INTERNAL FLOW – THERMAL ANALYSIS

LAMINAR  \( Re < 2300 \)

Entire fluid entrance region

**Fully developed hydrodynamics**

Entrance region

\( x_D = D \cdot 0.05 \cdot Re_p \)

\( T_0 = T_{in} \)

**Fully developed thermally**

\( x_D = x_D, x = 10 \cdot D \)

**Thermodynamics:**

**Heat transfer by advection**

\[ q = \int \rho c_p T \, dx \]

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**Energy balance for entire pipe**

\[ \sum q_{conv} = q_{in} - q_{out} \]

\[ q_{conv} = \frac{mc_p}{T_{in}} \]

Mean temperature distribution of fluid in a pipe:

\[ T_u(x) = T_{in} + \frac{q_{conv}}{mc_p} x \]

Initial condition:

\[ T_u(0) = T_{in} \]

**Rate of heat transfer:**

\[ q_{conv} = q_x \cdot (P \cdot L) \]

**Surface temperature:**

\[ T_x = T_u(x) + \frac{q_x}{h_l} = T_u(x) + \frac{T_x - T_u(x)}{h_l} \]

**Heat Transfer Equation for** \( T_u \)

\[ \frac{dT_u}{dx} = \frac{q_x}{mc_p} \]

**Overall Heat Transfer**

\[ \frac{dT_u}{dx} = \frac{U_l (x) P}{mc_p} \]

\[ \frac{dT_u}{dx} = \frac{U_l (x) P}{mc_p} \]

**Circular pipe**

\[ T_u = \frac{1}{U_l (x) P} \]

Overall convective coefficient:

\[ \frac{1}{U_l (x)} = \frac{r_2}{r_1} \frac{r_2}{r_1} \]

\[ T_u \text{ is } \text{ given instead of } T \text{ in } (8.42) \]

replace \( T \) by \( T_v \)

replace \( T \) by \( T_u \)