§19. Cryogenic Stability of LTS/HTS Hybrid Superconductors

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Large current capacity with high current density is supposed to be achieved by solid composite-type superconductors when they are extra stabilized with low resistive metals. Such an example is seen in the aluminum-stabilized superconductor used for the helical coils of the Large Helical Device (LHD). However, it was found in this conductor that the cold-end recovery current was lower than the expected value due to the enhancement of the magnetoresistivity of aluminum-copper composites by the generation of the so-called Hall currents under high magnetic field. Moreover, in the transient process, the minimum propagation current becomes even less due to the long magnetic diffusion time constant in the pure aluminum, and traveling normal-zones are observed to propagate only in one direction along the conductor [1].

If these problems with composite-type superconductors are solved, the cryogenic stability can be highly improved, and this type of conductors will still be used in the near future middle-scale or large-scale superconducting coils. In this connection, we consider that high-temperature superconducting (HTS) wires can be used as a stabilizer in place of pure aluminum. An HTS wire has effectively zero resistivity as long as the transport current is lower than the critical current, and thus they can be regarded as an ideal stabilizer. In such a "hybrid" conductor, we can assume that the transport current flows initially in the low-temperature superconducting (LTS) wires. When there is a normal-transition in the LTS wires due to some external disturbances, the transport current may immediately transfer to HTS and thus the heat generation can be suppressed and a quench will be avoided. Here it should be noted that HTS wires need not to be supplied in long length but in short pieces, and therefore, the problems related with mechanical robustness and AC losses can be solved. We believe that hybrid conductors will explore a new research field in terms of the cryogenic stability of LTS conductors. At the same time, they will also contribute in the development of full HTS conductors in the future.

In order to develop LTS/HTS hybrid conductors, we started by the combination of NbTi/Cu and Bi-2223/Ag wires. Figure 1 shows the cross-sectional view of the hybrid conductor, which is the modified version of the original aluminum-stabilized superconductor for the LHD helical coils by replacing the aluminum-stabilizer by a bundle of Bi-2223/Ag tapes. This conductor is now being fabricated and it will be tested soon. Before actually examining the properties of this conductor, we have prepared a series of small-scale samples in order to carry out proof-of-principle experiments. Here, a NbTi/Cu cable with the cross-sectional area and current capacity roughly ten times smaller than those of the LHD conductor was used and two and/or three tapes of Bi-2223/Ag wires were soldered together and thus hybrid conductors were formed. The stability tests were performed by initiating a quench in the NbTi/Cu cable using a resistive heater and the propagation of the generated normal-zone was investigated. The results are shown in Fig. 2 both for the two-tape and three-tape samples. As is expected, hybrid conductors show good stability and the minimum propagation current can be improved by using HTS tapes as a stabilizer.

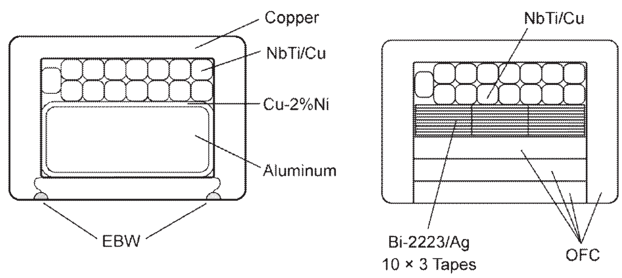

Fig. 1 Cross-sectional views of the aluminum-stabilized superconductor used for the LHD helical coils (left) and its modified version as a hybrid conductor (right).

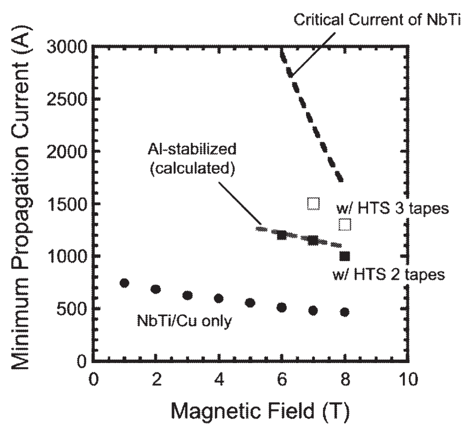

Fig. 2 Experimentally observed minimum propagation currents of small hybrid conductor samples (with two and three HTS tapes) as well as a NbTi/Cu cable.

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., to be published in Fusion Engineering and Design.