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Lista 4

01) $u = -2xy \qquad v = y^2 - x^2 \qquad w = 0$

* Escoamento permanente, incompressível e bidimensional

a) $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \; ? \rightarrow -2y + 2y = 0$, logo satisfaz a conservação da massa

b) $$\begin{cases} \cancel{\rho g_x}^{\,0} - \frac{\partial P}{\partial x} + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \cancel{\frac{\partial^2 u}{\partial z^2}}^{\,0 \to 2D}\right) = \rho \frac{du}{dt} \quad (1) \\ \cancel{\rho g_y}_{\,0} - \frac{\partial P}{\partial y} + \mu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \cancel{\frac{\partial^2 v}{\partial z^2}}_{\,0 \to 2D}\right) = \rho \frac{dv}{dt} \quad (2) \end{cases}$$

$$\frac{du}{dt} = \cancel{\frac{\partial u}{\partial t}}^{\text{regime perman}} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = (-2xy)\cdot(-2y) + (y^2 - x^2)\cdot(-2x) = 4xy^2 - 2xy^2 + 2x^3$$

$$\frac{dv}{dt} = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = (-2xy)\cdot(-2x) + (y^2 - x^2)\cdot(2y) = 4x^2y + 2y^3 - 2x^2y$$

$$(1)\; -\frac{\partial P}{\partial x} + \mu(0 + 0) = \rho(2xy^2 + 2x^3) \Rightarrow -\frac{\partial P}{\partial x} = \rho(2xy^2 + 2x^3) \quad (3)$$

$$(2)\; -\frac{\partial P}{\partial y} + \mu(2 - 2) = \rho(2x^2y + 2y^3) \Rightarrow -\frac{\partial P}{\partial y} = \rho(2x^2y + 2y^3) \quad (4)$$

$$(3)\; \int_{P_0}^{P} dP = -\rho \cdot 2 \int (xy^2 + x^3)\,dx \Rightarrow -2\rho \cdot \left[\frac{x^2y^2}{2} + \frac{x^4}{4}\right] + f(y) = P - P_0 \Rightarrow$$

$$\Rightarrow P = P_0 - \rho \cdot \left[x^2y^2 + \frac{x^4}{2}\right] + f(y) \; \underset{(7)}{} \xrightarrow[\frac{\partial P}{\partial y}]{} \frac{\partial P}{\partial y} = -\rho \cdot 2x^2y + \frac{df}{dy} \quad (5)$$

$$(5) = (4):\; -\rho\, \cancel{2x^2y} + \frac{df}{dy} = -\rho(\cancel{2x^2y} + 2y^3) \Rightarrow \frac{df}{dy} = -2\rho y^3 \Rightarrow$$

$$\Rightarrow \int df = -\int 2\rho y^3\,dy \Rightarrow f(y) = -\frac{\rho}{2}y^4 + C \quad (6)$$

$$(6) = (7):\; P = P_0 - \rho \cdot \left[x^2y^2 + \frac{x^4}{2}\right] - \frac{\rho}{2}y^4 + C \xrightarrow[\substack{Y=1 \\ P=0}]{p/x=0} 0 = P_0 + C \Rightarrow C = P_a$$

Logo, $P = P_0 - \rho\left[x^2y^2 + \frac{x^4}{2} - \frac{y^4}{2}\right]$

2) $\vec{v} = Kx\,\vec{i} + Ky\,\vec{j} - 2Kz\,\vec{k}$

Continuidade: $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \Rightarrow \frac{\partial(Kx)}{\partial x} + \frac{\partial(Ky)}{\partial y} + \frac{\partial(2Kz)}{\partial z} = 0 \Rightarrow$

$\Rightarrow K + K - 2K = \; \neq 0 \rightarrow$ Logo, satisfaz!

Navier: $\begin{cases} \text{Em } x \rightarrow -\frac{\partial P}{\partial x} + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right) = \rho\left(u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}\right) \Rightarrow \end{cases}$

$\Rightarrow -\frac{\partial P}{\partial x} + \mu(0 + 0 + 0) = \rho(K^2x + 0 + 0) \Rightarrow -\frac{\partial P}{\partial x} = \rho K^2 x \quad (1)$

$$Em\, y \Rightarrow -\frac{\partial P}{\partial y} + \mu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\right) = \rho\left(u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}\right) \Rightarrow$$

$$\Rightarrow -\frac{\partial P}{\partial y} = \rho K^2 y \quad (2)$$

$$Em\, z \Rightarrow -\frac{\partial P}{\partial z} + \rho g_z + \mu\left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2}\right) = \rho\left(u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z}\right) \Rightarrow$$

$$\Rightarrow -\frac{\partial P}{\partial z} + \rho g = 4K^2 z \Rightarrow -\frac{\partial P}{\partial z} = 4K^2 z - \rho g \quad (3)$$

$$(1) \int_{P_0}^{P} dP = \int \rho K^2 x \, dx \Rightarrow P = P_0 - \rho \cdot \frac{K^2 x^2}{2} + f(y,z)$$

$$(2) \int_{P_0}^{P} dP = \int \rho K^2 y \, dy \Rightarrow P = P_0 - \rho \frac{K^2 y^2}{2} + f(x,z)$$

$$(3) \int_{P_0}^{P} dP = \int (4K^2 z - \rho g)\, dz \Rightarrow P = P_0 + 2K^2 z^2 - \rho g z + f(y,z)$$

$$\Rightarrow \underline{P = P_0 - \rho g z - \frac{\rho}{2}K^2\left(x^2 + y^2 + 4z^2\right)} \;//$$

c) $\left(\cancelto{0}{\frac{\partial w}{\partial y}} - \cancelto{0}{\frac{\partial v}{\partial z}}\right)\vec{i} + \left(\cancelto{0}{\frac{\partial u}{\partial z}} - \cancelto{0}{\frac{\partial w}{\partial x}}\right)\vec{j} + \left(\cancelto{0}{\frac{\partial v}{\partial x}} - \cancelto{0}{\frac{\partial u}{\partial y}}\right)\vec{k} = 0 \rightarrow$ é irrotacional

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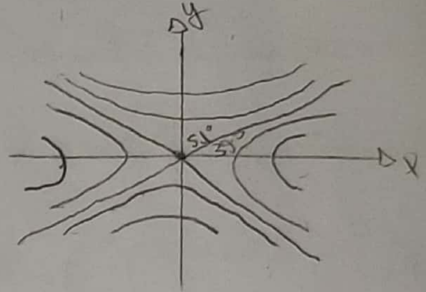
03) $V = 3y\vec{i} + 2x\vec{j}$ → incompressível, bidimensional e permanente

→ Continuidade: $\dfrac{\partial u}{\partial x} + \dfrac{\partial v}{\partial y} = 0 \rightarrow 0 + 0 = 0$, logo satisfaz

→ Corrente: $u = \dfrac{\partial \psi}{\partial y}$ $\quad v = -\dfrac{\partial \psi}{\partial x}$



$\cdot \int \partial\psi = \int 3y\, \partial y \Rightarrow \psi = \frac{3}{2}y^2 + f(x)$ $\quad \rightarrow \psi = \frac{3}{2}y^2 - x^2$

$\cdot \int \partial\psi = \int 2x\, \partial x \Rightarrow \psi = -x^2 + f(y)$

P/ $\psi = 0 \rightarrow 0 = \sqrt{\frac{3}{2}}\, y - x \rightarrow y = \dfrac{x}{\sqrt{\frac{3}{2}}} \rightarrow \theta = 39°$

P/ $\psi = \pm 1 \rightarrow \pm 1 = \sqrt{\frac{3}{2}}\, y^2 - x^2$

04) $P = f(Q, D, V, \eta, m)$ [$\eta \rightarrow \rho$, $m \rightarrow \mu$]

6 variáveis (P, Q, D, w, ρ, μ)

3 dimensões FLT^{-1}, $L^3 \cdot T^{-1}$, L, T^{-1}, FT^2L^{-4}, FTL^{-2}

3 grupos π:

$\pi_1 = \Omega^{a_1} \rho^{a_2} D^{a_3} \cdot P^1 = F^0T^0L^0 \Rightarrow (T^{-1})^{a_1} (FT^2L^{-4})^{a_2} \cdot (L)^{a_3} \cdot (FLT^{-1})^1 = F^0T^0L^0$

$\Rightarrow T^{-a_1} \cdot F^{a_2} \cdot T^{2a_2} \cdot L^{-4a_2} \cdot L^{a_3} \cdot F^1L^1T^{-1} = T^{-a_1+2a_2-1} \cdot F^{a_2+1} \cdot L^{-4a_2+a_3+1}$

$\pi_2 = \Omega^{b_1} \rho^{b_2} D^{b_3} \cdot Q^1 = F^0L^0T^0 = T^{-b_1} \cdot F^{b_2} T^{2b_2} \cdot L^{-4b_2} \cdot L^{b_3} \cdot L^3T^{-1} = F^0T^0L^0 \Rightarrow$

$\Rightarrow T^{-b_1+2b_2-1} F^{b_2} L^{-4b_2+b_3+3} = F^0T^0L^0$

$\pi_3 = \Omega^{c_1} \rho^{c_2} D^{c_3} \cdot \mu = F^0L^0T^0 \Rightarrow T^{-c_1} F^{c_2} T^{2c_2} \cdot L^{-4c_2} \cdot L^{c_3} \cdot F^1T^1L^{-2} = F^0L^0T^0 \Rightarrow$

$\Rightarrow T^{-c_1+2c_2+1} F^{c_2+1} L^{-4c_2+c_3-2} = F^0L^0T^0$

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$$\pi_1 = \begin{cases} -a_1 + 2a_2 = 1 \\ a_2 = -1 \\ -4a_2 + a_3 = -1 \end{cases} \qquad \begin{matrix} a_1 = -3 \\ a_2 = -1 \\ a_3 = -5 \end{matrix} \qquad \to \Omega^{-3} \rho^{-1} D^{-5} P^1 = \pi_1 = P^*$$

$$\pi_2 = \begin{cases} -b_1 + 2b_2 = 1 \\ b_2 = 0 \\ -4b_2 + b_3 = -3 \end{cases} \qquad \begin{matrix} b_1 = -1 \\ b_2 = 0 \\ b_3 = -3 \end{matrix}$$

$$\hookrightarrow \pi_2 = \Omega^{-1} D^{-3} Q^1 = Q^*$$

$$\pi_3 = \begin{cases} -c_1 + 2c_2 = -1 \\ c_2 = -1 \\ -4c_2 + c_3 = -2 \end{cases} \qquad \begin{matrix} c_1 = -1 \\ c_2 = -1 \\ c_3 = -2 \end{matrix}$$

$$\hookrightarrow \pi_3 = \Omega^{-1} \rho^{-1} D^{-2} \cdot \mu^1 = \mu^*$$

$$P = \frac{P^*}{\Omega^3 \rho D^5} \qquad Q = \frac{Q^*}{\Omega D^3} \qquad \mu = \frac{\mu^*}{\Omega \rho D^2}$$

$$\to \frac{P^*}{\Omega^3 \rho D^5} = f\left(\frac{Q^*}{\Omega D^3}, \frac{\mu^*}{\Omega \rho D^2}\right) //$$

05) $\tau \to M^1 L^{-1} \cdot T^{-2}$ $\quad V \to L^1 T^{-1}$ $\quad \varepsilon \to L^1$ $\quad \rho \to M^1 L^{-3}$ $\quad \mu \to M^1 L^{-1} T^{-1}$ $\quad D \to L^1$

6 variáveis e 3 dimensões (LTM), logo 3 grupos de π

Parametros repetidos: V, D e ρ

$$\pi_1 = V^{a_1} D^{a_2} \rho^{a_3} \cdot \tau = M^0 L^0 T^0 \Rightarrow L^{a_1} T^{-a_1} L^{a_2} M^{a_3} L^{-3a_3} \cdot M^1 L^{-1} T^{-2} = M^0 L^0 T^0$$

$$\Rightarrow \pi_1 = \begin{cases} -a_1 + a_2 - 3a_3 = 0 \Rightarrow a_2 = 0 \\ -a_1 - 2 = 0 \Rightarrow a_1 = -2 \\ a_3 + 1 = 0 \Rightarrow a_3 = -1 \end{cases} \qquad \to \pi = \frac{\tau}{\rho V^2}$$

$$\pi_2 = V^{b_1} D^{b_2} \rho^{b_3} \cdot \mu = M^0 L^0 T^0 \Rightarrow L^{b_1} T^{-b_1} L^{b_2} M^{b_3} L^{-3b_3} M^1 L^{-1} T^{-1} = M^0 L^0 T^0 \Rightarrow$$

$$\Rightarrow \pi_2 = \begin{cases} b_1 + b_2 - 3b_3 - 1 = 0 \\ -b_1 - 1 = 0 \\ b_3 + 1 = 0 \end{cases} \qquad \begin{matrix} b_1 = -1 \\ b_2 = -1 \\ b_3 = -1 \end{matrix} \qquad \to \pi_2 = \frac{\mu}{\rho \cdot V \cdot D} \to Re$$

$$\pi_3 = V^{c_1} D^{c_2} \rho^{c_3} \cdot \varepsilon = M^0 L^0 T^0 \Rightarrow L^{c_1} T^{-c_1} L^{c_2} M^{c_3} L^{-3a_3} \cdot L = M^0 L^0 T^0$$

$$\Rightarrow \pi_3 = \begin{cases} c_1 + c_2 - 3c_3 + 1 = 0 \Rightarrow c_2 = -1 \\ -c_1 = 0 \\ c_3 = 0 \end{cases} \qquad \to \pi_3 = \frac{\varepsilon}{D} \to \text{taxa rugosidade}$$

$$\Rightarrow f = \frac{8\tau}{\rho V^2} = f\left(\frac{\mu}{\rho V D}, \frac{\varepsilon}{D}\right)$$

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06) a) $v_m = 50 \text{ mi/h} = 22,352 \text{ m/s}$ $T_m = 25°C$ $T_p = 5°C$

A 25°C → $\rho = 1,184 \text{ kg/m}^3$ $\mu = 1,849 \cdot 10^{-5} \frac{kg}{m \cdot s}$

A 5°C → $\rho = 1,269 \text{ kg/m}^3$ $\mu = 1,751 \cdot 10^{-5} \text{ kg/m s}$

$Re = \frac{\rho \cdot V \cdot W}{\mu} \rightarrow Re_p = Re_m = \frac{1,184 \cdot 50 \cdot \cancel{X}}{1,849 \cdot 10^{-5}} = \frac{1,269 \cdot v_p \cdot \frac{\cancel{X}}{5}}{1,751 \cdot 10^{-5}} \Rightarrow$

$\Rightarrow v = 221 \text{ mi/h}$ //

b) $C_D = \frac{F_D}{\frac{1}{2}\rho v^2 A} \rightarrow C_{Dp} = C_{Dm} \Rightarrow \frac{21,2}{\cancel{0,5} \cdot 1,269 \cdot 221^2 \cdot \frac{A}{5^2}} = \frac{F_d}{\cancel{0,5} \cdot 1,184 \cdot 50^2 \cdot A} \Rightarrow$

$\Rightarrow F_d = 25,3 \text{ lbf}$ //

07) $\rho_{óleo} = 891 \text{ kg/m}^3$ $D = 5 \text{ cm} = 0,05 \text{ m}$ $Q = ?$

a) $T = 20°C \rightarrow \mu = 0,29 \frac{kg}{m \cdot s}$ $T = 100°C \rightarrow \mu = 0,01 \frac{kg}{m \cdot s}$

$Re_d = \frac{\rho \cdot v \cdot d}{\mu} \Rightarrow 2300 = \frac{891 \cdot v \cdot (0,05)}{0,29} \Rightarrow v = 14,97 \text{ m/s}$

$Q = V \cdot A = 14,97 \cdot \frac{\pi \, 0,05^2}{4} = 0,029 \text{ m}^3 = 103 \text{ m}^3/h$

b) $2300 = \frac{891 \cdot V \cdot 0,05}{0,01} \Rightarrow v = 0,5 \text{ m/s}$

$Q = V \cdot A = 1,01 \cdot 10^{-3} \text{ m}^3/s \Rightarrow Q = 3,68 \text{ m}^3/h$ //

08) $R = 0,04 \text{ m}$ $T = 20°C$ $\rho = 998 \text{ kg/m}^3$ $\tau = 72 \text{ Pa}$

a) Na horizontal: $\left.\frac{dP}{dx}\right|_{horizontal} = -\frac{2\tau}{R} = -\frac{2 \cdot 72}{0,04} = -3600 \text{ Pa/m}$

b) $\left.\frac{dP}{dx}\right|_{vertical} = -\frac{2\tau}{R} - \rho g = -\frac{2 \cdot 72}{0,04} - 998 \cdot 9,81 = -13390 \text{ Pa/m}$

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09) $\rho = 950 \, kg/m^3$ $v = 10 \, m/s$ $D = 0{,}05 \, m$

a) $h_f = \Delta z + \frac{\Delta P}{\rho g} = \frac{104000}{950 \cdot 9{,}81} = 11{,}16 \, m$

b) $\frac{\Delta P}{\Delta L}\Big|_{desenvolvido} = \frac{13000}{1} = \frac{4\tau}{d} = \frac{4\tau}{0{,}05} \Rightarrow \tau = 163 \, Pa$

c) $f = h_f \cdot \frac{D}{L} \cdot \frac{2g}{v^2} = 11{,}2 \cdot \frac{0{,}05}{6} \cdot \frac{2 \cdot 9{,}81}{10} \Rightarrow f = 0{,}0182$

10) $T = 20°C$ $v = 4 \, m/s$ $d = 0{,}06 \, m$ $h = 135$ $\Delta z = 3 \, m$

a)

$P_1 = (133100 - 9790)(0{,}135) + 9790 \cdot 3 + P_2 = 16650 + 29370 + P_2 \Rightarrow P_1 - P_2 = 46000 \, Pa$

b) $h_f = \frac{\Delta P}{\gamma} - \Delta z = \frac{46000}{9790} - 3 \Rightarrow h_f = 1{,}7 \, m$

c) $f = h_f \cdot \frac{d}{L} \cdot \frac{2g}{v^2} = 1{,}7 \cdot \frac{0{,}06}{5} \cdot \frac{2(9{,}81)}{4} \Rightarrow f = 0{,}025$

11) $\rho = 998 \, kg/m^3$ $\mu = 0{,}001 \, \frac{kg}{m\,s}$

$\rightarrow$ Eq. energia: $\cancel{\frac{P_{atm}}{\rho g}} + \cancel{\frac{v_1^2}{2g}} + z_1 = \cancel{\frac{P_{atm}}{\rho g}} + \frac{v_2^2}{2g} + z_2 + h_f \Rightarrow$

$\Rightarrow z_1 - z_2 = \frac{v_2^2}{2g} + h_f \Rightarrow H - \frac{v_2^2}{2g} = h_f \Rightarrow H - \frac{v_2^2}{2g} = h_f = \frac{32 \mu L}{\rho g d^2} V \Rightarrow$

$\Rightarrow 0{,}5 - \frac{v^2}{2 \cdot 9{,}81} = \frac{32 \cdot 0{,}001 \cdot 1 \cdot v}{998 \cdot 9{,}81 \cdot 0{,}002^2} \Rightarrow v = 0{,}6 \, m/s$

$Q = v \cdot A = 0{,}6 \cdot \pi \left(\frac{0{,}002}{2}\right)^2 = 1{,}88 \, m/s = 0{,}067 \, m^3/h$ p/ $H = 50 \, cm$

$Re = \frac{998 \cdot 0{,}590 \cdot 0{,}002}{0{,}001} = 1180$ (laminar)

$H_{máx} = 0{,}87$ (laminar) p/ $Re = 2000$

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12) $\rho = 1260\ kg/m^3$ $\quad \mu = 1{,}5\ kg/ms$

$$\frac{\Delta P}{L} = \frac{128\mu Q}{\pi d^4} \leq 100 \Rightarrow \frac{128 \cdot 1{,}5 \cdot 3{,}1}{\pi d^4} \leq 100 \rightarrow d \geq 1{,}17\ m$$

$$Re = \frac{4\rho Q}{\pi \cdot d\mu} \leq 2000 \Rightarrow \frac{4 \cdot 1260 \cdot 3{,}1}{\pi \cdot 1{,}5 \cdot d} = 2000 \rightarrow d \geq 1{,}67$$

Logo é 1,17 por ser mais restritiva

13) $\cancel{\frac{P_1}{\rho g}} + \cancel{\frac{v_1^2}{2g}} + \cancel{z_1} + h_{bomba} = \cancel{\frac{P_2}{\rho g}} + \cancel{\frac{v_2^2}{2g}} + \cancel{z_2} + h_p \rightarrow \begin{matrix} v_1 = v_2 \\ P_1 = P_2 \\ z_1 = z_2 \end{matrix} \rightarrow h_B = h_p$

$\Rightarrow f \cdot \frac{L}{d} \frac{v^2}{2g} = \eta \cdot \frac{Pot}{\rho g Q}$ * $\rightarrow$ $\rho_{querosene} = 804\ kg/m^3$ $\quad \varepsilon_{ferro} = 0{,}26\ mm$ $\rightarrow$

$\mu = 1{,}92 \cdot 10^{-3}\ kg/ms$

$\rightarrow Q = 0{,}15\ m^3/s$ $\quad v = \frac{Q}{A} = \frac{0{,}15}{\pi \cdot \left(\frac{0{,}16}{2}\right)^2} \Rightarrow v = 7{,}46\ m/s$

$L = 20\ km = 2000\ m$

$d = 0{,}16\ m$ $\quad Re_d = \frac{804 \cdot 7{,}46 \cdot 0{,}16}{1{,}92 \cdot 10^{-3}} = 499820$ (turbulento)

$\eta = 0{,}85$

$$\frac{\varepsilon}{d} = \frac{0{,}26 \cdot 10^{-3}}{0{,}16} = 0{,}001625$$

P/ diagrama de Moody: $f = 0{,}022$

$$* \ 0{,}022 \cdot \frac{20 \cdot 10^3}{0{,}16} \cdot \frac{7{,}46^2}{2 \cdot 9{,}81} = 0{,}85 \cdot \frac{Pot}{804 \cdot 9{,}81 \cdot 0{,}15} \Rightarrow Pot = \frac{7800 \cdot 804 \cdot 9{,}81 \cdot 0{,}15}{0{,}85}$$

$Pot = 10856{,}5\ kW$

14) $\varepsilon = 0{,}15\ mm$ $\quad Q = 3{,}067\ m^3/s$

$$V = \frac{Q}{A} = \frac{3{,}07}{\pi \left(\frac{1{,}22}{2}\right)^2} = 2{,}63\ m/s$$

$$Re = \frac{\rho\, v D}{\mu} = \frac{910 \cdot 2{,}63 \cdot 1{,}22}{0{,}01} = 292000$$

$$\frac{\varepsilon}{D} = \frac{0{,}15}{1220} = 0{,}000123 \xrightarrow{Moody} f = 0{,}0157$$

$$\Delta p = f \frac{L}{D} \frac{\rho v^2}{2} = 18000000 - 400000 = \frac{0{,}0157}{1{,}22} \cdot \frac{910}{2} \cdot 2{,}63^2$$

$L = 188000\ m = 188\ Km$

15- $T = 20° \rightarrow \rho = 998\ Kg/m^3$ $\mu = 1{,}002 \cdot 10^{-3}\ \frac{Kg}{m \cdot s}$ $\varepsilon = 0{,}00015\ m$

$\rightarrow \frac{\varepsilon}{D} = 0{,}003$

- Vide tabela:

$K_{entrada} = 1$ $K_{cotovelo} = 2 \cdot 0{,}41 = 0{,}82$ $K_{válvula\ gaveta} = 0{,}16$ $K_{saída} = 1$

* Sem cone:

$\rightarrow v = \frac{Q}{A} = \frac{0{,}0113}{\pi \cdot \left(\frac{0{,}05}{2}\right)^2} = 5{,}75\ m/s$

$Re = \frac{\rho \cdot v \cdot D}{\mu} = \frac{998 \cdot 5{,}75 \cdot 0{,}05}{1{,}002 \cdot 10^{-3}} = 286352{,}3$

$f\left(Re, \frac{\varepsilon}{D}\right) = 0{,}0266 \rightarrow h_{bomba} = \Delta z + \frac{v^2}{2g}\left(\frac{fL}{D} + \Sigma K\right) = D$

$\Rightarrow h_{bomba} = 6{,}1 + \frac{5{,}75^2}{2 \cdot 9{,}81}\left(0{,}0266 \cdot \frac{18{,}3}{0{,}05} + 2{,}98\right) = 27{,}50\ m$

$\rightarrow P_{bomba} = \frac{\rho g Q h_{bomba}}{\eta_{bomba}} = 998 \cdot 9{,}8 \cdot 0{,}0113 \cdot \frac{27{,}55}{0{,}7} = 4349{,}7\ W = 5{,}92\ hp$

* C/ cone:

$h_{bomba} = \Delta z + \frac{v^2}{2g}\left(\frac{fL}{D} + 1 + 0{,}3 + 0{,}16 + 0{,}82\right) = 26{,}37\ m$

$P_{bomba} = \frac{\rho g Q h_{b}}{\eta_b} = 998 \cdot 9{,}81 \cdot 0{,}0113 \cdot \frac{26{,}37}{0{,}7} = 4220{,}23\ W = 5{,}7\ hp$

$\% = \frac{5{,}92}{5{,}7} = 1{,}039 \rightarrow$ Aumento de 3,9%

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