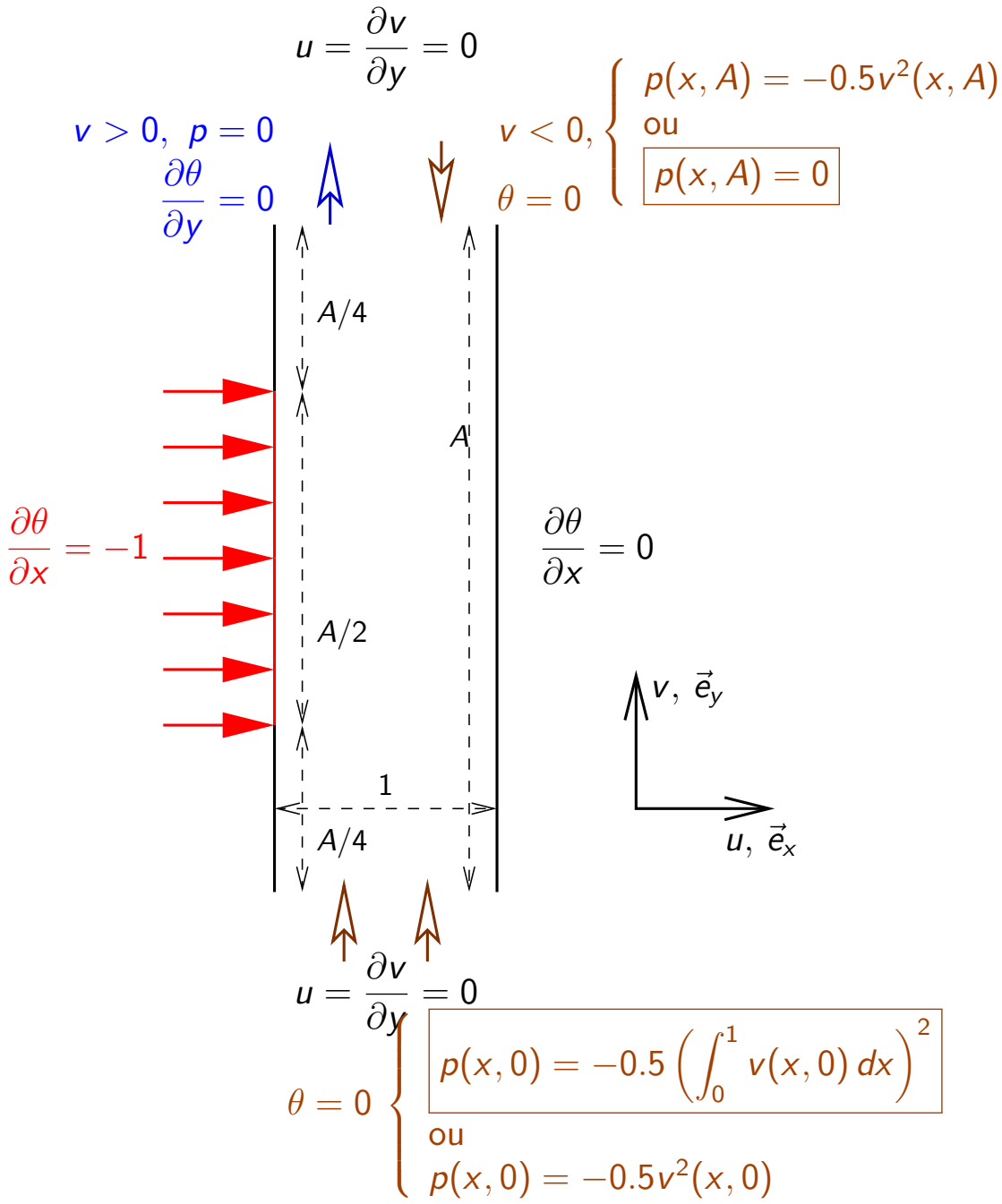
Simulation numérique de l'écoulement d'air dans un canal vertical partiellement chauffé
Exercice de comparaison

GDR AMETH

26 mai 2010

Problème


$u = \frac{\partial v}{\partial y} = 0$
$v > 0,\ p = 0$
$\frac{\partial \theta}{\partial y} = 0$
$v < 0,$
$p(x, A) = -0.5 v^2(x, A)$
ou
$p(x, A) = 0$
$\theta = 0$
$A/4$
A
$\frac{\partial \theta}{\partial x} = -1$
$\frac{\partial \theta}{\partial x} = 0$
$A/2$
$v,\ \vec{e}_y$
1
$A/4$
$u,\ \vec{e}_x$
$u = \frac{\partial v}{\partial y} = 0$
$\theta = 0$
$p(x, 0) = -0.5 \left(\int_0^1 v(x, 0)\, dx \right)^2$
ou
$p(x, 0) = -0.5 v^2(x, 0)$

Equations

$$\vec{\nabla} \cdot \vec{u} = 0$$
$$\frac{\partial}{\partial t}\vec{u} + \vec{\nabla} \cdot (\vec{u} \otimes \vec{u}) = -\vec{\nabla} p + Pr \Delta \vec{u} + Ra\, Pr\, \theta \vec{e}_y$$
$$\frac{\partial \theta}{\partial t} + \vec{\nabla} \cdot (\vec{u}\theta) = \Delta \theta$$

avec

- $\vec{u} = u\vec{e}_x + v\vec{e}_y$,
- $A = \frac{H}{l}$
- $Ra = \frac{g\beta \Delta T l^3}{\nu \alpha}$,
- $Pr = \frac{\nu}{\alpha}$

Laboratoires participants, maillages

- TREFLE (AQUILLON) : 100×1000,
- LIMSI : 256×2048,
- MSME : 256×1520,
- LPBS.

Vitesse moyenne – Débit entrant par le haut

	Vitesse moyenne	
MSME	7.76E+01	-1.13E+00%
LIMSI	8.15E+01	3.88E+00%
TREFLE	7.77E+01	-1.05E+00%
LPBS	7.71E+01	-1.71E+00%
Moyenne	7.85E+01	

	Débit entrant	
MSME	1.75E+01	2.92E+00%
LIMSI	1.51E+01	-1.14E+01%
TREFLE	1.77E+01	4.08E+00%
LPBS	1.78E+01	4.40E+00%
Moyenne	1.70E+01	

Nusselt

$$Nu_1(y) = \frac{1}{\theta(0,y)} \; ; \; \bar{N}u_1 = \frac{2}{A}\int_{A/4}^{3A/4} Nu_1(0,y)\,dy$$

	$\bar{N}u_1$	
MSME	6.92E+00	-5.27E-01%
LIMSI	6.95E+00	-1.59E-01%
TREFLE	6.98E+00	2.70E-01%
LPBS	6.99E+00	4.16E-01%
Moyenne	6.96E+00	

	y=3A/8		y=A/2		y=5A/8	
MSME	7.29E+00	6.95E-02%	6.24E+00	6.71E-02%	5.69E+00	5.07E-02%
LIMSI	7.30E+00	3.01E-01%	6.25E+00	2.91E-01%	5.70E+00	2.67E-01%
TREFLE	7.27E+00	-2.14E-01%	6.22E+00	-1.67E-01%	5.68E+00	-1.73E-01%
LPBS	7.27E+00	-1.57E-01%	6.22E+00	-1.91E-01%	5.68E+00	-1.44E-01%
Moyenne	7.28E+00		6.23E+00		5.69E+00	

	y=3A/4		y=7A/8		y=A	
MSME	5.67E+00	1.28E+00%	9.89E+00	-6.01E-02%	1.19E+01	-7.08E-01%
LIMSI	5.68E+00	1.47E+00%	9.93E+00	3.39E-01%	1.20E+01	-2.64E-01%
TREFLE	5.53E+00	-1.07E+00%	9.88E+00	-1.55E-01%	1.23E+01	1.90E+00%
LPBS	5.50E+00	-1.68E+00%	9.88E+00	-1.24E-01%	1.19E+01	-9.27E-01%
Moyenne	5.59E+00		9.89E+00		1.20E+01	

Nusselt

$$Nu_2(y) = \frac{1}{\theta(0,y) - \theta_d(y)} \; ; \; \bar{Nu}_2 = \frac{2}{A} \int_{A/4}^{3A/4} Nu_2(0,y)\, dy$$

	$\bar{Nu}_2$	
MSME	8.48E+00	*2.46E+00%* ; -1.77%
LIMSI	8.43E+00	*1.82E+00%* ; 2.35%
TREFLE	*7.21E+00*	*-1.29E+01%*
LPBS	8.99E+00	*8.59E+00%* ; 4.13%
Moyenne	*8.28E+00* ; 8.63	

	y=3A/8		y=A/2		y=5A/8	
MSME	8.26E+00	1.74E-01%	7.81E+00	3.49E-01%	7.85E+00	4.13E-01%
LIMSI	8.23E+00	-1.59E-01%	7.74E+00	-5.71E-01%	7.74E+00	-1.09E+00%
TREFLE	8.23E+00 7.43E+00	-1.17E-01%	7.79E+00 6.47E+00	8.54E-02%	7.83E+00 5.99E+00	1.76E-01%
LPBS	8.25E+00	1.02E-01%	7.79E+00	1.36E-01%	7.86E+00	5.04E-01%
Moyenne	8.69E+00		2.68E+01		5.24E+01	

	y=3A/4		y=7A/8		y=A	
MSME	8.92E+00	2.60E+00%	2.72E+01	1.49E+00%	5.17E+01	-1.21E+00%
LIMSI	8.70E+00	1.05E-01%	2.54E+01	-5.41E+00%	4.54E+01	-1.33E+01%
TREFLE	8.61E+00 5.93E+00	-9.73E-01%	2.73E+01 1.12E+01	1.78E+00%	5.85E+01	1.18E+01%
LPBS	8.54E+00	-1.74E+00%	2.74E+01	2.15E+00%	5.38E+01	2.73E+00%
Moyenne	8.69E+00		2.68E+01		5.24E+01	

Taille de la recirculation

	y=3A/8	y=A/2	y=5A/8	
MSME	-	-	1.33E-01	1.98E+01%
LIMSI	-	-	3.92E-02	-6.48E+01%
TREFLE	-	-	1.34E-01	2.08E+01%
LPBS	-	-	1.38E-01	2.42E+01%
Moyenne	-	-	1.11E-01	

	y=3A/4		y=7A/8		y=A	
MSME	5.39E-01	5.61E+00%	6.65E-01	1.27E+00%	7.07E-01	7.53E-01%
LIMSI	4.70E-01	-7.84E+00%	6.35E-01	-3.34E+00%	6.84E-01	-2.47E+00%
TREFLE	5.40E-01	5.86E+00%	6.60E-01	4.85E-01%	7.07E-01	8.21E-01%
LPBS	4.92E-01	-3.63E+00%	6.67E-01	1.58E+00%	7.08E-01	8.96E-01%
Moyenne	5.11E-01		6.57E-01		7.01E-01	

Taille de l'écoulement entrant

	y=3A/8	y=A/2	y=5A/8	
MSME	-	-	8.91E-02	2.02E+01%
LIMSI	-	-	2.60E-02	-6.50E+01%
TREFLE	-	-	9.02E-02	2.18E+01%
LPBS	-	-	9.11E-02	2.30E+01%
Moyenne	-	-	7.41E-02	

	y=3A/4		y=7A/8		y=A	
MSME	3.71E-01	3.12E+00%	4.64E-01	1.41E+00%	5.02E-01	1.17E+00%
LIMSI	3.22E-01	-1.06E+01%	4.40E-01	-3.77E+00%	4.79E-01	-3.37E+00%
TREFLE	3.72E-01	3.40E+00%	4.60E-01	5.11E-01%	5.00E-01	8.02E-01%
LPBS	3.75E-01	4.07E+00%	4.66E-01	1.84E+00%	5.03E-01	1.39E+00%
Moyenne	3.60E-01		4.58E-01		4.96E-01	

Température débitante

	y=3A/8		y=A/2		y=5A/8	
MSME	1.62E-02	1.08E+00%	3.23E-02	1.04E+00%	4.84E-02	1.02E+00%
LIMSI	1.54E-02	-3.77E+00%	3.07E-02	-3.79E+00%	4.61E-02	-3.82E+00%
TREFLE	1.62E-02	9.77E-01%	3.23E-02	1.16E+00%	4.85E-02	1.22E+00%
LPBS	1.63E-02	1.71E+00%	3.24E-02	1.59E+00%	4.86E-02	1.57E+00%
Moyenne	1.60E-02		3.19E-02		4.79E-02	

	y=3A/4		y=7A/8		y=A	
MSME	6.43E-02	1.01E+00%	6.44E-02	1.01E+00%	6.44E-02	8.12E-01%
LIMSI	6.12E-02	-3.80E+00%	6.13E-02	-3.81E+00%	6.13E-02	-4.01E+00%
TREFLE	6.45E-02	1.32E+00%	6.46E-02	1.34E+00%	6.45E-02	1.02E+00%
LPBS	6.46E-02	1.47E+00%	6.47E-02	1.46E+00%	6.53E-02	2.18E+00%
Moyenne	6.37E-02		6.38E-02		6.39E-02	

Nomenclature

$Nu_1(y) = \dfrac{1}{\theta(0,y)}$	nombre de Nusselt local
$\bar{N}u_1 = \dfrac{2}{A}\displaystyle\int_{A/4}^{3A/4} Nu_1(0,y)\,dy$	Nombre de Nusselt moyen
$Nu_2(y) = \dfrac{1}{\theta(0,y) - \theta_d(y)}$	nombre de Nusselt local
$\bar{N}u_2 = \dfrac{2}{A}\displaystyle\int_{A/4}^{3A/4} Nu_2(0,y)\,dy$	nombre de Nusselt moyen
$q_{in} = -\displaystyle\int_{x_0}^{1} v(x,A)\,dx$	débit entrant par le haut du canal
$Ra_m = \dfrac{2Ra}{A}$	nombre de Rayleigh modifié
$\bar{v} = \displaystyle\int_0^1 v(x,y)\,dx,\ \forall y \in]0;A[$	vitesse moyenne
$\theta_d(y) = \dfrac{1}{\bar{v}}\displaystyle\int_0^1 v(x,y)\theta(x,y)\,dx$	température débitante