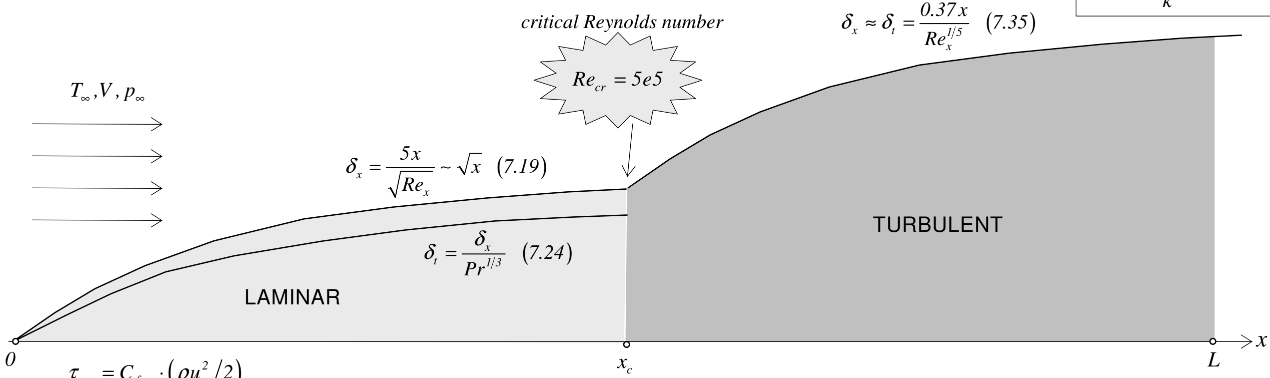
$$Re_x = \frac{V \cdot x}{\nu}$$

7.1-2 FLAT PLATE IN PARALLEL FLOW

$$Nu_x = \frac{h \cdot x}{k} \qquad h = \frac{k \cdot Nu_x}{x} \qquad Pr = \frac{\nu}{\alpha}$$

$$\overline{Nu}_L = \frac{\overline{h} \cdot L}{k} \qquad \overline{h} = \frac{k \cdot \overline{Nu}_L}{L} \qquad Pe = Re \cdot Pr$$



$$\tau_{s,x} = C_{f,x} \cdot \left(\rho u_\infty^2 / 2\right)$$

(7.20) $C_{f,x} = 0.664\, Re_x^{-1/2}$ (7.29) $\overline{C_{f,L}} = 1.328\, Re_L^{-1/2}$

$$x_c = (5e5) \cdot \frac{\nu}{V}$$

(7.34) $C_{f,x} = 0.0592\, Re_x^{-1/5}$ for $Re_x < 10^7$

all properties at film temperature

$$T_f = \frac{T_s + T_\infty}{2}$$

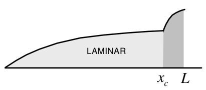
@ 1atm : $\rho,\ c_p,\ \mu,\ k,\ Pr$

@ given pressure:

$$\nu = \nu_{@\,1atm} \cdot \frac{1.013e5}{p_\infty, [Pa]}$$

$$\alpha = \alpha_{@\,1atm} \cdot \frac{1.013e5}{p_\infty, [Pa]}$$

fixed surface temperature $T_s = const$



LAMINAR *most of the flow is laminar* $\frac{L}{x_c} \le 1.05$

(7.23) $Nu_x = 0.332\, Re_x^{\frac{1}{2}}\, Pr^{\frac{1}{3}}$ $Pr \ge 0.6$

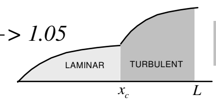
(7.30) $\overline{Nu}_x = 0.664\, Re_x^{\frac{1}{2}}\, Pr^{\frac{1}{3}}$ $Re_x < 5.3e5$ $Pr \ge 0.6$

(7.32) $Nu_x = 0.565\, Pe^{\frac{1}{2}} = 0.565\left(Re_x \cdot Pr\right)^{\frac{1}{2}}$ liquid metals $Pr \le 0.05$ $Pe_x \ge 100$

Churchill-Ozoe

(7.33) $Nu_x = \dfrac{0.3387\, Re_x^{\frac{1}{2}}\, Pr^{\frac{1}{3}}}{\left[1 + \left(0.0468/Pr\right)^{2/3}\right]^{1/4}}$ universal for all Pr $Pe_x \ge 100$

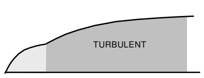
$\overline{Nu}_x = 2 Nu_x$ $\overline{h}_x = 2 h_x$ $Re_x < 5.3e5$



$\frac{L}{x_c} > 1.05$ MIXED LAMINAR / TURBULENT *both parts are important*

(7.38) $\overline{Nu}_L = \left[0.037\, Re_L^{\frac{4}{5}} - 871\right] Pr^{\frac{1}{3}}$ $0.6 < Pr < 60$

(7.40) $\overline{C_{f,L}} = \dfrac{0.074}{Re_L^{1/5}} - \dfrac{1742}{Re_L}$

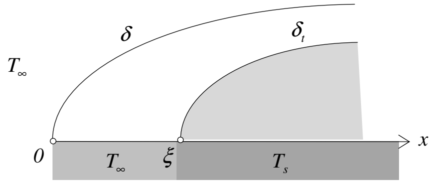


TURBULENT *most of the flow is turbulent* $Re_L > 10^8$

(7.36) $Nu_x = 0.0296\, Re_x^{\frac{4}{5}}\, Pr^{\frac{1}{3}}$ $0.6 < Pr < 60$

(7.38) $\overline{Nu}_L = 0.037\, Re_L^{\frac{4}{5}}\, Pr^{\frac{1}{3}}$

unheated starting length $T_s = T_\infty$ for $x < \xi$



ξ = length of unheated part of the plate

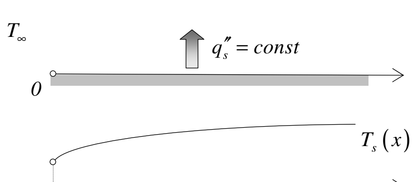
laminar

(7.42) $Nu_x = \dfrac{0.332\, Re_x^{\frac{1}{2}}\, Pr^{\frac{1}{3}}}{\left[1 - \left(\xi/x\right)^{3/4}\right]^{1/3}}$

turbulent

(7.43) $Nu_x = \dfrac{0.0296\, Re_x^{\frac{4}{5}}\, Pr^{\frac{1}{3}}}{\left[1 - \left(\xi/x\right)^{3/4}\right]^{1/3}}$

fixed heat flux $q_s'' = const$



laminar

(7.45) $Nu_x = 0.453\, Re_x^{\frac{1}{2}}\, Pr^{\frac{1}{3}}$ $Pr \ge 0.6$

turbulent

(7.46) $Nu_x = 0.0308\, Re_x^{\frac{4}{5}}\, Pr^{\frac{1}{3}}$ $0.6 < Pr < 60$

(7.47) $T_s(x) = T_\infty + \dfrac{q_s''}{h_x}$

(7.48) $\overline{T_s - T_\infty} = \dfrac{q_s'' L}{k\, \overline{Nu}_L}$ with $\overline{Nu}_L = 0.680\, Re_L^{\frac{1}{2}}\, Pr^{\frac{1}{3}}$ (7.49)

See: Fall 2005, Tyre Bateman, Kevin Price, and William Blattman "Flow Over Flat Plate (Comparison of ANSYS, FLUENT and Theoretical Solution)"