

## 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,

$$\text{Laminar , } Re \leq 2100$$

$$\text{Transitional flow, } 2100 < Re < 4000$$

$$\text{Turbulent , } Re \geq 4000$$

All these limitations are for internal flow.

- 4- Reynold Number, dimensionless number:

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

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

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

**OR in the Head Form**

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

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:

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

- 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 ( $\epsilon/D$ )

Where,  $\epsilon$  is pipe roughness and D is pipe diameter.

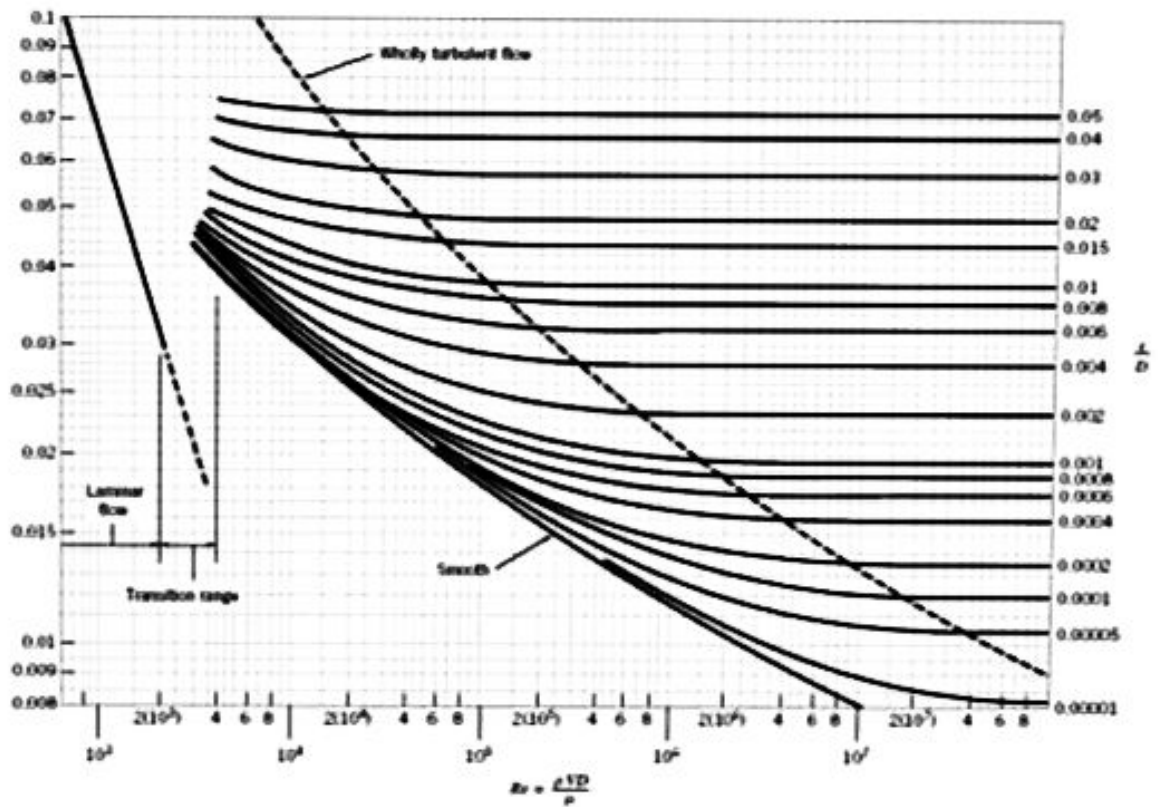
**For smooth pipe:**

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

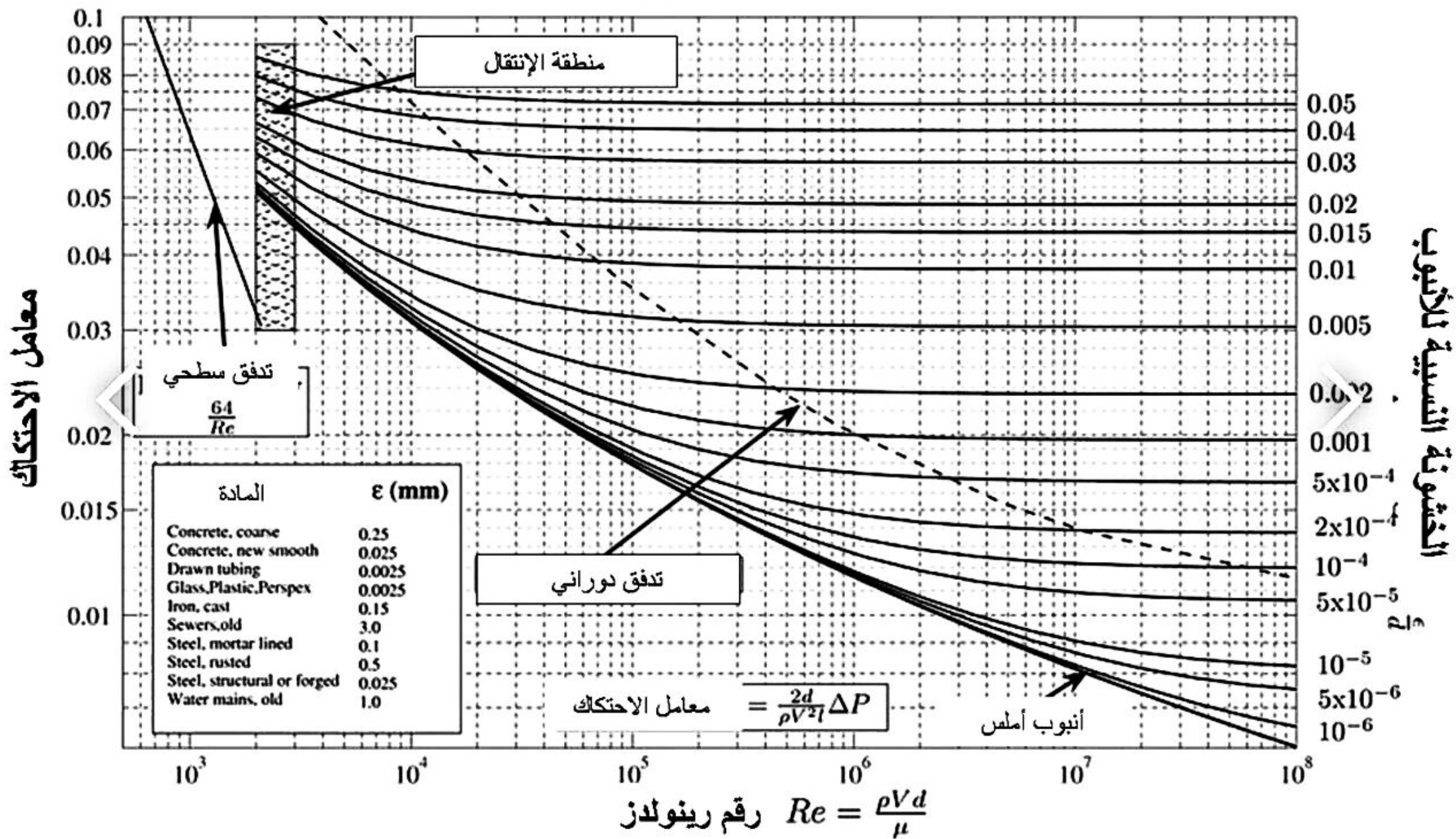
**For roughness pipe:**

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 ( $\epsilon/D$ ) and  $Re$  for the flow under consideration. Hence, use the chart with the calculated values to find the friction factor.



# مخطط مودي



**Example 1:** At 30 °C, glycerine (viscosity  $\mu = 0.4 \text{ N}\cdot\text{s}/\text{m}^2$ , density  $\rho = 1,260 \text{ kg}/\text{m}^3$ ) flows at a rate of 180 mL/min through a horizontal 25 mm diameter smooth steel pipe.

- Determine the Reynolds number of the flow;
- Calculate the pressure gradient in Pa/m.

**Solution:**

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

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

Now, Reynolds number can be calculated by:

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

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

- The pressure gradient can be calculated:

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

The friction factor can be calculated for laminar flow by:

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

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

**Example 2:** At 20 °C, glycerine (viscosity  $\mu = 0.62 \text{ N}\cdot\text{s}/\text{m}^2$ , density  $\rho = 1,260 \text{ kg}/\text{m}^3$ ) flows in a 25 mm diameter steel pipe at an average velocity of 0.3 m/s.

- Determine whether the flow is laminar or turbulent;
- Calculate the shear stress at the centre of the pipe and at the wall;
- If the pipe is vertical and the flow downward, what is the rate of change of pressure along the pipe?

**Solution:**

a-

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

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

b- Shear stress can be calculated by:

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

And we have the pressure drop as below:

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

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

The friction factor can be calculated for laminar:

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

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

c-

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