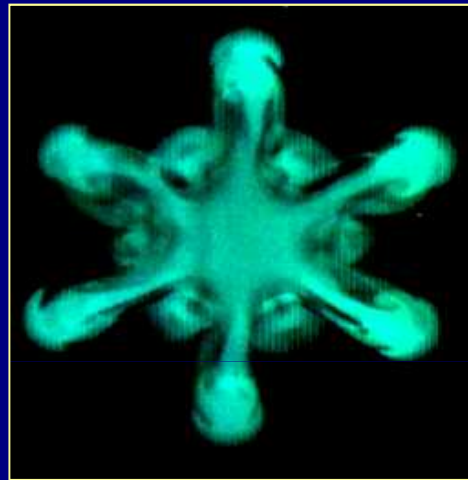




Contrôle passif des jets pour le traitement d'air du bâtiment - Diagnostic expérimental et optimisation numérique



Amina Meslem

Participants aux travaux de recherche: I. Nastase, M. El Hassan, C. Beghein, A. Dia

Journée thématique IBPSA - 3 mai 2011 La Rochelle

Remerciements: nos travaux bénéficient du soutien de l'ANR, La Région Poitou-Charentes, le FEDER, l'ADEME, OSEO, CIAT et ALSTOM

Plan de l'exposé



QUELS DIFFUSEURS D'AIR POUR LES BATIMENTS BBC ?

JETS LOBES DE BUSES

JETS LOBES D'ORIFICES

OPTIMISATION NUMERIQUE

CONCLUSIONS ET PERSPECTIVES

Quels diffuseurs d'air pour les bâtiments BBC?

Grenelle de l'Environnement
Réglementation Thermique 2012
Logements BBC: 50kWh/m²/an

À partir du 1^{er} Janvier 2013 tous
les permis de construire
devront respecter les normes BBC

Conséquence: baisse des puissances
et des débits à injecter dans les espaces de vie

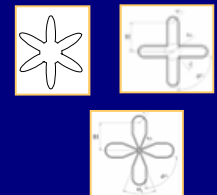
Besoin de mieux mélanger les jets de
traitement d'air à l'air ambiant

→ Contrôle actif : Excitation
acoustique ou mécanique

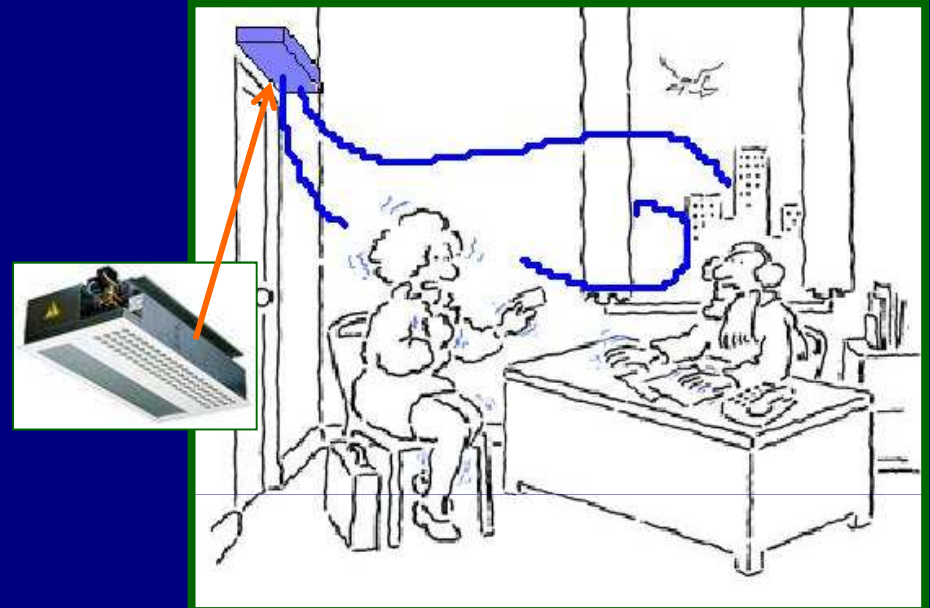


→ Contrôle passif, de mise en œuvre pratique et
moins coûteuse.

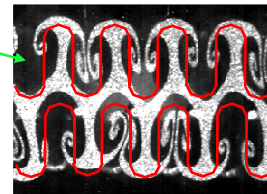
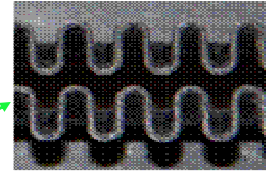
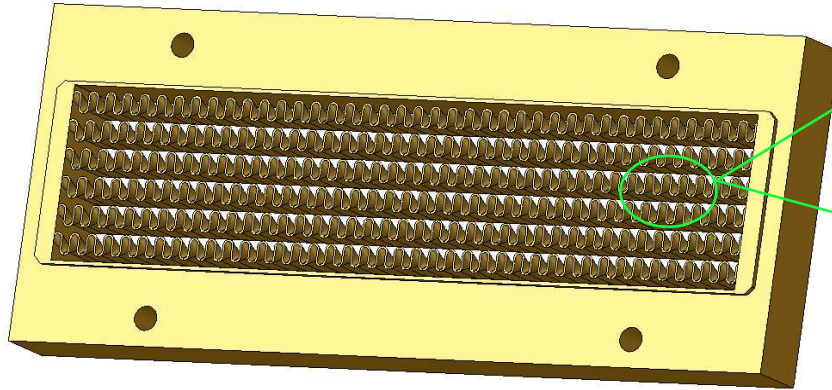
Soufflage par des diffuseurs lobés



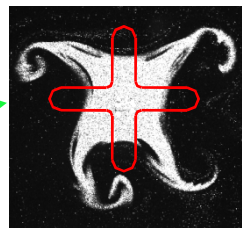
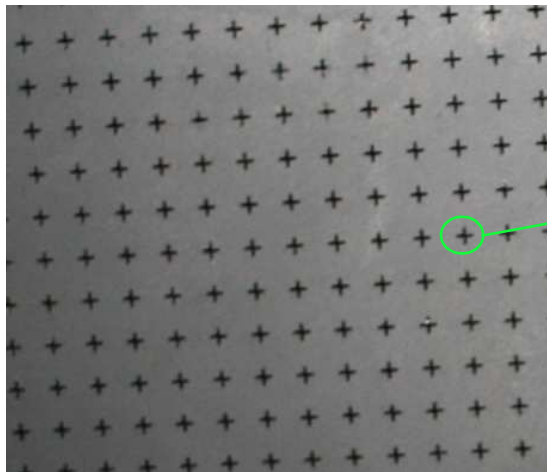
Adapter, caractériser, comprendre,
optimiser, intégrer puis optimiser



Quels diffuseurs d'air pour les bâtiments BBC?

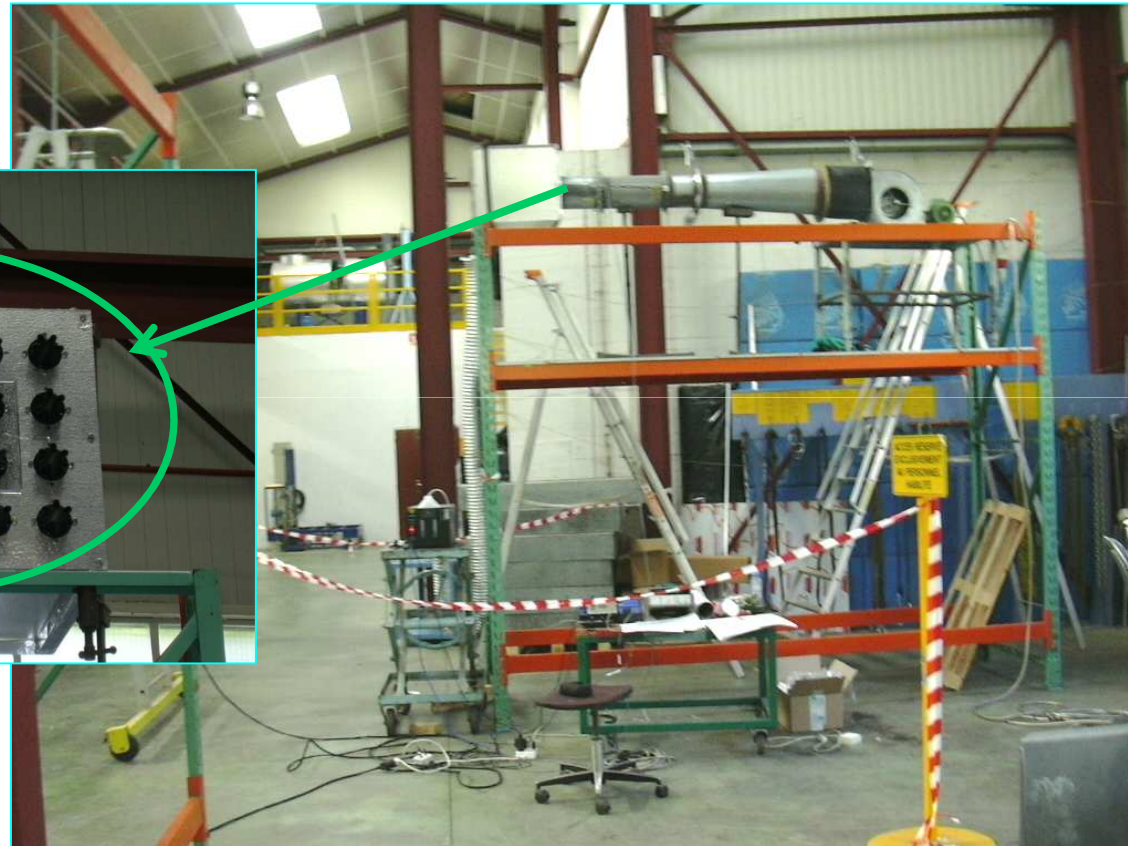
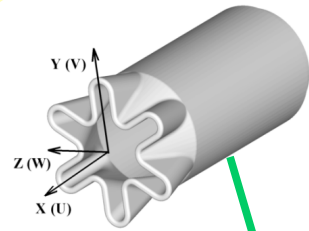


I. Nastase, A. Meslem ,
Iordache V., I. Colda, Lobed
grilles for high mixing
ventilation - An experimental
analysis in a full scale model
room, Building and
Environment, Volume 46,
Issue 3, March 2011, 547-
555



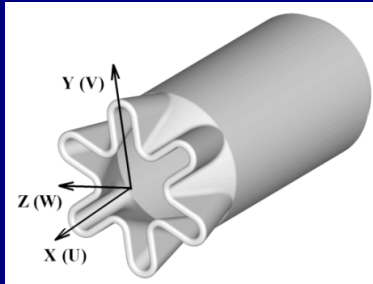
A. Meslem, I. Nastase, and
F. Allard, Passive mixing
control for innovative air
diffusion terminal devices for
buildings. Building and
Environment, Volume 45,
Issue 12, December 2010,
Pages 2679-2688

Quels diffuseurs d'air pour les bâtiments BBC?

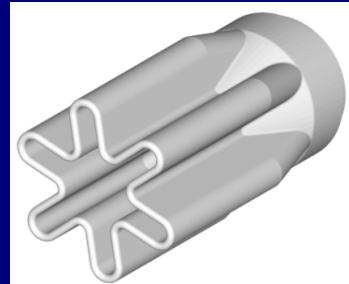


Jets lobés de buses

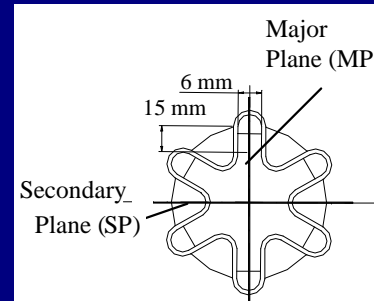
Analyse par LDV, Fil chaud et Tomographie rapide



Buse lobée 1
14/22



Buse lobée 2
0/0



Plan de soufflage

Nastase and Meslem 2010
Experiments in Fluids

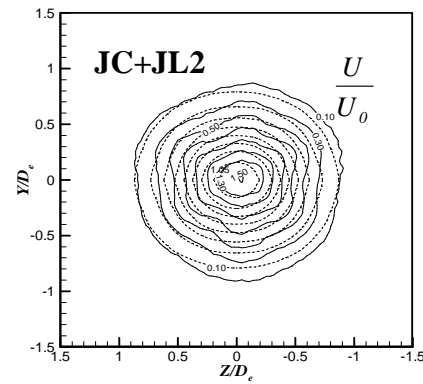
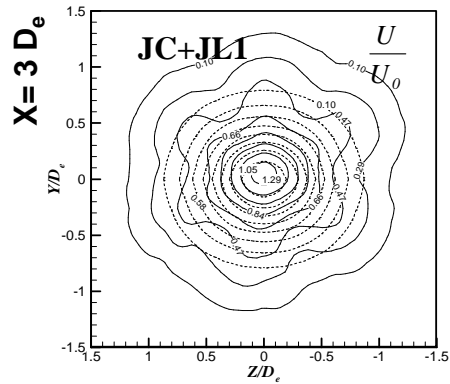
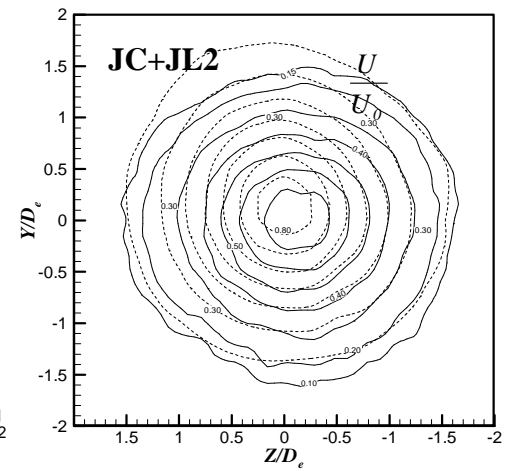
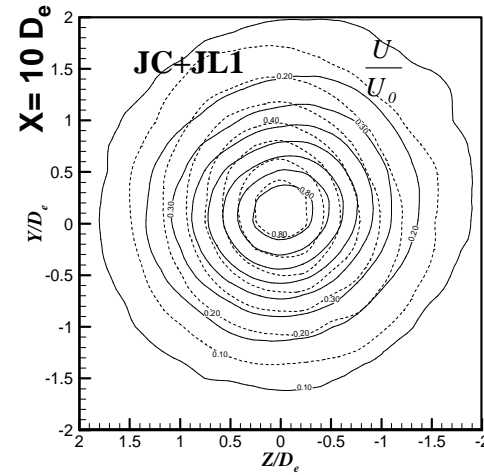
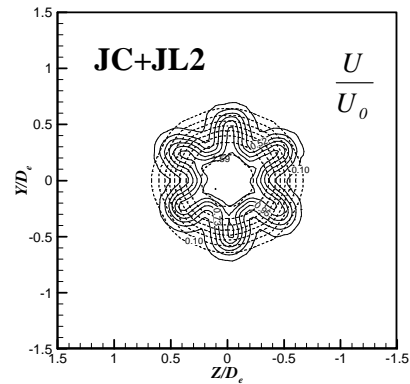
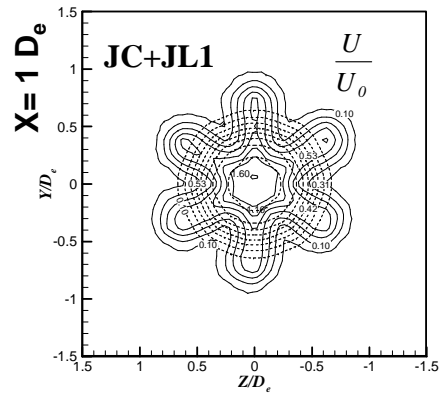
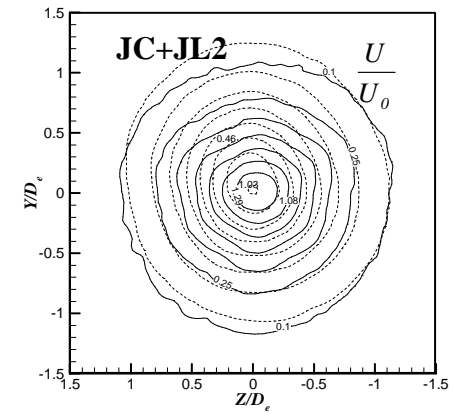
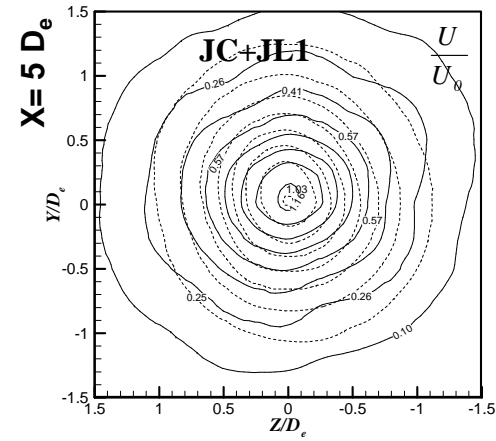
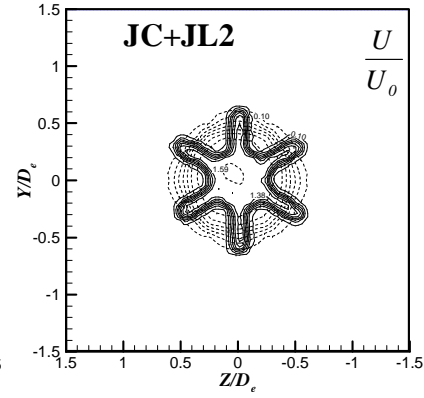
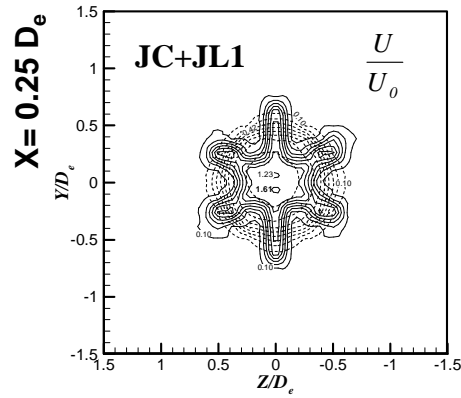
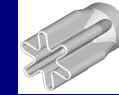
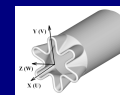
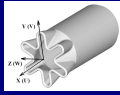
1^{ère} Campagne d'essais

Nozzle geometry	Q_0 (m ³ /s)	U_0 (m/s)	Re_0	U_{0c} (m/s)	θ_0 (mm)			f_n (Hz)		St_θ		$H=\delta^*/\theta_0$	
					MP	SP	lobe	MP	SP	SP	lobe	MP	SP
6-lobe 1	$4.70 \cdot 10^{-3}$	3.74	9 520	5.89	3.95	0.71	0.58	343	470	0.057	0.0195	2.66	3.14
6-lobe 2	$4.75 \cdot 10^{-3}$	3.78	9 600	5.82	1.43	1.38	0.31	168	224	0.053	0.0166	2.75	2.85
Circular	$4.82 \cdot 10^{-3}$	3.84	9 785	4.88	2.04			~70		~0.026		2.73	

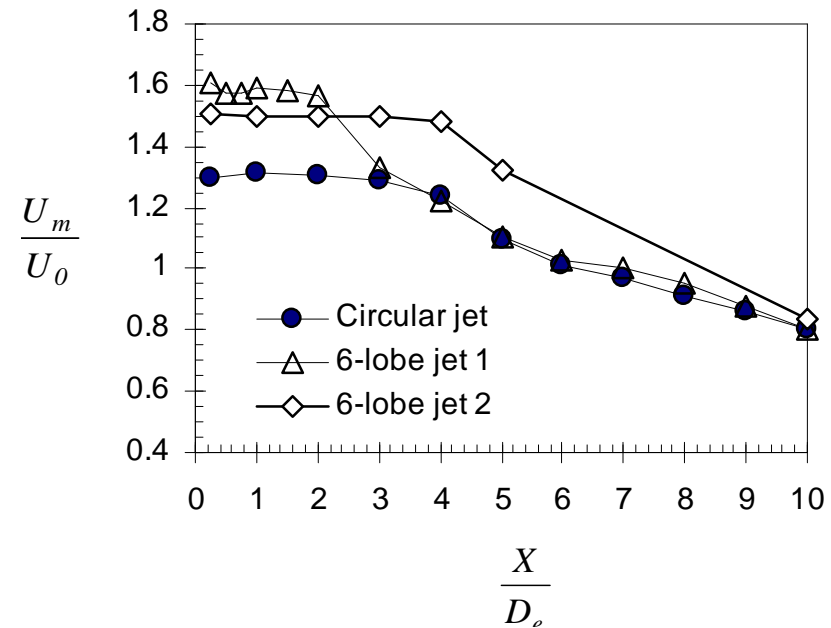
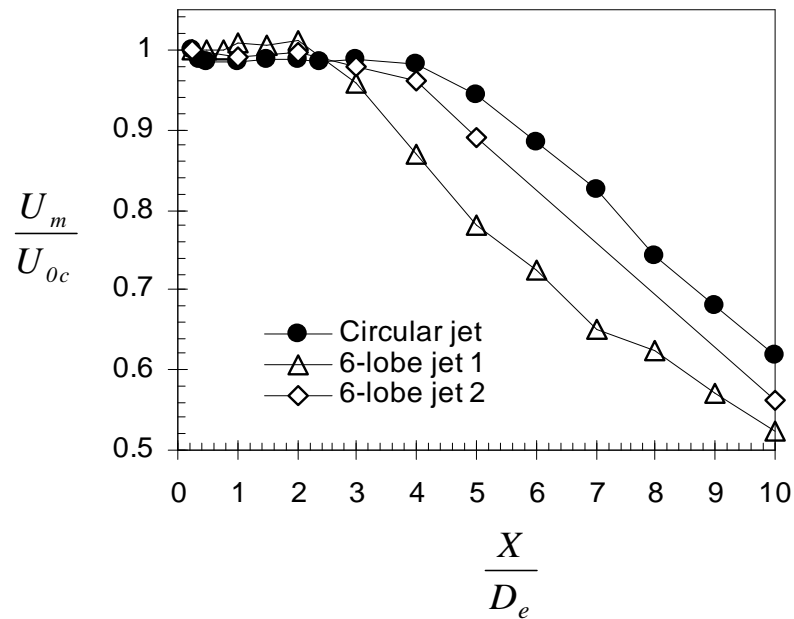
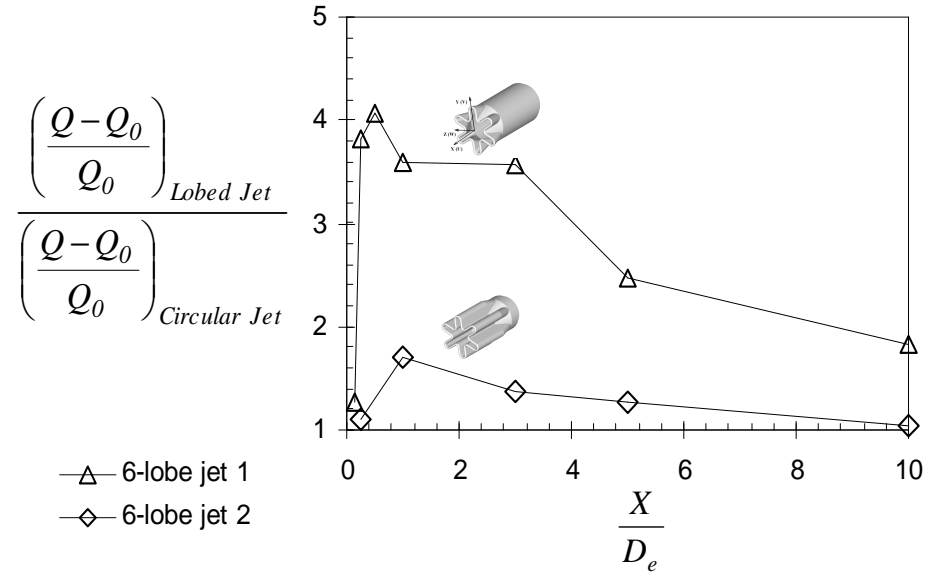
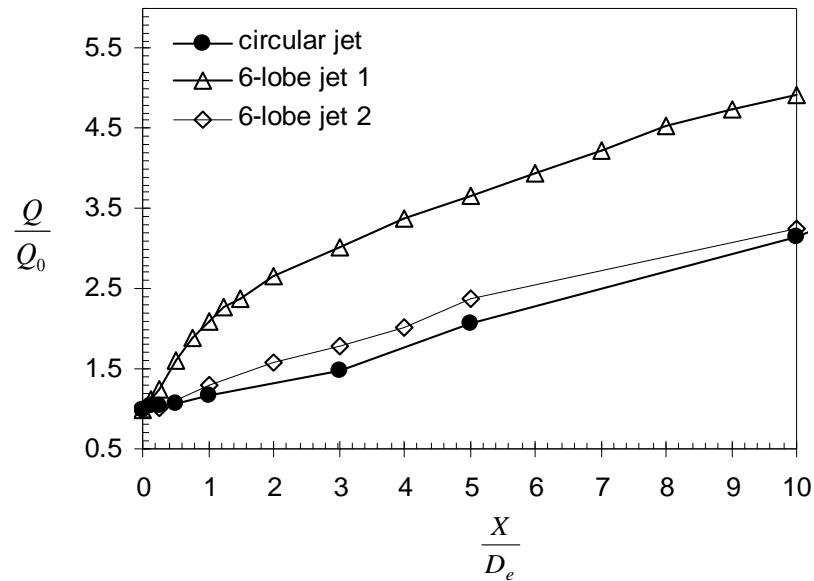
2^{ème} Campagne d'essais

Nozzle geometry	U_0 (m/s)	Re_0	U_{0c} (m/s)	θ_0 (mm)			f_n (Hz)		St_θ		$H=\delta^*/\theta_0$	
				MP	SP	lobe	MP	SP	SP	lobe	MP	SP
6-lobe 1	0.89	2267	1.59	1.54	0.39	0.67	83	112	0.0285	0.0178	2.62	2.84
6-lobe 2	0.96	2455	1.52	0.54	0.46	0.32	40	50	0.0153	0.0172	2.83	3.51
Circular	1.04	2655	1.32	0.94			24		0.0172		2.93	

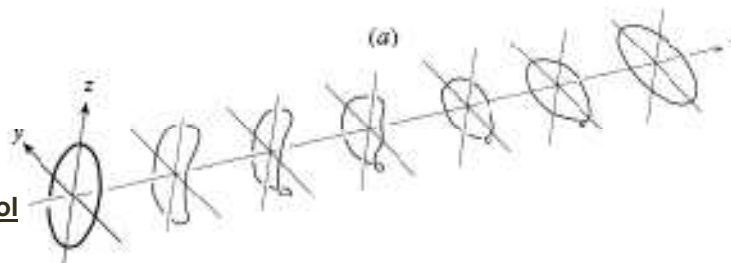
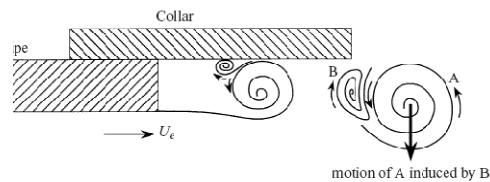
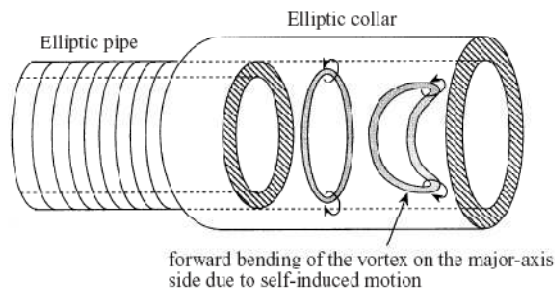
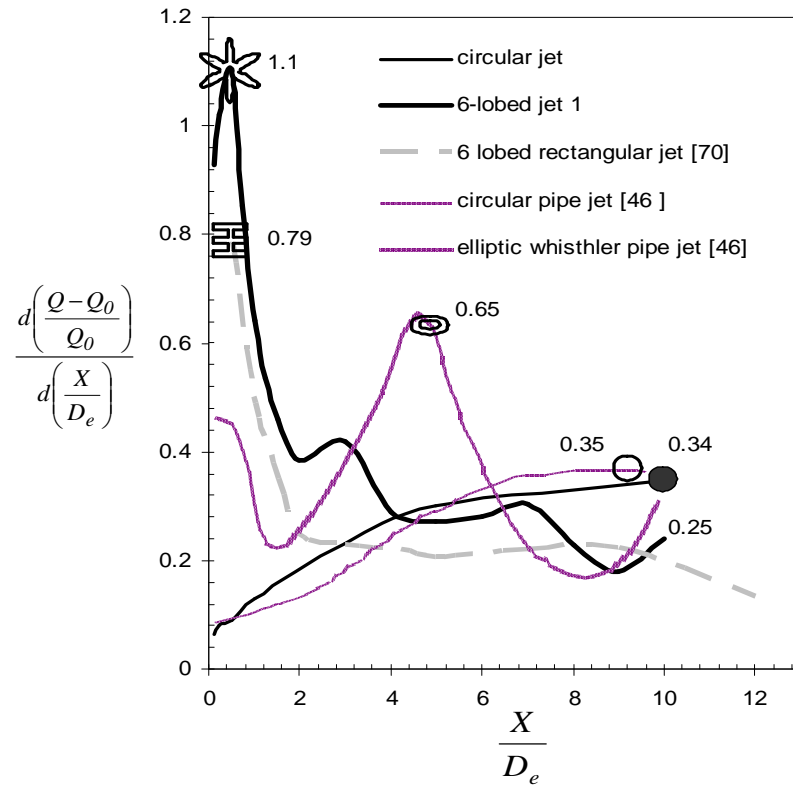
Jets lobés de buses



Jets lobés de buses

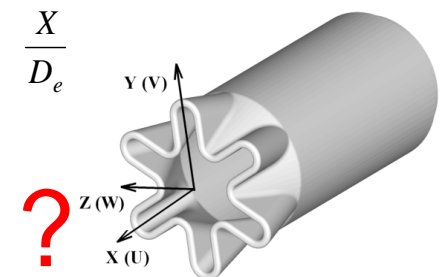
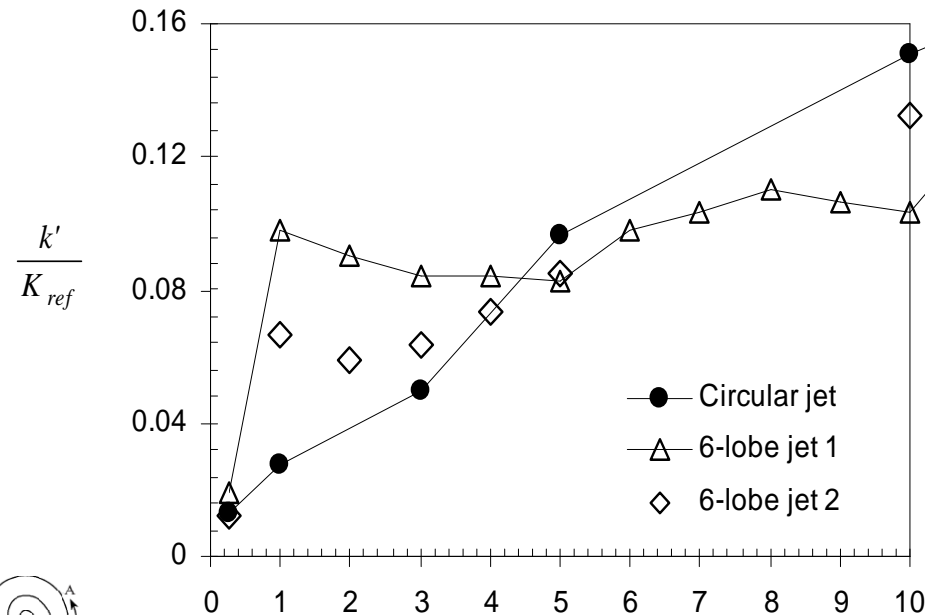


Jets lobés de buses



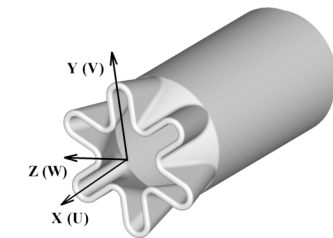
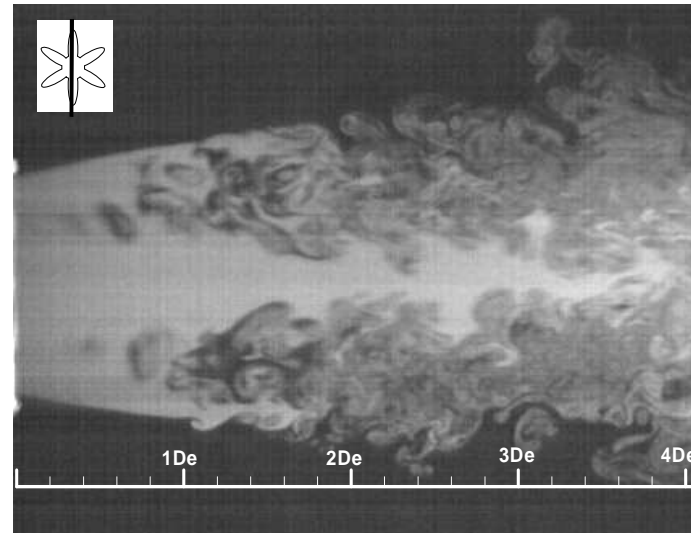
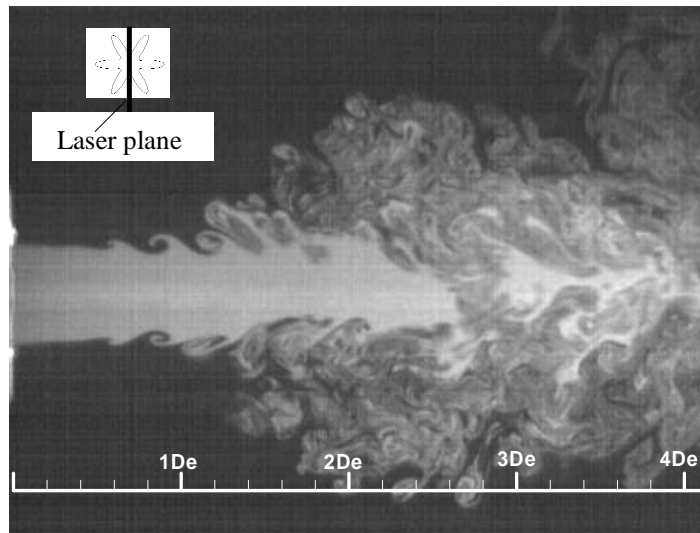
[46] Husain, H.S. and A.K.M.F. Hussain, *The elliptic whistler jet*. Journal of Fluid Mechanics, 1999. **397**: p. 23-44.

[70] Zaman, K.B.M.Q., F.Y. Wang, and N.J. Georgiadis, *Noise, Turbulence and Thrust of Subsonic Free Jets from Lobed Nozzles*. AIAA Journal, 2003. **41**(3)

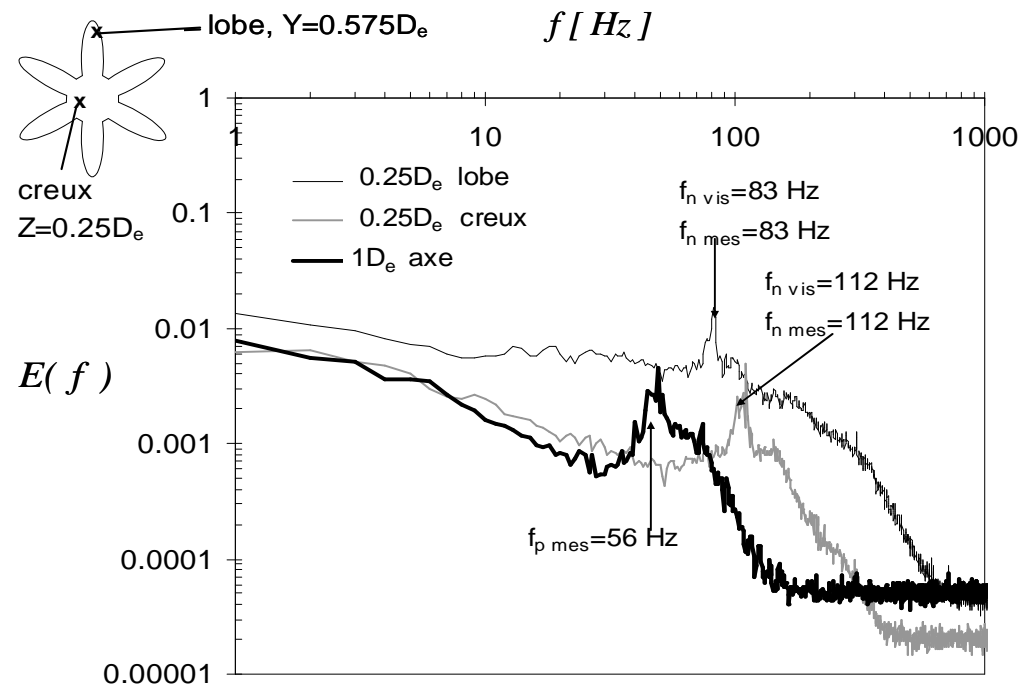
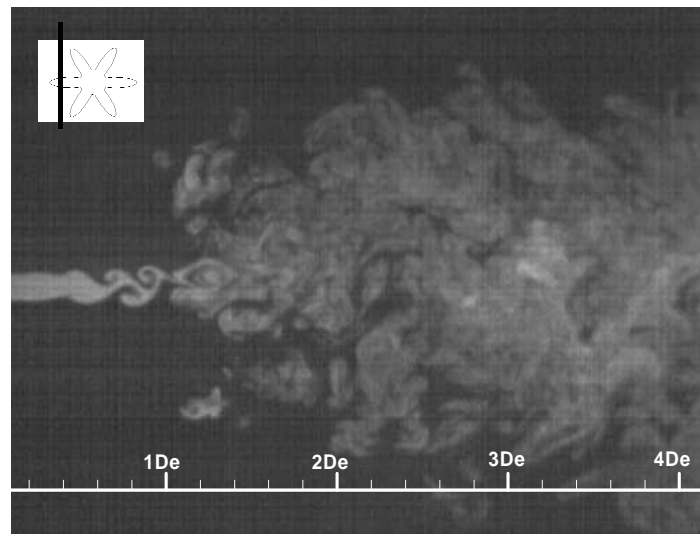


Tube elliptique petit rapport de forme sans col

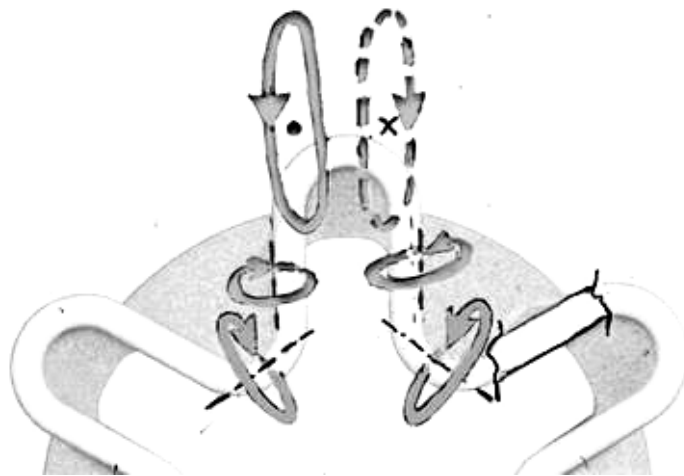
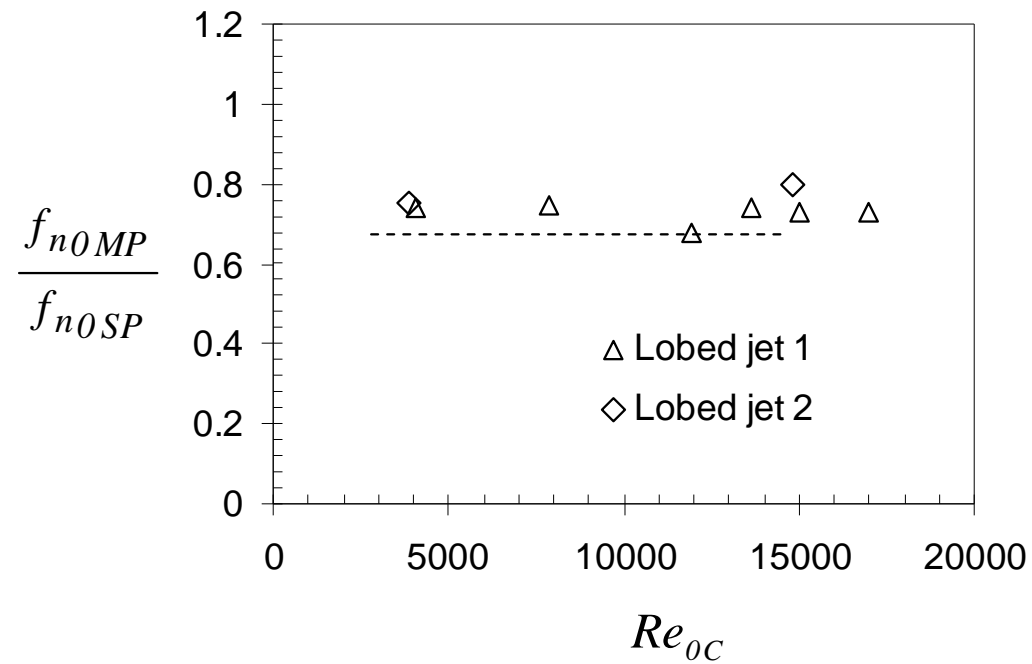
Jets lobés de buses



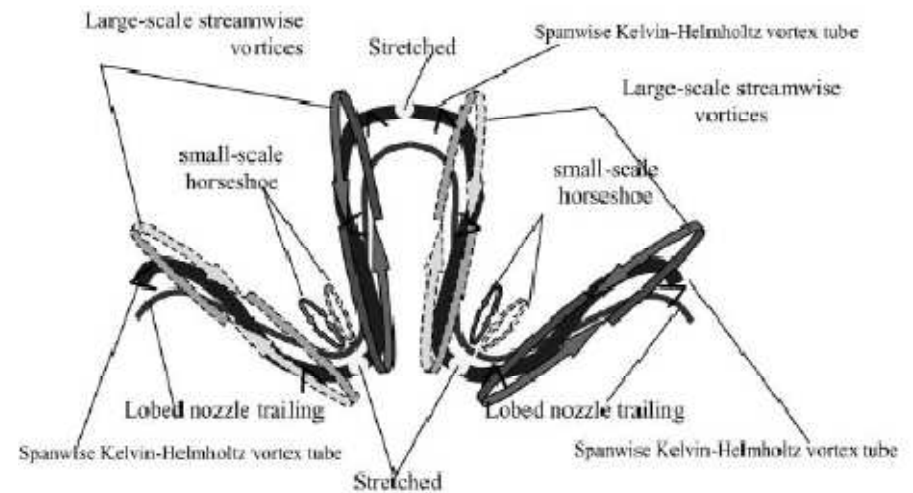
$$f_{n0 MP} / f_{n0 SP} = 0.74$$



Jets lobés de buses

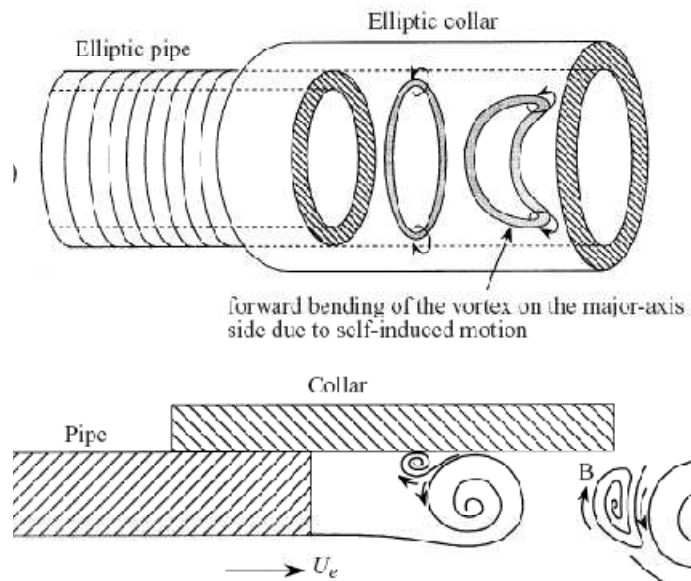


Nastase and Meslem (2010), Experiments in Fluids

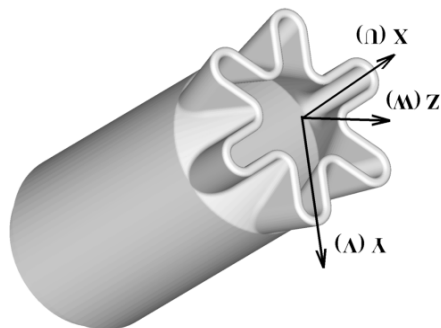


Hu et al. (2000), Experiments in Fluids

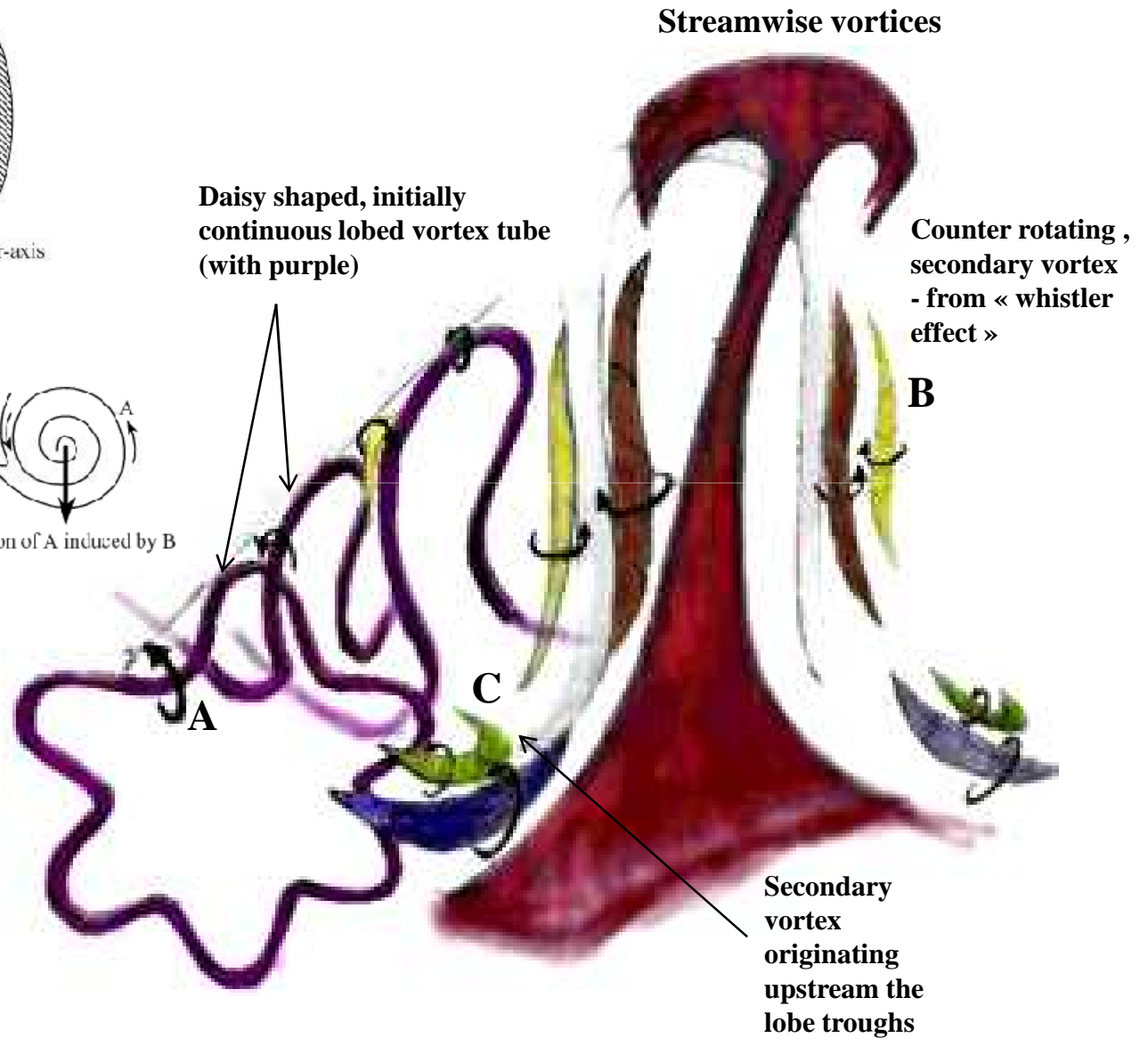
Jets lobés de buses



Husain and Hussain (1999)
Journal of Fluid Mechanics



Daisy shaped, initially continuous lobed vortex tube (with purple)

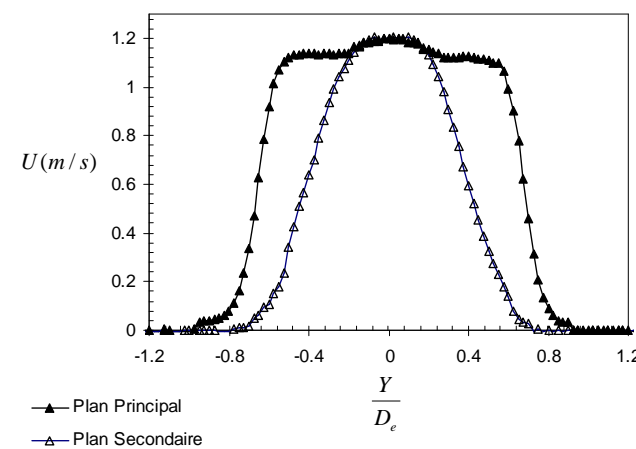
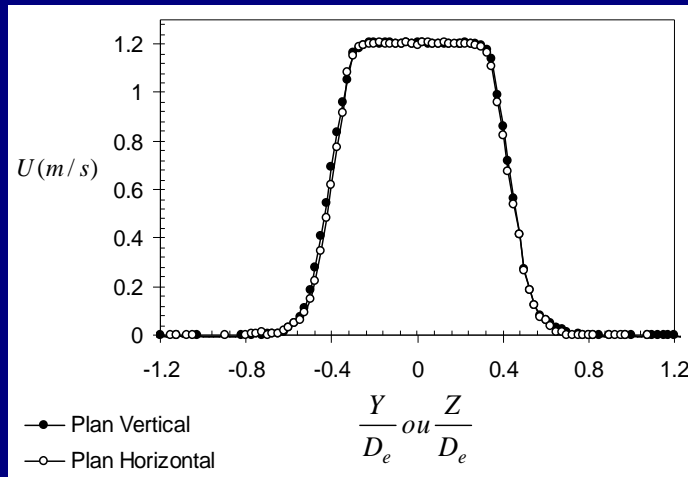
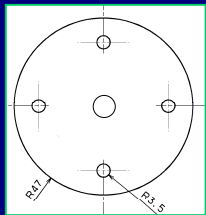


Nastase and Meslem (2010) Experiments in Fluids

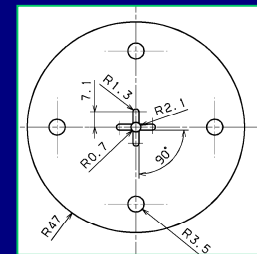
Jets lobés d'orifices

Analyse par PIV classique et par Tomographie rapide

Orifice circulaire



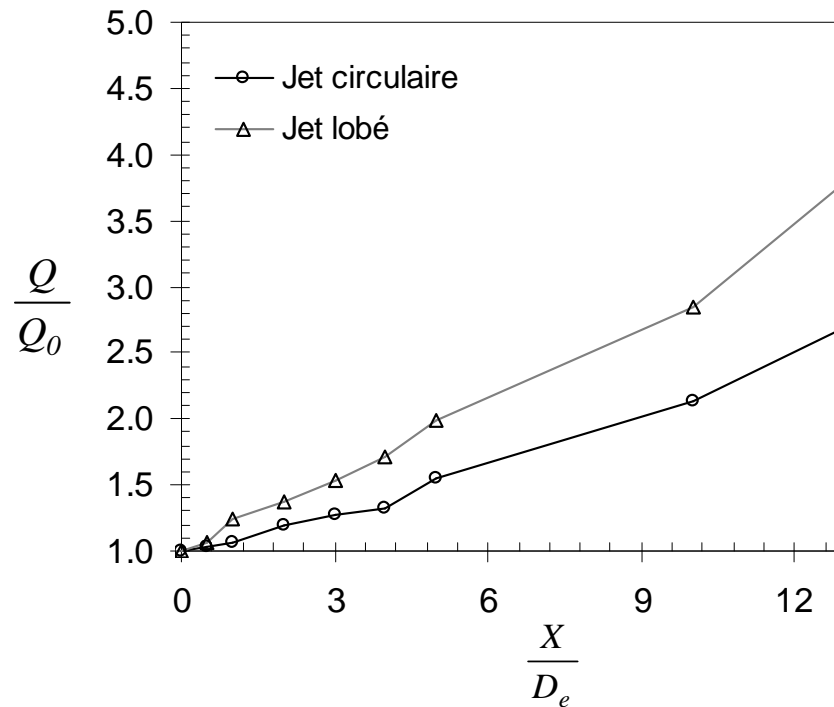
Orifice croix



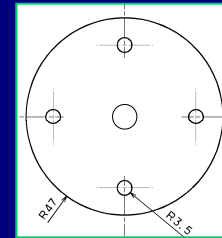
Orifice	$Q_0 (m^3/s)$	$U_0 (m/s)$	$U_{0C} (m/s)$	Re_{0m}	Re_0	$V_{0max} (m/s)$ <i>PP PS</i>	$\sqrt{u'^2}_{0C} (m/s)$	$\sqrt{v'^2}_{0C} (m/s)$	$\theta_0 (mm)$ <i>PP PS</i>
Circulaire	$7.87 \cdot 10^{-05}$	1.00	1.22	813	668	0.05	0.01	0.01	0.37
Croix	$7.26 \cdot 10^{-05}$	0.92	1.22	813	610	0.24 0.21	0.02	0.01	0.99 1.56

Jets lobés d'orifices

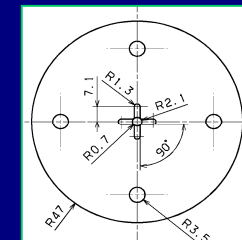
Débit volumique et débit entraîné



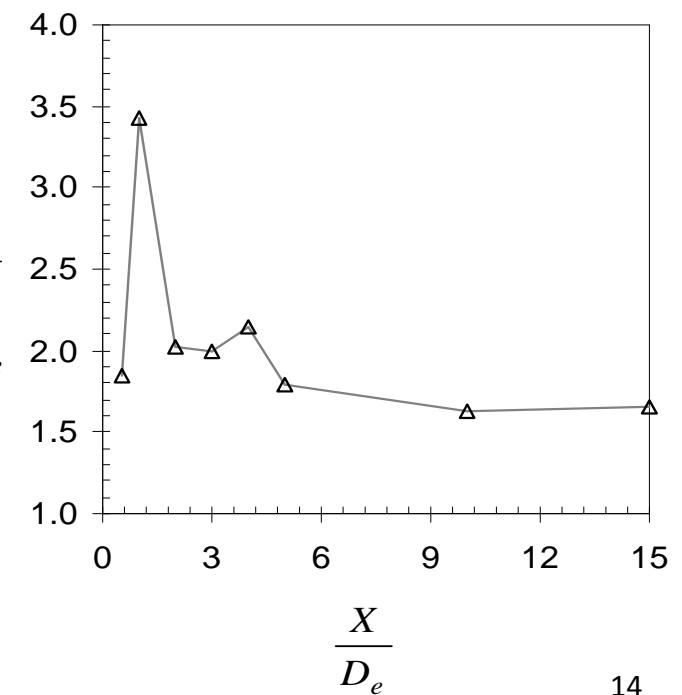
Orifice circulaire



Orifice croix



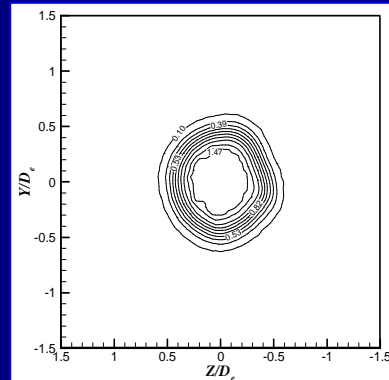
$$\frac{\left(\frac{Q-Q_0}{Q_0}\right)_{lobé}}{\left(\frac{Q-Q_0}{Q_0}\right)_{circulaire}}$$



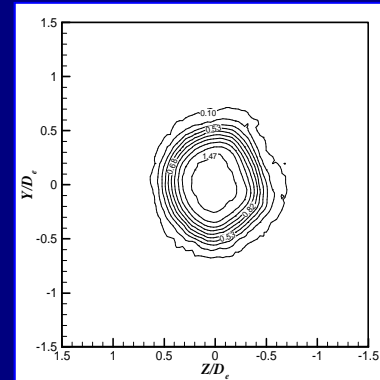
Jets lobés d'orifices

JET CIRCULAIRE

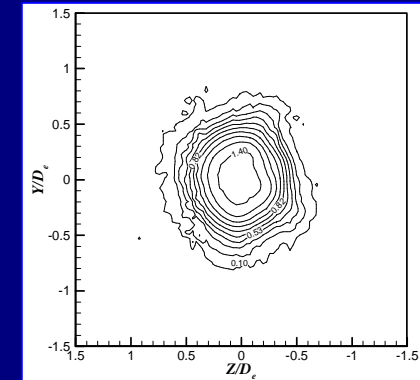
Isocontours de la vitesse
longitudinale normalisée
 U/U_0



$X=1D_e$

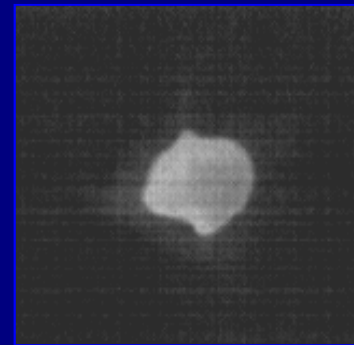
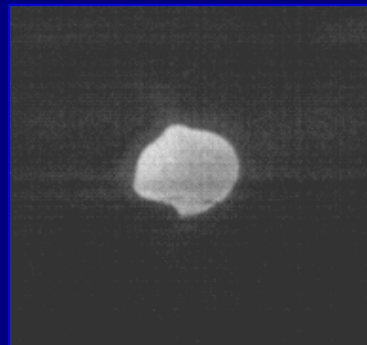


$X=2D_e$

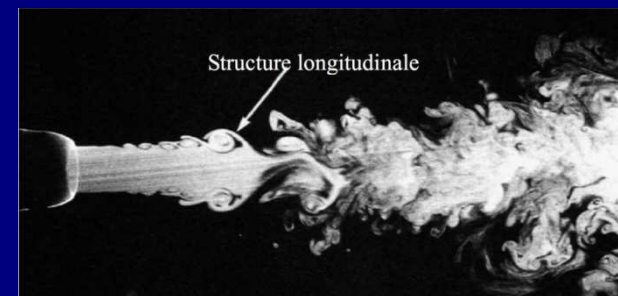


$X=3D_e$

Visualisation par
tomographie rapide

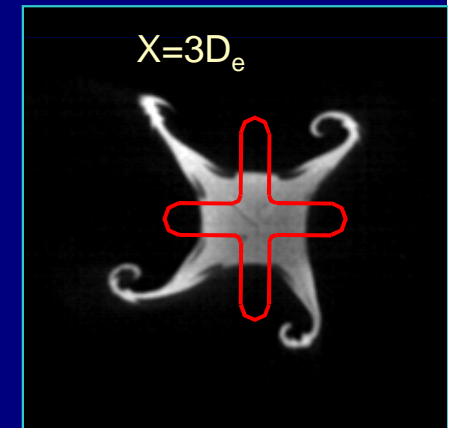
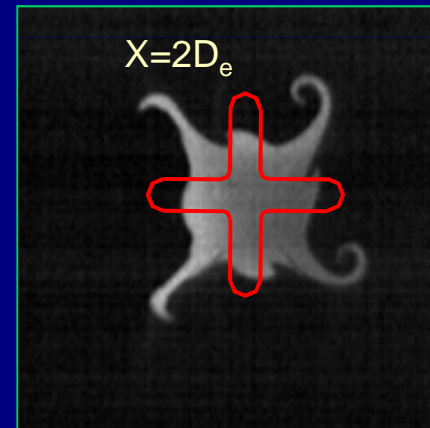
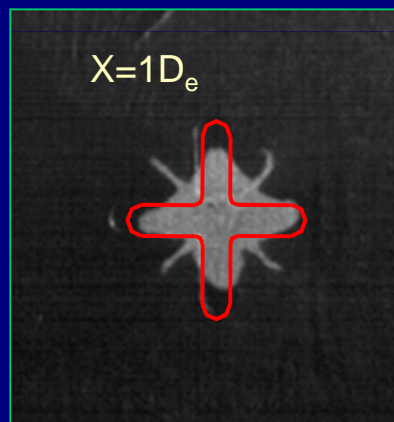
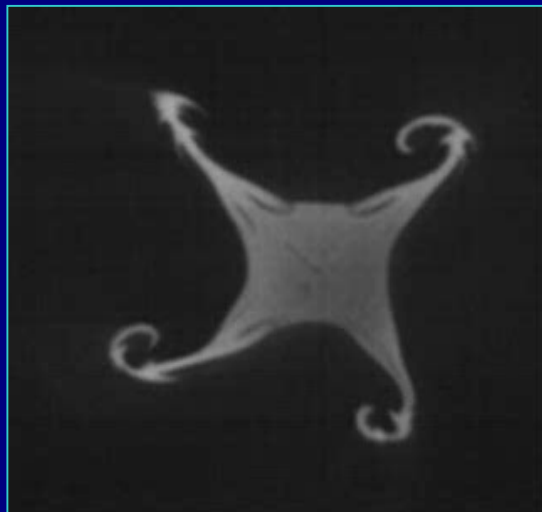
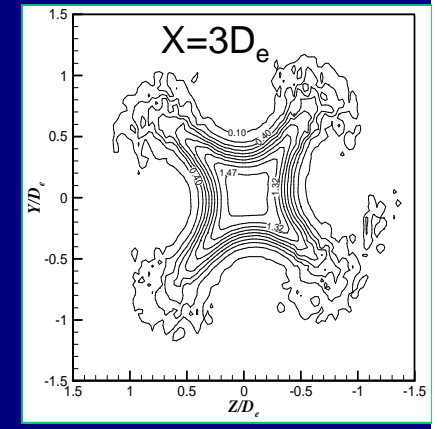
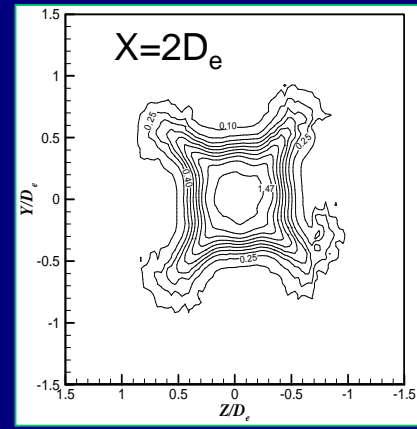
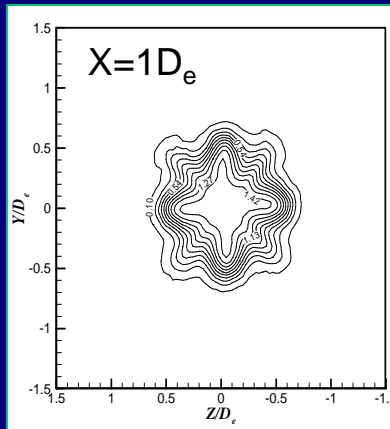
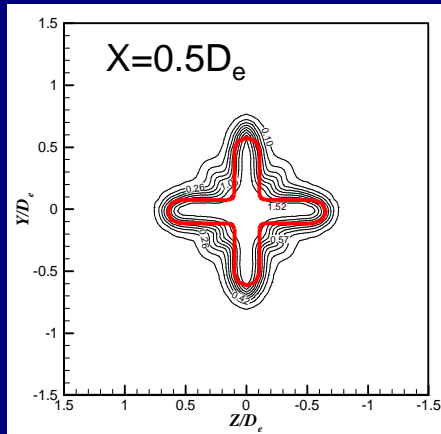


(Liepmann & Gharib, 1992)

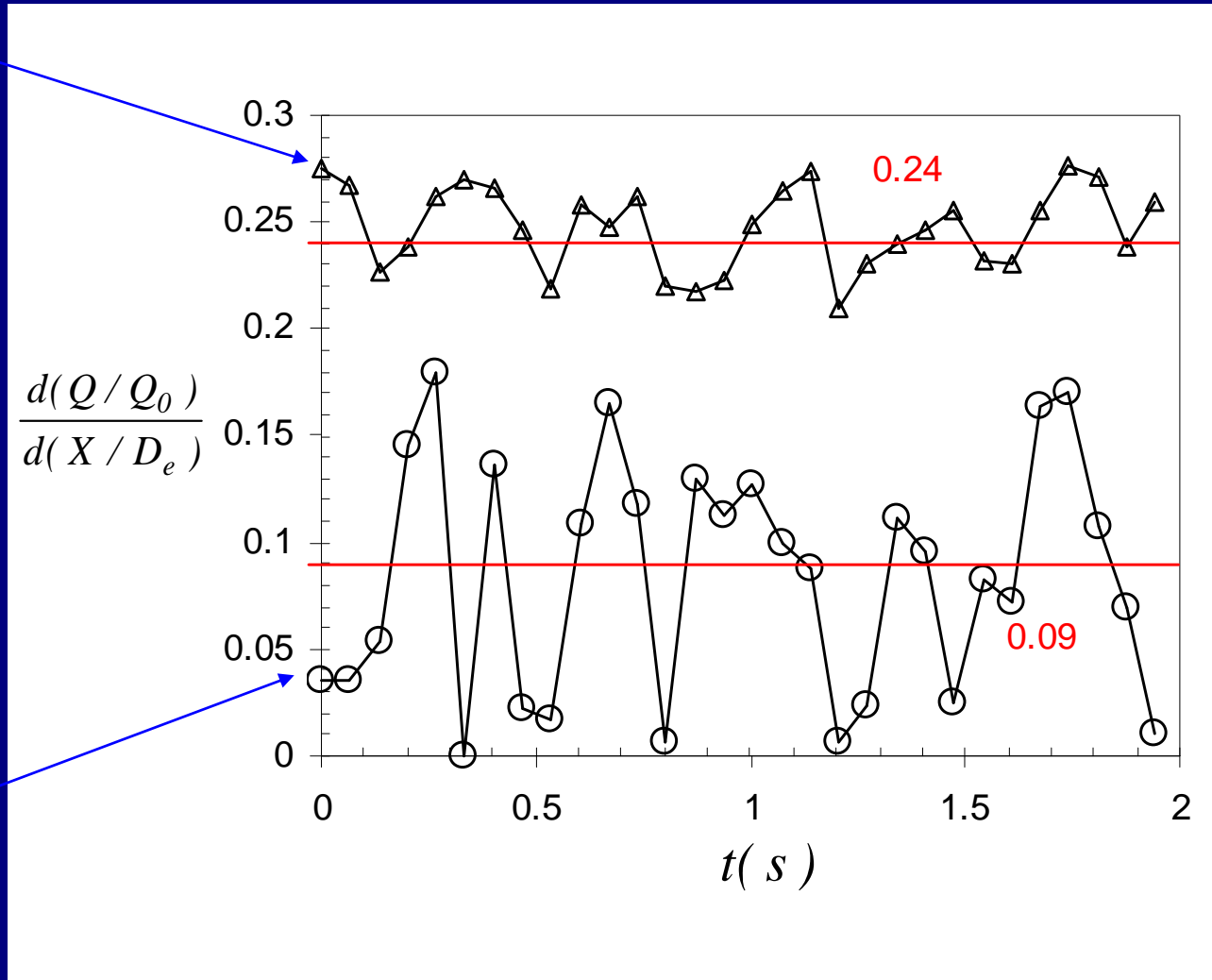
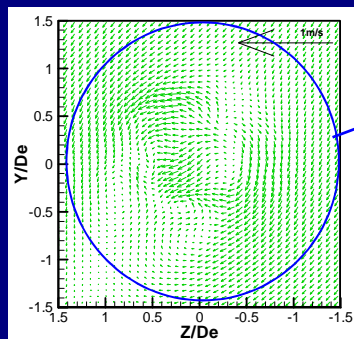
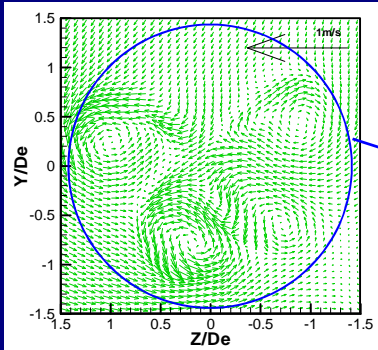


Jets lobés d'orifices

JET CROIX

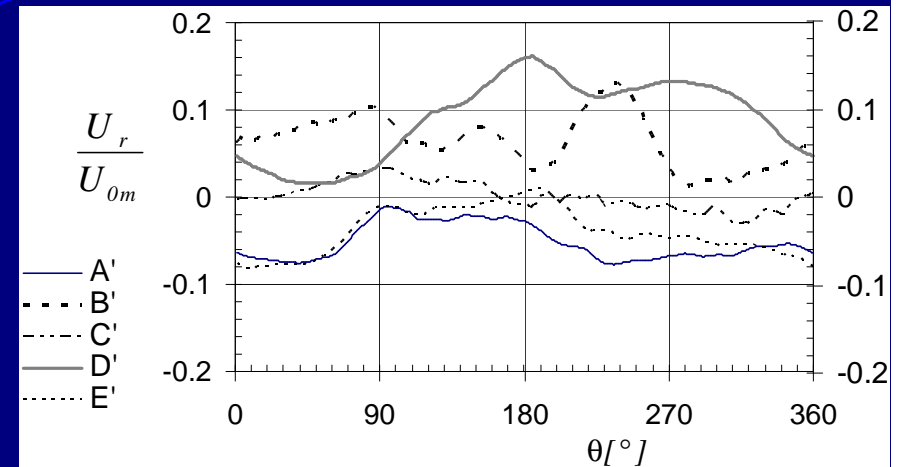
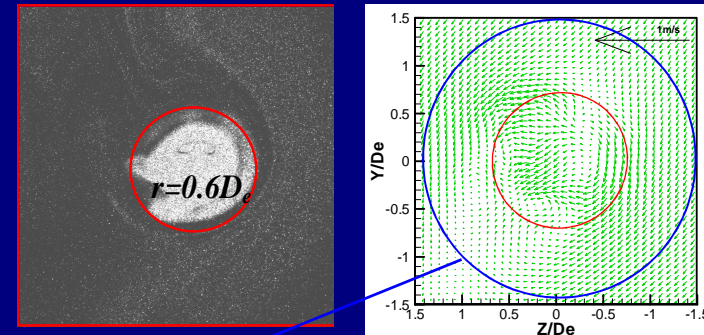
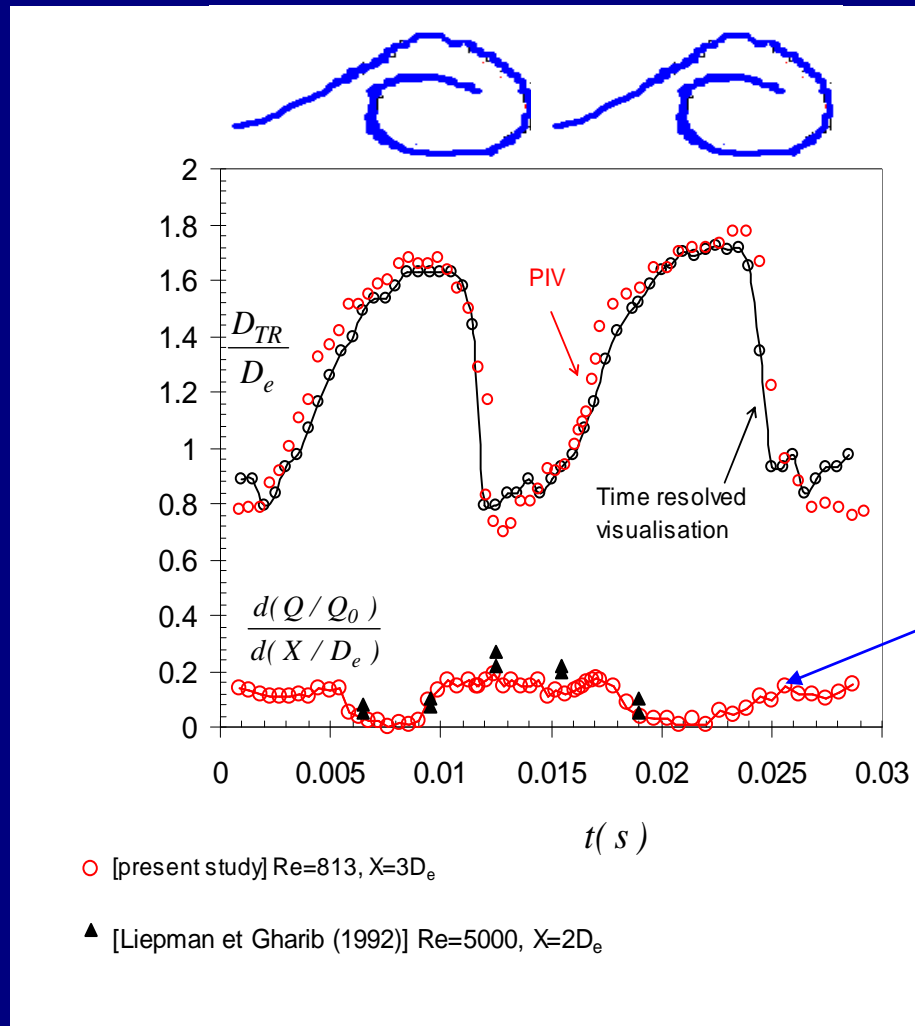


Jets lobés d'orifices



Jets lobés d'orifices

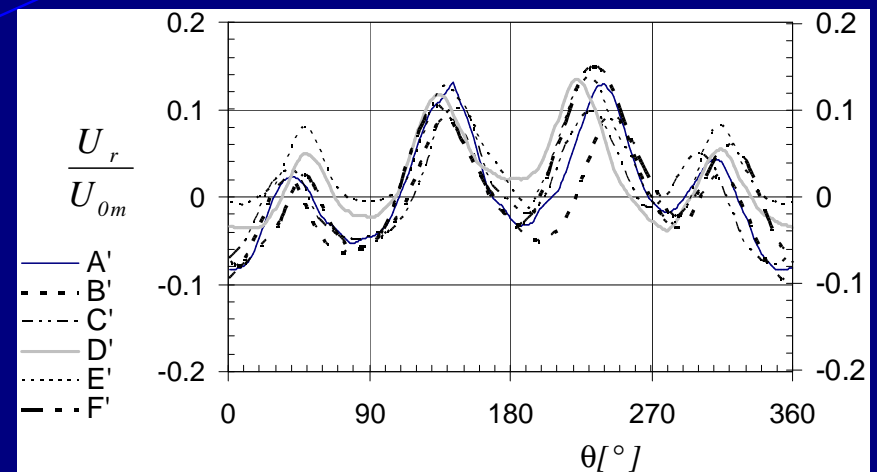
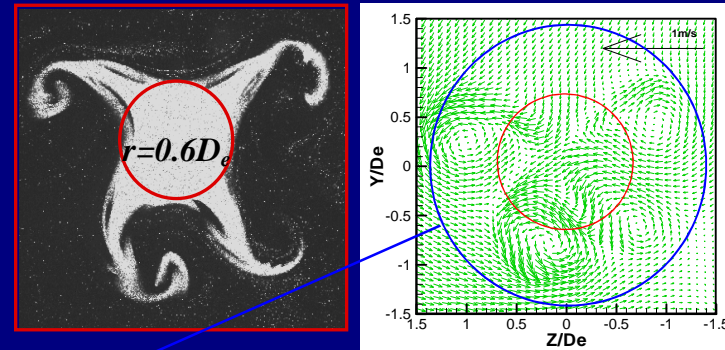
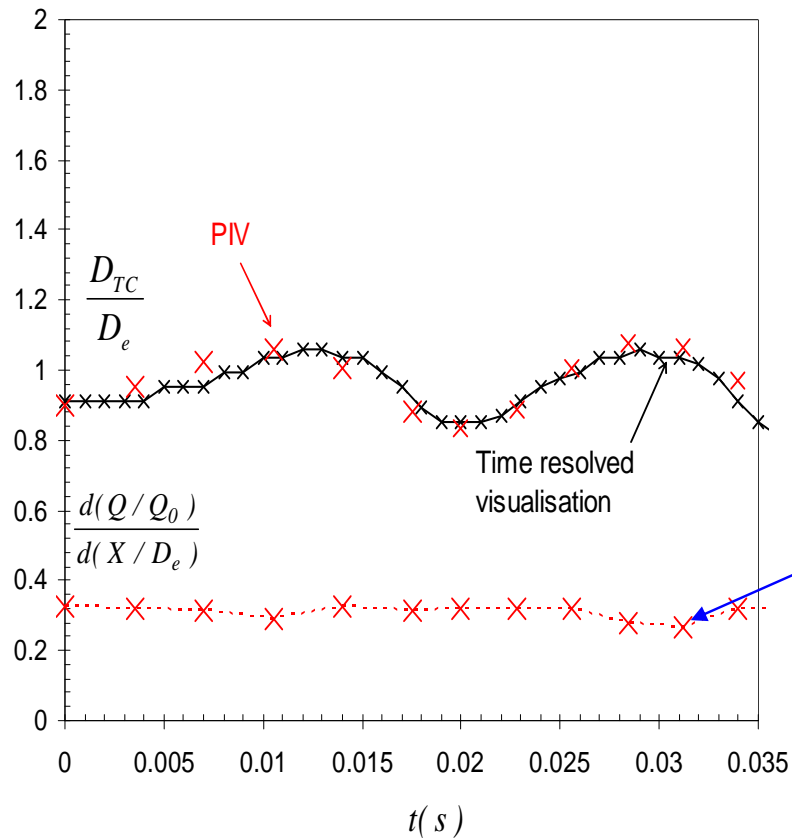
Orifice circulaire



Nastase, Meslem et al. (2008), Exp. in Fluids (44) 6 : 1027-1033

Jets lobés d'orifices

Orifice lobé croix



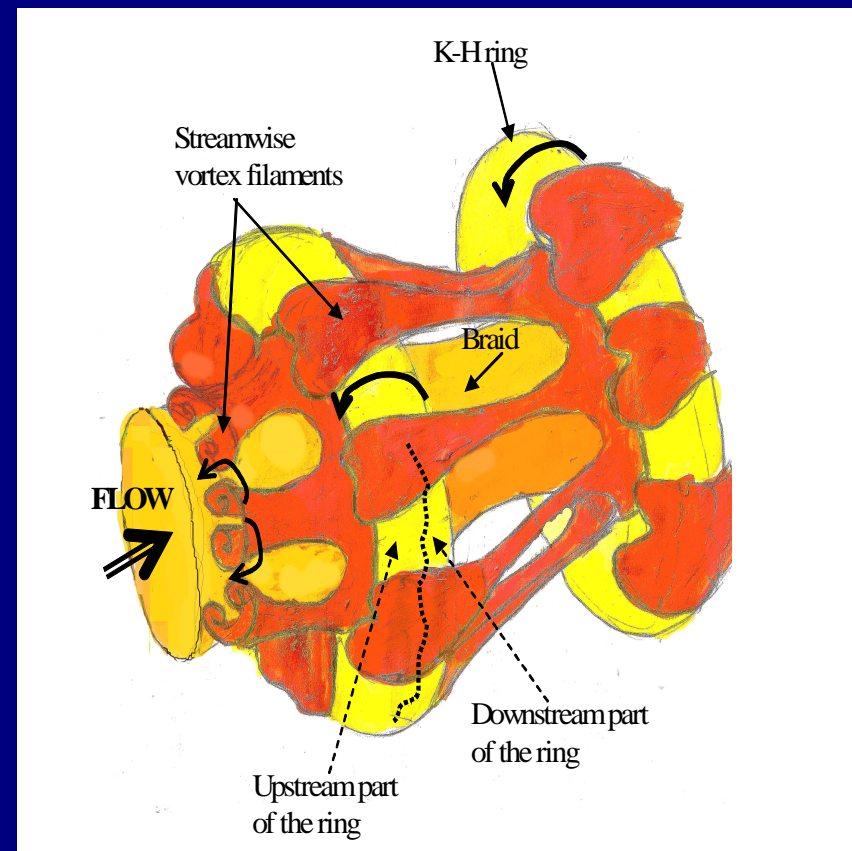
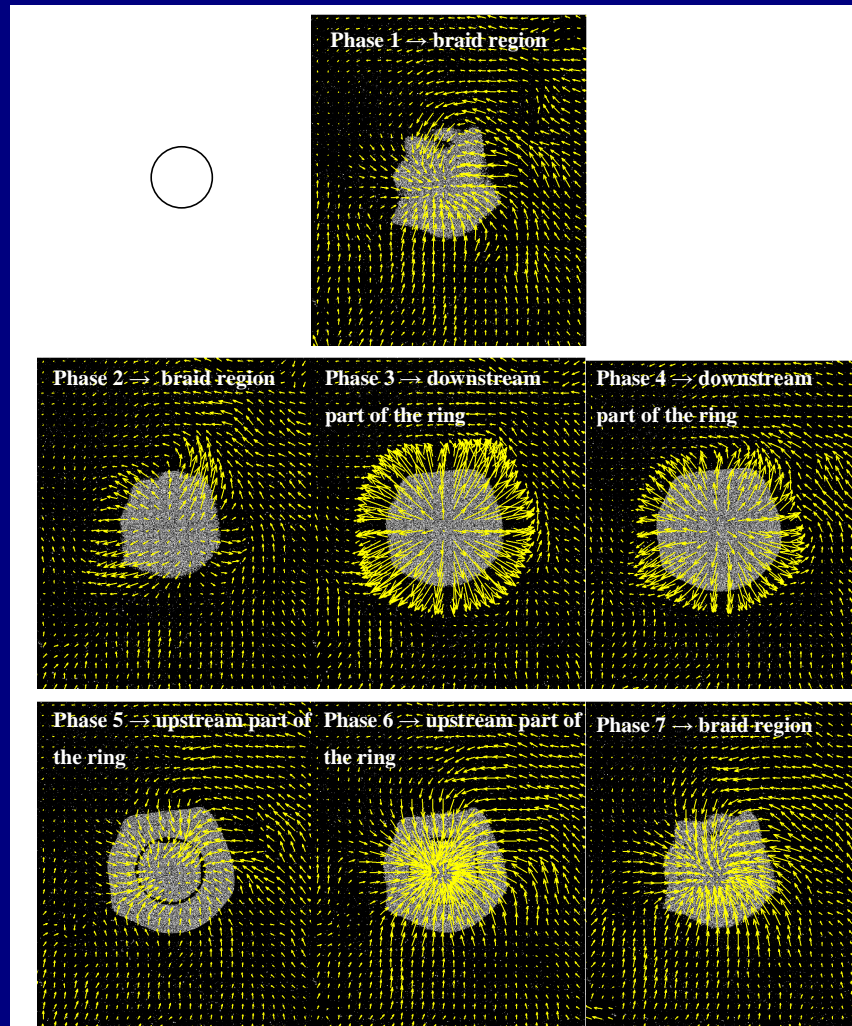
Nastase, Meslem et al. (2008), Exp. in Fluids (44) 6 : 1027-1033

Jets lobés d'orifices

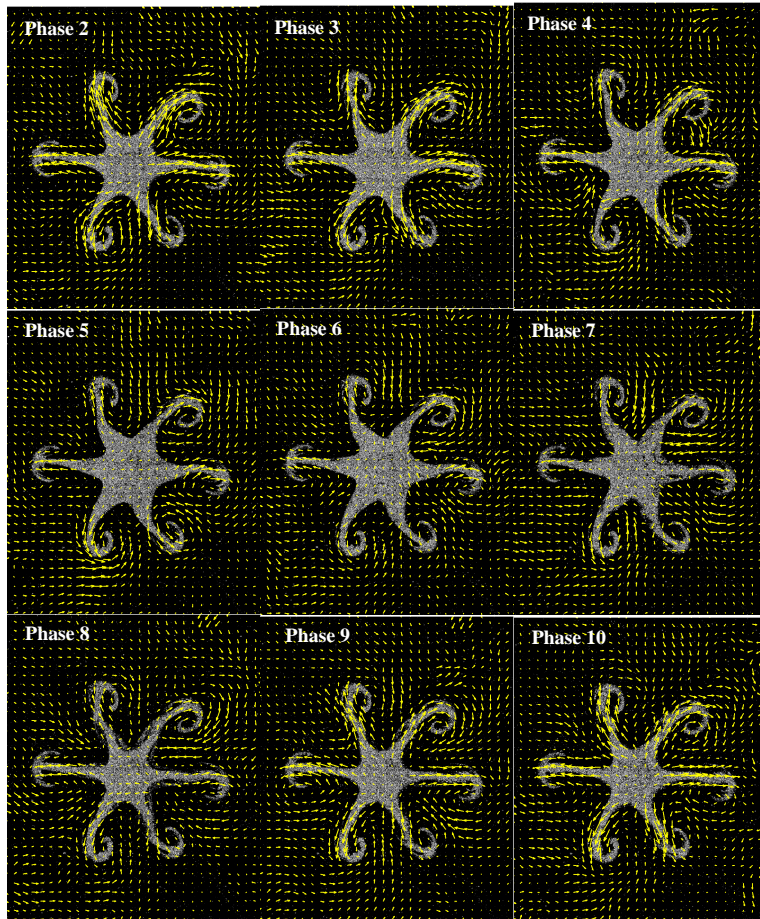
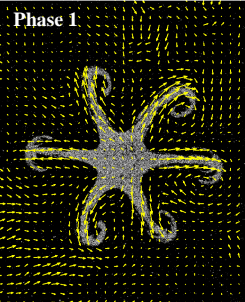
Poursuite de l'analyse par PIV rapide

- Meslem et al. Journal of Visualization (2010)
- EL Hassan and Meslem, Phys. of Fluids (2010)

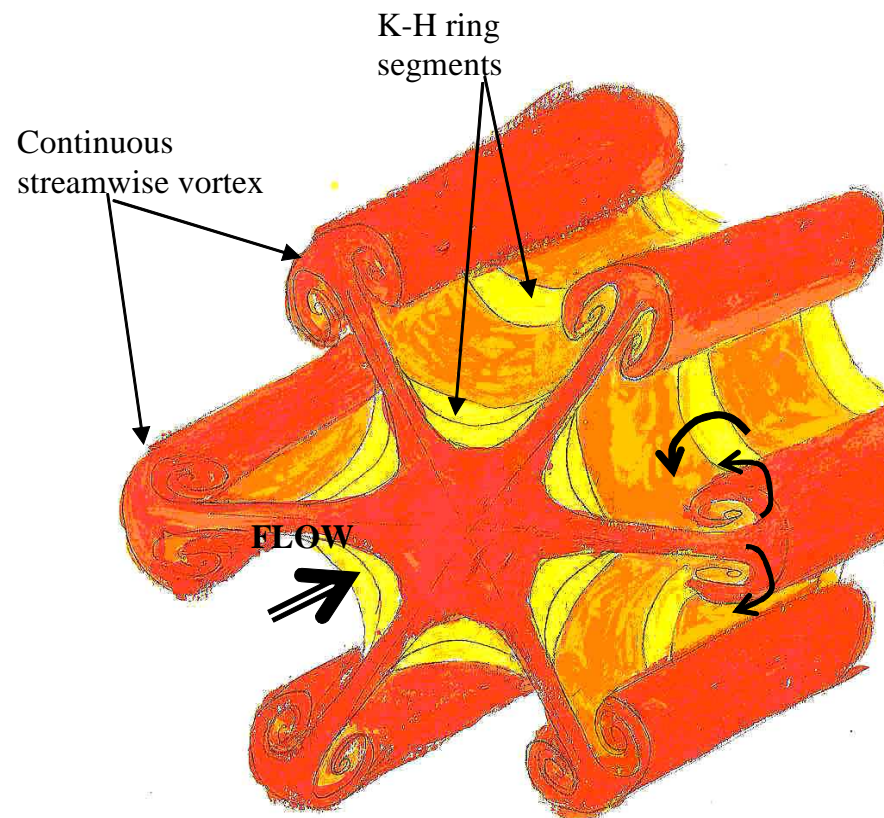
Circular jet at $X=3De$ – Chronological sequence of fields from high-speed PIV measurements, $dt=2ms$

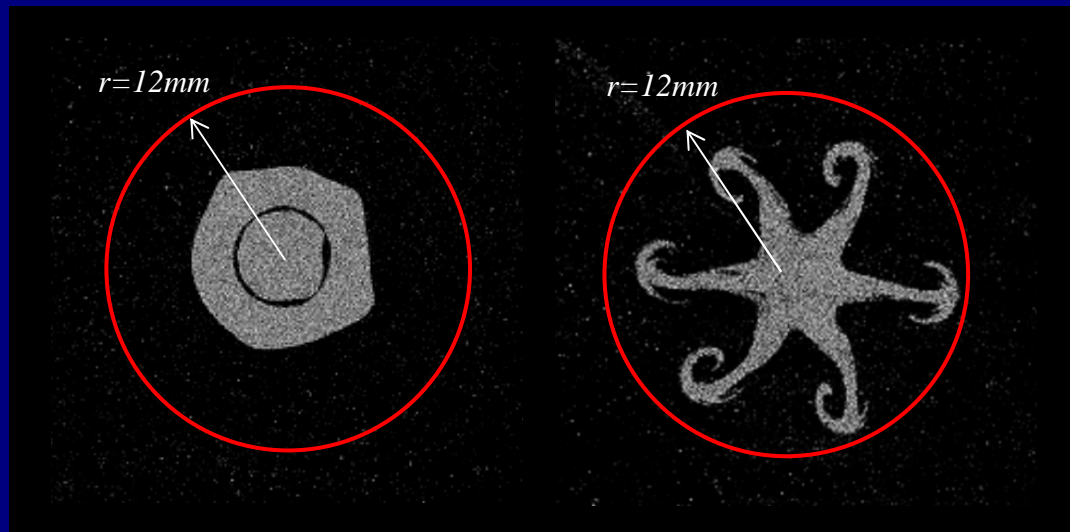


Analyse des jets lobés d'orifices



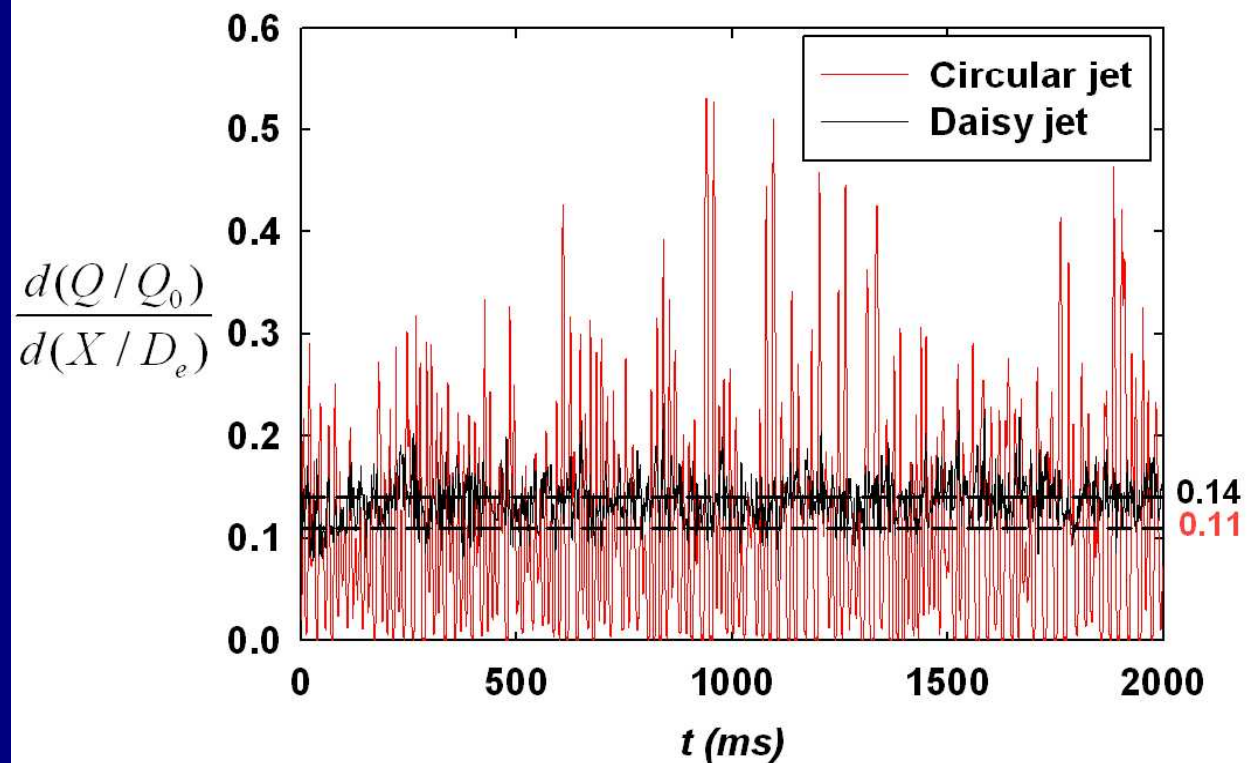
Daisy shaped jet at $X=3De$ – Chronological sequence of fields from high-speed PIV measurements, $dt=2ms$

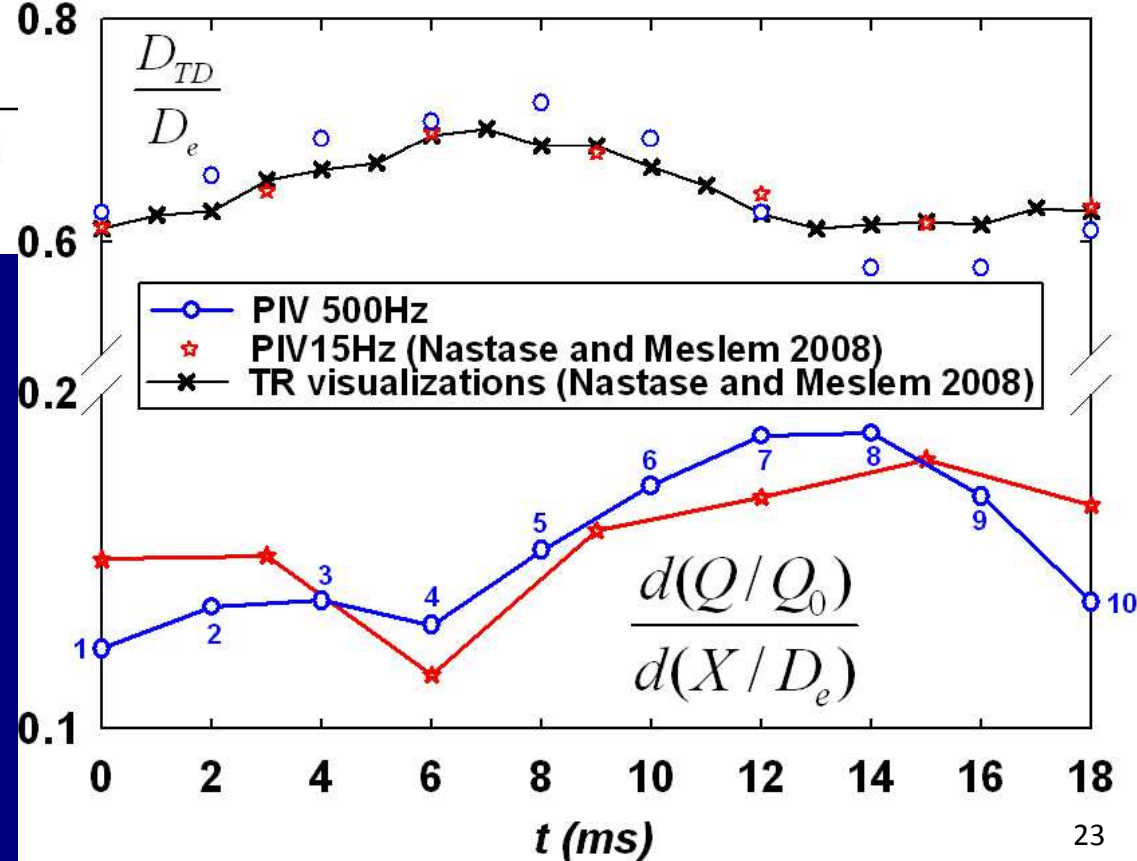
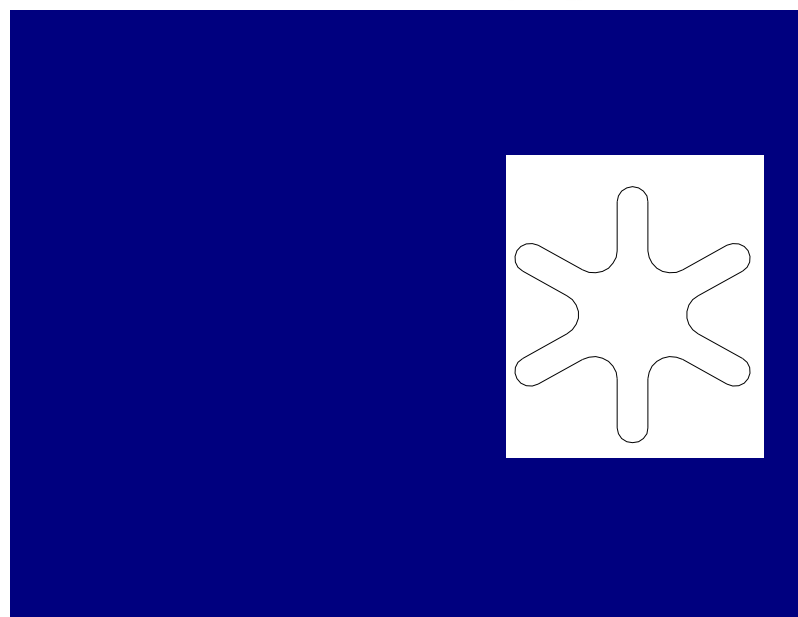
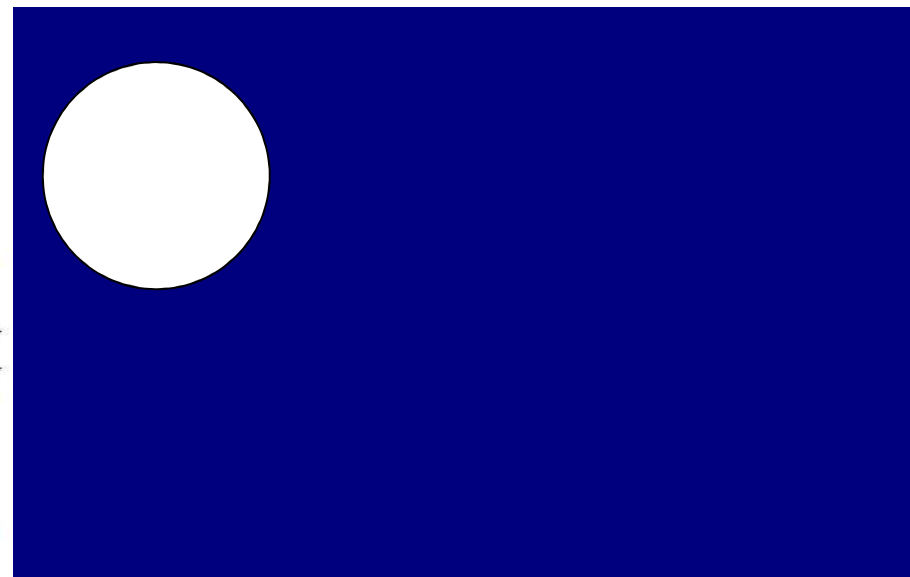
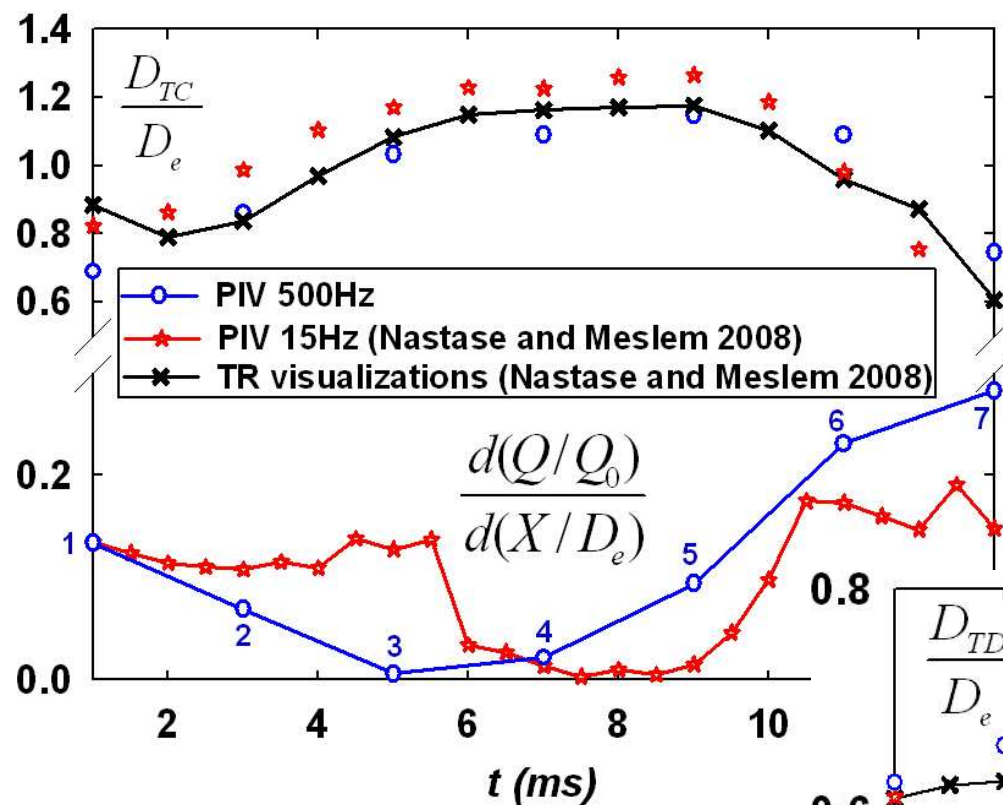




TR PIV images at $X=3D_e$ with a circle indicating the radial velocity integration position: a) Circular jet, b) Daisy jet

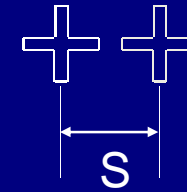
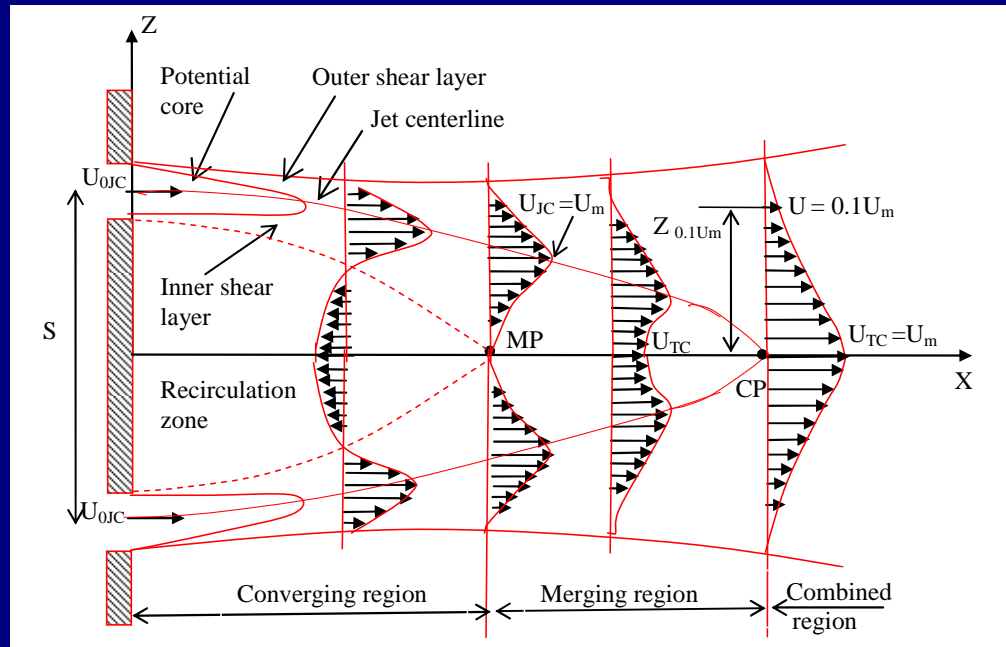
Instantaneous entrainment rate variation at $X=3D_e$ from TR PIV measurements



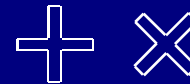


Optimisation numérique

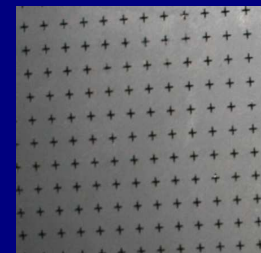
- Optimisation de la géométrie de l'orifice élémentaire : nombres de lobes, longueur et largeur de lobes, angles d'inclinaison...
- Optimisation de l'espacement entre deux orifices



- Optimisation de la disposition des orifices

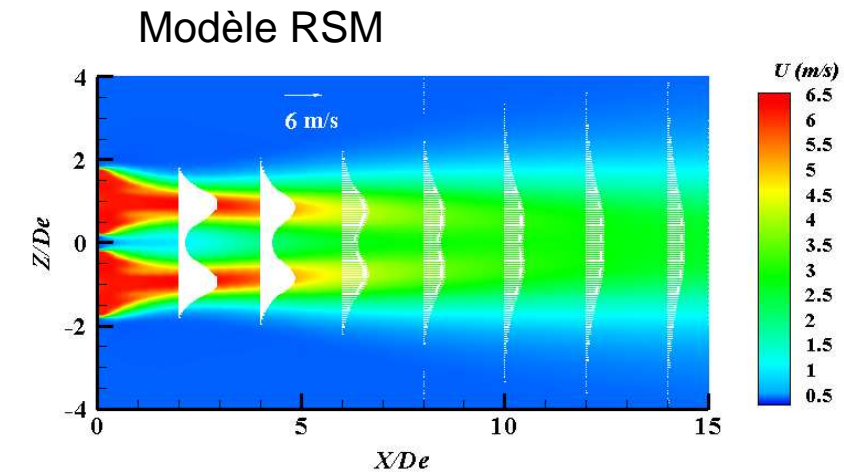
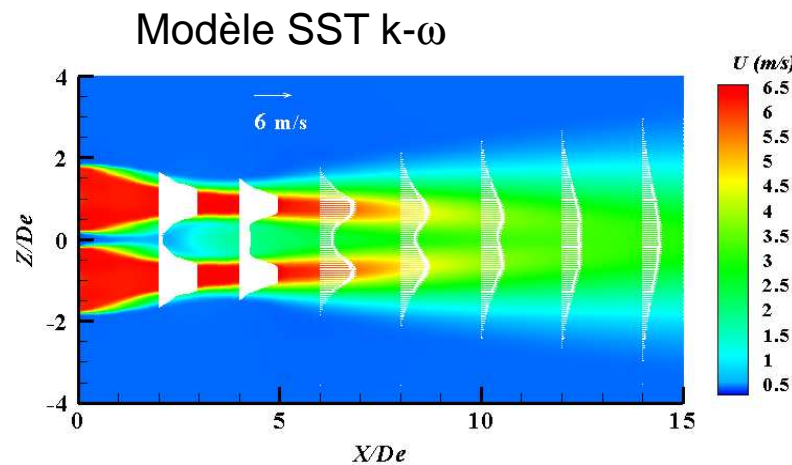
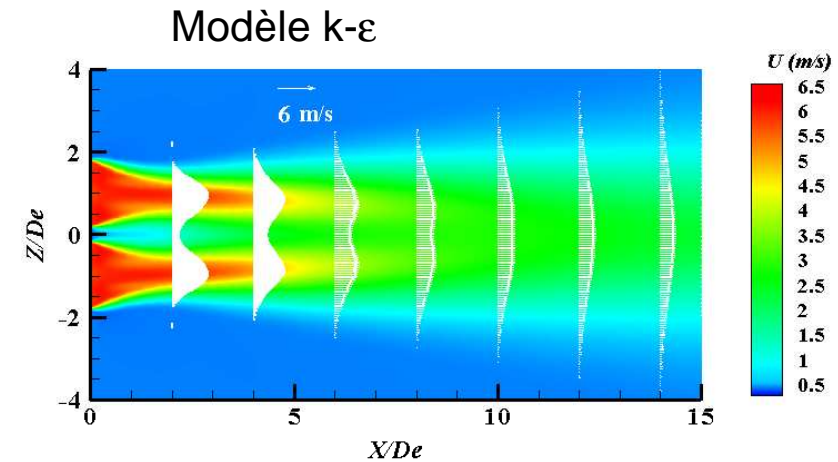
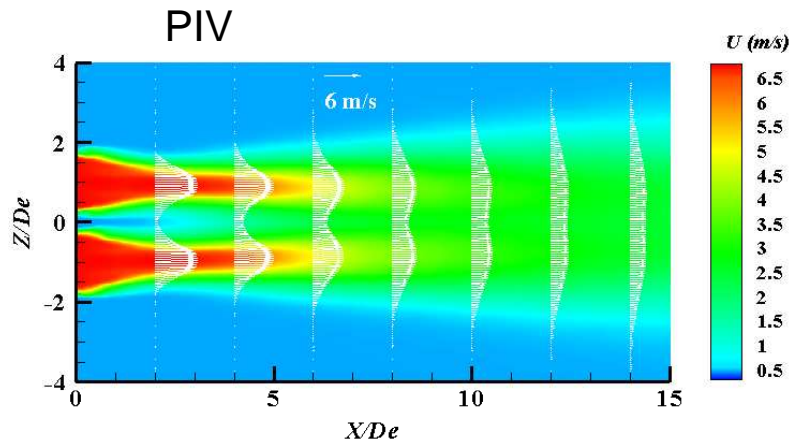
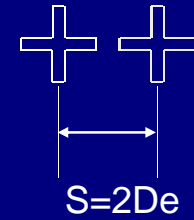


- Généralisation à plusieurs jets parallèles ?



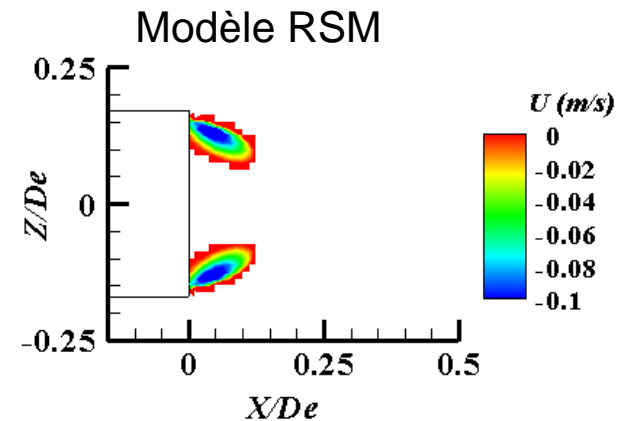
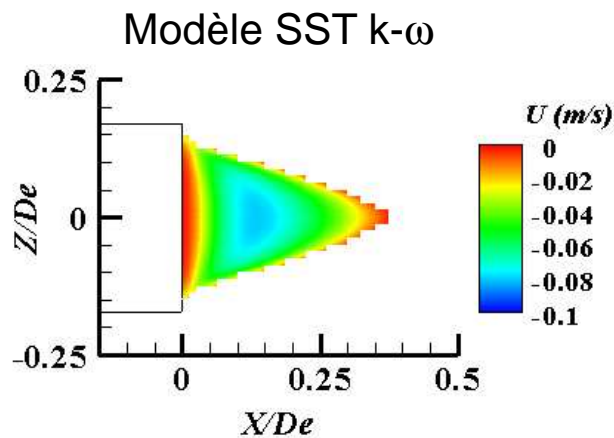
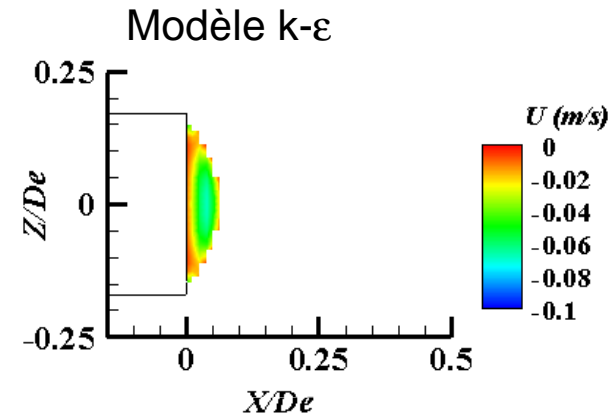
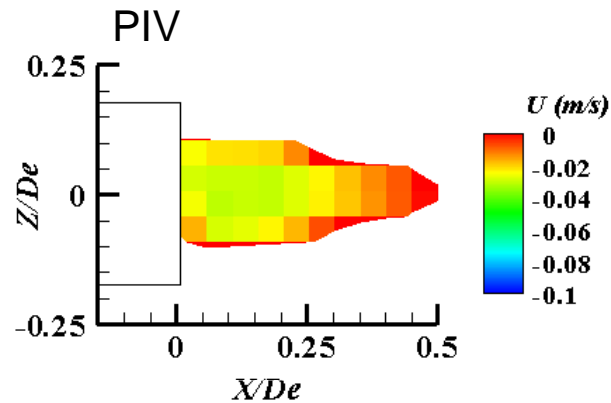
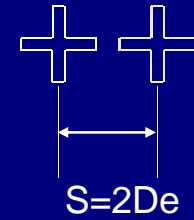
Optimisation numérique

Recherche du modèle le plus approprié pour la simulation de jets lobés en interaction



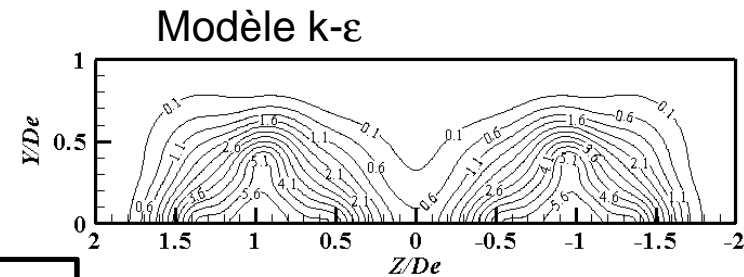
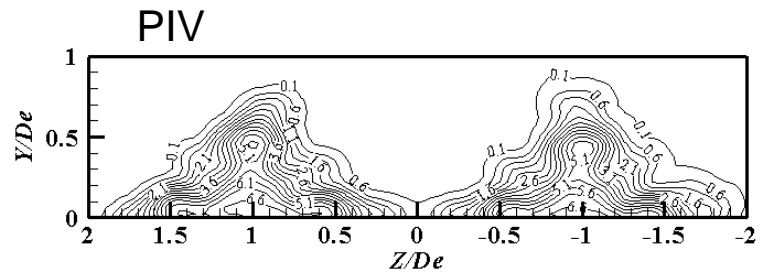
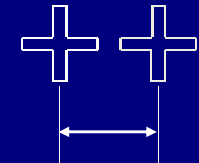
A. Meslem, A. Dia, C. Beghein, M. El Hassan, I. Nastase, P. J. Vialle, Three turbulence models comparison in the prediction of parallel lobed jets for perforated panel optimization, Building and Environment.

Recherche du modèle le plus approprié pour la simulation de jets lobés en interaction



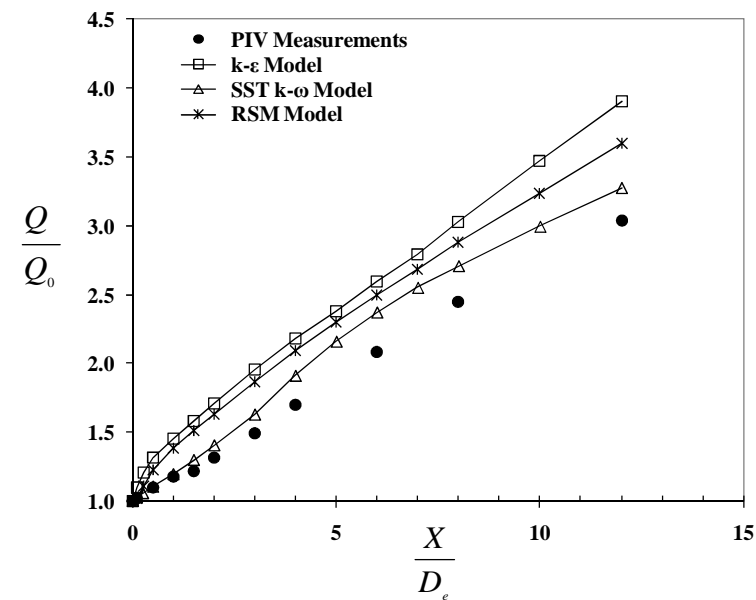
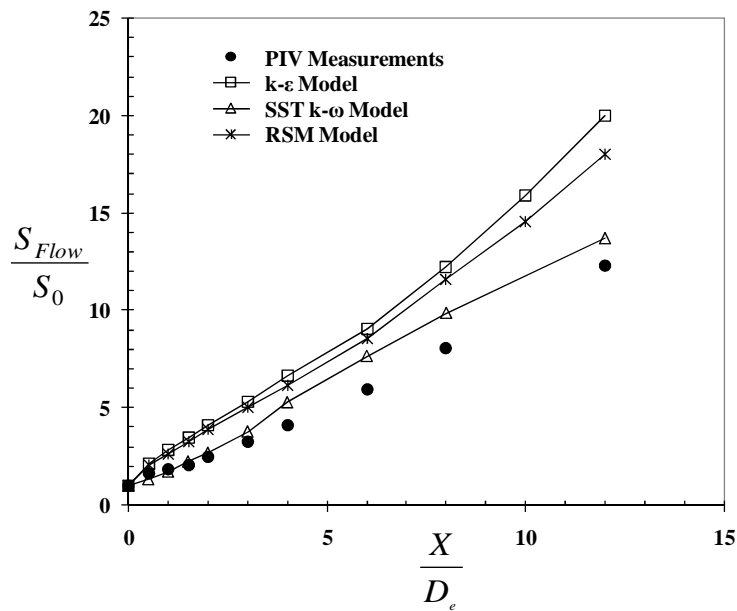
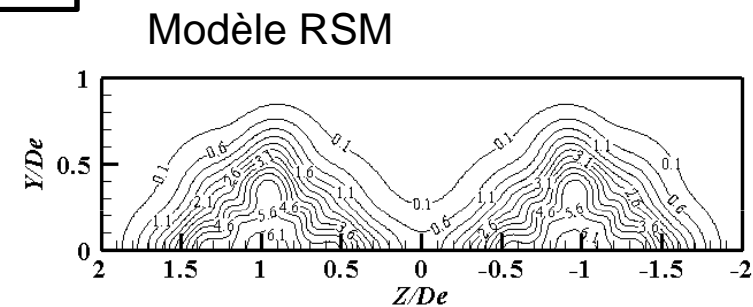
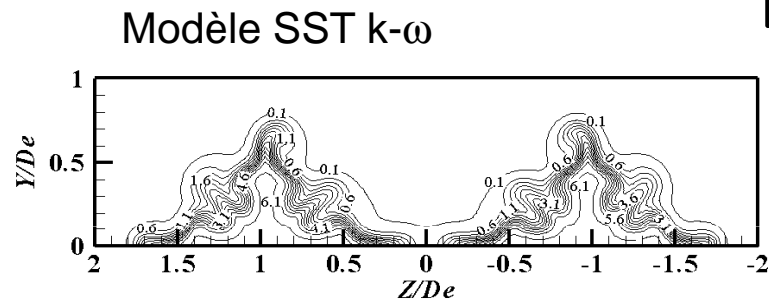
A. Meslem, A. Dia, C. Beghein, M. El Hassan, I. Nastase, P. J. Vialle, Three turbulence models comparison in the prediction of parallel lobed jets for perforated panel optimization, Building and Environment.

Optimisation numérique

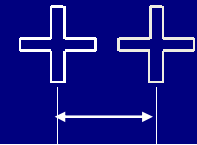


$S=2De$

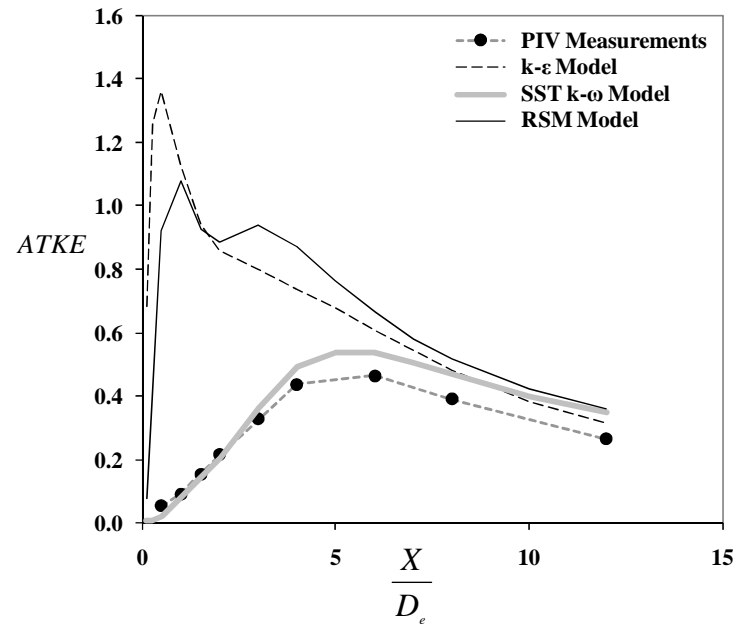
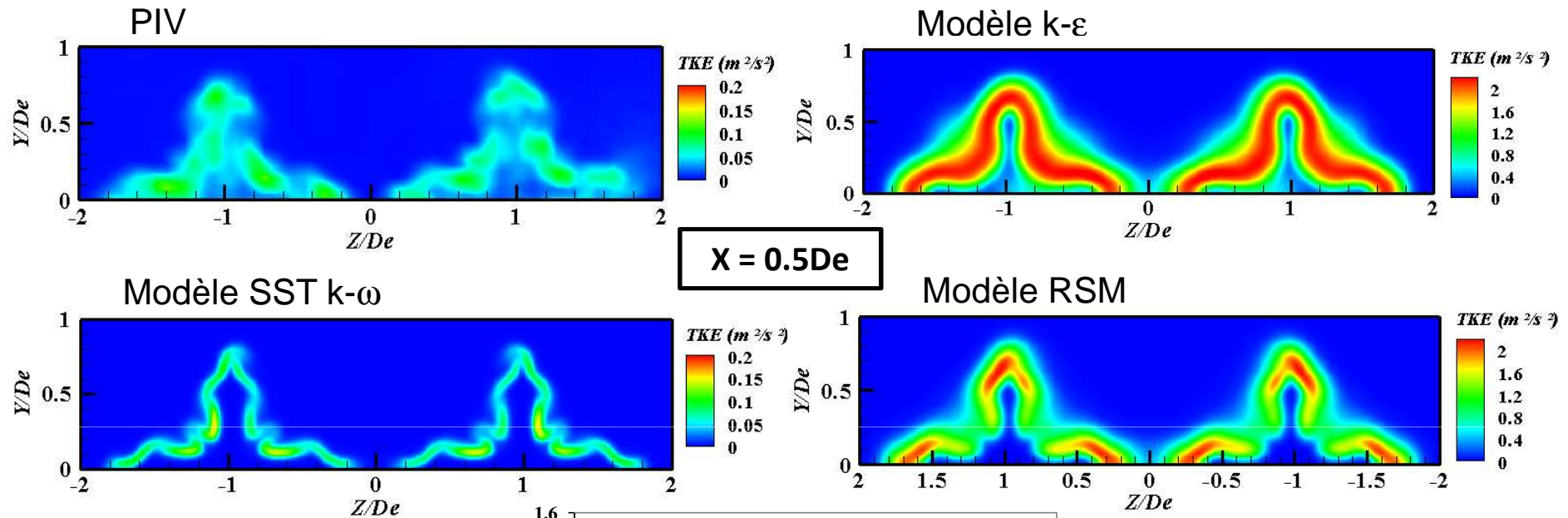
$X = 1De$



Optimisation numérique

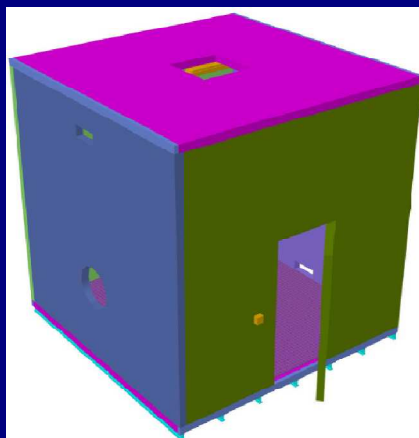


$$S = 2De$$



Conclusions et Perspectives

- Le bâtiment BBC sera-t-il aussi bon pour la santé qu'il sera bon pour la planète? Une des solutions résidera peut-être dans le choix de diffuseurs à haute induction pour distribuer au mieux les faibles débits d'air hygiénique et les faibles puissances thermiques.
- Des solutions finalisées sont proposées. Leur optimisation est en cours pour gagner en efficacité d'induction.
- Reste à démontrer et à convaincre par des mises en situation de ces grilles dans une cellule échelle 1 thermiquement gardée :
 - Evaluation du confort thermique autour d'un mannequin à 18 zones différentiellement chauffées
 - Calcul des gains énergétiques par rapport à des solutions classiques de référence pour un confort thermique constant



La toute nouvelle cellule de diffusion de l'air du LEPTIAB

Le mannequin thermique « fait mains » en collaboration avec l'UTCB

