Hydraulic Pump and Motor Problem

Example 3.17 from Esposito Fe

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Example 3-17

For the hydraulic system of Figure 3-29, the following SI metric data are given:

a. The pump is adding 3.73 kW (pump hydraulic power = 3.73 kW) to the fluid.

b. Pump flow is 0.001896 m³/s.

c. The pipe has a 0.0254-m inside diameter. Note that this size can also be represented in units of centimeters or millimeters as 2.54 cm or 25.4 mm, respectively.

d. The specific gravity of the oil is 0.9.

e. The elevation difference between stations 1 and 2 is 6.096 m.

Find the pressure available at the inlet to the hydraulic motor (station 2). The pressure at station 1 in the hydraulic tank is atmospheric (0 Pa or 0 N/m² gage). The head loss $H_L$ due to friction between stations 1 and 2 is 9.144 m of oil.

Solution: Write...
a. $P_{\text{pump}} = 3.73 \text{ kW}$

b. pump flow $= 0.001896 \text{ m}^3/\text{s}$

c. the pipe has a 0.0254 m inside diameter

d. $p = (0.9)(1000) = 900 \text{ kg/m}^3$

e. $\Delta h = 6.096 \text{ m} \quad 6.996 \text{ m}$

$H_L = 9.144 \text{ m}$

Flow $= 0.001896 \text{ m}^3/\text{s}$

$A = \pi r^2 = \left(\pi\right)\left(\frac{0.0254}{2}\right)^2 = 5.067 \times 10^{-4} \text{ m}^2$

$v_2 = \frac{Q}{A} = \frac{0.001896}{5.067 \times 10^{-4}} = 3.742 \text{ m/s}$
Head at point 1:

\[ h_1 + \frac{1}{2} \frac{v_1^2}{g} + \frac{p_1}{\rho g} \]

Head at point 2:

\[ h_2 + \frac{1}{2} \frac{v_2^2}{g} + \frac{p_2}{\rho g} \]

These should be equal if there are no sources or leaks between them.

However, there is a pump that will increase the head, and a pipe that will cause a loss in the head.

\[ \Rightarrow \quad h_{1} + Hp - H_{L} = h_{2} \]

\[ h_1 + \frac{1}{2} \frac{v_1^2}{g} + \frac{p_1}{\rho g} + Hp - H_L = h_2 + \frac{1}{2} \frac{v_2^2}{g} + \frac{p_2}{\rho g} \]

but \( v_1 = 0 \text{ m/s}, \ p_1 = 0 \) (or gage pressure)

Rearranging:

\[ Hp - H_L = (h_2 - h_1) + \frac{1}{2} \frac{v_2^2}{g} + \frac{p_2}{\rho g} \]
\[ HP - H_L = (h_2 - h_1) + \frac{1}{2} \frac{v_2^2}{g} + \frac{p_2}{\rho g} \]

\[
\left( \frac{3.73 \times 10^3}{0.001896} \right) - 9.144 = (6.096) + \frac{(3.742)^2}{2(9.81)} + \frac{p_2}{(9.81)(900)}
\]

\[
\left( 222.82 \text{ m} \right) - 9.144 = 6.096 + 0.7136 + \frac{p_2}{8829}
\]

\[
\left( 8829 \right) \left( 213.676 - 6.8096 \right) = p_2
\]

\[ p_2 = 1.826 \text{ MPa} \]

* The pump pressure:

\[ p_D = P \]

\[
\left( 3.73 \times 10^3 \right) = \left( 0.001896 \right) P
\]

\[ P = 1.9673 \text{ MPa} \]

\[ Hp = \text{head pump} = \frac{P_{\text{pump}}}{\rho g} = \frac{1.9673 \times 10^6}{(900)(9.81)} \]

\[ = 222.82 \text{ m} \]