NASA TECH BRIEF

Dynamics of Moving Bubbles in Single and Binary Component Systems

The dynamics of a single bubble moving in a quiescent liquid is analyzed for single and binary component systems. The analysis is made for the region in which the bubble dynamics is controlled by the transport of energy and/or mass, subject to thermodynamic phase-equilibrium at the bubble interface.

The dynamics of moving bubble in a single-component system is investigated initially. The interfacial temperature remains constant with time for this case. With the application of the boundary layer simplification and approximating the velocity field around the bubble as a uniform flow, two asymptotic solutions of the bubble dynamics for small and large times are obtained by means of the coordinate perturbation method. The bubble behavior during small times is dominated by diffusion and/or radial convection while at large times it is controlled by diffusion and axial convection. In the analysis, the temperature distribution in the liquid around the bubble is obtained as a function of dimensionless parameters and universal functions. Then the total heat flux over the entire bubble surface is evaluated and related to the interfacial energy balance condition. The resulting equation is integrated to yield the bubble growth or collapse rate. The solutions for small and large times may be joined successfully at an intermediate time. It is disclosed that the dimensionless parameter $\gamma = (\sqrt{2K}\ Pe^{1/2})/Ja$ governs the bubble dynamics, where K is a constant, Pe is the Peclet number, and Ja is the Jakob number. The results agree very well with experiments.

For binary component systems, both injection cooling and boiling are treated. The method employed is the extension of that used for the single-component system. Both the interfacial temperature and concentration vary with time.

The dynamics of a moving bubble in injection cooling is governed by the parameters γ and $\beta = Ja/\sqrt{Lu'}$ where Lu' is the Lukomskiy number for gaseous phase.

The dynamics in boiling binary component is a function of the parameters γ, $\beta_1 = Ja/\sqrt{Lu}\ \rho'/\rho\ \alpha_0 - \alpha_1/\alpha_0$ and $\beta_1 = Ja/\sqrt{Lu}\ \rho'/\rho\ X'_\infty - X_\infty/\alpha_0$ in which α_0 and α_1 are the temperature gradients of the phase-equilibrium curves, Lu is the Lukomskiy number for liquid phase, ρ and ρ' are the liquid and gaseous densities respectively, and $X'_\infty - X_\infty$ is the relative volatility. The analytical results for the injection cooling case agree well with experiments.

Note:

Inquiries concerning this analysis may be directed to:

Technology Utilization Officer
Marshall Space Flight Center
Huntsville, Alabama 35812
Reference: B68-10339

Patent status:

No patent action is contemplated by NASA.

Source: Naoyuki Tokuda, Wen Jei Yang,
John A. Clark, and Herman Merte, Jr.
of University of Michigan
under contract to
Marshall Space Flight Center
(MFS-14845)

Category 02