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Evolution of flow patterns and the associated heat and mass transfer characteristics during flow boiling in mini-/micro-channels

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Abstract

A three-dimensional numerical investigation of flow boiling in mini-/micro-channels is carried out using a coupled Volume of Fluid (VOF)/Level-set (LS) method (CLSVOF) in the present study. A phase change model based on the interfacial temperature gradient is implemented and the numerical approach is first validated by the experimental and numerical results in the literature. A fabricated cavity in lieu of the traditional methods of seed bubble or local superheat is treated as the nucleation site, where boiling occurs exclusively and periodic stream of single bubble emerges. The transitions of flow patterns from bubbly flow to slug flow and annual flow are observed, and the numerical wall temperatures agree with the experimental results. The growth rates of the radial diameter and axial length of vapor bubble are compared with the experimental data, and good agreement is found for the radial diameter while deviation is found for the axial length due to early coalescence of bubbles near the nucleation site. Meanwhile, the local heat transfer coefficients are found to be significantly influenced by the flow patterns. The variations of the local vapor qualities at five representative locations along the flow direction are also studied quantitatively and the fluctuations are found to be consistent with the local flow patterns. Finally, we present a numerical attempt on flow boiling with two nucleation sites, which shows a good potential of the present numerical approach to deal with the complicated flow boiling process. The information presented here is very useful to the design and operation of the mini-/micro-reactors.

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