

Homework 2.3

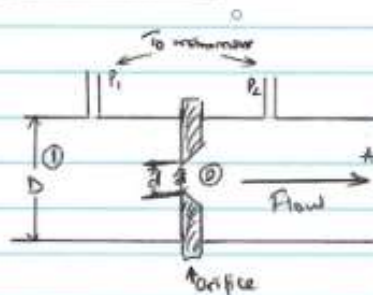
This week we learned about water hammer and cavitation. Water hammer is when water pressure builds against a closed valve and releases when the pressure backs up through the pipe and returns to the tank. It can be prevented by powering down pumps or closing valve slowly, or increasing diameter of the pipe. Cavitation is caused by low pressure in the pipe

system, and can be caused by air in the system. The equation $C = \frac{\sqrt{\frac{E_0}{l}}}{\sqrt{1 + \frac{E_0 * D}{E_s}}}$ is used to solve for the coefficient of the force of the water hammer.

Homework Problems

15.4

Problem 15.4



$$D = 10 \text{ in} = 0.833 \text{ ft}$$

$$Q = 25 \text{ gpm} = 0.0557 \text{ ft}^3/\text{s}$$

$$S_{\text{manometer}} = 0.83 \quad \gamma_{\text{man}} = 51.79 \text{ lb/ft}^3$$

$$\text{Dynamic viscosity} = 2.5 \times 10^{-6} \text{ lb-s/ft}^2$$

Calculate the deflection of a water manometer for orifice diameters a) 1.0 in b) 7.0 in

$$Q = C A_1 \sqrt{\frac{2gh[(\gamma/\gamma_f) - 1]}{(A_1/A_2)^2 - 1}}$$

To get the value of C , we need $d/D \Rightarrow$ Reynold's number

$$Q = VA : V = Q/A = 0.0557 \text{ ft}^3/\text{s} = 0.102 \text{ ft/s}$$

$$A_1 = \frac{\pi}{4} (0.833 \text{ ft})^2 = 0.545 \text{ ft}^2$$

$$Re = \frac{VD}{\mu} = \frac{0.102 \text{ ft/s} \times 0.833 \text{ ft} \times 51.79 \text{ lb/ft}^3}{2.5 \times 10^{-6} \text{ lb-s/ft}^2 \times 32.2 \text{ ft/s}^2} = 5.5 \times 10^4$$

$$A_{2,1} = \frac{\pi}{4} (1 \text{ in})^2 = 0.00545 \text{ ft}^2$$

$$\beta = d/D = \frac{1.0}{10} = 0.1 \quad \text{or} \quad \frac{7.0}{10} = 0.7$$

$$A_{2,2} = \frac{\pi}{4} (7 \text{ in})^2 = 0.458 \text{ ft}^2$$

$$C_1 = 0.595$$

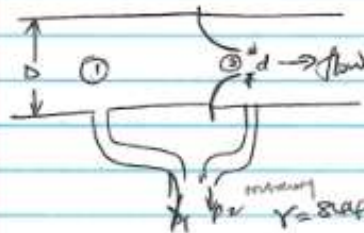
$$C_2 = 0.618$$

$$h = \frac{\left(\frac{Q}{A_1 C}\right)^2 \times \left[\left(\frac{A_1}{A_2}\right)^2 - 1\right]}{2g\left(\frac{\gamma}{\gamma_f} - 1\right)}$$

$$\text{for } d = 1.0 \text{ in} \quad h = \frac{\left(\frac{0.0557 \text{ ft}^3/\text{s}}{0.545 \text{ ft}^2 \times 0.595}\right)^2 \times \left[\left(\frac{0.545 \text{ ft}^2}{0.00545 \text{ ft}^2}\right)^2 - 1\right]}{2 \times 32.2 \text{ ft/s}^2 \times \left[\left(\frac{51.79 \text{ lb/ft}^3}{62.4 \text{ lb/ft}^3}\right) - 1\right]} \quad h_1 = 22.36 \text{ ft}$$

$$\text{for } d = 7.0 \text{ in} \quad h = \frac{\left(\frac{0.0557 \text{ ft}^3/\text{s}}{0.545 \text{ ft}^2 \times 0.618}\right)^2 \times \left[\left(\frac{0.545 \text{ ft}^2}{0.458 \text{ ft}^2}\right)^2 - 1\right]}{2 \times 32.2 \text{ ft/s}^2 \times \left[\left(\frac{51.79 \text{ lb/ft}^3}{62.4 \text{ lb/ft}^3}\right) - 1\right]} \quad h_2 = 0.008233 \text{ ft} = 0.01 \text{ in}$$

Problem 15.9



Linked oil $\rho = 0.930$, $\nu = 3.84 \times 10^{-4} \text{ ft}^2/\text{s}$

Range of flow

700 gal/min — 1000 gal/min

1.559 ft³/s 2.227 ft³/s

Range of manometer

0 in to 8 in

$D = 5 \text{ in inside} \rightarrow 4.805 \text{ in} = 0.404 \text{ ft}$

$A_1 = 0.1283 \text{ ft}^2$

$$Q = VA \quad V_1 = \frac{Q}{A_1} = \frac{2.227 \text{ ft}^3/\text{s}}{0.1283 \text{ ft}^2} \text{ — largest manometer deflection}$$

$$= 17.36 \text{ ft/s}$$

$$Q = VA \quad V_2 = \frac{Q}{A_2}$$

$$= \frac{1.559 \text{ ft}^3/\text{s}}{0.1283 \text{ ft}^2}$$

$$\text{Reynolds number } Re = \frac{V_1 D}{\nu} = \frac{17.36 \text{ ft/s} \times 0.404 \text{ ft}}{3.84 \times 10^{-4} \text{ ft}^2/\text{s}}$$

$$= 1.826 \times 10^4$$

$$V = 12.15 \text{ ft/s}$$

$$Re = \frac{V D}{\nu}$$

$$= \frac{12.15 \text{ ft/s} \times 0.404 \text{ ft}}{3.84 \times 10^{-4} \text{ ft}^2/\text{s}}$$

$$= 1.278 \times 10^4$$

Use the flow nozzle coefficient chart

$$C \approx 0.96$$

Use the formula $C = 0.955$

$$C_{mi} = 0.955$$

$$A = Re \left(\frac{0.955}{6.33} \right)^2$$

for $C = 0.96$,

for $C = 0.955$

$$A_2 = \frac{A_1}{\sqrt{\frac{2.34 \left(\frac{1}{C} - 1 \right)}{\left(\frac{Q}{A_1 C} \right)^2} + 1}} = \frac{0.1283 \text{ ft}^2}{\sqrt{\frac{2.34 \left(\frac{1}{0.96} - 1 \right)}{\left(\frac{2.227 \text{ ft}^3/\text{s}}{0.1283 \times 0.96} \right)^2} + 1}}$$

$$A_2 = \frac{0.1283}{\sqrt{\frac{2.34 \left(\frac{1}{0.955} - 1 \right)}{\left(\frac{2.227 \text{ ft}^3/\text{s}}{0.1283 \times 0.955} \right)^2} + 1}}$$

$$A_2 = 0.0768 \text{ ft}^2$$

$$A_2 = 0.077 \text{ ft}^2$$

$$d_2 = \sqrt{\frac{0.0768 \times 4}{\pi}}$$

$$d = 0.3132 \text{ ft}$$

$$= 0.3127 \text{ ft}$$

$$= 3.75 \text{ in.}$$

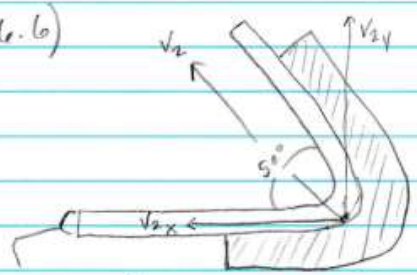
$$= 3.75 \text{ in.}$$

nozzle diameter = 3.75 in.

15.15

15.15 $T = 50^\circ\text{C}$ $h = 0.24\text{m} = 0.008096\text{m}$
 $\gamma_{\text{water}} = 9.69\text{ kN/m}^3$ $\gamma_{\text{air}} = 1.092\text{ kN/m}^3$
 $V_1 = \sqrt{2(9.81)(0.008096)(9.69 - 1.092)/1.092} = 0.97\text{ m/s}$

16.6

16.6)  $T = 170^\circ\text{F}$ $\theta = 130^\circ$
 $V_1 = 22\text{ ft/s}$
 $\rho = 1.883\text{ slugs/ft}^3$
 $Q = VA = (22)(0.0205) = 0.451\text{ ft}^3/\text{s}$
 $A = 2.95\text{ in}^2 = 0.0205\text{ ft}^2$
 $V_{2x} = V(\cos(180 - \theta)) = 22(\cos(50)) = 14.14\text{ ft/s}$
 $V_{2y} = V(\sin(180 - \theta)) = 22(\sin(50)) = 16.85\text{ ft/s}$
 $F_x = \rho Q(V_{2x} - V_{1x}) = (1.883)(0.451)(14.14 - (-22)) = \boxed{29.94\text{ lb}}$
 $F_y = \rho Q(V_{2y} - V_{1y}) = (1.883)(0.451)(16.85 - 0) = \boxed{13.96\text{ lb}}$

16.11

16.11 $Q = 100\text{ gal/min}$ $\text{Pipe} = 1\text{ in Schedule 40 Pipe}$
 $Q = 0.223\text{ ft}^3/\text{s}$ $\rho = 1.94\text{ slugs/ft}^3$ $A = 0.00499\text{ ft}^2$
 $V = \frac{0.223}{0.00499} = 44.689\text{ ft/s}$ $F = (1.94)(0.223)(44.689 - (-44.689)) = 38.667\text{ lb}$

16.20

16.20

$V_1 = 30 \text{ m/s}$ $D = 200 \text{ mm} = 0.2 \text{ m}$
 $Q = \frac{\pi}{4} \cdot 0.2^2 \cdot 30 = 0.9425 \text{ m}^3/\text{s}$ $A = 0.0314$
 $\rho = 1000 \text{ kg/m}^3$ $V_{out} = 12 \text{ m/s}$

$R'_x = (1000)(30)(0.9425)(1 + \cos 15) = 55586.553 \text{ N}$
 $R_y = (1000)(30)(0.9425)(0 + \sin 15) = 4988.737 \text{ N}$

$V_x = 30 \cos(15) = 28.98 \text{ m/s}$
 $V_y = 30 \sin(15) = 7.76 \text{ m/s}$
 $V_2 = 28.98 - 12 = 16.98 \text{ m/s}$
 $V_R = \sqrt{(16.98)^2 + (7.76)^2} = 18.669 \text{ m/s}$
 $\tan^{-1}\left(\frac{7.76}{16.98}\right) = 24.56^\circ$ $\beta = 24.56 - 15 = 9.56^\circ$
 $Q = (1000)(0.0314)(18.669) = 586.2066 \text{ m}^3/\text{s}$
 $V_R \cos(9.56) = 18.41 \text{ m/s}$
 $R_x = 586.2066(18.669 - 16.98) = 990.1029 \text{ N}$
 $R_y = 586.2066(7.76) = 4548.96 \text{ N}$

16.29

Problem 16.29

water stream at 15°C $\rho = 1000 \text{ kg/m}^3$
 Diameter = 7.50 mm
 Velocity = 25 m/s
 Compute forces on the blade

Assume that $V_1 = V_2$
 $V_1 = 25 \text{ m/s}$ $V_{1x} = V_1 \cos 10$ $V_2 = 25 \text{ m/s}$ $V_{2x} = -V_2 \cos 60$
 $V_{1y} = V_1 \sin 10$ $V_{2y} = V_2 \sin 60$

$Q = VA = 25 \text{ m/s} \times \frac{\pi}{4} \left(\frac{7.5 \text{ mm}}{1000}\right)^2$
 $= 1.104 \times 10^{-3} \text{ m}^3/\text{s}$

$\Sigma F = \rho Q \Delta V$
 $F_x = \rho Q \Delta V_x = \rho Q (-V_2 \cos 60 - V_1 \cos 10)$
 $= 1000 \text{ kg/m}^3 \times 1.104 \times 10^{-3} \text{ m}^3/\text{s} (-12.5 \text{ m/s} - 24.62 \text{ m/s})$
 $R_x = 40.98 \text{ N}$

$F_y = \rho Q \Delta V_y = \rho Q (V_2 \sin 60 - V_1 \sin 10)$
 $= 1000 \text{ kg/m}^3 \times 1.104 \times 10^{-3} \text{ m}^3/\text{s} (21.63 - 4.34)$
 $R_y = 19.11 \text{ N}$