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Stabilization of flow boiling in a micro tube with air injection

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ABSTRACT

Air injection as a stabilization method is evaluated for flow boiling in a micro tube. Pyrex glass tube coated by ITO film is employed as a test tube for flow visualization with water as a working fluid. Air bubble and liquid slug lengths are controlled by changing air and liquid mass velocities. Wall temperatures and inlet/outlet pressures show very large fluctuations during flow boiling without air injection. Severe reverse flow is also observed from flow visualization. On the other hand, wall temperature and inlet/outlet pressures as well as visualized flow patterns become very stable with air injection. In addition, much higher heat transfer coefficients are obtained for air injected cases. It is observed from the flow visualization that the flow becomes much stable and shows regular patterns.

1. Introduction

Flow boiling in micro channels attracts great attention as an effective method to effectively transfer heat [3]. Independence on gravity and high volume density are also notable advantages of micro tube heat transfer. Due to these advantages, flow boiling in micro channels has been investigated extensively in the past few years [2,21,11,18]. However, it is reported that large pressure and temperature fluctuations occurred without a valve or orifice. [5,19]. These instabilities caused by severe reverse flow makes it difficult to adopt micro channel boiling in real systems. In order to take full advantage of micro channel boiling, stable flow pattern should be obtained.

Hetsroni et al. [9] investigated flow boiling of water in parallel micro channels. It was observed that rapid bubble growth pushed the vapor–liquid interface toward both upstream and downstream. It was attributed to the sudden expansion of vapor bubble after nucleation. The flow pattern observed through visualization was different from normal annular flows with intermitted liquid slugs. It was described as explosive boiling with periodic wetting and dryout. Heat transfer coefficient showed strong dependence on vapor quality.

Huh et al. [10] conducted flow boiling experiments in a single micro channel with a hydraulic diameter of $D_h = 103.5$ μm. Both pressure and temperature showed long period and large amplitude fluctuations. The periodic flow pattern transition between bubbly/slug and elongated slug/semi-annular flows completely corresponded to the fluctuations in pressure and temperature. It was reported that the flow pattern transition instability is the reason for the periodic fluctuations. As the heat flux and vapor quality increased, both frequency and amplitude of the fluctuations also increased.

Wang and Cheng [16] conducted flow boiling instability experiments in a single micro channel with a hydraulic diameter of $D_h = 155$ μm. The cycles of pressure and temperature oscillations were longer than 100 s. Exit quality was introduced as the evaluation parameter for stable and unstable flow boiling. Critical value of exit quality was set to $x_e = 0.013$. At $x_e > 0.013$, flow became unstable and different flow patterns, e.g., bubbly flow, elongated bubbly/slug flow, semi-annular flow and annular/mist flow were observed at the outlet.

Several stabilization methods have been proposed for flow boiling in micro channels. Kandlikar et al. [12] evaluated two stabilization methods, i.e., pressure drop element and artificial nucleation sites. Six parallel channels with an average dimension of 1054×197 μm were used as a test conduit. In their experiments, flow instability was evaluated from pressure drop and pressure fluctuation. Test results were compared with the case without pressure drop element and artificial nucleation sites. Combination of pressure drop elements and artificial nucleation sites was recommended for the stabilization of flow boiling in micro channels.

Bergles and Kandlikar [4] suggested that installing the inlet orifices could stabilize both upstream compressible volume instability and excursive instability. Individual inlet orifices are demonstrated to work well in multi-channels [1,17]. Wang et al. [17] investigated pressure and temperature fluctuations in

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