Vendredi 10 Septembre 2004- 29ème congrès SB

Asymmetrical effects in a 2D flow, application to pharyngeal fluid flow in obstructive sleep apnea

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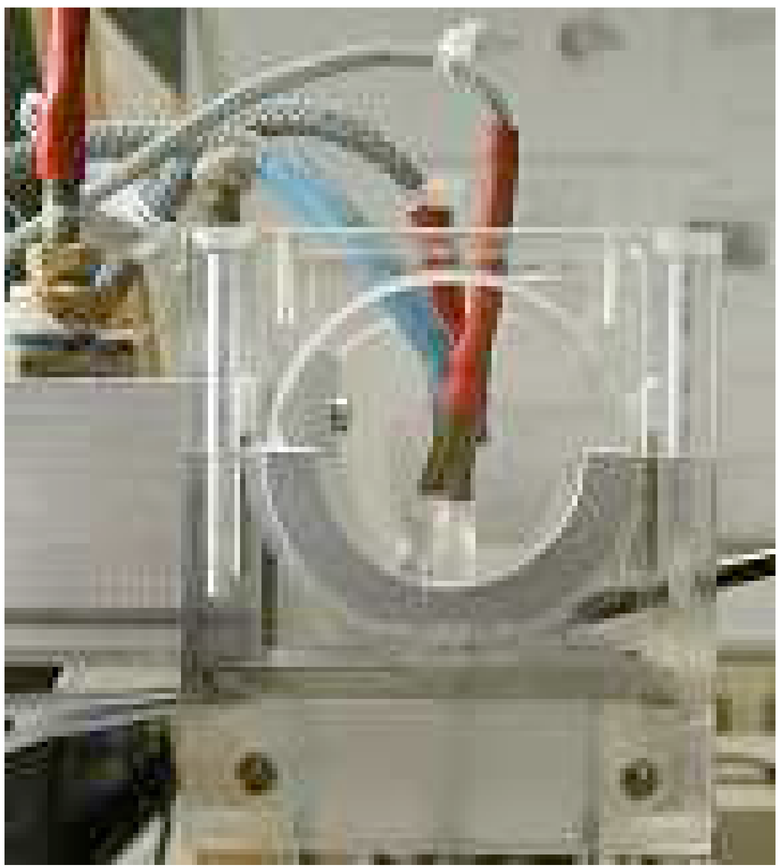
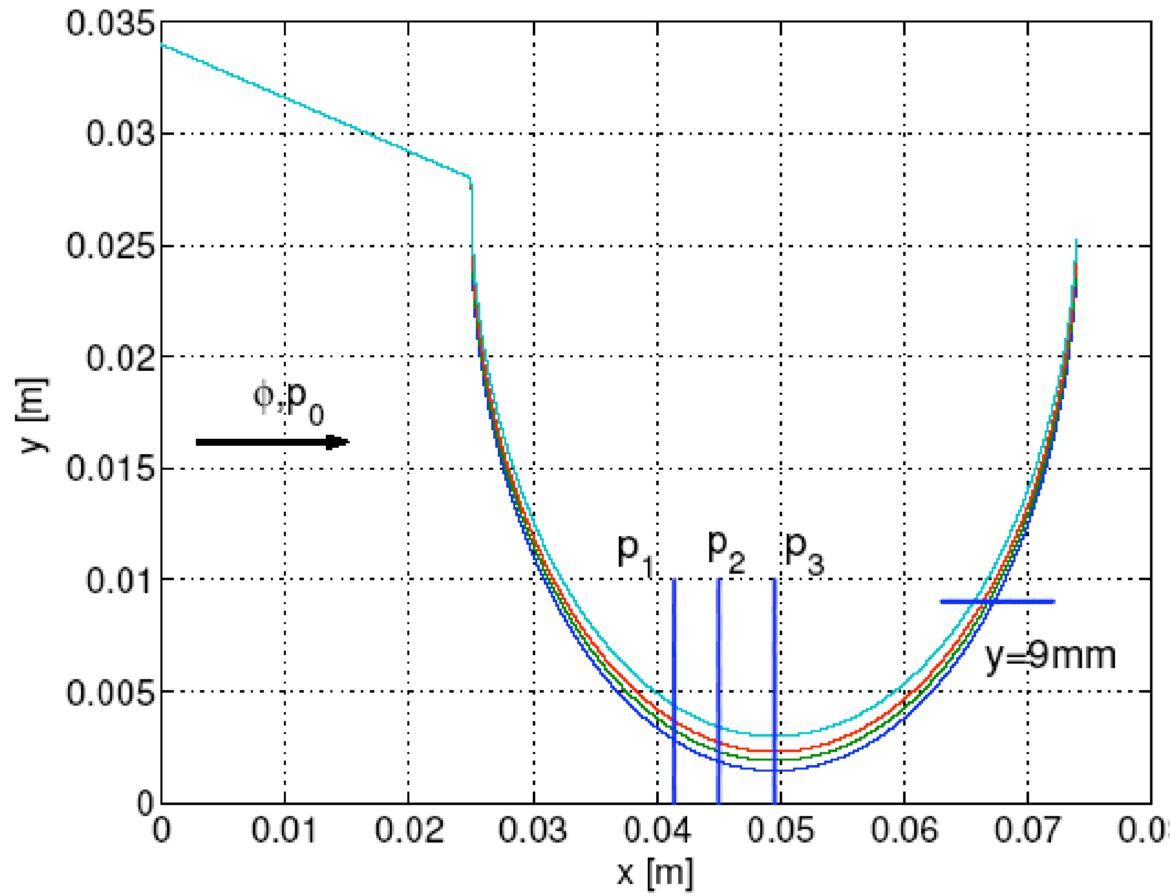
Apnée du Sommeil

- OSA (Obstructive Sleep Apnea): cessation de la respiration pendant le sommeil
- 4% des hommes 2% des femmes
- conséquences cardiovasculaires, hypertension
- traitement “mécanique”/
- opération (50 à 78% de réussite)

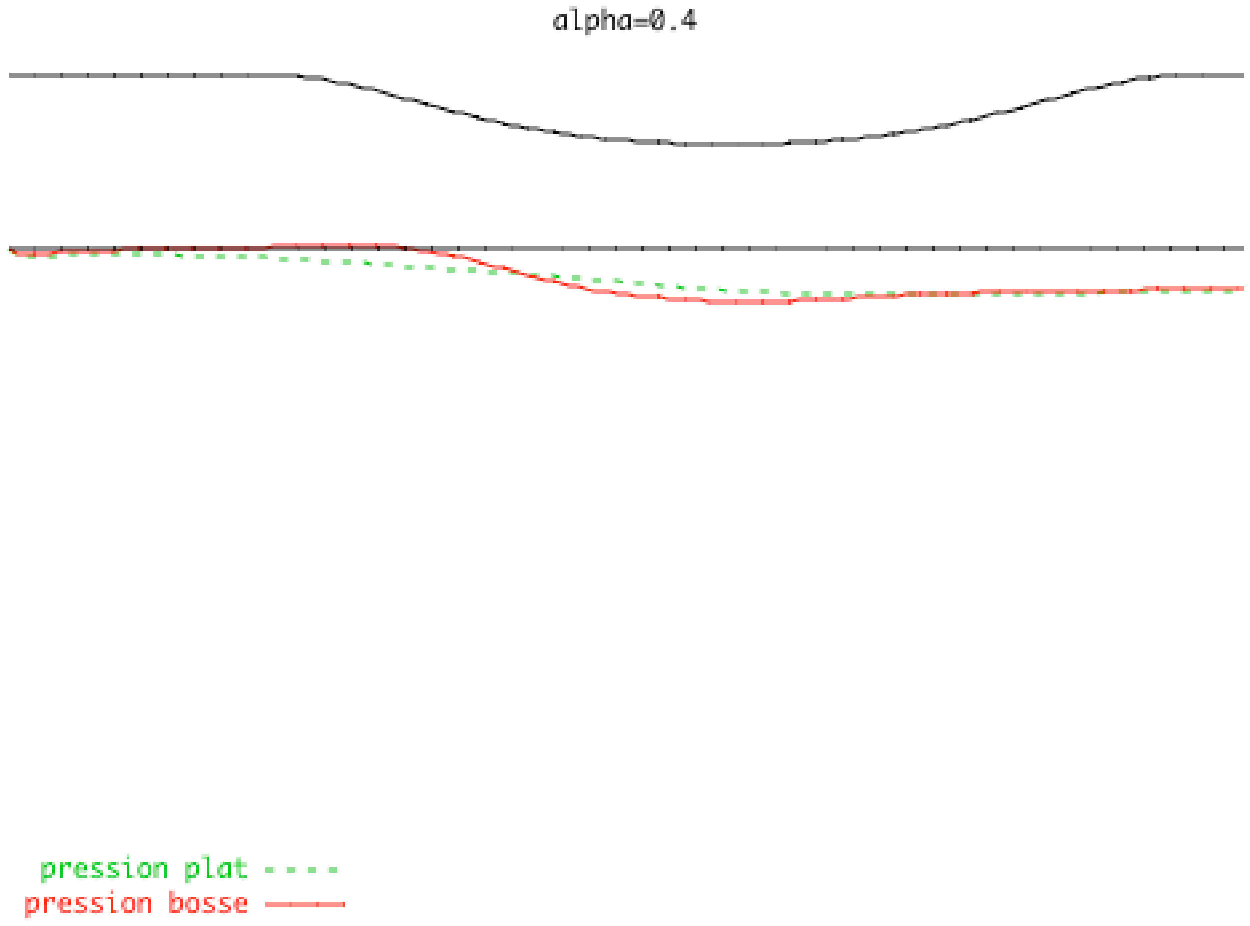
PAROIS RIGIDES



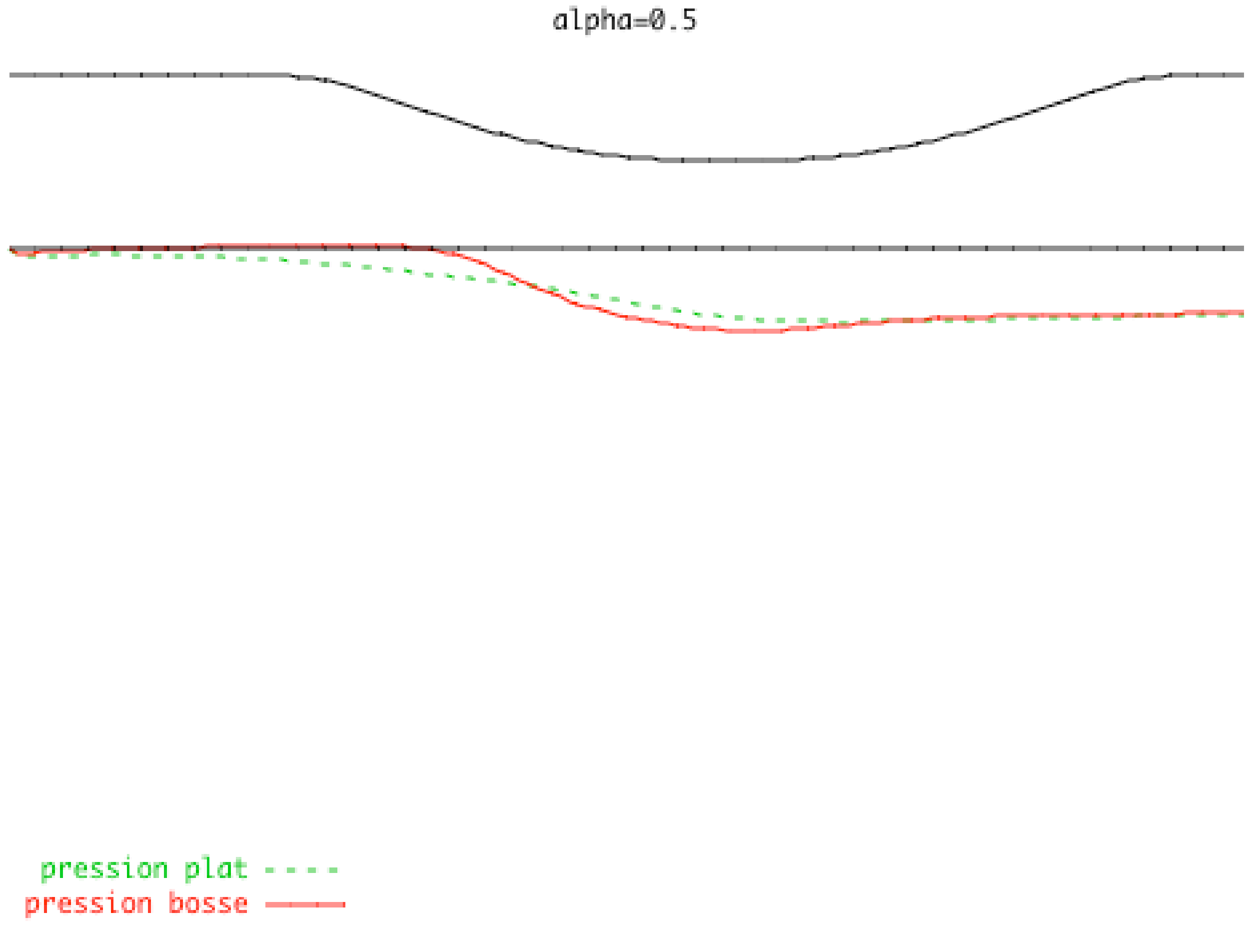


Mécanisme

- la diminution de section
- entraîne une accélération
- donc une dépression
- d'où la fermeture du conduit



alpha=0.4
pression plat
pression bosse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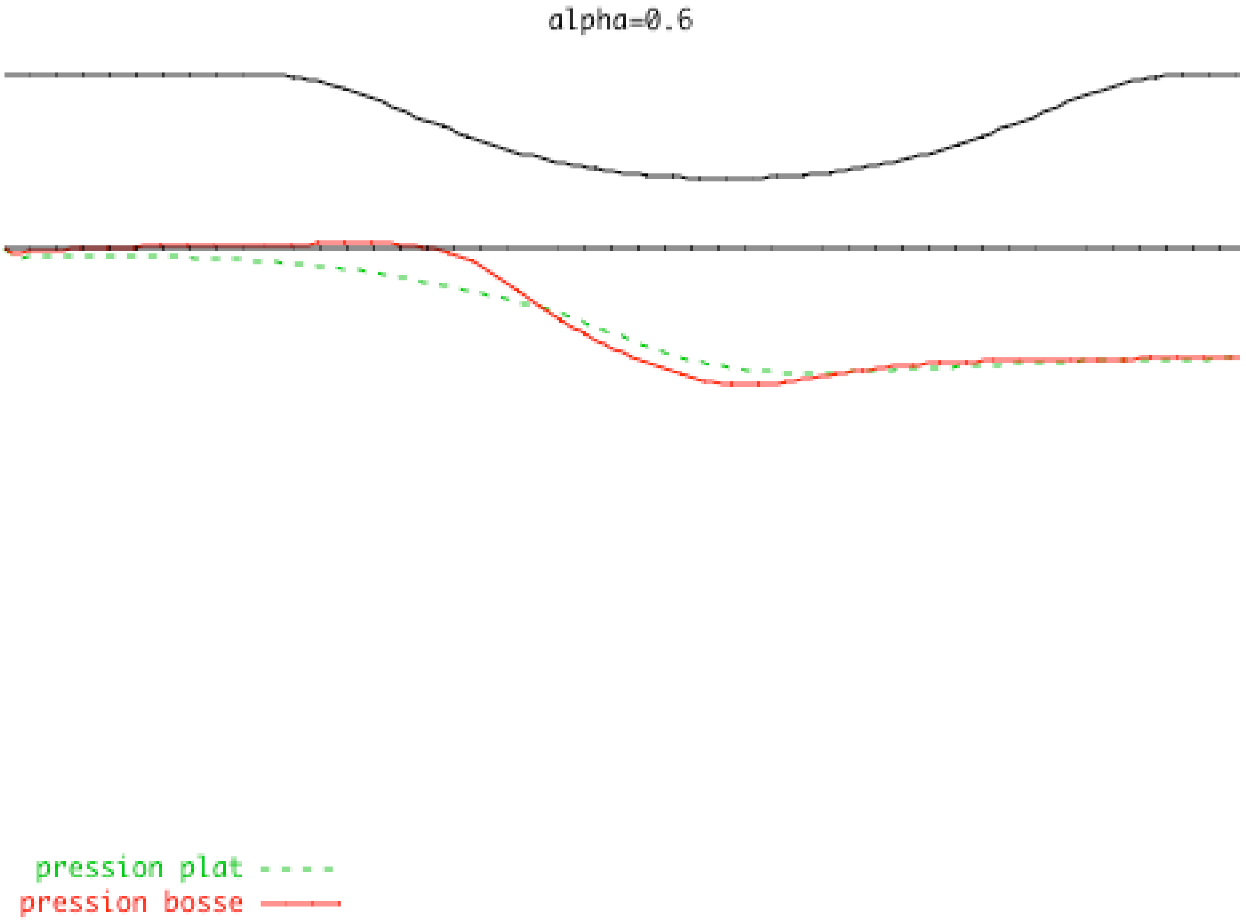
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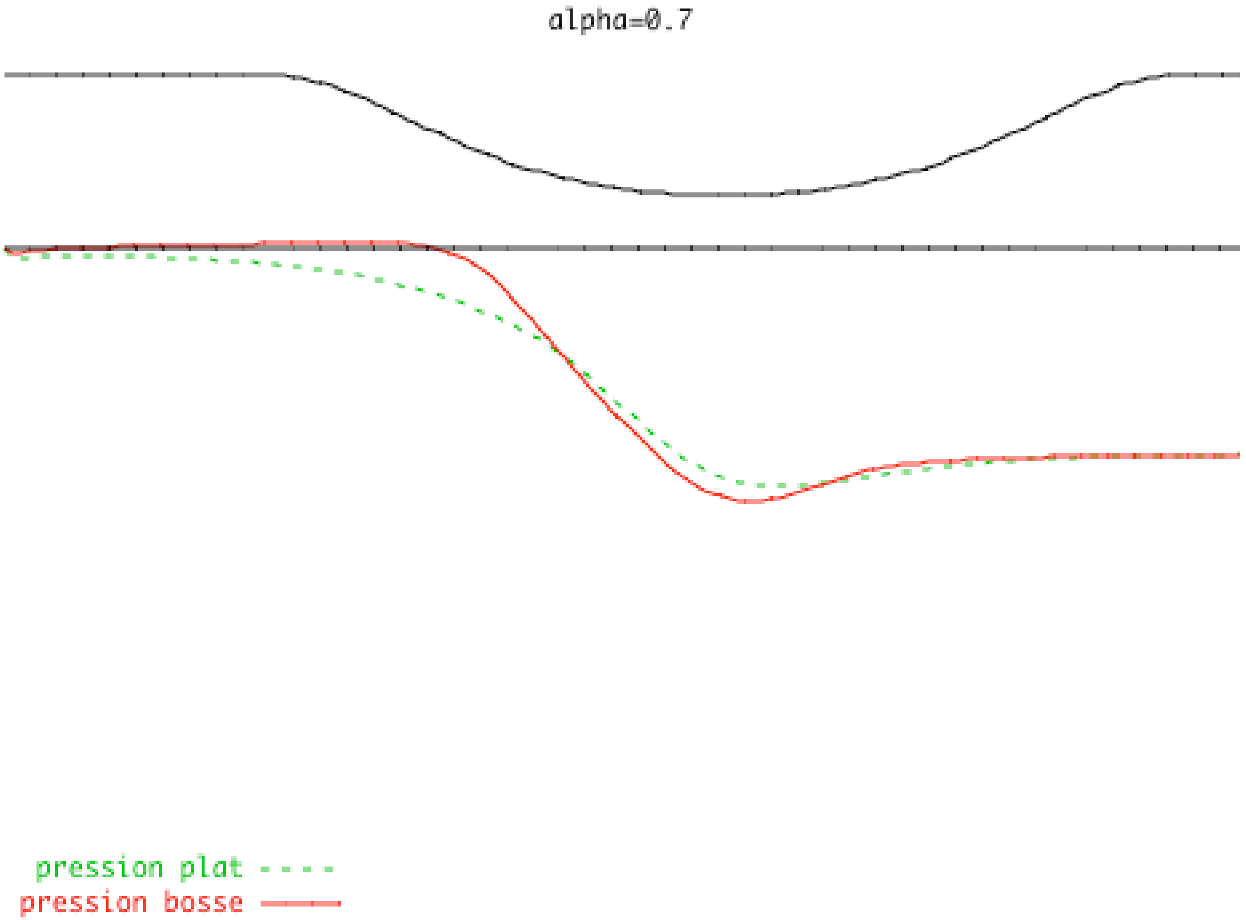
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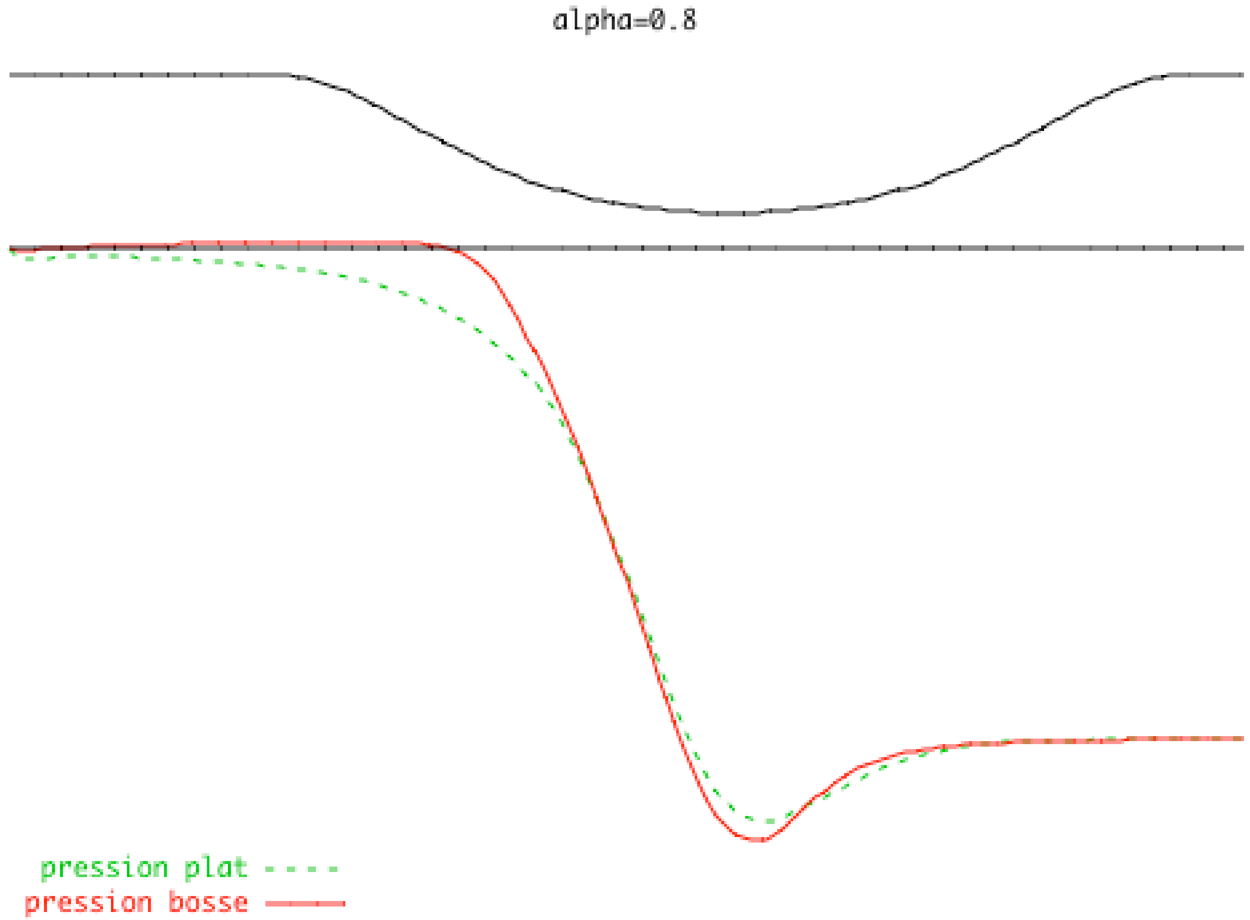
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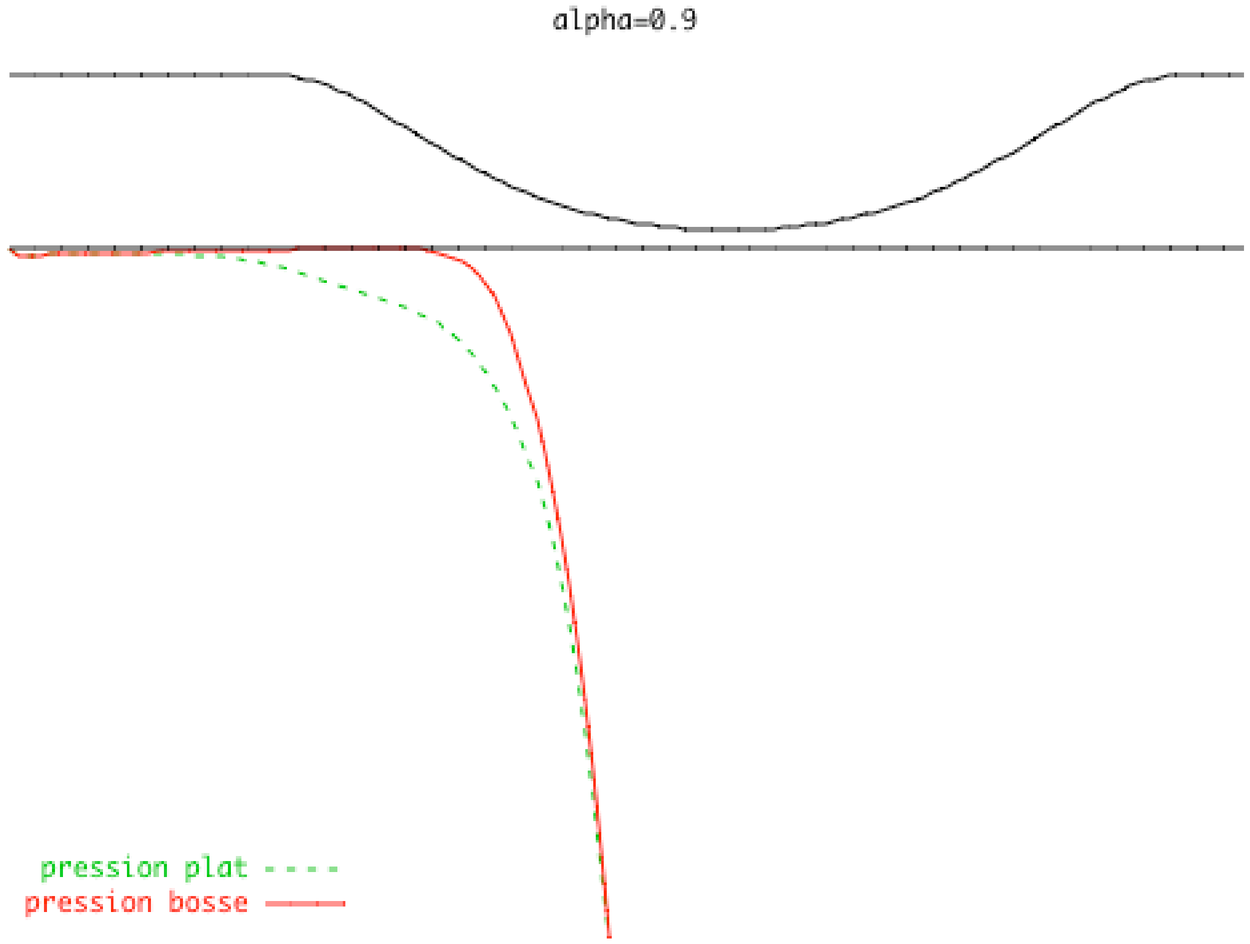
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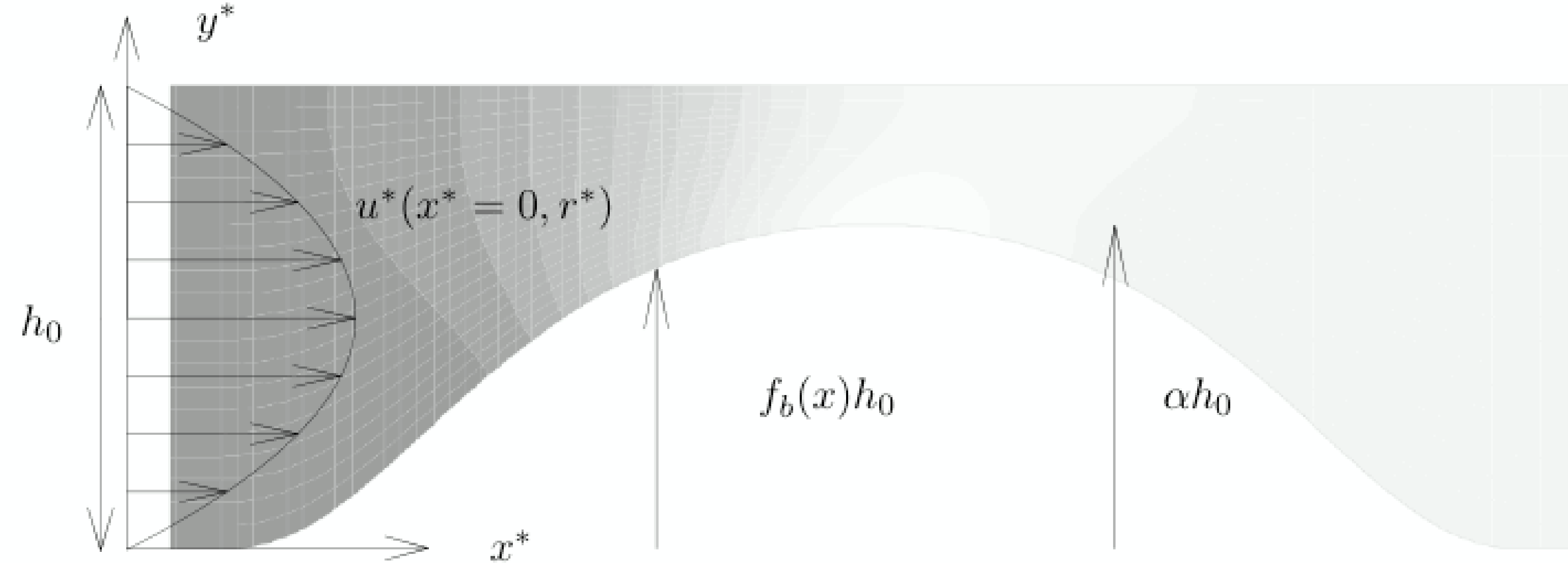
pression plat
pression bosse

ce que nous allons présenter:

- Différents jeux d’équations simplifiées pour le fluide
- comparaisons avec des calculs Navier Stokes
- comparaisons expérimentales

géométrie de calcul



Navier Stokes

$$\frac{\partial}{\partial x}u + \frac{\partial}{\partial y}v = 0$$

$$u\frac{\partial}{\partial x}u + v\frac{\partial}{\partial y}u = -\frac{\partial p}{\rho \partial x} + \nu\frac{\partial^2}{\partial y^2}u + \nu\frac{\partial^2}{\partial x^2}u$$

$$u\frac{\partial}{\partial x}v + v\frac{\partial}{\partial y}v = -\frac{\partial p}{\rho \partial y} + \nu\frac{\partial^2}{\partial y^2}v + \nu\frac{\partial^2}{\partial x^2}v$$

Castem 2000

Navier Stokes

$$\frac{\partial}{\partial x}u + \frac{\partial}{\partial y}v = 0$$

$$u\frac{\partial}{\partial x}u + v\frac{\partial}{\partial y}u = -\frac{\partial p}{\rho \partial x} + \nu \frac{\partial^2}{\partial y^2}u$$

$$u\frac{\partial}{\partial x}v + v\frac{\partial}{\partial y}v = -\frac{\partial p}{\rho \partial y} + \nu \frac{\partial^2}{\partial y^2}v$$

Navier Stokes

$$\frac{\partial}{\partial x}u + \frac{\partial}{\partial y}v = 0$$

$$u\frac{\partial}{\partial x}u + v\frac{\partial}{\partial y}u = -\frac{\partial p}{\rho \partial x} + \nu \frac{\partial^2}{\partial y^2}u$$

$$0 = -\frac{\partial}{\partial y}p$$

ReducedNavier Stokes

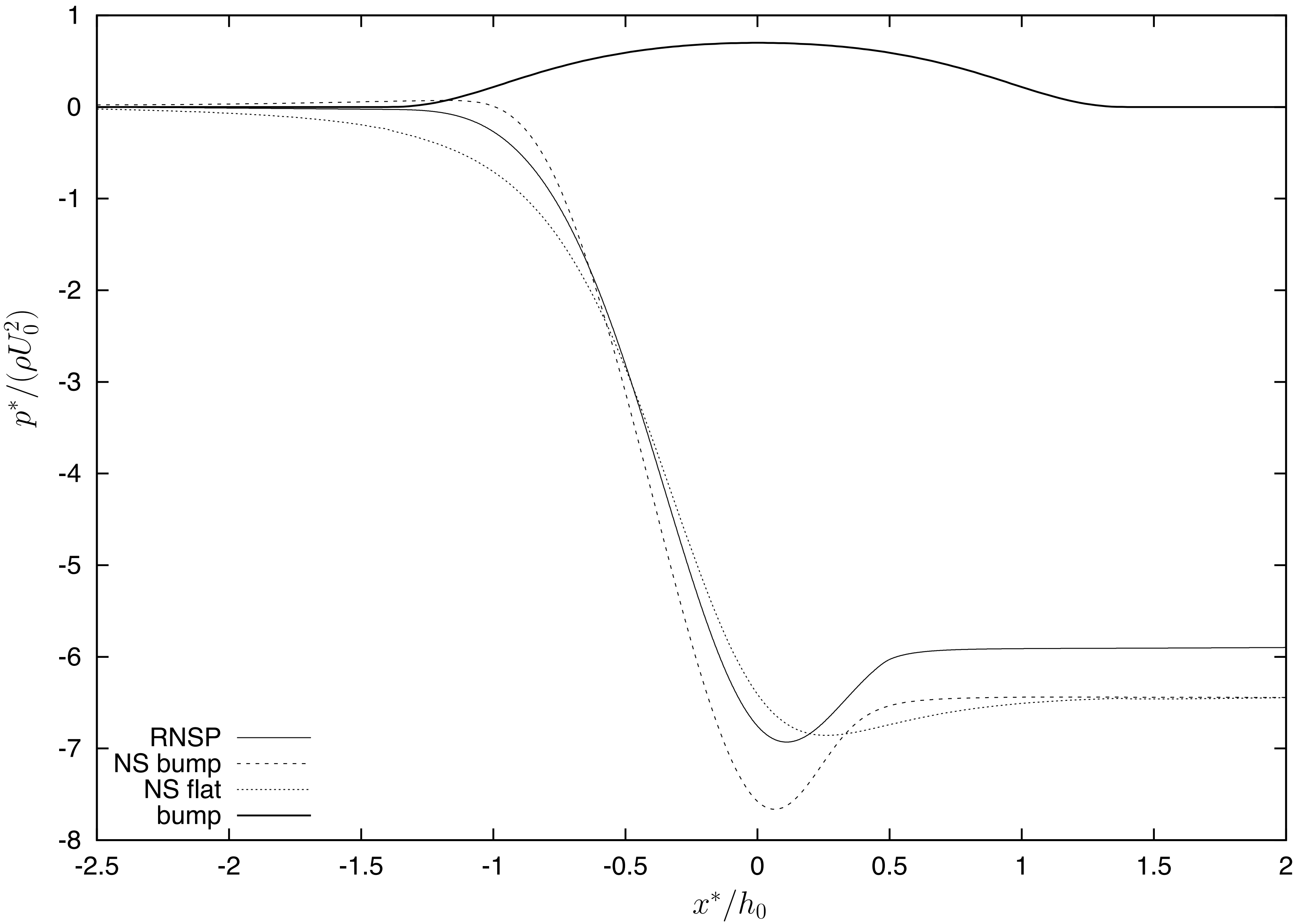
$$\frac{\partial}{\partial x}u + \frac{\partial}{\partial y}v = 0$$

$$u\frac{\partial}{\partial x}u + v\frac{\partial}{\partial y}u = -\frac{\partial}{\partial x}p + \frac{\partial^2}{\partial y^2}u$$

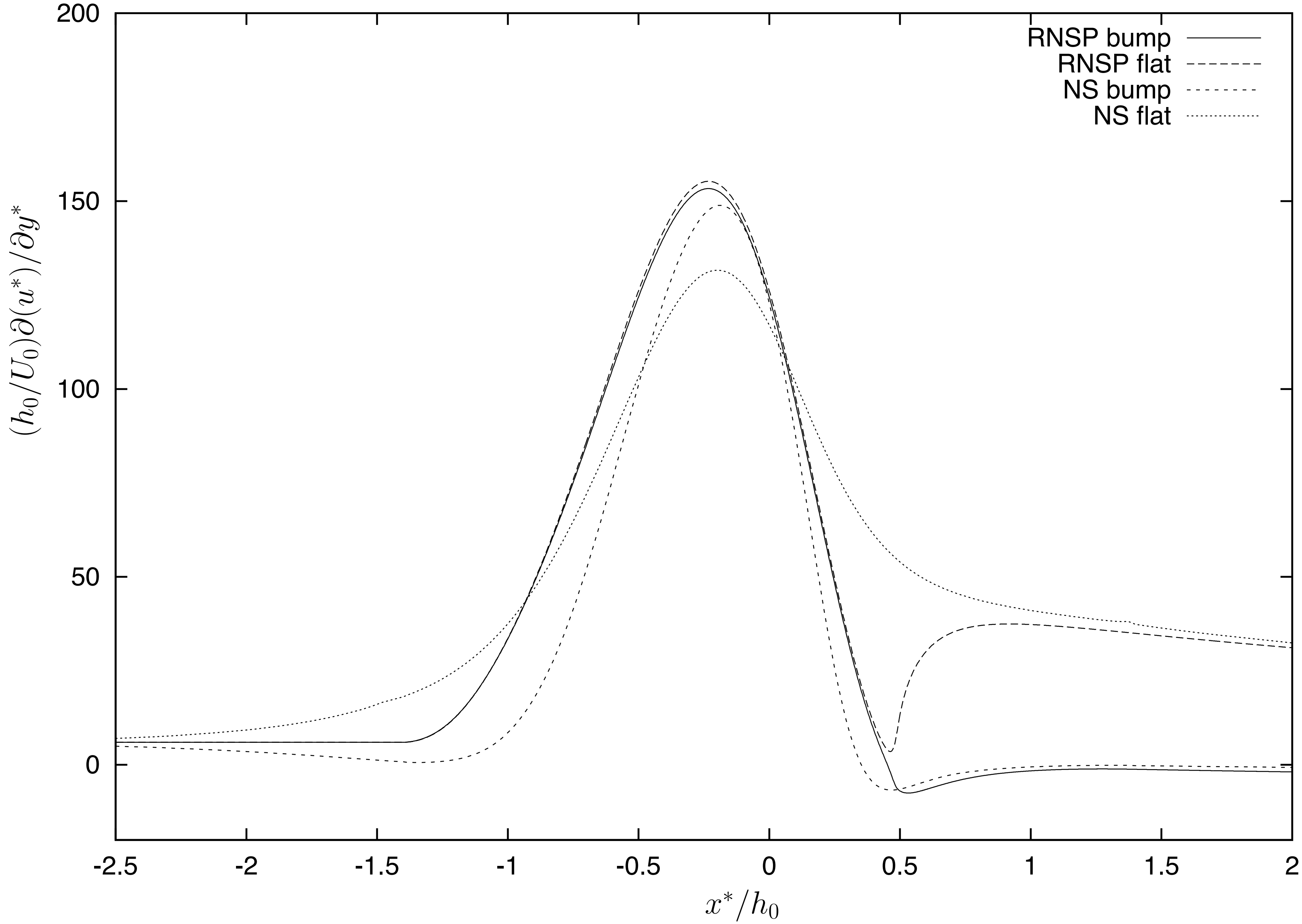
$$0 = -\frac{\partial}{\partial y}p$$

avec un adimensionnement *ad hoc*

premiers exemples



pression RNSP et NS sur les deux parois



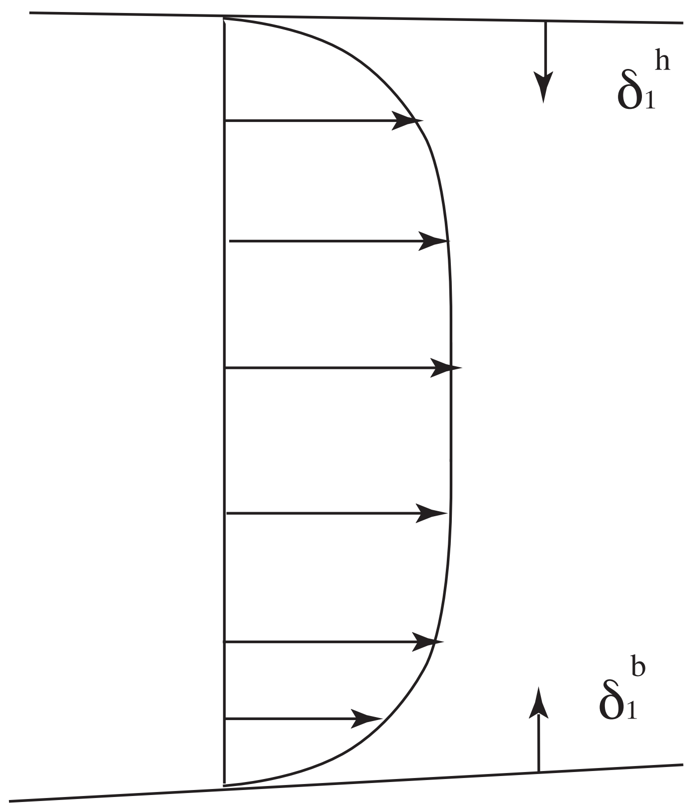
frottement pariétal RNSP et NS sur les deux parois

- Légère dissymétrie
- décomposition Fluide Parfait/Couche limite
- Utilisation d’une méthode intégrale

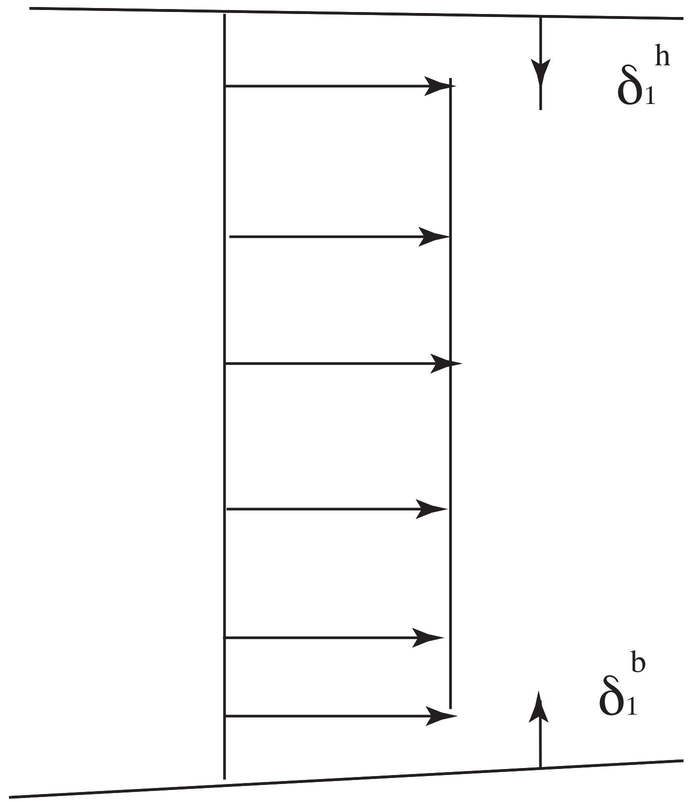
Epaisseur de déplacement de la couche limite

$$\delta_1^h = \int_0^\infty (1 - \frac{u}{u^h_{y=f^h}} dy) \qquad \delta_1^b = \int_0^\infty (1 - \frac{u}{u^b_{y=f^b}} dy)$$

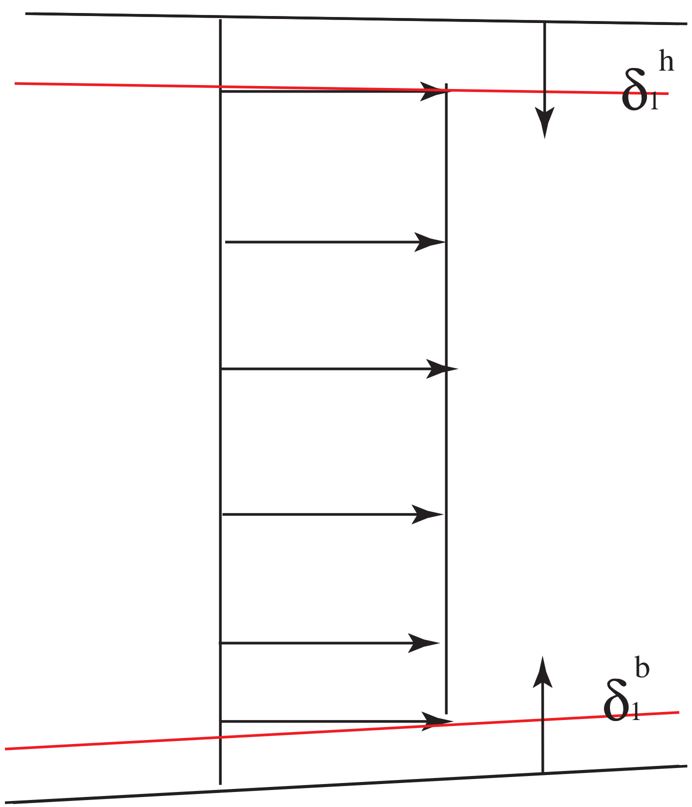
Utilisation d'une méthode intégrale

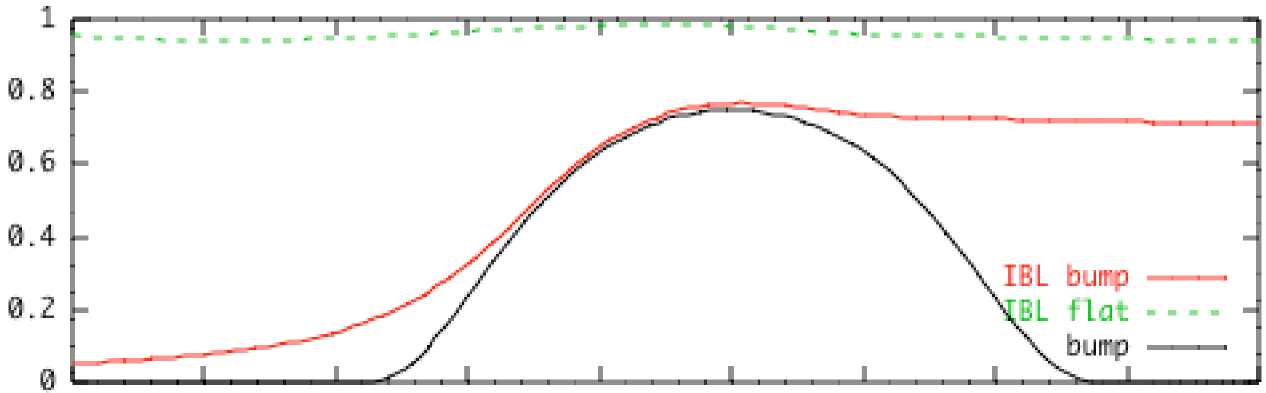


Utilisation d'une méthode intégrale



Utilisation d'une méthode intégrale





les deux couches limites finales
“conduit” réel

Relation de couplage

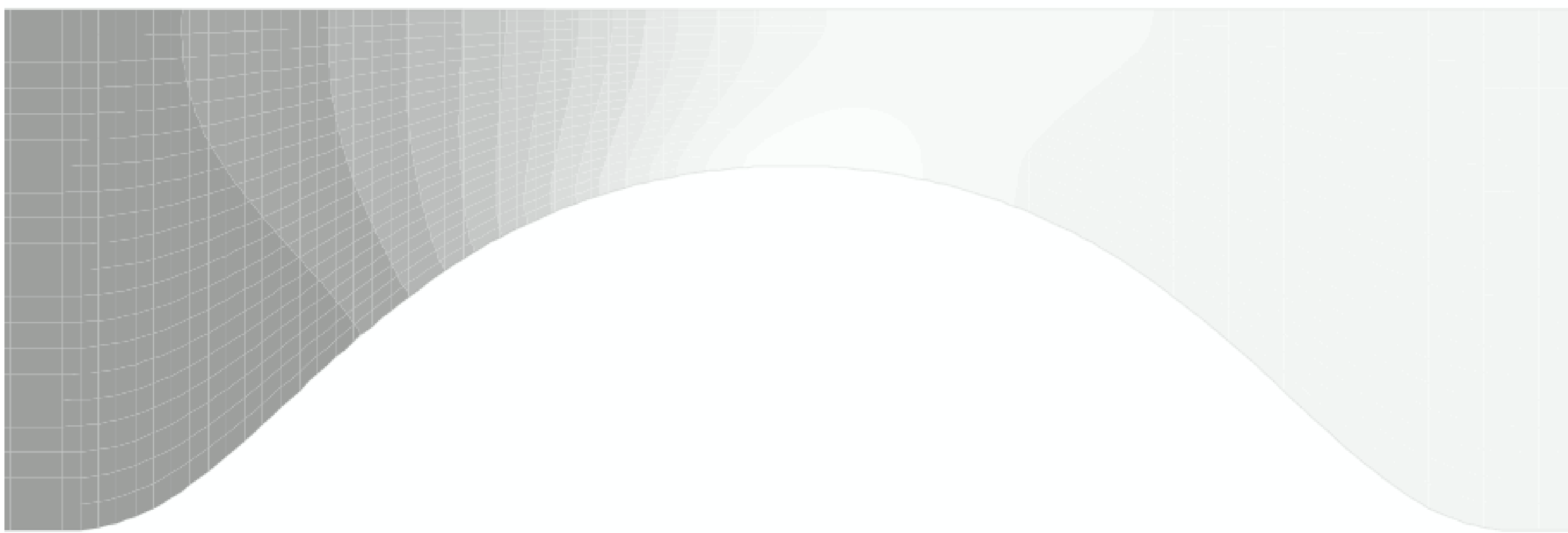
- Fluide parfait flux corrigé:

$$U_0(1-(f_h+\delta_1^h)-(f_b+\delta_1^b))=1$$

variation de pression au travers de la section

$$\Delta P_0 = \varepsilon^2 \Big(\frac{((f_h' + \delta_1'^h)^2 - (f_b' + \delta_1'^b)^2)}{1 - (f_b + \delta_1^b) - (f_h + \delta_1^h)} + \frac{(f_h'' + \delta_1''^h - f_b'' - \delta_1''^b)}{2} \Big).$$

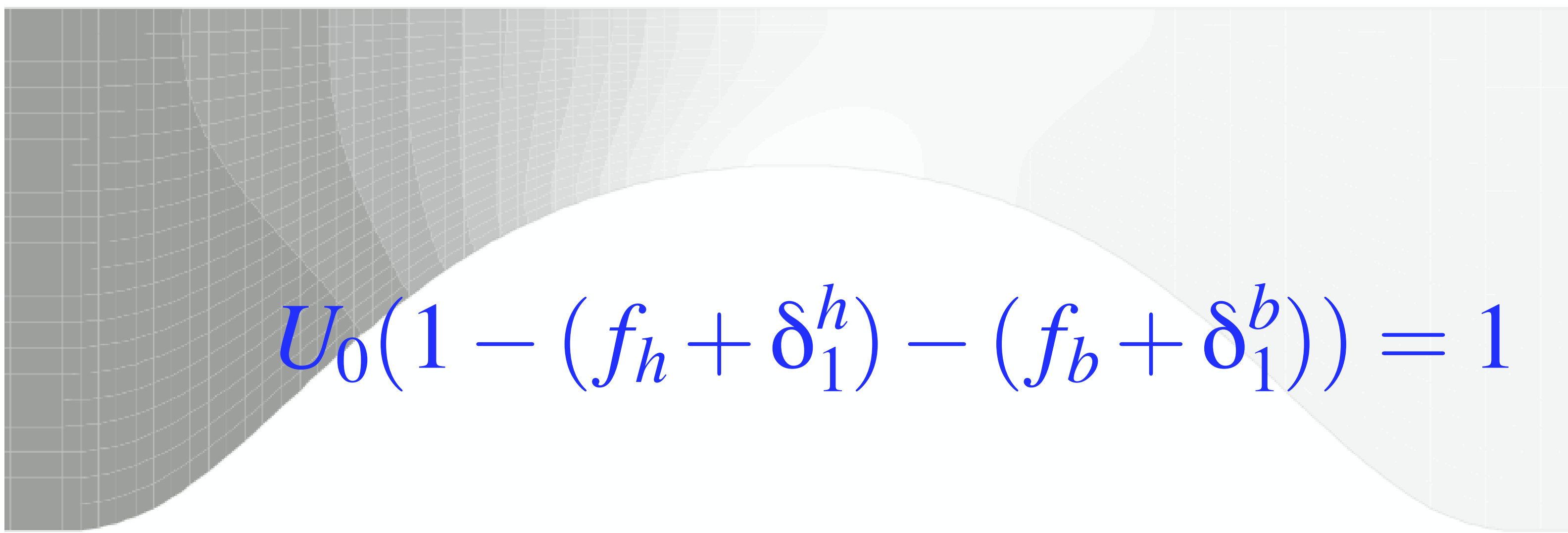
$$\varepsilon = Re^{-1}$$



$$\frac{d}{dx}\left(\frac{\delta_1^h}{H}\right) + \frac{\delta_1^h}{u_e^h}\left(1 + \frac{2}{H}\right)\frac{du_e^h}{dx} = \frac{f_2 H}{\delta_1^h u_e^h}, \qquad \delta_1^h = F(p_e^h)$$

$$\frac{d}{dx}\left(\frac{\delta_1^b}{H}\right) + \frac{\delta_1^b}{u_e^b}\left(1 + \frac{2}{H}\right)\frac{du_e^b}{dx} = \frac{f_2 H}{\delta_1^b u_e^b}, \qquad \delta_1^b = F(p_e^b)$$

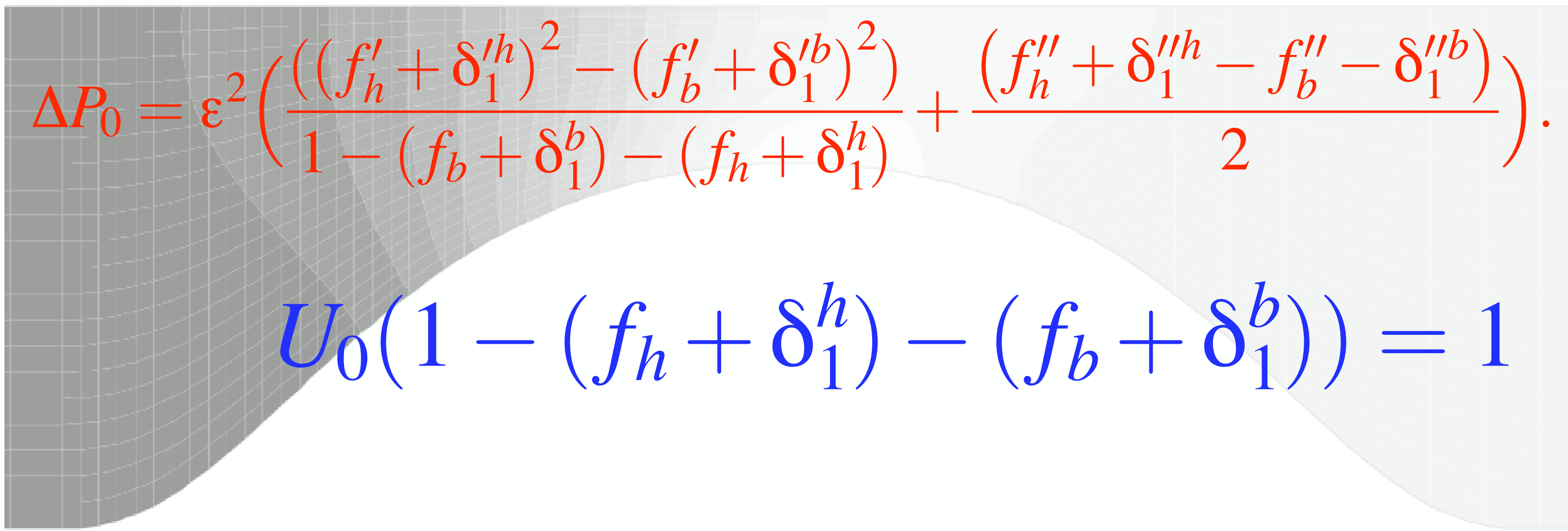
$$\frac{d}{dx}\left(\frac{\delta_1^h}{H}\right) + \frac{\delta_1^h}{u_e^h}\left(1 + \frac{2}{H}\right)\frac{du_e^h}{dx} = \frac{f_2 H}{\delta_1^h u_e^h}, \qquad \delta_1^h = F(p_e^h)$$



$$U_0\left(1 - (f_h + \delta_1^h) - (f_b + \delta_1^b)\right) = 1$$

$$\frac{d}{dx}\left(\frac{\delta_1^b}{H}\right) + \frac{\delta_1^b}{u_e^b}\left(1 + \frac{2}{H}\right)\frac{du_e^b}{dx} = \frac{f_2 H}{\delta_1^b u_e^b}, \qquad \delta_1^b = F(p_e^b)$$

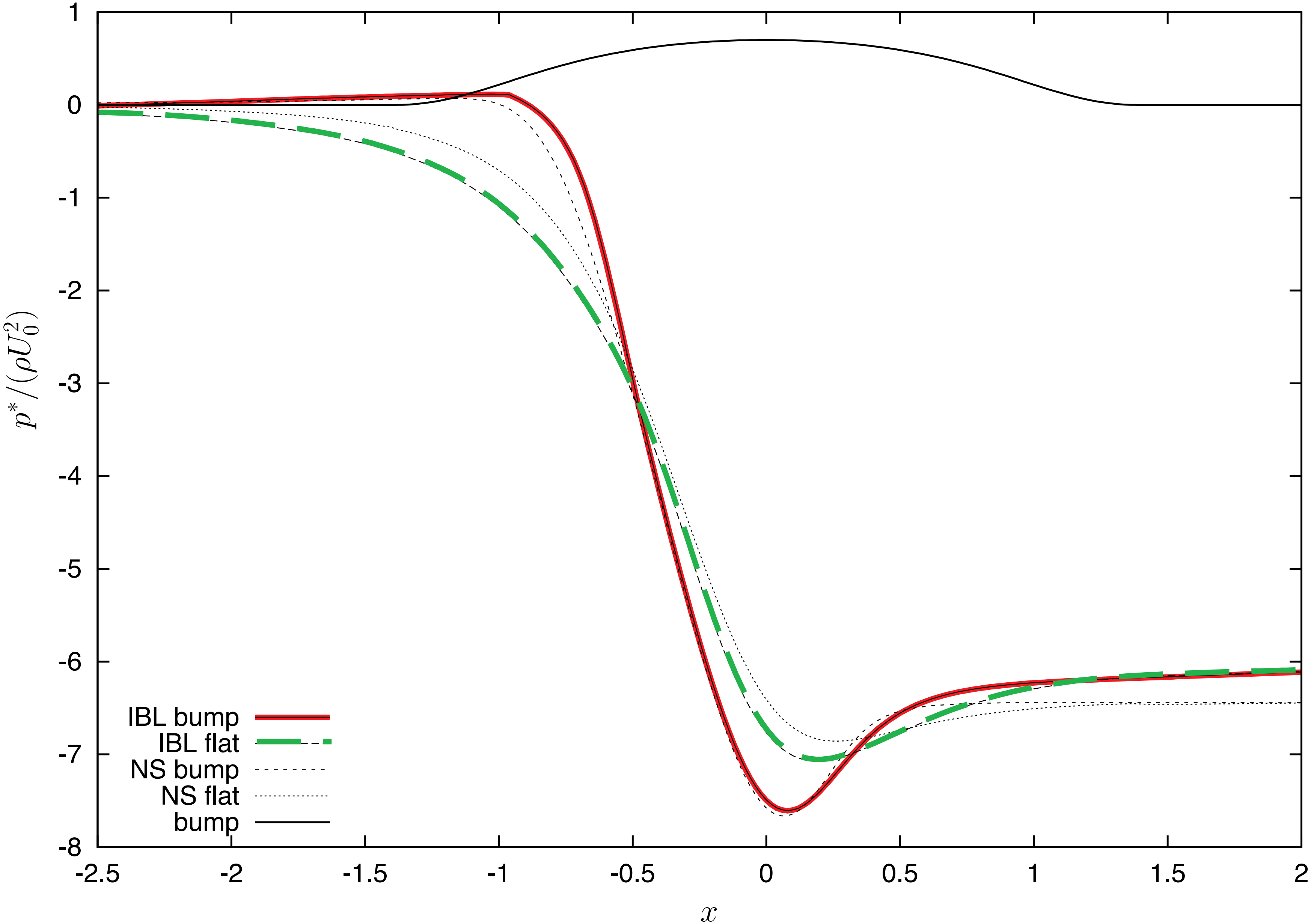
$$\frac{d}{dx}\left(\frac{\delta_1^h}{H}\right)+\frac{\delta_1^h}{u_e^h}\left(1+\frac{2}{H}\right)\frac{du_e^h}{dx}=\frac{f_2H}{\delta_1^h u_e^h}, \qquad \delta_1^h=F(p_e^h)$$



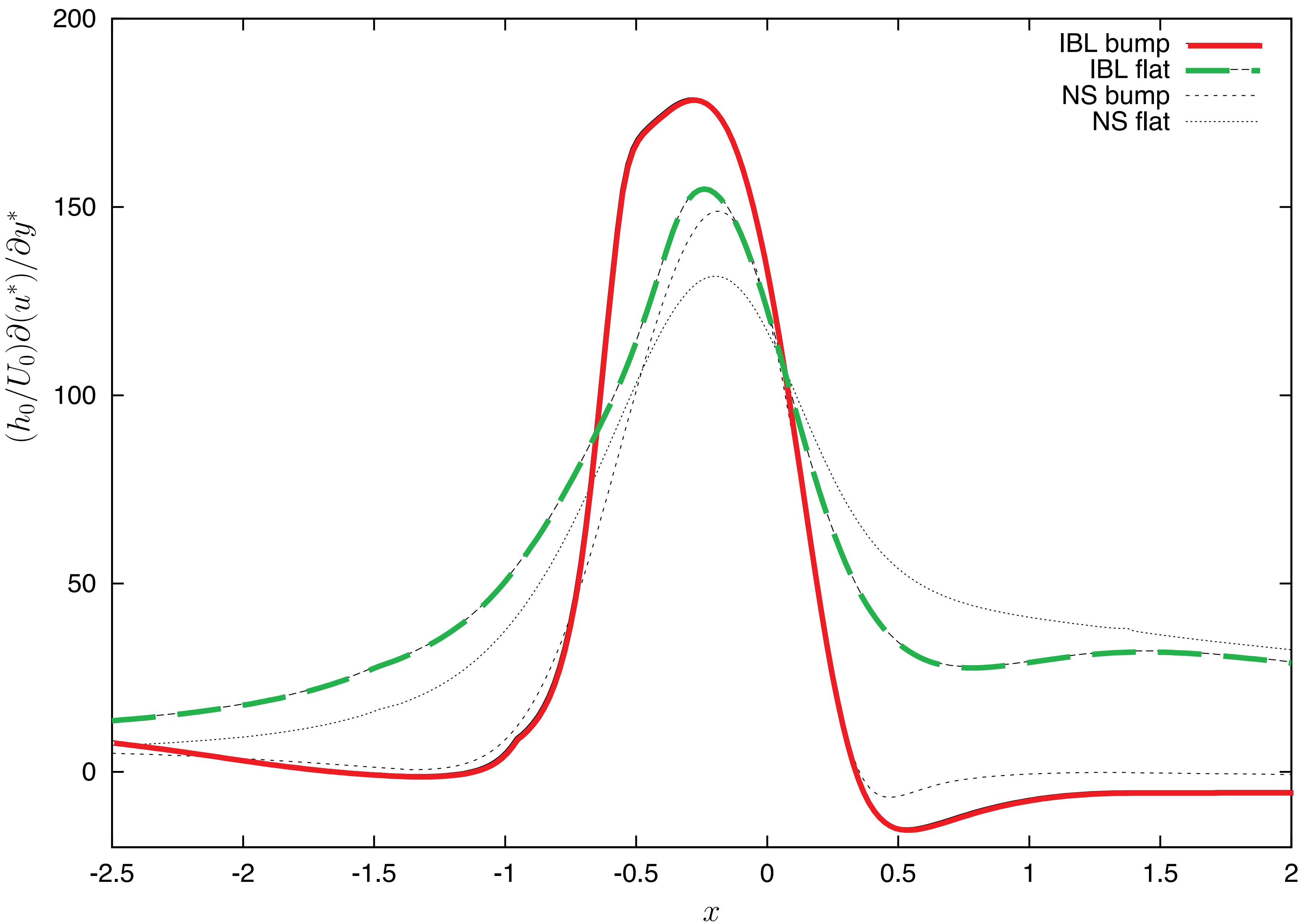
$$\Delta P_0=\varepsilon^2\left(\frac{\left((f_h'+\delta_1'^h)^2-(f_b'+\delta_1'^b)^2\right)}{1-(f_b+\delta_1^b)-(f_h+\delta_1^h)}+\frac{\left(f_h''+\delta_1''^h-f_b''-\delta_1''^b\right)}{2}\right).$$

$$U_0\left(1-(f_h+\delta_1^h)-(f_b+\delta_1^b)\right)=1$$

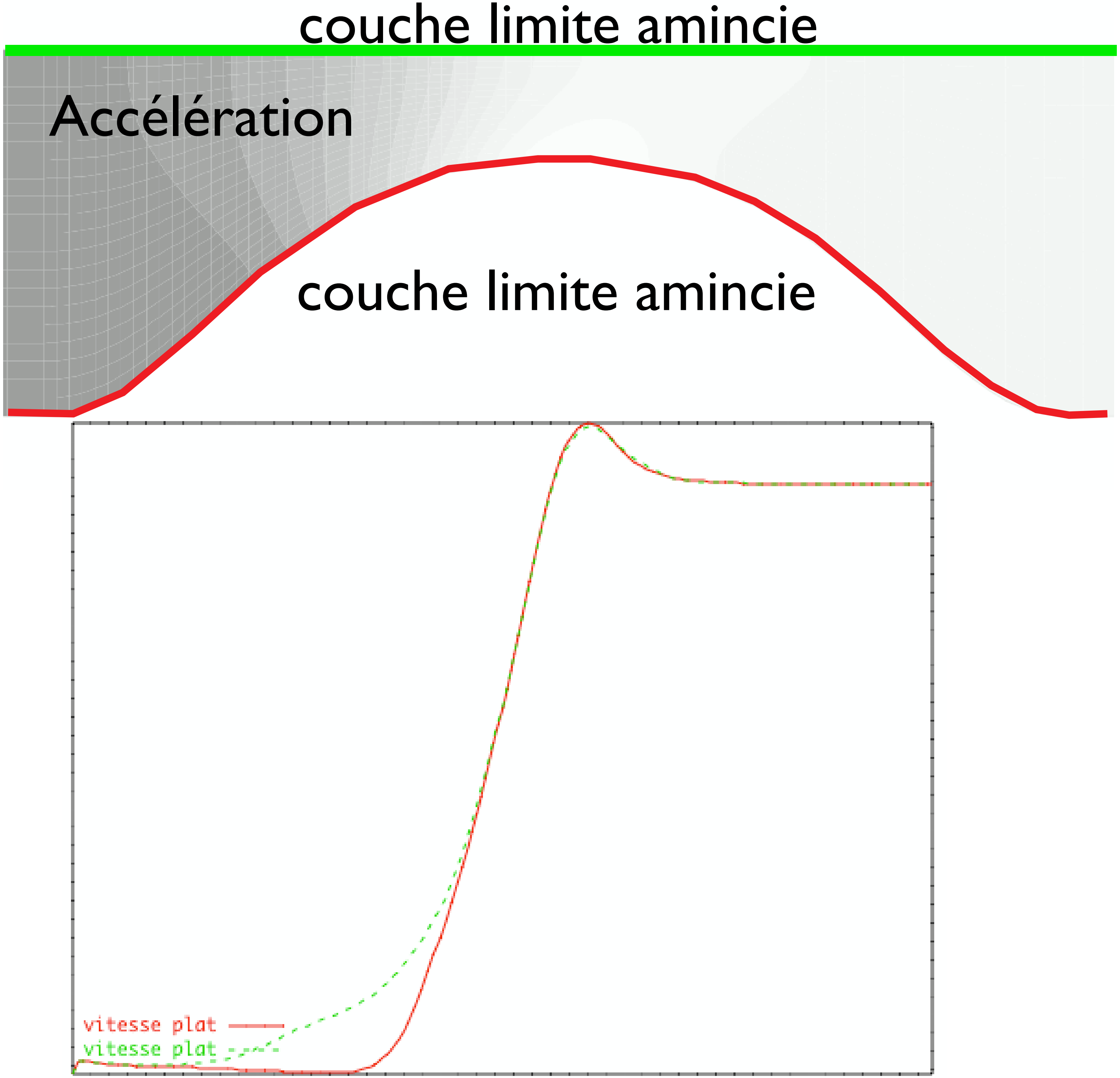
$$\frac{d}{dx}\left(\frac{\delta_1^b}{H}\right)+\frac{\delta_1^b}{u_e^b}\left(1+\frac{2}{H}\right)\frac{du_e^b}{dx}=\frac{f_2H}{\delta_1^b u_e^b}, \qquad \delta_1^b=F(p_e^b)$$

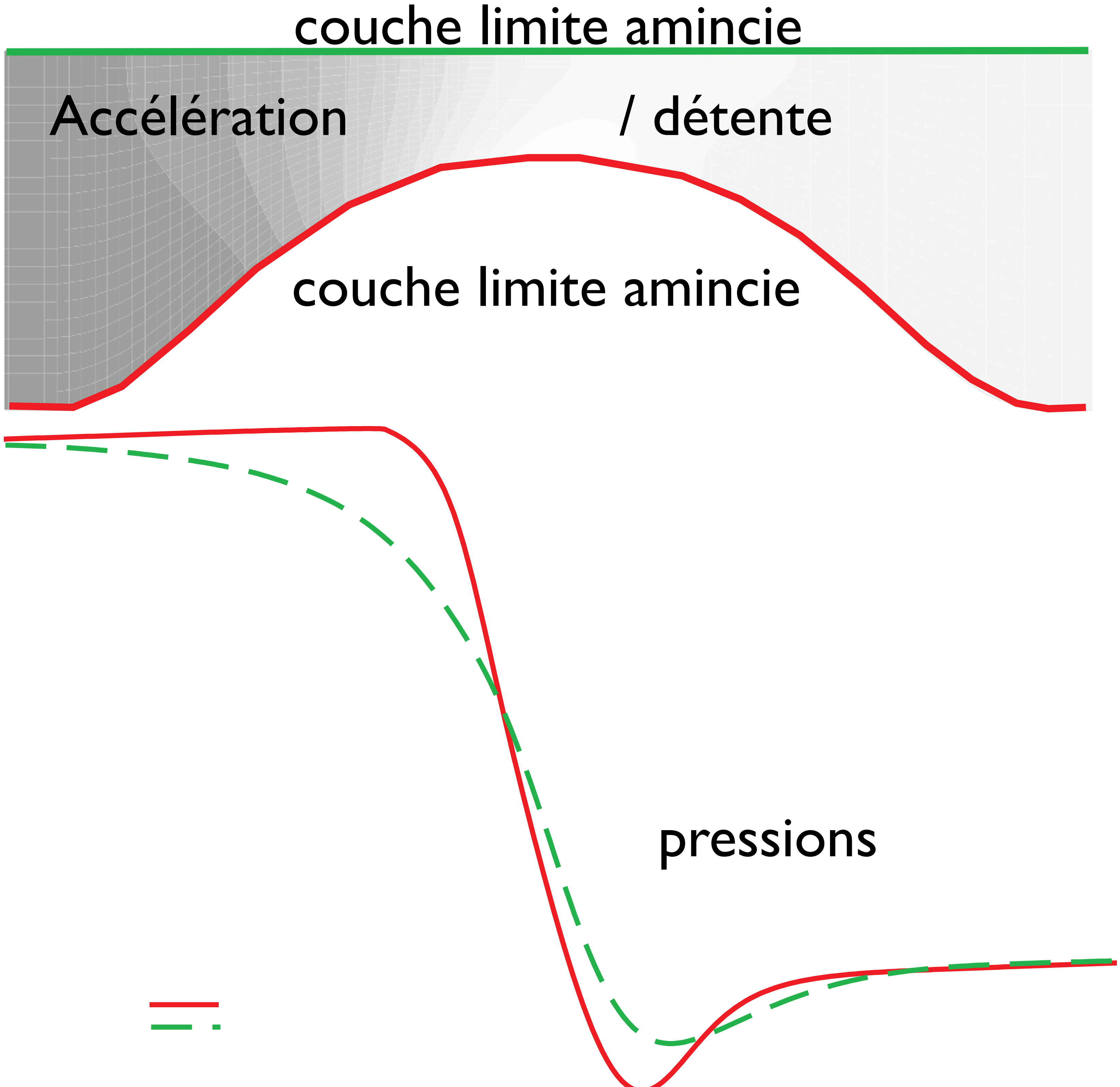


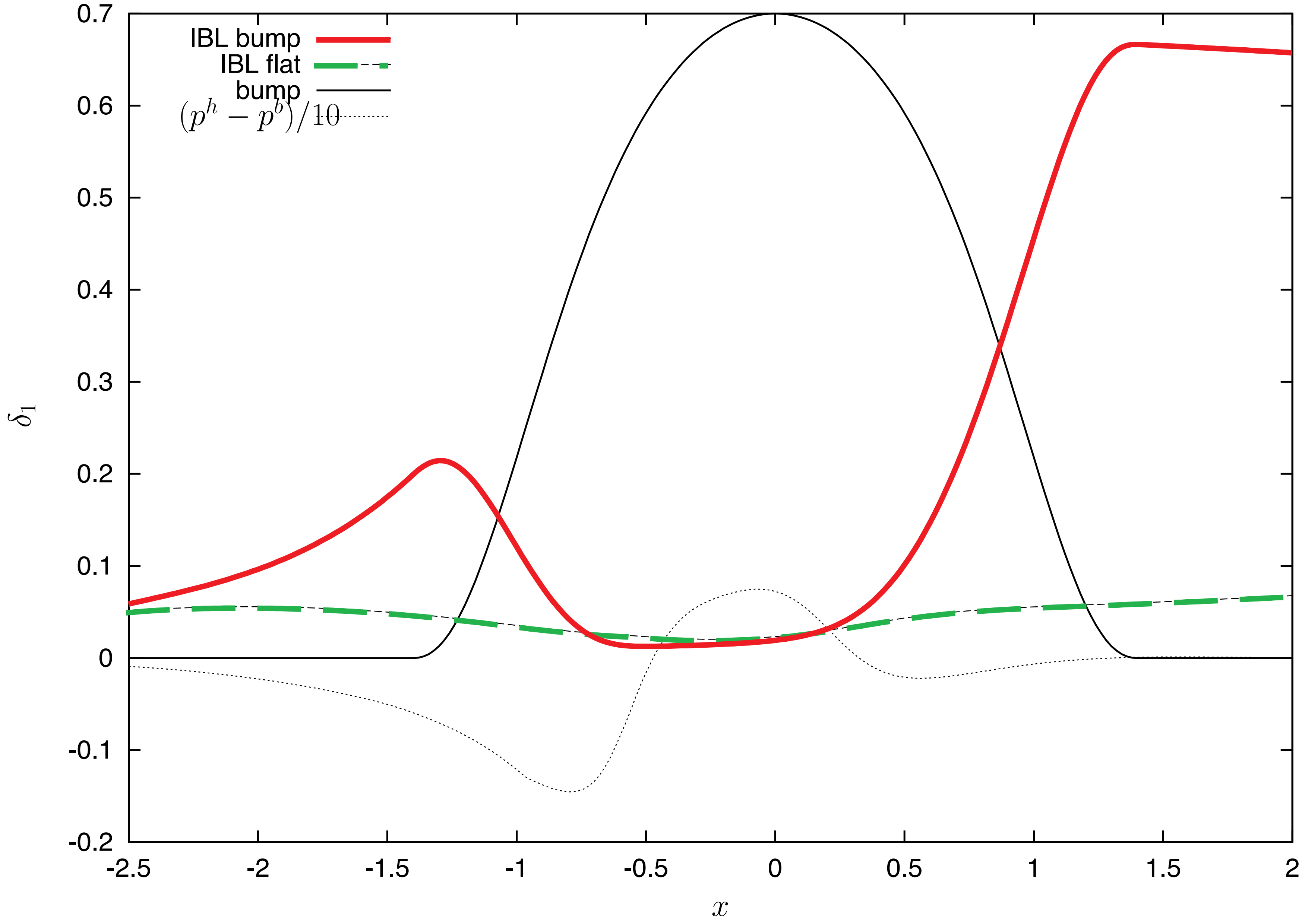
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
$p^*/(\rho U_0^2)$
x
IBL bump
IBL flat
NS bump
NS flat
bump

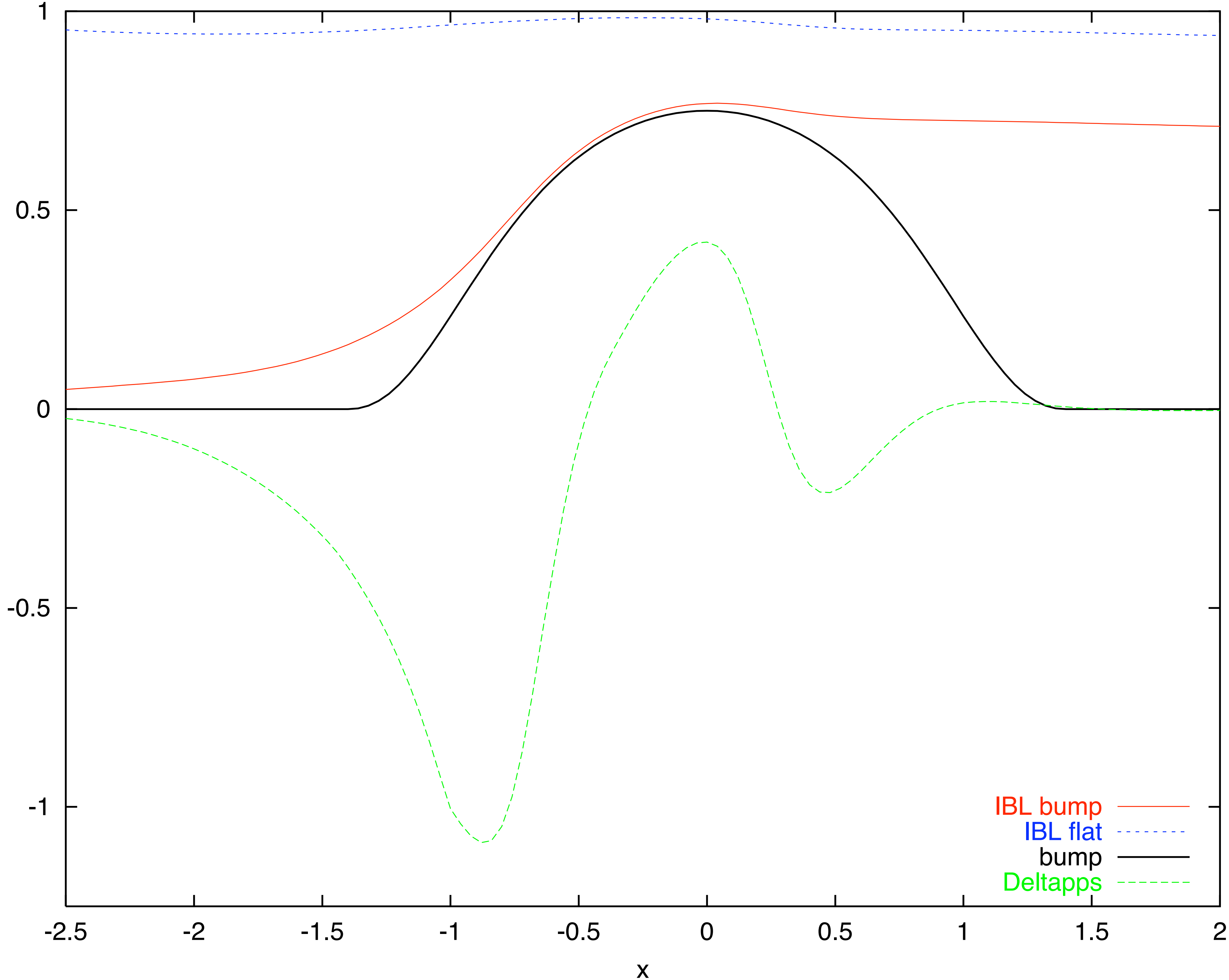


IBL bump
IBL flat
NS bump
NS flat
200
150
100
50
0
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
$(h_0/U_0)\partial(u^*)/\partial y^*$
x

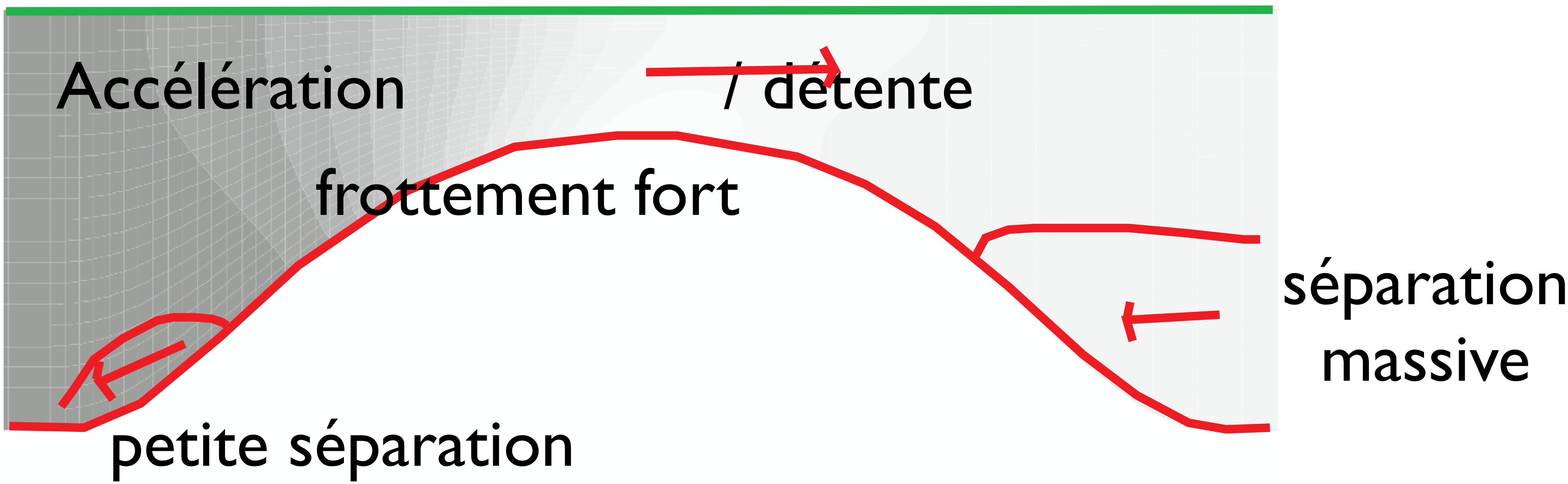

couche limite amincie
Accélération
couche limite amincie
vitesse plat
vitesse plat


couche limite amincie
Accélération
/ détente
couche limite amincie
pressions

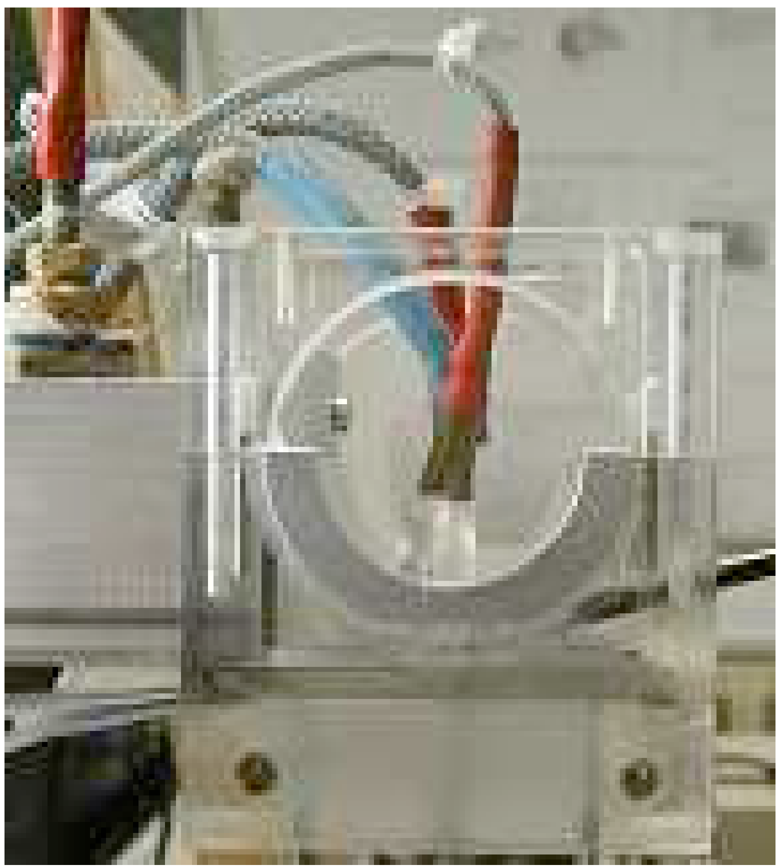

IBL bump
IBL flat
bump
$(p^h - p^b)/10$
δ_1
x
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2

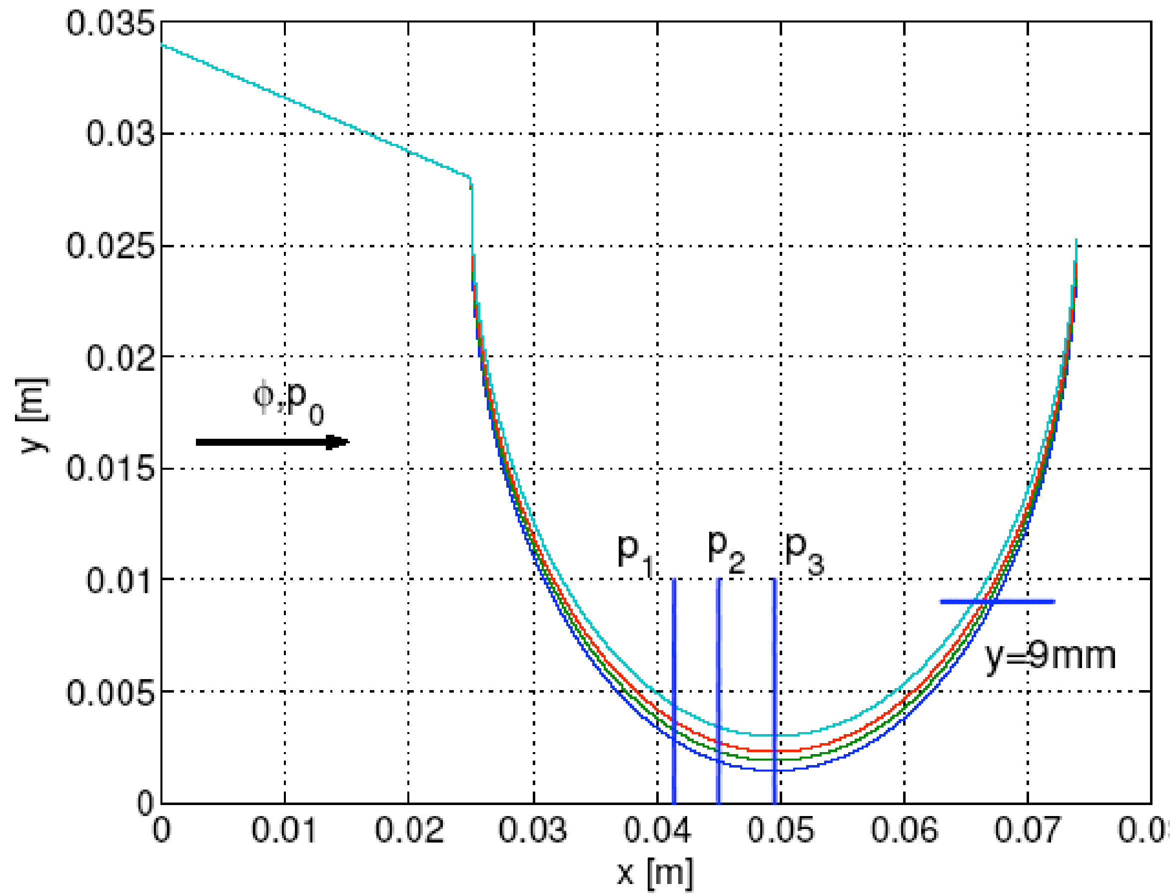


1
0.5
0
-0.5
-1
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
x
IBL bump
IBL flat
bump
Deltapps


Accélération
/ détente
frottement fort
séparation
massive
petite séparation

modèle expérimental





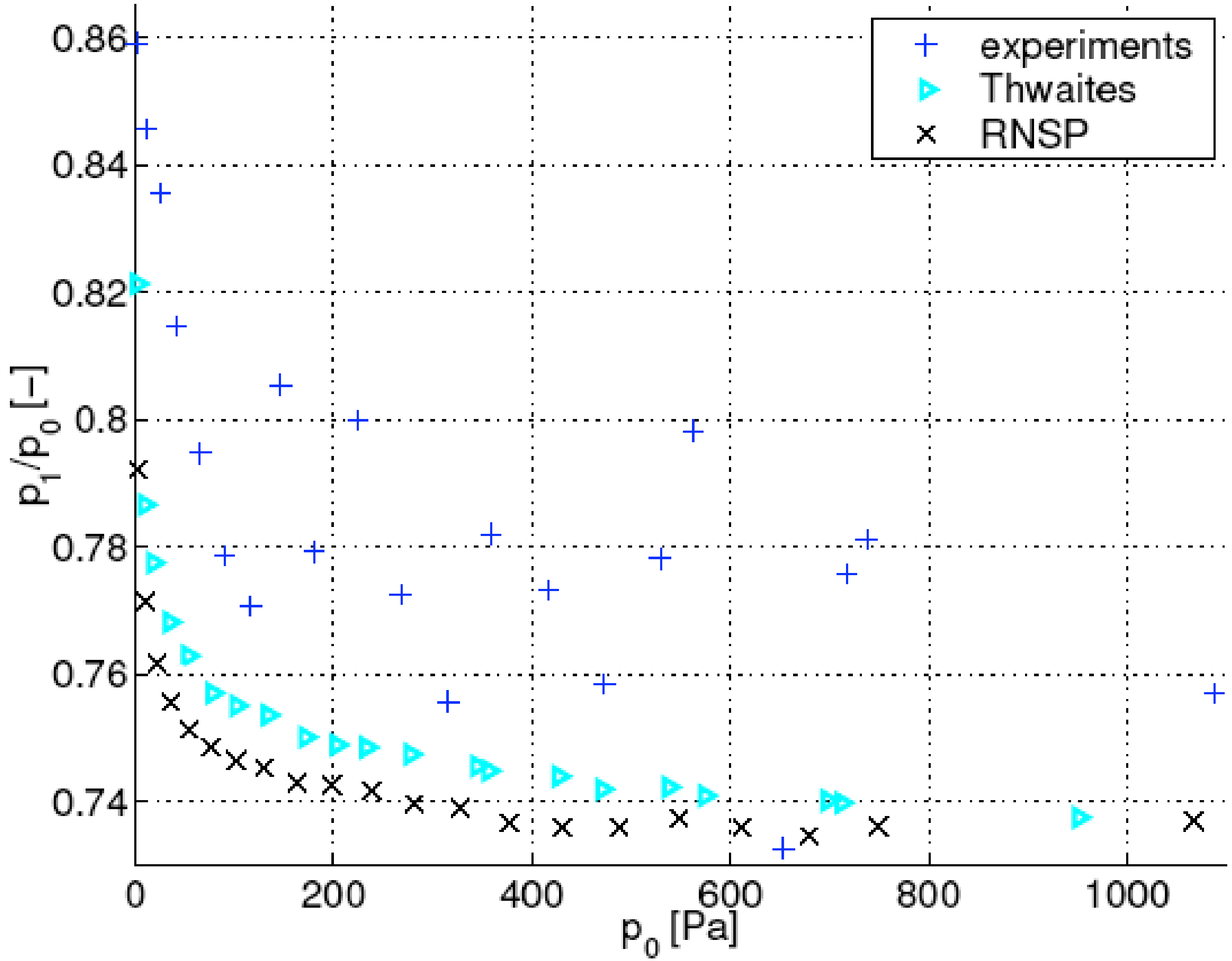


Figure 10. Normalized pressure at position p_1 for $h_{min} = 1.45mm$: measured data (+), Thwaites (▷) and RNSP (x).

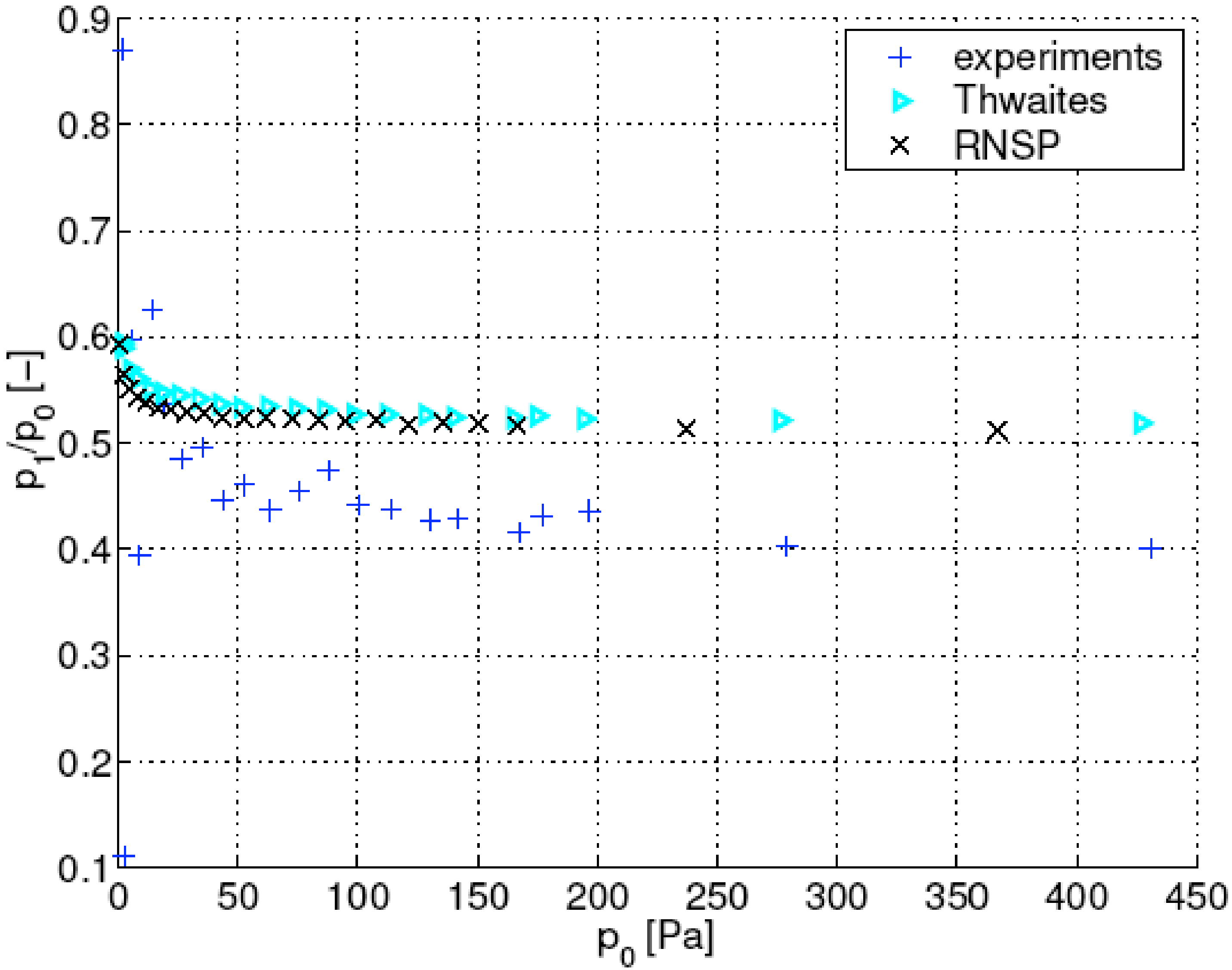


Figure 13. Normalized pressure at position p_1 for $h_{min} = 3.00mm$: measured data (+), Thwaites (▷) and RNSP (x).

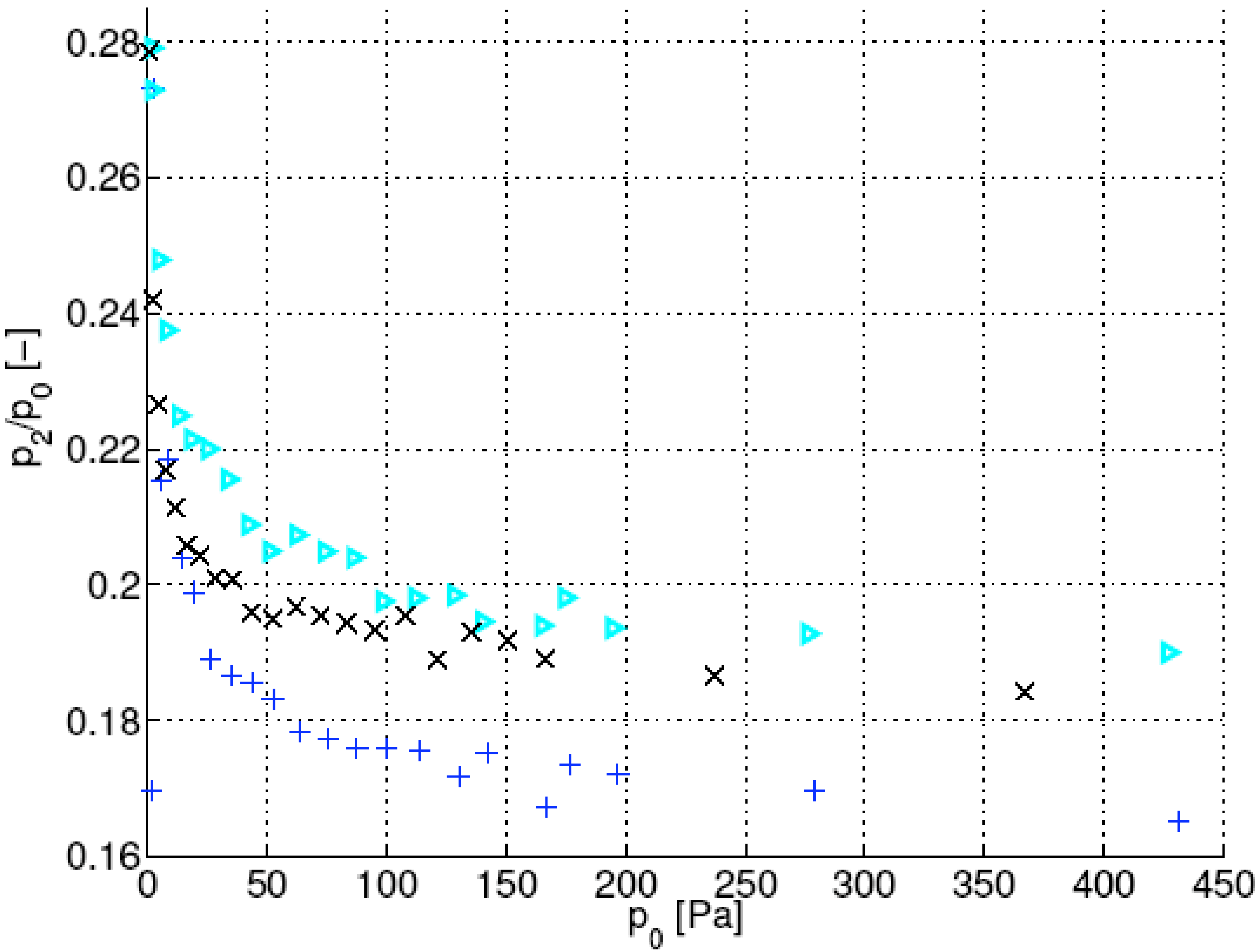


Figure 14. Normalized pressure at position p_2 for $h_{min} = 3.00mm$: measured data (+), Thwaites (▷) and RNSP (x).

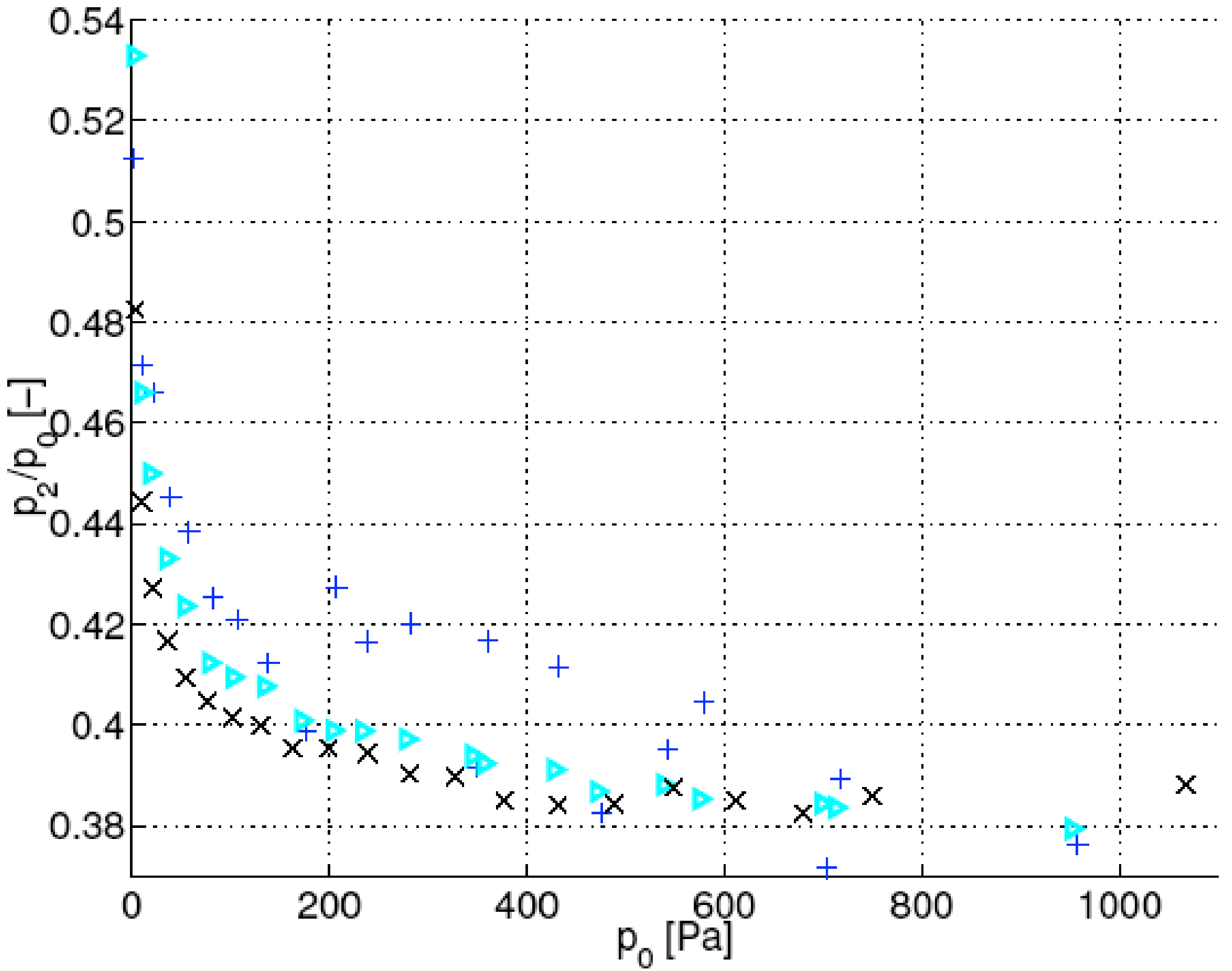


Figure 11. Normalized pressure at position p_2 for $h_{min} = 1.45mm$: measured data (+), Thwaites (▷) and RNSP (x).

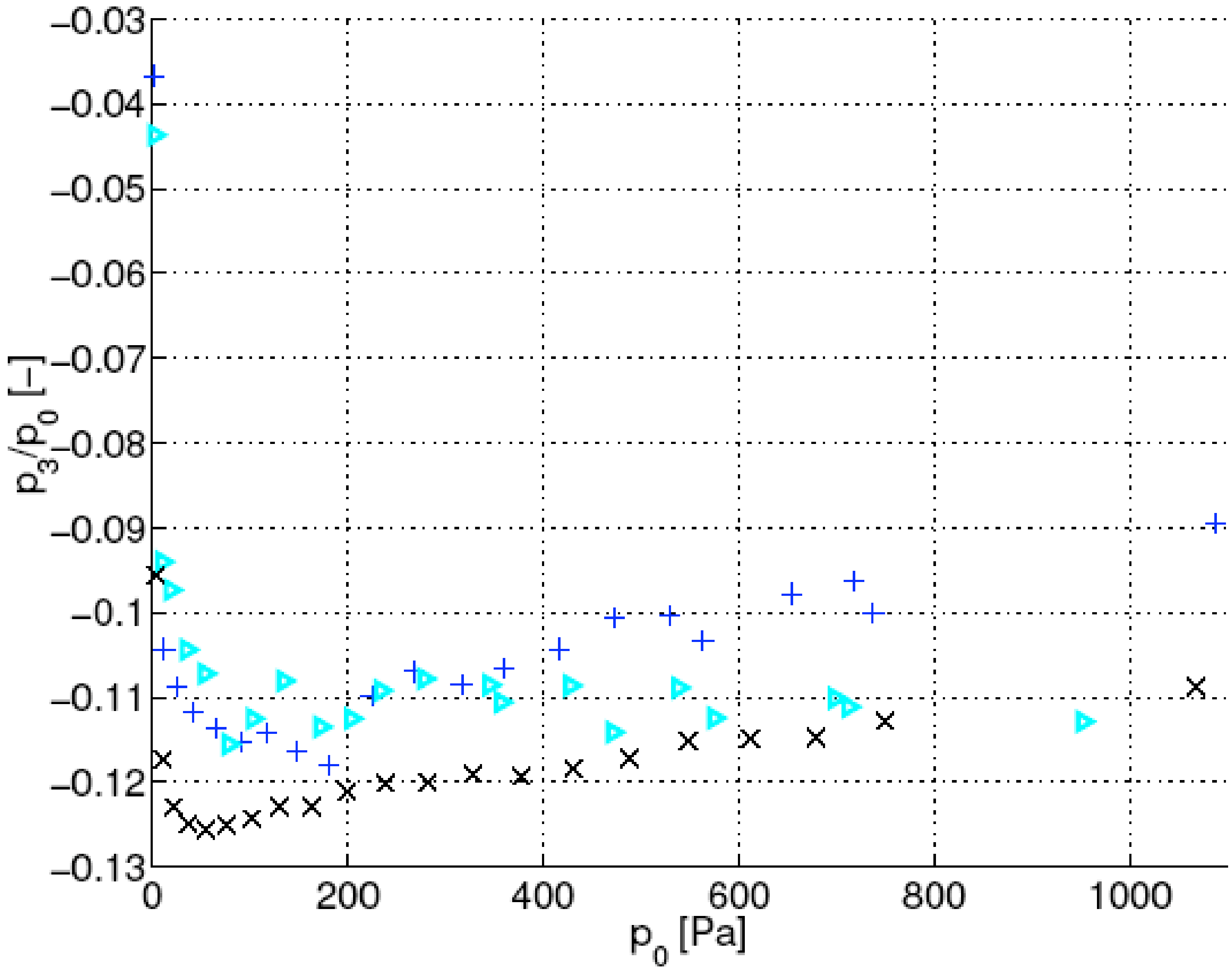


Figure 12. Normalized pressure position p_3 for $h_{min} = 1.45mm$: measured data (+), Thwaites (▷) and RNSP (x).

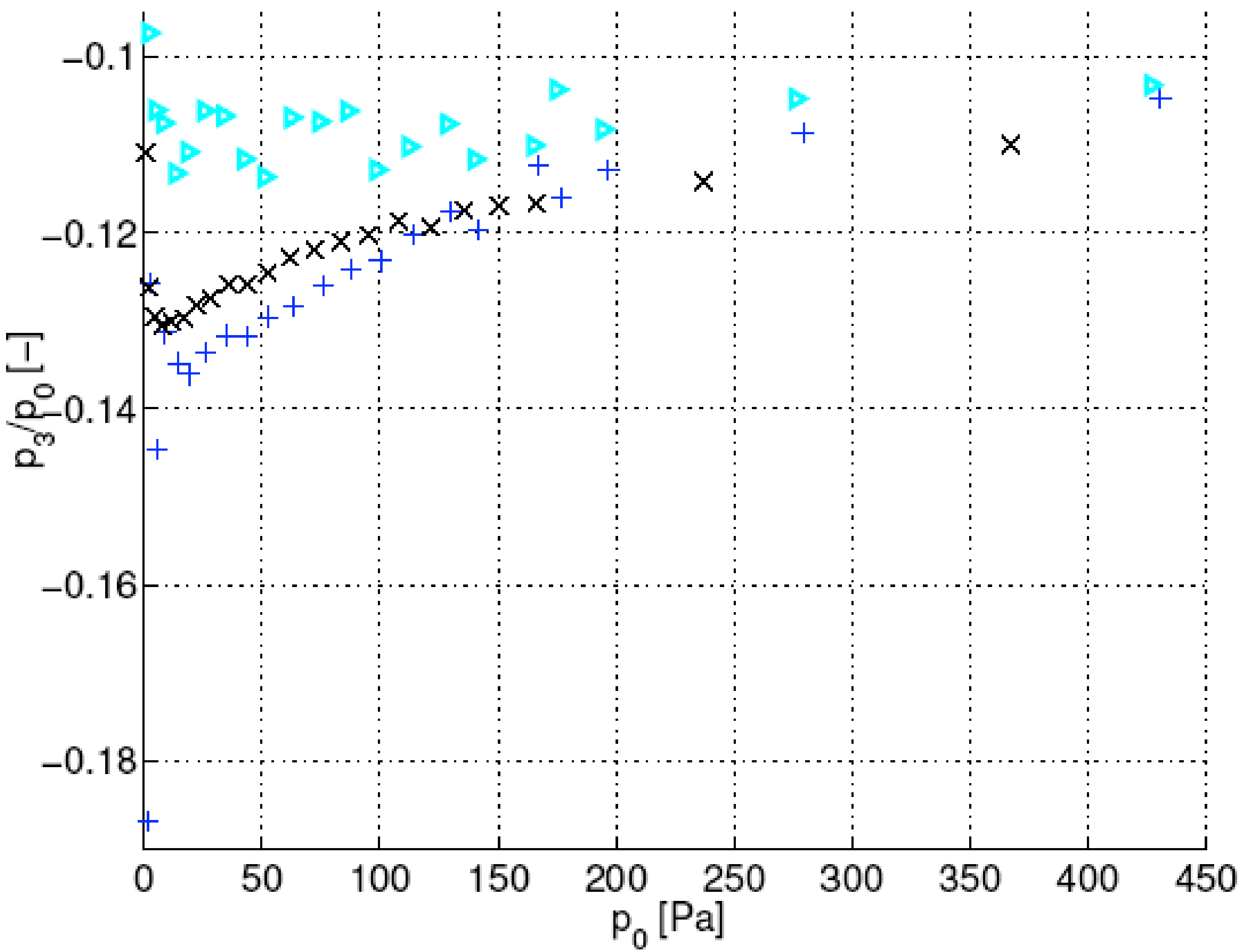


Figure 15. Normalized pressure at position p_3 for $h_{min} = 3.00mm$: measured data (+), Thwaites (▹) and RNSP (x).

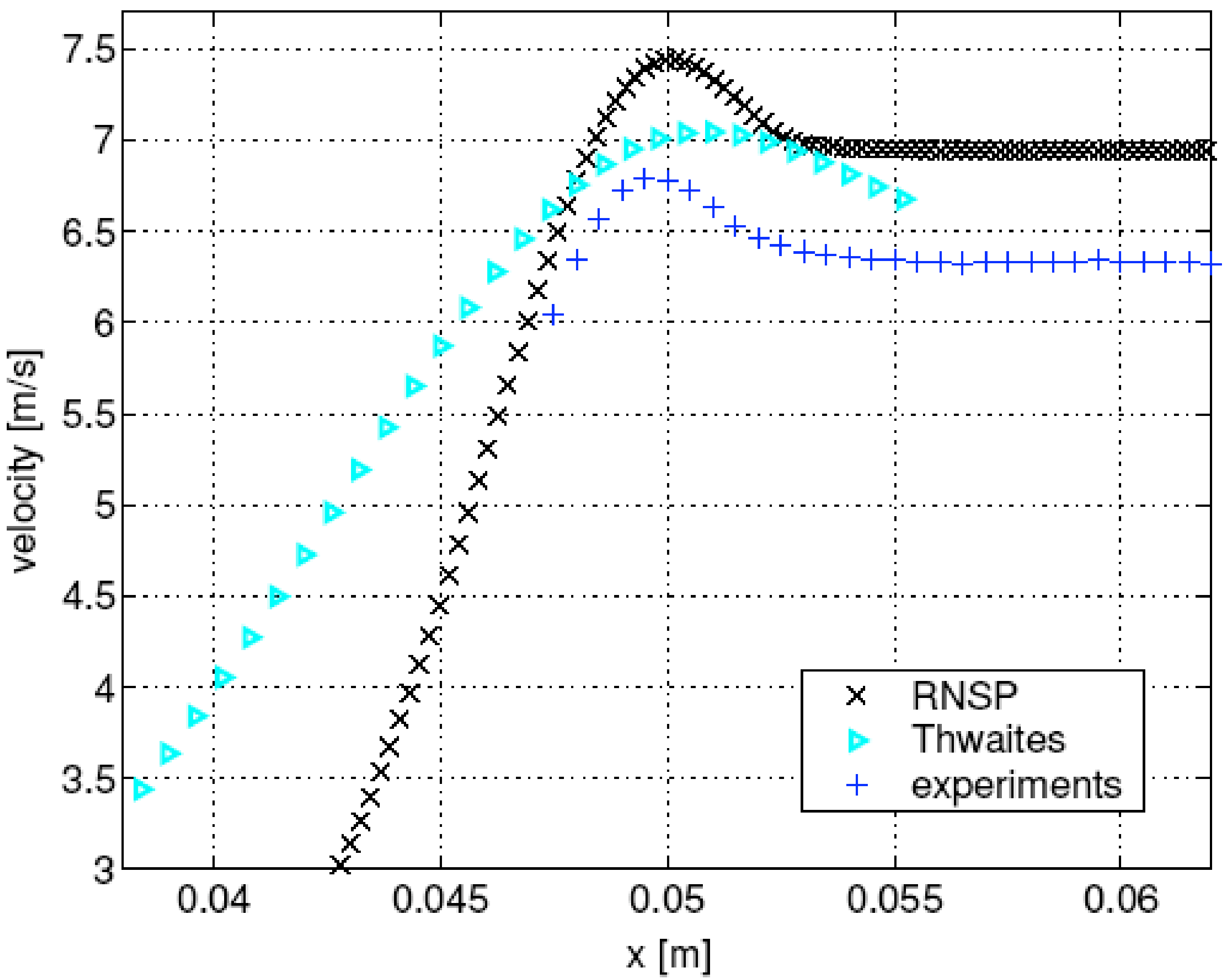
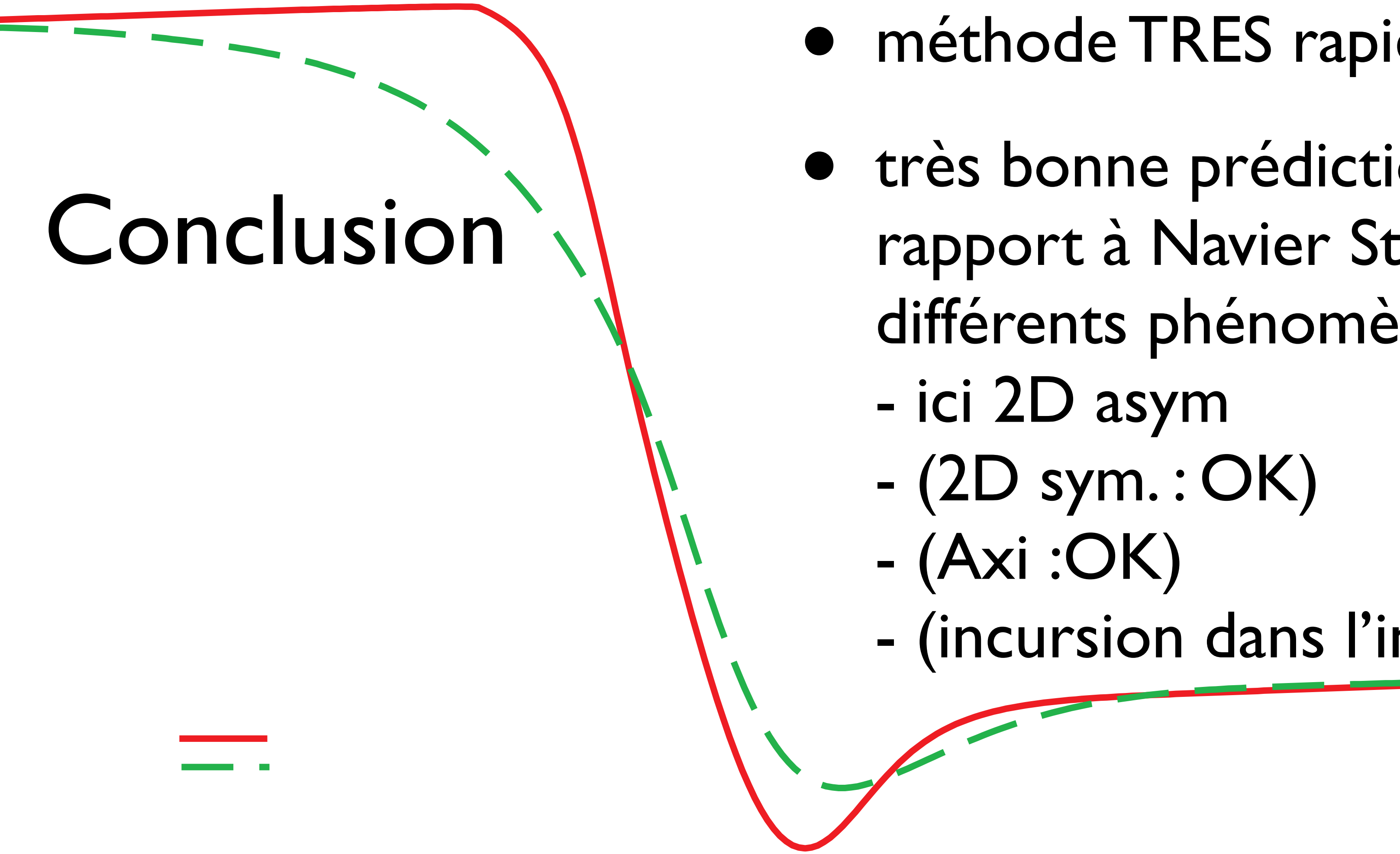


Figure 8. Longitudinal velocity profile with a step of Δx = 1.0mm for $h_{min} = 3.00mm$ and ϕ=40l/min: measured data (+), Thwaites (▷) and RNSP (x).

Conclusion



- méthode TRES rapide
- très bonne prédiction (par rapport à Navier Stokes) des différents phénomènes
  - ici 2D asym
  - (2D sym. : OK)
  - (Axi :OK)
  - (incursion dans l'instationnaire)
- prédiction assez correcte par rapport à l'expérience (transition...)
- Application à une paroi souple...

Vendredi 10 Septembre 2004- 29ème congrès SB

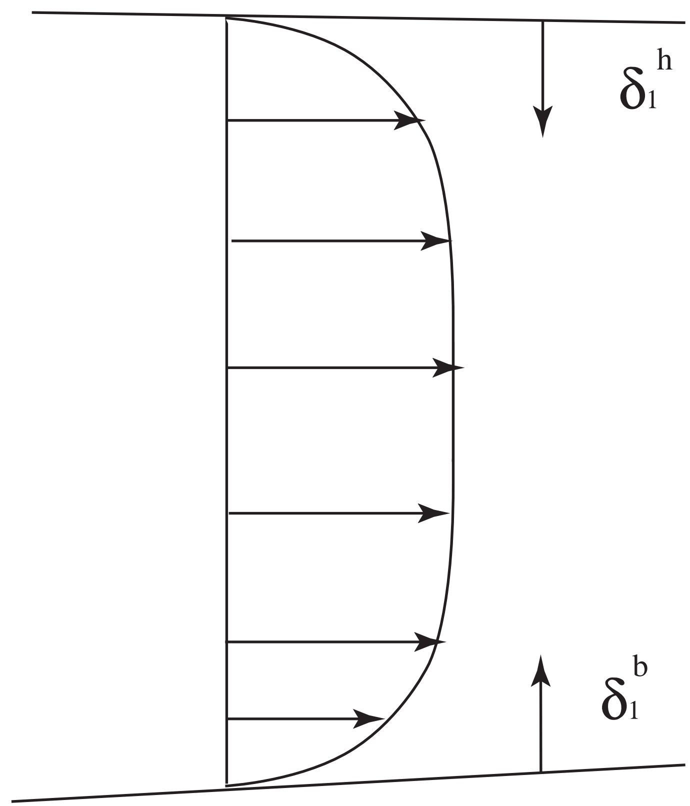
- P.-Y. Lagrée & S. Lorthois:
  "The RNS/Prandtl equations and their link with other asymptotic descriptions. Application to the computation of the maximum value of the Wall Shear Stress in a pipe", to appear in Int J Eng Sci.

- A. Van Hirtum, X. Pelorson & P.-Y. Lagrée:
  "In-vitro validation of some flow assumptions for the prediction of the pressure distribution during obstructive sleep apnea". sous presse Medical & biological engineering & computing

- P.-Y. Lagrée, E. Berger, M. Deverge, C. Vilain & A. Hirschberg:
  "Characterization of the pressure drop in a 2D symmetrical pipe: some asymptotical, numerical and experimental comparisons". sous presse ZAMM

- M. Deverge, X. Pelorson, C. Vilain, P.-Y. Lagrée, F. Chentouf, J. Willems & A. Hirschberg (2003):
  "Influence of the collision on the flow through in-vitro rigid models of the vocal folds".
  J. Acoust. Soc. Am. 114 , pp. 3354 - 3362.

Utilisation d'une méthode intégrale



Utilisation d'une méthode intégrale