Coupling of a Jet-Slot Oscillator With the Flow-Supply Duct: Flow-Acoustic Interaction Modeling

M. Glesser[1], A. Billon[1], V. Valeau[2], and A. Sakout[1]
mglesser@univ-lr.fr

[1]LEPTAB
La Rochelle University, France

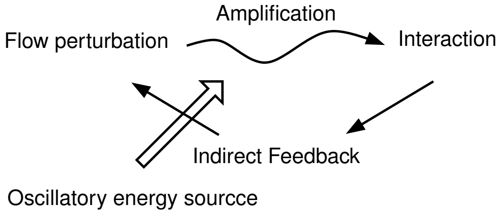
[2]LEA
Poitiers University, France

12th AIAA/CEAS Aeroacoustics Conference, May 2006

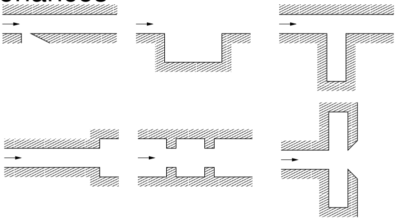
Outline

Basic principle

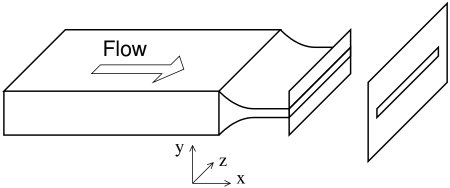
- Scheme of the feedback loop [Powell, 1990]



- Highltly energetic whistling is produced
- Geometrical configuration producing flow-induced acoustic resonances



Coupling of a Jet-Slot Oscillator With the Flow-Supply Duct



Billon et al.
Two Feedback Paths for a Jet-Slot Oscillator
Journal of Fluids and Structures, 21:121–132, 2005.

An expression for the flow-acoustic interactions modeling

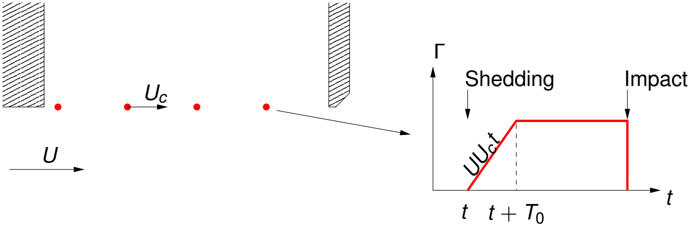
- Flow-induced acoustic resonances = acoustic resonance + flow-acoustic interactions
- Acoustic power generated or absorbed by flow-acoustic interactions:

$$\mathcal{P} = -\left\langle \rho_0 \iiint_V (\omega \wedge \boldsymbol{v}) . \boldsymbol{u_a} dV \right\rangle_{T_0}$$

  - ω: vorticity field
  - $\boldsymbol{v}$: vortices convection speed
  - $\boldsymbol{u_a}$: acoustic velocity field
- Emitted frequency $=>$ maximization of $\mathcal{P}$

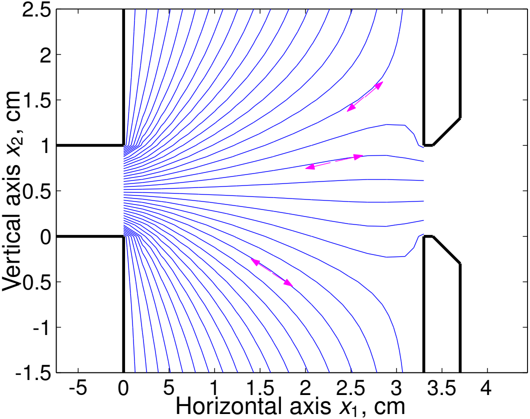
Vorticity Field Modeling

Vortex-point model [Nelson, 1983 & Bruggeman, 1987]



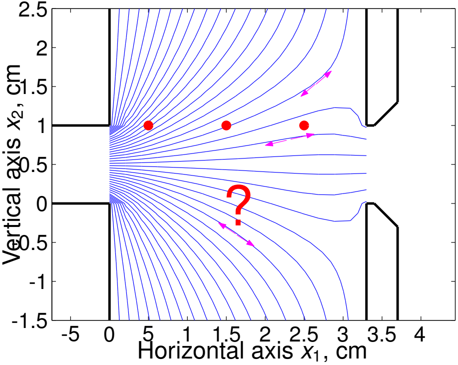
- Vortices convected in a straigth path
- Vorticity only concentrated on vortex cores
- Linear growth of the vortex circulation
- Saturation of the vortex circulation

Acoustic Field Modeling



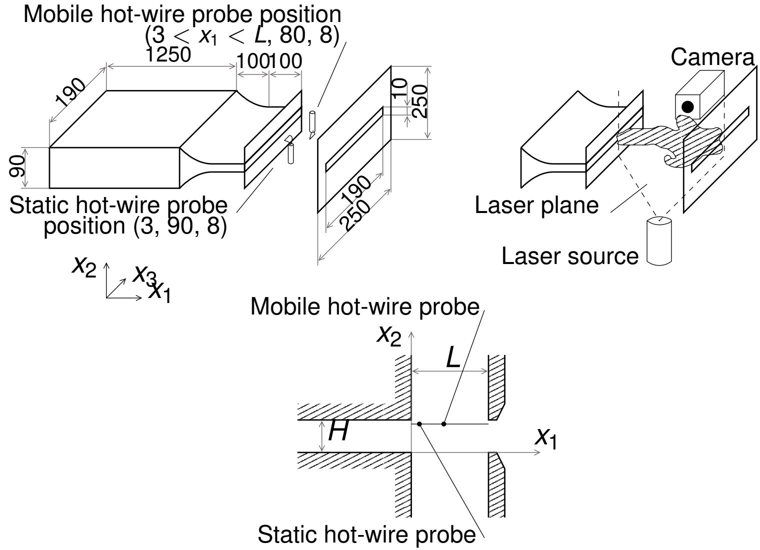
$$\boldsymbol{u_a} = \boldsymbol{\nabla}\varphi'(\boldsymbol{x}, t) = cos(2\pi f_0 t + \theta)\ \boldsymbol{\nabla}\left(\varphi'_{pot}(\boldsymbol{x})\right)$$

Missing Parameters

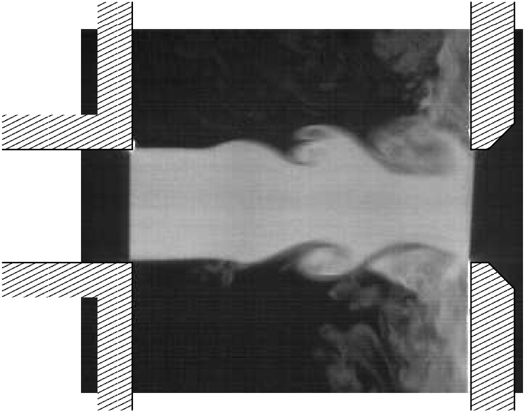


- Shape of the potential flow ?
- Acoustic field / vortex shedding synchronization ?
- Jet mode & Vortices convection speed

Experimental Set-up

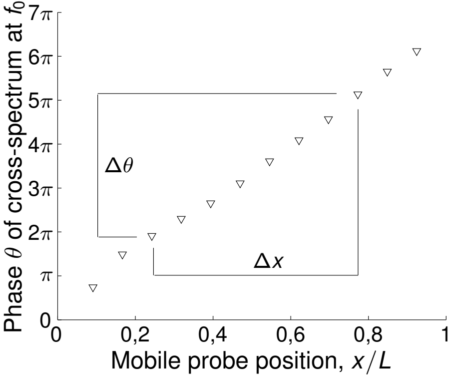


Jet Oscillation Mode



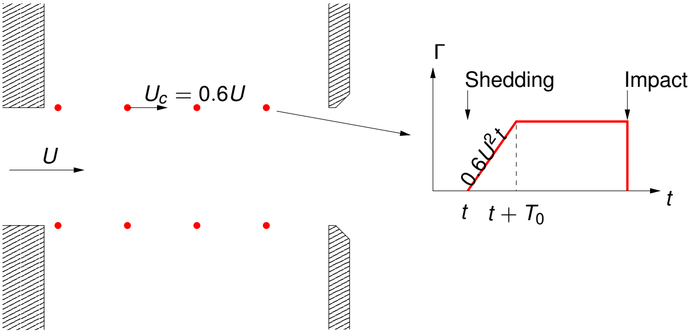
- Symmetric jet mode
- Rather constant vortices convection speed

Vortices Convection Speed

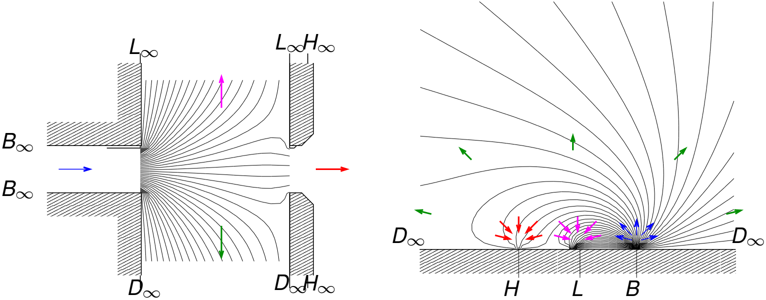


- Convection speed: $Uc = 2\pi f_0 \left(\frac{\Delta\theta}{\Delta x}\right)^{-1}$
- $Uc = 0.6U$

Fields Modeling 1
Vorticity Field



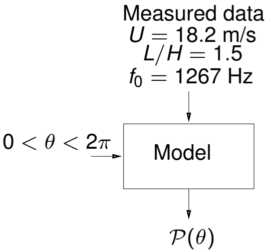
Fields Modeling 2
Acoustic Field

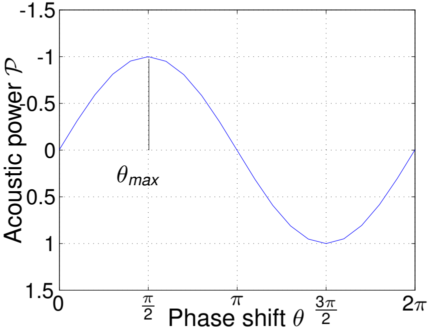


Physical plane ($z = x_1 + ix_2$) Canonical plane ($\zeta = \xi + i\eta$)

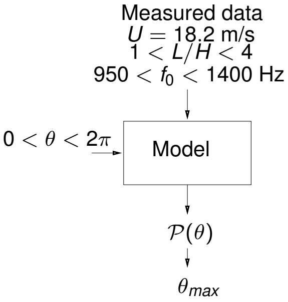
$$\varphi_0(\zeta) = \frac{M}{\pi}\log(\zeta - \xi_b) - \frac{(1-\alpha)M}{\pi}\log(\zeta - \xi_h) - \frac{(\alpha/2)M}{\pi}\log(\zeta - \xi_l)$$

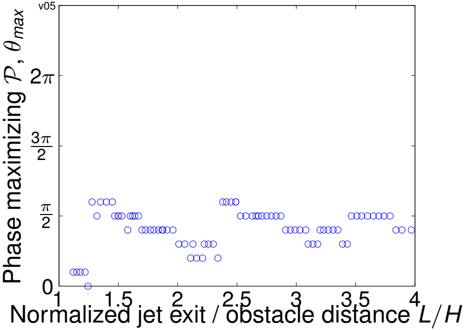
Acoustic/Vorticity Fields Synchronisation 1
Principle





Acoustic/Vorticity Fields Synchronisation 2
Result





Validation

Input data

$1 < L/H < 5$, $U = 18.2$ m/s

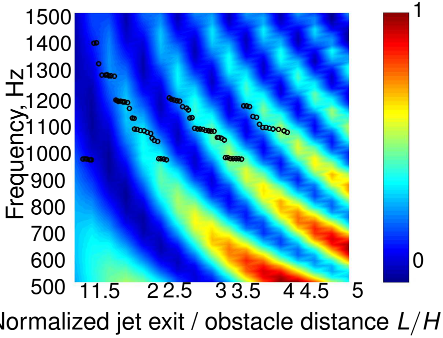
500 Hz $< f_0 <$ 1500 Hz

↓

Model

↓

$\mathcal{P}(L/H, f_0)$



Summary

- Development of a model for the flow-acoustic interactions involved in the coupling of a self-sustained oscillator with the flow-supply duct's resonance
- Frequency predictions

- Outlook
  - Better understanding of the optimal lock-in conditions
  - Emitted level prediction