MET330 Fluid Mechanics

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Test 2

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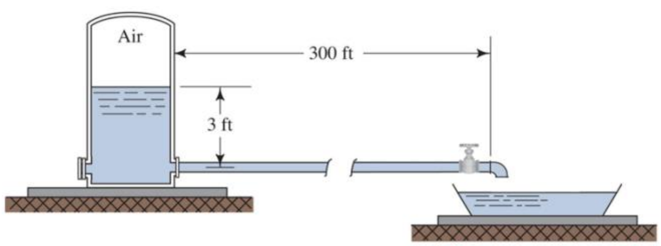
Purpose

Finish the previous engineers design of a pipe system, that delivers water to an open channel. Follow the steps below:

1) Compute the water depth in the trapezoid open channel and the total horizontal and vertical forces in the whole pipe system.
2) Determine the largest wood log the open channel can carry and prove that it is stable using equations.
3) Calculate the pressure drop across a flow nozzle.
4) Determine the pressure increments after a sudden valve close and if there is any chance of cavitation in the system.
5) Calculate the drag force experienced by a log half the size of the one in part '2'.
6) Compute the force acting upon the blind flange and determine where the force is located.

Diagrams



Sources

- Mott R. & Untener J. Applied Fluid Mechanics. 7th Edition. Pearson. 2014
- Lecture Notes

Design Considerations

- 1 ½ Schedule 40 steel pipe
- Pressurized storage tank to an trapezoidal Open channel
- Incompressible Fluids
- Constant Properties

Data and Variables

T =	60	F
Q =	75	gpm
L =	300	ft
Elasticity=	200	Gpa
p =	830	kg/m^3

Materials

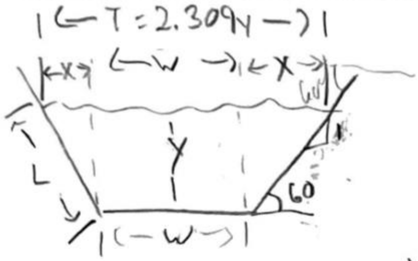
- H20
- Hickory wood logs
- Schedule 40 steel pipe

Procedure

a. Compute the depth of water for the open channel by using the AR equation, insert this equation into excel and iterate values of h to find the correct y value.
b. Find the force in the elbows, then compute for the pressure at point 1. Solve for the force in the straight pipe section giving the total vertical and horizontal forces of each part.
c. Use buoyancy equations to find the different values on the log, this allows me to find the maximum width of the log for it to remain stable.
d. Use the flow nozzle equation presented in class to find the area of the flow nozzle.
e. Compute for the Force on the value and Pressure change when the valve is shut suddenly by first finding C value.
f. Divide the maximum log size found in part c and solve for the drag force using the equation.
g. Determine the fluid force and position of the force. Then solve for the force acting upon the blind flange on the left hand side of the tank.

Calculations

a.



$A = W \cdot Y + X \cdot Y$

$WP = W + 2L$

$R = A/WP$

$S = 0.001 = 0.1\%$ Slope

$n = 0.017$

* Table 14.1 *

$T = W + 2zY$

Channel Slope

$A = (W + 2y)y$

$WP = W + 2y\sqrt{1+z^2}$

$R = \dfrac{(W+2y)y}{W + 2y\sqrt{1+z^2}}$

$T = 2.309Y$

1) Pick Geometry
2) Pick Material
3) Pick Typical Slope

$Q = 75\ gpm$

$Q = \left(\dfrac{1.49}{n}\right) A R^{2/3} S^{1/2}$

$S = \left(\dfrac{Qn}{1.49 A R^{2/3}}\right)$

$Q = 75\ gpm = 0.167\ ft^3/s$

$L = \sqrt{x^2 + y^2}$

$AR^{2/3} = \dfrac{nQ}{1.49 S^{1/2}} \Rightarrow AR^{2/3} = \dfrac{0.017(0.167\ ft^3/s)}{1.49 \cdot (0.001)^{1/2}} = 0.06025$

Excel Equation to find AR

$\dfrac{h}{2}\left(\dfrac{1}{2}\dfrac{h}{h+\sqrt{1+h^2}}\right)^{2/3} = 0.06025$

$Y = 0.4397\ ft$ (0.01% diff)

Analysis

I started by drawing a FBD of the trapezoid open channel to determine values I had and needed to find. Using equations found in the book and lecture I was able to compute for ‘AR’ which allowed me to input values of ‘h’ into excel.
I have shown the excel cells below, and attach the file with my submission.

Excel

RHS=	0.06025	
h (ft)	LHS	% diff
0.5	0.071985	19.48%
0.6	0.092012	52.72%
0.4	0.052738	-12.47%
0.3	0.034771	-42.29%
0.45	0.062238	3.30%
0.47	0.06611	9.73%
0.43	0.058405	-3.06%
0.42	0.056504	-6.22%
0.44	0.060316	0.11%
0.441	0.060508	0.43%
0.44	0.060316	0.11%
0.43	0.058405	-3.06%
0.439	0.060125	-0.21%
0.4399	0.060297	0.08%
0.43995	0.060307	0.09%
0.4397	0.060259	0.01%

The water height 0.4397 has a % difference of 0.01% making it close enough.

b.

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

$D: 1.61 = 0.134\ ft$

$Q = 75\ GPM = 0.167\ ft^3/s$

$\rho_w = 1.94\ lb \cdot s^2$

FBD

$V = \frac{Q}{\pi/4 \cdot D^2} = \frac{0.167\ ft^3/s}{\pi/4 \cdot (0.134)^2\ ft} = 11.842\ ft/s^2$

$V_1 = V_2$

$V_1 = 11.842\ ft/s^2$

$A = \frac{\pi}{4}(0.134)^2 = \underline{0.0141\ ft}$ *Area of Pipe*

Forces in x direction

$F_x = \rho Q V_1 = 1.94\ l \cdot s^2 \times 0.167\ ft^3/s \times 11.842\ ft/s^2$

$\underline{F_x = 3.837\ lb}$

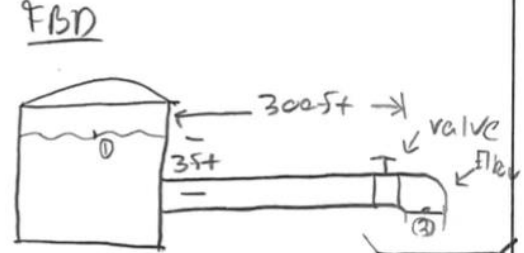
$F_y = \rho Q (V_2 - 0) = 1.94 \times 0.167\ (11.842\ ft/s^2)$

$F_y = 3.837\ lb$

"R_x"

$R_x = \rho Q V_1 + P_1 A_1$

FBD



Solve for Pressure at ①

$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_L$ (gage)

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

$\Rightarrow \frac{P_1}{\gamma} + z_1 = \frac{V_2^2}{2g} + f \frac{L}{D} \frac{V^2}{2g}$

$\gamma_{water} = 62.4\ lb$

$g = 32.17\ ft/s^2$

$\Rightarrow \frac{P_1}{62.4\ lb} + 3\ ft = \frac{(11.842\ ft/s^2)^2}{2 \times 32.2} + f\left(\frac{300\ ft}{0.134}\right)\left(\frac{(11.842\ ft/s^2)^2}{2 \times 32.2}\right)$

solve for f

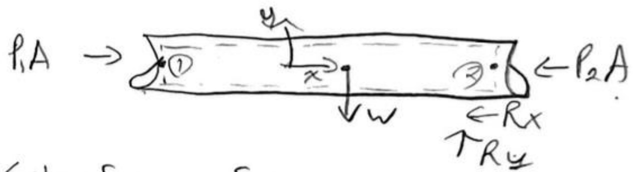
$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7(D/\varepsilon)} + \frac{5.74}{Re^{0.9}}\right)\right]^2} = \underline{0.02}$

$\nu_w = 1.21E\text{-}5\ ft^2/s$

solve for P

$P = 6032.76\ lbf/ft^3$ or $\underline{41.894\ psi}$

b) Calculate total horizontal and vertical forces in whole system pipe-elbow



Solve for x force

$P_1A - P_2A + R_x = 0$

$\Rightarrow R_x = (P_1 - P_2)A$

$R_x = (1032.7\ lbf/ft^2)\ 0.0141$ [illegible]

$R_x = 85.062\ lb$

Solve for y force

$R_y = W$

<u>Analysis</u>

In order to solve for the total horizontal and vertical forces we must first find the forces in the elbow. Rx and Ry are both the same amount since the velocity does not change.

After this, I use Bernoulli's to solve for pressure in order to solve for the horizontal forces (Rx) in the straight pipe.

The vertical force in the straight pipe is simply just the weight of water moving through the pipe.

c.

C.) $\gamma = 62.4\,lb/ft^3$

$L_{cb} + MB > L_{cg}$

$L_{cb} = \frac{0.4397\,ft}{2} = 219.85E\text{-}3$

$MB > L_{cg} - L_{cb}$ $\qquad MB > 0.4397\,ft$

$MB = \frac{I}{V_d}$ $\qquad I = \frac{l + W_{min}}{L_{cb}}$

we know the $W = 1.155y = 1.155(0.4397\,ft) = 507.85E\text{-}3\,ft$

max length of the Log is the 'w' of the open channel

$I = \frac{507.85E\text{-}3 + W_{min}^3}{219.85E\text{-}3}$

$V_d = W_{min} \cdot 507.85E\text{-}3\,ft \cdot 0.4397\,ft$

$\frac{I}{V_d} > 0.4397\,ft \implies \frac{\frac{507.85E\text{-}3 + W_{min}^3}{219.85E\text{-}3}}{W_{min} \cdot 507.85E\text{-}3 \cdot 0.4397\,ft} > 0.4397\,ft$

$\implies 10.3612\,W_{min}^3 > 0.4397\,ft$

$W_{min} > 0.206\,ft$

<u>Analysis</u>

I wrote down Wmin, however, The Wmax width of the hickory wood log is 0.206ft

d.

d.) $A_2 = \dfrac{A_1}{\sqrt[2]{\dfrac{2gh\left(\gamma_m/\gamma_w - 1\right)}{\left(\frac{Q}{A_1 \times C}\right)^2} + 1}}$ Assume C is 0.61

$\Rightarrow \dfrac{0.0141\,ft^2}{\sqrt[2]{\dfrac{2 \times (32.2)(0.132\,ft)\left(\dfrac{844.9\,lb/ft^3}{62.4\,lb/ft^3} - 1\right)}{\left(\dfrac{0.167\,ft^3/s}{0.0141\,ft^2 \times 0.61}\right)}}}$

$\Rightarrow \dfrac{0.0141\,ft^2}{\sqrt[2]{\dfrac{106.215}{52.196}}}$ $A_2 = 9.79\,E{-3}$

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

<u>Analysis</u>

I was unable to correctly solve for the pressure drop across the flow nozzle. I believe this equation gave me the area of the flow nozzle but I am not sure what to do next.

e.

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

e) $\delta = 0.145 \text{ in} = 0.00368 \text{M}$ $\quad D = 1.61 \text{ in} = 0.0408 \text{ M}$ $\quad E = 200 \text{ GPa} = 2E11 \text{ N/M}^2$ $\quad E_o = 316{,}000 \text{ psi} = 2.178 E9 \text{ N/M}^2$

$\rho = 1000 \text{ Kg/m}^3$

$$C = \frac{\sqrt{2.178E9 \text{ N/M}^2 / 1000 \text{ Kg/M}^3}}{\sqrt{1 + \frac{2.178E9 \text{ N/M}^2 \cdot 0.0408 \text{ M}}{2E11 \text{ N/M}^2 \cdot 0.00368 \text{ M}}}} = 1429.85$$

$F = \rho C A V$ $\qquad V = 11.842 \text{ ft/s}^2 = 3.609 \text{ m/s}^2$ $\qquad A = 0.0141 \text{ ft or } 0.00429$

$F = (1000 \text{ Kg/m}^3)(1429.85)(0.00429 \text{ m})(3.609 \text{ m/s}^2)$

$F = 22{,}137.81$ * Force on valve

$\Delta P = \rho C V$

$\Delta P = (1000 \text{ Kg/M}^3)(1429.85)(3.609 \text{ m/s}^2)$

$\Delta P = 5.16E6$

Analysis

Pressure caused from cavitation is 5.16E6 lb/ft, large enough to cause severe damage to the whole system.

f.

F.) Alog half the size $W = \frac{507.85E\text{-}3\,ft}{2} = 253.93E\text{-}3$

Drag force

$$F_D = C_D\left(\frac{\rho V^2}{2}\right)A$$

Drag coefficient for Square cylinder

$C_D = 1.60$

Area of a square

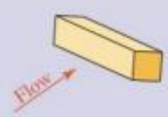
$A = 253.93\,E\text{-}3^2$

$A = 64.478E\text{-}3$

$$F_D = 1.60\left(\frac{1000\,kg/m^3 \times 11.842\,ft/s^2}{2}\right) \times 64.478E\text{-}3$$

$F_D = 610.83$ lb Max drag force

TABLE 17.1 Typical drag coefficients (*continued*)

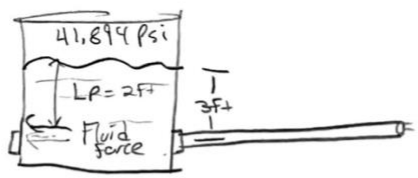
Shape of body	Orientation	C_D
Square cylinder Flow is perpendicular to the flat front face.		1.60
Semitubular cylinders		1.12

<u>Analysis</u>

Only the part of the log that is submerged is effect by drag force. Giving us the area of a square, this is used to calculate the Drag force. The drag force coefficient was found in Table 17.1.

g.

g.) FBD



$D = 0.134\,ft$

$A = 0.0141\,ft$

$\gamma_w = 62.4\,lb\,\cancel{ft}$

Solve for Fluid Force

$F_F = \gamma \times h_c \times A \qquad h_c = \frac{3ft}{2} = 1.5ft$

$F_F \times (3ft - L_p)ft = F_{Flange} \times 0.134ft$

$F_{Fluid} = 62.4\frac{lb}{ft} \times 1.5ft \times 0.0141ft$

$F_{Fluid} = \underline{1.319\ lb/ft}$

$L_p = \frac{2}{3} \times 3ft = \underline{2ft}$

$F_{Flange} = F_{Fluid} \cdot \frac{(3ft - 2ft)ft}{0.0141ft}$

$F_{Flange} = \underline{93.546\ lb}$

<u>Analysis</u>

The force on the blind Flange in 93.546 lb while the force is located at 2ft