Measurement of Overall Thermal Conductance and Thermal Contact Resistance in No-Insulation ReBCO magnet

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Background

Electrical characteristics of Ni wires are well described with a lumped circuit [2, 7] or distributed circuit model [8-11] with electric contact resistances between turns. Although thermal contact conductance (TCR) has strong influence on thermal stability of Ni wires, its quantitative value is not well known unlike electric resistance. In conduction cooling system, TCR is related with cooling efficiency and temperature distribution inside the coils. When the Ni coil is in a bath of liquid helium, TCR is related with thermal diffusion and quench propagation in the event of quench.

Objectives

- Measurement of overall thermal conductance using a model coil, which have no conduction plates and epoxy layer from 10 to 40 K
- Measurement TCR using the measured overall thermal conductance and published known transversal thermal conductivity of ReBCO
- Application of TCR to a coil with conduction plates and epoxy layers using FEM analysis

Conclusion

- In this study, the overall thermal conductance was measured with a Ni ReBCO coil and it was possible to quantitatively obtain TCR by analyzing experimental results with the previously reported thermal properties of ReBCO wire.
- The resultant TCR was 1.5x10⁻⁴ to 1x10⁻² K m/W depending to the temperature, which is 10 times larger than that from ReBCO wire itself.
- By applying the measured TCR to coil 2, which have conduct plate and epoxy layer to enhance the overall thermal conductance, it was possible to estimate the overall thermal conductance of coil 2 with reasonable accuracy.
- Since TCR may depend on radial stress distribution in the coils of ReBCO wire, more quantitative measurement will be followed under various stress conditions by controlling the winding tension force with various ReBCO wires.

Test coils

- A bare coil and a coil with conduction plates by Ni winding scheme for the measurement of overall thermal conductance and TCR
- Six fine type thermocouples (Au90W10) between winding turns to measure the coil temperature
- Ni-Cu heater wire outside the coil to make temperature gradient inside the coil

Conduction cooling measurement system

- Installation of the test coils on the 2nd stage cold head of a GM cryocooler (Sumitomo, RDK-4110) to be cooled down to measuring temperatures
- Minimization of radiation heat leak from environment by two radiation shields, thermally connected to the 1st and 2nd stage of cold head
- Installation of a cold junction at the 2nd stage of cold head for the precise measurement of the temperature
- Measurement of temperature variations by precise data acquisition system (National instrument, SCXI-1125)

Overall thermal conductance

- Determination of heating power to make 5 K temperature difference
- The heating power of 0.05 to 0.16 W and 0.4 to 1.7 W for coil 1 and 2, respectively
- Removal of offset temperature from thermal voltage of signal wires before heating

Experimental Results

- Definition of overall thermal conductance: $S = \frac{Q}{\Delta T} [W/K]$ where $Q$: applied heating; $\Delta T$: temperature difference (95 turn – 5 turn)

Thermal contact resistance

- Much enhanced the overall thermal conductance of coil 1 by conduction plate and epoxy layer
- Application of TCR for the thermal modeling of coil 2 to get the enhanced overall thermal conductance by FEM (Finite Element Method)

Application of thermal contact resistance

- Using the measured TCR, it was possible to predict overall thermal conductance of coil 2 in an accuracy within 20 %

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