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Experiments to Understand Bubble Dynamics and Associated Heat Transfer for a Single Bubble During Nucleate Flow Boiling on a Steel Surface

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Extended Abstract

With the increasing demand for high heat flux applications, nucleate boiling has garnered significant attention in recent years due to its exceptional heat transfer efficiency. This phase-change process, where a liquid transitions into vapor upon heating, is especially valued in industrial and engineering applications for its ability to efficiently manage high heat flux [1]. Among the various boiling regimes, flow boiling has emerged as a key method for managing high heat flux in various applications, as it combines the high heat transfer rates of nucleate boiling, primarily through microlayer evaporation, with the enhanced convective heat transfer provided by fluid flow [2]. The bubble dynamics in nucleate boiling are strongly governed by the properties of the fluid, surface wettability and the wall superheat [3–5]. To comprehensively analyze boiling behavior, the simultaneous measurement of bubble dynamics, bulk temperature, and surface temperature is crucial. While numerous studies have been conducted on the simultaneous measurement of bubble dynamics and surface temperature under pool boiling using various techniques on different substrate [6,7]. However, such detailed studies under flow boiling conditions are relatively scarce in the literature. Addressing this gap, the present study conducted flow boiling experiments in a vertically oriented channel with varying heating conditions, flow rates, and subcooling levels. This study examines the intricate relationship between bubble dynamics, surface temperature, and heat transfer rates.

A steel foil was used as the heater surface, with an artificial nucleation site created using indentation to generate a single nucleation site. Bubble dynamics and the whole-field temperature around the bubble were mapped using rainbow schlieren deflectometry (RSD) from the side view, while the surface temperature beneath the vapor bubble was measured using an infrared (IR) camera in tandem. The captured data were then analyzed and discussed based on various bubble dynamic parameters such as bubble diameter and base diameter, along with their impact on surface temperature, evaporative heat flux, and heat transfer coefficient. The results revealed that, similar to microlayer dynamics, the heater surface temperature and heat flux distribution follow a similar asymmetric pattern. It was found that the maximum heat flux transferred to the vapor bubble during the initial stages via microlayer evaporation exceeded 2 MW/m² for the range of experimental conditions employed.

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