hybrid conductors together with the original aluminum-stabilized superconductor for the LHD helical coils. The Type-A conductor was equipped with 30 HTS tapes, whereas 75 for Type-B. For each conductor, the HTS tapes were prepared with 900 mm length at the central region where the external magnetic field was applied, and the stacks of tapes were soldered together in a copper jacket. As there were gaps between the central HTS bundles and the other ones at both ends, the transport current could be initially supplied only to the NbTi/Cu cables from the current leads. Once they are made normal-conducting by injecting heat disturbances using the attached stainless-steel heaters, the current will be transferred into the HTS stabilizers. The samples were tested in the bias magnetic field of 7 and 8 T, and the normal-zone propagation was monitored by voltage taps.

The significantly high cryogenic stability of the hybrid conductors can be confirmed by comparing the voltage waveforms observed for the hybrid conductors with those obtained with the original aluminum-stabilized conductor. As shown in Fig. 2, it was previously observed for the original conductor that the transport current of 15 kA was well above the minimum propagation current at 7 T, and the normal-zone propagated and not disappeared. On the contrary, the hybrid conductor (Type-A) showed a very short normal-transition, and recovered back to the superconducting state within 0.2 s.

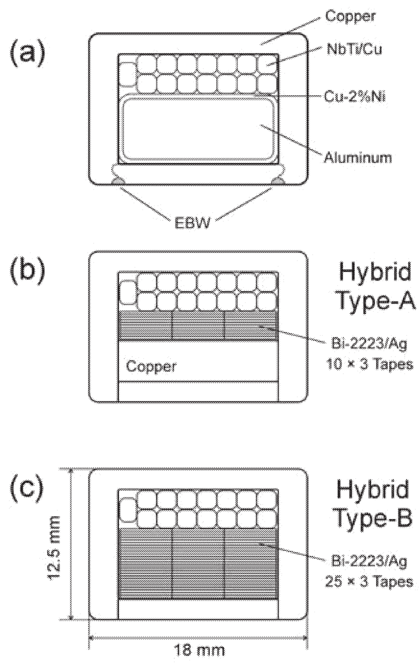

Fig. 1 Cross-sectional views of (a) the aluminum-stabilized conductor used for the LHD helical coils, (b) hybrid conductor “Type-A” and (c) hybrid conductor “Type-B”.

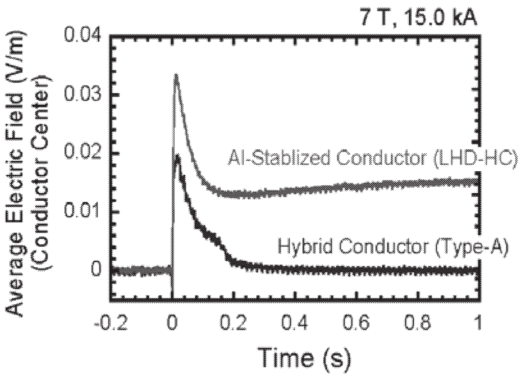

Fig. 2 Comparison of the voltage waveforms (at the heater positions) between the hybrid conductor (Type-A) and the original aluminum-stabilized conductor at 7 T, 15 kA.

References
1) Yanagi, N., Imagawa, S., et al., IEEE Trans. Appl. Supercond. Vol.14, No.2 pp.1507-1510.
2) Bansal, G., Yanagi, N., et al., Fusion Eng. and Des. 81 (2006) 2485.
3) Yanagi, N. et al.: to be published in IEEE Trans. on Appl. Supercond. (2007).