Fluid Mechanics - Homework #3.1

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This week we learned about series pipeline flows and how to apply Bernoulli's equation to them. We learned a general approach to the problems that will solve any series fluid problem and learned about several classes of problems involving finding flow rate, pipe diameter, K of a valve, and pipe length. As a class, we learned how to iterate to find these variables when guessing some of them, and make the iteration converge towards an answer. We also went over using the energy equation, identifying laminar and turbulent flow, and finding the friction losses in pipes and fitting. Due to the numerous real-world systems using different elements, we had to learn how to combine these using calculations (elbows, enlargements, reductions etc). Each valve, fitting, or change in the size or direction of the flow path causes energy losses in the system.

11.5 Oil is flowing at the rate $0.015\ m^3/s$ in the system. Data for the system are as follows:

$\gamma_{oil} = 8.80\ kN/m^3$ $\rho_{oil} = 897\ kg/m^3$

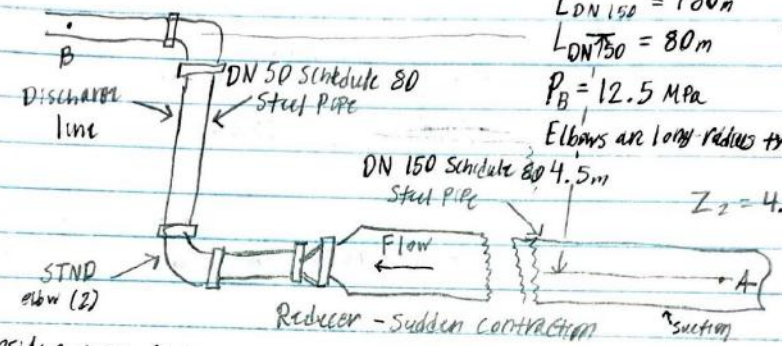
$\nu_{oil} = 2.12 \times 10^{-5}\ m^2/s$ $\eta = 1.902 \times 10^{-2}\ Ns/m^2$

$L_{DN\,150} = 180\ m$

$L_{DN\,150} = 80\ m$ $D_d = 0.0492\ m$

$P_B = 12.5\ MPa$ $D_s = 0.1463\ m$

Elbows are long radius type



$Q = 0.015\ m^3/s$

$A_{150} = 1.682 \times 10^{-2}\ m^2$

$A_{50} = 1.905 \times 10^{-3}\ m^2$

Consider all pipe friction and minor losses, calculate the pressure at A.

$$\frac{P_1}{\gamma} + Z_1 + \frac{V_1^2}{2g} - h_L = \frac{P_2}{\gamma} + Z_2 + \frac{V_2^2}{2g}$$

$$\frac{P_1}{\gamma} + Z_1 - h_L = \frac{P_2}{\gamma} + Z_2$$

$$\frac{P_A}{\gamma} = \frac{P_B}{\gamma} + Z_2 - Z_1 + h_L$$

$V_s = \frac{0.015\ m^3}{s} \times \frac{1}{1.682 \times 10^{-2}\ m^2} = 0.892\ m/s$

$V_d = \frac{0.015\ m^3}{s} \times \frac{1}{1.905 \times 10^{-3}\ m^2} = 7.87\ m/s$

$\frac{V_s^2}{2g} = \frac{(0.892\ m/s)^2}{2(9.81\ m/s^2)} = 0.041\ m$ $\frac{V_d^2}{2g} = \frac{(7.87\ m/s)^2}{2(9.81\ m/s^2)} = 3.16\ m$

$$N_{R_s} = \frac{(2.12 \times 10^{-5}\ m^2/s)(0.1463\ m)(897)}{1.902 \times 10^{-2}\ Ns/m^2} = 14627.23091$$

$D_s/\varepsilon = 0.1463/(4.6 \times 10^{-5}) = 3180.43$

$f_s = 0.0287$

$$N_{R_D} = \frac{(2.12 \times 10^{-5}\ m^2/s)(0.0492\ m)(897)}{1.902 \times 10^{-2}\ Ns/m^2} = 4919.06877$$

$D_D/\varepsilon = 0.0492/(4.6 \times 10^{-5}) = 1069.57$

$f_D = 0.0388$

Suction

$$h_1 = (0.0287)\left(\frac{180\ m}{0.1463\ m}\right)(0.041\ m) = 1.45\ m$$

elbows

$$h_2 = 2(f_{DT}) \times \frac{L_e}{D} \times \frac{V_d^2}{2g} = (2)(0.015)(20)(3.16\ m) = 2.844\ m$$

discharge

$h_4 = f_d \times \frac{L}{D} \times \frac{V_d^2}{2g} = (0.0388) \times \left(\frac{80m}{0.0492m}\right) \times (3.16m) = 199.36m$

exit loss

$h_5 = 1.0\left(\frac{V_d^2}{2g}\right) = (1.0) \times (3.16m) = 3.16m$

reducer

Sudden contraction

$K_3 = 0.5\left(1 - \frac{d_2^2}{d_5^2}\right) = 0.5\left(1 - \frac{0.0492^2}{0.1463^2}\right) = 0.443$

$h_3 = K_3(V_5^2/2g) = 0.443(0.041m) = 0.0182m$

$h_L = h_1 + h_2 + h_3 + h_4 + h_5$

$= 1.45m + 2.84m + 0.0182m + 199.36m + 3.16m$

$= 206.83m$

$\frac{P_A}{\gamma} = \frac{P_B}{\gamma} + Z_B - Z_A + h_L$

$P_A = \left(12.5\ MPa \times \frac{1000\ KN/m^2}{1\ MPa}\right) + 4.5m + 206.83m$

$P_A = 12.7\ MPa$

HW 11-13

Determine the velocity of flow from the nozzle if the pressure at the bottom is 20 and 80 psig

f = .026

$N_R = \frac{V_2 D}{\nu} \rightarrow$

P = 20180 = 2880 lb/ft and 11520 lb/ft

K = 0.15

$D_1 = .25 = .02$ ft

$T_L = 20.0$

$D_2 = .5 = .041$ ft

T = 100°F ν of water @ 100° = 955 = 598

$\frac{D}{\varepsilon} = \frac{0.041}{1.5 \times 10^{-4}} \cdot u = 277.7$

$h_L = \left(\frac{P_A - P_B}{\gamma}\right) + \left(\frac{V_A^2}{2g} - \frac{V_B^2}{2g}\right) + Z_A + Z_B$

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

$\frac{\pi}{4}(0.041)^2$

$A = .00132$

$h_L = \left(\frac{2880}{598}\right) + (-18)$ $h_L = \left(\frac{11520}{598}\right) + (18)$

$h_L = 30.161$ $h_L = 174.64$

$Q = \sqrt{\frac{2g\left(\frac{P_A - P_B}{\gamma} + Z_A - Z_B \text{ or } h_L\right)}{f\left(\frac{L}{D}\right)\frac{1}{D^2} + (K)\frac{1}{D^2} + \frac{1}{A_2^2} - \frac{1}{A_1^2}}}$

$Q_1 = .045$ and $.091$

$V = \frac{Q}{A}$ $\frac{.045}{.00132}$ $\frac{.091}{.00132}$

$V = 34.1$ ft/s @ 2 psig and $V = 68.9$ ft/s

$\sqrt{30.161}$ and $\sqrt{174.64}$

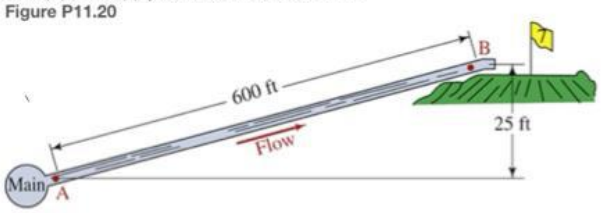
$\frac{0.0168(8)(18)}{(32.2)}\frac{1}{(0.041)^2} + (0.5)\frac{18}{32.2}\left(\frac{1}{0.041^2}\right)$

11.20

11.20

11.20 **Figure P11.20** shows a pipe delivering water to the putting green on a golf course. The pressure in the main is at 80 psig and it is necessary to maintain a minimum of 60 psig at point B to adequately supply a sprinkler system. Specify the required size of Schedule 40 steel pipe to supply $0.50\ \text{ft}^3$ of water at 60°F.

Figure P11.20



$$h_L = \frac{\Delta P}{\gamma} + \Delta z \rightarrow \frac{\left(20\frac{lb}{in^2}\right)\left(144\frac{in^2}{ft^2}\right)}{\left(62.4\frac{lb}{ft^3}\right)} + 25\,ft$$

$$h_L = 71.15\,ft$$

$$D = 0.66\left[\varepsilon^{1.25}\left(\frac{LQ^2}{gh_L}\right)^{4.75} + \nu Q^{9.4}\left(\frac{L}{gh_L}\right)^{5.2}\right]^{0.04}$$

$h_L = 71.15\,ft \quad \nu = 1.21\times10^{-5}\,ft^2/s \quad Q = 0.50\frac{ft^3}{s}$

$\varepsilon = 1.5\times10^{-4}\,ft \quad L = 600\,ft$

$$D = 0.66\left[(1.5\times10^{-4})^{1.25}\left(\frac{(600)(0.5)^2}{(32.2)(71.15)}\right)^{4.75} + (1.21\times10^{-5})(0.50)^{9.4}\left(\frac{600}{(32.2)(71.15)}\right)^{5.2}\right]^{0.04}$$

$D = 0.389\,ft$

Diameter must be larger than 0.389 ft or 4.67 in.

The recommended minimum Schedule 40 pipe is 5 in diameter

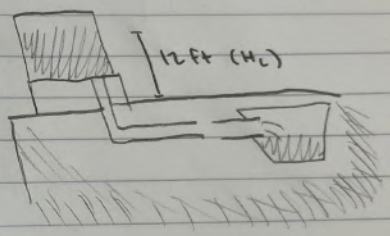
11-22

11-22

Determine the size of new pipe to carry 400 gal/min through system

$L = 75$ ft $Q = 400$ gpm $= 0.89$ ft^3/s

$k_{elbow} = 0.75$ $k_{valve} = 6$ (table)



$$H_{L\,elbow} = \frac{0.75V^2}{2g}$$

$$H_{L\,valve} = \frac{6V^2}{2g}$$

$$H_{total} = 12 - \frac{0.75V^2}{2g} - \frac{3V^2}{g}$$

$$V = \sqrt{2gH_{total}} = \frac{V^2}{2g} = 12 - \frac{0.75V^2}{2g} - \frac{3V^2}{g}$$

$$\therefore V = \sqrt{\frac{12 \times 2 \times 32.2}{7.75}} = 9.98 \text{ ft/s}$$

$Q = AV$ $\therefore$ $0.89 = \frac{\pi}{4} \times D^2 \times 9.98$

$D^2 = 0.11$

$D = 0.33' = \boxed{3.69 \text{ in}}$

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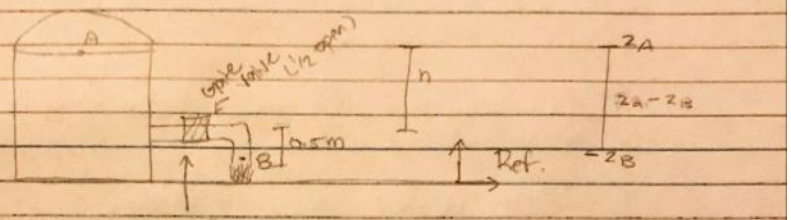
Home work 3.1 - Fluid Mechanics

11.23



DN 90 Schedule 40 steel pipe

Notes: Problem statement says Q = 1500 L/min, $h_{L\,fric.} = 0$, T = 25°C, $\gamma_{Oil} = 0.68$, consider minor losses.

Given Q, D, A therefore solve for h. I will use Bernoulli's after my reference is set.

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

$$\frac{P_B - P_A}{\gamma} + \frac{V_B^2 - V_A^2}{2g} + z_B - z_A = h_L$$

$V_A = 0$, $V_B = 0.025\ m^3/s$, $z_A = 0.5 + h$ [m], $z_B = 0$, $P_A = 1$, $P_B = 101.325$ kPa

$$\frac{P_B - P_A}{\gamma} + \frac{(0.025\ m^3/s)^2}{2g} + 0.5 + h = h_L$$

$$h_L = h_{EIB} + h_{VALVE} + h_{EH}$$

$$h_L = K_{EIB}\frac{V_B^2}{2g} + K_{VALVE}\frac{V_B^2}{2g} + K_{SQ}\frac{V_B^2}{2g}$$

$$\frac{V_B^2}{2g} + 0.5 + h = \frac{V_B^2}{2g}(K_{EIB} + K_{VALVE} + K_{SQ})$$

$$\frac{V_B^2}{2g} + 0.5 + h = \frac{V_B^2}{2g}\left(K_{EIB} + K_{valve} + K_{EXIT}\right)$$

$$\frac{2g}{V_B^2}\left(\frac{V_B^2}{2g} + 0.5 + h\right) - K_{EIB} - K_{EXIT} = K_{valve}$$

$$\frac{g}{V_B^2} + h - K_{EIB} - K_{EXIT} = K_{valve}$$

$$K_{valve} = \frac{gA}{Q} + h - K_{EIB} - K_{EXIT}$$

$$K_{valve} = \frac{g\frac{\pi D^2}{4}}{Q} + h - K_{EIB} - K_{EXIT}$$

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

$A = \pi r^2$

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