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Discussion

Discussion: "Dynamics of Bubble Motion and Bubble Top Jet Flows From Moving Vapor Bubbles on Microwires" (Christopher, D. M., Wang, H., and Peng, X., 2005, Journal of Heat Transfer, 127, pp. 1260–1268)

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In the paper [1] the results of experimental investigation and numerical modeling are presented of sliding vapor bubble dynamics through subcooled boiling on microwires. A conclusion is made on the nongravity character of the observed phenomena and the primary role of thermocapillary Marangoni flow. In the following discussion, insufficient relevancy of the model [1] is shown in the context of evaluation of the role of thermocapillarity.

In the view of the further development of boiling heat transfer theory, it is an essentially proper interpretation of experimental data on boiling nongravity dynamical effects [1–6]. Comprehensive multifactorous modeling of subcooled flow boiling [7], among other factors, involves also bubble sliding effects. Another, so-called model of "the theatre of director" [8–10] (leading to universal correlation of developed boiling heat transfer data) is built upon the assumption on the triggering of liquid jets by growing bubbles (pumping effect of growing bubble (PEGB) [11,12]). Besides, just this effect claims to play a leading role in the main part of the fixed-in [1–6] phenomena.

PEGB is linked to the sharp variability of evaporative reactive force applied to a bubble interface during the start of its growth in the zone of the highest temperature gradient [11,12]. Generated in such a way, the pressure gradient covers all liquid boundary layer [13] speeding-up liquid jet flow [12] efficiently contributing in integral heat transfer. To the point, an assumption on the decisive role of the same evaporative reactive force [11,12] forms a basis for the advanced new model of a boiling heat transfer crisis [14].

As distinct to PEGB, Marangoni flow is drived by surface force generated by the gradient of surface tension on an interface with a variable temperature, although both flow schemes are roughly similar.

During boiling of saturated liquid, directly measured and indirectly evaluated jet flow velocities vary in the range 1–5 m/s [2–4,15]. According to a review of experimental data [16], steady-state Marangoni flow around a stationary air bubble varies in the range 0.1–5.0 mm/s. Thereby a sensible contribution of this flow in saturated boiling effects is out of the question, moreso as the temperature field on the vapor bubble interface is strongly smoothed by phase conversion.

Subcooled boiling dynamical effects [1,5,6] (bubble slippage 15–40 mm/s, fluid flows 15–100 mm/s) mainly are observed at the stage of decay of PEGB. At such low velocities the contribution of Marangoni flow in general may be much more tangible. However, interpretation by the model [1] of these dynamical effects evidently contrasts the aforementioned typical values.

There are two potential sources of the overestimation of Marangoni flow velocities by the model [1]: the usage of a very small value of accommodation coefficient (0.03) and considering of steady-state flow.

According to [17], the accommodation coefficient is near unity at the vapor-liquid interface. However, as it is indicated in [1], phase conversion may be affected by noncondensable airs. Nevertheless, the absence of the concrete substantiation of accepted value makes its accuracy questionable. Besides, no consideration is made of the concentration of noncondensables on the condensation side of the bubble interface.

As regards the steady-state approach, it fully excludes the possibility of analysis of the main ("explosive") stage of PEGB. Slippage of a bubble is much calmer but the unsteady-state by its nature phenomenon resulted by a fluid asymmetric unsteady-state temperature field.

The sliding bubble permanently enters new zones and redevelops a fluid velocity field. Besides, parallel to the microwire, the component of fluid flow even changes sign through bubble passage. A corresponding correction may significantly reduce the velocities evaluated by the model [1].

Problems with the adaptation of the Marangoni effect to studied phenomena manifest itself also through an analysis of double-jet flow observed during the same process of subcooled boiling [6].

As thermocapillary Marangoni flow may generate liquid outflow only from the zone of minimum surface temperature, fixed in [6], liquid jets (outgoing from the zone of maximum temperature between a bubble and microwire) may not be linked to thermocapillarity. These jets evidently are speeded-up by volume forces generated under the bottom part of the bubble (as regards division of the jet flow, it may be linked to specific geometry of the system bubble microwire). Accordingly, double-jet flow [6] turns out to be another proof of the basic role of PEGB in nongravity boiling dynamics.

As regards the problem of the full-scale theoretical and experimental investigation of PEGB in general, it still remains pressing with respect to further research of the wide diversity of boiling heat transfer processes.

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