Fluid Mechanics - Homework #3.2
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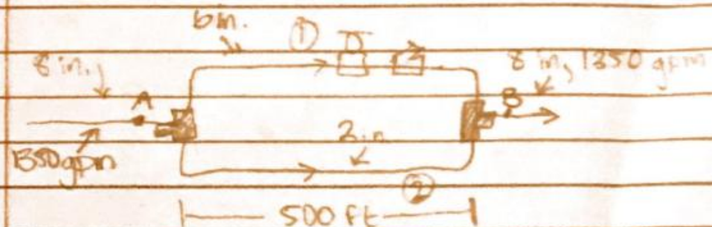
What we learned: For chapter 11, we learned about the specific aspects of fluid flow in pipes and tubes. Using the energy equation, we were able to identify laminar and turbulent flow, friction losses in pipes and fittings, and minor losses due to friction. In chapter 12, we focused on parallel and branching pipe systems, and how the fluid flows through the pipelines. This concept explains how fluids can flow through several pipes at once, and be distributed using control valves. We learned how to approach parallel piping systems and calculate various parameters of the system such as flow rate through each branch, total flow rate of the system, and pipe diameter. The method we learned to use in these chapters is known as iteration and it allowed us to converge on a solution through successful approximations and error reduction strategies.

11.26: **Ethan E.**

12.3: **Josiah**

12.4: **Ethan K.**

Diagram



$K_{GLOBE} = 340 f_T$; $K_{SWING} = 100 f_T$; $K_{TEE} = 60 f_T$

First, we place reference points A and B. Then, we write Bernoullis.

$$\frac{P_A}{\gamma} + \frac{V_A^2}{2g} + z_1 = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + z_2 + h_L$$

Then, we cancel and simplify:

$$\frac{\Delta P}{\gamma} = h_L$$

Write out losses and adjust for each path:

(1) $$\frac{\Delta P}{\gamma} = h_{f_1} + h_{GLOBE} + h_{SWING} + 2h_{TEE}$$

(2) $$\frac{\Delta P}{\gamma} = h_{f_2} + 2h_{TEE}$$

Since $Q_A = Q_B = Q_1 + Q_2$, find Q_1 with $Q_A - Q_2$

$$\frac{\Delta P}{\gamma} = f_2 \cdot \frac{L_2}{D_2} \cdot \frac{V_2^2}{2g} + 2 \cdot K_{TEE} \cdot \frac{V_2^2}{2g}$$

$K_{TEE} \approx 60\, f_{T_2}$ so

$$\frac{\Delta P}{\gamma} = f_2 \frac{L_2}{D_2} \cdot \frac{V_2^2}{2g} + 2 \cdot 60 \cdot f_T \cdot \frac{V_2^2}{2g}$$

$$\frac{\Delta P}{\gamma} = \left(\frac{f_2 L_2}{D_2} + 120\, f_T \right) \frac{V_2^2}{2g}$$

$Q = VA$

$V = \frac{Q}{A}$

$$Q_2 = \sqrt{\frac{2g\Delta P}{\gamma \left(\frac{f_2 L_2}{D_2} + 120\, f_T \right)}} \cdot \frac{\pi D_2^2}{4}$$

$A_c = \pi r^2$

$r = \frac{1}{2} D$

$A_c = \pi \left(\frac{1}{2} D \right)^2$

$\pi \frac{D^2}{4}$

Now ①:

$$\frac{\Delta P}{\gamma} = f_1 \frac{L_1}{D_1} \frac{V_1^2}{2g} + 340\, f_{T_1} \frac{V_1^2}{2g} + 100\, f_{T_1} \frac{V_1^2}{2g} + 2 \cdot 60\, f_{T_1} \frac{V_1^2}{2g}$$

$$Q_1 = \sqrt{\frac{2g\Delta P}{\gamma \left(f_1 \frac{L_1}{D_1} + 340\, f_{T_1} + 100\, f_{T_1} + 120\, f_T \right)}} \cdot \frac{\pi D_1^2}{4}$$

Finally,

$$Q_A = Q_1 + Q_2$$

$$1500 = \sqrt{\frac{2g\Delta P}{\gamma \left(f_1 L_1/D_1 + 340\, f_{T_1} + 100\, f_{T_1} + 120\, f_T \right)}} \cdot \frac{\pi D_1^2}{4}$$

$$+ \sqrt{\frac{2g\Delta P}{\gamma \left(\frac{f_2 L_2}{D_2} + 120\, f_T \right)}} \cdot \frac{\pi D_2^2}{4}$$

Unknown: f_{T_1}, f_{T_2}, f_1, f_2, ΔP

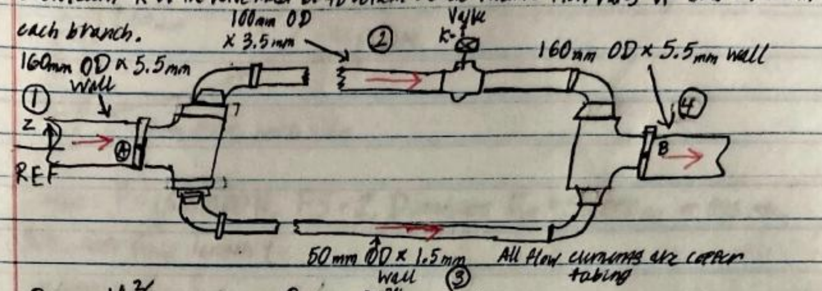
Solution: Iterate using Excel.

Assume $f = 0.014$ through Moody chart, $f_{T_1} = 0.015$
$f_{T_2} = 0.019$,

Iterations converge to $Q_1 = 1.5489\ \frac{ft^3}{s}$ with 0.5% margin of error.

12.5: **Gershon**

12.5) A 160 mm pipe branches into a 100 mm and a 50 mm pipe. Both pipes are hydraulic copper tubing and 30 m long (the fluid is water at 10°C). Determine what the resistance coefficient K of the valve must be to obtain equal volume flow rates of 500 L/min in each branch.



$Q = 500\ L/min$

$L_2 = L_3 = 30m$

$K_{valve} = ?$

$\gamma = 9.81\ KN/m^3$

$\nu = 1.30 \times 10^{-6}\ m^2/s$

$D_1 = 0.149m$

$D_2 = 0.093m$

$D_3 = 0.046m$

$L_e/D_{elbow} = 30$

$L_e/D_{valve} = 240$

$L_e/D_{Tee} = 60$

$\varepsilon = 1.5 \times 10^{-6}\ m$

$A_2 = 6.793 \times 10^{-3}\ m^2$

$$\frac{P_A}{\gamma} + \cancel{\frac{V_A^2}{2g}} + \cancel{Z_A} = \frac{P_B}{\gamma} + \cancel{\frac{V_B^2}{2g}} + \cancel{Z_B} + h_{L_{A-B}}$$

$$\frac{\Delta P}{\gamma} = h_{L_{AB}}$$

$$\frac{\Delta P}{\gamma} = h_{L_{AB③}} \qquad \frac{\Delta P}{\gamma} = h_{L_{AB②}}$$

$$\frac{\Delta P}{\gamma} = 2h_{L_{Tee①}} + h_{L_{Red③}} + 2h_{L_{Elb③}} + h_{L_③} + h_{L_{EXP③}} + h_{④}$$

$$\frac{\Delta P}{\gamma} = 2K_{Tee}\frac{16Q_1^2}{\pi^2 D_1^4} + K_{RED}\frac{16Q_3^2}{\pi^2 D_3^4} + 2K_{elb}\frac{16Q_3^2}{\pi^2 D_3^4} + f_3 \cdot \frac{L_3}{D_3} \cdot \frac{16Q_3^2}{\pi^2 D_3^4}$$
$$+ K_{EXP}\frac{16Q_3^2}{\pi^2 D_3^4} + f_4 \frac{L_4}{D_4}\frac{16Q_4^2}{\pi^2 D_4^4}$$

$$\boxed{\frac{\Delta P}{\gamma} = \left(2K_{Tee} + f_4\frac{L_4}{D_4}\right)\frac{16Q_1^2}{\pi^2 D_1^4} + \left(K_{Red_{1-3}} + 2K_{Elb} + f_3\frac{L_3}{D_3} + K_{EXP}\right)\frac{16Q_3^2}{\pi^2 D_3^4}} \quad Q_3$$

$$\boxed{\frac{\Delta P}{\gamma} = \left(2K_{Tee} + f_4\frac{L_4}{D_4}\right)\frac{16Q_1^2}{\pi^2 D_1^4} + \left(K_{Red} + 2K_{Elb} + f_2\frac{L_2}{D_2} + K_{EXP} + K_{valve}\right)\frac{16Q_2^2}{\pi^2 D_2^4}} \quad Q_2$$

$$Q_1 = Q_2 + Q_3$$

$$\mathrm{I} \rightarrow 0.0083\ m^3/s = \sqrt{\frac{\frac{\Delta P}{\gamma} - \left(2K_{Tee} + f_4\frac{L_4}{D_4}\right)\frac{8Q_1^2}{g\pi^2 D_1^4}}{\left(K_{Red_{1-2}} + 2K_{elb} + f_2\frac{L_2}{D_2} + K_{EXP_{1-2}} + K_{valve}\right)\frac{8}{g\pi^2 D_2^4}}} \quad +$$

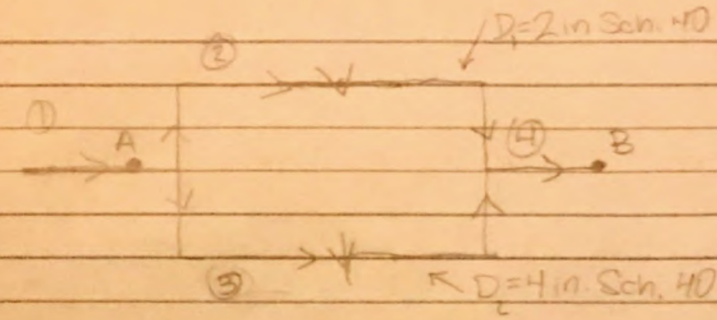
$$\sqrt{\dfrac{\dfrac{\Delta P}{\gamma} - \left(2K_{Tee} + f_4 \dfrac{L_4}{D_4}\right) \dfrac{8\,Q_1^2}{g\,\pi\,D_1^4}}{\left(K_{Red_{1\times 3}} + 2K_{elb} + f_3 \dfrac{L_3}{D_3} + K_{Exp_{1\times 3}}\right) \dfrac{8}{g\,\pi^2 D_3^4}}}$$

old

$$Re_3 = \frac{4\,Q_3}{\pi D_3 \nu} = \frac{4\,(0.01\ m^3/s)}{\pi(0.046\,m)(1.30\times 10^{-6}\ m^2/s)} = 212916.3118$$

12.6: **Ethan K.**

Diagram



= Valve (gate)

> = Flow direction

(#) - Branch label

$P_A = 20$ psig; $K_{ELB} = 0.9$; $h_p = 0$; $D_1 = 2$ in.; $D_2 = 4$ in.
$D_A = ? = D_B$; $P_B = 0$ psig; Fluid assumed as water

$K_{valve,1} = 5$ when open, $K_{valve} = 10$ when closed

$$\frac{P_A}{\gamma} + \cancel{\frac{V_A^2}{2g}} + \cancel{z_A} = \frac{P_B}{\gamma} + \cancel{\frac{V_B^2}{2g}} + h_{L_{12}} + \cancel{z_B}$$

$$\frac{P_A - P_B}{\gamma} = h_{L_2}$$

$$\frac{\Delta P}{\gamma} = K_{VALVE_2}\frac{V_2^2}{2g} + 2K_{ELB_2}\frac{V_2^2}{2g}$$

$$\frac{\Delta P}{\gamma} = (K_{VALVE_2} + 2K_{ELB_2})\frac{V_2^2}{2g}$$

$$\frac{P_A - P_B}{\gamma} = h_{L_3}$$

$$\frac{\Delta P}{\gamma} = K_{VALVE_3}\frac{V_3^2}{2g} + 2K_{ELB_3}\frac{V_3^2}{2g}$$

$$\frac{\Delta P}{\gamma} = (K_{VALVE_3} + 2K_{ELB_3})\frac{V_3^2}{2g}$$

$$\therefore Q_1 = Q_4 = Q_2 + Q_3$$

$$\sqrt{\frac{2g\Delta P}{\gamma(K_{VALVE_2} + 2K_{ELB_2})}} = V_2 \rightarrow \text{constant}$$

$$\sqrt{\frac{2g\Delta P}{\gamma(K_{VALVE_3} + 2K_{ELB_3})}} = V_3 \rightarrow \text{constant}$$

$Q_4 = Q_2 + Q_3 \rightarrow V_4 A_1 = V_2 A_2 + V_3 A_3 \rightarrow$ Don't know A_1, must iterate

Iterations done in Excel.

Iterations converge to $q_1 = 0.16359$ ft^3/s

For valve on branch 2, when it is closed,

$$q_1 = 0.038 \ ft^3/s$$