Growth and Dynamics of Vapor Bubbles in Various Regimes of Boiling with and without External Electric Field

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Abstract

In the present investigation, we performed coupled level set volume of fluid (CLSVOF) based direct numerical simulations to predict the liquid-vapor instability, bubble generation, bubble growth and its departure during pool boiling. As a part of the process of bubble growth, the dynamical disturbances destabilize the liquid-vapor interface. The wavy interface culminates into vapor bubbles, which grow and finally buoy away. The instability mode transforms from Rayleigh-Taylor at the low wall-superheat temperature to Taylor-Helmholtz at the higher superheat values, altering the separation distances between the sites of bubble generation.

The discrete bubbles are observed at the lower range of superheat values while continuous vapor columns emanate in the cases of high superheat values. The detachment of the bubbles and the ebullition cycles follow a regular periodic pattern (in space and time).

Application of external electric field results in destabilizing the interface entailing the enhancement of the bubble growth rate. It is observed that the application of the electric field, normal to the heating surface, results in increase of both spatial and temporal frequency of bubble-formation along the heated surface. The dominant wavelength of disturbance decreases which in its turn decreases the separation-distance between the adjacent bubbles.

Thermal buoyancy is one of the pertinent parameters influencing the growth-dynamics of the vapor bubbles. The changes in the gravity-level result in a significant variation in boiling characteristics. Analyses have been performed at different levels of gravity to understand the changes in bubble morphology and heat-transfer rate.

The application of an external electric field compensates for the reduction in the heat transfer rate brought about by the condition of reduced gravity. During the initial stage of bubble growth, the interfaces exhibit self-similar profiles, i.e. the bubble interface at different instants of time can be converged on a single profile defined by a fitting function in which the variables are normalized using proper scaling parameters.

In the case of nucleate boiling, the bubble generation is not an interface-instability driven phenomenon but a random process which depends on the heat flux from the surface and the surface-properties. In this study, the growth rate is found to be affected by the surface-superheat, the wettability of the surface and the degree of subcooling of the ambient liquid.