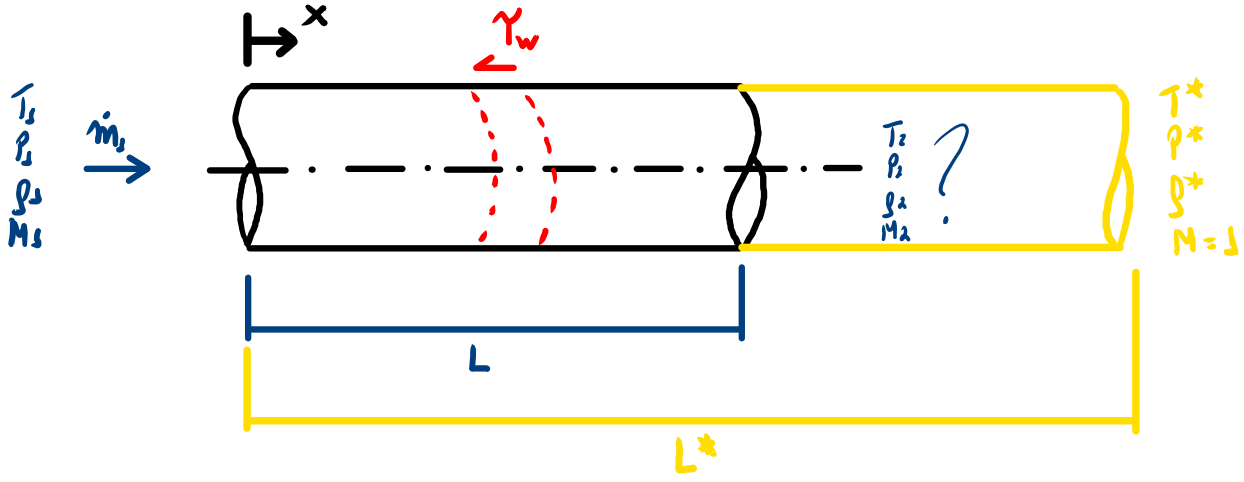
ESCOAMENTO COMPRESSÍVEL

ESCOAMENTO DE FANNO

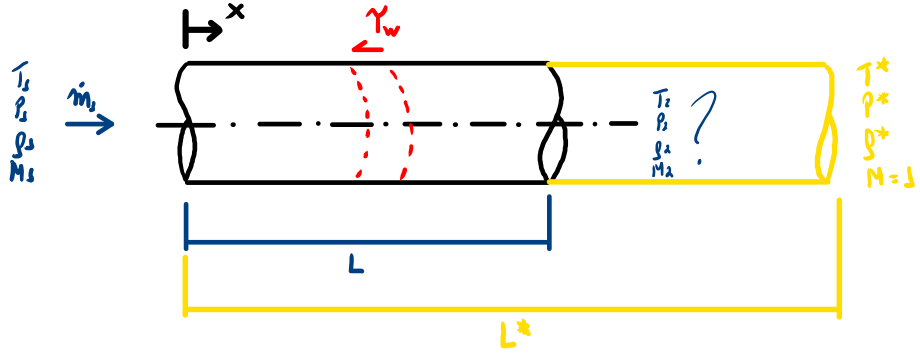
EXERCÍCIO UTILIZANDO FÓRMULAS PARA CONDIÇÃO SÔNICA



ESCOAMENTO DE FANNO

ESCOAMENTO COM ATRITO

Escoamento de Fanno se refere a um escoamento adiabático com atrito, através de um duto de área constante.



$$\int_{x_1}^{x_2} \frac{4f\,dx}{D} = \left[-\frac{1}{kM^2} - \frac{k+1}{2k} \ln\left(\frac{M^2}{1 + \frac{k-1}{2} M^2} \right) \right]_{M_1}^{M_2}$$

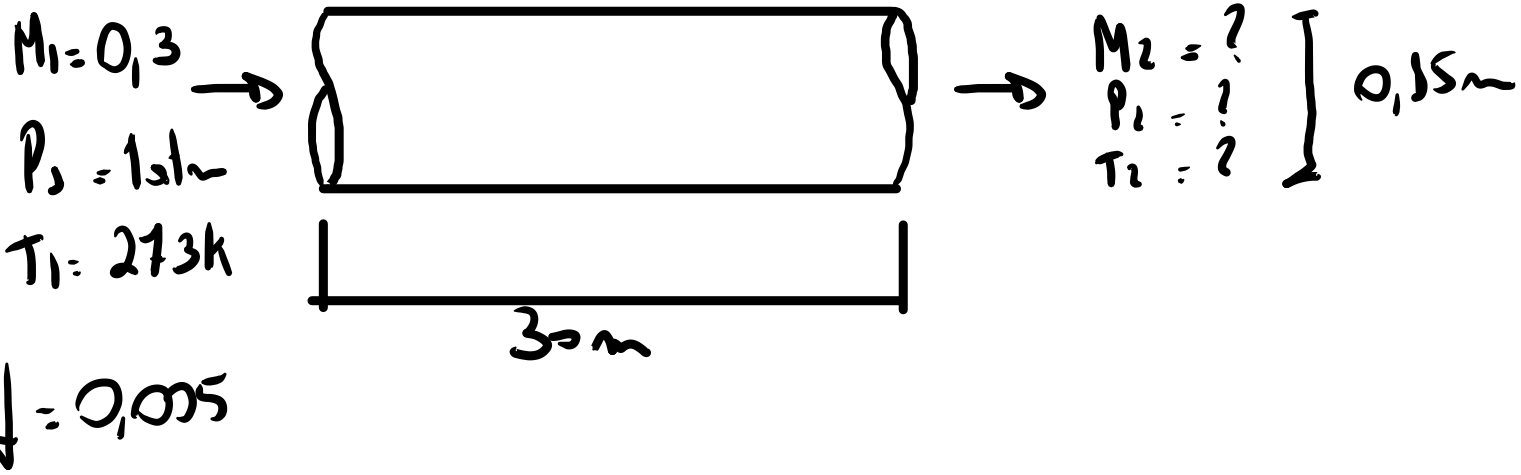
$$\frac{T_2}{T_1} = \frac{2 + (k-1) M_1^2}{2 + (k-1) M_2^2}$$

$$\frac{\rho_2}{\rho_1} = \frac{M_1}{M_2} \left[\frac{2 + (k-1) M_1^2}{2 + (k-1) M_2^2} \right]^{1/2}$$

$$\frac{Q_2}{Q_1} = \frac{M_1}{M_2} \left[\frac{2 + (k-1) M_1^2}{2 + (k-1) M_2^2} \right]^{-1/2}$$

$$\frac{P_{o2}}{P_{o1}} = \frac{M_1}{M_2} \left[\frac{2 + (k-1) M_2^2}{2 + (k-1) M_1^2} \right]^{\frac{(k+1)}{[2(k-1)]}}$$

Considere o escoamento de ar ao longo de um duto com diâmetro D=0,15m e comprimento 30m. As condições de entrada são M_1=0,3 P_1=1atm T_1=273K. Assumindo f=0,005, calcule as condições no escoamento na saída. M_2,T_2,P_2, P_{o2}



$$\rho_1 = \frac{P_1}{RT_1} = 1,2763 \frac{kg}{m^3}$$

CALCULAR PROPRIEDADES SÔNICAS

$$\frac{T^*}{T} = \frac{2+(k-1)M^2}{k+1} \rightsquigarrow T^* = T_1\left[\frac{2+0,4\cdot 0,3^2}{2,4}\right] \Rightarrow T^* = 231,535\,k$$

$$\frac{p^*}{p} = M\left[\frac{2+(k-1)M^2}{k+1}\right]^{1/2} \rightsquigarrow p^* = p_1\cdot 0,3\left[\frac{2+(0,4)\cdot 0,3^2}{2,4}\right]^{1/2} \Rightarrow p^* = 0,2763\,atm$$

$$\frac{\rho^*}{\rho} = M\left[\frac{2+(k-1)M^2}{k+1}\right]^{-1/2} \rightsquigarrow \rho^* = \rho_1\cdot 0,3\left[\frac{2+0,4\cdot 0,3^2}{2,4}\right]^{-1/2} \Rightarrow \rho^* = 0,4157\,\frac{kg}{m^3}$$

$$\frac{p_0^*}{p_0} = M\left[\frac{k+1}{2+(k-1)M^2}\right]^{\frac{(k+1)}{2(k-1)}}$$

$$\frac{p_{01}}{p_1} = \left(\frac{T_{01}}{T_1}\right)^{k/k-1} = \left(1+\frac{k-1}{2}M_1^2\right)^{k/k-1} \rightsquigarrow p_{01} = 1,0644\,atm$$

CALCULAR PROPRIEDADES SÔNICAS

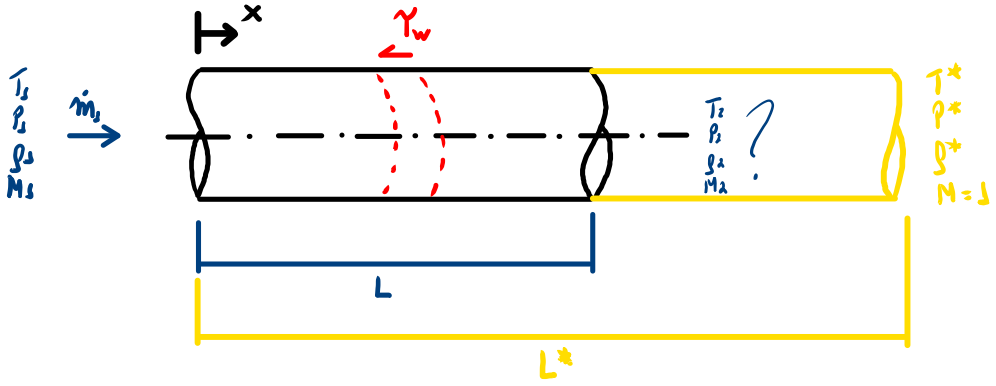
$$\frac{T^*}{T} = \frac{2+(k-1)M^2}{k+1} \rightsquigarrow T^* = T_1\left[\frac{2+0,4\cdot 0,3^2}{2,4}\right] \Rightarrow T^* = 231,535\,k$$

$$\frac{p^*}{p} = M\left[\frac{2+(k-1)M^2}{k+1}\right]^{1/2} \rightsquigarrow p^* = p_1\cdot 0,3\left[\frac{2+(0,4)\cdot 0,3^2}{2,4}\right]^{1/2} \Rightarrow p^* = 0,2763\,atm$$

$$\frac{\rho^*}{\rho} = M\left[\frac{2+(k-1)M^2}{k+1}\right]^{-1/2} \rightsquigarrow \rho^* = \rho_1\cdot 0,3\left[\frac{2+0,4\cdot 0,3^2}{2,4}\right]^{-1/2} \Rightarrow \rho^* = 0,4157\,\frac{kg}{m^3}$$

$$\frac{p_0^*}{p_0} = M\left[\frac{k+1}{2+(k-1)M^2}\right]^{\frac{(k+1)}{2(k-1)}} \rightsquigarrow p_0^* = 1,0644\,atm\cdot 0,3\left[\frac{2,4}{2+0,4\cdot 0,3^2}\right]^{\frac{2,4}{0,8}} \Rightarrow p_0^* = 0,5230\,atm$$

CALCULAR L^* e L_2



$$\frac{4fL^*}{D} = \left[-\frac{1}{k} - \frac{k+1}{2k}\ln\left(\frac{1}{1+(k-1)/2}\right)\right] - \left[-\frac{1}{kM_1^2} - \frac{k+1}{2k}\ln\left(\frac{M_1^2}{1+0{,}5(k-1)M_1^2}\right)\right]$$

$$\frac{4fL^*}{D} = 5{,}299$$

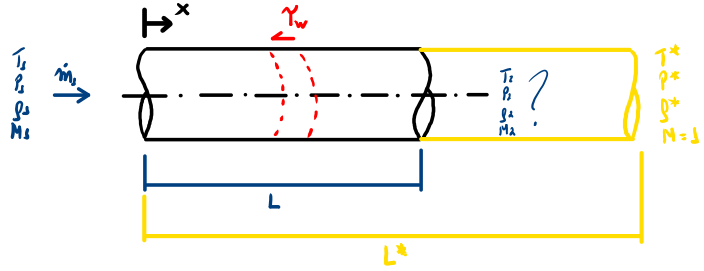
$f = 0{,}005$

$D = 0{,}15$

$L^* = 39{,}14\ m$

$L_2 = L^* - L$

$L_2 = 39{,}14 - 30 = 9{,}14\ m$



$$\frac{4}{D}\frac{L_2^*}{} = \left[-\frac{1}{k} - \frac{k+1}{2k}\ln\left(\frac{1}{1+(k-1)/2}\right)\right] - \left[-\frac{1}{kM^2} - \frac{k+1}{2k}\ln\left(\frac{M^2}{1+0{,}5(k-1)M^2}\right)\right]$$

$L_2 = 9{,}14\ m$

$$\frac{4}{D}\frac{L_2}{} = \frac{4 \cdot 0{,}025 \times 3{,}14}{0{,}15} = 1{,}2932$$

$$1{,}2932 = \left[\frac{-1}{1{,}4} - \frac{2{,}4}{2{,}8}\ln\left(\frac{1}{3{,}2}\right)\right] - \left[-\frac{1}{1{,}4\,M_2^2} - \frac{2{,}4}{2{,}8}\ln\left(\frac{M_2^2}{1+0{,}2\,M_2^2}\right)\right]$$

$$1{,}8512 = \frac{1}{1{,}4\,M_2^2} + \frac{2{,}4}{2{,}8}\ln\left(\frac{M_2^2}{1+0{,}2\,M_2^2}\right)$$

$$1,8512 = \frac{1}{1,4\,M_2^2} + \frac{2,4}{2,8}\ln\left(\frac{M_1^2}{1+0,2\,M_2^2}\right)$$

p/ $M_1 < 1$ ~D $M_2 \leq 1$

	gráfico	função
$M = 0,47$	$\rightarrow 1,86$	$1,9021$
$M = 0,48$	$\rightarrow 1,85$	$1,80335$

$1,9021 \quad 0,47$
$1,8512 \quad M_2 \Rightarrow M_2 = 0,4745$
$1,80335 \quad 0,48$

CALCULAR PROPRIEDADES NA SAÍDA

$$\frac{T^*}{T} = \frac{2 + (k-1)M^2}{k+1} \rightarrow T_2 = \frac{231{,}595\ k}{\frac{2 + (0{,}4)\cdot 0{,}4745^2}{2{,}4}} \rightarrow T_2 = 265{,}94\ k$$

$$\frac{P^*}{P} = M\left[\frac{2 + (k-1)M^2}{k+1}\right]^{1/2} \rightarrow P_2 = \frac{0{,}2763\ atm}{0{,}4745\left[\frac{2 + 0{,}4\cdot 0{,}4745^2}{2{,}4}\right]^{1/2}} \rightarrow P_2 = 0{,}624\ atm$$

$$\frac{\rho^*}{\rho} = M\left[\frac{2 + (k-1)M^2}{k+1}\right]^{-1/2} \rightarrow \rho_2 = \frac{0{,}4157}{0{,}4745\left[\frac{2 + 0{,}4\cdot 0{,}4745^2}{2{,}4}\right]^{-1/2}} \rightarrow \rho_2 = 0{,}8376\ \frac{kg}{m^3}$$

$$\frac{P_0^*}{P_0} = M\left[\frac{k+1}{2 + (k-1)M^2}\right]^{\frac{(k+1)}{2(k-1)}} \rightarrow P_{02} = \frac{0{,}5230}{0{,}4745\left[\frac{2{,}4}{2 + 0{,}4\cdot 0{,}4745^2}\right]^{2{,}4/0{,}8}} \rightarrow P_{02} = 0{,}728\ atm$$

$$\Delta s = c_p \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{P_2}{P_1}\right)$$

$$\Delta s = 1{,}004 \frac{kJ}{kg\,K} \ln\left(\frac{265{,}34}{273}\right) - 0{,}287 \frac{kJ}{kg\,K} \ln\left(\frac{0{,}624}{1}\right)$$

$$\Delta s = 0{,}109 \frac{kJ}{kg\,K}$$

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