§23. Stability of Superconducting Coil with Various Surface Conditions in Pressurized He II

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Stability tests were carried out with two superconducting coils wound with a bare wire on a G-FRP bobbin (Coil-I), and with a surface oxidized wire on a G-FRP bobbin (Coil-II). The first wire is a 0.50 mm-diameter NbTi/Cu composite bare wire with the copper ratio of 1.3. The second is the same wire with a chemically oxidized copper surface. The schematic illustration of the test coil is shown in Fig. 1. Each superconducting wire is wound about 30 turns around the bobbin respectively. The wire is fixed in the groove on the bobbin only with tension. A manganin insulated heater is buried inside the bobbin. Experiments were performed according to the following procedure. 1) Set up a fixed external magnetic field and the constant current to the test coil. 2) Give the pulsive heat input by use of the heater to cause a bud of normal transition in the wire. 3) Measure the tap voltages and the temperature signals along the wire to know the behavior of the normal zone propagation. The tests were performed for the magnetic flux densities, B, from 1.1 T to 7.6 T and the bulk liquid helium temperatures, T_b, from 1.6 K to 4.2 K.

Characteristics of the normal zone propagation are classified into the following three groups depending on the magnetic flux density and the test coil current, I. (Group I) The normal zone is generated only around the heater as soon as the heat input was applied to the wire. After shutting off the heat input, the wire recovers to the superconducting state. (Group II) As shown in Fig. 2(a), the generated normal zone does not shrink even after shutting off the heat input. The normal zone neither spreads nor shrinks, that is, a stationary normal zone is observed. (Group III) As shown in Fig. 2(b), the tap voltages arise one after another. The normal zone continues to spread through each of the taps until a quench protection circuit shuts off the test coil current. Additionally, the wire temperature continues to rise up sharply. It means that the heat transfer on the wire surface shifts to the film boiling.

We define the recovery current I_R as the largest current for which a normal zone will automatically disappear, and the film-boiling current I_F as the smallest current with which the heat transfer on the wire surface in normal state will shift to film boiling regime. Fig. 3 shows the stability test results at T_b = 4.2 K and 2.0 K. I_F for both coils at a certain magnetic field increase greatly by shifting to He II cooling from He I cooling. The difference between I_F of Coil-I and that of Coil-II at 2.0 K is small since the critical heat flux (CHF) on a wire surface in He II hardly depends on the wire surface condition. However, the difference between I_R of Coil-I and that of Coil-II becomes very large. Even if a stationary normal zone occurs, the coil will not quench. However, the wire cannot recover to the superconducting state unless the transport current is lowered to less than I_R. The stationary normal zone will deeply affect the stability of a superconducting coil immersed in He II. The stationary normal zone originates from lower T_c of NbTi at higher magnetic field, and it is observed for larger current area with decreasing the Kapitza Conductance on the wire surface[1,2]. Making the Kapitza conductance as large as possible is important in order to make the effective use of the high CHF of He II and improve the stability of a superconducting coil immersed in He II.

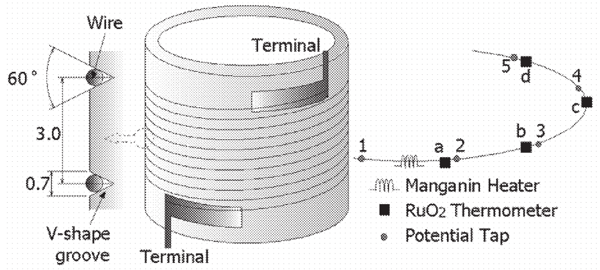

Fig. 1 Schematic illustration of test coil and test part

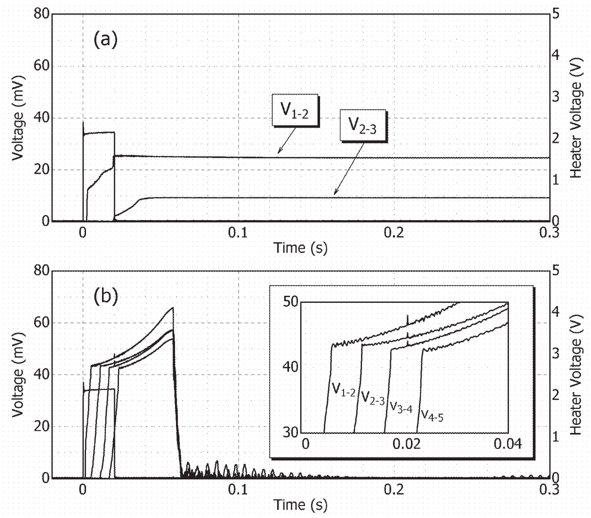

Fig. 2 Typical waveforms of the voltages for Coil-II at T_b = 4.2 K and B = 7.2 T. (a) I = 130 A, (b) I = 152 A

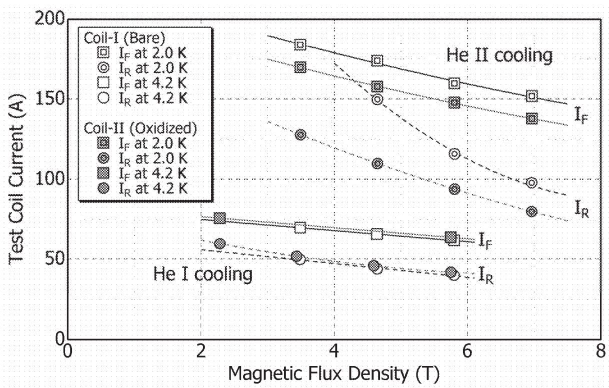

Fig. 3 Stability test results at T_b = 4.2 K and 2.0 K

Reference
1) Ohya, M. et al.: IEEE transactions on Applied Superconductivity **15** (2005) p.1703-1706.
2) Shigemasu, S. et al.: IEEE transactions on Applied Superconductivity **15** (2005) p.1707-1710.