§ 5. Measurement of the Temperature Rise of a Quenching Cable-in-conduit Conductor

Takahata, K.

When we apply a cable-in-conduit conductor (CICC) to large-scale applications such as a fusion reactor, a sudden temperature rise during an unexpected quench must be estimated to assure the safety of the superconducting coil system. In this case, heat transfer from the bundle to the conduit affects the temperature rise because the heat capacity of the conduit is comparable to that of the bundle. In this study, the temperature rises of a short CICC sample have been measured by using liquid nitrogen and investigated the heat transfer behavior.

Table I shows the specifications of the sample conductor. The conductor consists of 486 insulated strands and a 1-mm-thick conduit. Figure 1 shows the schematic experimental setup. The conduit of both ends 0.3 m long was removed from the sample conductor 1.6 m long. The ends were soldered to copper terminals. The terminals were then connected to a 6 kA power supply. Two strands were extracted from the bundle to measure the average temperature in the bundle. We can convert the resistance of the strands to the temperature by using the temperature dependence of resistivity of copper. The temperatures of the conduit were measured by thermocouples. In the experiments, the sample was first submerged into liquid nitrogen. After lifting the sample from the liquid, we applied the current to the sample till the bundle temperature reached 250 K.

Figure 2 shows the temperature rises when the current of 6 kA was applied. The temperature of the conduit increased more slowly than that of the bundle. This indicates that an interface thermal resistance exists between the bundle and conduit. Here an interface thermal conductance is defined as[1]

$$h = q/(T_{bundle} - T_{conduit}) \quad (1)$$

where q is the heat flux, T_{bundle} and $T_{conduit}$ the temperature of the bundle and conduit, respectively. We then analyzed the temperature rises by using a zero-dimensional heat balance equation. The broken lines in Fig. 2 indicate the analyses where $h = 150\ W/(m^2 \cdot K)$. The analyses agree well with the measurements. The estimated values of the conductance were almost constant where the current was decreased down to 2 kA. Another experiment indicated that the temperature rise in an atmosphere of helium were consistent with that in an atmosphere of nitrogen. The results suggest that we can apply a single value of the interface thermal conductance for the estimation of temperature rises of a quenching cable-in-conduit. In practice, the interface thermal conductance of a manufactured conductor must be measured only at room temperature because it may depend on the conductor structure.

Table I Specifications of the cable-in-conduit conductor

Superconducting material	NbTi
Conduit dimension	17.0 mm×22.3 mm
Conduit thickness	1 mm
Strand diameter	0.673 mm
Strand insulation	Formvar, 11.5 μm
Composition (NbTi:Cu:CuNi)	1.0:1.65:0.4
Number of strands	486

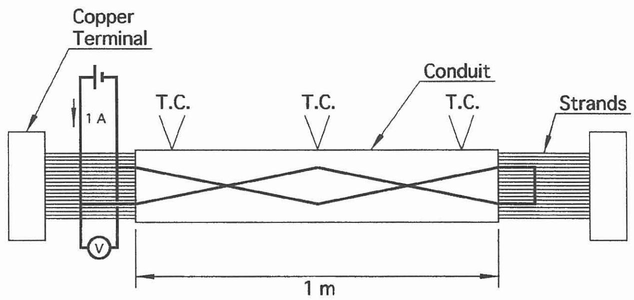

Fig. 1. Schematic experimental setup.

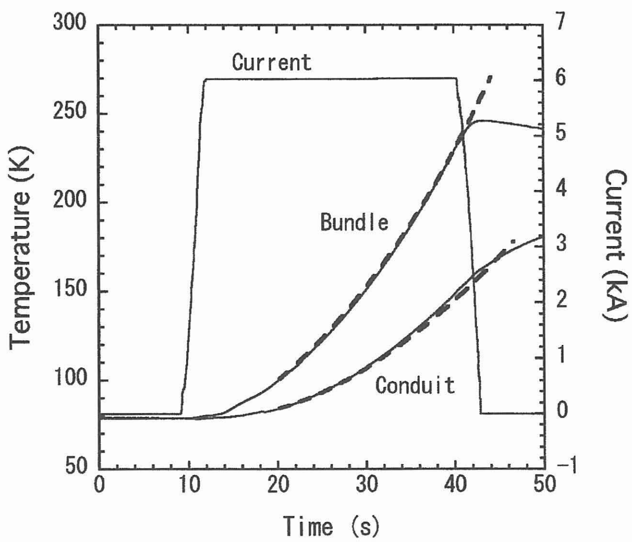

Fig. 2. Temperature rises when the current of 6 kA was applied.

Reference

1) Handbook of Heat Transfer, edited by Warren M. Rohsenow and James P. Hartnett, McGRAW-HILL BOOK COMPANY (1973) p.3-14.