FT I – Exercicios

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Conteúdo

Questão 3 – 1

Calcular a queda de pressão devido ao atrito de um óleo que flui a uma velocidade média de $2.4\,\mathrm{m\,s^{-1}}$ através de um tubo liso com $30\,\mathrm{m}$ de comprimento e $7.6\,\mathrm{cm}$ de diâmetro (comparar com comprimento $20\,\mathrm{m}$, $30\,\mathrm{m}$ e $50\,\mathrm{m}$).

- $\mu = 5\,\mathrm{cP}$ (comparar com $4\,\mathrm{cP}$ e $8\,\mathrm{cP}$)
- $\rho = 960\,\mathrm{kg\,m^{-3}}$

E qual a queda de pressão devido ao atrito se rugosidade do tubo = $0.08\,\mathrm{mm}$? (comparar com $0.2\,\mathrm{mm}$ e $0.8\,\mathrm{mm}$). E qual a queda de pressão devido ao atrito se tubo liso com 2 joelhos em ângulo recto?

Resposta – 3
(i)

$$-\mathit{\Delta} P_{at} = 4\,\phi\,L\,\rho\,v^2/D;$$
$$\phi\,(Re, 0) = \phi\left(\frac{\rho\,v\,D}{\mu}, 0\right) = \phi\left(\frac{960 * 2.4 * 7.6\ \mathrm{E}{-2}}{5\ \mathrm{E}{-2} * 10^{-3}/10^{-2}}, 0\right) =$$
$$= \phi\left(\frac{9.6 * 2.4 * 7.6}{5}\,10^2, 0\right) \cong \phi\,(35\,020.800, 0) \cong 0.00275$$
$$\therefore -\mathit{\Delta} P_{at} \cong 4 * 0.00275 * 30 * 960 * (2.4)^2/7.6\ \mathrm{E}{-2} =$$
$$= \frac{4 * 2.75 * 3.0 * 9.60 * (2.4)^2}{7.6}\ \mathrm{E}\,2 \cong 2.401\,\mathrm{E}4$$

Resposta – 3
(ii)

L/m :	20	30	50
$-\mathit{\Delta} P_{at}$:	$160.067\,\mathrm{E}2$	$2.401\,\mathrm{E}4$	$400.168\,\mathrm{E}2$

Resposta – 3
(iii)

$$-\mathit{\Delta} P_{at} = 4\,\phi\,L\,\rho\,v^2/D;$$
$$\phi\,(Re, \varepsilon/D) = \phi\,(35\,020.800, 0.08\ \mathrm{E}{-3}/7.6\ \mathrm{E}{-2}) =$$
$$= \phi\,(35\,020.800, 8\ \mathrm{E}{-3}/7.6) \cong \phi\,(35\,020.800, 1.053\,\mathrm{E}{-3}) \cong 0.0052$$
$$\therefore -\mathit{\Delta} P_{at} \cong 2.401\,\mathrm{E}4\,\frac{0.0052}{0.00275} \cong 4.540\,\mathrm{E}4$$

Resposta – 3
(iv)

$$\varepsilon > \varepsilon_0 \implies \phi > \phi_0 \implies -\mathit{\Delta} P_{at} > -\mathit{\Delta} P_{at,0}$$

Resposta – 3
(v)

$$-\mathit{\Delta} P_{at} = 4\,\phi\,L_{eq}\,\rho\,v^2/D \cong 2.401\,\mathrm{E}4\frac{L_{eq}}{L} =$$
$$= 2.401\,\mathrm{E}4\frac{(L + 2 * 40 * D)}{L} = 2.401\,\mathrm{E}4(1 + 2 * 40 * 7.6\ \mathrm{E}{-2}/30) \cong$$
$$\cong 2.888\,\mathrm{E}4$$

Questão 3 – 2

Corre água a $2.5\,\mathrm{dm}^3\,\mathrm{s}^{-1}$ através dum alargamento súbito de um tubo de $3.6\,\mathrm{cm}$ de diâmetro para um de $4.8\,\mathrm{cm}$. Qual é a perda de carga em m?

$$-\Delta P^{at}_{al\ arg} = \rho\,(v_1 - v_2)^2/2$$

Resposta

$$\frac{-\Delta P_{at}}{\rho\,g} = \frac{\rho\,(\Delta v)^2/2}{\rho\,g} = \frac{\left(\Delta\frac{G_v}{\pi\,r^2}\right)^2}{2\,g} = \left(\frac{G_v}{\pi\ \Delta r^2}\right)^2 (2\,g)^{-1} \cong$$

$$\cong \left(\frac{2.5\ \mathrm{E}{-3}}{\pi\,((3.6\ \mathrm{E}{-2}/2)^2 - (4.8\ \mathrm{E}{-2}/2)^2)}\right)^2 (2 * 9.780) =$$

$$= 8\,\left(\frac{2.5}{\pi\,((3.6)^2 - (4.8)^2)}\right)^2 9.780^{-1} * 10^2 \cong 5.903\,\mathrm{E}{-2}$$

Questão 3 – 3

Qual é a queda de pressão, e a potência necessária para bombear 0.04 $\mathrm{m^3\,s^{-1}}$ de água, através dum condensador com 400 tubos de 4.5 m de comprimento e diâmetro interno de 1 cm sabendo que o coeficiente de contracção à entrada dos tubos (C_c) é 0.6 e rugosidade aço comercial = 0.046 mm $\mu = 10^{-3}\,\mathrm{kg\,m^{-1}\,s^{-1}}$.

$$-\Delta P_{cont} = \frac{\rho\,v^2}{2}(C_c^{-1} - 1)^2$$

Resposta – (i)

$$-\Delta P_{tot} = -\Delta P_{at\ 1} * n - \Delta P_{at\ 2} = n\,\frac{4\,\phi\,\rho\,v^2\,L_1}{D} + \frac{\rho\,v^2}{2}(C_c^{-1} - 1)^2 =$$
$$= \rho\,v^2\,\left(\frac{4\,\phi\,L_1\,n}{D} + \frac{(C_c^{-1} - 1)^2}{2}\right)$$

$$\phi\,(Re, \varepsilon/D) = \phi\left(\frac{D\,\rho\,\bar{v}}{\mu}, \varepsilon/D\right) = \phi\left(\frac{10^{-2} * 10^3 * 1.27}{10^{-3}}, \frac{0.046\ \mathrm{E}{-3}}{10^{-2}}\right) =$$
$$= \phi\,(1.27 * 10^4, 0.046\ \mathrm{E}{-1}) \cong 0.0052$$

$$\therefore -\Delta P_{tot} \cong 10^3\,(1.27)^2\,\left(\frac{4 * 0.0052 * 4.5 * 400}{1\ \mathrm{E}{-2}} + \frac{(0.6^{-1} - 1)^2}{2}\right) \cong 6039.056\,\mathrm{E3}$$

Resposta – (ii)

$$W_{bomba} = -\Delta P_{at\ bomba} * \frac{G_v}{n} \cong 6039.056\,\mathrm{E3} * \frac{0.04}{400} \cong 6.039\,\mathrm{E2}$$

Questão 3 – 4

Quer-se bombear água dum tanque para um depósito 12 m acima do nível daquele, a um caudal de 1.25 $\mathrm{dm^3\,s^{-1}}$, através dum tubo de ferro de 25 mm de diâmetro e 30 m de comprimento. O tanque e o reservatório encontram-se à pressão atmosférica. Qual é a potência da bomba necessária?

- $\mu = 1.30 * 10^{-3}\,\mathrm{kg\,m^{-1}\,s^{-1}}$
- $\rho = 1000\,\mathrm{kg\,m^{-3}}$
- Rugosidade do ferro $= 0.046\,\mathrm{mm}$

Resposta

$$
\begin{aligned}
W_b &= -\Delta P_b\,G_v = h_b\,\rho\,g\,G_v = \\
&= \left(Z_2 + \frac{v^2}{2\,g} + h_{at}\right)\,\rho\,g\,G_v = \\
&= \left(Z_2 + \frac{v^2}{2\,g} + \frac{-\Delta P_{at}}{\rho\,g}\right)\,\rho\,g\,G_v = \\
&= Z_2\,\rho\,g\,G_v + \left(\frac{v^2}{2} + \frac{4\,\phi\,\rho\,v^2\,L/D}{\rho}\right)\,\rho\,G_v = \\
&= Z_2\,\rho\,g\,G_v + \left(\frac{1}{2} + \frac{4\,\phi\,L}{D}\right)\,v^2\,\rho\,G_v = \\
&= Z_2\,\rho\,g\,G_v + \left(\frac{1}{2} + \frac{4\,\phi\,L}{D}\right)\,\left(\frac{G_v}{\pi\,(D/2)^2}\right)^2\,\rho\,G_v = \\
&= Z_2\,\rho\,g\,G_v + \left(2^3 + \frac{4^3\,\phi\,L}{D}\right)\,\frac{G_v^3\rho}{\pi^2\,D^4};
\end{aligned}
$$

$$
\begin{aligned}
\phi\,(Re, \varepsilon/D) &= \phi\left(\frac{\rho\,D\,\bar{v}}{\mu}, \varepsilon/D\right) = \phi\left(\frac{10^3 * 25 * 10^{-3} 2.55}{1.30 * 10^{-3}}, \frac{0.046\ \mathrm{E}-3}{25\ \mathrm{E}-3}\right) = \\
&= \phi\left(\frac{25 * 2.55}{1.30}\,10^3, 0.046/25\right) \cong \phi\,(49.038\,\mathrm{E}3, 1.840\,\mathrm{E}{-3}) \cong 0.00255
\end{aligned}
$$

$$
\begin{aligned}
\therefore W_b &= 12 * 10^3 * 9.780 * 1.25 * 10^{-3} + \\
&+ \left(2^3 + \frac{4^3 * 0.00255 * 30}{25 * 10^{-3}}\right)\,\frac{(1.25 * 10^{-3})^3 * 10^3}{\pi^2\,(25 * 10^{-3})^4} = \\
&= 12 * 9.780 * 1.25 + \left(2^3 + \frac{4^3 * 2.55 * 30}{25}\right)\,\frac{(1.25)^3}{\pi^2\,(25)^4} * 10^6 \cong 249.971
\end{aligned}
$$

Questão 3 – 5

Pretende-se bombear $4\,\mathrm{dm^3\,s^{-1}}$ de uma solução de ácido sulfúrico através dum tubo de $2.5\,\mathrm{cm}$ de diâmetro, em chumbo, e a uma altura de $25\,\mathrm{m}$. O tubo tem $30\,\mathrm{m}$ de comprimento e contém dois joelhos em ângulo recto. Calcular a potência da bomba teoricamente necessária.

- $\rho_{sol\ ac} = 1531\,\mathrm{kg\,m^{-3}}$
- $\mu_{sol\ ac} = 0.065\,\mathrm{kg\,m^{-1}\,s^{-1}}$
- rugosidade chumbo $= 0.05\,\mathrm{mm}$

Resposta

$$\begin{aligned}
W_b &= -\Delta P_b\, G_v = h_b\, \rho\, g\, G_v = \\
&= (Z_2 + h_{at})\ \rho\, g\, G_v = \\
&= Z_2\, \rho\, g\, G_v + \left(\frac{-\Delta P_{at}}{\rho\, g}\right)\ \rho\, g\, G_v = \\
&= Z_2\, \rho\, g\, G_v + \left(4\, \phi\, \rho\, v^2\, L_{eq}/D\right)\ G_v = \\
&= Z_2\, \rho\, g\, G_v + \left(\frac{G_v}{\pi\, r^2}\right)^2\ (L + 2*40*D)\ \frac{4\, \phi\, \rho\, G_v}{D} = \\
&= Z_2\, \rho\, g\, G_v + \frac{4^3\, \phi\, \rho\, (L + 2*40*D)\, G_v^2}{\pi^2\, D^5} = \\
&= Z_2\, \rho\, g\, G_v + \frac{4^3\, \phi\, \rho\, (L + 2*40*D)\, G_v^2}{\pi^2\, D^5};
\end{aligned}$$

$$\begin{aligned}
\phi\,(Re, \varepsilon/D) &= \phi\left(\frac{\rho\, D\, \bar{v}}{\mu}, \varepsilon/D\right) = \phi\left(\frac{\rho\, D}{\mu}\frac{G_v}{\pi\,(D/2)^2}, \varepsilon/D\right) = \\
&= \phi\left(\frac{\rho\, G_v\, 4}{\mu\, \pi\, D}, \varepsilon/D\right) = \phi\left(\frac{1531*4*10^{-3}*4}{0.065*\pi*2.5*10^{-2}}, \frac{0.05*10^{-3}}{2.5*10^{-3}}\right) = \\
&= \phi\left(\frac{1.531*4^2}{6.5*\pi*2.5}*10^4, 2*10^{-2}\right) \cong \phi\,(4.798\,\mathrm{E3}, 2*10^{-2}) \cong 0.0069
\end{aligned}$$

$$\begin{aligned}
W_b &\cong 25*1531*9.780*4*10^{-3} + \\
&+ \frac{4^3*0.0069*1531*(30+2*40*2.5*10^{-2})*(4*10^{-3})^2}{\pi^2*(2.5*10^{-2})^5} = \\
&= 2.5*1.531*9.780*40 + \frac{4^5*6.9*1.531*(3+2*4*2.5*10^{-2})}{\pi^2*2.5^5}10^5 \cong \\
&\cong 3.593\,\mathrm{E6}
\end{aligned}$$