EX 24

1

$$\rho = \frac{p}{R_* T} = 1{,}204 \ [kg/m^3]$$

PRESSION ATMOSPHERIQUE: $p = 101325\ [Pa]$

$T = 293\ [K]$

$R_* = R/M$: $8{,}314$ / $2{,}9\ 10^{-2}$ = $287{,}1\ [J/kg K]$

CONSTANTE DE L'AIR $\neq$ 8,314 CONSTANTE DES GAZ !

$$\rho = 1{,}204\ [kg/m^3]$$

$$\nu = \frac{\mu}{\rho} = 1{,}5\ 10^{-5}\ [m^2/s]$$

2

$$Re = \frac{\bar{v}_m D}{\nu} = 166\,609$$

($\bar{v}_m = 50$, $D = 5\ 10^{-2}$, $\nu = 1{,}5\ 10^{-5}$)

$$Re = 1{,}7\ 10^5$$

TURBULENT OF COURSE !

3

$$Pr = \frac{\nu}{\alpha} = \frac{\mu c_p}{k} = 0{,}7$$

4

$$Ec = \frac{\bar{v}_m^{\,2}}{c_p(\bar{T}_m - \bar{T}_w)} = 0{,}25$$

$Ec = 0{,}25$

$Ec\,Pr = 0{,}176 \ll 1$?

DISSIPATION VISQUEUSE FAIBLE MAIS PAS TOTALEMENT NEGLIGEABLE EN REALITE :-(

5

$$Ma = \frac{\bar{v}_m}{\sqrt{\gamma R_* \bar{T}_m}} = 0{,}14$$

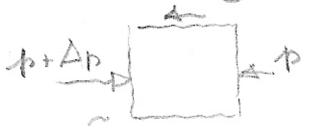
ON PEUT CONSIDERER L'ECOULEMENT COMME INCOMPRESSIBLE !

6

$$Nu = \frac{\bar{q}_w}{k\Delta T/D} = \underbrace{\frac{\bar{q}_w}{\rho c \bar{v}_m \Delta T}}_{St}\ \underbrace{\frac{\rho c \bar{v}_m D}{k}}_{= Pe = Pr\,Re}$$

7

RAPPEL DE LA SEANCE 1 ! $\bar{\tau}_w$



$$\pi R^2 \Delta p = 2\pi R\, \Delta x\, \bar{\tau}_w$$

$$2\bar{\tau}_w = R\, dp/dx$$

$$C_f = \frac{\bar{\tau}_w}{\rho \bar{v}_m^2/2}$$

$$\lambda = \frac{dp/dx}{\rho \bar{v}_m^2/2D}$$

$$4 C_f = \lambda$$

8

$$\frac{1}{\sqrt{\lambda}} = -2\log_{10}\left[\frac{2.51}{Re}\frac{1}{\sqrt{\lambda}}\right]$$

$\to \lambda = 1{,}61\ 10^{-2}$

$$St = \frac{\lambda}{8}\frac{1}{1 + 13(Pr^{2/3}+1)\sqrt{\lambda/8}}$$

$\to St = 2{,}31\ 10^{-3}$

$Nu = 2{,}71\ 10^2$

9

$$\frac{1}{\sqrt{\lambda}} = -2\log_{10}\left[\frac{2.51}{Re}\frac{1}{\sqrt{\lambda}} + \frac{1}{3.71}\frac{\varepsilon}{D}\right]$$

$\to \lambda = 3{,}82\ 10^{-2}$

$\varepsilon^+ = 115$

C'EST BIEN RUGUEUX

$$St = \frac{\lambda}{8}$$

$\to St = 4{,}78\ 10^{-3}$

$Nu = 5{,}61\ 10^2$

10

$\lambda = 64/Re = 3{,}84 \; 10^{-4}$

$St = \dfrac{C_f}{2\, Pr^{2/3}}$

$\rightsquigarrow St = 6{,}07 \; 10^{-5}$

$Nu = 7{,}12$

AUTRES OPTIONS

$T = ct \quad Nu = 9{,}6$

DISSIPATION NEGLIG. $\quad Nu = 3{,}66$

SUMMARY

	RUGUEUX	LISSE	LAMINAIRE
	⟵ TURBULENT ⟶		
λ	$4 \; 10^{-2}$	$2 \; 10^{-2}$	$4 \; 10^{-4}$
Nu	561	271	3 ... 9

LE TRANSFERT DE CHALEUR EST PLUS IMPORTANT EN TURBULENT RUGUEUX .... MAIS LES PERTES DE CHARGES AUSSI !

C'EST LE PRIX À PAYER

DIXIT GREGOIRE :-)

11

$$\Delta p = \lambda \, \frac{10 \; \rho \, \bar{U}_m^2}{2D}$$

0,079 [bar] LISSE

0,159 [bar] RUGUEUX

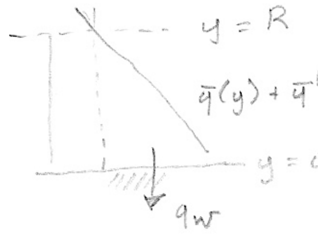
C'EST PAS SI NEGLIGEABLE QUE CELA ⟶ SI T CONSTANT ALORS ρ VARIE D'UN FACTEUR 2 !

13 **14**

VOIR PROGRAMME PYTHON :-)

12

$$ct \simeq \frac{d}{dy}\left[\bar{q} + \bar{q}^t\right]$$



$$\bar{q}(y) + \bar{q}^t(y) = \bar{q}_w \,(1 - y/R)$$

ZONE PROCHE PAROI $\quad y/R \ll 1$:-)

$$-\alpha \frac{d\bar{T}}{dy} - \alpha_t \frac{d\bar{T}}{dy} = \frac{\bar{q}_w}{\rho c}$$

ZONE A DOM. LAMINAIRE

$$T_w - \bar{T}(y) = \underbrace{\frac{\nu}{\alpha}}_{Pr} \; \underbrace{\frac{\bar{q}_w}{\rho c \bar{U}_\tau}}_{\bar{T}_\tau} \; \underbrace{\frac{\bar{U}_\tau y}{\nu}}_{\bar{y}^+}$$

$$\bar{T}^+ = Pr \; \bar{y}^+$$

ZONE A DOMINANCE TURBULENTE $\quad Pr_t = 1$

$$-\nu^t(y) \frac{d\bar{T}}{dy} = \frac{\bar{q}_w}{\rho c}$$

CAR $Pr_t = 1$:-)

$\nu^t(y) = \kappa \, y \, \bar{U}_\tau$

DEPEND DU Pr :-)

$$\bar{T}^+ = \frac{1}{\kappa} \log(\bar{y}^+) + A$$

CAS RUGUEUX $\quad y \rightsquigarrow y/\varepsilon$

$$\bar{T}^+ = \frac{1}{\kappa} \log\left(\frac{y}{\varepsilon}\right) + B$$