§22. Development of Large Current Capacity HTS Conductors for Fusion Reactor Magnets

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High temperature superconductors (HTS) are being considered for high field magnets in fusion reactors due to their better performances in high magnetic field and elevated temperature operations. The HTS conductors may be used at ~20 K in fusion reactors and therefore reduces the operational cost as compared to their counterparts, i.e., low temperature superconductors (LTS) which are used at ~4.2 K. At elevated temperatures, the specific heat of materials increases significantly. Therefore, the HTS conductors operating at ~20 K become invulnerable to quench and show much higher cryogenic stability as compared with LTS. Due to these advantages of HTS over LTS, the HTS conductor option is already being considered in the design of Tokamak Power Reactor (VECTOR) at JAEA [1] and LHD-type reactor (FFHR) at NIFS.

As the first step towards the development of large current capacity HTS conductor for fusion reactor magnets, we have started with a 10 kA-class HTS conductor using Bi-2223/Ag HTS wires (each wire having ~120 A critical current at self-field and 77 K). The HTS conductor consists of 34 HTS wires in 2 stacks and the expected critical current of the conductor is ~17 kA at 4.2 K in 8 T parallel field, whereas it is ~12 kA at 20 K in 8 T parallel field (without self-field effect). The HTS conductor is tested at 4.2 K as well as at elevated temperature up to 20 K. For elevated temperature measurements, the conductor is insulated with epoxy and GFRP and stainless-steel (SS) heaters are attached on the conductor to raise the temperature. Cross-sectional views of the HTS conductor to be tested at 4.2 K and 20 K are shown in Fig 1. The experimental items are planned to be the critical current measurements, stability measurements with uniform current distribution, stability measurements with non-uniform current distributions, and ramp rate limitation tests. These experiments will be performed both at 4.2 K and 20 K in different bias magnetic fields. An array of Hall sensors are installed around the conductor cross-section to monitor the current distribution in the conductor, whereas Cernox temperature sensors are used to monitor the temperature evolution of the conductor during normal-zone propagations. Voltage taps are used to monitor the normal-zone growth along the conductor. Fig 2 shows the calculated stability margin of the HTS conductor at 4.2 K and 20 K in 8 T bias magnetic field considering uniform current distribution. The stability margin is calculated by summing up the available enthalpy of materials in the HTS conductor from the operational temperature to the current sharing temperature. Fig 3 shows a photograph of the fabricated HTS conductor sample installed in the 8 T split coil.

One experimental campaign has already been carried out and the critical current of the HTS conductor was measured to be ~15 kA at 4.2 K and 7 T. The conductor showed high stability and no quench with ~65W of heater power at 15 kA and 4.2 K. An elevated temperature of 20 K was also successfully achieved using SS heaters with ~40 W total heater power in 0 T bias field. Another experimental campaign will be carried out soon to rigorously test the HTS conductors.

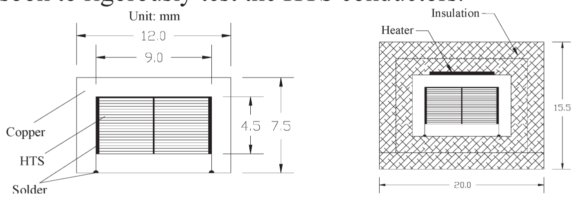

Fig 1: Cross-sectional views of the HTS conductors: (a) to be tested at 4.2 K and (b) to be tested at elevated temperature up to 20 K.

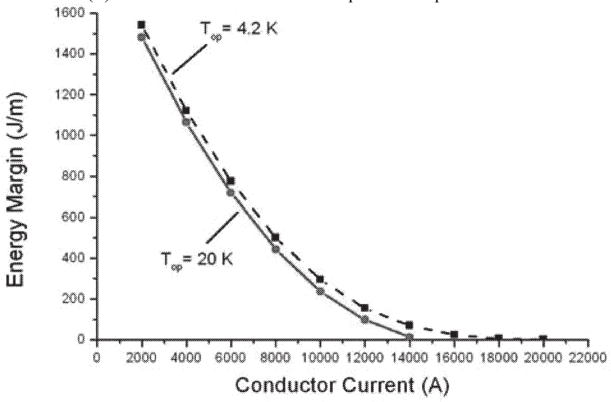

Fig 2: Calculated stability margin of the HTS conductor at 8 T

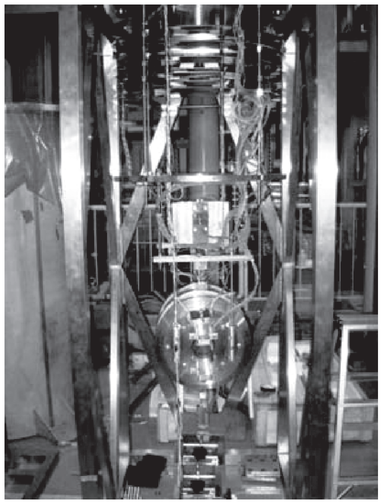

Fig 3: Photograph of the HTS conductor sample installed in the 8 T split coil.

Reference:
[1] Ando, T. et al.: IEEE Trans. on Applied Superconductivity 14 (2004) 1481.