§7. 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 at NIFS. 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. The current transport capacity is degraded by defects in the bulk. Before assembling the setup of the current transport test, we carried out a precise survey of internal defects in the fabricated large bulk conductors. Fig. 1 shows a result of a survey of internal defects in the fabricated bulk conductor by the magnetizing process developed by Nippon Steel Co. The magnetic field is applied to the conductor at the room temperature, and the applied magnetic field is removed after cooling the conductor below the critical temperature. The spatial distribution of trapped magnetic flux in the conductor is obtained by scanning a surface magnetic field with a Hall probe with holding the conductor in the superconducting state. Since the magnetic flux is trapped by the internal defect, the surface magnetic field map indicates the internal defect distribution. The magnetic field map in Fig. 1 shows a smooth and symmetric distribution and indicates the high quality of the conductor without the internal defect.

The prototype conductor was assembled into the current feed through test setup as shown in Fig.2. 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 17.5 kA. Fig. 3 shows the transport current and the voltage drop across the prototype conductor during 17.5 kA and 20 kA operation tests. In the 17.5 kA operation, no normal conducting transition was observed from the voltage drop curve in Fig. 2. The NbTi/Cu stranded cables were wired from the cold ends of the gas tooled current leads to the both ends of the prototype conductor. At the transport current of 19.6 kA, the NbTi/Cu cable quenched and burned out. The values of the electric resistance of the joint regions at both sides were obtained to be 3.1 and 3.5 nΩ, respectively in the 17.5 kA operation. The Joule heat generation in the joint region of the bulk conductor estimated to be lower than 1 W per joint at 17 kA by using the joint resistance of 3.5 nΩ.

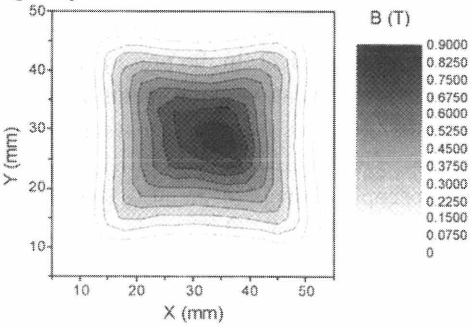

Fig. 1 Map of magnetization of YBCO bulk conductor.

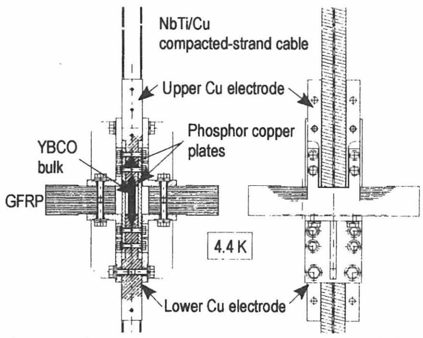

Fig. 2 Setup of prototype HTS current feed through.

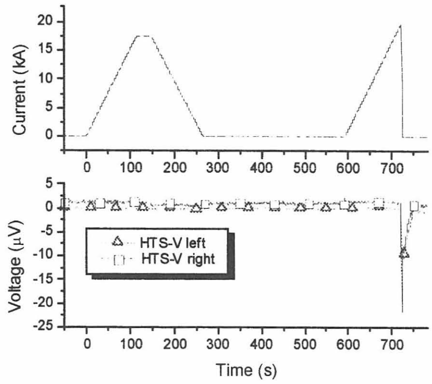

Fig. 3 Transport current and voltage drop in the prototype bulk conductor.