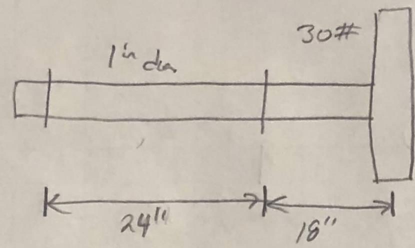
Jacob Schwartz | MET320 | Hw9 | 3-31-20

1) Given:



Find: Value of the critical speed for the given steel shaft.

$$Y = \frac{Pb^2 l}{3EI}$$

$$I = \frac{\pi}{64} d^4 = \frac{\pi}{64}(1)^4$$

$$I = 0.049 \text{ in}^4$$

$$\downarrow$$

$$Y = \frac{(30\text{lb})(18\text{in})^2(42\text{in})}{3(30{,}000{,}000\text{psi})(0.049)}$$

$$Y = 0.0925\text{in}$$

Calculate the number of cycle per second (f) of rotational shaft

$$f = \frac{1}{2\pi}\sqrt{\frac{gPy}{Py^2}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{g}{Y}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{386\text{in}/\text{s}^2}{0.0925\text{in}}}$$

$$f = 10.27 \text{ cycles/s}$$

$$n_{cr} = 10.27 \text{ cycle/s} \left(\frac{60\text{sec}}{1\text{min}}\right)$$

$$\boxed{n_{cr} = 617\text{rpm}}$$

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43) Proposal 1 (Pipe Bend)

$1\ L/min = \frac{1}{1000(60)}\ m^3/s$

$750\ L/min = \frac{\frac{1}{1000(60)}\ m^3/s}{1\ L/min}(750\ L/min)$

$\underline{= 0.0125\ m^3/s}$

$d = D - 2t$

$= 50 - 2(2)$

$= 46mm$

$\underline{d = 0.046m}$

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

$= \frac{\pi(0.046)^2}{4}$

$\underline{A = 1.662\times10^{-3}\ m^2}$

$V = Q/A$

$= 0.0125/1.662\times10^{-3}$

$\underline{V = 7.52\ m/s}$

$T/D = \frac{750}{46}$

$\underline{= 16.3}$

$Le/D = \underline{43}$

$\varepsilon = \underline{1.5\times10^{-6}\ m}$

$N_R = \frac{vD\rho}{\eta}$

$\eta = 1.92\times10^{-3}\ Pa\cdot s$

$\rho = 802\ kg/m^3$

$N_R = \frac{7.52(0.046)(802)}{1.92\times10^{-3}}$

$N_R = 144493.67$

relative roughness $= \frac{D}{\varepsilon} = \frac{0.046}{1.5\times10^{-6}} = 30666.67$

$f_T = 0.0095 \qquad f = 0.0162$

$K = f_T\left(\frac{Le}{D}\right)$

$= 0.0095(43)$

$\underline{K = 0.4085}$

$h_L = K\frac{v^2}{2g}$

$= 0.4085\left(\frac{7.52^2}{2(9.81)}\right)$

$\boxed{h_L = 1.177m}$

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43) Proposal 2 (Bend + tube)

$$\frac{r}{D} = \frac{150}{46}$$

$$= 3.261$$

$$Le/D = 13$$

$$h_{L_{bend}} = f_T\left(\frac{Le}{D}\right)\left(\frac{v^2}{2g}\right)$$

$$= 0.0095(13)\left(\frac{7.52^2}{2(9.81)}\right)$$

$$h_{L\,bend} = 0.356m$$

$$h_{L\,tube} = f\left(\frac{L}{D}\right)\left(\frac{v^2}{2g}\right)$$

$$= 0.0162\left(\frac{1.2}{0.046}\right)\left(\frac{7.52^2}{2(9.81)}\right)$$

$$h_{L\,tube} = 1.218m$$

$$h_L = h_{L\,bend} + h_{L\,tube}$$

$$= 0.356m + 1.218m$$

$$\boxed{h_L = 1.574m}$$

46) $d_1 = D_1 - 2t_1$

$= 50 - 2(2)$

$= 46mm$

$d = 0.046m$

$d_2 = D_2 - 2t_2$

$= 100 - 2(3.5)$

$= 93mm$

$d_2 = 0.093m$

$A_1 = \frac{\pi}{4}(d_1^2)$

$= \frac{\pi}{4}(0.046)^2$

$A_1 = 1.662 \times 10^{-3} m^2$

$A_2 = \frac{\pi}{4}(d_2^2)$

$= \frac{\pi}{4}(0.093)^2$

$A_2 = 6.8 \times 10^{-3} m^2$

$V_1 = Q/A_1$

$= 6.0 \times 10^{-3} / 1.662 \times 10^{-3} m^2$

$V_1 = 3.61 m/s$

$V_2 = Q/A_2$

$= 6.0 \times 10^{-3} / 6.8 \times 10^{-3} m^2$

$V_2 = 0.8823 m/s$

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

$$h_L = \frac{P_1 - P_2}{\gamma} + (z_1 - z_2) + \frac{V_1^2 - V_2^2}{2g} \quad --- \text{①}$$

$P_1 + \gamma_w(0.25) + \gamma_m(0.35) - \gamma_w(1.10) = P_2$

$P_1 - P_2 = \gamma_m(0.35) + \gamma_w(1.10 - 0.25)$

$$\frac{P_1 - P_2}{\gamma_w} = \frac{\gamma_m(0.35)}{\gamma_w} + 0.85$$

$$= \frac{132.8(0.35)}{9.69} + 0.85$$

$$\frac{P_1 - P_2}{\gamma_w} = 5.65m$$

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46)

$$h_L = \frac{P_1 - P_2}{\gamma} + (z_1 - z_2) + \frac{v_1^2 - v_2^2}{2g}$$

$$h_L = 5.65 - 1.20 + \frac{3.61^2 - 0.8823^2}{2(9.81)}$$

$$\boxed{h_L = 5.0745\,m}$$

$$h_L = k\left(\frac{v^2}{2g}\right)$$

$$5.0745 = k\left(\frac{3.61^2}{2(9.81)}\right)$$

$$5.0745 = 0.6642k$$

$$\boxed{k = 7.64}$$

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48) $Q = 27.5$ gal/min
$D_o = 1\frac{1}{4}$ in
$t = 0.083$ in
$r = 3.25$ in

$h_L = K(v^2/2g)$ ---① $\longrightarrow$ $h_L = (0.2775)\left(\frac{9.559^2}{2(32.2)}\right)$

$\frac{r}{D} = \frac{3.25(\frac{1}{12})}{0.09033}$

$\boxed{h_L = 0.3937 ft}$

$r/D = 2.998$

$L_e/D = 12.5$

$\varepsilon = 1.5\times10^{-4} ft$

$D/\varepsilon = 0.09033/1.5\times10^{-4}$

$D/\varepsilon = 602.2$

$f_T = 0.0222$

$K = f_T\left(\frac{L_e}{D}\right)$

$= (0.0222)(12.5)$

$K = 0.2775$

$V = \frac{Q}{A}$

$Q = 27.5(0.1337)\left(\frac{1}{60}\right)$

$Q = 0.06127 ft^3/s$

$V = \frac{0.06127}{6.409\times10^{-3}}$

$v = 9.559 ft/s$

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Problem 20

10.20

$$h_L = K\left(\frac{V_2^2}{2g}\right)$$

Given;

- Outside D = 60.3mm
- thickness of wall = 5.54mm
-

Inside diameter

$D_1 = D_{OD} - 2t$

$D_1 = 141.3 - 2(9.5)$

$= 122.3mm$

$= 0.1223m$

$D_2 = D_{OD} - 2t$

$= 60.3 - 2(5.54)$

$49.22m$

$= 0.04922m$

$$\frac{D_1}{D_2} = \frac{0.1223}{0.04922} = 2.485$$

$A_2 = \pi/4 (D_2^2)$

$= \pi/4 \times (0.04922m)^2$

$= 19.035 \times 10^{-4} m$

$$V_2 = \frac{Q}{A_2} = \frac{500L/min}{19.035 \times 10^{-4} m^2} \times \frac{1m^3/s}{60000L/min}$$

$= 4.378m/s$

$$\therefore h_L = K \times \left(\frac{V_2^2}{2g}\right) = (0.39)\left(\frac{4.378m/s^2}{2 \times 9.81m/s^2}\right) = 0.381N$$

$\therefore$ Energy loss $= \boxed{0.381N}$

Problem 37

10.37

Diameter $= 0.0518 ft$

$Q = 12.5 gal/min$
$= 0.0278 ft^3/s$

Given info in diagram;

Equation to use is

$$\frac{P_1}{\gamma} + z_1 + \frac{v_1^2}{2g} - h_f - h_L = \frac{P_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

$$v = \frac{Q}{A} = \frac{0.0278}{0.00211}$$

$v = 13.175 ft/s$

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

$\nu = 1.59 \times 10^{-4} ft^2/s$
$\gamma = 68.47 lb/ft^3$

$$\frac{D}{\varepsilon} = \frac{0.0518}{1.5 \times 10^{-4}}$$

$D/\varepsilon = 345.33$

$$N_R = \frac{13.175 \times 0.0518}{1.59 \times 10^{-4}}$$

$N_R = 4292.232$

$$K = f_1 \left(\frac{L}{D}\right)$$

$K = (0.026)(50)$

$K = 1.3$

$$h_L = K\left(\frac{v^2}{2g}\right)$$

$$h_L = 1.3 \times \left(\frac{(13.175)^2}{2(32.2)}\right)$$

$h_L = 3.503 ft$

$$h_f = f \times \frac{L}{D} \times \frac{v^2}{2g} = 0.0415 \times \frac{8}{0.0518} \times \frac{13.178^2}{2 \times 32.}$$

$h_f = 17.275 ft$

$P_1 - P_2 = \gamma(h_L - h_f)$

$= (68.47)(3.503 + 17.275)$

$P_1 - P_2 = 1422.669 lb/ft^2 \times \frac{1}{144}$

$P_1 - P_2 = \boxed{9.87 psi}$

Problem 39

10.39

$A = 0.05132 \, mm^2$

$f = 0.017$

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

$$v = \frac{Q}{A}$$

$$v = \frac{0.40}{0.05132}$$

$$= 7.794 \, ft/s$$

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

$$= (0.017)(20)\left(\frac{7.794)^2}{2(32.2)}\right.$$

$\therefore$ Energy loss through the Standard tee is $\boxed{0.32 ft}$

Paragraph:

When we are looking for loses in fittings in pipes we have to look at the K values. When we are looking for Loses in a T joint in a pipe it matters on the direction of flow. If we are just looking for a specific value through pipes we use the K value, But when we are just looking for a pump we use another equation although its not as acreate. Also the Back of the book hes tables for all the areas when solving problems to elemanate trying to find the area.

chapter 11 20.

20.) Known: 400 gal/min

$80°F \quad L = 75 ft$

$h = 12 ft$ Schedule 40

$\varepsilon = 1.5 \times 10^{-4} ft$

$\nu = 9.15 \times 10^{-6} ft^2/s$ from tables

So $$D = .66\left(\left(1.5\times10^{-4}\right)^{1.25} \left(\frac{\left(\frac{400 \times 1 ft^3/s}{449 \frac{gal}{min}}\right)^{2}}{\left(32.2 \frac{ft}{s^2} \times 12 ft\right)} \right)^{4.75} + \left(9.15\times10^{-6}\right)\left(\frac{400 \cdot 1}{449 gal/min}\right)^{9.4} \left(\frac{75}{32.2 \frac{ft}{s^2} \times 12 ft}\right)^{5.2} \right)^{.04}$$

$$\boxed{D = .3006 ft}$$

Q11-5) By calculating the cross-sectional area at the pipe in side-A

$$A_a = \frac{\pi \times D_a^2}{4}$$

$$= \frac{\pi \times 0.1463^2}{4} = 1.682 \times 10^{-2}\ m^2$$

for calculating the cross-sectional area of the pipe in side-B

$$A_b = \frac{\pi \times D_b^2}{4}$$

$$= \frac{\pi \times 0.0493^2}{4} = 1.905 \times 10^{-3}\ m^2$$

The velocity of the fluid in side-A

$$V_a = \frac{Q_a}{A}$$

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

The velocity of the fluid in side-B

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

By calculating Reynolds number in side-A

$$N_{Ra} = \frac{V_a \times D_a}{(\mu / \rho)} = \frac{0.892 \times 0.1463}{2.12 \times 10^{-15}} = 6.15 \times 10^{3}$$

for D/E

$$\frac{D}{\varepsilon} = \frac{0.1463}{4.6 \times 10^{-5}} = 3180$$

So friction factor will be:-

$f_{sa} = 0.035 \quad f_T = 0.019$

For side (B)

$N_{Rb} = \frac{V_b \times D_b}{(M/P)} = \frac{7.87 \times 0.0493}{2.12 \times 10^{-5}} = 1.83 \times 10^4$

For D/ε

$\frac{D}{\varepsilon} = \frac{0.0493}{4.6 \times 10^{-5}} = 1072$

so, friction factor will be:

$f_{sb} = 0.028, \quad f_T = 0.019$

The friction loss in Pipe side (A)

$h_1 = f_{sa} \cdot \frac{L_a}{D_a} \cdot \frac{V_a^2}{2 \cdot g} = 0.035 \times \frac{180}{0.1463} \times \frac{0.892^2}{2 \times 9.81} = 1.746332\,m$

For side (B)

$h_2 = f_{sb} \cdot \frac{L_b}{D_b} \cdot \frac{V_b^2}{2 \cdot g}$

$h_2 = 0.028 \times \frac{8}{0.0493} \times \frac{7.87^2}{2 \times 9.81} = 14.34338\,m$

For elbow loss:-

$h_3 = 2 \times 20 \times f_T \times \frac{V_b^2}{2 \cdot g}$

$h_3 = 2 \times 20 \times 0.019 \times \frac{7.87^2}{2 \times 9.81} = 2.399187\,m$

For side (B)

$$h_2 = f_{sb} \cdot \frac{L_b}{D_b} \cdot \frac{V_b^2}{2 \cdot g}$$

$$h_2 = 0.028 \times \frac{8}{0.0493} \times \frac{7.87^2}{2 \times 9.81} = 14.34338\,m$$

For elbow loss:-

$$h_3 = 2 \times 20 \times f_T \times \frac{V_b^2}{2 \cdot g}$$

$$h_3 = 2 \times 20 \times 0.019 \times \frac{7.87^2}{2 \times 9.81} = 2.399187\,m$$

for contraction loss:-

$$h_4 = 0.37 \times \frac{V_b^2}{2 \cdot g}$$

$$h_4 = 0.37 \times \frac{7.87^2}{2 \times 9.81} = 1.68025\,m$$

Total energy loss:

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

$$h_L = 1.746332 + 14.34338 + 2.399187 + 1.168025$$

By calculating P_A:

$$\frac{P_A}{\gamma} + Z_A + \frac{u_A^2}{2 \cdot g} - h_L = \frac{P_B}{\gamma} + Z_B + \frac{u_B^2}{2 \cdot g}$$

$$P_A = \gamma\left[h_L + \frac{P_B}{\gamma} + (Z_B - Z_A) + \left(\frac{u_B^2}{2g} - \frac{u_A^2}{2g}\right)\right]$$

So,

$$P_A = 8.80\left[19.65693 + \frac{12.5\times10^6}{8.80} + 4.5 + \left(\frac{0.897^2}{2\times9.81} - \frac{7.87^2}{2\times9.81}\right)\right]$$

$= 12.74$ MPa

Conversion factor $9.81\ kN/m^3$

So pressure in side A will be 12.74MPa

Q11-13

By calculating the cross-sectional area of pipe

$$A = \frac{\pi\times D^2}{4} \quad A = \frac{\pi\times D^2}{4} = \frac{\pi\times\left(\frac{0.5}{12}\right)^2}{4} = 0.0013635\,ft^2$$

$$\text{for } \frac{D}{\varepsilon} = \frac{0.5}{1.5\times12\times10^{-4}} = 277.777$$

By calculating the frictional loss in the pipe:

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

$$h_L = \left(\frac{2880}{62.4}\right) + \left(0 - \frac{0}{2g}\right) + Z_A - Z_B$$

$$= \left(\frac{2880}{62.4}\right) + (0 - 18) = 28.15\,ft$$

Flowrate:-

$$Q = -2.22 \times D^2 \sqrt{\frac{2.D.h_L}{L}} \log\left(\frac{1}{3.7\,D/\varepsilon} + \frac{1.784.\nu}{D\sqrt{\frac{2.D.h_L}{L}}}\right)$$

$$= -2.22 \times 0.041667^2 \sqrt{\frac{32.2 \times 0.041667 \times 28.5}{20}} \log\left(\frac{1}{3.7 \times 2777.778} + \frac{1.784 \times 7.37 \times 10^{-6}}{0.041667\sqrt{\frac{32.2 \times 0.041667 \times 28.15}{20}}}\right)$$

$$= 0.0425\ ft^3/s$$

The velocty of fluid

$$Q = A \times V$$

$$= \frac{Q}{A} = \frac{0.04250}{0.0013635} = 32.24\ ft/s$$

$\boxed{b}$ The frictional loss in pipe

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

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

$$= \left(\frac{11520}{62.4}\right) + \left(0 - \frac{0}{2g}\right) + Z_A - Z_B$$

$$= 166.615\ ft$$

For flow rate: (deric)

$$Q = -2.22 \times D^2 \sqrt{\frac{g.D.h_L}{L}} \log\left(\frac{1}{3.7D/\varepsilon} + \frac{1.784.v}{D\sqrt{\frac{g.D.h_L}{L}}}\right)$$

$$= -2.22 \times 0.041667^2 \sqrt{\frac{32.2 \times 0.041667 \times 166.61}{20}} \times$$

$$\log\left(\frac{1}{3.7 \times 277.778} + \frac{1.784 \times 7.37 \times 10^{-6}}{0.041667\sqrt{\frac{32.2 \times 0.041667 \times 166.61}{20}}}\right)$$

$= 0.110294 \ ft^3/s$

For velocity of fluid:

$$Q = A \times V \Rightarrow V = Q/A = \frac{0.110294}{0.0013635}$$

$= 81.48 \ ft/s$

so, velocity is equal to

81.48 ft/s