Universiti Malaysia PAHANG
Engineering • Technology • Creativity

Chapter 5
Flow in Pipelines

by

Dr. Nor Azlina binti Alias
Faculty of Civil and Earth Resources Engineering
azlina@ump.edu.my

Topics

WEEK	CHAPTER	TOPIC		
9	5	**Flow in Pipelines**		
		5.1	Category of Flow in Pipes	
		5.2	Laminar Flow in Pipes	
10		5.3	Turbulent Flow in Pipes	
11		5.4	Flowrate and Velocity Measurement in Pipes	
			5.4.1	Pitot
			5.4.2	Orifice

Course outcome CO4 : Analyze the pipeline systems as related to civil engineering.

Types of Fluid Flow Problems

In the design and analysis of piping systems, we usually encounter three types of problems :

1. Determining the **pressure drop** or **head loss** when the pipe length and diameter (for a specified flow rate or velocity)
2. Determining the **flow rate** when the pipe length and diameter (for a specified pressure drop or head loss)
3. Determining the **pipe diameter** when the pipe length and flow rate (for a specified pressure drop or head loss)

5.1 Category of Flow in Pipes

As the water flows from a faucet at a very low velocity, the flow appears to be smooth and steady. The stream has a fairly uniform diameter and there is little or no evidence of mixing of the various parts of the stream.

LAMINAR FLOW

TURBULENT FLOW

When the faucet is nearly fully open, the water has a rather high velocity. The elements of fluid appear to be mixing chaotically within the stream.

5.1.1 Differences Between Flows

LAMINAR FLOW	TURBULENT FLOW
• Re < 2000 • 'low' velocity • Dye does not mix with water • Fluid particles move in straight lines • Simple mathematical analysis possible • Rare in practice in water systems.	• Re > 4000 • 'high' velocity • Dye mixes rapidly and completely • Particle paths completely irregular • Average motion is in the direction of the flow • Cannot be seen by the naked eye • Changes/fluctuations are very difficult to detect. Must use laser. • Mathematical analysis very difficult - so experimental measures are used • Most common type of flow.

5.1.2 Reynold's Number, Re

- Osborne Reynolds was the first to demonstrate that laminar or turbulent flow can be predicted if the magnitude of a dimensionless number, now called the Reynolds (Re) number is known.
- The following equation shows the basic definition of the Reynolds number, Re:
- $$\text{Re} = \frac{\text{inertial force}}{\text{viscous force}}$$

$$\text{Re} = \frac{\rho v D}{\mu} = \frac{vD}{\upsilon}$$

where;

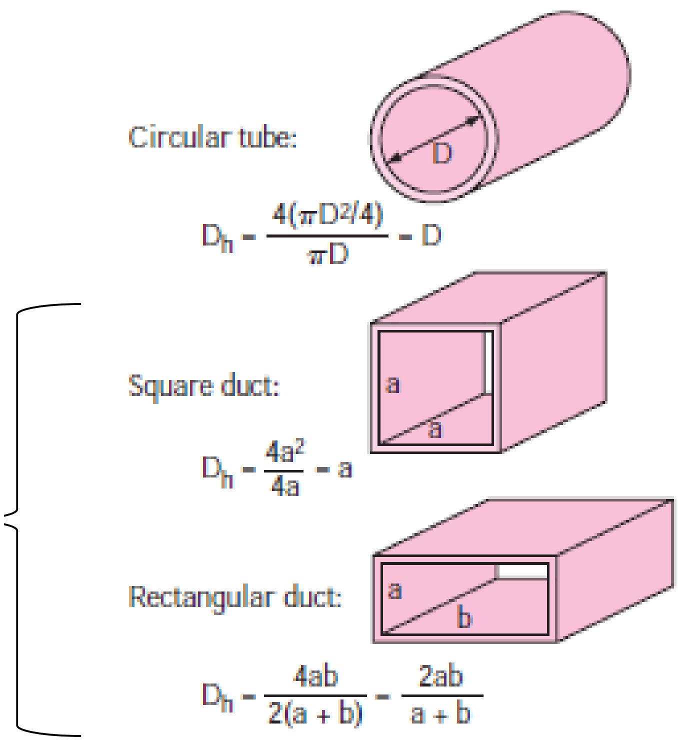
fluid density ρ

fluid viscosity υ

pipe diameter *D*

velocity of flow *v*.

Non circular pipe



5.13 Energy loss in Pipes

- The energy loss due to friction in flows for circular pipes can be calculated either from:

  i) The Darcy's Equation (Laminar & Turbulent)

  - From Bernoulli's theorem, the general energy equation is :
  - $$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + Z_1 - h_L = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + Z_2$$

term h_L is defined as the energy loss from the system.

where $$h_L = \frac{fLv^2}{2gD}$$

h_L = energy loss due to friction (m)
L = length of flow stream (m)
D = pipe diameter (m)
v = average velocity (m/s)
f = friction factor

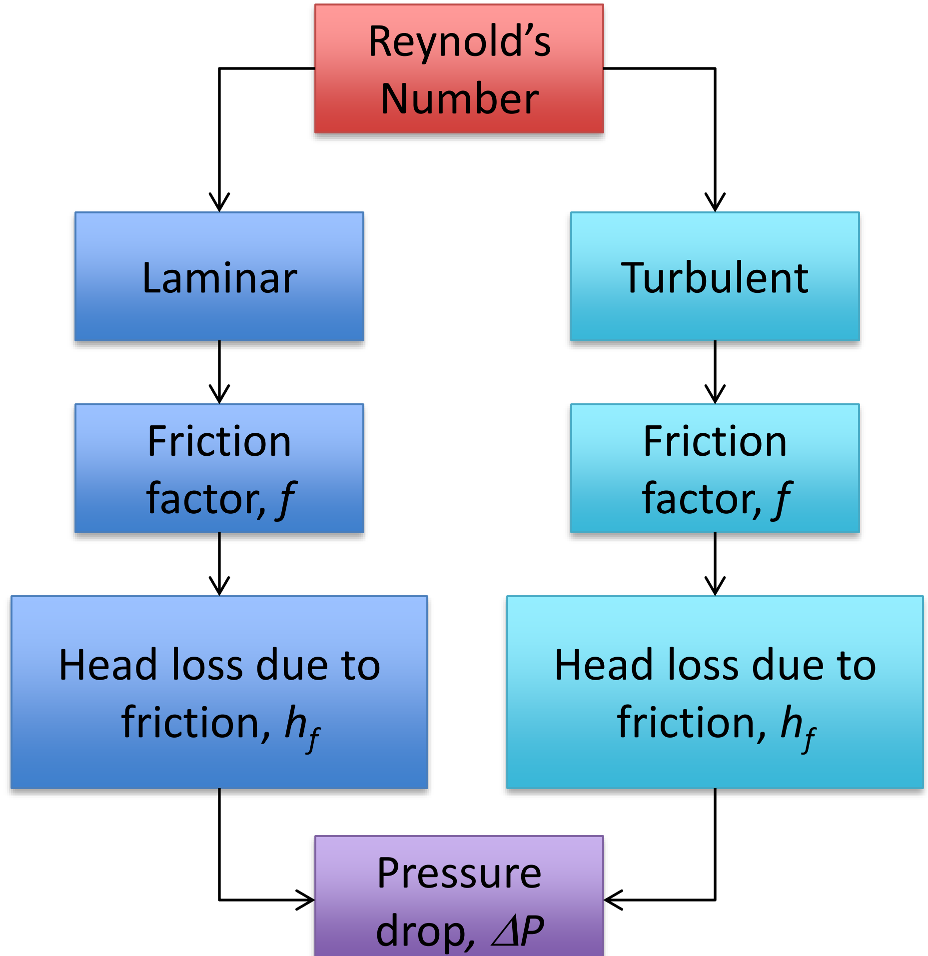
  ii) The Hagen–Poiseuille Equation (Laminar)

  - The Hagen–Poiseuille equation to calculate head/energy loss can be derived from the energy loss and the measurable parameters of the flow system and given as: $$h_L = \frac{32\mu Lv}{\gamma D^2}$$

The Hagen–Poiseuille equation valid only for laminar flow (**Re < 2000**).

5.1.4 Friction Factor, *f*

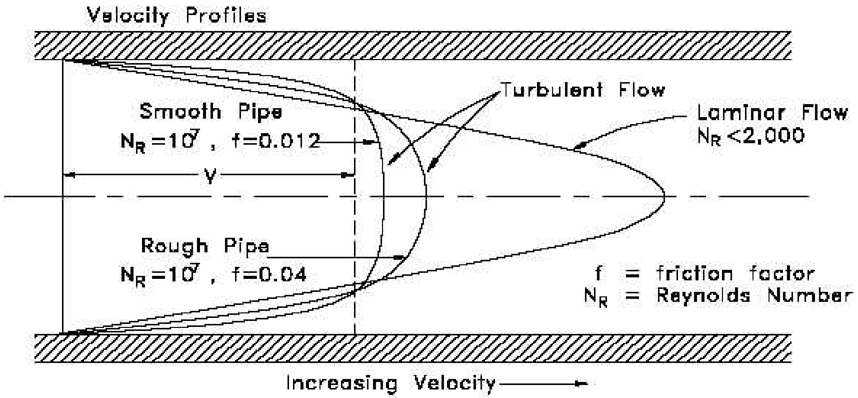
- The value of f must be chosen correctly to avoid incorrect head loss (due to friction).
- The value of losses due to friction in fluid are as follows:
  - hf $\propto$ L
  - hf $\propto$ v2
  - hf $\frac{1}{\infty}$ d
  - hf depends on
    - Pipe roughness
    - Fluid density and viscosity

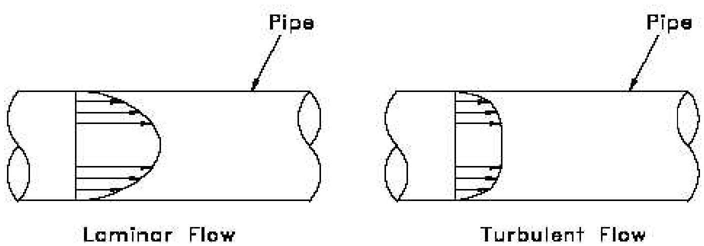


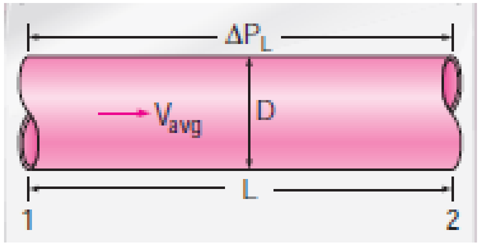
5.1.5 Pressure Drop

- In practice, it is found convenient to express the pressure loss for all types of fully developed internal flows (laminar or turbulent flows, circular or noncircular pipes, smooth or rough surfaces, horizontal or inclined pipes) as :

$$\Delta P = \frac{fLv_{ave}^{\;2}}{2D}\rho$$







The mean velocity in pipeline system is :

$$v_{ave} = \frac{\rho g S_f D^2}{32\mu}$$

$$v_{ave} = \frac{\rho g h_L D^2}{32 L\mu}$$

$$h_L = \frac{32\mu L v}{\rho g D^2}$$

$$h_L = \frac{32\mu L v}{\gamma D^2}$$

$$S_f = \frac{h_L}{L}$$

$$v_{ave} = \frac{v_{max}}{2}$$

Hagen–Poiseuille equation