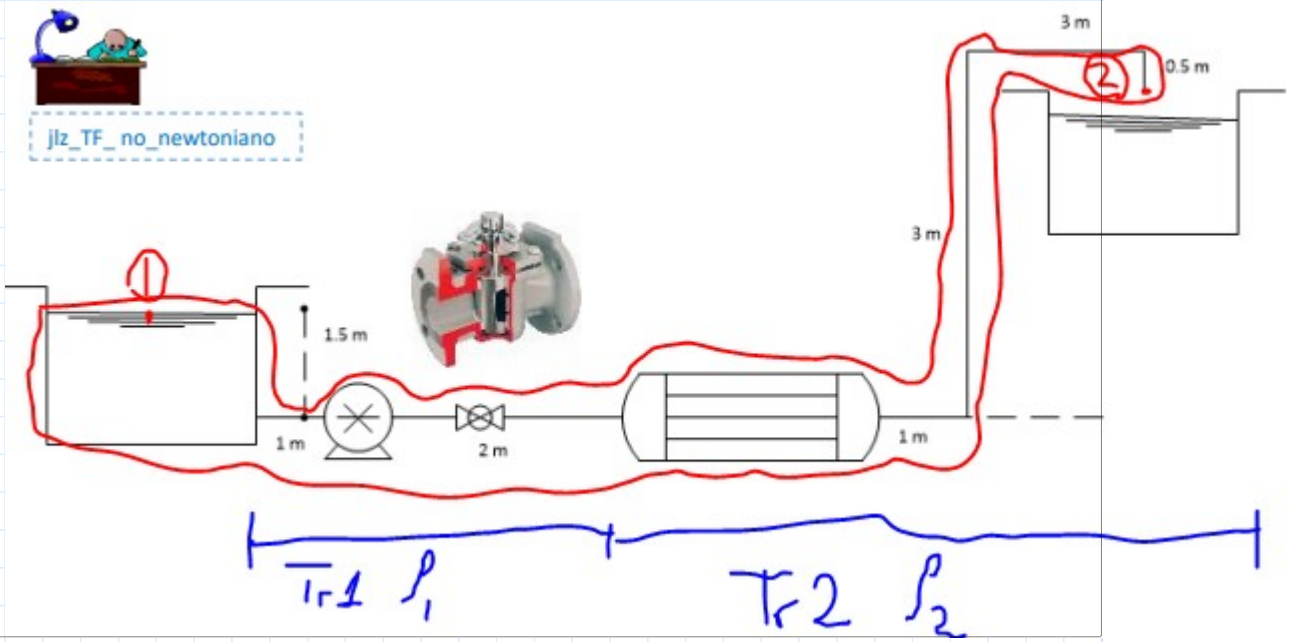
Problema y sistema

Se requiere transportar 1.97 kg.s^{-1} de un fluido no-Newtoniano (densidad, 1250 kg.m^{-3}) de
ambos abiertos, mediante un ducto de 1.25" # 40s. La caída de presión a través del STHE
incremento de la temperatura del fluido, su densidad disminuye un 6%. Asuma que el
comportamiento reológico modelable por LP. Asuma que el KL de la *plug valve* es 2. Det
necesaria de bombeo en los casos en que, a) el coeficiente de consistencia es 5.2 Pa.s^n y el ín
b) el coeficiente de consistencia es 0.25 Pa.s^n y el índice reológico, 0.45.



DATOS

$P_1 := 1\ atm = (1.013 \cdot 10^5)\ Pa$ $P_2 := P_1 = (1.013 \cdot 10^5)\ Pa$ $Q_m := 1.97\ \frac{kg}{s}$ $D_{nom} :=$

$z_1 := 1.5\ m$ $z_2 := 3\ m - 0.5\ m = 2.5\ m$ $\delta_1 := 1250\ \frac{kg}{m^3}$ $\delta_2 := 1175\ \frac{kg}{m^3}$ $Long_1 := 1\ m$

$\Delta P := 100\ kPa = (1 \cdot 10^5)\ Pa$ $Long_2 := 1\ m + 3\ m + 3\ m + 0.5\ m = 7.5\ m$

$v_1 := 0\ \frac{m}{s}$ $v_2 := \frac{4 \cdot Q_m}{\pi \cdot D^2 \cdot \delta_2} = 1.737\ \frac{m}{s}$ $Q_{v1} := \frac{Q_m}{\delta_1} = (1.58 \cdot 10^{-3})\ \frac{m^3}{s}$ $Q_{v2} := \frac{Q_m}{\delta_2} = (1.68$

Incógnitas

Pot_{bomb}

Ecuaciones

$$v\left(Q_m, D, \delta\right) := \frac{4 \cdot Q_m}{\pi \cdot D^2 \cdot \delta}$$

$$GRey\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) := \frac{D^{n_{indice}} \cdot v\left(Q_m, D, \delta\right)^{\left(2 - n_{indice}\right)} \cdot \delta}{8^{\left(n_{indice} - 1\right)} \cdot K_{coef}} \cdot \left(\frac{4 \cdot n_{indice}}{3 \cdot n_{indice} + 1}\right)^{n_{indice}}$$

$$GRey_{crit}\left(n_{indice}\right) := \frac{6464 \cdot n_{indice} \cdot \left(2 + n_{indice}\right)^{\frac{2 + n_{indice}}{1 + n_{indice}}}}{\left(1 + 3 \cdot n_{indice}\right)^2}$$

$$f_D\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) := \frac{64}{GRey\left(K_{coef}, D, Q_m, \delta, n_{indice}\right)}$$

$$\alpha_{RL}\left(n_{indice}\right) := \frac{3 \cdot \left(3 \cdot n_{indice} + 1\right)^2}{\left(2 \cdot n_{indice}\right) \cdot \left(5 \cdot n_{indice} + 3\right)}$$

$$DP\left(Temp\right) := \left(\frac{P_1}{\delta} + g \cdot z_1 + \alpha_1 \cdot \frac{{v_1}^2}{2}\right) - \left(\frac{P_2}{\delta} + g \cdot z_2 + \alpha_2 \cdot \frac{{v_2}^2}{2}\right)$$

$$Ft_{RL}\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) := \frac{500}{GRey\left(K_{coef}, D, Q_m, \delta, n_{indice}\right)}$$

Irrever por trayectoria

$$e_{Lp}\left(K_{coef}, D, Q_m, \delta, n_{indice}, Long\right) := f_D\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) \cdot \frac{Long}{D} \cdot \frac{\left(\frac{4 \cdot Q_m}{\pi \cdot D^2 \cdot \delta}\right)^2}{2}$$

Irrever por entrada

$K_{Lcon} := 0.5$

$$e_{Lcon}\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) := Ft_{RL}\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) \cdot K_{Lcon} \cdot \frac{\left(\frac{4 \cdot Q_m}{\pi \cdot D^2 \cdot \delta}\right)^2}{2}$$

Irrever por válvula de regulación

$$K_{Lvalpl}\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) := 3 \cdot f_D\left(K_{coef}, D, Q_m, \delta, n_{indice}\right)$$

$$e_{Lvalpl}\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) := Ft_{RL}\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) \cdot K_{Lvalpl}\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) \cdot \frac{\left(\frac{4 \cdot$$

Irrever por equipo

$$e_{LSTHE}\left(\Delta P, \delta\right) := \frac{\Delta P}{\delta}$$

Irrever por accesorio, codos 90°

$$K_L\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) := 30 \cdot f_D\left(K_{coef}, D, Q_m, \delta, n_{indice}\right)$$

$$e_{Lacc}\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) := Ft_{RL}\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) \cdot K_L\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) \cdot \frac{\left(\frac{4 \cdot Q_m}{\pi \cdot D^2 \cdot \delta}\right)^2}{2}$$

DESARROLLO

INCISO A

$n_{indice} := 0.45$

$$K_{coef} := 5.2\ Pa \cdot s^{0.45} = 5.2\ \frac{kg}{m \cdot s^{\frac{31}{20}}}$$

$GRey_{crit}\left(n_{indice}\right) = 2.394 \cdot 10^3$

Tramo 1

$GRey\left(K_{coef}, D, Q_m, \delta_1, n_{indice}\right) = 316.834$

$f_D\left(K_{coef}, D, Q_m, \delta_1, n_{indice}\right) = 0.202$

Tramo 2

$GRey\left(K_{coef}, D, Q_m, \delta_2, n_{indice}\right) = 327.802$

$f_D\left(K_{coef}, D, Q_m, \delta_2, n_{indice}\right) = 0.195$

$$\alpha_{RL}(n_{indice}) = 3.506$$

$$DP := \left(\frac{P_1}{\delta_1} + g \cdot z_1 + \alpha_{RL}(n_{indice}) \cdot \frac{v_1^2}{2}\right) - \left(\frac{P_2}{\delta_2} + g \cdot z_2 + \alpha_{RL}(n_{indice}) \cdot \frac{v_2^2}{2}\right)$$

$$DP = -20.273 \ \frac{m^2}{s^2}$$

Cálculo de irreversibilidades

Tramo 1

$$e1 := \begin{bmatrix} e_{Lp}(K_{coef}, D, Q_m, \delta_1, n_{indice}, Long_1) \\ e_{Lvalpl}(K_{coef}, D, Q_m, \delta_1, n_{indice}) \\ e_{Lcon}(K_{coef}, D, Q_m, \delta_1, n_{indice}) \end{bmatrix} = \begin{bmatrix} 23.057 \\ 1.275 \\ 1.052 \end{bmatrix} \frac{m^2}{s^2}$$

$$e_{L1} := \sum_{j=0}^{2} e1_j = 25.385 \ \frac{m^2}{s^2}$$

Tramo 2

$$e2 := \begin{bmatrix} e_{Lp}(K_{coef}, D, Q_m, \delta_2, n_{indice}, Long_2) \\ e_{LSTHE}(\Delta P, \delta_2) \\ 2 \cdot e_{Lacc}(K_{coef}, D, Q_m, \delta_2, n_{indice}) \end{bmatrix} = \begin{bmatrix} 63.054 \\ 85.106 \\ 26.97 \end{bmatrix} \frac{m^2}{s^2}$$

$$e_{L2} := \sum_{j=0}^{2} e2_j = 175.13 \ \frac{m^2}{s^2}$$

Valores de prueba

$$w_s := 1 \ \frac{m^2}{s^2}$$

Restricciones

$$DP + w_s = e_{L2} + e_{L1}$$

Solver

$w_s := \text{find}(\mathbf{w_s}) = 220.788 \ \frac{m^2}{s^2}$

$Pot_{bomb} := w_s \cdot Q_m = 0.435 \ kW$

$H_s := \frac{w_s}{g} = 22.514 \ m$

INCISO b

$n_{indice} := 0.45$

$K_{coef} := 0.25 \ Pa \cdot s^{0.45} = 0.25 \ \frac{kg}{m \cdot s^{\frac{31}{20}}}$

$GRey_{crit}(n_{indice}) = 2.394 \cdot 10^3$

Tramo 1

$GRey(K_{coef}, D, Q_m, \delta_1, n_{indice}) = 6.59 \cdot 10^3$

$f_D(K_{coef}, D, Q_m, \delta_1, n_{indice}) = 0.01$

$\alpha_{RT} := 1$

$DP := \left(\frac{P_1}{\delta_1} + g \cdot z_1 + \alpha_{RT} \cdot \frac{v_1^2}{2}\right) - \left(\frac{P_2}{\delta_2} + g \cdot z_2 + \alpha_{RT} \cdot \frac{v_2^2}{2}\right)$

$DP = -16.49 \ \frac{m^2}{s^2}$

$Ft_{RL}(K_{coef}, D, Q_m, \delta, n_{indice}) := 1$

Tramo 2

$GRey(K_{coef}, D, Q_m, \delta_2, n_{indice}) = 6.818 \cdot 10$

$f_D(K_{coef}, D, Q_m, \delta_2, n_{indice}) = 0.009$

de prueba

$f_f := 1$

Valores

Restricciones

$$\frac{1}{\sqrt[2]{f_f}} = \left(\frac{4}{n_{indice}^{0.75}}\right) \cdot log\left(GRey\left(K_{coef}, D, Q_m, \delta_1, n_{indice}\right) \cdot f_f^{\left(1-\frac{n_{indice}}{2}\right)}\right) - \left(\frac{0.4}{n_{indice}^{1.2}}\right)$$

Solver

$$f_{f1} := \text{find}\left(f_f\right) = 5.2 \cdot 10^{-3}$$

$$f_{D1} := 4 \cdot f_{f1} = 0.02079$$

$$e_{Lp1}\left(K_{coef}, D, Q_m, \delta, n_{indice}, Long\right) := f_{D1} \cdot \frac{Long}{D} \cdot \frac{\left(\frac{4 \cdot Q_m}{\pi \cdot D^2 \cdot \delta}\right)^2}{2}$$

$$e_{Lp2}\left(K_{coef}, D, Q_m, \delta, n_{indice}, Long\right) := f_{D2} \cdot \frac{Long}{D} \cdot \frac{\left(\frac{4 \cdot Q_m}{\pi \cdot D^2 \cdot \delta}\right)^2}{2}$$

Irrever por entrada

$$K_{Lcon} := 0.5$$

$$e_{Lcon}\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) := Ft_{RL}\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) \cdot K_{Lcon} \cdot \frac{\left(\frac{4 \cdot Q_m}{\pi \cdot D^2 \cdot \delta}\right)^2}{2}$$

Irrever por válvula de regulación

$$K_{Lvalpl} := 3 \cdot f_{D1}$$

$$e_{Lvalpl}\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) := Ft_{RL}\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) \cdot K_{Lvalpl} \cdot \frac{\left(\frac{4 \cdot Q_m}{\pi \cdot D^2 \cdot \delta}\right)^2}{2}$$

Irrever por equipo

$$e_{LSTHE}\left(\Delta P, \delta\right) := \frac{\Delta P}{\delta}$$

Irrever por accesorio, codos

90°

$K_L := 30 \cdot f_{D2}$

$$e_{Lacc}\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) := Ft_{RL}\left(K_{coef}, D, Q_m, \delta, n_{indice}\right) \cdot K_L \cdot \frac{\left(\frac{4 \cdot Q_m}{\pi \cdot D^2 \cdot \delta}\right)^2}{2}$$

Cálculo de irreversibilidades

Tramo 1

$$e1 := \begin{bmatrix} e_{Lp1}\left(K_{coef}, D, Q_m, \delta_1, n_{indice}, Long_1\right) \\ e_{Lvalpl}\left(K_{coef}, D, Q_m, \delta_1, n_{indice}\right) \\ e_{Lcon}\left(K_{coef}, D, Q_m, \delta_1, n_{indice}\right) \end{bmatrix} = \begin{bmatrix} 2.373 \\ 0.083 \\ 0.667 \end{bmatrix} \frac{m^2}{s^2}$$

$$e_{L1} := \sum_{j=0}^{2} e1_j = 3.123 \frac{m^2}{s^2}$$

Tramo 2

$$e2 := \begin{bmatrix} e_{Lp2}\left(K_{coef}, D, Q_m, \delta_2, n_{indice}, Long_2\right) \\ e_{LSTHE}\left(\Delta P, \delta_2\right) \\ 2 \cdot e_{Lacc}\left(K_{coef}, D, Q_m, \delta_2, n_{indice}\right) \end{bmatrix} = \begin{bmatrix} 6.637 \\ 85.106 \\ 1.861 \end{bmatrix} \frac{m^2}{s^2}$$

$$e_{L2} := \sum_{j=0}^{2} e2_j = 93.605 \frac{m^2}{s^2}$$

Valores de prueba

$w_s := 1 \frac{m^2}{s^2}$

Restricciones

$DP + w_s = e_{L2} + e_{L1}$

Solver

$$w_s := \text{find}(w_s) = 113.218 \ \frac{m^2}{s^2}$$

$$Pot_{bomb} := w_s \cdot Q_m = 0.223 \ kW$$

$$H_s := \frac{w_s}{g} = 11.545 \ m$$