CHE 203

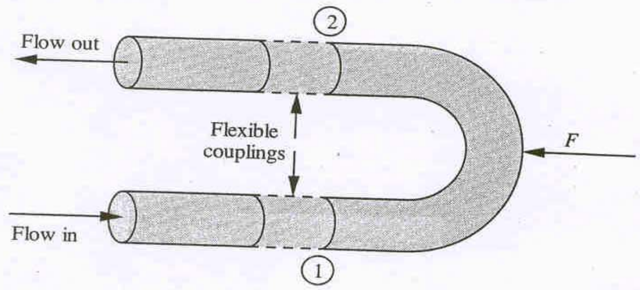
Transport Phenomena I

Quiz # 3

Name

ID #

Water flows at a velocity of 10 m/s through the return elbow shown in the figure below. The pipe has an internal diameter of 0.10 m. The gauge pressures at points 1 and 2 are 3.0 and 2.5 bar, respectively. Calculate the horizontal force *F* needed to keep the retrn elbow in position.



Solution :

momentum balance;

$$m u_1 - (-m u_2) + P_1 A - (-P_2 A) - F = 0$$

$$\Rightarrow 2 m u_1 + P_1 A + P_2 A - F = 0$$

$$\Rightarrow F = (P_1 + P_2) A + 2 m u_1$$

Diameter is the same $\Rightarrow u_1 = u_2$

$$A = \frac{\pi (0.1)^2}{4} = 7.85 \times 10^{-3} \, m^2$$

$$m = \rho A u_1 = 1000 \frac{kg}{m^3} \times 7.85 \times 10^{-3} m^2 \times 10 \frac{m}{s} = 78.54 \frac{kg}{s}$$

$$\therefore F = (3.0 + 2.5) \times 10^5 \frac{Nm^{-2}}{bar} \times 7.85 \times 10^{-3} m^2 + 2 \times 78.54 \times 10$$

$$= 4,317.5 + 1,571 = \underline{5,888.5 N}$$

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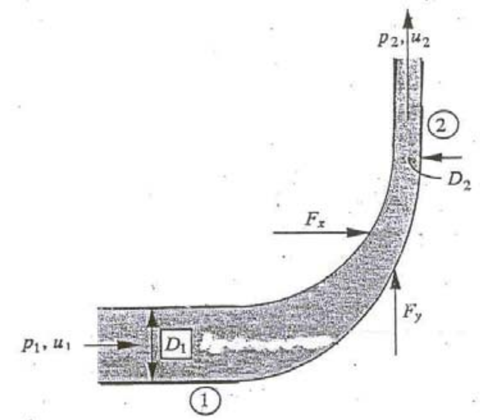
The figure below shows a reducing elbow located in a horizontal plane. Water flows through the elbow at an inlet velocity u_1 of 10 m/s. The inlet pressure p_1 is 3.0 bar and the diameters D_1 and D_2 are 20 and 10 cm. Calculate the forces F_x and F_y required to hold the elbow in position.



Solution:

* X-direction;

$M_{in} - M_{out} + \Sigma F_x = 0$

$\dot{m}u_1 + P_1A_1 + F_x = 0$

$\Rightarrow F_x = -\dot{m}u_1 - P_1A_1$

$= -\left(314 \frac{kg}{s} \times 10 \frac{m}{s}\right) - \left(3.0\times10^5 \frac{N}{m^2} \times 3.14\times10^{-2} m^2\right)$

$= -12,560$ N.

$A_1 = \pi \frac{(0.2)^2}{4} m^2$

$= 3.14 \times 10^{-2} m^2$

$\dot{m} = \rho A_1 u_1$

$= 1000 \frac{kg}{m^3} \times 3.14\times10^{-2} m^2 \times 10 \frac{m}{s}$

$= 314$ kg/s

* Y-direction;

$-\dot{m}u_2 - P_2A_2 + F_y = 0$

$\Rightarrow F_y = \dot{m}u_2 + P_2A_2$

$= (314\times40) + (-448,500 \times 7.85\times10^{-3})$

$\simeq 9,039.3$ N

$A_2 = \pi \left(\frac{(0.1)^2}{4}\right) m^2$

$= 7.85 \times 10^{-3} m^2$

$A_1u_1 = A_2u_2 \Rightarrow u_2 = \frac{(0.2)^2}{(0.1)^2} \times 10$

$= 40$ m/s

B-E

$\frac{u_2^2 - u_1^2}{2} + \frac{P_2 - P_1}{\rho} = 0 \Rightarrow P_2 = -448,500 \frac{N}{m^2}$