§ 4. Development of a Current Feeder System for LHD by Using High Temperature Superconducting Conductors

Maehata, K., Ishibashi, K., Takeo, M. (Kyushu Univ. Eng.)
Tachikawa, K., Yamada, Y. (Tokai Univ. Eng.)
Shintomi, T. (KEK)
Iwamoto, A., Motojima, O., Yamada, S., Mito, T.

In the first phase of the Large Helical Device (LHD) project, superconducting helical coils produce a magnetic field of 3 T in 13 kA operation of a conventional liquid helium cooling at a temperature of 4.4 K. In the second phase, the helical coils are planned to be cooled down to 1.8 K by the pressurized superfluid helium to raise the magnetic field up to 4 T with 17.3 kA. The power supply leads for the helical coils in the second phase consist of gas cooled current leads which introduce the current into the conventional liquid helium bath at 4.4 K and the current bus line between the cold ends of current leads at 4.4 K and the helical coils operated at 1.8 K. Current feed devices in the current bus line are required to have high current transport density and low thermal conductivity. High temperature superconductors (HTSs) are promising materials for high current feed devices in the superfluid cooling systems. Because of the large pinning force, YBCO based devices are expected to have a compact structure in the application to transport high currents up to 20 kA.

A bulk YBCO conductor fabricated by employing the QMG method was demonstrated high current transport capacity up to 25 kA in the bath-cooling condition at 4.2 K. The test conductor was manufactured from the disk shaped YBCO bulk conductor of 65 mm in diameter and 15 mm thick. The region of 1.8 K cooled by the pressurized superfluid helium is separated by the λ-plate from the conventional liquid helium at 4.2 K. Since the λ-plate is designed to be thicker than 70 mm, it is necessary to fabricate larger bulk conductor for the current feed through mounted in the λ-plate. A fabrication process of large bulk conductors was developed for the 20 kA-class current feed-through in the λ-plate. A prototype YBCO bulk conductor 40 mm wide, 50 mm long and 15 mm thick was manufactured from a bulk sample fabricated by the developed process. In preliminary experiments, an operation test of the prototype YBCO bulk conductor was interrupted at a transport current of 19.6 kA by an accidental burned-out in the NbTi/Cu stranded cable of current feed line from the cold ends of gas cooled current leads to the bulk conductor. To simulate the operational condition of the current feed-through in the λ-plate, the prototype YBCO bulk conductor was mounted in a cylindrical block made by a glass fiber reinforced plastic (GFRP). The conductor was glued in the channel of the plug by an epoxy resin for stopping the super-leak. The trial current feed-through was assembled into the current transport test setup. The current transport tests with trapezoidal wave were carried out successfully up to 20 kA. The value of the electric resistance of the joint regions at both sides was obtained to be 3.8 nΩ at 20 kA. The transport current was held to be constant at 18 kA for 300 seconds. During the constant current operation at 18 kA, the voltage drop across the current feed through was observed to be constant and a stable operation was demonstrated.

Three rectangle shaped YBCO bulk conductors 20 mm wide, 140 mm long and 10 mm thick were manufactured for the 20 kA-class current feed-through mounted on the λ-plate of the superfluied cryostat. The quality of the conductors was confirmed by a precise survey of internal defects in the fabricated large bulk conductors. Fig.1 shows the λ-plate current feed-through assembled into the current transport test setup. The 1.8 K current feed-through consisted of two large YBCO bulk conductors laid with a phosphor bronze of 3 mm thick going through the cylindrical GFRP block of 75 mm thick. The setup was inserted into the large cryostat and cooled down to 4.2 K. The current transport tests with trapezoidal wave were carried out successfully up to 20 kA. Fig. 2 shows the transport current and the voltage drop across the λ-plate current feed-through in 20 kA operation tests. The transport current was held at 20 kA longer than 300 seconds. During the 20 kA operation, the voltage drop was observed to be constant in the joints between the YBCO bulk conductor and the copper electrodes. The joint resistance was obtained to be 1.8 nΩ/conductor at 20 kA.

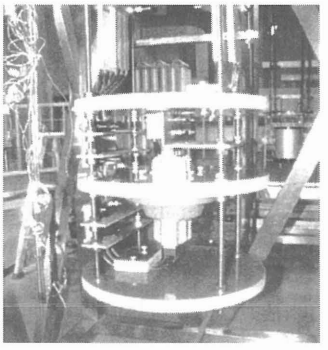

Fig.1 Photograph of the current transport setup of the λ-plate current feed-through.

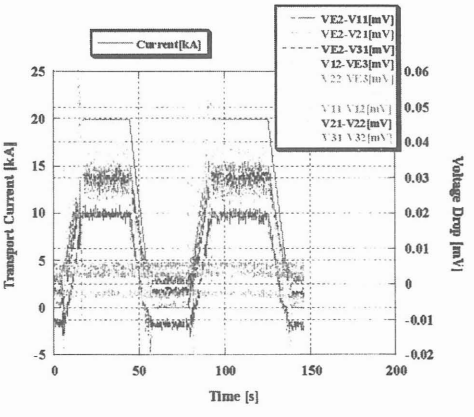

Fig.2 Voltage drop across the λ-plate current feed-through with holding the transport current at 20 kA.