§21. Dependence of Film Boiling Heat Transfer Coefficient on Surface Orientation

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Heat transfer to liquid helium has been studied for the stability analysis of pool boiling superconducting magnets. Some applications, for example, the Large Helical Device (LHD) in the National Institute for Fusion Science (NIFS), etc, their conductors were wound with angular variation because of their complicated configurations. Heat transfer performance from a conductor surface is important to realize a stable superconducting magnet.[1] To date, the surface orientation dependence of liquid helium (LHe) heat transfer has been studied.[2-4] Small discrepancy exists among the measurements because of variations of their experimental conditions. We have also studied the dependence of LHe heat transfer on surface orientation for LHD construction.[5,6] Useful information for the stability analysis of helical coils was provided. However there were discrepancy between our measurement and others, too. In this study, it is confirmed whether our experimental results follow the equation based on two-phase boundary layer treatment of free convection film boiling.[7]

For heat transfer measurements in LHe under atmospheric pressure, a polished copper surface was employed. Its details were described in reference 6, and therefore, just a brief explanation on the experiment is done in this paper. Fig. 1 shows the sample with the mechanism changing the surface orientation to simulate the angular variation of a superconductor. The heat transfer surface was 18 mm in width and 76 mm in length. It was covered by a Glass Fiber Reinforced Plastic (GFRP) holder except for the heat transfer surface. The surface temperature was measured by AuFe-Chromel thermocouples attached in a 1 mm depth from the surface. The orientation was varied from a horizontal (upward), 0º via vertical, 90º to downward, 180º surface.

Film boiling heat transfer coefficient was discussed based on two-phase boundary layer treatment.[8] Heat transfer coefficient, $h(\theta)$ was proposed to express the equation [7]:

$$h(\theta) = h(90^\circ)\sin^{1/4}\theta\,. \qquad (1)$$

Our experimental data of $h(\theta)$ with the temperature difference of 1.5 K are compared to those by the equation as shown in Fig. 2 and are consistent with the theory. As described in reference 8, around the angle close to the horizontal surface, experimental results do not follow the equation.

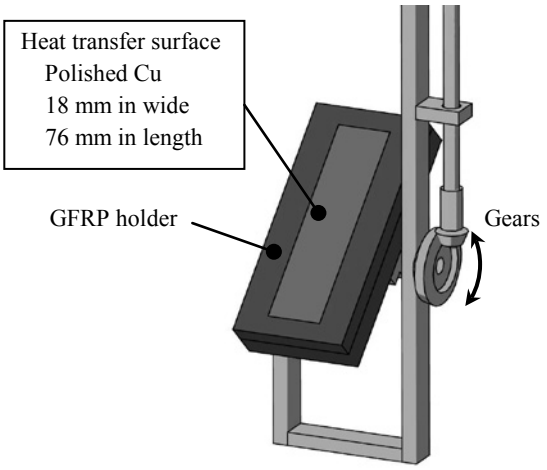

Fig. 1. Sample with the mechanism changing the surface orientation.

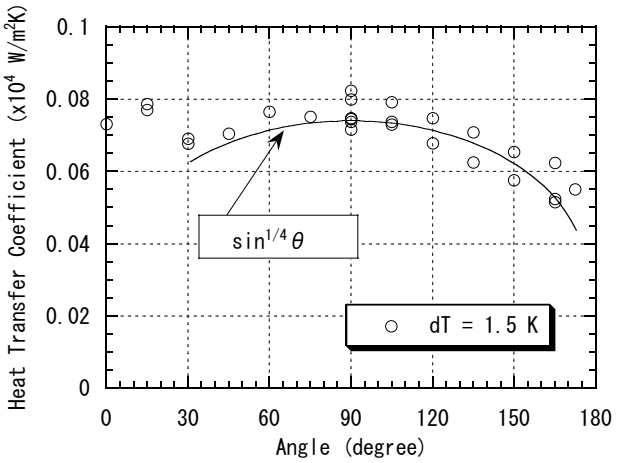

Fig. 2. Dependence of film boiling heat transfer coefficient on surface orientation.

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