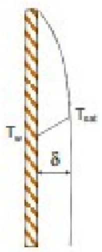
Topic - Nusselt’s theory of condensation,

Nusselt Analysis - Assumptions

- Laminar condensate film
- Gravitational and viscous forces only
- Heat transfer by conduction through the film
- Thermodynamic equilibrium at the interface
- Uniform -
  - Physical properties
  - Wall temperature

Nusselt Analysis - I



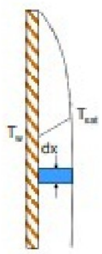
From film analysis

$$\dot{V} = \frac{(\rho_l - \rho_g) g \delta^3 W}{3\eta}$$

We define the mass flow rate per unit width as

$$\Gamma = \frac{\dot{V}\rho_l}{W} = \frac{\rho_l(\rho_l - \rho_g) g \delta^3}{3\eta}$$

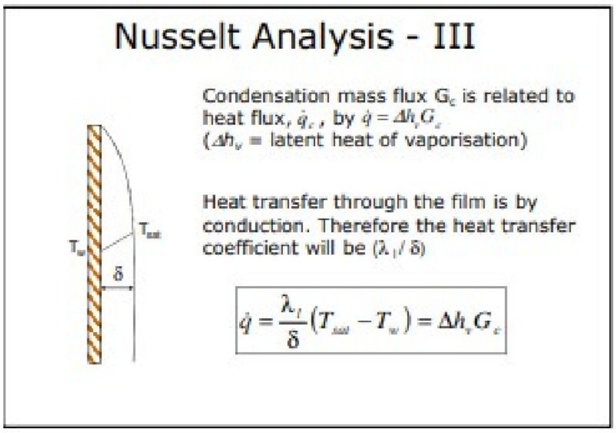
Nusselt Analysis - II

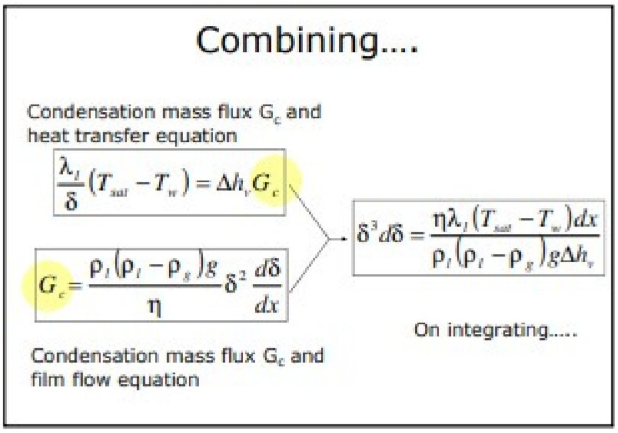


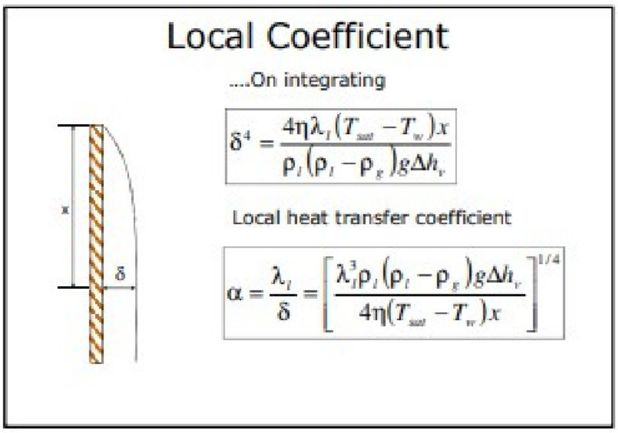
Liquid film flowrate, G, increases with distance, x. If G_c is condensation mass flux then from mass balance $G_c = d\Gamma / dx$

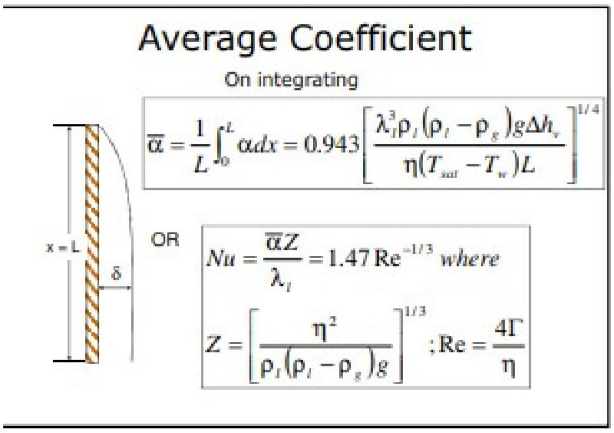
As $$\Gamma = \frac{\rho_l(\rho_l - \rho_g) g \delta^3}{3\eta}$$

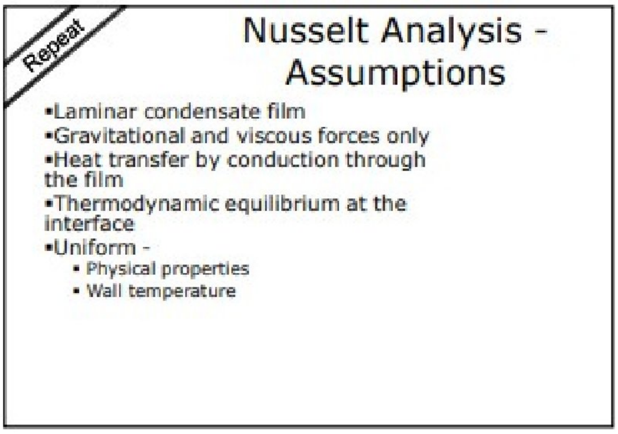
$$G_c = \frac{d\Gamma}{dx} = \frac{\rho_l(\rho_l - \rho_g) g}{3\eta} 3\delta^2 \frac{d\delta}{dx}$$


Nusselt Analysis - III
Condensation mass flux G_c is related to heat flux, $\dot{q}_c$, by $\dot{q} = \Delta h_v G_c$
(Δh_v = latent heat of vaporisation)
Heat transfer through the film is by conduction. Therefore the heat transfer coefficient will be (λ_l / δ)
T_w
T_{sat}
δ
$\dot{q} = \frac{\lambda_l}{\delta}(T_{sat} - T_w) = \Delta h_v G_c$


Combining....
Condensation mass flux G_c and heat transfer equation
$\frac{\lambda_l}{\delta}(T_{sat} - T_w) = \Delta h_v G_c$
$G_c = \frac{\rho_l(\rho_l - \rho_g)g}{\eta}\delta^2\frac{d\delta}{dx}$
Condensation mass flux G_c and film flow equation
$\delta^3 d\delta = \frac{\eta\lambda_l(T_{sat} - T_w)dx}{\rho_l(\rho_l - \rho_g)g\Delta h_v}$
On integrating.....


Local Coefficient
....On integrating
$\delta^4 = \frac{4\eta\lambda_l(T_{sat} - T_w)x}{\rho_l(\rho_l - \rho_g)g\Delta h_v}$
Local heat transfer coefficient
$\alpha = \frac{\lambda_l}{\delta} = \left[\frac{\lambda_l^3\rho_l(\rho_l - \rho_g)g\Delta h_v}{4\eta(T_{sat} - T_w)x}\right]^{1/4}$
x
δ


Average Coefficient
On integrating
$\overline{\alpha} = \frac{1}{L}\int_0^L \alpha dx = 0.943\left[\frac{\lambda_l^3 \rho_l(\rho_l - \rho_g) g \Delta h_v}{\eta(T_{sat} - T_w)L}\right]^{1/4}$
x = L
δ
OR
$Nu = \frac{\overline{\alpha} Z}{\lambda_l} = 1.47\,\mathrm{Re}^{-1/3}$ where
$Z = \left[\frac{\eta^2}{\rho_l(\rho_l - \rho_g)g}\right]^{1/3}$; $\mathrm{Re} = \frac{4\Gamma}{\eta}$


Repeat
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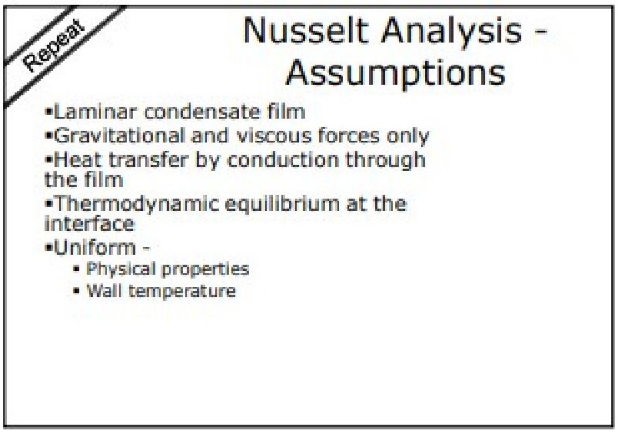
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References:

1. Kothandaraman C.P "Fundamentals of Heat and Mass Transfer" New Age International, New Delhi,4th Edition 2012 (Unit I, II, III, IV, V).
2. Frank P. Incropera and David P. DeWitt, "Fundamentals of Heat and Mass Transfer", John Wiley and Sons, New Jersey,6th Edition1998(Unit I,II,III,IV, V)
3. MIT open courseware – https://ocw.mit.edu/courses/mechanical-engineering

Other web sources