Chapter 5
ANALYSIS OF FLUID FLOW IN SINGLE STRAIGHT PIPE
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Learning Outcomes

Upon completing this chapter, the students are expected to be able to:
1. *Identify different types of pipes used in Civil Engineering problems.*
2. *List and determine the flow condition in pipe.*
3. *Identify the general formula for head loss in pipe flow.*
4. *List the two types of head loss in pipe flow.*
5. *Identify the different friction loss coefficients.*
6. *Calculate the friction head loss in pipe.*
7. *Solve straight pipe problems incorporating friction loss using Bernoulli's equation.*

5.1)   Introduction

- Pipes are used to covey fluid from one place to another.
- Fluid is able to flow in pipe when there is a pressure difference between two points in the pipe.
- Civil Engineering Pipes – for water supply:
  - Asbestos Cement (AC)
  - Unplasticized Polyvinyl Chloride (uPVC)
  - High Density Polyethylene (HDPE)
  - Cast Iron (CI)
  - Ductile Iron (DI)
  - Glass Fiber Reinforced Plastic (GRP)
  - Steel Pipes (Mild Steel)
  - Galvanized Iron (GI)
  - Copper (Cu)
  - Mild Steel, etc

Flow Conditions:
The flow in pipe may Laminar, Transition or Turbulent depending on the **Reynolds number, R_e**:

$$R_e = \frac{vd\rho}{\mu} = \frac{vd}{\upsilon} \qquad \longleftarrow \qquad \text{no unit, just a number.}$$

1. Laminar Flow: $R_e < 2000$

2. Transition Flow: $2000 \le R_e \le 4000$

3. Turbulent Flow: $R_e > 4000$

For plain water, $\rho = 1000$ **kg/m^3**, $\mu = 1 \times 10^{-3}$ **Pa.s, and** $\upsilon = 1 \times 10^{-6}$ **m^2/s**

5.2) Head Losses

The Bernoulli's equation for fluid flowing from point 1 to point 2 is:

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2 + \sum h_L$$

Total head loss

General formula for head loss:

$$h_L = k\frac{v^2}{2g}$$

where k = head loss coefficient

v = average flow velocity (m/s)

$$= \frac{Q}{A} \qquad \text{where } Q = \text{flow rate (m}^3\text{/s)}$$

$$= \frac{4Q}{\pi d^2} \qquad \text{where } d = \text{inner pipe diameter (m)}$$

Two types of head losses:
1. Friction Loss – largest head loss
2. Minor Losses – will be discussed in Chapter 6.

5.3) Friction Head Loss

$$h_f = k_f\frac{v^2}{2g}$$

where k_f = friction loss coefficient which are:

a) Hagen-Poiseuille: $k_f = \frac{64\mu L}{\rho v d^2}$ for laminar flow.

where L = actual pipe length (m)

b) Blasius: $k_f = \frac{L}{21.55 d v^{0.6}}$

c) **Hazen-Williams:** $k_f = \frac{133.9L}{C^{1.85} d^{1.165} v^{0.15}}$

C = Hazen-Williams' coefficient, depends only on the type of pipe material.

d)   **Darcy-Weisbach:** $k_f = \dfrac{4fL}{d}$

where f = friction factor (no unit)

The value of f can be obtained by using two methods:

(i)   Using Formula

1. For Laminar Flow: $f = \dfrac{16}{R_e}$

2. For Transition Flow:

Von-Karman & Prandtl (for smooth pipes)

$$\frac{1}{\sqrt{4f}} = 2\log\left(R_e\sqrt{4f}\right) - 0.80$$

Colebrook & White (for rough pipes)

$$\frac{1}{\sqrt{4f}} = -2\log\left(\frac{e/d}{3.71} + \frac{2.51}{R_e\sqrt{4f}}\right)$$

e = pipe roughness

3. For Turbulent Flow:

$$\frac{1}{\sqrt{4f}} = 2\log\left(\frac{d}{2e}\right) + 1.74$$

(ii)   Using Moody Diagram

Moody diagram – f depends on Reynolds number, R_e and relative roughness of pipe (e/d) or (d/e), where d is the inner pipe diameter and e is the thickness of the roughness of the pipe wall.

5.4   The FRICTION Computer Program

FRICTION is a medium sized executable computer program to solve any friction in pipes. It is developed by Mr. Amat Sairin Demun using MS DOS based Fortran programming language. It is able to calculate the friction factor and head loss in simple pipes. The students can copy the file from Mr. Amat Sairin Demun at no cost. To run the computer program, the students will have to and double click the FRICTION file and just follow the instructions appear on the computer screen. If you have difficulties running the computer program, please feel free to contact Mr. Amat Sairin Demun.