Frictional Losses in Pipe Flow

Introduction

When fluids move through pipes, fittings, and other equipment, they lose energy due to **frictional effects**. These frictional losses are split into two categories: **major losses** (from pipe walls) and **minor losses** (from bends, valves, entrances, exits, etc.). They directly affect pressure drop and pumping power requirements, making them central to fluid transport design.

Key Concepts

- Major Losses (pipe wall friction)
- Friction Factor (f)
- Minor Losses (fittings, expansions, contractions)
- Head Loss (h_f)
- Correlations

Definitions

- **Major Loss:** Energy loss due to viscous shear along straight pipe walls.
- **Minor Loss:** Energy loss caused by disturbances such as bends, valves, entrances, and exits.
- **Head Loss (h_f):** The energy loss expressed as an equivalent fluid column height.
- **Friction Factor (f):** Dimensionless number characterizing resistance to flow, dependent on Reynolds number and relative roughness.

Major Losses

Major losses are calculated using the **Darcy–Weisbach equation**:

$$h_{f,major} = f \frac{L}{D} \frac{\bar{V}^2}{2g}$$

where:

- f = friction factor (Moody chart or correlations),
- L = pipe length,
- D = pipe diameter,
- $\bar{V}$ = average velocity,
- g = gravitational acceleration.

This dominates in long, straight pipe sections.

Friction Factor

The friction factor f is an intricate number and can be calculated in so many different ways. A big way to find f is through a Moody chart:

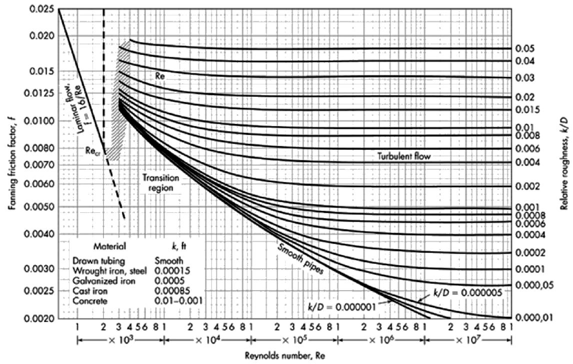

Figure 1: Moody Chart

In order to use the Moody chart, you need to know the Reynolds number, pipe material, and the pipe diameter.
You can also find f through a number of correlations, which are basically just equations fit to experimental data. In ChE 354 you may come across the follow:

- Churchhills Correlation:
$$f = 2\left[\left(\frac{8}{Re}\right)^{12} + \frac{1}{(A+B)^{\frac{3}{2}}}\right]^{\frac{1}{12}}$$
Where:
$$A = \left[2.457\ln\left(\frac{1}{(7/Re)^{0.9} + .27(\epsilon/D)}\right)\right]^{16} \text{ and } B = \left(\frac{37530}{Re}\right)^{16}$$
Churchill can be helpful because it is explicit, unlike some correlations.
- Haaland Correlation:
$$f = \left[3.6\log\left(\frac{6.9}{Re} + \left(\frac{\epsilon}{3.7D}\right)^{1.11}\right)\right]^{-2}$$
Dr. Edison uses this, so you may see it in ChE 319

Minor Losses

Minor losses are represented as:
$$h_{f,minor} = K_i\frac{v^2}{2g}$$
where K is the loss coefficient specific to each fitting or disturbance. Examples:

- Sudden contraction or expansion
- Bends and elbows
- Valves (fully open, partially open, throttling)
- Pipe entrances and exits

While called "minor," they can dominate total losses in systems with many fittings or short pipe runs. There are different values for different losses, depending on where you look.

Total Head Loss

Combining both contributions:
$$h_f = h_{f,major} + h_{f,minor}$$
$$h_f = \left(f\frac{L}{D} + \sum K_i\right)\frac{v^2}{2g}$$

Recap

- **Major losses:** scale with pipe length and friction factor.
- **Minor losses:** scale with number/type of fittings and K values.
- Both losses increase required pumping power and reduce system efficiency.

Frictional losses are unavoidable—your only job is to minimize them with smart design and account for them correctly in calculations.