ME-446 Liquid-Gas Interfacial Heat and Mass Transfer

Homework 7 - Solution

Problem 1: Rohsenow's correlation

A Matlab code is uploaded separately. CoolProp was used to obtain the thermophysical properties of saturated water. The boiling curve obtained with Rohsenow's correlation is shown below.

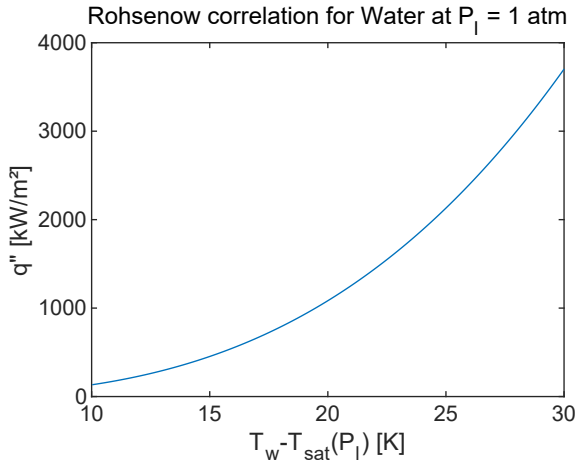

Figure 1: Boiling curve for water with $P_l = 1atm$.

Problem 2: Bubble departure

Consider the vertical force balance, the buoyancy force is

$$F_b = \Delta\rho V_B g$$

where, V_B is the volume of the bubble expressed as a function of r, the radius of the bubble:

$$V_B = \frac{\pi}{3} r^3 (2 + \cos\theta)(1 - \cos\theta)^2$$

The surface tension force is

$$F_s = \pi D_{cl} \sigma \sin\theta$$

where the contact line can be expressed as:

$$D_{cl} = 2r \sin\theta = 2 \left(\frac{3V_B}{\pi(2 + \cos\theta)(1 - \cos\theta)^2} \right)^{\frac{1}{3}} \sin\theta$$

The force balance requires $F_s = F_B$

$$\Delta\rho V_B g = 2 \left(\frac{3V_B}{\pi(2 + \cos\theta)(1 - \cos\theta)^2} \right)^{\frac{1}{3}} \sin^2\theta \pi\sigma$$

Therefore

$$V_B = \sqrt{24}\pi \left(\frac{\sigma}{\Delta\rho g} \right)^{\frac{3}{2}} \sin^3\theta (2 + \cos\theta)^{-\frac{1}{2}} (1 - \cos\theta)^{-1}$$

Problem 3: Transient conduction in a semi-infinite solid

A) The solution for the semi-infinite solid transient conduction for a sudden temperature T_f at the surface is (Eq. 5.50 in Lienhart):

$$\theta = \text{erf}\left(\frac{\zeta}{2}\right)$$

where θ is the nondimensional temperature,

$$\theta = \frac{T(x,t) - T_f}{T_i - T_f}$$

and ζ is the second similarity variable used to solve the heat equation

$$\zeta = \frac{x}{\sqrt{\alpha t}}$$

The timescale τ of the thermal response at L_c is:

$$\tau = \frac{L_c^2}{4\alpha}$$

B) When the solid surface is suddenly exposed to a fluid of temperature T_f and a convective heat transfer coefficient h, the solution of the transient conduction is (Eq. 5.53 in Lienhart):

$$\theta = \text{erf}\left(\frac{\zeta}{2}\right) + \exp(\beta\zeta + \beta^2)\left[\text{erfc}\left(\frac{\zeta}{2} + \beta\right)\right]$$

where a new similarity variable β is needed to solve the heat equation

$$\beta = \frac{h\sqrt{\alpha t}}{k}$$

in this case we have two timescale

$$\tau_1 = \frac{L_c^2}{4\alpha}$$

and

$$\tau_2 = \frac{k^2}{h^2\alpha}$$

In the case of a bubble growing at the surface ($L_c = 0$) the characteristic timescale of the rewetting induced convection is given by τ_2.