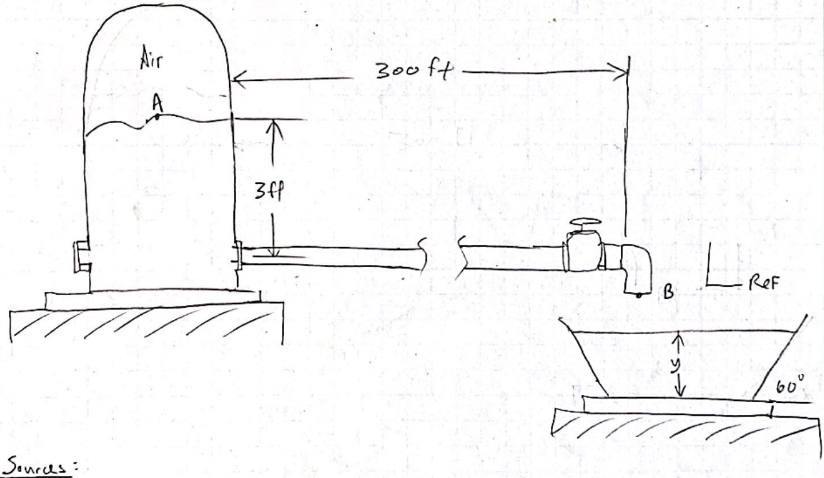
Purpose :

(a) Calculate for the water depth (y) in the open channel.
(b) Calculate for the total horizontal & Vertical forces in the whole system pipe elbow.
(c) Determine what is the largest hickory wood log can the open channel carry and if it is stable.
(d) using the flow nozzle detemine the pressure drop arcoss the nozzle.
(e) Determine the pressure increment if the valve in the pipe suddenly closes and if there any change of cavitation in the system.
(f) Determine the largest Drag force the log would experience if it stuck to the bottom of the channel.
(g) Compulte the force acting upon the blind flange at the left side of the tank and point out the location of the force.

Drawing :



Sources :

Mott, R., and Untener, J. Applied Fluid Mechanics 7th Edition. 2015.

Design Consideration:

Incompressible fluid
Isothermal process
Steady State

Data & Variable :

$1\frac{1}{2}$ in Schedule 40 steel pipe
- Flow Area = $0.01414\ ft^2$
- Inside diameter : $0.1342\ ft$
- Wall thickness = 0.145 in

Modulus of elasticity of steel = 200GPa

$I_c = \frac{\pi d^4}{32}$, $A = \pi r^2$

$E_o = 2179\ MPa$

flow rate 75 gpm

Water 60°F

$\gamma_w = 62.4\ lb/ft^3$

$\rho_{water} = 1.94\ slug/ft^3$

Wood density = $830\ kg/m^3$

$\beta = 0.5$ ratio.

Procedure :

(a). For this question I will use the open channel equation to solve for the depth y.

(b) This question I will use Force equation to solve for horizontal & vertical forces. To do that we need to solve for velocity and pressure before plugging everything into Force equation.

(c) This question I will slove for largest log the open channel can carry using the Buoyancy Force equation. Then using $y_{mc} = y_{cb} + MB$ to determine if it is stable.

(d) In this question I will use $V_1 = C\sqrt{\frac{2g(P_1-P_2)/\gamma}{(A_1/A_2)^2-1}}$ to solve for $P_1 - P_2 = \Delta P$

(e) In this question I will use $\Delta P = \rho c v$ to solve for pressure increment and use $c = \frac{\sqrt{E_o/\rho}}{\sqrt{1+\frac{E_o D}{E\delta}}}$ to Find c.

(f) This question I will slove by using drag force equation. using the half size of the largest wood found from question c.

(g) For this question first I will solve for pressure at the centroid of area and area. Next we can use the two results to solve force at flange. For the force location I will use $h_p = h_c + \frac{I_c}{h_c \cdot A}$ to solve for location of the force.

Calculation:

(a)

Book:

Area $= 1.73y^2$

$WP = 3.46y$

$R = y/2$

$n = 0.017$

Given:

Open slope $= 0.1\% = 0.001$

Flow rate $= Q = 75$ gpm

$$Q = 75\,\text{gal/min}\left(\frac{0.1337\,ft^3}{1\,gal}\right)\left(\frac{1\,min}{sec}\right) = 0.167\,ft^3/s$$

$$\frac{nQ}{1.49\,S^{1/2}} = AR^{2/3}$$

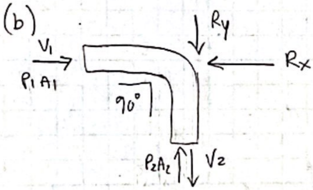
$$\frac{(0.017)(0.167\,ft^3/s)}{(1.49)(0.001)^{1/2}} = (1.73y^2)(y/2)^{2/3}$$

* Plug in the equation above into excel to solve for y

From excel 0.5 ft : 0.060253 = 0.171638 which is 1.85% diff

$$\boxed{y = 0.5\,ft}$$

(b)



$$V = \frac{Q}{A} = \frac{0.167\,ft^3/s}{0.01414\,ft^2} = 11.81\,ft/s$$

$\rho = 1.94$ slug/ft^3 , $D = 0.1342$ ft

Need to find pressure.. from drawing find pressure at point B.

$R_x = \rho Q V_1 + P_1 A_1$

$R_y = \rho Q (V_2 - V_1)$

$$\frac{P_A}{\gamma_W} + \cancel{\frac{V_A^2}{2g}}^{\,0} + z_A - h_L = \cancel{\frac{P_B}{\gamma_W}}^{\,0} + z_B + \frac{V_B^2}{2g}$$

$$P_A = \left(z_B - z_A + \frac{V_B^2}{2g} + h_{L_{A-B}}\right)\gamma_W$$

$$h_{L_{A-B}} = h_L + h_{L\,valve} + h_{L\,elbow}$$

$$h_L = f\,\frac{L}{D}\,\frac{v^2}{2g}$$

$$N_R = \frac{vD}{\nu_s} = \frac{(11.81\,ft/s)(0.1342\,ft)}{(1.21\times10^{-5}\,ft^2/s)} = 1.31\times10^5$$

(b) Con't

$$\frac{D}{\varepsilon} = \frac{0.1342}{1.5\times10^{-4}} = 894.7$$

$$h_L = (0.022)\left(\frac{300\ ft}{0.1342 ft}\right)\left(\frac{(11.81\ ft/s)^2}{(2)(32.2\ ft/s^2)}\right) = 106.51\ ft$$

$$h_{L\,Valve} = K\frac{V^2}{2g} = (8)(0.019)\left(\frac{(11.81\ ft/s)^2}{(2)(32.2\ ft/s^2)}\right) = 0.325\ ft$$

$$h_{L\,elbow} = K\frac{V^2}{2g} = (30)(0.021)\left(\frac{(11.81\ ft/s)^2}{(2)(32.2\ ft/s^2)}\right) = 1.367\ ft$$

$$h_{L_{A-B}} = 106.51\ ft + 0.325\ ft + 1.367\ ft = 108.2\ ft$$

$$P_A = \left(z_B - z_A + \frac{V_B^2}{2g} + h_{L_{A-B}}\right)\gamma_W$$

$$P_A = \left(0 - 3ft + \frac{(11.81\ ft/s)^2}{(2)(32.2 ft/s^2)} + 108.2\ ft\right)(62.4\ lb/ft^3)$$

$$P_A = 6699.89\ lb/ft^2\left(\frac{1\ ft^2}{144 in^2}\right) = 46.5\ psi$$

(b) Cont Next Sheet.

(b) Con't

$V_A = V_1 = 0$

$R_x = \rho Q V_1 + P_1 A_1$

$= (1.94\ slug/ft^3)(0.167\ ft^3/s)(0) + (6699.89\ lb/ft^2)(0.01414\ ft^2)$

$\boxed{R_x = 97.74\ lb}$

$R_y = \rho Q (V_2 - V_1)$

$= (1.94\ slug/ft^3)(0.167\ ft^3)(11.81 - 0)$

$= 3.83\ slug \left(\frac{32.2\ lb}{1\ slug}\right)$

$\boxed{R_y = 123.20\ lb}$

(c)

$W = F_b$

$W - F_b = 0$

$\gamma_{Lg} V_{Log} - \gamma_W V_d = 0$

$\gamma_{Log} x^2 L - \gamma_w (y)(x)(L) = 0$

$\gamma_{Log} x - \gamma_w y = 0$

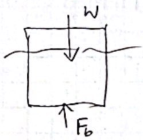
$\frac{\gamma_{Log} x}{\gamma_{Log}} = \frac{\gamma_w y}{\gamma_{Log}}$

y = depth from (a) $= 0.5\ ft \times \frac{1 m}{3.28 ft}$

$y = 0.152 m$

$\gamma_W = 1000\ Kg/m^3$

$\gamma_L = 830\ Kg/m^3$



$x = \frac{\gamma_w y}{\gamma_{Log}} = \frac{1000\ Kg/m^3 (0.152 m)}{830\ Kg/m^3} = 0.183\ m \times \frac{3.28 ft}{1 m}$

$\boxed{x = 0.60\ ft}$

$I = \frac{bh^3}{12} = \frac{(0.5 ft)(0.5 ft)^3}{12} = 5.2 \times 10^{-3}\ ft^3$

$V_d = (0.5 ft)^2 (0.60 ft) = 0.15\ ft^3$

$MB = I / V_d = \frac{5.2 \times 10^{-3}\ ft^3}{0.15\ ft^3} = 0.035$

$y_{cb} = x/2 = 0.60 ft/2 = 0.30 ft$

$y_{mc} = y_{cb} + MB$

$= 0.30 ft + 0.035$

$= 0.335\ ft$

$\boxed{0.335 ft > y_{cd} \text{ making it stable}}$

(d)

From previous question we know that :

$\phi_{nozzle} = 0.5(1.5in) = 0.75 in = 0.0625 ft$

$V = 11.81 ft/s$

Flow $A = A_1 = 0.01414 ft^2$

$\beta = 0.5$, $60°F = 1.21 \times 10^{-5} ft^2/s$

Inside $D = 0.1342 ft$

$$V_1 = C\sqrt{\frac{2g(p_1-p_2)/\gamma_w}{(A_1/A_2)^2 - 1}}$$

$$A_2 = \frac{\pi(0.0625 ft)^2}{4} = 0.0031 ft^2$$

We are solving for $(p_1 - p_2) = \Delta p$

$$\Delta p = \left(\frac{V_1}{C}\right)^2\left(\left(\frac{A_1}{A_2}\right)^2 - 1\right)\left(\frac{\gamma}{2g}\right)$$

$$C = 0.9975 - 6.53\sqrt{\beta/N_R}$$

$$N_R = \frac{V_1 D}{Vis} = \frac{(11.81 \cancel{ft/s})(0.1342 \cancel{ft})}{(1.21 \times 10^{-5} \cancel{ft^2/s})} = 1.31 \times 10^5$$

$$C = 0.9975 - 6.53\sqrt{0.5/1.31 \times 10^5} = 0.9847$$

$$\Delta p = \left(\frac{(11.81 ft/s)}{0.9847}\right)^2\left[\left(\frac{0.01414 ft^2}{0.0031 ft^2}\right)^2 - 1\right]\left(\frac{62.4 lb/ft^3}{(2)(32.2 ft/s^2)}\right)$$

$$\Delta p = (143.84 ft^2/s^2)(20.81 - 1)(0.9689 lb ft/s^2)$$

$$\Delta p = 2760.85 lb/ft^2 \times \left(\frac{1 ft^2}{144 in^2}\right)$$

$$\boxed{\Delta p = 19.17 psi}$$

(e) $\Delta p = \rho C V$

$$C = \frac{\sqrt{E_0/\rho}}{\sqrt{1+\frac{E_0 D}{E \delta}}}$$

$\rho_w = 1000\ kg/m^3$ $\quad V_1 = 11.81\ ft/s \times \frac{1m}{3.28ft}$

$V_1 = 3.6\ m/s$

$D = 1.5\ in \times \frac{1m}{39.4\ in}$

$D = 0.038\ m$

thickness $= 0.145\ in \times \frac{1m}{39.4in}$

$\delta = 0.0037\ m$

$E_0 = 2179\ MPa \times \frac{1\ Pa}{1000\ MPa}$

$= 2.179\ pa$

$= 2.179\ kg/ms^2$

$E = 200\ GPa \times \frac{1\ pa}{1\times 10^{-9}\ GPa} = 2\times10^{11}\ pa = 2\times10^{11}\ kg/ms^2$

Plus everything in for C $= \dfrac{\sqrt{\dfrac{2.179\ kg/ms^2}{1000\ kg/m^3}}}{\sqrt{1+\dfrac{(2.179\ kg/ms^2)(0.038m)}{(2\times10^{11}\ kg/ms^2)(0.0037m)}}}$

$C = \frac{0.04668}{1}$

$C = 0.04668$

$\Delta p = \rho C V = (1000\ kg/m^3)(0.04668\ m/s^2)(3.6\ m/s)$

$\Delta p = 168.048\ kg/ms^2$ or $\boxed{168.05\ pa}$

(f) largest log $= 0.60\text{ ft}/2 = 0.30\text{ ft}$ $\quad y = 0.5\text{ ft}$

Drag Force $= \quad F_D = C_D\left(\frac{1}{2}\rho v^2\right)A$

Area of the open channel $= 1.73y^2 = 1.73(0.5\text{ ft})^2 = 0.433\text{ ft}^2$

$V = \frac{Q}{A} = \frac{0.167\text{ ft}^3/\text{s}}{0.433\text{ ft}^2} = 0.386\text{ ft/s}$

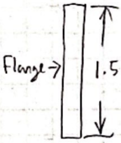
$C_D = 1.16$ from Table 17.1

$F_D = (1.16)\left(\frac{1}{2}\,62.4\text{ lb/ft}^3\,(0.386\text{ ft/s})^2\right)(0.433\text{ ft}^2)$

$F_D = (1.16)(4.649)(0.433)$

$\boxed{F_D = 2.34\text{ lb}}$

(g)



$r = 1.5/2 = 0.75\text{ in} \times \left(\frac{1\text{ ft}}{12\text{ in}}\right) = 0.0625\text{ ft} \times 2 = D = 0.125\text{ ft}$

$A = \pi r^2 = \pi(0.0625\text{ ft})^2 = 0.0123\text{ ft}^2$

$F = PA \qquad P = P_{air} + \gamma h_c$

$P = (6699.89\text{ lb/ft}^2) + (62.4\text{ lb/ft}^3)(3\text{ ft})$

$P = 6887.09\text{ lb/ft}^2$

$F = (6887.09\text{ lb/ft}^2)(0.0123\text{ ft}^2) = \boxed{84.71\text{ lb}}$

$h_p = h_c + \frac{I_c}{h_c \cdot A}$ $\qquad I_c = \frac{\pi d^4}{32} = \frac{\pi(0.125\text{ ft})^4}{32} = 2.39\times10^{-5}\text{ ft}^4$

$h_p = 3\text{ ft} + \frac{(2.39\times10^{-5}\text{ ft}^4)}{(3\text{ ft})(0.0123\text{ ft}^2)}$

$\boxed{h_p = 3.0006\text{ ft}}$

Summary :

(a). The Water depth (y) is 0.5 ft

(b) The horizontal force is 93.24 lb & Vertical force is 123.20 lb

(c). The largest side log is 0.60ft and ymc is greater than ycd making the log stable

(d) The pressure drop at nozzle is 19.17 psi

(e) pressure increment is 168.05 pa

(f) The drag force is 2.34 lb

(g) Force at Flange is 83.41 lb and the force location is at 3.0006 ft below the water line.

Material : water
hickory Wood

Analysis :

From the open channel and the log in this case It barely floating. We know that the log can't be bigger than the width of the channel. So when when solving for f we assume the log was half the size which allow better Flow.