Email: ammarali@wrec.uoqasim.edu.iq

Fluid Flow in Pipes

What you have to know before start?

1- Real Flow, this mean that the viscosity term work affectively ($\mu \neq 0$).
2- Ideal Flow, this mean that the viscosity term can be neglected ($\mu = 0$).
3- Reynold Number, this number can be used to test whether the flow is **Laminar or Turbulent**. Where,

$$Laminar\ ,Re \leq 2100$$
$$Transitional\ flow,\ 2100 < Re < 4000$$
$$Turbulent\ ,Re \geq 4000$$

All these limitations are for internal flow.

4- Reynold Number, dimensionless number:

$$Re = \frac{\rho * V * D}{\mu}$$

5- Total head loss can be calculated by using Darcy Weisbach Equation:

$$\Delta P = \frac{f.L}{D} * \frac{V^2}{2}$$

OR in the Head Form

$$h_f = \frac{f.L}{D} * \frac{V^2}{2g}$$

is very important for the engineering design and operation of pipe systems. It shows that the pressure drop of a fully-developed pipe flow is a function of three parameters, i.e., **the friction factor** *f*, **pipe geometry** (L/D).

The friction factor *f*, it can be calculated for both cases by:

a- Laminar Flow:

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

By substitute in the main equation will get:

$$h_f = \frac{32.\mu.L.V}{\rho.g.D^2}$$

b- *Friction factor for turbulent flow:*

for turbulent flow, it is impossible to analytically derive the friction factor *f*, which can ONLY be obtained from experimental data. In addition, most pipes, except glass tubing, have rough surfaces. The pipe surface roughness is quantified by a dimensionless number, relative pipe roughness (ε/D)

Where, ε is pipe roughness and D is pipe diameter.

For smooth pipe:

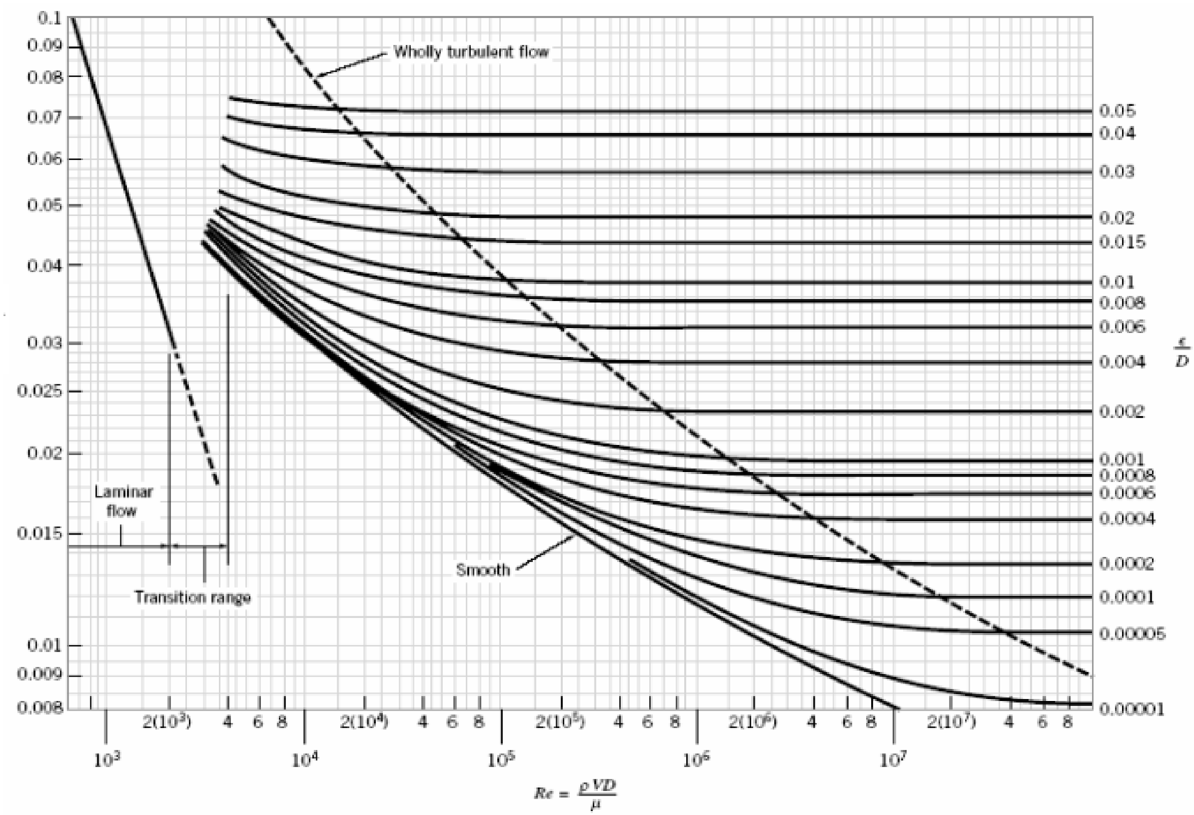
Email: ammarali@wrec.uoqasim.edu.iq

$$f = \frac{0.316}{Re^{0.25}}$$

For roughness pipe:

The best way to find friction factor f, for rough pipe by using **Moody chart**.

To use the Moody chart, we need to calculate the relative roughness (ε/D) and Re for the flow under consideration. Hence, use the chart with the calculated values to find the friction factor.



Email: ammarali@wrec.uoqasim.edu.iq

Example 1: At 30 °C, glycerine (viscosity μ = 0.4 N·s/m2, density ρ = 1,260 kg/m3) flows at a rate of 180 mL/min through a horizontal 25 mm diameter smooth steel pipe.
(a). Determine the Reynolds number of the flow;
(b). Calculate the pressure gradient in Pa/m.

Solution:

a- $Q = 180 \frac{mL}{min} = 0.18 \frac{L}{min} = 3 * 10^{-6}\ m^3/sec$

$$velocity = \frac{discharge}{Area} = \frac{3 * 10^{-6}}{\frac{\pi}{4} * 0.025^2} = 0.0061\ m/sec$$

Now, Reynolds number can be calculated by:

$$Re = \frac{\rho * u * d}{\mu} = \frac{1260 * 0.0061 * 0.025}{0.4} = 0.48$$

Base on the Reynolds number, the flow is laminar cause it is less than 2300.

b- The pressure gradient can be calculated:

$$\frac{\Delta p}{L} = f * \frac{1}{D} * \frac{\rho * u^2}{2}$$

The friction factor can be calculated for laminar flow by:

$$f = \frac{64}{Re} = \frac{64}{0.48} = 133.3$$

$$\frac{\Delta p}{L} = 133.3 * \frac{1}{0.025} * \frac{1260 * 0.0061^2}{2} = 125\ pa/m$$

Example 2: At 20 °C, glycerine (viscosity μ = 0.62 N·s/m², density ρ = 1,260 kg/m³) flows in a 25 mm diameter steel pipe at an average velocity of 0.3 m/s.
(a). Determine whether the flow is laminar or turbulent;
(b). Calculate the shear stress at the centre of the pipe and at the wall;
(c). If the pipe is vertical and the flow downward, what is the rate of change of pressure along the pipe?

Solution:

a-

$$Re = \frac{\rho * u * d}{\mu} = \frac{1260 * 0.3 * 0.025}{0.62} = 15.24$$

Email: ammarali@wrec.uoqasim.edu.iq

Base on the Reynolds number, the flow is laminar cause it is less than 2300.

b- Shear stress can be calculated by:

$$\Delta p = \frac{\tau_w * 4L}{d}$$

And we have the pressure drop as below:

$$\Delta p = f * \frac{L}{D} * \frac{\rho * u^2}{2} = \frac{\tau_w * 4L}{d}$$

$$\tau_w = \frac{f * \rho * u^2}{8}$$

The friction factor can be calculated for laminar:

$$f = \frac{64}{Re} = \frac{64}{15.24} = 4.2$$

$$\tau_w = \frac{4.2 * 1260 * 0.3^2}{8} = 59.53 \frac{N}{m^2}$$

c-

$$\frac{\Delta p}{L} = f * \frac{1}{D} * \frac{\rho * u^2}{2} = 4.2 * \frac{1}{0.025} * \frac{1260 * 0.3^2}{2} = 9524 \frac{pa}{m}$$

Test Yourself

1- Oil (*ρ = 800 kg/m³*) flow through a *50mm*-diameter smooth pipe at a velocity of *2m/s*, the pressure drops due to friction loss in the pipe *5023 pa*. The pipe length is 10m.

a- Calculate the friction factor, *f*.

b- Determine whether the flow is laminar or turbulent.

c- Calculate the oil viscosity.

(b) 0.0157 (d) 487×10-6 N·s/m²]

2- A steel pipe (ε = 0.045mm), 500 mm in diameter and 5 km long carries 100,000 m³. water (viscosity μ = 1.15 × 10-3 N·s/m², density ρ = 1,000 kg/m³) per day. (a) Determine the pressure drop in the line; (b) Determine the pressure drop in a same-size concrete (ε = 0.91mm) pipe; (c). If the concrete pipe is of a rectangular shape (length = 800 mm, width = 400 mm), what is the pressure drop in the line?

[Ans. (a) 2.19 MPa (b) 3.97 MPa (c) 2.84 MPa]

Email: ammarali@wrec.uoqasim.edu.iq

3- A capillary tube is 30 mm long and 1 mm bore. The head required to produce a flow rate of 8 mm^3/s is 30 mm. The fluid density is 800 kg/m^3. Calculate the dynamic and kinematic viscosity of the oil.

$\mu = 0.0241 N\ s/m$

4- Water at 15 C° flows through a 25 cm diameter riveted steel pipe of length 450 m and roughness ε = 3.2 mm. The head loss is known to be 7.30 m. Find the volumetric flow rate of water in the pipe.

U=1.39 m/s