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On the effects of thermocapillary driven oscillations on bubble growth during boiling of FC-72 on a thin wire

G.R. Duursma [a,*], F. Jiang [a,b], K. Sefiane [a], S. Duff [a], H. Beji [c]

[a] University of Edinburgh, Mayfield Road, Edinburgh EH9 3JL, UK
[b] Tianjin University, Tianjin 300072, PR China
[c] Département Génie Civil, Université Picardie Jules Verne, Amiens, France

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ABSTRACT

Despite being a familiar and well-studied topic, the physical nature of boiling is still not well understood. There is a complex coupling of mass, momentum and energy transport that occurs between the solid surface, the wetting liquid and the vapour produced to generate bubbles. Our work investigated pool boiling of FC-72, a highly-wetting dielectric liquid, on a submerged electrically-heated platinum wire. The bulk fluid temperatures ranged from ambient to saturation allowing a range of subcooled and saturated boiling scenarios to be investigated. The boiling chamber could be pressurised and boiling of FC-72 was studied for pressures from 1–3 bar. High-speed digital video was used to record boiling phenomena and these were subsequently analysed. Thermocapillary convection was clearly visible and more noticeable as the degree of subcooling increased. Once vapour bubbles were initialised at a nucleation site, their growth and detachment frequency were recorded. Frequency was correlated with degree of subcooling and a power-law dependence established. After detachment, not all bubbles immediately rose to the surface. There was bubble slippage along the wire, driven by the distortions in the local temperature field. Slippage was also influenced by the presence of adjacent nucleation sites and bubbles (which themselves also influenced the local temperature field). The observed thermocapillary "tails" of the bubbles were affected by bubble motion. The slip velocity was plotted for the case of pure translational motion and also for periodic motion between nucleation sites. Oscillating bubbles are found to grow faster than stationary bubbles. This is attributed to the contribution of the superheated layer, which was measured and discussed. A form of the law for the growth of oscillating bubbles was proposed. Horizontal coalescence of two bubbles drawn towards each other is also presented and analysed.

1. Introduction

Despite being a fundamental process as well as being at the heart of various applications, boiling heat transfer and its underlying mechanisms remain elusive, Lin and Sefiane [6]. Indeed, the physical mechanisms of boiling remain incompletely understood. With the necessity for high heat fluxes in microsystems heat transfer, the need to understand boiling (especially on a small scale) is evident and many questions about fundamental boiling mechanism need to be answered. Kim [5] alluded to the debate about mechanisms controlling vapour bubble growth and discussed three possible models: (i) transient conduction through a superheated fluid layer, (ii) evaporation of a wedge-shaped microlayer at the base of a vapour bubble and (iii) contact line heat transfer. He also discussed experiments with flat heat transfer surfaces to assist in model validation and concluded that all models were inconsistent with the experimental data. Hence there is a need for further work here. Unlike large flat heaters, for boiling on a thin wire the lengthscale of bubbles is of the same order of magnitude as the heater. Capillary-related phenomena are important on this lengthscale and have frequently been neglected in previous work on macroscale boiling. Many mechanisms observed during boiling phenomena on small heaters and their contribution to heat transfer remain to be fully quantified. The effects of pressure as well as degree of bulk liquid subcooling on bubble growth rate and frequency are examples of areas where further investigation is needed Hutter et al. [3]. Buffone et al. [2] studied Marangoni instabilities on an evaporating vapour–liquid interface. Other mechanisms like thermocapillary convection, although extensively studied for simple cases in controlled environments (see [11]),

* Corresponding author. Tel.: +44 131 650 4868.
E-mail address: gail.duursma@ed.ac.uk (G.R. Duursma).

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