Esercitazione 11 -

Come calcolare h?

$$Re = \rho \frac{\bar{w} L_c}{\mu} \qquad Pr = \frac{\mu c_p}{k} \qquad Nu = \frac{h L}{k}$$

Correlazioni a seconda di geometria

- Lastra piana

$\hookrightarrow Nu_L = 0{,}664\, Re^{0,5}\, Pr^{0,33}$ regime laminare $\Longleftrightarrow Re_L < 500000$

Lastra

$Nu_L = (0{,}037\, Re_L^{0,8} - 871)\, Pr^{0,33}$ flusso turbolente

- Cilindro (geometria esterna ortogonale all'asse)

$Nu_D = C\, Re_D^{m}\, Pr^{0,33}$ C ed m $f(Re_D)$ e si trovano in tabella

- Sfera

$Nu_D = 2 + 0{,}3\, Re_D^{0,6}\, Pr^{0,4}$ Laminare

$Nu_D = 2 + (0{,}4\, Re_D^{1/2} + 0{,}06\, Re^{2/3})\, Pr^{0,4}$ Turbolente

Geometria Interna (Tubi e roba simile)

$Nu = 3{,}66$ $\quad f = \frac{64}{Re}$ laminare $Re < 2300$ Temperatura Costante Imposta

$Nu = 4{,}36$ " " " $\dot{Q}$ imposto

Aumentando $\dot{w}$ non cambia niente

$$Nu = 0{,}023\, Re^{0{,}8}\, Pr \quad \begin{matrix} 0{,}3 \rightarrow \text{raffredda} \\ 0{,}4 \rightarrow \text{scalda} \end{matrix}$$

Turbolento

Dittus-Böelter

Fattore di attrito

$$Nu = \frac{(f/8)(Re - 1000)Pr}{1 + 12{,}7\sqrt{f/8}\,(Pr^{2/3} - 1)}$$

$$f = [1{,}82 \log Re - 1{,}64]^{-2}$$

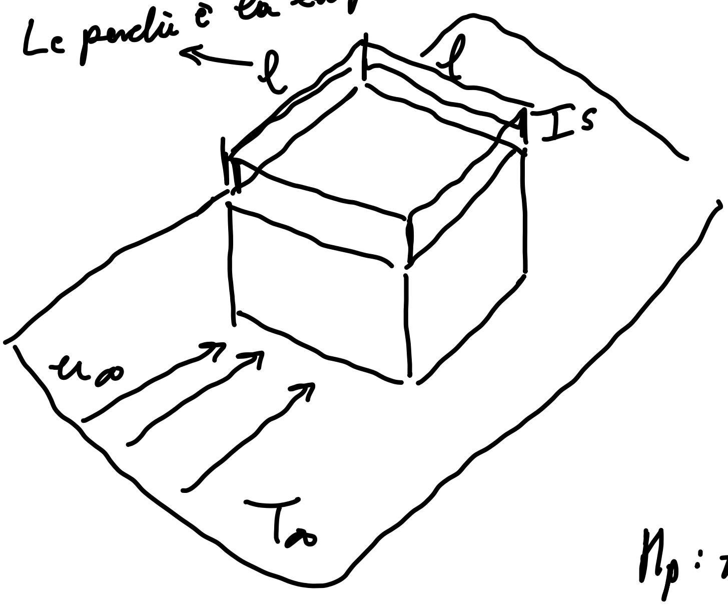
Gnielinski Turbolento

Diametro idraulico

$$D_h = \frac{4 \cdot Area}{Perimetro}$$

Esercizio 1

Lc perchè è la lunghezza coperta dal flusso



$l = 0{,}04\ m$

$s = 0{,}00025\ m$

$k_R = 1{,}5\ \frac{W}{mK}$

$T_\infty = 297{,}15\ K$

$u_\infty = 8{,}2\ m/s$

Hp: facce lato e base isolato

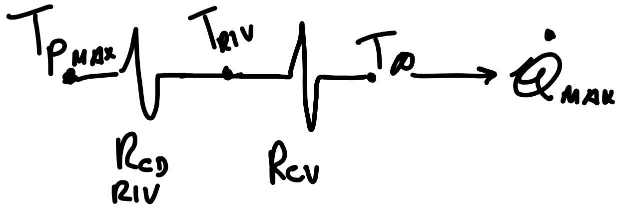
1° caso peggiore

$$Nu_L = 0{,}664\ Re_L^{0{,}5}\ Pr^{1/2}$$

? $\dot{Q}_{MAX} \rightarrow T_{MAX} = 353{,}15\ K$

$\rho_m = 1{,}118\ kg/m^3 \qquad c_p = 1007{,}3\ \frac{J}{kgK}$

$\mu = 19{,}07 \cdot 10^{-6}\ \frac{kg}{ms} \qquad k_g = 0{,}0273\ \frac{W}{mK}$



$$R_{TOT} = R_{CD} + R_{CV}$$

$R_{CD} = \frac{1}{k_R A} = 0{,}104\ \frac{K}{W} \qquad R_C = \frac{1}{hA} \qquad h$ è incognita

$$Re = \rho \frac{u_\infty L_c}{\mu} = 19231 < 500000$$ va bene l'equazione

L_c → In questo caso l

$$Pr = \frac{\mu C_p}{k_{ARIA}} = 0{,}704$$

→ Pr dell'aria è sempre intorno a 0,7

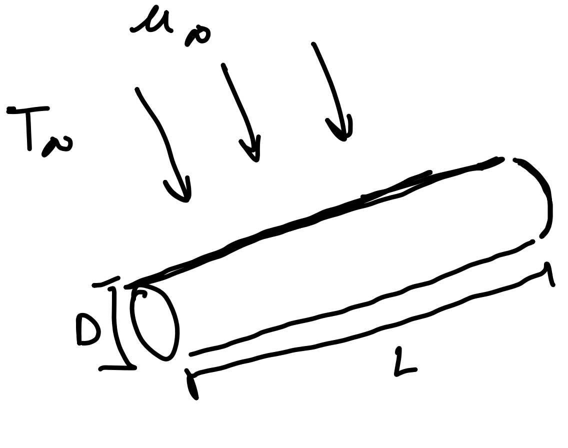
$$Nu_L = 81{,}9 = \frac{hL}{k_{ARIA}} \Rightarrow h = \frac{Nu_L k}{l} = 55{,}9 \ \frac{W}{m^2 K}$$

$$\Rightarrow R_{cv} = \frac{1}{hA} = 11{,}181 \ \frac{K}{W}$$

$$Q_{MAX} = \frac{T_{pMAX} - T_\infty}{R_{TOT}} = 4{,}96 W$$

Per migliorare è meglio cambiare R_{cv} che R_{CD}

Esercizio 2



$D = 0{,}01 \ m$

$L = 0{,}1 m$

$T_\infty = 293{,}15 K$

$u_\infty = 25 m/s$

$T_w = 333{,}15 K$

$$Nu_D = C \, Re_D^m \, Pr^{0{,}33}$$

Hp: Trascuriamo radiazione

? $\dot{Q}^{\rightarrow}_{cil}$

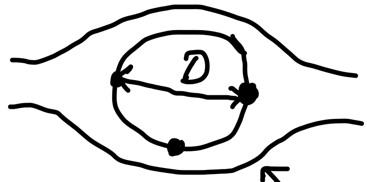
Proprietà dell'aria (ρ, c_p, k)

$$\dot{Q}^{\rightarrow}_{cil} = hA(T_w - T_\infty)$$ → possiamo trascurare la parte interna

$$A = \text{Area laterale} = \pi D L = 0{,}00314\, m^2$$

L_c per questo caso

$$Re_D = \frac{\rho u_\infty D}{\mu} = 15780 \xrightarrow{\text{Tabelle}} C = 0{,}193 \text{ e } m = 0{,}618$$



h cambia dipendendo da dove è preso, per i nostri scopi useremo la media

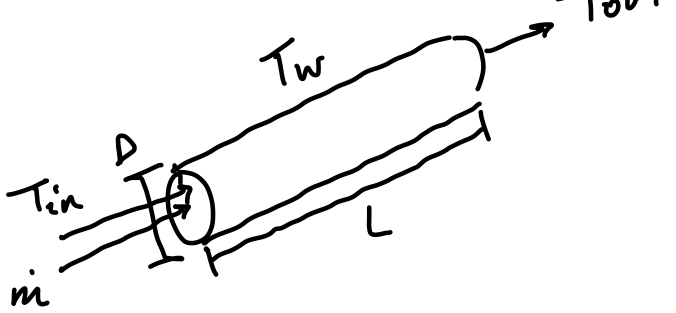
$$P_r = \frac{\mu c_p}{k} = 0{,}705$$

$$Nu_D = 0{,}193\, Re_D^{0{,}618}\, Pr^{0{,}33} = 67{,}59$$

$$\Rightarrow h = 177{,}1 \frac{W}{m^2 K}$$

$$\Rightarrow \dot{Q}_{cil} = 22{,}33\, W$$

Esercizio 3



$\dot{m} = 2\, kg/s$

$D_i = 0{,}04 m$

$T_{in} = 25°C$

$T_{out} = 75°C$

$T_W = 90\,°C$

$Nu = 0{,}023\, Re^{0,8}\, Pr^{0,33}$

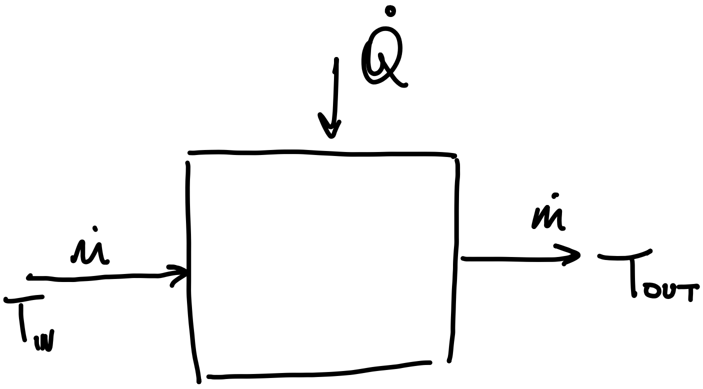
$\rho = 987\ kg/m^3$

$?L \qquad ?\Delta P \rightarrow f = 0{,}184\, Re^{-0,2}$

$c_p = 4186\ \frac{J}{kgK}$

$\mu = 0{,}523 \cdot 10^{-3}\ kg/m^3$

$k = 0{,}645\ \frac{W}{mK}$



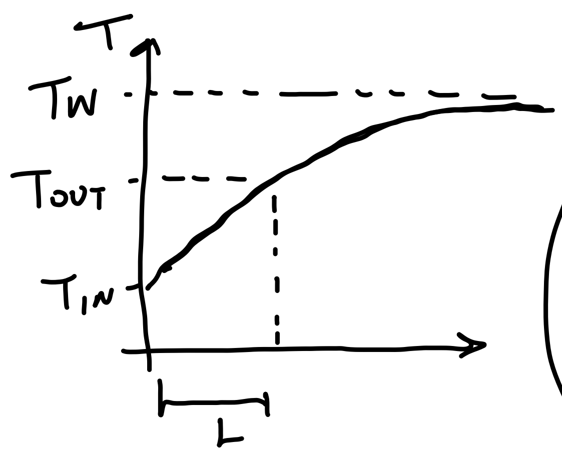
$\dot{Q} = \dot{m}\,(h_2 - h_1) = mc\,(T_{OUT} - T_{IN}) = 4181000\ W$

$\dot{Q} = hA\,\Delta T_{m\,lm} = h\,(\pi D_i L)\,\Delta T_{m,lm}$

$\rightarrow L = \frac{\dot{Q}}{\pi D_i\, h\, \Delta T_{lm}} = 13{,}84\ m$

Per T fissata

$$\boxed{\Delta T_{lm} = \frac{\Theta_{IN} - \Theta_{OUT}}{\ln \frac{\Theta_{IN}}{\Theta_{OUT}}}}$$



$\Theta_{IN} = T_W - T_{IN} = 65\,K$

$\Theta_{OUT} = T_W - T_{OUT} = 15\,K$

$= 34{,}1\,K$

$Re = \frac{\rho u D}{\mu} = \frac{\rho\, \dot{m} \cdot 4 \cdot D}{\rho D^2 \pi \mu} = \frac{\dot{m} \cdot 4}{D \pi \rho} = 120\,572 \rightsquigarrow Re > \underset{2300}{\underset{\shortparallel}{Re_{cr}}} \Rightarrow$ Turbolento

$\dot{m} = \rho \bar{w} A \qquad \bar{w} = \frac{\dot{m}}{\rho A} = \frac{\dot{m} \cdot 4}{\pi D^2 \rho}$

$$Pr = \frac{\mu c}{k} = 3{,}43$$

$$Nu_D = 0{,}023\,(120\,572)^{0{,}8} \cdot (3{,}43)^{0{,}37} = 402$$

$$h = \frac{Nu_D\, k}{D} = 6482\ \frac{W}{m^2 K}$$

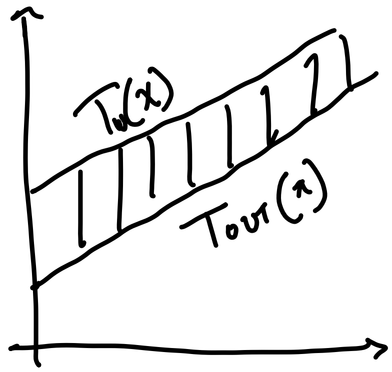
$$\boxed{\Delta p = f \cdot \frac{1}{2} \rho w^2 \cdot \frac{L}{D_i}}$$

$$f = 0{,}184\,(120\,572)^{-0{,}2} = 0{,}018$$

$$\bar{w} = \frac{\dot{m}}{\rho A} = 1{,}613\ \frac{m}{s}$$

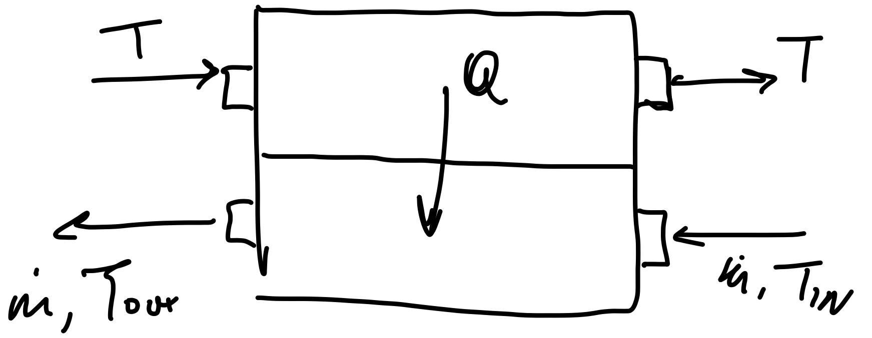
$$\Delta p = 8701{,}5\ Pa$$

Con $\dot{Q}$ fissata:

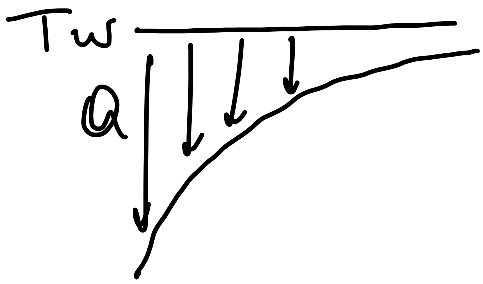


$\theta_{FLUIDO} = T_w - T_{FLUIDO} = cost.$

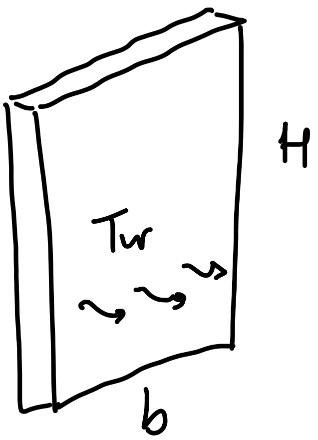
L_c dei tubi è D



se si condensa sta cambiando fase e T rimane costante



Esercizio 4



$T_\infty = 20°C$

$b = 0,4\,m$

$H = 0,25\,m$

$Nu = 0,59\,Ra^{0,25}$

Hp: $\dot{Q}$ altre 5 facce trascurabile

? Q_{MAX} affinché $T \leq 50°C$

$$\dot{Q} = \frac{T_w - T_\infty}{R_{cv}} \qquad R_{cv} = \frac{1}{hA}$$

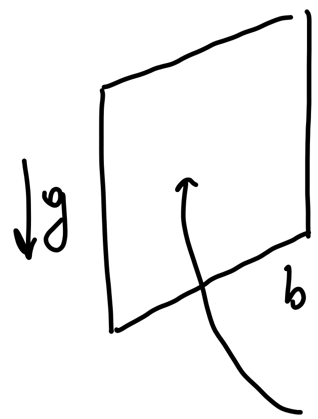
$$T_w = \dot{Q} R_c + T_\infty \leq T_{wMAX}$$

$$\dot{Q} \leq (T_{wMAX} - T_\infty)\, h A$$

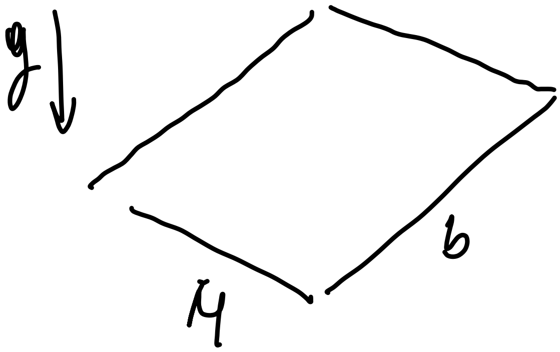
$$Gr = \frac{\rho^2 g \alpha_p (T_w - T_\infty) L^3}{\mu^2}$$

$$\alpha_p = \frac{1}{T_{film}} \qquad T_{film} = \frac{T_w - T_\infty}{2}$$

$$L = 3,25 \cdot 10^{-3}$$



superficie verticale $L = H$



superficie orizzontale $L = \frac{Area}{Perimetro}$

$$Gr = 4,99 \times 10^7$$

se $\frac{Gr}{Re^2} \gg 1 \rightarrow$ convezione naturale

se $\frac{Gr}{Re^2} \ll 1$ convezione forzata

se $\frac{Gr}{Re^2} \simeq 1$ convezione mista

$Pr = 0,7$

$Ra = Gr\,Pr = 3,493 \cdot 10^7$

$$Nu_z = 0{,}59\, Ra^{0{,}25} = 45{,}36$$

$$h = \frac{Nu \cdot \lambda}{h} = 4{,}95 \ \frac{W}{m^2 K}$$