§63. A Model for the CHF of One-wall Heated Rectangular He II Channel

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The critical heat flux at which normal-fluid appears at the center of a heated surface distributed along the inner wall of a rectangular He II channel was studied by Kobayashi et al. [1]. They reported that the CHFs became smaller than the values calculated from the theory of Gorter-Mellink heat conduction with the increase in the ratio of channel gap d to the channel length L. However the mechanism of the reduction has not been clarified until now.

On the other hand, the authors[2] presented the following CHF correlation for a flat plate of width, w, and length, L, in He II by modifying their theoretical CHF correlation for a cylinder[3] based on the Gorter-Mellink equations

$$q_{cr,fp} = 0.58\left[\frac{2}{Lw/\{2(L+w)\}}\int_{T_B}^{T_\lambda}\frac{1}{f(T)}dT\right]^{\frac{1}{3}} \tag{1}$$

They reported that their data were well expressed by the equation.

Figure 1 shows the rectangular He II channel considered here. Both ends of the channel are opened in large He II pool with the bulk liquid temperature of T_B at atmospheric pressure. The channel has a heated wall of width w and length L and has a gap d. Let the liquid temperature at both ends of the channel $(x = L/2)$ averaged over the cross sectional area, T_i, be somewhat higher than the bulk liquid temperature, T_B. Then, the heat flux q_i^* [w/m²] averaged over the cross sectional area at $x = L/2$ can be evaluated by the following equation based on the same heat transfer equation from a flat plate to He II as used to derive Eq. (1)

$$q_i^* = 0.58\left[\frac{2}{dw/\{2(d+w)\}}\int_{T_B}^{T_i}\frac{1}{f(T)}dT\right]^{\frac{1}{3}} \tag{2}$$

Considering that the critical heat flux on the heated wall is determined by the condition that the liquid adjacent to the heated wall at $x = 0$ reaches the λ temperature, the following CHF equation is obtained from Gorter-Mellink and heat balance equations,

$$q_{cr} = 4dL^{-4/3}\left[\int_{T_i}^{T_\lambda}\{1/f(t)\}dT\right]^{1/3} = (2d/L)q_i^* \tag{3}$$

By the iterative calculation to obtain the value of T_i that satisfies Eqs. (2) and (3), the critical heat fluxes for the corresponding conditions are obtained.

Figure 2 shows the CHF data by Kobayashi et al.[1] for the short test channel of $w = L = 8$ mm versus bulk liquid temperature with the channel gap d as a parameter. The CHF values predicted by the present model are shown as a solid curve for each channel gap. The predicted CHF values agree with the data. within 10 % difference. Broken lines on the figure show the values predicted by the model of Kobayashi et al. with the boundary condition that the liquid temperature at both ends of the channel equals to the bulk liquid temperature. As reported by them, the CHFs became smaller than the predicted values with the increase in the ratio of channel gap d to the channel length L, although the CHFs for narrow channels with small d/L values almost agreed with the predicted ones.

Figure 3 shows the values of T_i calculated from Eqs. (2) and (3) for the channel with $w = L = 8$ mm and d =0.5 and 2 mm. The straight line in the figure shows the relation of $T_i = T_B$ supposed by Kobatyashi et al.. As seen from the figure, this supposition almost holds for the bulk liquid temperature higher than 2 K. However, the value of T_i becomes higher than T_B with the decrease in T_B from the value, and this trend is more significant for a larger channel gap.

References

1) H. Kobayashi et al., Advances in Cryogenic Engineering, (1996) 41, 281-287.
2) M. Shiotsu et al., Cryogenic Engineering Conference, July 28-August 1, 1997, Portland, Oregon, Paper No. BE-1, 1997.
3) M. Shiotsu, et al., Advances in Cryogenic Engineering, (1992) 37A, 37-46.

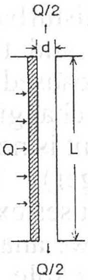

Fig.1 Schematic of a rectangular channel in He II.

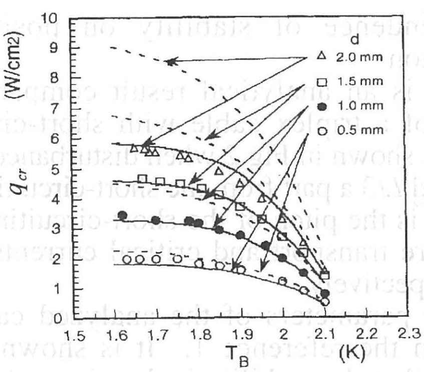

Fig.2 Critical heat flux versus bulk liquid temperature with channel gap as a parameter.

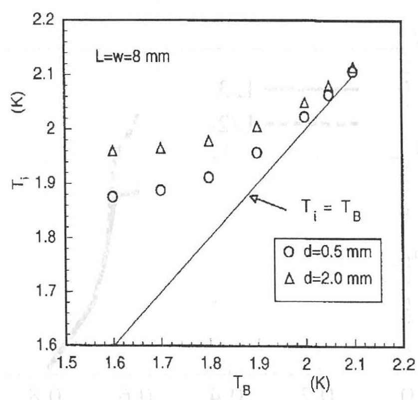

Fig.3 Channel entrance liquid temperature at CHF versus bulk liquid temperature.