Module 8: Boiling

Lecture 35: Detachment of Vapor Bubbles

The Lecture Contains:

Bubble Departure Diameter and Bubble Release Frequency

In principle, one could use the expressions developed in the previous sections with respect to bubble growth rate and forces that act on the bubble to obtain bubble diameter at departure. However, in a real boiling system such an approach meets with little success.

Some of the reasons for this are:

1. Cavities of different sizes and shapes exist on the surface. Waiting times between cavities may differ significantly.

2. Because of the differences in waiting times, thickness of thermal layers may differ from cavity to cavity. This is true, however, only as long as sufficient distance exists between cavities.

3. Evaporation from liquid film (micro/macro layer) underneath a bubble can contribute significantly to bubble growth. This process has not been included in the bubble growth model described earlier.

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4. Because of the development of flow field and interaction between neighboring sites, thermal layers around bubbles may be distorted.

5. Merger of bubbles at neighboring sites can alter the bubble shape and size and thereby significantly influence the bubble departure diameters and frequency

As such, several correlations have been suggested in the literature for bubble diameter at departure and bubble release frequency. Based on bubble departure diameters observed with several liquids, Rohsenow **(1985) has given a correlation of the type:**

For water

$$D_d\sqrt{\frac{g(\rho_l-\rho_v)}{\sigma}} = 1.5\times 10^{-4} Ja^{*5/4} \qquad \textbf{(8.97)}$$

For other liquids

$$D_d\sqrt{\frac{g(\rho_l-\rho_v)}{\sigma}} = 4.65\times 10^{-4} Ja^{*5/4} \qquad \textbf{(8.98)}$$

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where

$$J_{a^*} = \frac{\rho_l c_{pl} T_{sat}}{\rho_v h_{fg}} \qquad (8.99)$$

As opposed to Fritz's correlation, the correlation of Rohsenow includes the Jakob number based on the saturation temperature of the liquid but does not account for the effect of the contact angle. Since the bubble release frequency is influenced by the bubble diameter at departure (i.e.larger bubbles taking longer to grow), generally correlations combining bubble departure diameter and frequency have been reported in the literature. General form of such correlations is

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$$f D_d^n \equiv C \qquad (8.100)$$

where C is a constant.

Values of n between **1/2 and 3** have been suggested. **Jakob (1949)** suggested a value of unity, while **Ivey (1967)** suggested that **n = 2** when bubble growth is dynamically controlled and **1/2** when it is thermally controlled. For dynamically controlled bubble **growth Cole (1967)** has suggested the constant **C** to be.

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$$C = \frac{4g(\rho_l - \rho_v)}{3\rho_l} \qquad (8.101)$$

Zuber on the other hand assumed that bubble growth rate was proportional to terminal bubble rise velocity and that waiting time was much smaller than the growth time.Under these assumptions he obtained that exponent n should have a value of unity and the constant **C** should be **.**

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$$C = 0.59\left[\frac{\sigma g(\rho_l - \rho_v)}{\rho_v^2}\right]^{1/4} \qquad (8.102)$$

In the above equation, **the factor 0.59** was obtained by matching the predictions with the data. More recently**,** **Malenkov (1971)** has suggested a correlation of the type **.**

$$fD_d = \frac{V_d}{\pi\left[1 - \frac{1}{1+(V_d\ \rho_v\ h_{fg})/q}\right]} \qquad (8.103)$$

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where,

$$V_d = \left[\frac{gD_d(\rho_l - \rho_v)}{2(\rho_l + \rho_v)} + \frac{2\sigma}{D_d(\rho_l + \rho_v)}\right]^{1/2} \qquad \textbf{(8.104)}$$

For bubbles with large diameter at departure.

$$V_d \sim D_d^{1/2} \qquad \textbf{(8.105)}$$

whereas for small bubbles.

$$V_d \sim D_d^{-1/2} \qquad \textbf{(8.106)}$$

Thus for bubbles with thermally controlled growth rates, **Malenkov's expression reduces to a form similar to that of Ivey**

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