Chapter 6
ANALYSIS OF FLUID FLOW IN PIPILINES SYSTEMS
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Learning Outcomes

Upon completing this chapter, the students are expected to be able to:

1. *Calculate the minor head losses using the loss coefficient method and the equivalent pipe length method.*
2. *Calculate the total head loss incorporating friction loss and minor losses using the loss coefficient method and the effective pipe length method.*
3. *Solve pipeline problems connected in series.*
4. *Solve pipeline problems connected in parallel.*

6.1) Bernoulli's Equation

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

Total head loss, $\sum h_L = \sum k \frac{v^2}{2g}$ ← v = velocity in pipe

$\sum k$ = total loss coefficient

$$\sum k = k_f + \sum k_m$$

$\sum k_m$ ← Total minor losses **coefficients**

k_f ← Friction loss **coefficient** (Chapter 5)

Therefore, the total head loss is:

$$\boxed{\sum h_L = \left(k_f + \sum k_m\right)\frac{v^2}{2g}}$$

For Darcy Weisbach: $\sum h_L = \left(\underbrace{\frac{4fL}{d}}_{k_f}+\sum k_m\right)\frac{v^2}{2g}$

For Hazen William: $\sum h_L = \left(\underbrace{\frac{133.9L}{C^{1.85}d^{1.165}v^{0.15}}}_{k_f}+\sum k_m\right)\frac{v^2}{2g}$

6.2) Minor Losses

Minor losses are due to pipe fittings and valves – elbow, bends, tee joints, tapers, etc.

Two methods may be used for minor losses calculations:

6.2.1) Using Loss Coefficient, k_m

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

The values of k_m of various types of fittings and valves can be obtained from any text book or from local water authority design manual/guidelines.

6.2.2) Using Equivalent Pipe Length, L_{eq}

- The minor losses can be expressed as the loss through an equivalent length of straight pipe.
- The equivalent length (L_{eq}) is added to the actual pipe length to obtain the effective pipe length (L_{ef}).
- The L_{ef} is then used in the k_f value to obtain the loss coefficient which include both friction and minor losses:

Darcy-Weisbach: $$k_{fm} = \frac{4fL_{ef}}{d}$$

Hazen-Williams: $$k_{fm} = \frac{133.9L_{ef}}{C^{1.85}d^{1.165}v^{0.15}}$$

$$L_{ef} = L + L_{eq}$$

Stop valve

in which k_{fm} is the total loss coefficient including friction and minor losses.

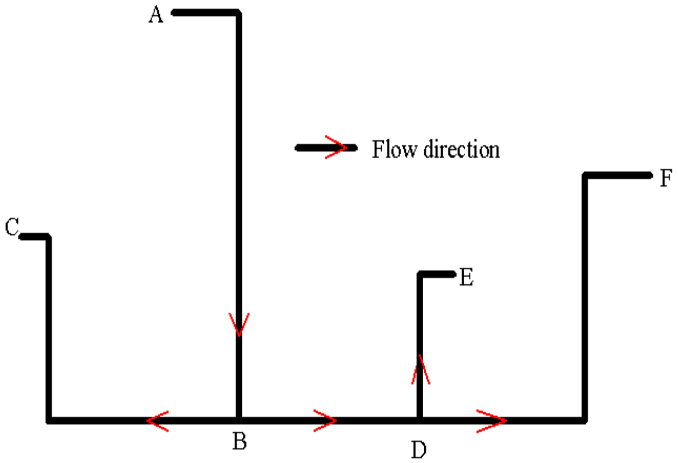
- The value of equivalent pipe length of various fittings and valves is obtained by using equation:

$$\boxed{L_{eq} = \alpha d} \longleftarrow \quad d = \text{pipe diameter (m)}$$

- The values of coefficients α can be obtained from any textbook or from the local water authority design manual or guidelines.

6.3) Pipe Branching (Dead End Pipe Network System)

The following figure shows pipe branching.



To analyze flow in pipe branching, apply the following concepts:

i) Continuity Equation: $\Sigma Q_{in} = \Sigma Q_{out}$

i.e: $Q_{BD} = Q_{DE} + Q_{DF}$

$Q_{AB} = Q_{BC} + Q_{BD}$

ii) Apply Bernoulli's Equation from the starting point to the end point.

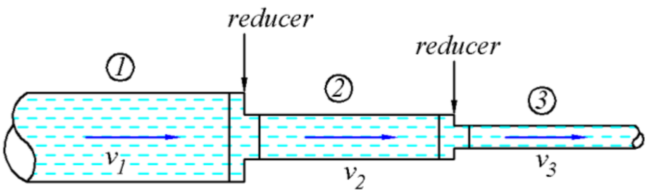
i.e: $$\frac{P_A}{\rho g} + \frac{v_A^2}{2g} + z_A = \frac{P_C}{\rho g} + \frac{v_C^2}{2g} + z_C + \sum h_{L(AB)} + \sum h_{L(BC)},$$

$$\frac{P_A}{\rho g} + \frac{v_A^2}{2g} + z_A = \frac{P_E}{\rho g} + \frac{v_E^2}{2g} + z_E + \sum h_{L(AB)} + \sum h_{L(BD)} + \sum h_{L(DE)}, \text{ and}$$

$$\frac{P_A}{\rho g} + \frac{v_A^2}{2g} + z_A = \frac{P_F}{\rho g} + \frac{v_F^2}{2g} + z_F + \sum h_{L(AB)} + \sum h_{L(BD)} + \sum h_{L(DF)}$$

6.4) Pipelines Connected in Series

- Two or more pipes connected in series.



- No branching.

- The flow rate in each pipe is the same: $Q_1 = Q_2 = Q_3$

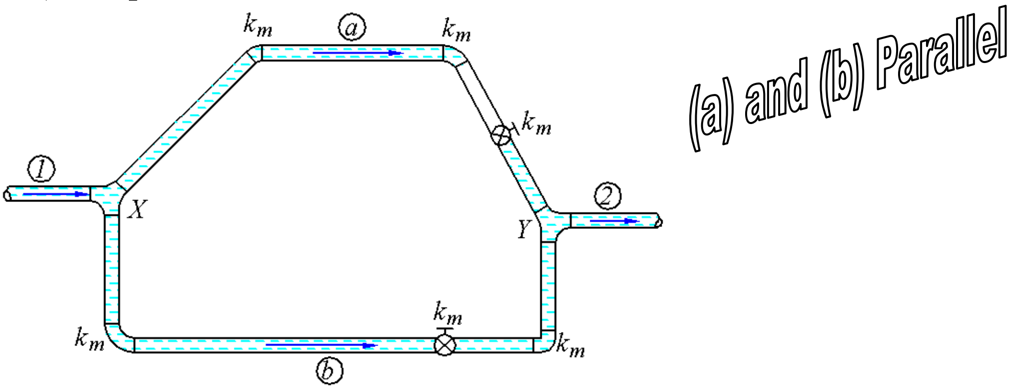
- Analysis – use one of the flow velocity – whether v_1 or v_2 or v_3.

- Solution technique - Use continuity equation.
  $Q_1 = Q_2 = Q_3$
  $A_1v_1 = A_2v_2 = A_3v_3$

  - Use Bernoulli's equation where in the Bernoulli's equation,

  $$\sum h_L = \sum h_{L1} + \sum h_{L2} + \sum h_{L3} + \ldots . \sum h_{Ln}$$
  where n = numbers of pipes connected in series.

6.5) Pipelines Connected in Parallel



Pipe (a) and (b) is in parallel because it meets again at point Y. Pipe (1) and (a) is in series, pipe (b) and (2) is in series.

<u>Solution Technique:</u>

1. Continuity equation

   $Q_a + Q_b = Q_1$

2. The **Total Head Losses for the pipes in Parallel are the same**.

   $$\sum h_{L(a)} = \sum h_{L(b)}$$

   or

   $$\sum k_a \frac{v_a^2}{2g} = \sum k_b \frac{v_b^2}{2g}$$

   where pipe *a* and pipe *b* are connected in parallel

3. Apply Bernoulli's equation through one of the parallel pipe. (If necessary).

<u>NOTE:</u>

Referring to the following figure, pipe (a) and (b) is **NOT** considered as pipe connected in parallel. This is because both pipes does not joint again as compared to the previous figure.

Therefore, for the following figure, the **total head loss** in pipe (a) and (b) is **NOT the same** as compared to the above figure.

Therefore, the following figure is considered as **Pipe Branching** or **Dead End Pipe system** similar to the one in Paragraphs 6.3.