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# Some Unexplored Aspects of Pool and Flow Boiling*

Vijay K. Dhir[1] and Gihun Son[2]

[1]Henry Samueli School of Engineering and Applied Science, UCLA,
Los Angeles, CA 90095, U.S.A.
[2]Deparment of Mechanical Engineering, Sogang University, Seoul, KOREA

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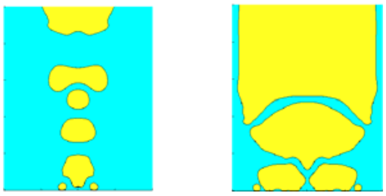
Numerical simulations of the boiling process have been shown in the recent past to be a very effective tool in modeling the process. Because of the complexity of the process involving vapor-liquid interfaces that evolve, merge and break up in time and the microlayer that forms between the solid and the vapor phase near the wall, the past numerical simulations have been limited to pool boiling at relatively low heat fluxes. These studies both for nucleate and film boiling have been limited to pool boiling and have been conducted for flat plate heaters where the radius of curvature of the heater is infinite. In the present work three dimensional transient simulations have been carried out for

(i) nucleate boiling on a flat plate at relatively high heat fluxes
(ii) film boiling on a cylinder at different gravity levels
(iii) single bubble dynamics on a flat plate with flow parallel to the surface.

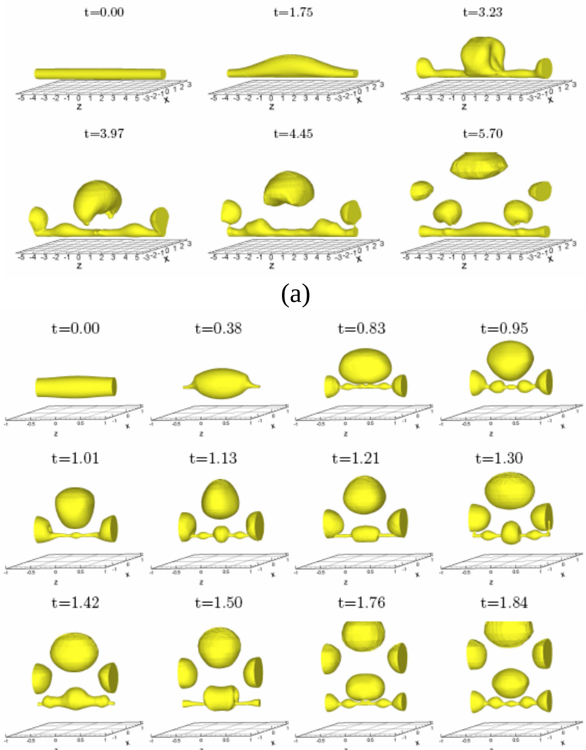
A finite difference method is used to solve the equations governing the conservation of mass, momentum and energy in vapor and liquid phases. A level set approach for tracking the liquid-vapor interface is formulated to include the effects of phase change at the interface and contact angle at the wall. The evaporative heat flux from the thin liquid film that forms underneath a bubble attached to the wall is incorporated in the analysis. The effects of wall superheat, number density of active nucleation sites and waiting period on the bubble dynamics and heat transfer are analyzed. As another application of complete numerical simulation, film boiling on a horizontal cylinder has been investigated numerically. The level set formulation is further extended to treat the no-slip condition at the fluid-solid interface. The effects of cylinder diameter and gravity on the interfacial motion and heat transfer in film boiling are quantified. In flow boiling the interacting effect of magnitude of gravity and flow velocity on bubble departure diameter, lift-off diameter and growth period is investigated.

Figure 1 shows numerical results of bubble dynamics during nucleate boiling at high wall superheats. As the superheat increases, the bubble merger occurs both in the vertical and horizontal directions, which leads to formation of vapor columns and mushroom type bubbles. Figure 2 demonstrates evolution patterns of the liquid-vapor interface during film boiling on a horizontal cylinder. For a small-diameter cylinder (D=1.25mm) discrete vapor bubbles are released only on the top portion of the cylinder. With further decrease in cylinder diameter (D=0.125mm) the bubble merger pattern also appears as part of the vapor removal. This is consistent with visual observations reported in the literature.



(a) (b)

**Figure 1:** Bubble growth patterns during nucleate boiling for different wall superheats: (a) 13°C and (b) 20°C




(a)

(b)

**Figure 2:** Evolution of the liquid-vapor interface during film boiling on a horizontal cylinder: (a) D=1.25mm and (b) D=0.125mm

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