Homework 3.3

This was the final week of the course; however, we still discussed a very important topic. The primary topic was how to select pumps and how to read graphs and charts to find the correct pump for a system. Pumps are usually thrown onto a graph with a great deal of overlap as pumps can cover certain ranges of speed and flow rate. Companies sometimes have these graphs in pamphlets to help sell their pumps or as a user's manual. The homework problems focused on chapter 13 and finding the Net Positive Suction Head or NPSH.

Homework Problems

Problem 13.17

For a given centrifugal pump, if the speed of rotation of the impeller is cut in half, how does the total capability change?

$$\frac{h_{a_1}}{h_{a_2}} = \left(\frac{N_1}{N_2}\right)^2 \qquad \text{If } N_2 = \tfrac{1}{2}N_1$$

$$\frac{h_{a_1}}{h_{a_2}} = \left(\frac{N_1}{\frac{1}{2}N_1}\right)^2 = 4$$

$$\frac{h_{a_1}}{h_{a_2}} = 4 \Rightarrow h_{a_1} = 4h_{a_2}$$

$$\therefore h_{a_2} = \frac{h_{a_1}}{4}$$

⇒ If the speed of rotation of the impeller is cut in half, the total capability reduces by a factor of 4.

Problem 13.19

For a given size of centrifugal pump casing, if the diameter of the impeller is reduced by 25%, how much does the capacity change?

$$\frac{Q_1}{Q_2} = \frac{D_1}{D_2} \qquad \text{if } D_2 = 0.25D_1$$

$$\frac{Q_1}{Q_2} = \frac{D_1}{0.25D_1} \Rightarrow \frac{Q_1}{Q_2} = \frac{1}{0.25} \Rightarrow 0.25Q_1 = Q_2$$

$$\therefore Q_2 = 0.25Q_1$$

⇒ If the diameter of the impeller is reduced by 25%, the capacity reduces by 25%.

Problem 13.22

Describe each part of this centrifugal pump design: 1½x3-6

- → 1½-in discharge connection
- → 3-in suction connection
- → A casing that can accomodate an impeller with a diameter of 6-in or smaller.

Problem 13.23

Suitable pump size for delivering 100 gal/min of water at a total head of 300 ft.

Pump size: 1½x3-10

Problem 13.25

For a 2x3-10 pump, describe the performance that can be expected from a pump with an 8-in impeller operating against a system head of 200 ft.

Capacity – ~~235~~ 23.5 gal/min

Power required – 22.5 hp

Efficiency – 53%

Required $NPSH_R$ – 11 ft.

Problem 13.34

For each of the following sets of operating conditions, list the appropriate type of pump

a) 500 gal/min of water at 80 ft of total head.
- Centrifugal pump - 3500 rpm.

b) 500 gal/min of water at 800 ft of head
- Reciprocating pump

f) 8000 gal/min of water at 200 ft of head.
- mixed flow pump

Ch 13

55 Find NPSH T = 80°C P = 101.8 kPa

water level 2m below pump

DN 80 Sch 40 pipe - steel

DN 50 Sch 40 pipe, 1.5m long radius elbow

Q = 300 L/min γ = 9.53 $\nu = 3.60 \cdot 10^{-7}$

$\frac{101.8 \cdot 10^3}{9.53 \cdot 10^3} = 10.682$ m

DN 80 $V = \frac{300\ L/min}{(4.768 \cdot 10^{-3})} \cdot \frac{1\ m^3/s}{60000\ L/min} = 1.048$ m/s

$N_R = \frac{(1.048)(0.0779)}{3.6 \cdot 10^{-7}} = 226775.556$ $f_{80} = 0.019$

$\frac{D}{\epsilon} = \frac{0.0779}{4.6 \cdot 10^{-5}} = 1693.478$ $\frac{1.048^2}{2(9.81)} = 0.0559$

DN 50 $V = \frac{300\ L/min}{2.168 \cdot 10^{-3}} \cdot \frac{1}{60000} = 2.306$ m/s

$N_R \frac{(2.306)(0.0525)}{3.6 \cdot 10^{-7}} = 336291.667$ $f_{50} = 0.025$

$(0.019)\left(\frac{2}{0.0779}\right)(0.0559) + \left(75 \cdot 0.018 \cdot \frac{1.048^2}{2(9.81)}\right) + \left(20 \cdot 0.018 \cdot \frac{1.048^2}{2(9.81)}\right)$

$+ 0.025\left(\frac{1.5}{0.0525} \cdot \frac{2.306^2}{(2 \cdot 9.81)}\right) = 0.3166$ m

NPSH = 10.682 − 2 − 0.3166 − 4.967 = 3.3984 m

Ch 13

65 Propane 45°C sg = 0.48 1.84m below pump

h_f suction = 0.92m P_{atm} = 98.4 kPa $NPSH_A$ = 1.50m

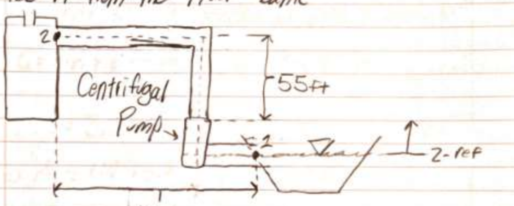
$\gamma = 0.48 \cdot 9.81 = 4.7088$ h_{vp} = 340m

P = [4.7088(1.5 + 1.84 + 0.92 + 340)] − 98.4

= 1522.6515 kN/m²

Design problem #3 Trey Ward

Design a System to pump water at 80°F from a river to a tank elevated 55ft above the Surface of the river. Minimum flowrate is 1500 gal/min. The tank is to be set back 125 ft from the river bank



$$\left\{\frac{P_1}{\gamma} + \frac{v_1^2}{2g} + Z_1 - h_L = \frac{P_2}{\gamma} + \frac{v_2^2}{2g} + Z_2 - h_{pump}\right\}$$

• Both points 1 & 2 are open to atmosphere with no velocity of note. $\Rightarrow P_1 = 0, P_2 = 0, v_1 = 0, v_2 = 0$

$\Rightarrow \{Z_1 - h_L = Z_2 - h_{pump}\}$ • $Z_1 = 0 = Z_{ref}$

$\Rightarrow \{h_{pump} - h_L = Z_2\}$ $Z_2 = 55ft$

$\Rightarrow \{h_{pump} - h_L = 55ft\}$

Water @ 80 F

$\gamma = 62.2\ lb/ft^3$

System Info

$Q = 1500 \frac{gal}{min} = 25 \frac{gal}{sec} = 3.34 \frac{ft^3}{sec}$

$L_{pipe} = 55 + 125 = 180ft$

$\eta = 1.77 \cdot 10^{-5}$

• Assuming $V = 10\ ft/s$

Calculating for Cross Section of pipe & diameter

$\{Q = V \cdot A\}$ & $V = 10\ ft/s$, $Q = 3.34\ ft^3/s$

$\Rightarrow A = 3.34 \frac{ft^3}{s} / 10 \frac{ft}{s} = 0.334\ ft^2$

$\Rightarrow A = 48.1\ in^2$ $\{A = \pi \cdot r^2\}$

$\Rightarrow \left\{r = \sqrt{\frac{A}{\pi}}\right\} \Rightarrow r = 3.91 \Rightarrow D = 7.83$

• Round up for efficiency losses

$\Rightarrow D = 8in$ • Use NPS 8 schedule 40 steel pipe

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

Reynolds # Calculations

$$\left\{N_R = \frac{v \cdot D \cdot \gamma}{\eta}\right\} = \frac{10\frac{ft}{s} \cdot 0.6667ft \cdot 62.2\frac{lb}{ft^3}}{1.77 \cdot 10^{-5}\ lb\text{-}s/ft^2}$$

$= N_R = 23428666.67 = 2.3 \cdot 10^7$

$\frac{D}{\varepsilon} = \frac{0.6667ft}{1.5 \cdot 10^{-4}ft} = f = 0.015$

Calculating energy losses in 180 ft of NPS 8 Schedule 40 Steel pipe, when water at 80°F is flowing through it at 10 ft/s

$$\left\{h_L = f \cdot \frac{L}{D} \cdot \frac{v^2}{2g}\right\}$$

$f = 0.015$

$L = 180ft$ $D = 0.6667\ ft$

$v = 10\ ft/s$ $g = 32.2\ ft/s^2$

$\Rightarrow \frac{180}{0.6667} = 270$ $v^2 = 100\frac{ft^2}{s^2}$ $2g = 64.4\ ft/s^2$

$$\Rightarrow 0.015 \cdot 270 \cdot \frac{100\frac{ft^2}{s^2}}{64.4\frac{ft}{s^2}} = 6.3\ ft$$

Calculating neccesary pump head for given losses & System

$\{h_{pump} = 55ft + h_L\} \Rightarrow 55ft + 6.3ft = 61.3ft$

$\Rightarrow h_{pump} = 61.3\ ft$ • based off figure 13-20 we know a Centrifugal pump Should deliver the neccesary pump head.