



# Impact d'un jet compressible

Etude expérimentale aéro-thermique

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X. T. Trinh  
E. Dorignac

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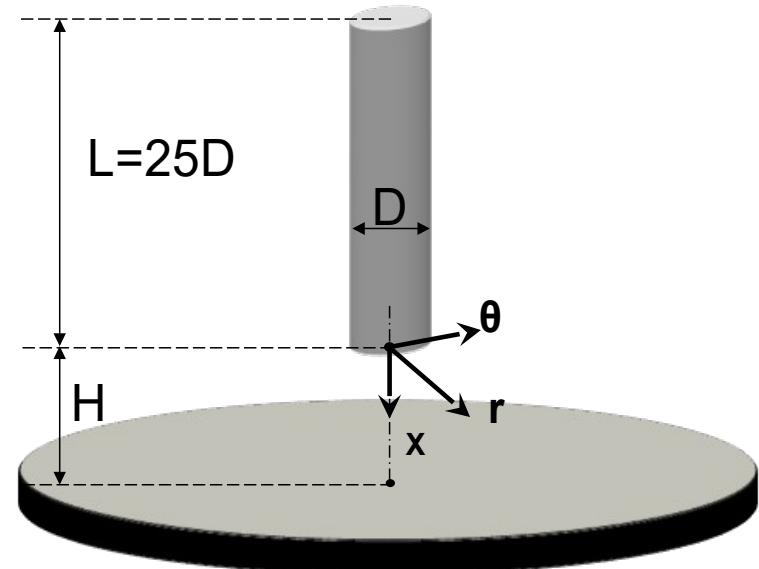
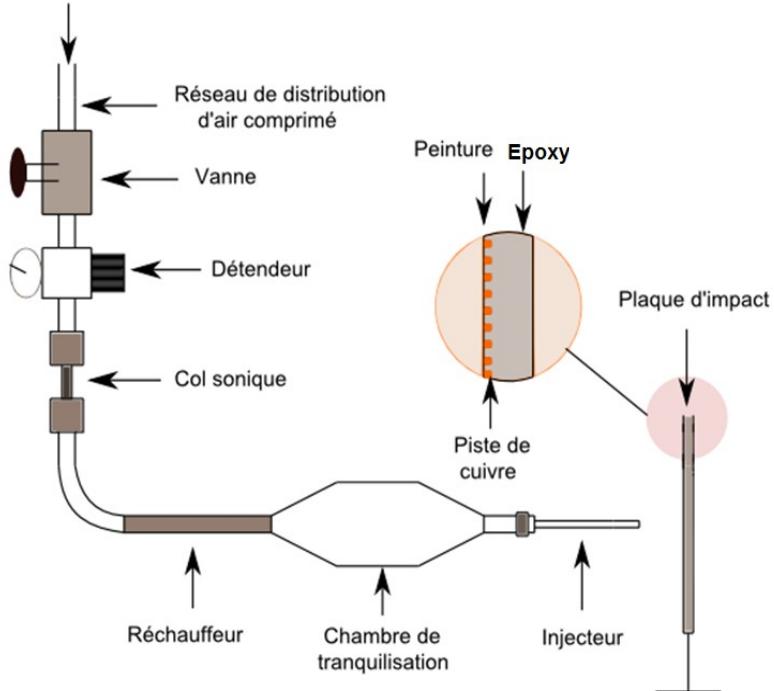


# Jet en impact: Effets de compressibilité

- Peu d'études expérimentales sur les effets thermiques de la compressibilités:
  - Résultats relativement contradictoires
  - Pas d'étude dynamique/thermique

	$Re_j$	$M_j$		
<b>Brevet et al.</b>	7200→71500	0.35→0.69	Injection tubulaire	$\nearrow qd M_j \nearrow$
<b>Goodro et al.</b>	60000	0.16→0.74	Matrice de jets Perforations dans une plaque	$Nu \nearrow qd M_j \nearrow$
<b>Limaye et al.</b>	44000→221000	0.2→1	Injection tubulaire	Effets de compressibilité fonction de H/D $Nu \nearrow qd M_j \nearrow$ au point d'impact $Nu \searrow qd M_j \nearrow$ loin du point d'impact

## ○ Banc d'essai



- Aérodynamique: PIV:
  - Caractéristiques:
    - 25Hz (temps inter impulsion 0.7  $\mu$ s)
    - Particules d'huile  $\sim 1\mu\text{m}$ ;
    - Exploitation:
      - moyenne sur 3000 images, Traitement: adaptative cross-correlation 64x64 à 16x16 – overlap 50%,
      - resolution spatiale:  $\Delta X \approx 0.015D$

- Thermique:

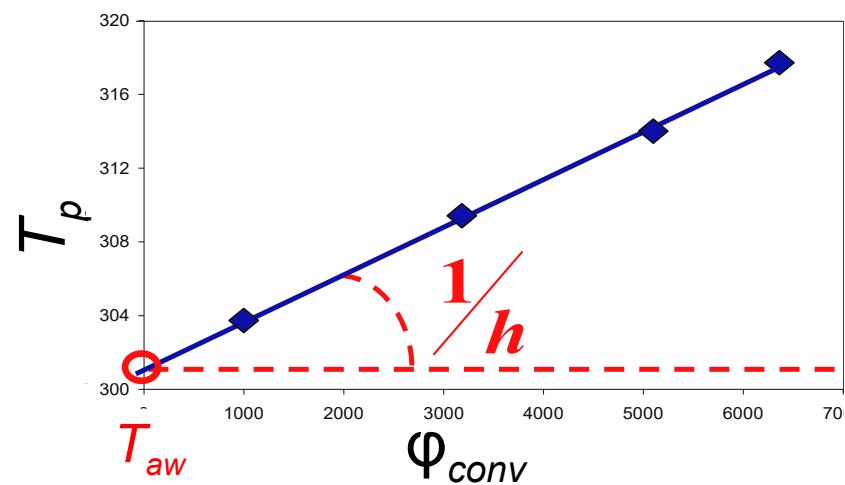
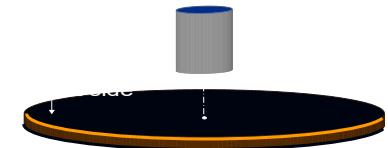
- Détermination de  $T_{ref}$  et  $h$ :

- Régession linéaire:

- pente:  $1/h$
- origine :  $T_{ref}$

- $T_{ref} = T_p$  pour  $\Phi_{conv} = 0$

$$\Rightarrow T_{ref} = T_{aw}$$



- Application de la méthode:

- Flux:

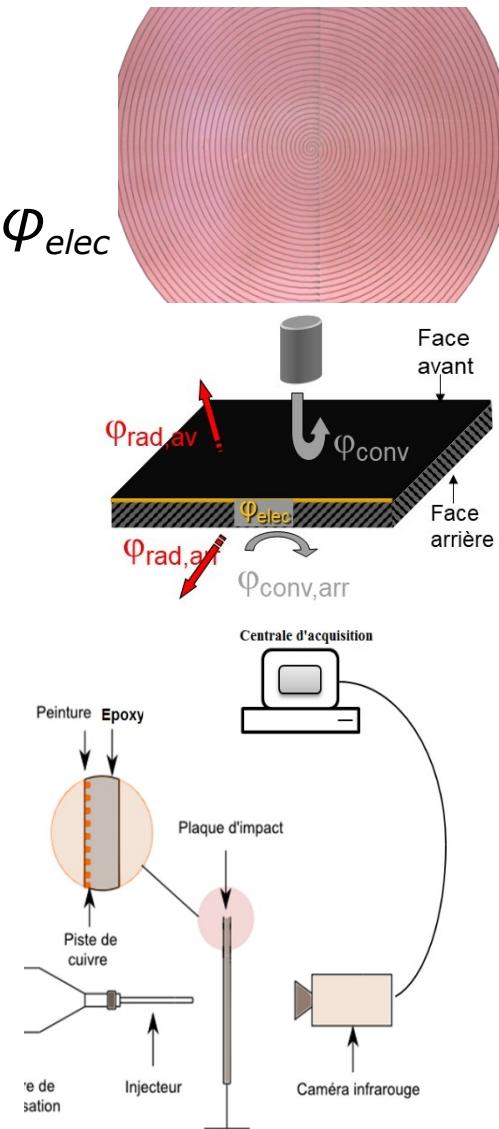
- Plaque d'impact chauffée par effet Joule  $\varphi_{elec}$
    - Calcul des pertes:  $\varphi_{ray,av}$ ;  $\varphi_{ray,arr}$ ,  $\varphi_{conv,arr}$ 
      - $\Sigma$  pertes < 7% de  $\varphi_{elec}$

- Température :

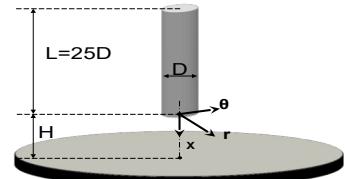
- caméra IR

- $Nu$  et  $T_{aw}$

- Moyenne azimutale
    - Incertitudes
      - $Nu \approx 6\%$ ,



# Principe de l'étude



## ○ Etude:

- $Re = 110\,000$
- $T_{tj} = T_{amb} \approx 20^\circ\text{C}$

## ○ Modification du diamètre d'injection

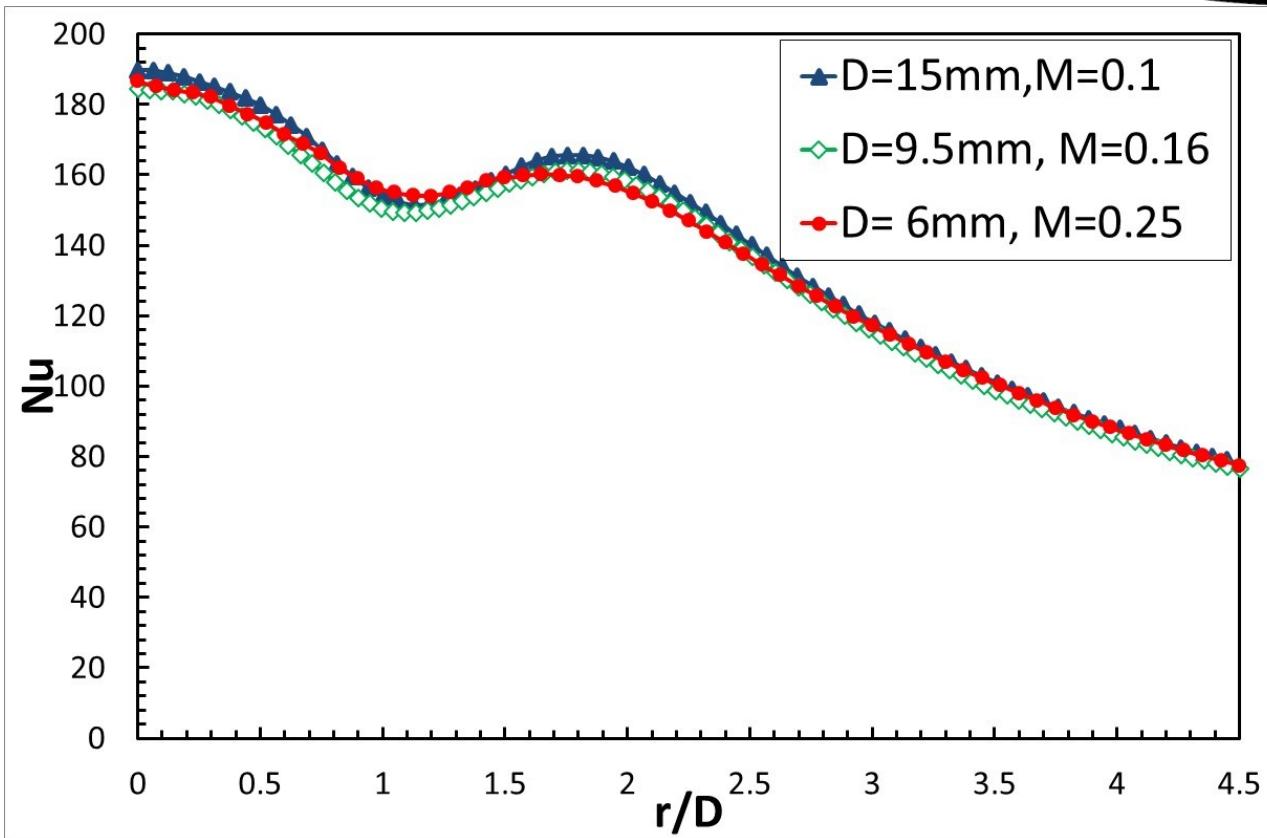
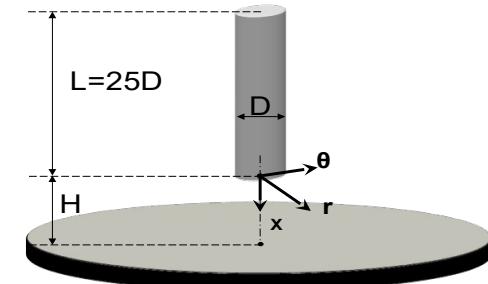
- $D = 6\text{mm}; 9.5 \text{ et } 15\text{mm}$
- $M = 0.8; 0.5 \text{ et } 0.3$
- $H/D = 1; 5$

## ○ Présentation des résultats:

- En dynamique:  $M = 0.8 \text{ et } 0.3$
- En thermique:  $M = 0.8; 0.5 \text{ et } 0.3$

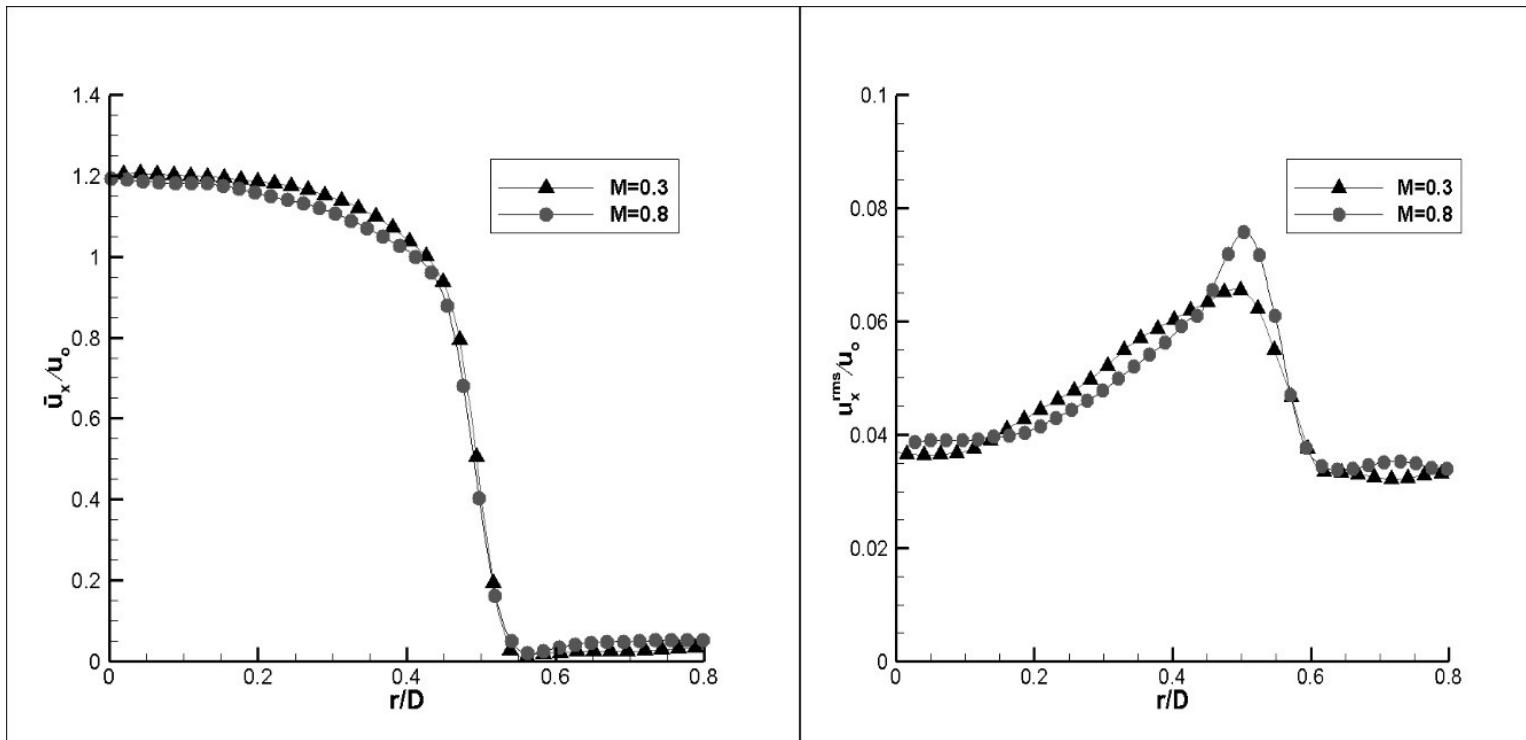
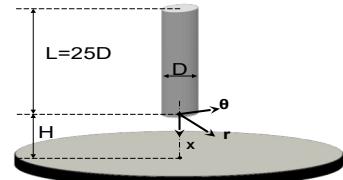
## ○ Validation

- $Re=35000, H/D=1$

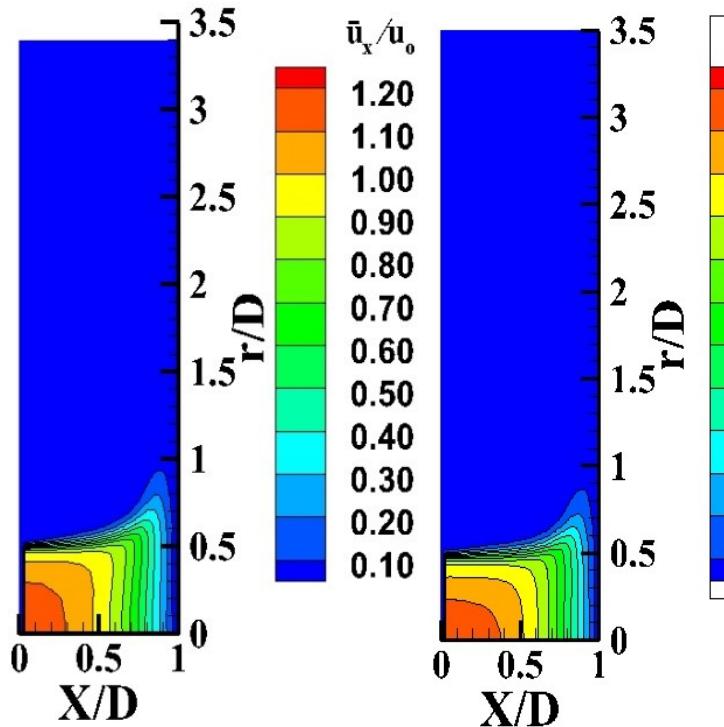


# Résultats aérodynamiques

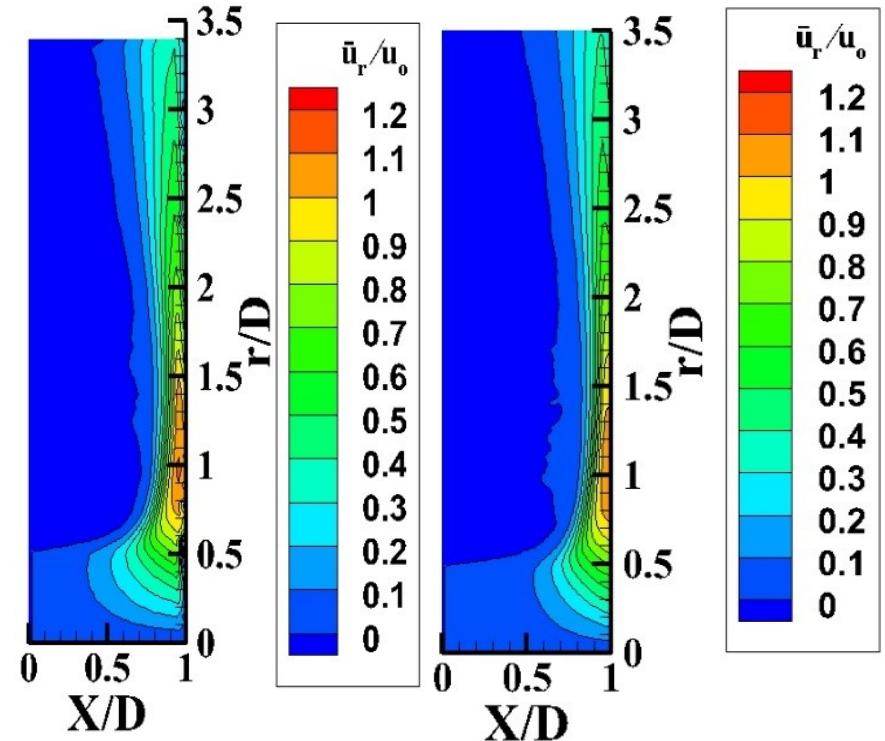
- Injection
  - Profils de vitesse à l'injection



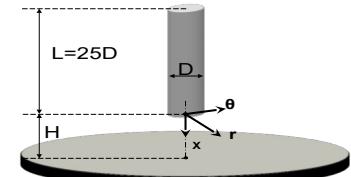
## ○ Résultats aérodynamiques:



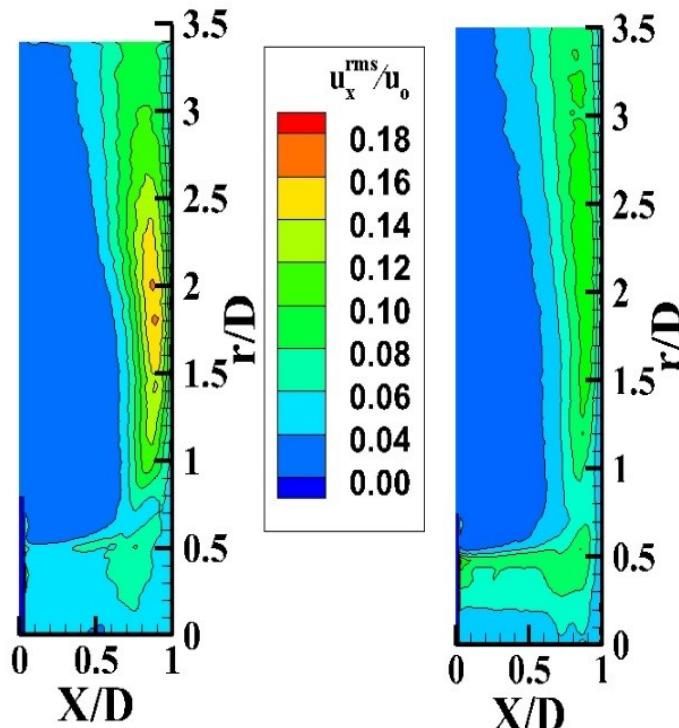
$M=0.3$   
Vitesse moyenne axiale  
adimensionnée



$M=0.3$   
Vitesse moyenne radiale  
adimensionnée

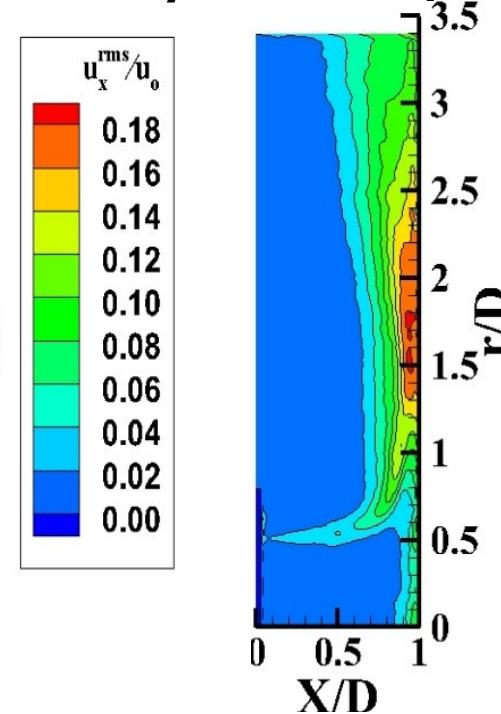


## ○ Résultats aérodynamiques:



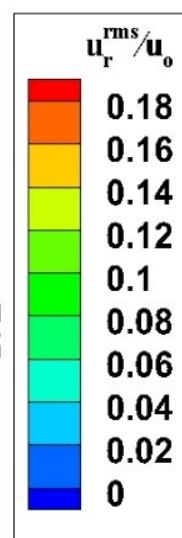
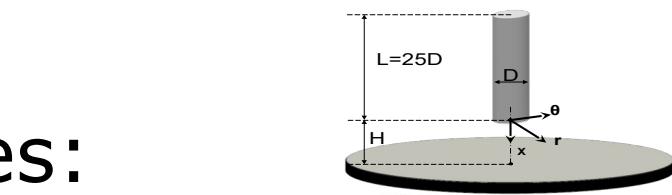
$M=0.3$

Fluctuations de vitesse  
axiale adimensionnées

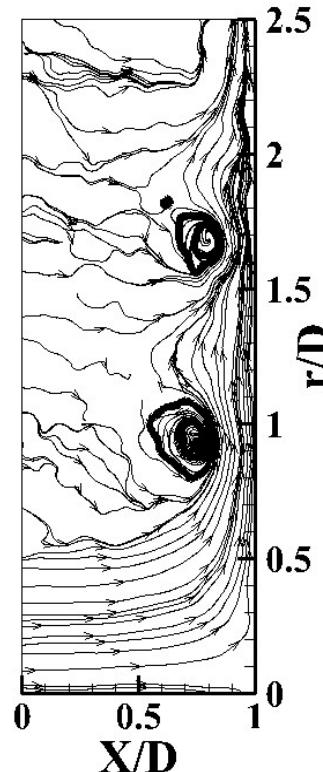


$M=0.3$

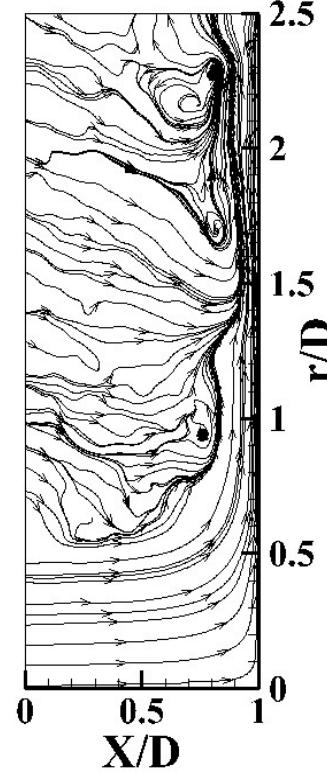
Fluctuations de vitesse  
radiale adimensionnées



- Résultats aérodynamiques:

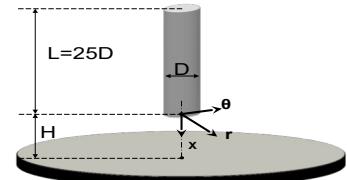


$M=0.3$

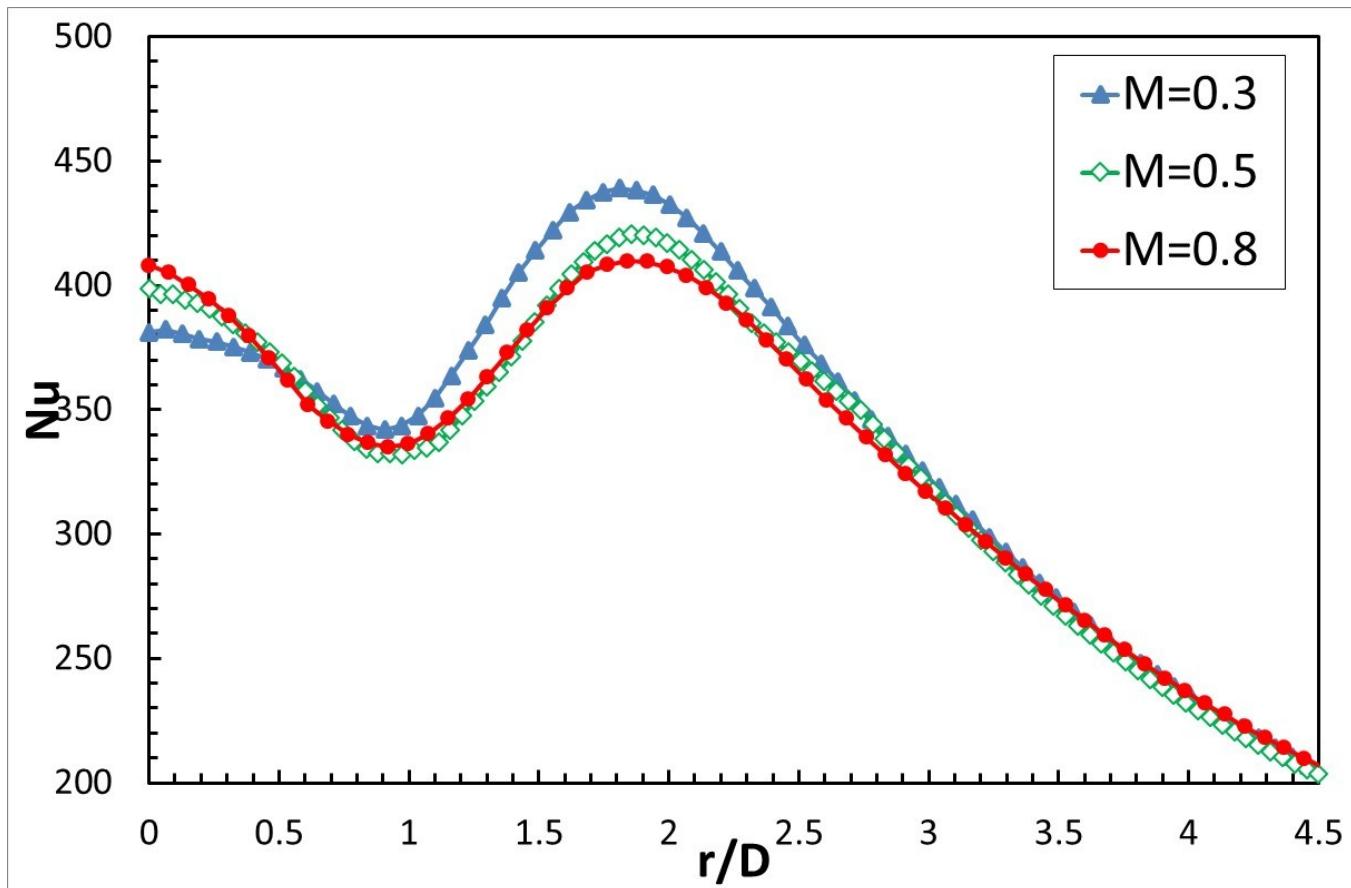


$M=0.8$

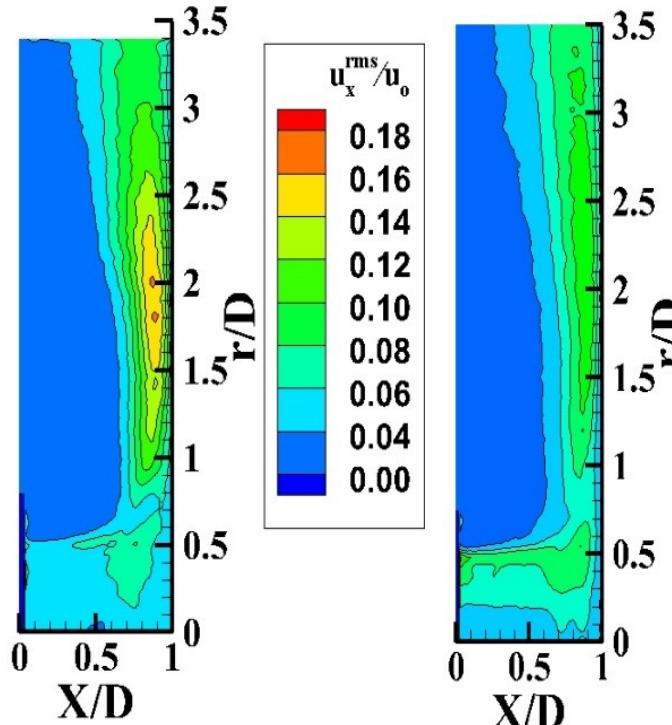
Lignes de courant



- Résultats thermiques:

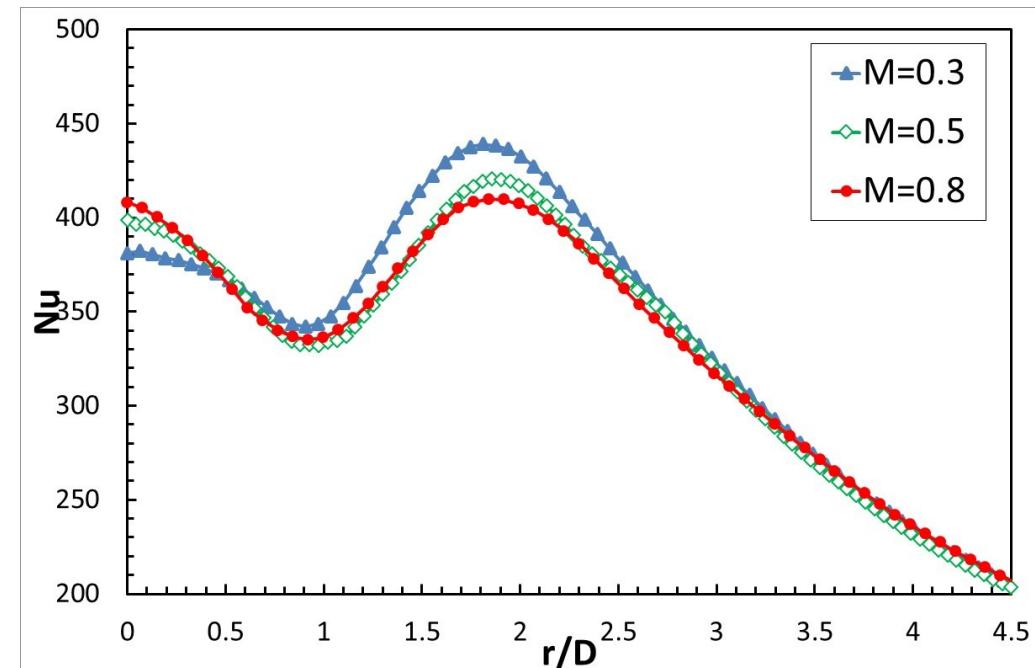


- Résultats thermiques:

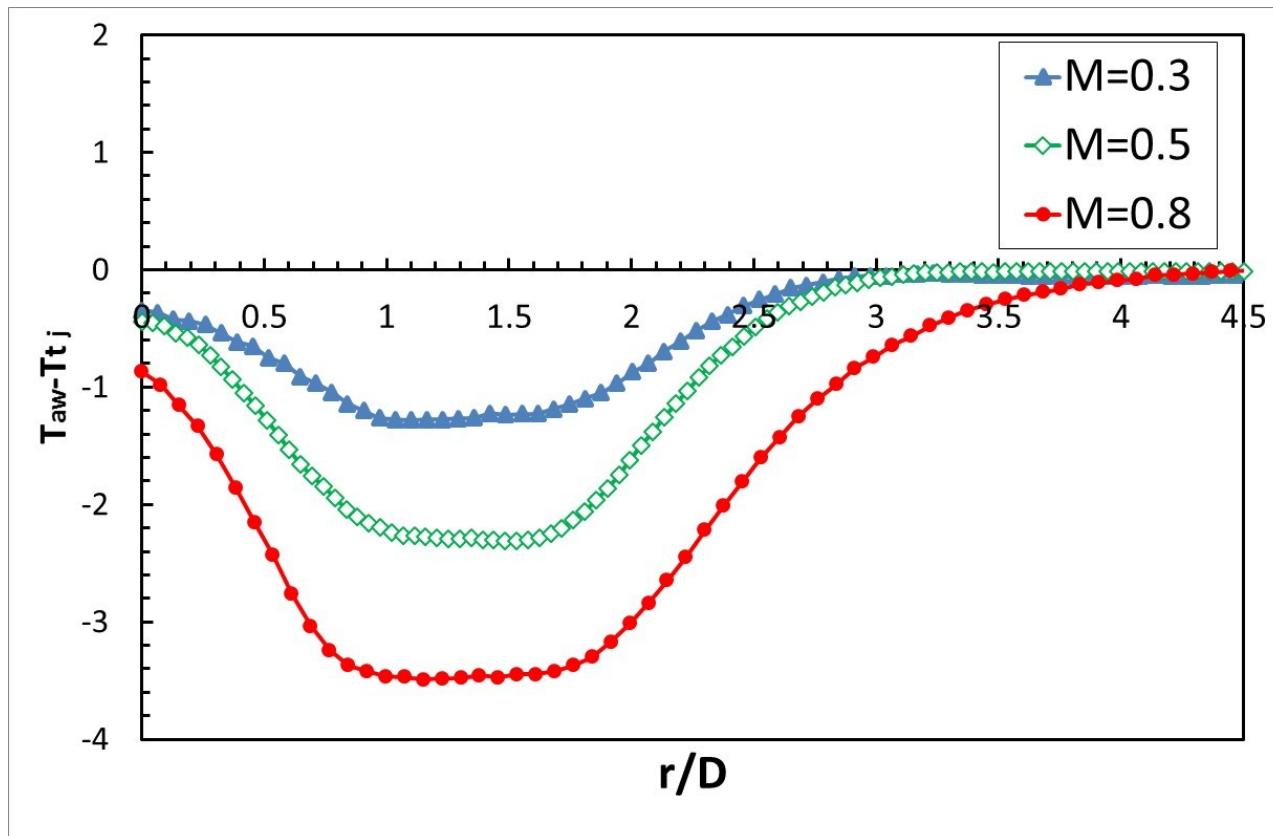


$M=0.3$      $M=0.8$

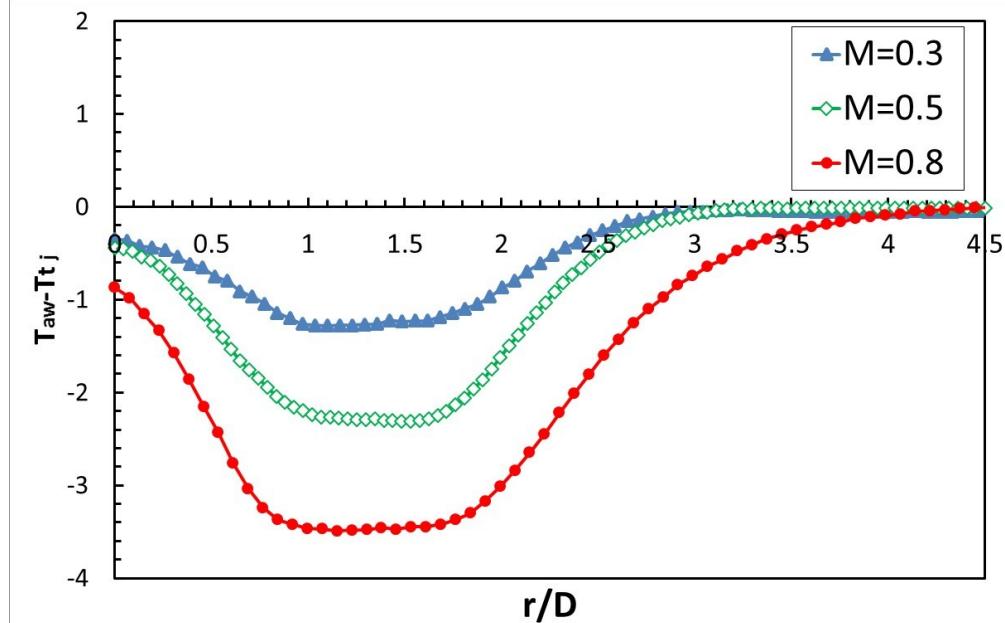
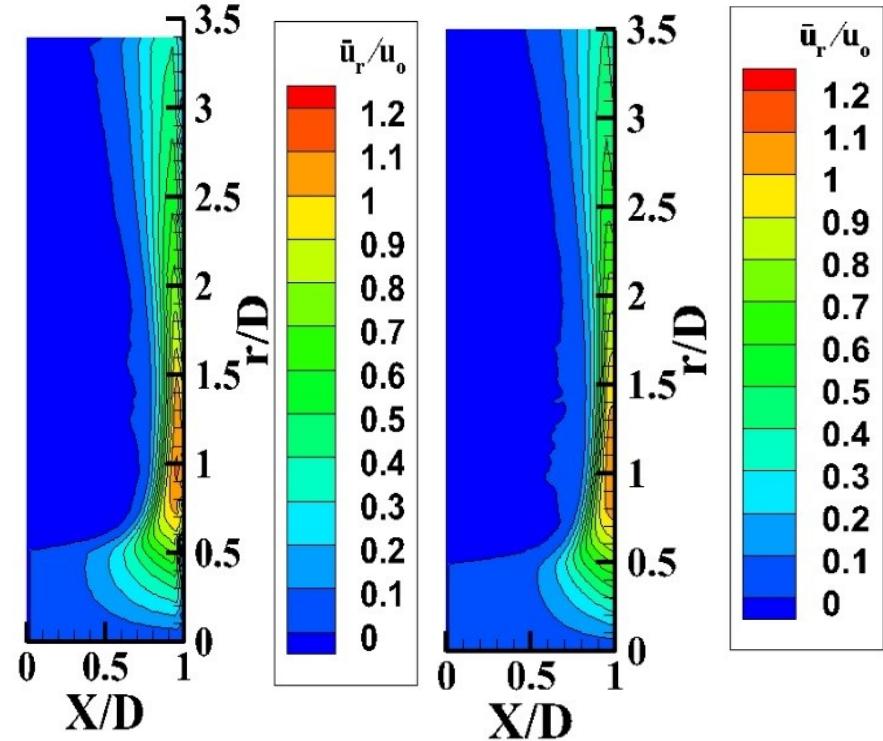
Fluctuations de vitesse  
axiale adimensionnées



- Résultats thermiques:



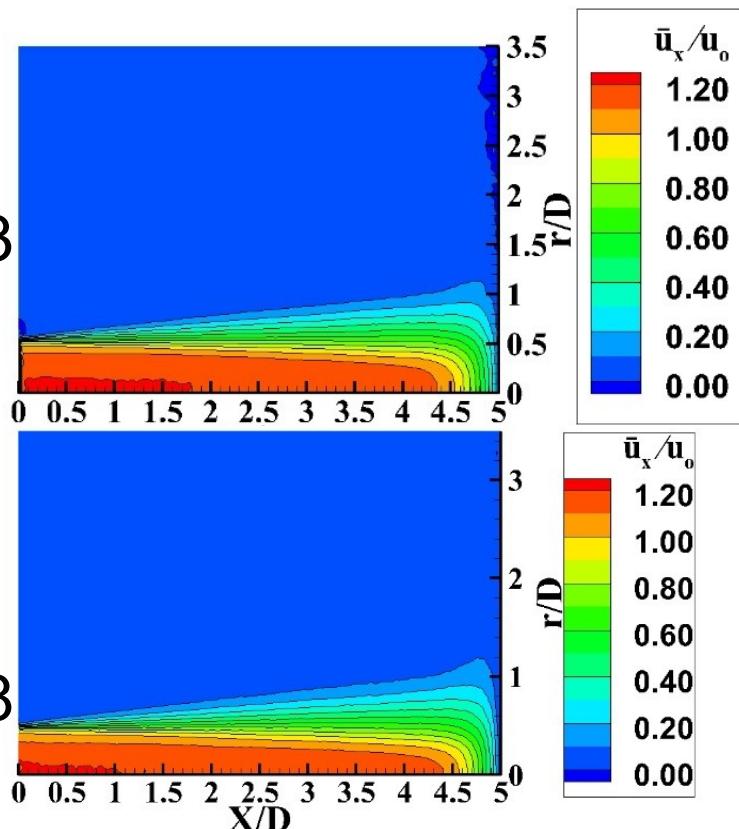
## ○ Résultats thermiques:



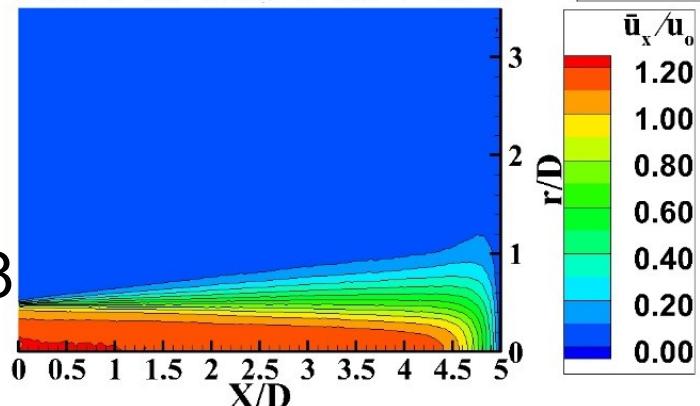
Vitesse moyenne radiale  
adimensionnée

- Résultats aérodynamiques:

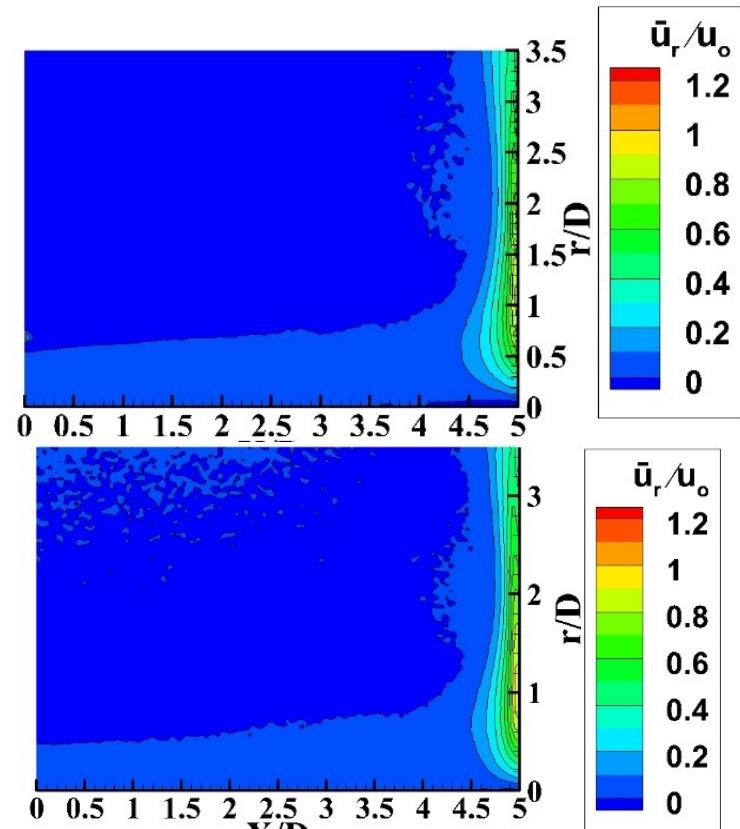
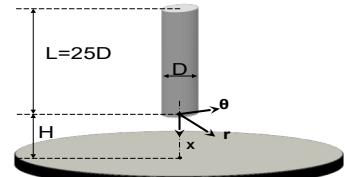
$M=0.3$



$M=0.8$

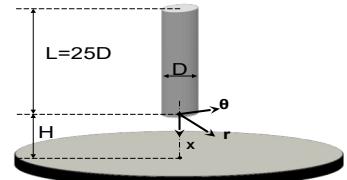


Vitesse moyenne axiale  
adimensionnée

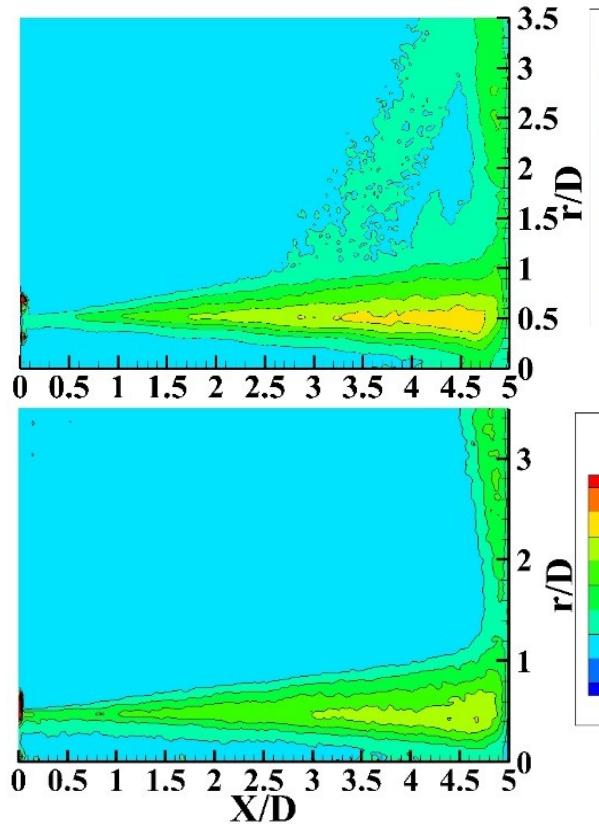


Vitesse moyenne radiale<sub>7</sub>  
adimensionnée

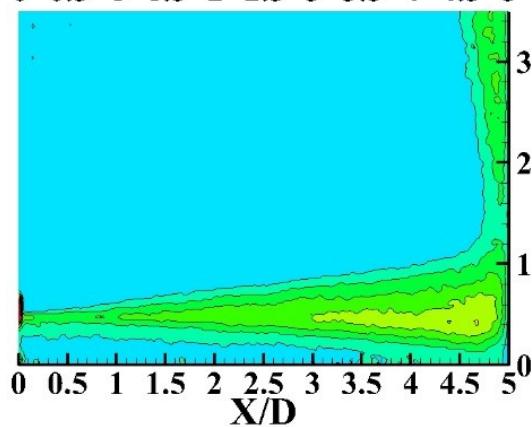
- Résultats aérodynamiques:



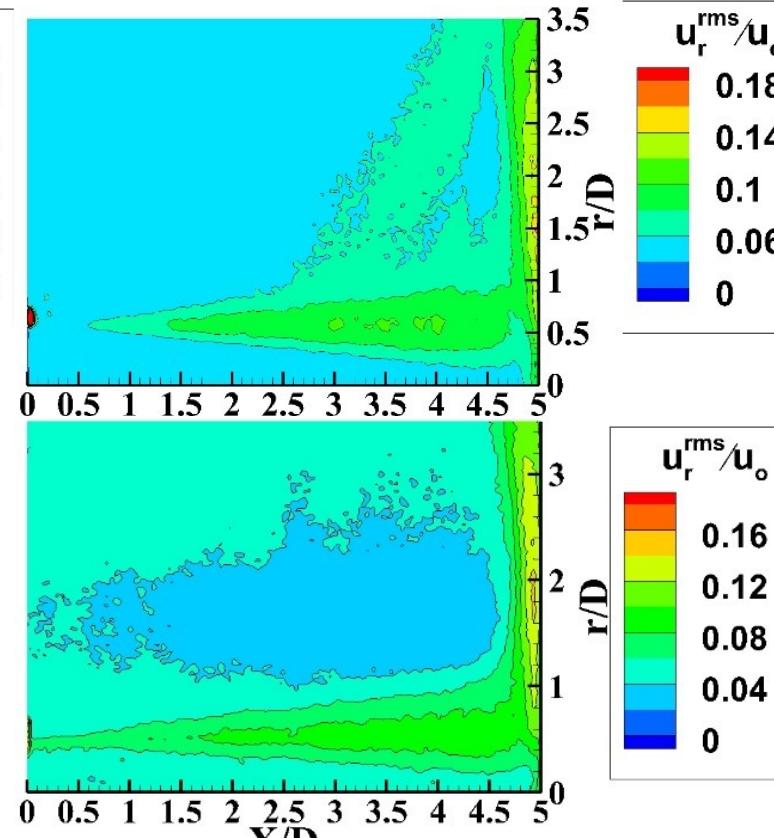
$M=0.3$



$M=0.8$

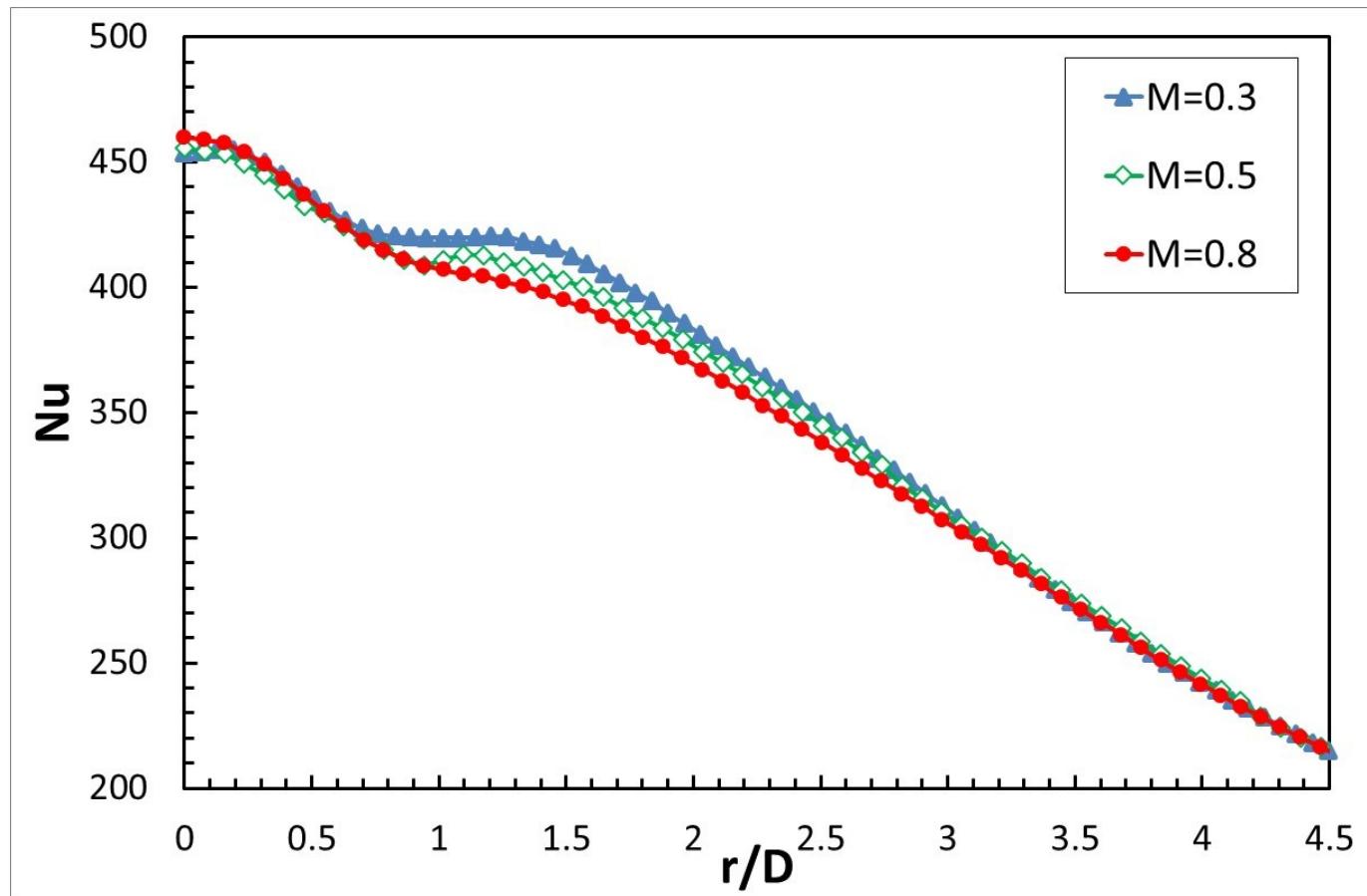


Fluctuations de vitesse  
axiale adimensionnées

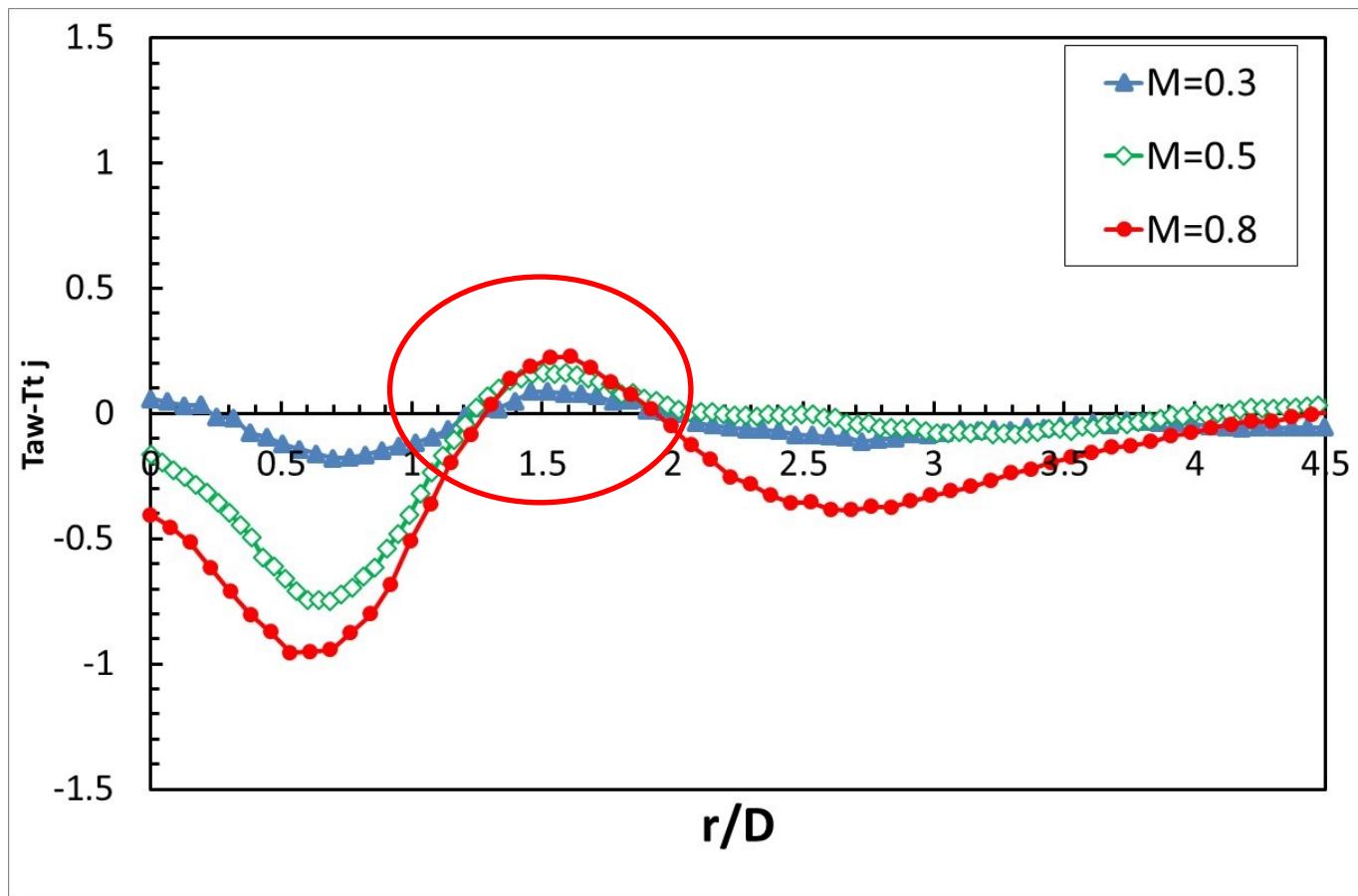


Fluctuations de vitesse  
radiale adimensionnées

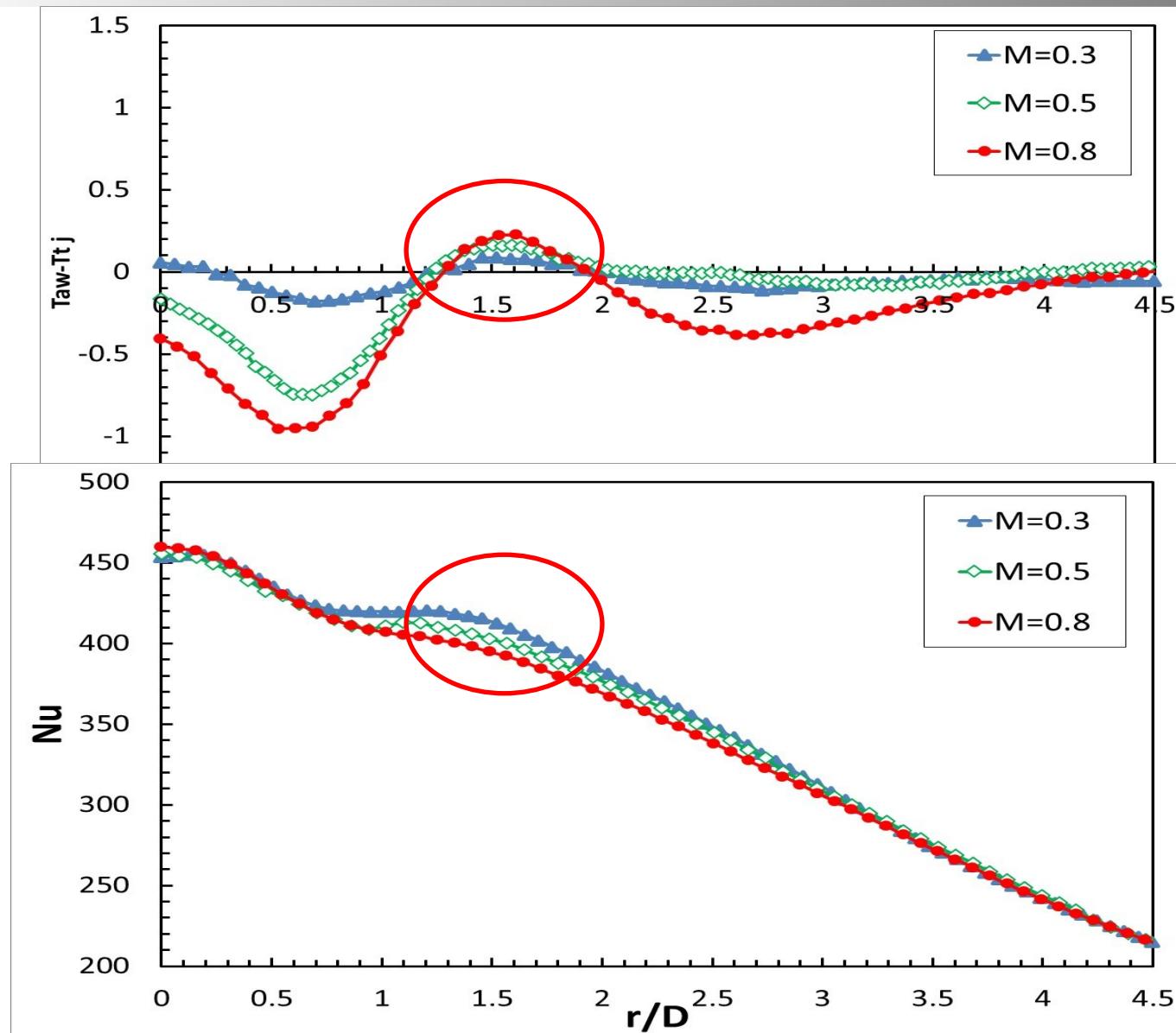
- Résultats thermiques:



- Résultats thermiques:



# Grandes distances d'impact: $H/D=5$



- Effets de compressibilité (Mach) sur un jet en impact:
  - $Re_j = 110\ 000$ ;  $T_{t_j} = T_{amb} \approx 20^\circ C$
  - $M = 0.3, 0.5, 0.8$

- Effets du nombre de Mach :
  - Disparition des structures de Kelvin-Helmholtz
    - ↗ fluctuations dans la couche de cisaillement
    - ↘ fluctuations dans le jet de paroi
  - Avec les conséquences sur Nu
    - Surtout pour de faibles H/D

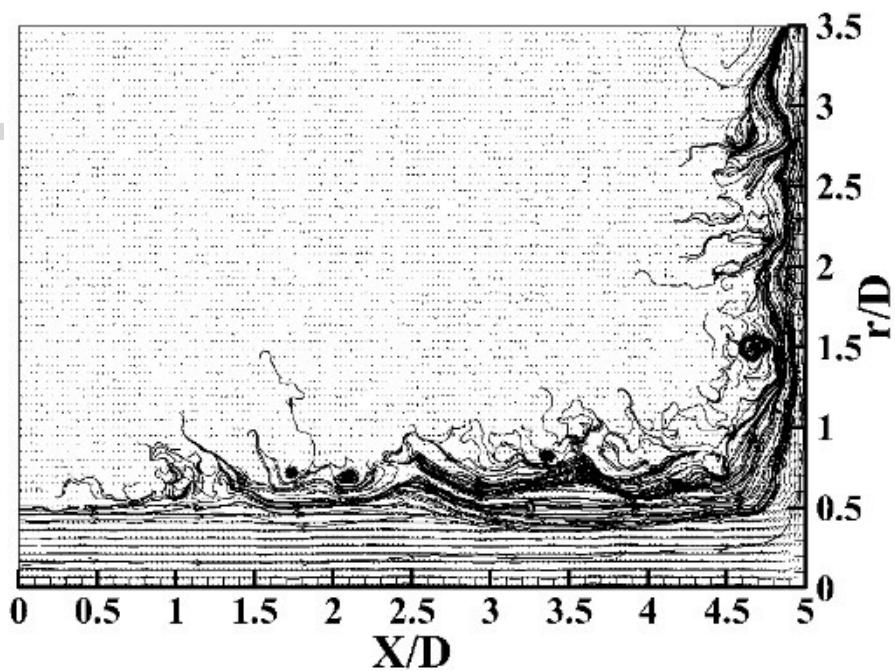
- Effets du nombre de Mach :
  - Sur la température de référence
    - A faible H/D:
      - Effets visqueux et vitesses radiales  $\Rightarrow T_{aw} < T_{tj}$ .
    - A plus grand H/D,
      - le mélange avec  $T_{amb} \Rightarrow$  ponctuellement  $T_{aw} > T_{tj}$

*Merci de votre attention*

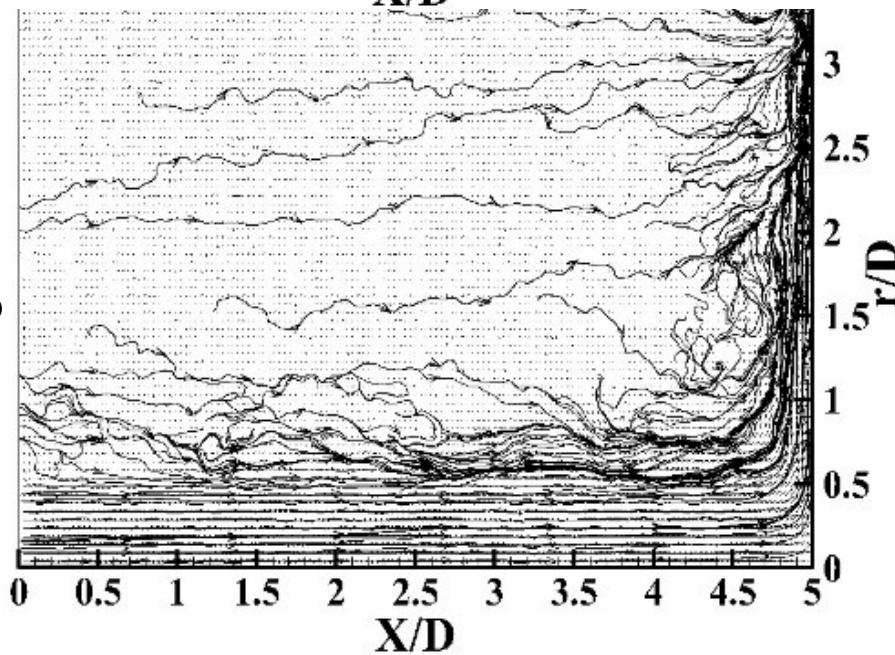


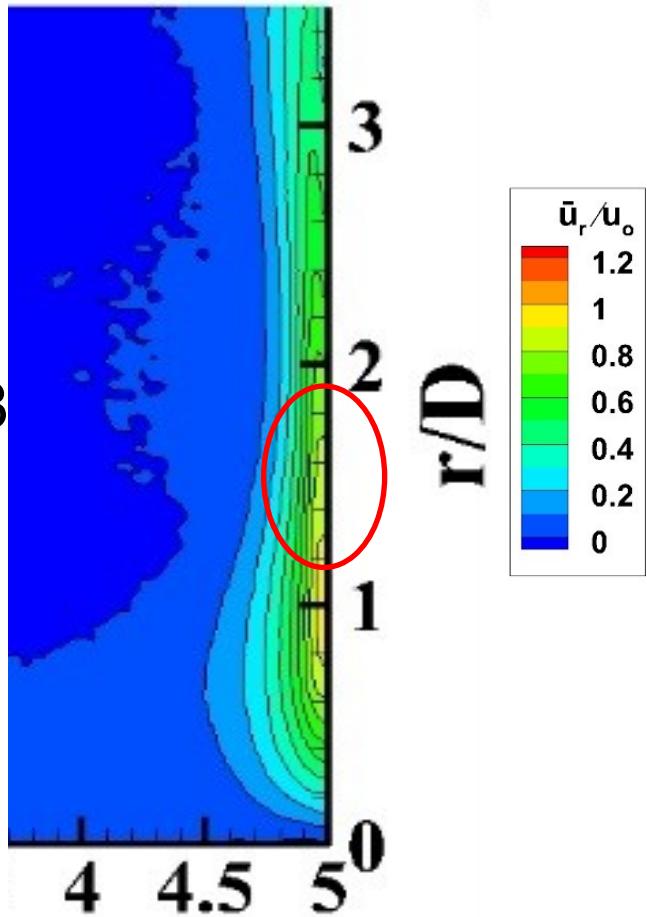


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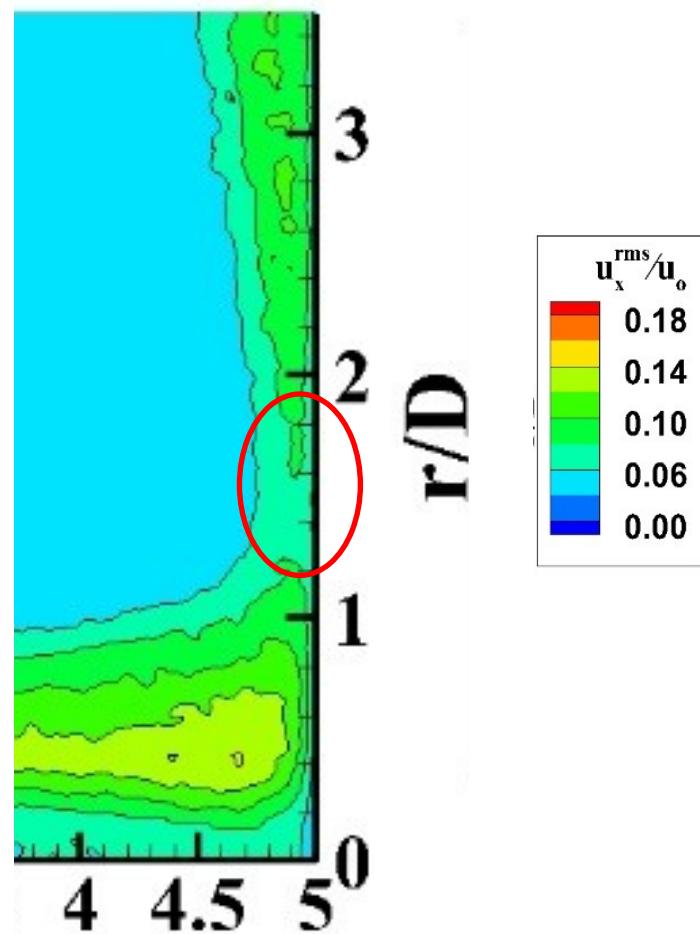


M=0.8



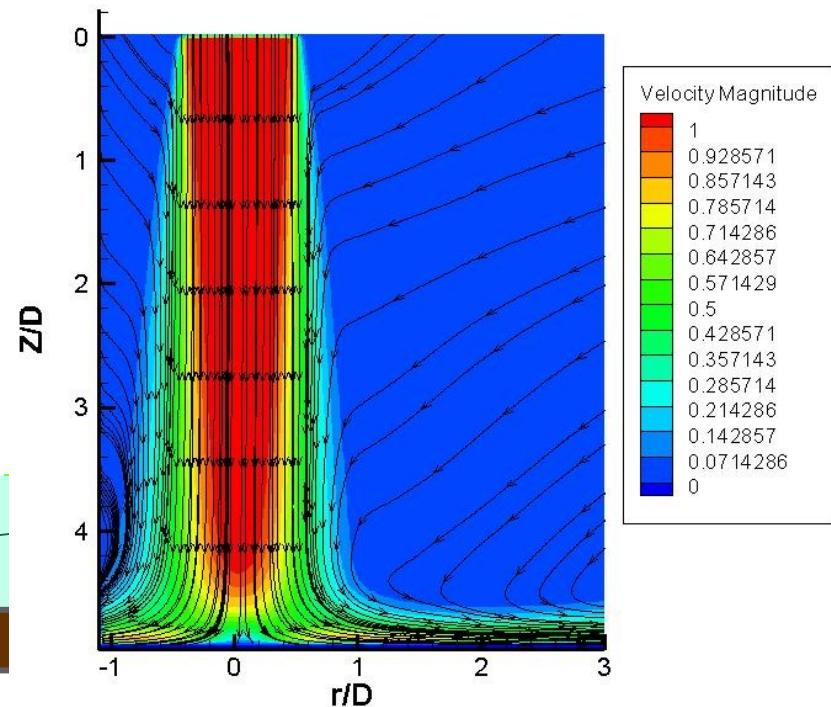
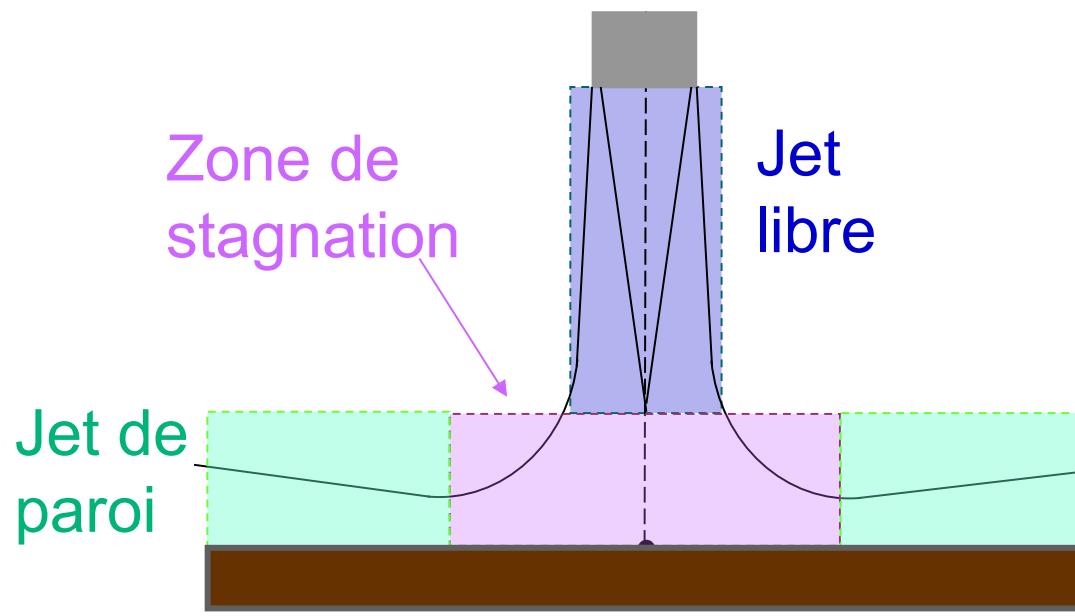
$M=0.8$ 

Vitesse moyenne radiale  
adimensionnée



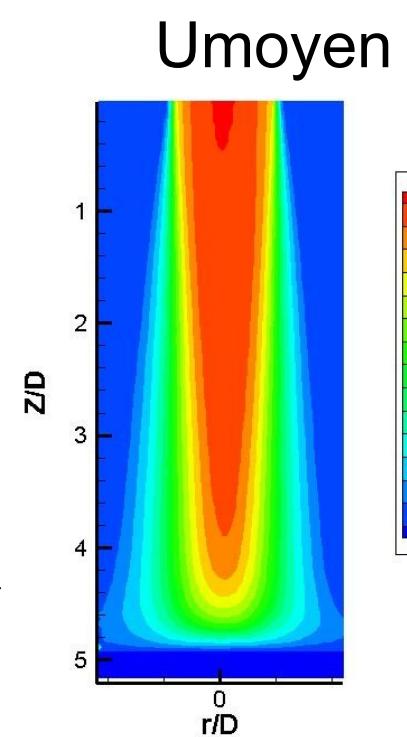
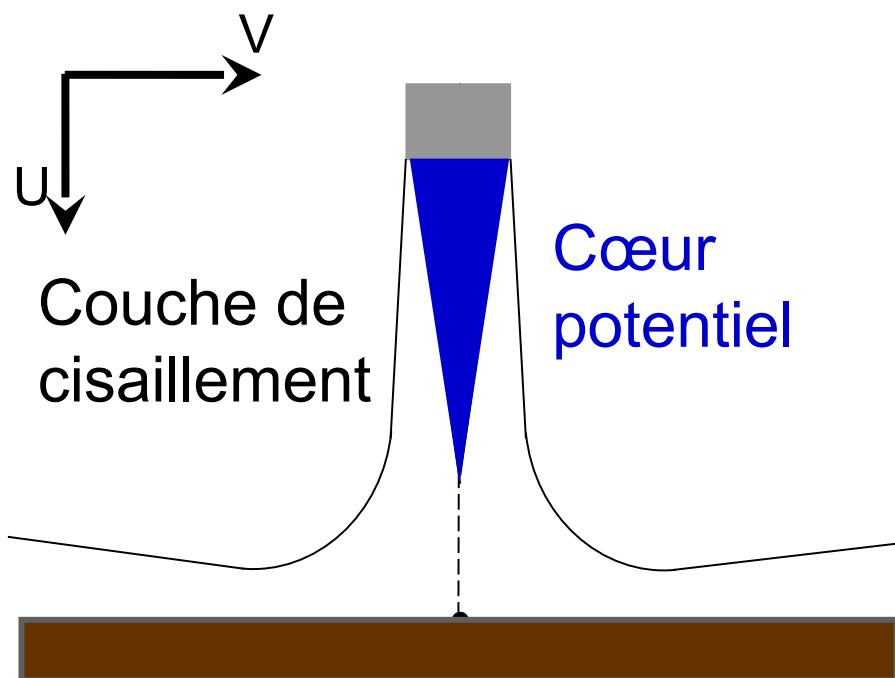
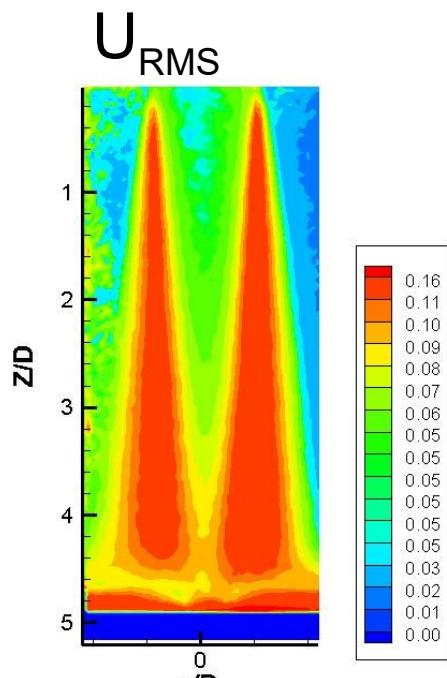
Fluctuations de vitesse  
radiale adimensionnées <sup>29</sup>

- Dynamique d'un jet d'air:

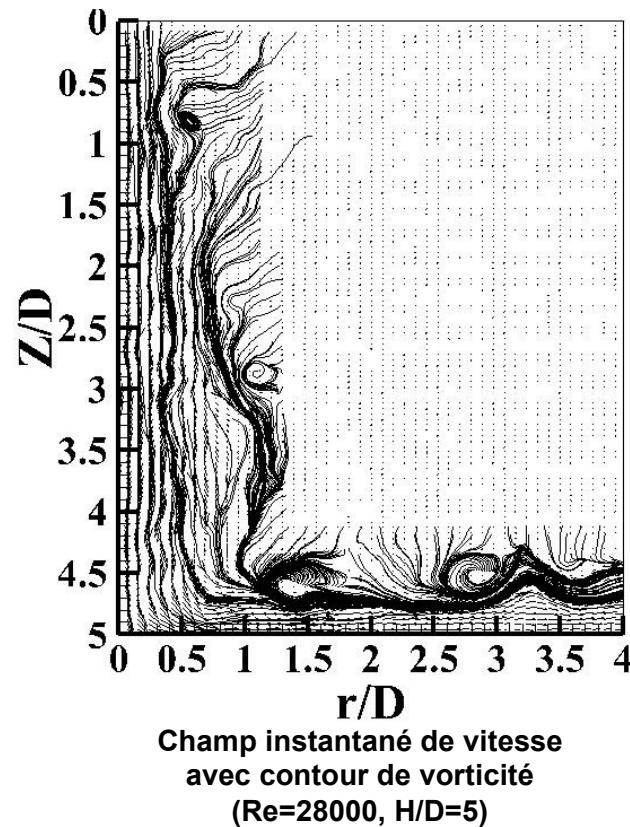
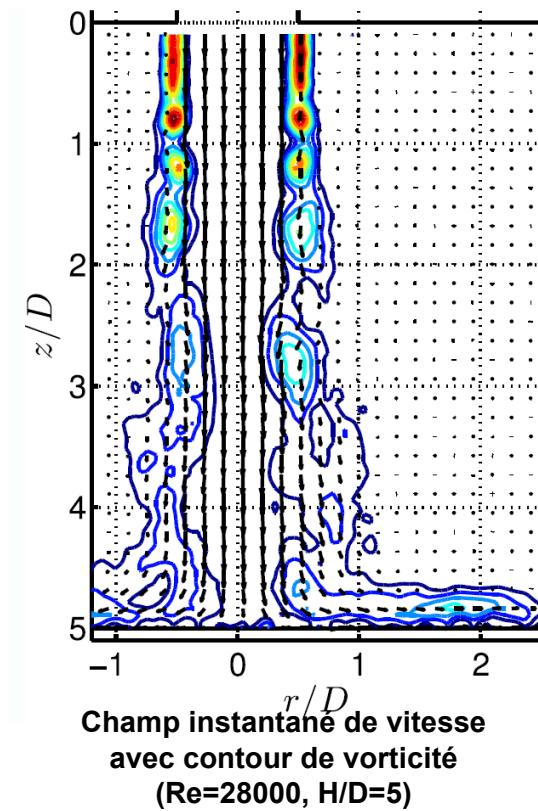


Champ de vitesse moyenne et  
lignes de courant (Re=23000,  
injection tubulaire, H/D=5)

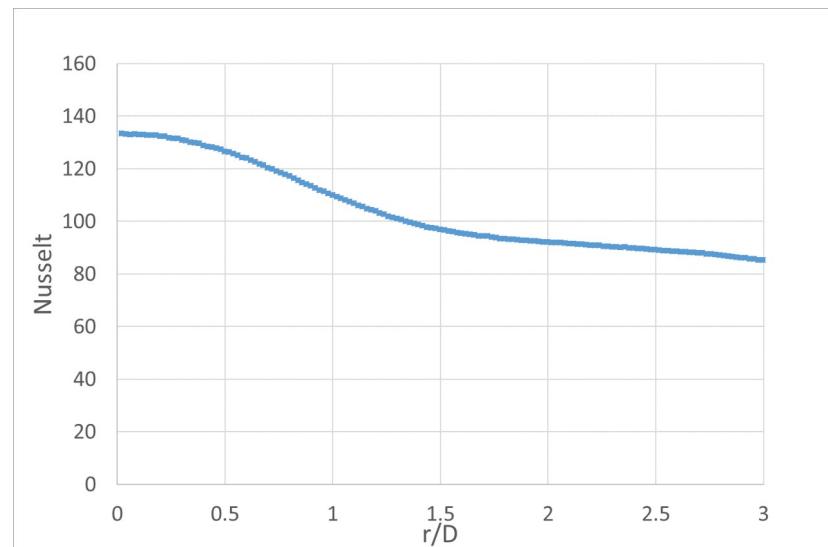
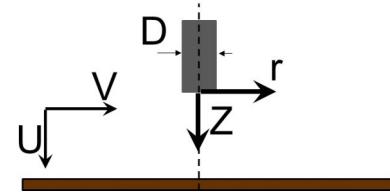
- Dynamique d'un jet d'air:



- Dynamique d'un jet d'air:
  - Couche de cisaillement



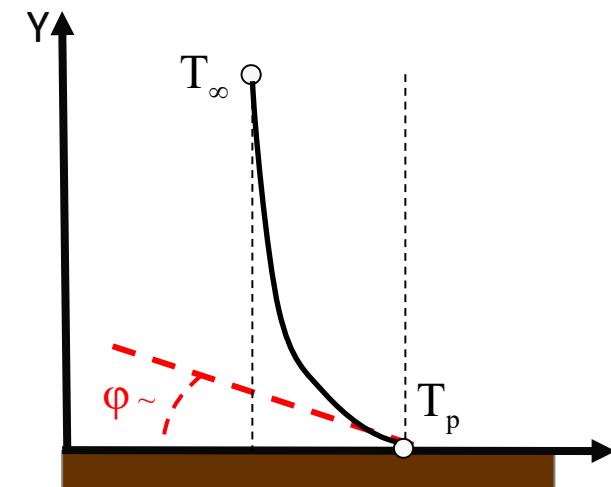
- Thermique d'un jet d'air:
  - Transferts de chaleur



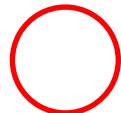
- Thermique d'un jet d'air:
  - Transferts de chaleur



- Si

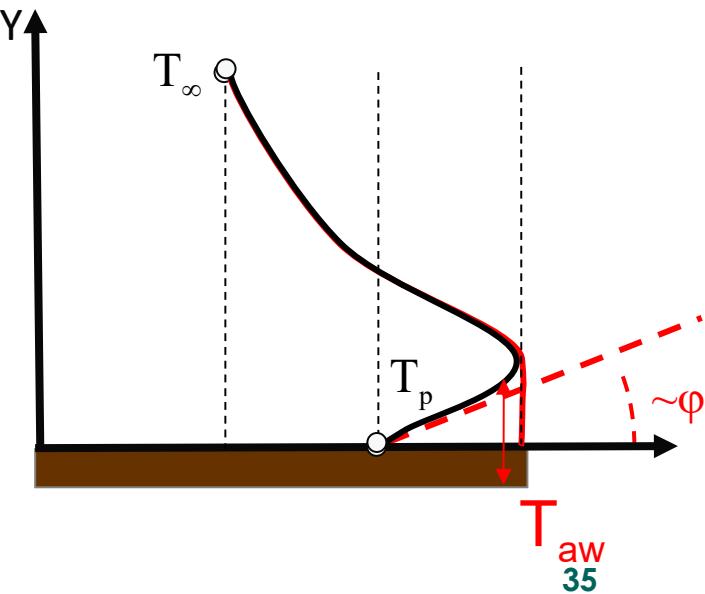


- Thermique d'un jet d'air:
  - Transferts de chaleur



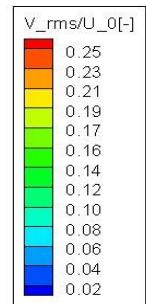
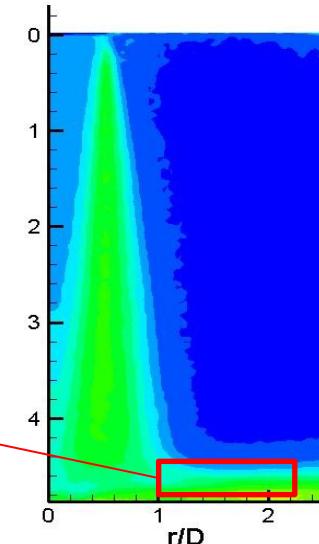
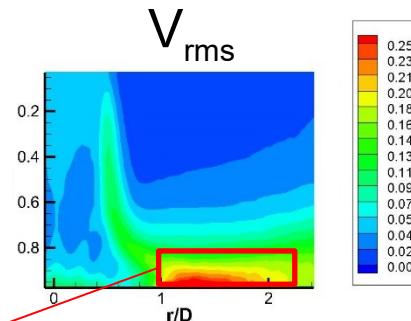
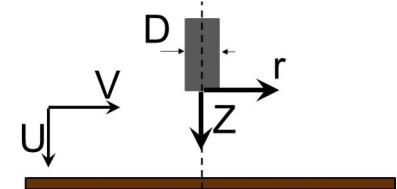
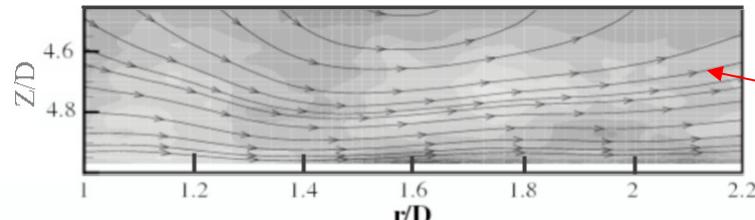
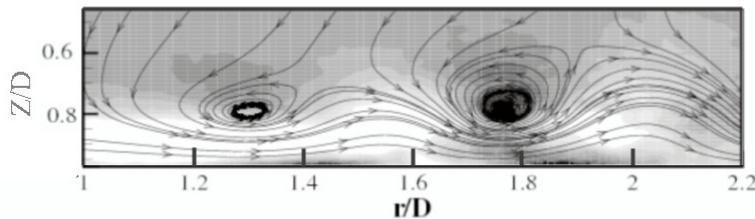
○ Si

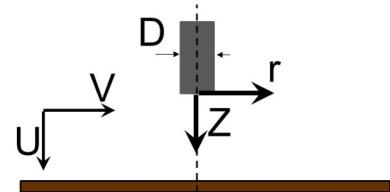
- $T_{ref} = T_{aw}$



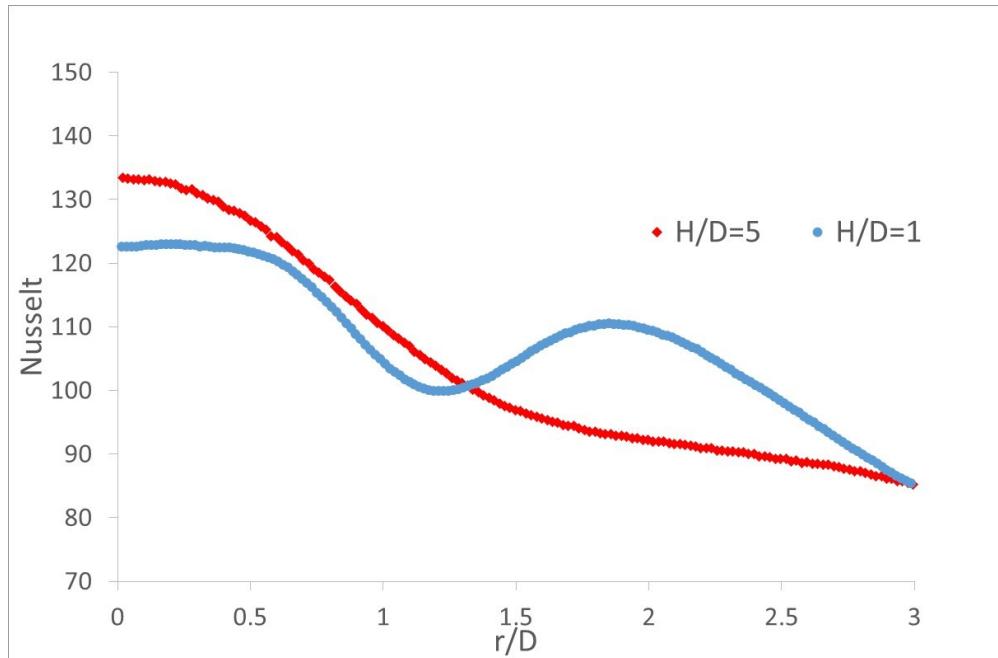
- Paramètres d'influence:
  - Distance d'impact H/D
  - Conditions d'injection
  - Nature et condition de la paroi d'impact
  - ...

- Paramètres d'influence:
  - Distance d'impact  $H/D$ 
    - Dynamique

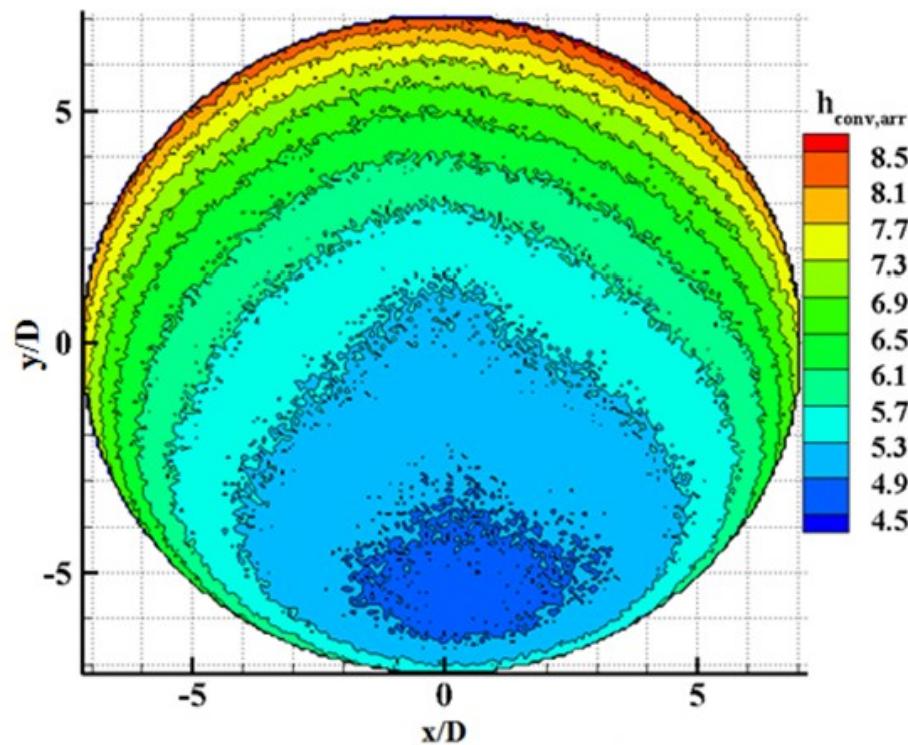




- Paramètres d'influence:
  - Distance d'impact  $H/D$ 
    - thermique



- Paramètres d'influence:
  - Conditions d'injection
    - *M=nb de Mach*
    - *Profil et forme d'injection*



- Résultats thermiques:

