§1. Development of Power Supply Leads for Superfluid Cooling Superconducting Coils

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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.

An "H" shaped bulk conductor has been developed. The "H" shaped conductor was cut from the YBCO fabricated by a modified quench and melt growth (QMG) process. In preliminary research, we experimentally demonstrated the feasibility of the YBCO bulk conductor for high current transport in dc operation up to 25 kA at 4.2 K and 11.7 kA at 77K. Therefore, we have decided to construct a prototype of the current feed device by the use of "H" shaped YBCO bulk conductor.

The prototype of the current feed device was designed to be installed in the large superfluid helium cooling cryostat for the large superconductor test facility at NIFS. A pair of "H" shaped conductors is mounted in the thick lambda plate of the cryostat. The straight section of the conductor passes through the lambda plate and the electrodes of both ends require a large surface area to reduce Joule heating in the soldering region. Owing to these specifications, the prototype conductor needs larger geometrical dimensions than those of the preliminary conductor described above. Therefore we investigated a fabrication process of the high quality YBCO bulk material 140 mm long, 60 mm wide and 10 mm thick. Figure 1 shows a photograph of the "H" shaped YBCO bulk conductor for the prototype current feed device. The cross sectional area and the length of the straight section of the conductor is 10mm × 10mm and 50 mm, respectively. A pair of the "H" shaped bulk conductors were mounted in the central plug of the lambda plate made of GFRP. The straight sections of both conductors were glued in the channels in the plug to seal the superfluid helium. The electrodes of the "H" shaped conductor were carefully soldered to the copper blocks with cables of metal superconductor. The ends of the cable in the 1.8K-bath were short-circuited, while the other ends were connected to the gas cooled current leads. Figure 2 shows the assembled prototype current feed device. The device has the support structure against the large electromagnetic force. The current feed device was installed into the large superfluid helium cooling cryostat. During cooling down of the device, the "H" shaped conductor showed the transition into the superconducting phase. In the pressurized superfluid cooling, the current feed device was kept at 1.8 K without the superleak. However, in the dc current transport test, the normal conducting phase was observed in the "H" shaped conductor below 2 kA. This degradation in the current transport property may be caused by a mechanical damage in the HTS bulk conductor. The mechanical damage might have been produced in the fabrication process of the large bulk conductor specialized for the prototype current feed device. Although special cares had been taken in the mounting the HTS bulk conductor into the cryostat, the large thermal stress might be applied to the conductor due to the composit structure of the device. It is important to find the origin of the mechanical damage and establish the fabrication process of the large bulk conductor and a reliable structure of the current feed device mounted in the lambda plate of the large superfluid helium cooling cryostat.

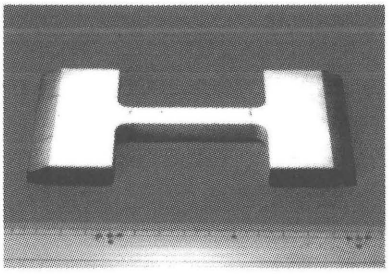

Fig. 1 Photograph of the "H" shaped YBCO bulk conductor for the prototype current feed device.

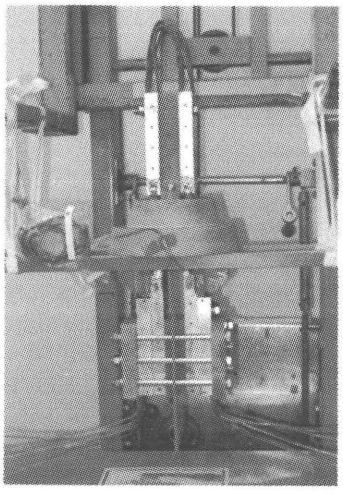

Fig. 2 The prototype current feed device assembled in the center plug of the lambda plate.