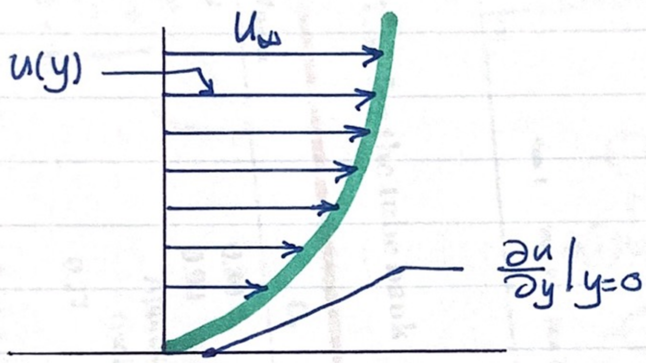
Chapter 7

Flow can be

laminar

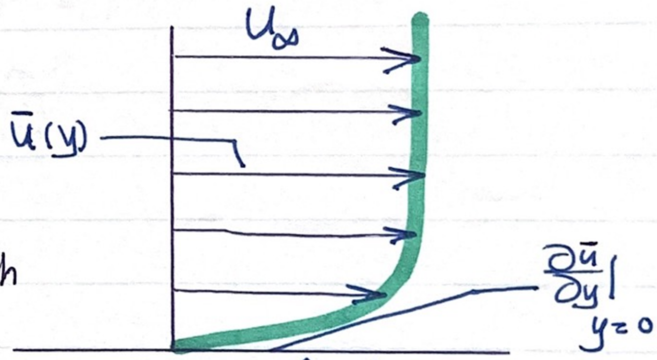
- fluid motion is highly ordered and stream lines are well defined along which particles move



laminar

Turbulent

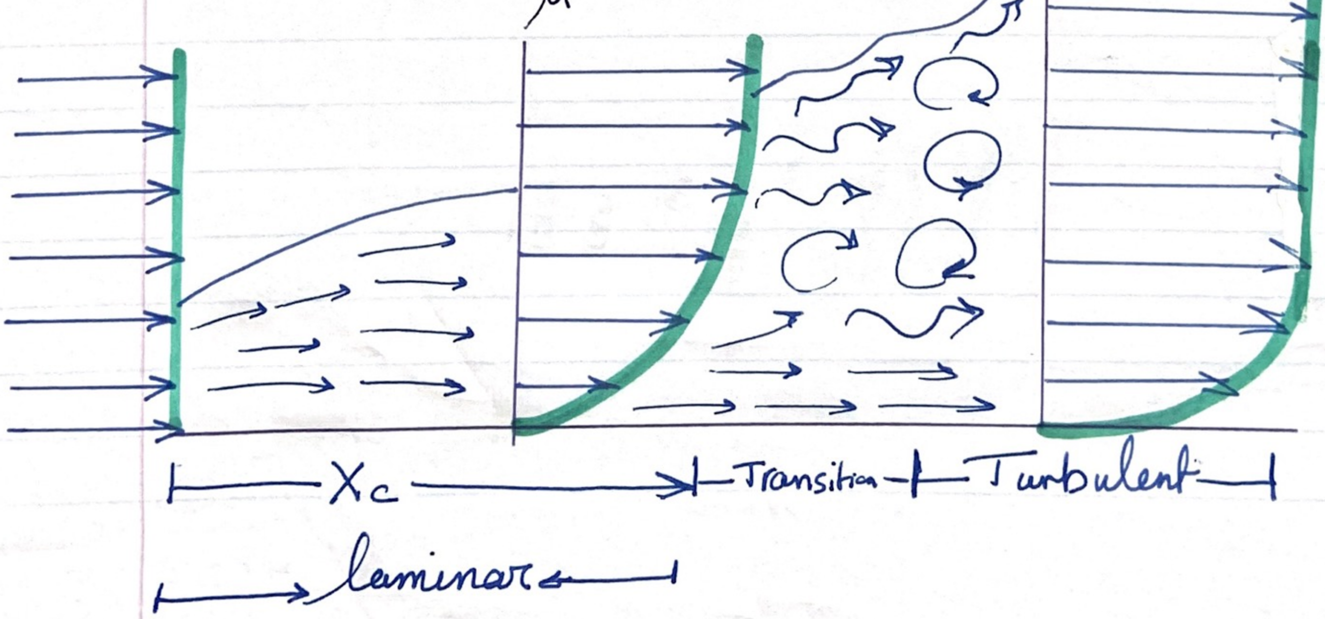
- fluid motion is highly irregular and is characterized by velocity fluctuation. These enhance the transfer of momentum, energy and species.
It increases surface friction and convection heat transfer



Turbulent

Distant at which Transition starts

$$Re_{x_c} = \frac{\rho U_\infty x_c}{\mu} = 5 \times 10^5$$



h_x: local convection coefficient
$\bar{h}$: Average convection coefficient
Don't use All turbulent unless Given

Flow over a flat plate

K: for the fluid flowing not the plate
Properties are found at $T_f = T_s + T_\infty / 2$

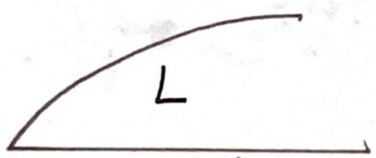
All laminar

Local:

$$h_x = 0.332K\left(\frac{U_\infty}{\upsilon x}\right)^{\frac{1}{2}} Pr^{\frac{1}{3}}$$

Average:

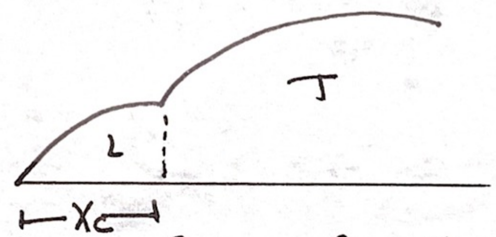
$$\bar{h} = 0.664\, K\left(\frac{U_\infty}{\upsilon x}\right)^{\frac{1}{2}} Pr^{\frac{1}{3}}$$



Mixed flow

Average (for All):

$$\overline{Nu}_L = (0.037 Re_x^{\frac{4}{5}} - 871) Pr^{\frac{1}{3}}$$



Here : $q_{total} = q_L + q_T$

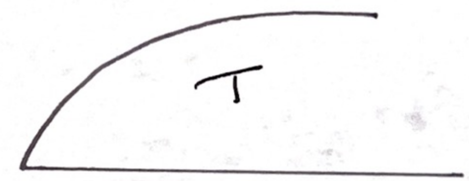
All Turbulent

Local:

$$h_x = (K/X)(0.0296 Re_x^{\frac{4}{5}} Pr^{\frac{1}{3}})$$

Average:

$$\bar{h} = (K/X)(0.037 Re_x^{\frac{4}{5}} Pr^{\frac{1}{3}})$$



Nusselt Number

$$Nu_x = \frac{h_x X}{K}$$

$$Nu_L = \frac{\bar{h} L}{K}$$

Heat Transfer

local: $q_x'' = h_x (T_s - T_\infty)$ ← heat flux

Average: $q = \bar{h} A (T_s - T_\infty)$

Note, to find rate of change of temperature use $-E_{out} = \dot{E}_{st} \sim \rho \delta L^2 c \frac{dT}{dt}$ (or $E_{in} = E_{st}$)

δ: thickness

If Air is used for heat Transfer

$$\upsilon = \upsilon_{atm} \times \frac{P_{atm}}{P_\infty}$$

P_∞: Given

Reynolds

$R_{critical} = 5 \times 10^5$

$$Re_{x_c} = \frac{U_\infty X_c}{\upsilon}$$

Convection over cylinders

- when h is calculated Experimentally and q given

$$\bar{h} = \frac{q}{A_s (T_s - T_\infty)}$$

- $Re_D = \frac{VD}{\nu}$

- Equation we use:-

$$\overline{Nu}_D = \frac{\bar{h} D}{K} = C \, Re_D^{m} (Pr)^{1/3}$$

C, m are obtained from Table 7.2

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

- For non circular correlations

Same equation above But
C, m obtained from Table 7.3
Properties obtained at $T_f = \frac{T_s + T_\infty}{2}$

- IF T_s, T_∞ are different (largly)

use : $\overline{Nu}_D = C Re_D^{m} \, Pr^{n} \left(\frac{Pr}{Pr_s} \right)^{1/4}$

obtained at T_s

flow over a sphere

- Equation we use

$$\overline{Nu}_D = 2 + \left(0.4\, Re_D^{1/2} + 0.06\, Re_D^{2/3}\right) Pr^{0.4} \left(\frac{\mu}{\mu_s}\right)^{1/4} = \frac{D\bar{h}}{K} \text{ for fluid}$$

→ μ_s : at T_s

→ All properties evaluated at T_∞

$$Re = \frac{VD}{\nu}$$

Flow across Banks of Tubes → Heat transfer per unit length

$$\overline{Nu}_D = \frac{\bar{h} D}{K} = C_1 Re_{D,max}^{m} Pr^{0.36} \left(\frac{Pr}{Pr_s}\right)^{1/4} \quad N_L \geq 20$$

يعني عند السرعة الـ maximum

→ N_L : Number of pipe rows

→ Aligned or Staggered: Given

→ C_1, m obtained from C_1, m

→ Properties obtained at mean of T_i, T_o inlet & outlet Tempretures

Aligned

① $V_{max} = \dfrac{S_T}{S_T - D} V$

Staggered

$V_{max} = \dfrac{S_T}{2(S_D - D)} V$

$S_D = \left[S_L^2 + \left(\frac{S_T}{2}\right)^2\right] < \frac{S_T + D}{2}$

if larger use ①

$$q' = N(\bar{h} \pi D \Delta T_{lm})$$

number of Tubes

$\Delta T_{lm} \to \dfrac{T_i + T_o}{2}$

or

$$\Delta T_{lm} = \frac{(T_s - T_i) - (T_s - T_o)}{\ln\left(\frac{T_s - T_i}{T_s - T_o}\right)}$$

- To find T_o :-

$$\frac{T_s - T_o}{T_s - T_i} = e^\wedge\left(-\frac{\pi D N \bar{h}}{\rho V N_T S_T c_p}\right)$$

- Aligned & Staggered are Shown in Tables

$$\overline{Nu}_{D\,(N_L<20)} = \frac{\bar{h} D}{K} = C_2\, \overline{Nu}_D \Big|_{N_L \geq 20} \quad : C_2 \text{ obtained from Table 7.6}$$