§15. Evaluation of Effects of Hall Currents on the Thermal Conductivity in a Composite Conductor of Aluminum and Copper

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Increase of resistivity of composite conductors made from aluminum and copper in the magnetic field is experimentally confirmed, and its theoretical explanation is also developed[1), 2)]. The increase of resistivity is cased by the opposite direction electric field which is induced by interaction between the external magnetic field and the Hall current that is induced by the difference of Hall voltage in the two material. The additional loss caused by the electric field is equal to the Joule heating of the Hall current. The influence of Hall current on the thermal conductivity, however, is not clearly understood. Since the influence of electric field on the thermal properties is small, it is considered that the decrease of the thermal conductivity caused by the Hall current is as small as the thermoelectric effect. The purpose of this research is to quantitatively examine the influence of Hall current in a composite conductor on the thermal conductivity for more precise analysis of the propagation of a normal-zone in the LHD helical coil conductor.

A schematic design of a testing sample is shown in Fig. 1. A copper clad aluminum wire with a diameter of 2.09 mm is prepared. The ratio of cross-sectional area of aluminum is 77%. The wire is helically wound in one of double thread grooves on a plastic pipe, turned back at the bottom end, and wound back in the rest groove. The wire is covered with an outer concentric plastic pipe for preventing the movement by the electromagnetic force. The assembly is installed in a vacuum chamber for thermal insulation, and the terminals of the wire are connected to a pair of current leads, the upper parts of which are immersed with liquid helium. The wire is heated by its own joule heating in the external magnetic field. Since the wire is cooled with thermal conduction to the current leads, the bottom of the wire is the hot end. Au-Fe chromel thermocouples are used to measure the temperature gradient in the wire. The thermal conductivity of the wire can be estimated from its temperature gradient and the heating power. We plan to estimate the effect of Hall current by holding the heating power with the current control in deferent external fields. The increase of resistivity of the aluminum is given by

$$\Delta\rho = \frac{\pi}{4}\frac{\left(R_{Al}B\right)^2}{R_{HC}} \tag{1}$$

where R_{Al}, B, R_{HC} are the Hall coefficient of aluminum, external magnetic field, and resistance of Hall current circuit in the wire cross-section, respectively. Since the effect of magnetic field on the thermal conductivity of aluminum itself is small, the effect of Hall current on it can be estimated from the dependence of temperature gradient to the external field.

1) Eckels, P. W. et al.: Cryogenics, 29 (1989) 748-752.
2) Kaneko, H. et al.: Cryogenics, 32 (1992) 1114-1120.

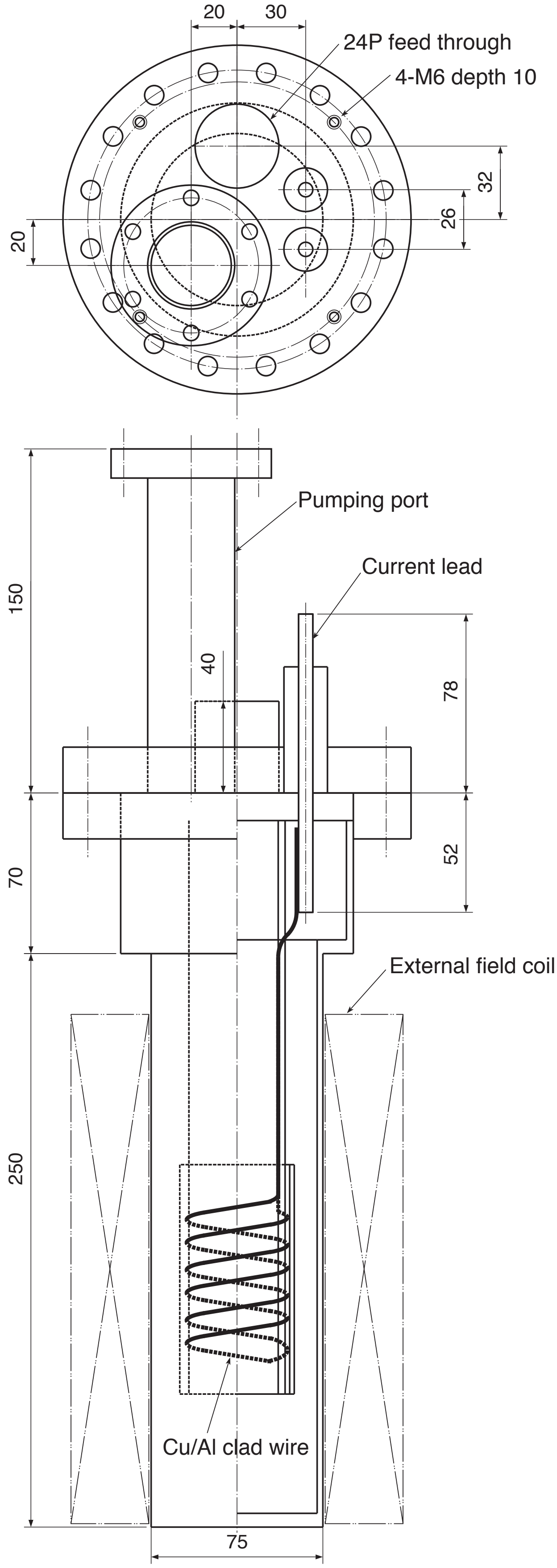

Fig. 1. Schematic drawing of a testing sample. A copper clad aluminum wire is wound on a plastic tube that is inserted in a vacuum chamber.