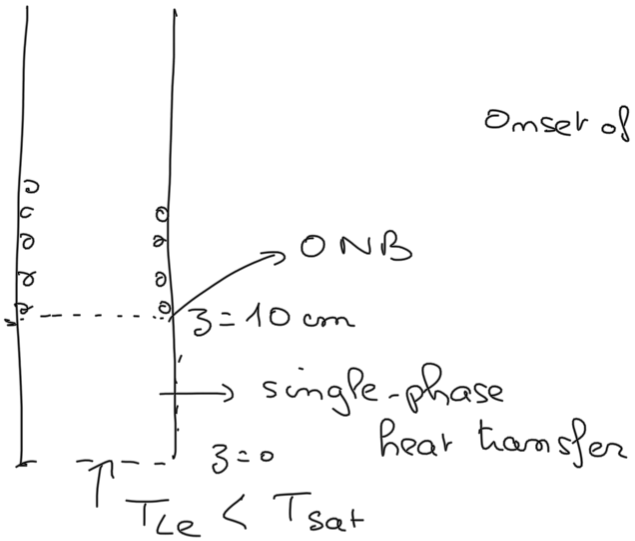
Exercice 1



$T_p = 281\,°C$

ONB if $T_p - T_{sat} > \left[\frac{8\sigma T_{sat} q_{ONB}}{\lambda_L \rho_v h_{LV}} \right]^{1/2} \frac{1}{P_{r_L}}$

Onset of Nucleate Boiling

$$q_{ONB} < \frac{\lambda_L \rho_v h_{LV}}{8\sigma T_{sat}} \left[P_r (T_p - T_{sat}) \right]^2$$

In single-phase liquide flow

$q_p = h (T_p - T_L(3))$

$Nu = \frac{hD}{\lambda_L} = 0.023\, Re^{0.8} P_r^{1/3}$

$\pi D q_p = \pi D h (T_p - T_L(3)) = \underbrace{GA}_{\dot{m}} C_p \frac{dT_L}{dz}$

$q_{ONB} = 4.3\ MW/m^2$

$\frac{dT_L}{T_p - T_L} = \frac{h \pi D}{G A C_p} dz = \frac{4h}{DGC_p} dz$

$A = \frac{\pi D^2}{4}$

$\frac{dT_L}{T_p - T_L} = \frac{4h}{DGC_p} dz \rightarrow \frac{T_p - T_L}{T_p - T_{Le}} = e^{-\frac{4hz}{DGC_p}}$

$q_p = h(T_p - T_L) = h (T_p - T_{Le}) e^{-\frac{4hz}{DGC_p}}$

$q_p(z = 0.1m) = q_{ONB} \rightarrow T_p - T_{Le} = \frac{q_{ONB}}{h e^{-\frac{4hz}{DGC_p}}}$

$Re_L = \frac{GD}{\mu_L} = 907258$

$Nu = 1282$

$h = 74\,464\ W/m^2/K$

$T_p - T_{Le} = 61,64\,°C$

$T_{Le} = 219,36\,°C$

$T_{sat} - T_{Le} = 277 - 219.36 = 57,64°C$

Exercice 2

Ethanol → $50°C = T_L$ $\quad T_{sat} = 100°C \quad T_p = 140°C$

$T_L = T_L(3)$

$q = q_m + q_l = H(T_p - T_L)$

q_m ↙ boiling ; q_l ↘ convection in the liquid

$$q_m = \mu_L h_{LV} \left[\frac{g(\rho_L-\rho_V)}{\sigma}\right]^{1/2} Pr^{-5} \left[\frac{C_p(T_p-T_{sat})}{0.013\, h_{LV}}\right]^3 = 16\,957 \text{ w/m}^2$$

$q_e = H_e (T_p - T_L)$ $\qquad Nu = \frac{H_L D}{\lambda_L} = 0.023\, Re^{0.8}\, Pr^{1/3}$

$H_L = 1693 \text{ w/m}^2\text{/K}$ $\qquad Re = \frac{GD}{\mu_L} = 22\,930$

$$H = \frac{q_m + q_e}{T_p - T_L} = H_L + \frac{q_m}{T_p - T_L} = 2034 \text{ w/m}^2\text{K}$$

H_L → 1693 $\qquad$ $\frac{q_m}{T_p-T_L}$ → ≈ 300 (↑ of 20% due to boiling).

To calculate the evolution of liquid temperature $T_L(3)$

$$G C_p \frac{dT_L(3)}{dz} = \frac{4 q_p}{D} = \frac{4}{D}\left(q_m + H_L(T_p - T_L)\right)$$

$$\frac{dT_L}{\frac{q_m}{H_L} + T_p - T_L} = \frac{4 H_L}{DGC_p} dz \Rightarrow \frac{q_m}{H_L} + T_p - T_L = \left(\frac{q_m}{H_L} + T_p - T_{Le}\right) \times e^{-\frac{4 H_L z}{DGC}}$$

$T_L(3) = 90°C$ for $z = 1.85 m$

Exercice 3 = Comparison of the correlations of Kandlikar and Gunger and Winterton

Nitrogen $\qquad x = 0.2 \qquad x = 0.6$

Gunger and Winkenton

$$H = H_L \left[1 + 3000\, Bo^{0.86} + \left(\frac{x}{1-x}\right)^{3/4} \left(\frac{\rho_L}{\rho_g}\right)^{0.41}\right]$$

$Bo = \frac{q}{G h_{LV}} = 6.17.10^{-4}$ $\qquad H_L = 0.023 \frac{\lambda_L}{D} \left(\frac{G(1-x)D}{\mu_L}\right)^{0.8} Pr^{1/3}$

For $x = 0.2$ $\qquad H_L = 742 \text{ w/m}^2\text{/K}$

$H_{GW} = 5528 \text{ w/m}^2\text{/K}$

For $x = 0.6$ $\qquad H_L = 425 \text{ w/m}^2\text{/K}$

$H_{GW} = 4666 \text{ w/m}^2\text{/K}$

Kandlikar

$$H = H_L \left[C_1\, Co^{C_2} + C_3\, Bo^{C_4}\, F_K\right] \qquad F_K = 4.70$$

$x = 0.2$

$C_0 = \left(\frac{1-x}{x}\right)^{0.8} \sqrt{\frac{\rho_g}{\rho_l}} = 0.652 > 0.65 \rightarrow$ nucleate boiling regime

$C_1 = 0.6683$

$C_2 = -0.2$

$C_3 = 1058$

$C_4 = 0.7$

$H_K = 21360 \ W/m^2/K$

$x = 0.6$

$C_0 = 0.155 < 0.65 \rightarrow$ convective boiling regime

$C_1 = 1.1360$

$C_2 = -0.9$

$C_3 = 667.2$

$C_4 = 0.7$

$H_K(0.6) = 10125 \ W/m^2/K$