§ 3. Study on Stability of Superconducting Coil Cooled by Subcooled He I and He II at Atmospheric Pressure

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He II is expected as a coolant for superconducting magnets that realizes the downsizing and the large capacitization. Knowledge on cooling stability of a superconducting coil is important for the design of superconducting magnets.

The stability test of a small test coil using a superconducting wire wound 33 times on a stainless steel bobbin of 10 cm in diameter was performed. The wire was a 0.80 mm-diameter NbTi composite wire with the copper ratio of 6.5, and with PVF insulation film on the surface. The test coil was installed in a superconducting magnet that impressed magnetic field to the test part. A 0.30 mm diameter Manganin wire was non-inductively wound around the superconducting wire as a heater to induce a pulsewise local thermal disturbance at the center of the bobbin. Voltage-taps and a RuO_2 thermometer were attached on the positions shown in Fig. 1(a).

Experiments were performed by the following way. After setting up the fixed magnetic field and the constant current to the specimen, the heater generated the thermal disturbance and it caused a bud of normal transition. The cooling stability was studied by measuring the voltage-taps and the temperature signals along the windings of the coil.

The stability limits were obtained for magnetic fields from 1.1 T to 6.7 T and bulk liquid temperatures from 1.8 K to 4.2 K at atmospheric pressure. Fig. 1 shows the results of the resistivity between each taps (Fig. 1(b)) and the RuO_2 temperature (Fig. 1(c)) at the liquid temperature of 1.8 K, magnetic flux density of 3.38 T, the test coil current of 200 A and the heat input of 73 mJ (from 0 to 0.1 s). As shown in Fig. 1(b), the resistance was arisen in the superconducting wire and the normal section spread as soon as the heat input was applied, and the resistance did not return to zero even after the loss of the heat input. However, as the resistivity between Tap3 and 4 was small compared with the one between Tap2 and 3, the normal section had not spread in the whole coil and the front of the normal section existed between Tap3 and 4. In this balancing state of the heat generation and He cooling, the temperature of the RuO_2 thermometer that seems to indicate the temperature of Cu stabilizer was also constant at 6.11 K as shown in Fig. 1(c). The heat flux of the wire surface was calculated to be constant as 1.76×10^4 W/m^2. Substitute this value for a heat transfer equation of Kapitza Conductance (eq. (1)) given by M. Shiotsu[1], it gives the temperature of the wire surface as 2.81 K.

$$q = 600(T_w^{3.5} - T_B^{3.5}) \tag{1}$$

Comparing this calculated value with the measured one indicated in Fig. 1(c), it turns out that the measured Cu temperature was quite higher. The cause of this temperature rise is PVF film on the wire sureface[2]. Because of the temperature slope in the PVF film and the aggravation of heat transfer in the Kapitza Conductance regime, the measured Cu temperature was very much higher than the one with no insulation film and the wire did not recover to the superconducting state. As shown in this case, insulation on a superconducting wire has a great influence in cooling stability of the wire.

The stability limit was determined as a maximum direct current to the test coil without spreading of a normal section after giving a pulse input to the heater. The limiting current under a constant magnetic field became slightly higher with the decrease of liquid temperature from 4.2 K down to near the λ-temperature. It increased dramatically by shifting to He II cooling from He I cooling. Namely, the cooling stability of the coil improved greatly. In addition, the change of the limiting currents was not seen about the heat input of 47 mJ and 1168 mJ, and the normal part did not spread nor remain at the heat input of 26 mJ.

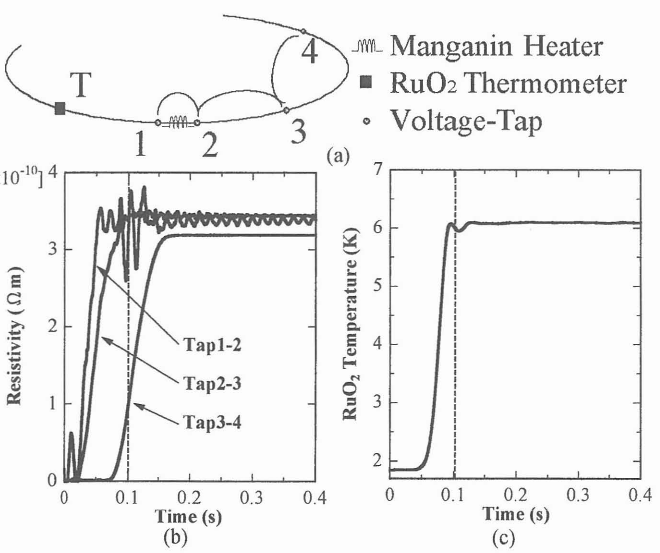

Fig. 1. Positions of measuring elements, and measured waveforms of resistivity and temperature

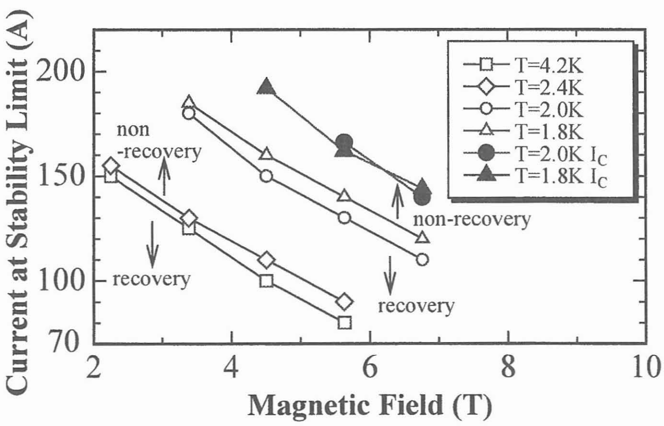

Fig. 2. Stability limits for test coil for 73 mJ heat input

References
1) Shiotsu, M. et al.: ASME Publication, HTD211(1992)19
2) Iwamoto, A. et al.:Cryogenics41(2001)367