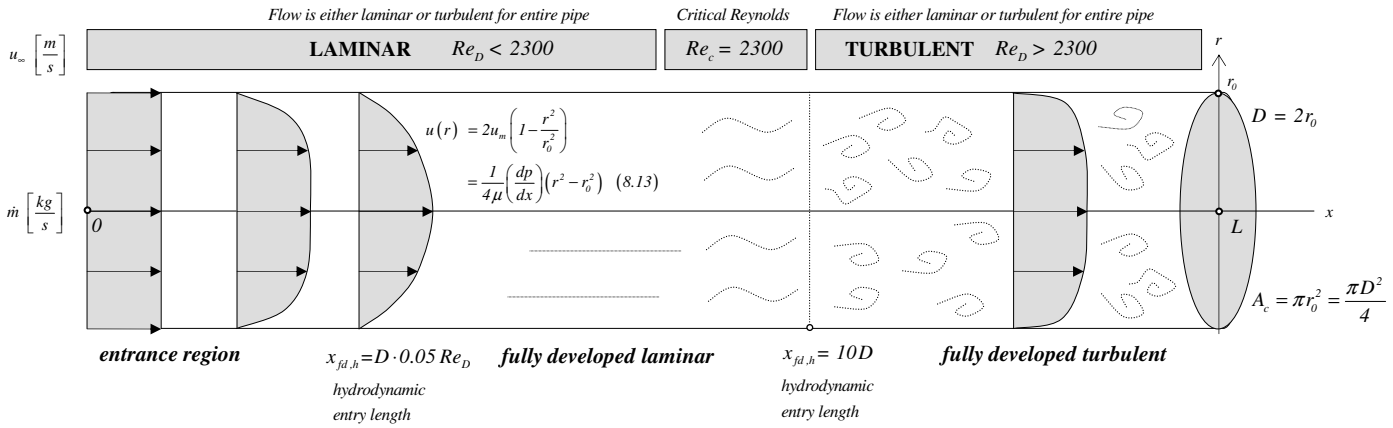
INTERNAL FLOW – HYDRODYNAMICS

circular tube



mass flow rate

$$\dot{m} = \int_{A_c} \rho u(r)\, dA_c = \rho \frac{\int_{A_c} u(r)\, dA_c}{A_c} A_c = \rho u_m A_c = \frac{\rho u_m \pi D^2}{4}$$

mean velocity

$$u_m = \frac{\int_{A_c} u(r)\, dA_c}{A_c} = \frac{\int_{A_c} \rho u(r)\, dA_c}{\rho A_c} = \frac{4\dot{m}}{\pi \rho D^2}$$

$$Re_D = \frac{D u_m}{\nu} = \frac{\rho D u_m}{\mu} = \frac{4\dot{m}}{\mu \pi D}$$

Moody friction factor

$$f = \frac{-\left(\frac{dp}{dx}\right) D}{\rho \frac{u_m^2}{2}}$$

laminar

$$f = \frac{64}{Re_D}$$

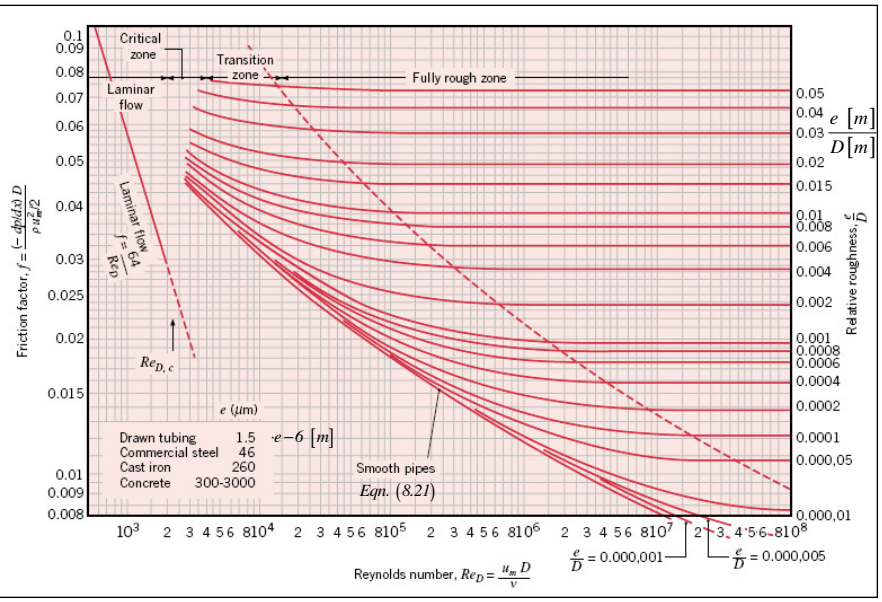
smooth surface turbulent Petukhov (8.21)

$3000 \le Re_D \le 5e6$

$$f = \frac{1}{\left(0.79 \ln Re_D - 1.64\right)^2}$$

friction coefficient

$$C_f = \frac{f}{4} = \frac{\tau_s}{\rho u_m^2 / 2}$$



$$u_m = -\frac{r_0^2}{8\mu}\frac{dp}{dx} \quad (8.14)$$

pressure drop (8.22a)

$$\Delta P = P_2 - P_1 = f \frac{\rho u_m^2 / 2}{D}\left(x_2 - x_1\right)$$

pump power (8.22b)

$$\dot{W} = \left(P_2 - P_1\right)\cdot\frac{\dot{m}}{\rho} = f \frac{\rho u_m^3}{8}\left(x_2 - x_1\right)\pi D \quad [W]$$