Bubble Departure Diameter and Bubble Release Frequency Measurement from TAMU Subcooled Flow Boiling Experiment

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ABSTRACT

The bubble departure diameter and bubble release frequency were obtained through the analysis of TAMU subcooled flow boiling experimental data. The numerous images of bubbles at departure were analyzed for each experimental condition to achieve the reliable statistics of the measured bubble parameters. The results are provided in this report with simple discussion.
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1. INTRODUCTION

The TAMU subcooled flow boiling experimental data was analyzed for the purpose of achieving information for the bubble departure diameter and bubble release frequency. The boiling bubble images taken under 16 different subcooled flow boiling conditions were analyzed and the results are provided in this report. Since the bubble release frequency was already reported through the previous documents [1, 2], the following discussion is focused on the bubble departure diameter.

2. TEST BOUNDARY CONDITIONS AND RESULTS

2.1. TAMU subcooled flow boiling experiment and test conditions

The detailed description of TAMU subcooled flow boiling experiment is given in Yoo et al. [1, 3]. This section describes only the main features of the experiment. The TAMU subcooled flow boiling experiment was performed in a vertical square test channel and a heater wall was placed on one side of the test section to create the boiling (total heated length $L_0=224$ mm, see Figure 1). The working fluid was refrigerant NOVEC 7000 (3M, Inc.). During the whole process of experiment only a single active nucleation site was maintained to facilitate the observation of boiling bubbles through visualization. Three high speed cameras and one infrared (IR) camera were used as shown in Figure 1 to observe the bubble characteristics and associated wall heat transfer, respectively. The experiment was performed at 16 different test conditions, and bubbles were typically observed to slide along the heated surface after departing from a single nucleation site within these conditions.
2.2. Results and discussion

The main issue of measuring the bubble departure diameter from the TAMU subcooled flow boiling experiment is that it is difficult to define the exact moment of bubble departure at the nucleation site. This is mainly because the boiling bubbles interacted vigorously at the nucleation site and the bubbles typically showed bouncing motion (i.e., detaching from the wall and reattaching to the wall) before they left the nucleation site through sliding. The effect of bouncing motion on the bubble growth behavior is shown as bouncing peak in Figure 2 (the axial location of sliding bubbles is represented as L/L₀; L is the relative axial location within the total heated length L₀). In order to overcome the difficulties of measuring the bubble size at departure, we measured the bubble diameter at the moment when the bubbles began to slide and considered it as bubble departure diameter (the bubble release frequency was measured similarly [1]).

The test boundary conditions and measured values of bubble release frequency (fₜ₈₀) and bubble departure diameter (Dₚ) are summarized in Table 1. About 300–500 departure bubbles were analyzed to obtain the average diameter at departure and bubble release frequency. The uncertainty of the bubble size measurement was estimated ±17.5 μm [3].

The experimental results for the bubble departure diameter were compared with the model predictions. The results are shown in Figure 3. A total of four models were used for this comparison: Unal [4], Basu et al. [5], Prodanovic et al. [6], and Thorncroft [7]. The static angle, which was not measured from the experiment but required as model input, was taken as 45° or 20° while applying Basu et al. [5] and
Thorncroft et al. [7]’s model. The model predictions with Basu et al. [5] and Thorncroft et al. [7] showed good agreement with the experimental data while the model predictions with Unal [4] and Prodanovic et al. [6] significantly underestimated the measurements. It is considered that the discrepancy mainly arises from the empiricism in the model predictions. Also, the performance of the individual component models used in the force balance model of Thorncroft et al. [7] (e.g., bubble growth model, drag force model) needs more investigation.

Figure 2. A typical growth behavior of sliding bubble after departure from a single nucleation site in TAMU subcooled flow boiling experiment
Table 1. Test boundary conditions and measured bubble parameters

<table>
<thead>
<tr>
<th>Exp. No.</th>
<th>$G$ (kg/m$^2$s)</th>
<th>$q_w$ (kW/m$^2$)</th>
<th>$\Delta T_{sub,in}$ (K)</th>
<th>$Ja^a$</th>
<th>$f_{s0,b}$ [Hz]</th>
<th>$D_d$ [mm]</th>
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$^a$ Jacob number at the elevation of nucleation site (estimated based on the average wall temperature measured at $L/L_0 \approx 0.41$)

$^b$ Bubble release frequency from a single nucleation site

Figure 3. Comparison of measured bubble departure diameter with model predictions
REFERENCES


