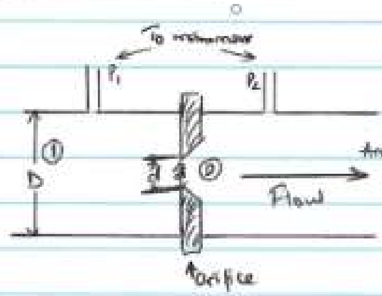
Homework 2.3

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 in = 0.833 ft

Q = 25 gal/min = 0.0557 ft³/s

$Sg_{turpentine} = 0.83$ $\gamma_{turp} = 51.79$ lb/ft³

Turpentine Dynamic viscosity = 2.5×10^{-6} lb-s/ft²

Calculate the deflection of a water manometer for orifice diameter a) 1.0 in

b) 7.0 in

$$Q = CA_1 \sqrt{\frac{2gh[(\gamma_m/\gamma_f) - 1]}{(A_1/A_2)^2 - 1}}$$

To get the value of C, we need d/D & Reynold number

$Q = VA \therefore V = Q/A = \frac{0.0557 \text{ ft}^3/s}{\pi/4 (0.833 ft)^2} = 0.102$ ft/s

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

$A_{2,1} = \pi/4 (1/12 ft)^2 = 0.00545 ft^2$

$A_{2,2} = \pi/4 (7/12 ft)^2 = 0.458 ft^2$

$Re = \frac{VD}{\nu} = \frac{0.102 \text{ ft/s} \times 0.833 \text{ ft} \times 51.79 \text{ lb/ft}^3}{2.5\times10^{-6} \text{ lb-s/ft}^2 \times 32.2 \text{ ft/s}^2}$

$= 5.5 \times 10^4$

$\beta = d/D = \frac{1.0}{10} = 0.1$ ① or $\frac{7.0}{10} = 0.7$ ②

$C_1 = 0.595$ $C_2 = 0.618$

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

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

for d = 7.0 in
$$h = \frac{\left(\frac{0.0557 \text{ ft}^3/s}{0.545 ft^2 \times 0.618}\right)^2 \times \left[\left(\frac{0.545 ft^2}{0.458 ft^2}\right)^2 - 1\right]}{2 \times 32.2 \text{ ft/s}^2 \left[\left(\frac{62.4 \text{ lb/ft}^3}{51.79 \text{ lb/ft}^3}\right) - 1\right]}$$
$h_2 = 0.0008233$ ft
$= 0.01$ in

15.9

Problem 15.9

Linseed oil $sg = 0.930$, $\gamma = 58$, $\nu = 3.84\times10^{-4}\ ft^2/s$

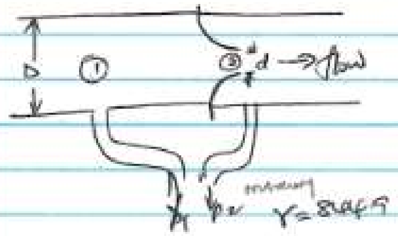
Range of flow

700 gal/min — 1000 gal/min

$1.559\ ft^3/s$ — $2.227\ ft^3/s$

Range of manometer

0 in to 8 in



$\gamma = 844.9$ (mercury)

$D = 5$ in inside → 4.805 in $= 0.404$ ft

$A_1 = 0.1283\ ft^2$

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

$= 17.36$ ft/s

Reynolds number $N_R = \frac{VD}{\nu} = \frac{17.36\ ft/s \times 0.404\ ft}{3.84\times10^{-4}\ ft^2/s}$

$= 1.826\times10^4$

Using the flow nozzle coefficient chart

$C \approx 0.96$

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

$\beta = N_R\left(\frac{0.9975 - C}{6.53}\right)^2$

for $C = 0.96$,

$$A_2 = \frac{A_1}{\sqrt{\frac{2g\ell(\gamma_m/\gamma_o - 1)}{\left(\frac{Q}{A_1 C}\right)^2} + 1}} = \frac{0.1283\ ft^2}{\sqrt{\frac{2\times32.2\times0.67\left[\left(\frac{844.9}{58}\right) - 1\right]}{\left(\frac{2.227\ ft^3/s}{0.1283\times0.96}\right)^2} + 1}}$$

$A_2 = 0.0768\ ft^2$

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

$= 0.3127$ ft

$= 3.75$ in

$Q = VA$ $\quad V = Q/A$

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

$V = 12.15$ ft/s

$N_R = \frac{VD}{\nu}$

$= \frac{12.15\ ft/s \times 0.404\ ft}{3.84\times10^{-4}\ ft^2/s}$

$= 1.278\times10^4$

$C_{min} \approx 0.955$

for $C = 0.955$

$$A_2 = \frac{0.1283}{\sqrt{\frac{2\times32.2\times0.67\left(\frac{844.9}{58} - 1\right)}{\left(\frac{2.227\ ft^3/s}{0.1283\times0.955}\right)^2} + 1}}$$

$A_2 = 0.077\ ft^2$

$d = 0.3132$ ft

$= 3.76$ in

nozzle diameter $= 3.75$ in

15.15

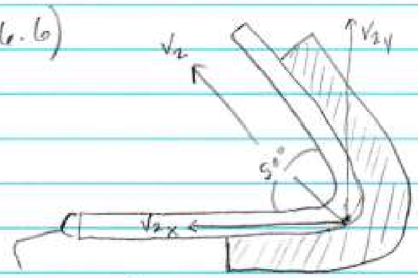
15.15 $T = 50^\circ C$ $h = 0.24\text{ in} = 0.006096\text{ m}$

$\gamma_{water} = 9.69\ kN/m^3$ $\gamma_{Air} = 1.092\ kN/m^3$

$v_1 = \sqrt{2(9.81)(0.006096)(9.69-1.092)/1.092} = 0.97\ m/s$

16.6

16.6)



$T = 180^\circ F$ $\theta = 130^\circ$

$v_1 = 22\ ft/s$

$\rho = 1.883\ slugs/ft^3$

$Q = vA = (22)(0.0205) = 0.451\ ft^3/s$

$A = 2.95\ in^2$
$= 0.0205\ ft^2$

$V_{2x} = v(\cos(180-\theta))$
$= 22(\cos(50)) = 14.14\ ft/s$

$V_{2y} = v(\sin(180-\theta))$
$= 22(\sin(50)) = 16.85\ ft/s$

$F_x = \rho Q(V_{2x} - V_{1x})$
$= (1.883)(0.451)(14.14-(-22)) = \boxed{29.94\ lb}$

$F_y = \rho Q(V_{2y} - V_{2x})$
$(1.883)(0.451)(16.85-0) = \boxed{13.96\ lb}$

16.11

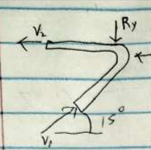
16.11 $Q = 100\ gal/min$ Pipe = 1in Schedule 40 pipe

$Q = 0.223\ ft^3/s$ $\rho = 1.94\ /ft^3$ $A = 0.00499\ ft^2$

$V = \frac{0.223}{0.00499} = 44.689\ ft/s$ $F = (1.94)(0.223)(44.689-(-44.689))$
$= 38.667\ lb$

16.20

16.20



$V_1 = 30\ m/s \quad D = 200\ mm = 0.2\ m$

$Q = \frac{\pi}{4} \cdot 0.2^2 \cdot 30 = 0.9425 \quad A = 0.0314$

$\rho = 1000\ kg/m^3 \quad V_{car} = 12\ m/s$

A. $R_x = (1000)(30)(0.9425)(1 + \cos 15) = \boxed{55586.553\ N}$

$R_y = (1000)(30)(0.9425)(0 + \sin 15) = \boxed{4988.737\ N}$

B. $V_x = 30 \cos(15) = 28.98\ m/s$

$V_R = 28.98 - 12 = 16.98\ m/s$

$V_y = 30 \sin(15) = 7.76\ m/s$

$V_R = \sqrt{(16.98)^2 + (7.76)^2} = 18.669\ m/s$

$\tan^{-1}\left(\frac{7.76}{16.98}\right) = 24.56 = \alpha \quad \beta = 24.56 - 15 = 9.56^\circ$

$Q = (1000)(0.0314)(18.669) = 586.2066\ kg/s$

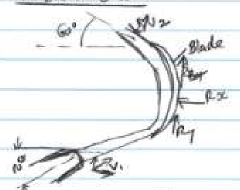
$V_p\ (18.669) \cos(9.56) = 18.41\ m/s$

$R_x = 586.2066(18.669 - 16.98) = \boxed{990.1029\ N}$

$R_y = 586.2066(7.76) = \boxed{4548.96\ N}$

16.29

Problem 16.29



water stream at 15°C $\rho = 1000\ kN/m^3$

Diameter = 7.50 mm

Velocity = 25 m/s

Compute forces on the blade

Assume that $V_1 = V_2$

$V_1 = 25\ m/s \quad V_{1x} = V_1 \cos 10 \quad V_{1y} = V_1 \sin 10^\circ$

$V_2 = 25\ m/s \quad V_{2x} = -V_2 \cos 60^\circ \quad V_{2y} = V_2 \sin 60^\circ$

$Q = VA = 25\ m/s \times \frac{\pi}{4}\left(\frac{7.5\ m}{1000}\right)^2$

$= 1.104 \times 10^{-3}\ m^3/s$

$\Sigma F = \rho Q \Delta \vec{V}$

$F_x = \rho Q \Delta V_x = \rho Q(-V_2 \cos 60 - V_1 \cos 10)$

$= 1000\ kN/m^3 \times 1.104 \times 10^{-3}\ m^3/s\ (-12.5\ m/s - 24.62\ m/s)$

$R_x = 40.98\ N$

$F_y = \rho Q \Delta V_y = \rho Q(V_2 \sin 60 - V_1 \sin 10)$

$= 1000\ kN/m^3 \times 1.104 \times 10^{-3}\ m^3/s\ (21.65 - 4.34)$

$R_y = 19.11\ N$