A Mechanistic Modeling for the Critical Heat Flux of Subcooled Flow Boiling

管内強制流動サブクール沸騰限界熱流束の機構論的モデリング

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March, 2000

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ABSTRACT

The critical heat flux (CHF) mechanism is considered tightly connected to the flow pattern. According to the most often-encountered subcooled boiling flow pattern (the first kind of flow pattern), a new mechanistic CHF model is developed for vertical subcooled flow boiling. The model is based on the liquid sublayer dryout mechanism. The model is simple with explicit physics meaning, and is characterized by the absence of empirical constant. The model is tested over a very large data bank, showing a general good accuracy.

The model is compared to the Celata model in the prediction ability for the CHF and important parameters (U_B, L_B, D_B, δ). Although the prediction approaches of the two models differ greatly, it is interesting to see that the important parameters are predicted with no big difference existing. The parametric trends of the CHF are summarized and interpreted in the paper from the model theory viewpoint. The CHF is an increasing function of the coolant subcooling and mass flux. The influence of the pressure on the CHF turns out to be negligible. The effect of the inner diameter is to decrease the CHF as it increases. The ratio of the tube length to inner diameter L/D is ascertained to be an independent characteristic parameter on the CHF. The effect of L/D is to decrease the CHF when L/D increases, showing a threshold inside which the L/D effect is very significant while beyond which the influence of L/D is small.

Although originally developed for peripheral uniform heating, straight tube condition with water used as coolant, the model also shows good adaptation to non-uniform, twist tape insert and non-water system (liquid nitrogen and refrigerant 113). The model is also adapted successfully to the both emergences of the twist tape and peripheral non-uniform heating conditions.

The model is found showing a tendency of over-prediction at low L/D condition, especially at high-pressure condition. The possible reasons are analyzed. Besides, the model also shows a phenomenon that under some extreme conditions, such as at extremely high pressure or extremely high mass flux, sometimes the final calculated q doesn't equal to the assumed q_m even after the assumed q_m has converged to a point. Although the CHF under such circumstance can be predicted quite well by doing a little modification to the calculation of the vapor blanket equivalent diameter D_B, the true reason is analyzed due to the change of the flow pattern (The first kind of flow pattern is replaced by the second kind of flow pattern) near the CHF, which consequently causes the change of the CHF triggering mechanism. A criterion is developed for the determination of the flow pattern near the CHF and further, the CHF triggering mechanism for the second kind of flow pattern is discussed.

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