



SYNDICAT MIXTE D'AMÉNAGEMENT
ET DE PROMOTION DE LA TECHNOPOLE DU MANS



UNION EUROPÉENNE
CE PROJET EST COFINANCÉ PAR
LE FONDS EUROPÉEN DE DÉVELOPPEMENT RÉGIONAL



Impedance of perforated and micro-perforated liners with grazing shear flow : Does the impedance make sense with flow ?

E. PORTIER – CTTM

X. DAI, Y. AUREGAN – LAUM

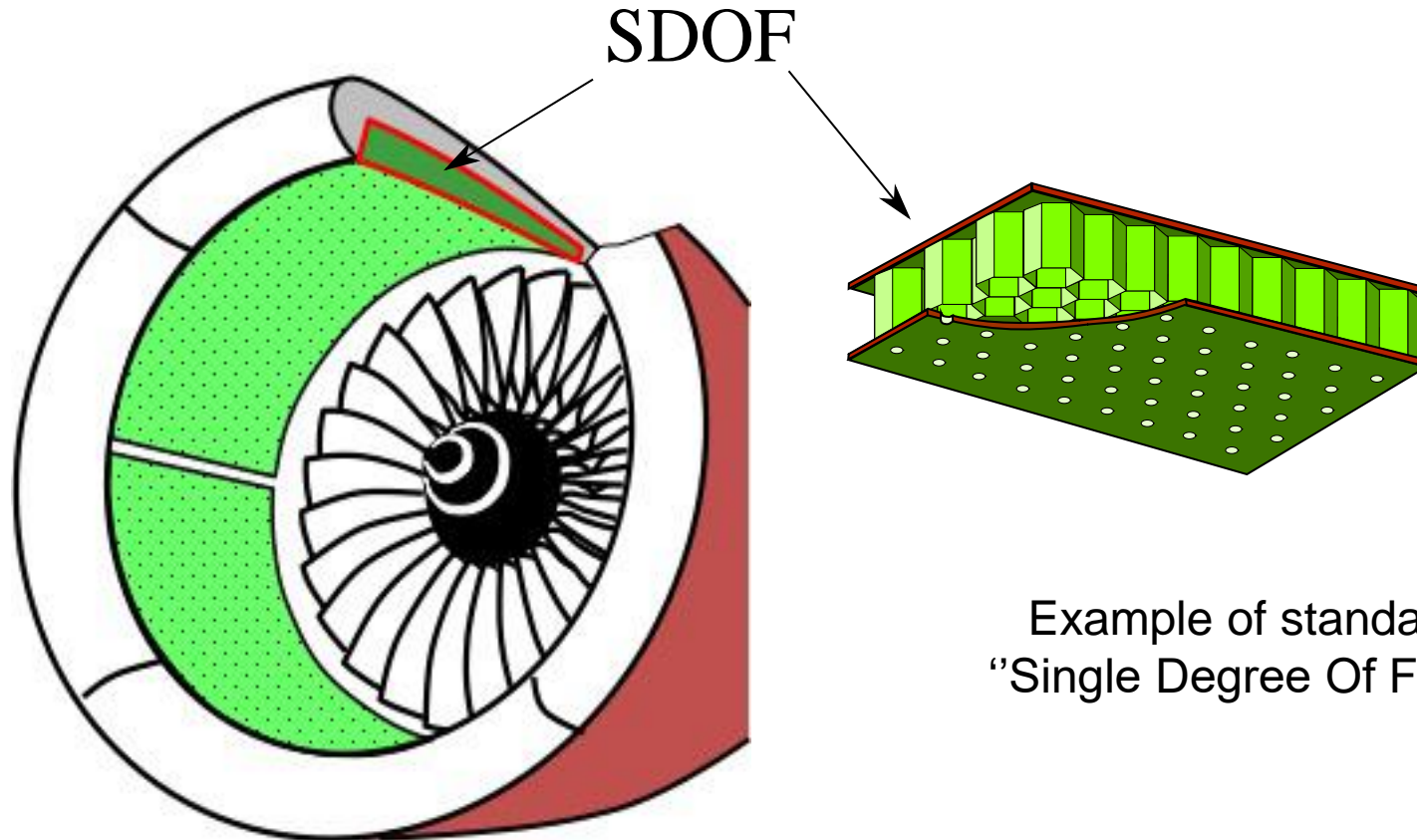
20th workshop of the Aeroacoustics Specialists committee of the CEAS
Measurement Techniques and Analysis Methods for Aircraft Noise

www.cttm-lemans.com

Context

Surface Impedance Measurement of « liners »

- Acoustic treatment of engine nacelles

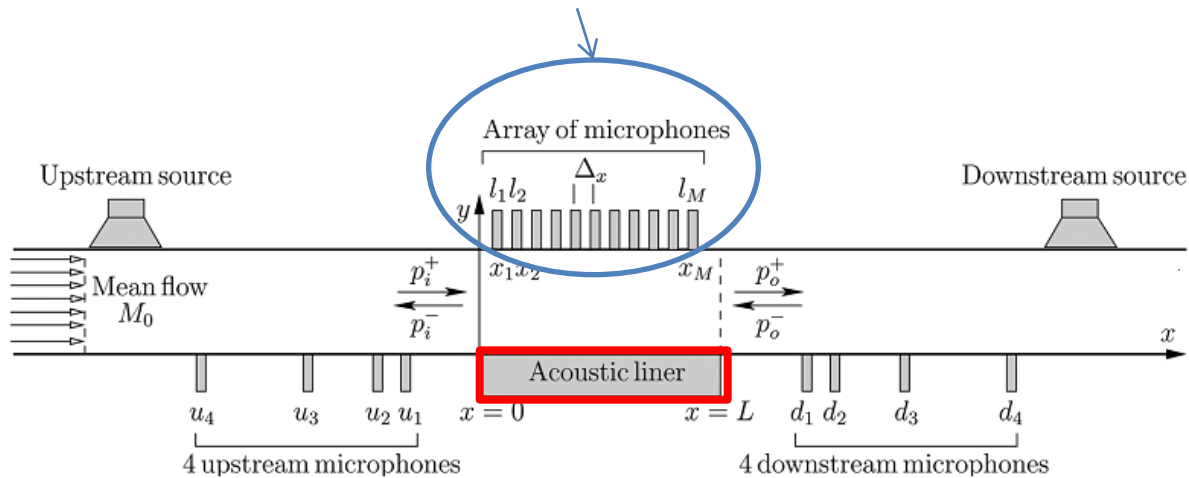


Example of standard treatment
“Single Degree Of Freedom liner”

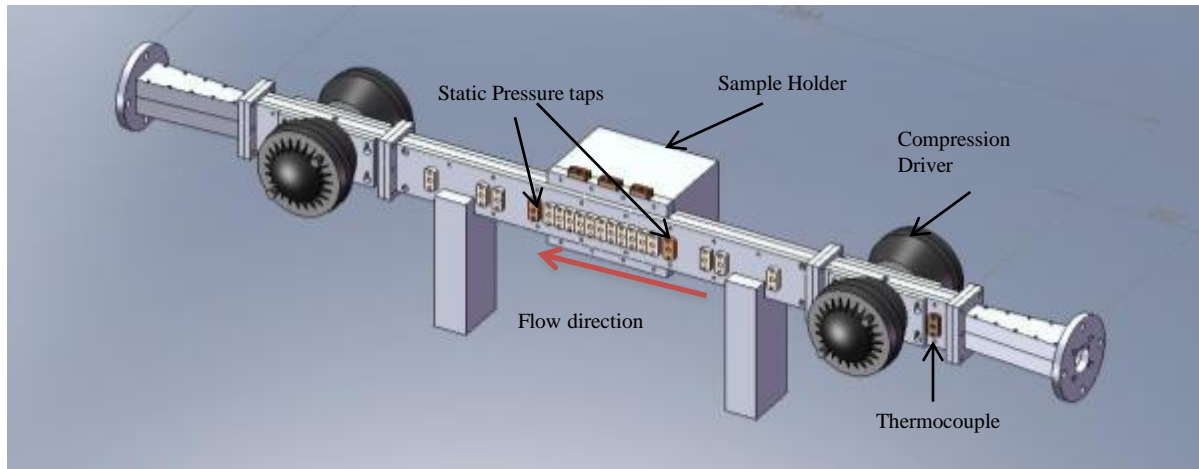
Experimental Set-Up

Measurement of the wave numbers on a dedicated test bench with flow

method using a microphone array



Experimental Set-Up



CTTM Design
Located at LAUM

Main Characteristics

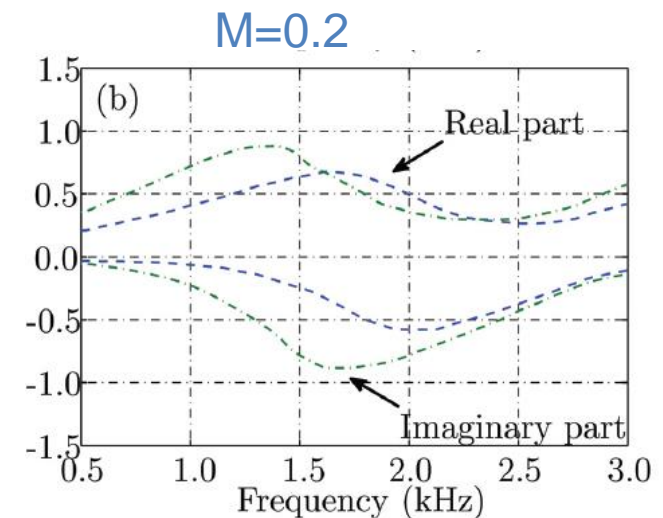
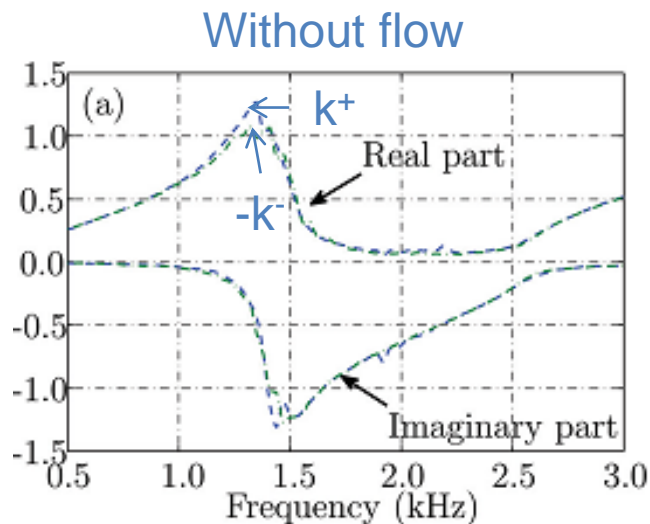
- Rectangular section 20 x 50 mm
- Sample 50 x 200 mm
- 11 x ¼" B&K pressure microphones
- **Maximum Mach Nb ~ 0,5**
- **Maximum excitation level (sinus) ~160 dB**
- Up to ~6 kHz (apparition of the 2nd transverse mode)



Measurement of axial wavenumbers

- We consider only the least attenuated mode : plane wave mode
- Modal decomposition of the pressure opposite to the lined wall

$$p_m = \sum_{n=0}^{\infty} b_n^+ e^{-ik_n^+(x_m-x_1)} + \sum_{n=0}^{\infty} b_n^- e^{-ik_n^-(x_m-x_1)}, m = 1 \dots M$$



First Method : Impedance Eduction with Uniform flow and Ingard-Myers BC

Impedance of a locally reacting liner

$$Z_w = \frac{p}{v_w}$$

Pressure
Normal acoustic velocity

Assuming a continuity of acoustic displacement (Ingard-Myers BC)

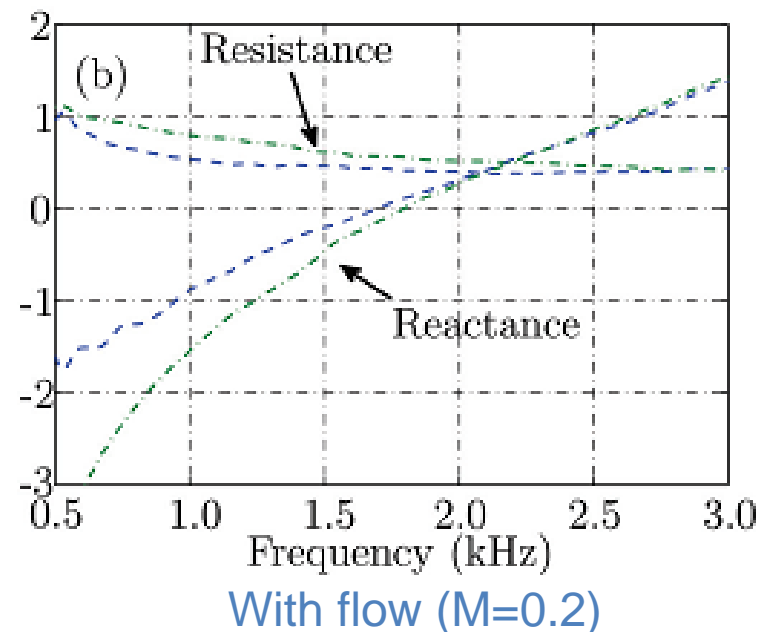
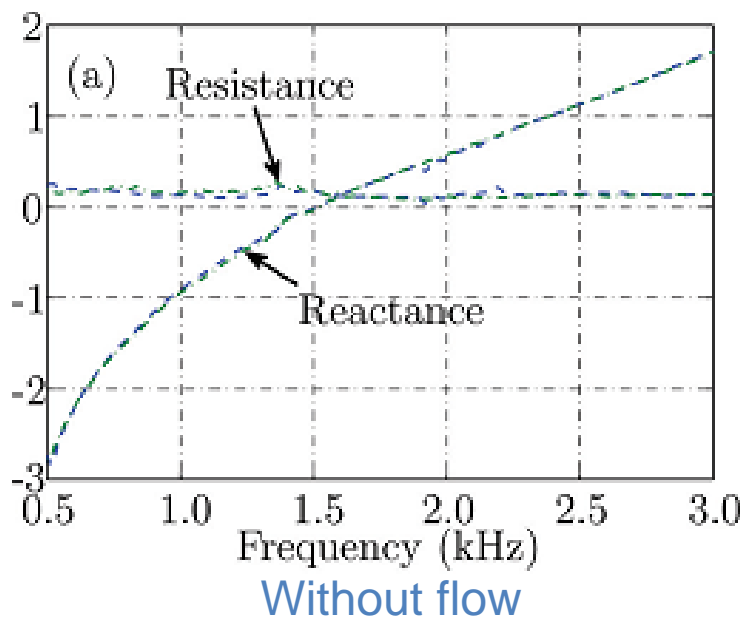
➤ Dispersion equation $k_y^2 = (\omega - M_0 k)^2 - k^2$

➤ Wall impedance $k_y \tan(k_y) = \frac{(i\omega - iM_0 k)^2}{i\omega Z_w}$

=> Resolution of the impedance Z_w

First Method : Impedance Eduction with uniform flow and Ingard-Myers BC

- Two wall impedances are calculated for both downstream and upstream acoustic propagation
- Renou and Aurégan (LAUM) in 2011 showed that they dramatically vary according to the flow



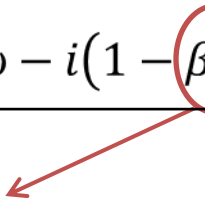
Which one is the right one ?

Y. Renou and Y. Aurégan,

Failure of the Ingard-Myers boundary condition for a lined duct: an experimental investigation,
The Journal of the Acoustical Society of America, **130**, 52-60, (2011)

First Method : Impedance Eduction with uniform flow and Ingard-Myers BC

They proposed a modified Ingard-Myers BC to obtain a single impedance :

$$k_y \tan(k_y) = \frac{(i\omega - i(1 - \beta_v)M_0 k)(i\omega - iM_0 k)}{i\omega Z_w}$$


Between 0 and 1 (Computed from measurements)

$\beta_v=0$: continuity of the acoustic displacement (Ingard-Myers BC)

$\beta_v=1$: continuity of acoustic velocity

What can the explanation be for this difference in the impedances deduced from upstream and downstream propagations?

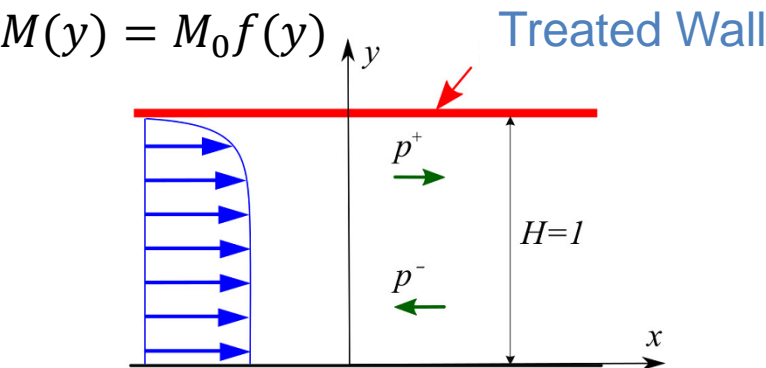
- **Effect of viscosity?**
- **Effect of the shear flow?**
- **Intrinsic problem in the impedance definition?**

Y. Renou and Y. Aurégan,

Failure of the Ingard-Myers boundary condition for a lined duct: an experimental investigation,
The Journal of the Acoustical Society of America, **130**, 52-60, (2011)

Second Method : Impedance Eduction in shear flow

- Assumption : a shear flow effect ?
- Integration of Pridmore-Brown equation



$$dP/dy = YP \quad \text{Measured wavenumbers}$$

$$\frac{dY}{dy} = -Y^2 - \frac{2M_0 k}{\omega - M_0 f k} \frac{df}{dy} Y - (\omega - M_0 k f)^2 + k^2$$

Shape of the mean velocity profile

Integration with a Runge-Kutta scheme (4th order) with

- $y=0, Y(0)=0$ (no viscosity in the hard-wall)

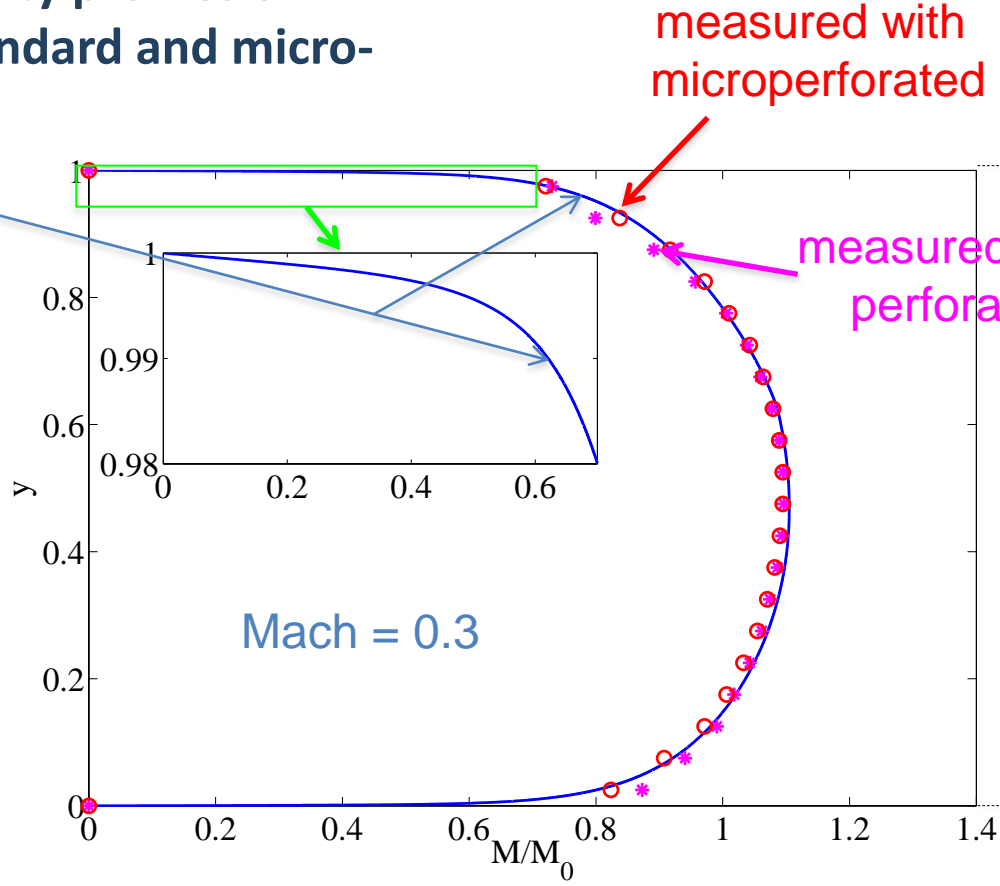
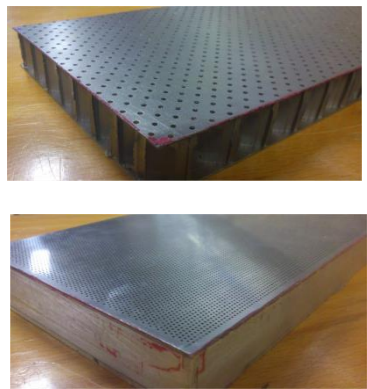
Equivalent liner impedance :

$$Z_{eq} = -i\omega / Y(1)$$

Second Method : Impedance Eduction in shear flow

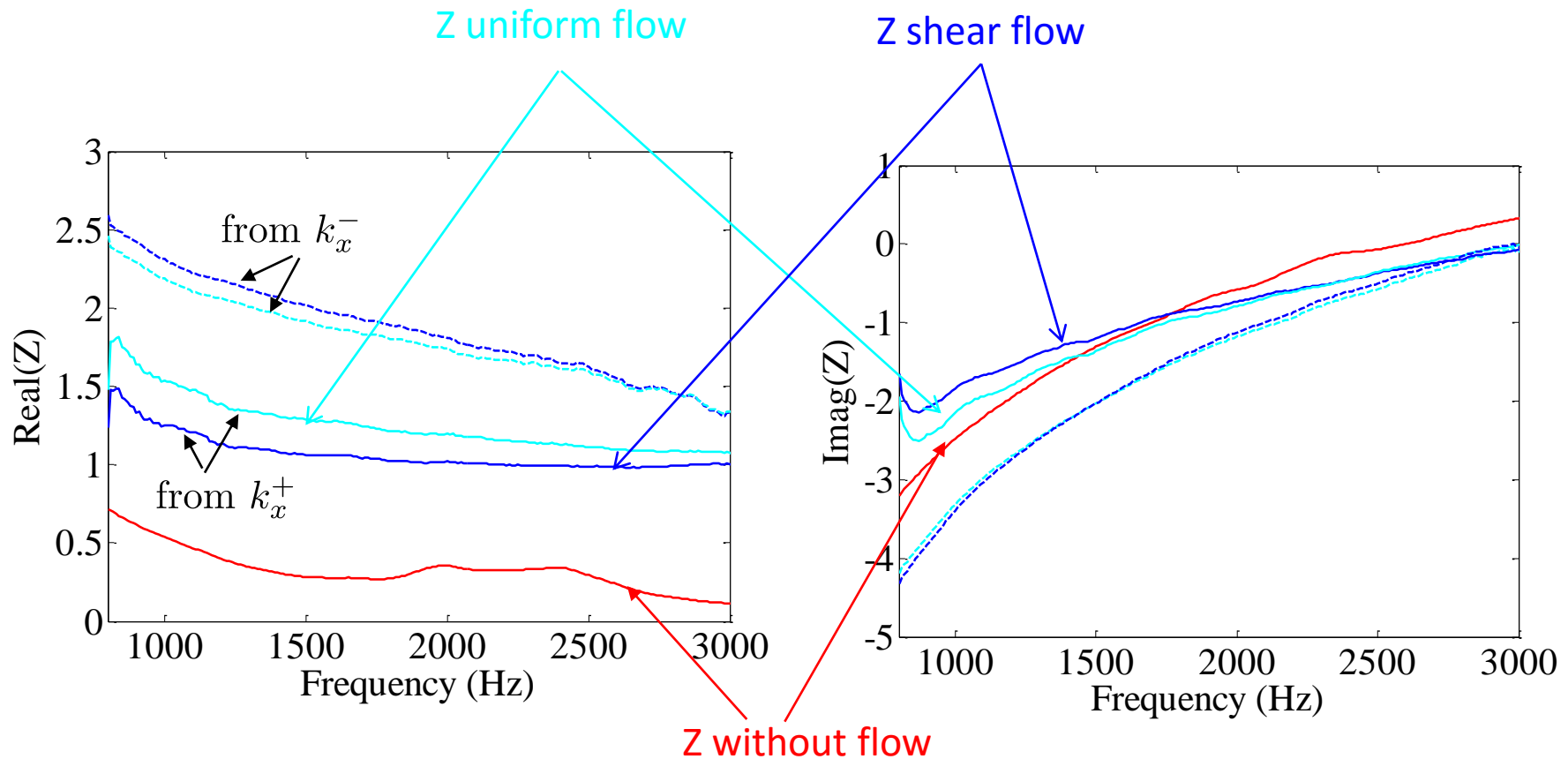
Mean velocity profiles on two liners : standard and micro-perforated

Cess model
 $u_\tau = 4.792 \text{ m/s}$



Second Method : Impedance Eduction with integration of the Pridmore-Brown equation

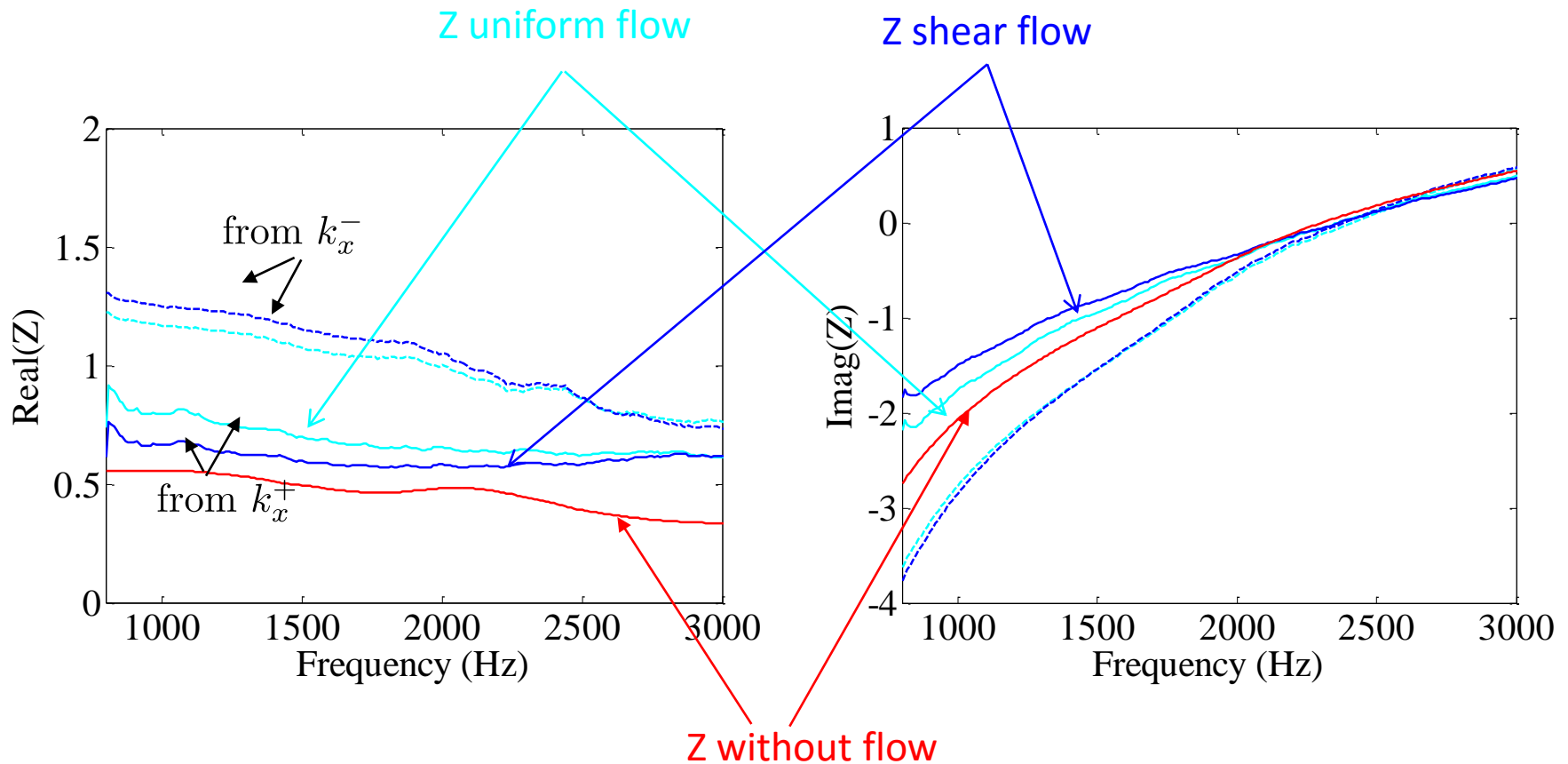
Standard Perforated liner



When a shear flow is considered, the gap between the two impedances is even more pronounced !

Second Method : Impedance Eduction with integration of the Pridmore-Brown equation

Micro-Perforated liner



Same behaviour

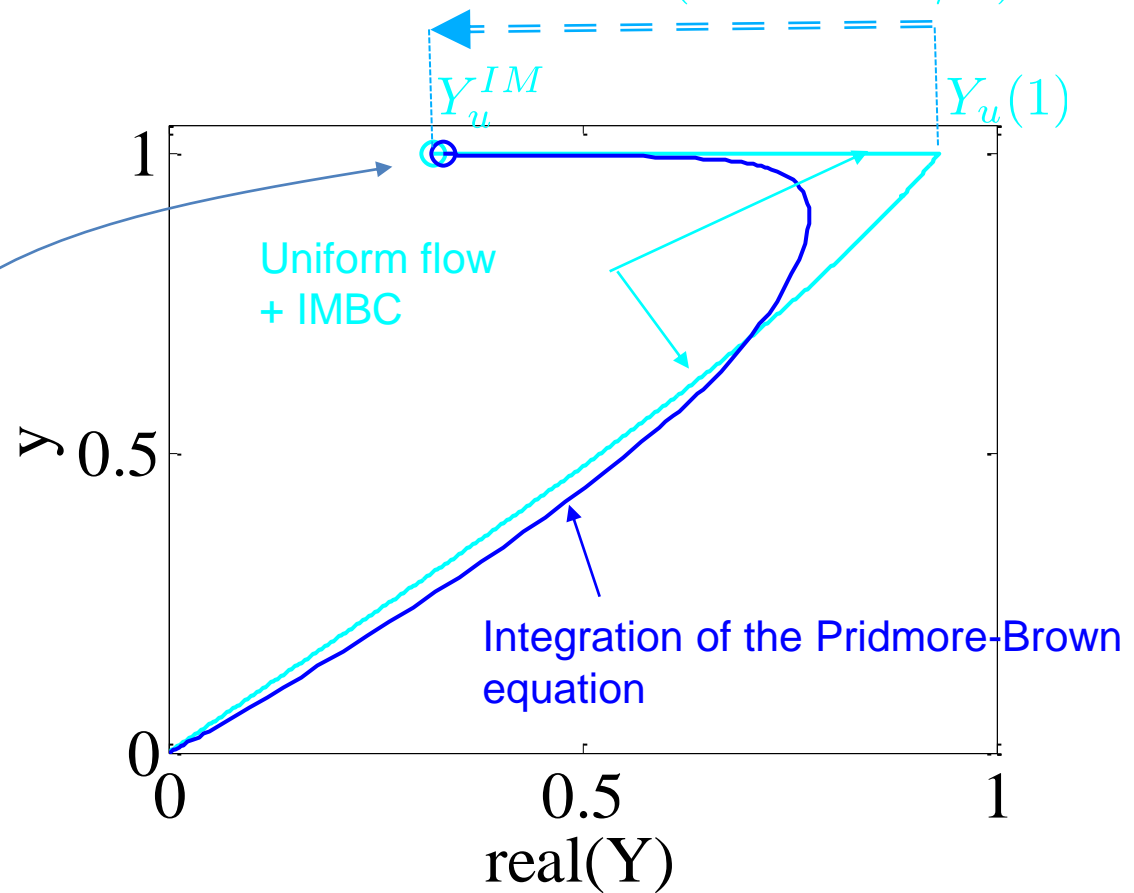
Comparison between the two methods

Shape of the admittance for standard case

$$Y_u^{IM} = \frac{Y_u(1)}{(1 - M_0 k c_0 / \omega)^2}$$

$$dP/dy = YP$$

$$Z_{eq} = -i\omega/Y(1)$$



The impedance is nearly the same close to to the liner

Conclusion

- ✔ There is a systematic difference in the impedances deduced from upstream and downstream propagations.

This has been verified at CTTM and at LAUM on a very large number of samples (industrial and academic) on various conditions of flow and SPL.

- ✔ This difference cannot be explained by shear flow effects.
- ✔ We have demonstrated that this difference appears even when no viscosity is present. (X. Dai and Y. Aurégan, AIAA paper and JASA)

→ There is an intrinsic problem in the definition of impedance with flow

