Head Loss in Pipe Flow
Major and Minor Losses
ME 322 Lecture Slides, Winter 2007

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Head Loss Correlations (1)

Empirical data on viscous losses in straight sections of pipe are correlated by the dimensionless *Darcy friction factor*

$$f \equiv \frac{\Delta p}{\frac{1}{2}\rho V^2}\frac{D}{L} \tag{1}$$

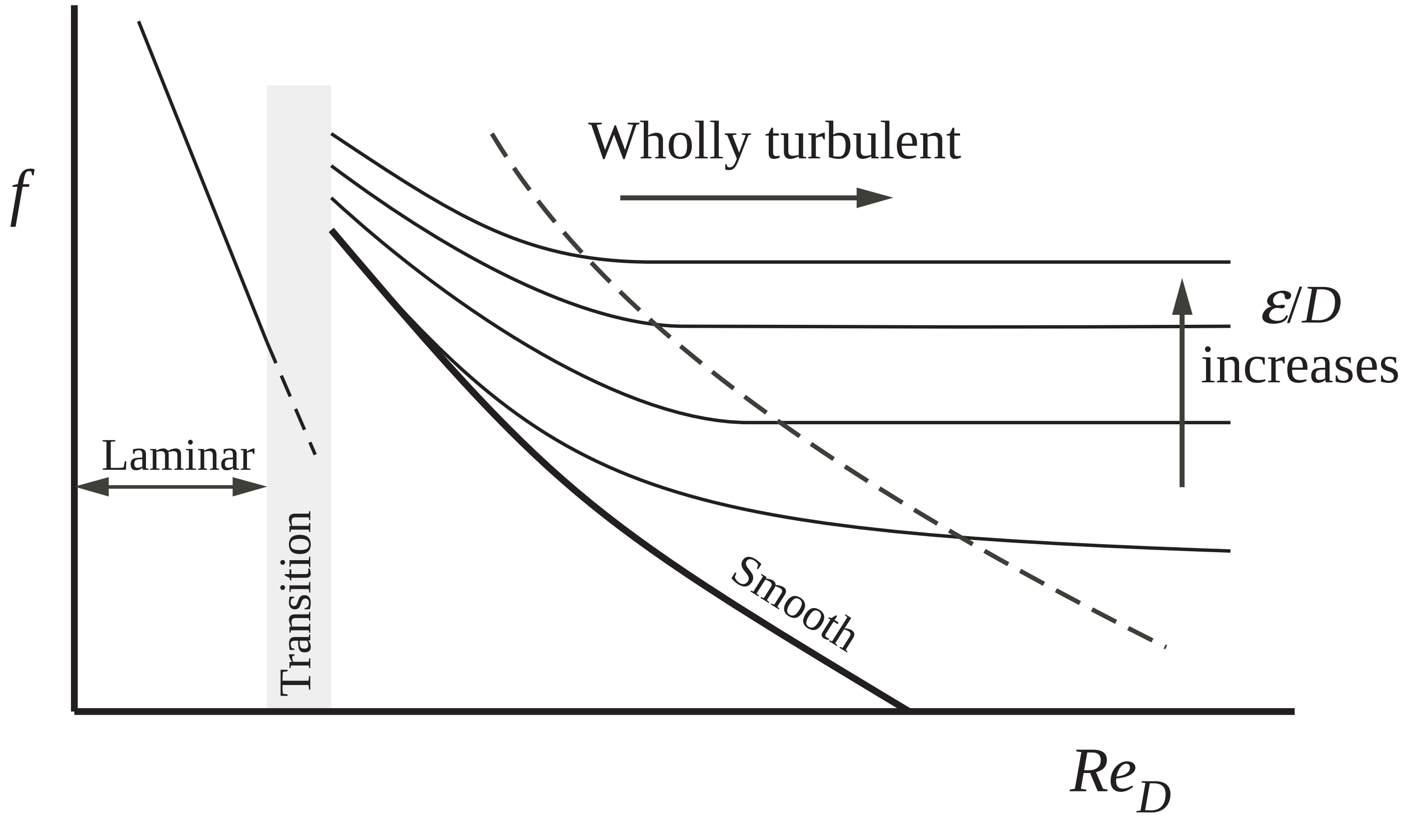
For fully-developed laminar flow in a round pipe

$$\boxed{f_{\mathsf{lam}} = \frac{64}{\mathrm{Re}_D}}$$

For fully-developed turbulent flow in a round pipe

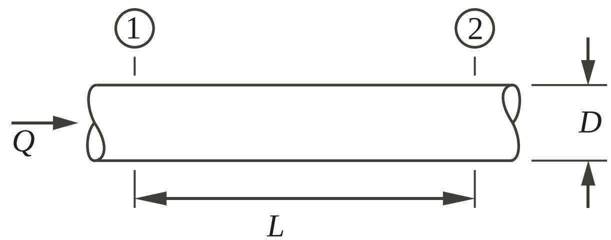
$$\boxed{\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right)} \tag{2}$$

Moody Diagram



Head Loss in a Horizontal Pipe (1)

Consider fully-developed flow (laminar or turbulent) in a horizontal pipe



Apply the steady-flow energy equation

$$\left[\frac{p}{\gamma} + \frac{V^2}{2g} + z\right]_{\text{out}} = \left[\frac{p}{\gamma} + \frac{V^2}{2g} + z\right]_{\text{in}} + h_s - h_L$$

Use $z_{\text{out}} - z_{\text{in}}$ (horizontal), $h_s = 0$ (no pump), and $V_{\text{out}} = V_{\text{in}}$ (constant cross section), to simplify as

$$h_L = \frac{p_{\text{in}} - p_{\text{out}}}{\gamma} = \frac{\Delta p}{\gamma} \tag{3}$$

Head Loss in a Horizontal Pipe (2)

Use the definition of the Darcy friction factor – Equation (1)

$$f = \frac{\Delta p}{\frac{1}{2}\rho V^2}\frac{D}{L} \quad \Longrightarrow \quad \Delta p = f\,\frac{1}{2}\rho V^2 \frac{L}{D} \tag{4}$$

Combine Equation (3) and Equation (4) from preceding slide to get

$$h_L = \frac{\Delta p}{\gamma} = \frac{1}{\gamma} f\,\frac{1}{2}\rho V^2 \frac{L}{D} = f\frac{V^2}{2g}\frac{L}{D}$$

This is the *Darcy-Weisbach* equation

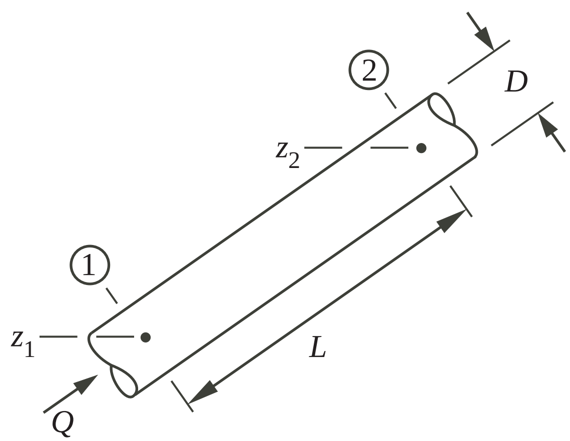
$$\boxed{h_L = f\frac{L}{D}\frac{V^2}{2g}} \tag{5}$$

Head Loss in an Inclined Pipe

The Darcy-Weisbach equation gives h_L when f is known

$$h_L = f \frac{L}{D} \frac{V^2}{2g} \tag{5}$$

This formula was derived for horizontal flow in a pipe, but it applies to flow on an incline.



- Use $h_L = f \frac{L}{D} \frac{V^2}{2g}$ to compute h_L
- Substitute h_L into Energy equation to compute Δp

Formulas for Head Loss in a Horizontal Pipe

$$\mathrm{Re}_D = \frac{\rho V D}{\mu} \qquad V = \frac{Q}{A}$$

$$f_{\textsf{lam}} = \frac{64}{\mathrm{Re}_D} \qquad \text{or} \qquad \frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right)$$

$$\left[\frac{p}{\gamma} + \frac{V^2}{2g} + z\right]_{\mathrm{out}} = \left[\frac{p}{\gamma} + \frac{V^2}{2g} + z\right]_{\mathrm{in}} + h_s - h_L$$

$$h_L = f\frac{L}{D}\frac{V^2}{2g}$$

Basic Head Loss Calculation

Given L, D, Q (or V)

1. Look up fluid properties ρ, μ
2. Compute Re_D to determine whether the flow is laminar or turbulent
3. If turbulent, look up ε for the pipe material
4. Use the Colebrook equation or the Moody chart to find f
5. Use the Darcy-Weisbach equation to compute h_L
6. Use the steady-flow energy equation to find other terms, e.g. pressure drop