A New Device for Fluid Equivalent Parameters Assessment

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1 Introduction

Several experimental methods have been developed for the estimation of poro-elastic fluid equivalent parameters: low or high frequencies acoustical methods, non acoustical methods. Low frequencies acoustical methods [1, 2, 3,] are based on the measurements of the equivalent dynamic density and bulk modulus of the porous medium. They can be divided into analytical and inverse methods. The advantage of these methods is that they do not require specific or expensive equipment. However, most of these methods require prior knowledge or estimation of the static flow resistivity and open porosity.

In this paper, we present a new approach based on the use of an impedance sensor [4] with significant low frequency extension than classical duct methods. Dynamic density and bulk modulus are therefore measured over a wide frequency range, and the static air flow resistivity and open porosity can be directly obtained from the low frequency asymptotes (of the equivalent dynamic density and bulk modulus), an approach which is not possible with classical duct methods. The remaining fluid equivalent parameters can be analytically obtained from the same measurements using the well-known analytical methods [1,2].

2 Description of the Method

The proposed approach uses an impedance sensor developed by CTTM and LAUM [4]. This sensor performs accurate impedance measurements at low frequencies. Typically, the frequency range 20Hz – 5000Hz can be covered which offers new possibilities compared to multi-microphones duct measurements methods.

The porous density and bulk modulus are obtained from the measurement of two impedances (Figure 1). The surface impedance of the porous sample is measured for two mounting conditions:

- Z_s^∞ is the measured surface impedance with a rigid back (infinite impedance),
- Z_s^A is the measured surface impedance with the sample loaded by the impedance Z_A.

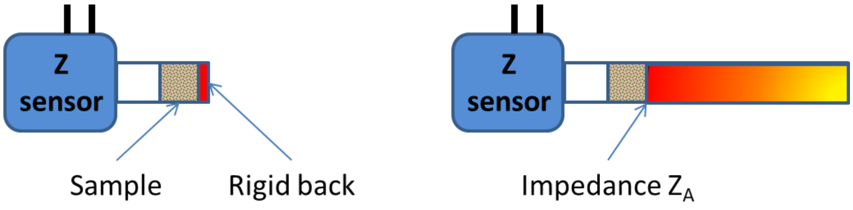

Figure 1: Measurement procedure with two acoustic loads

Then, the equivalent characteristic impedance and wave number of the porous media are given by:

$$Z_{eq}^2 = Z_s^A(Z_A + Z_s^\infty) - Z_A Z_s^\infty$$
$$k_{eq} = \arctan(-jZ_{eq}/Z_s^\infty)/d$$

where d is the sample thickness. Dynamic density is calculated with $\rho_{eq} = Z_{eq}k_{eq}/\omega$ and bulk modulus with $K_{eq} = \omega Z_{eq}/k_{eq}$.

Considering the poroelastic media described by the JCAL model [5], the low frequency asymptotes of dynamic density and dynamic bulk modulus allow the estimation of the open porosity ϕ and the static air flow resistivity σ by:

- $\phi = P_0 / \lim_{\omega \to 0} \left(real(K_{eq}) \right)$
- $\sigma = -\omega \times \lim_{\omega \to 0} \left(imag(\rho_{eq}) \right)$

where P_0 is the atmospheric pressure.
To optimise the approach, it is better to take non resonant acoustic loads. Thus, for the impedance Z_A, we have chosen a high performance and compact anechoic end [6].

3 Results

Figure 2 below presents some results for the estimation of open porosity and static air flow resistivity, showing that measurement below 100Hz are often requested to reach asymptote value of the parameters.

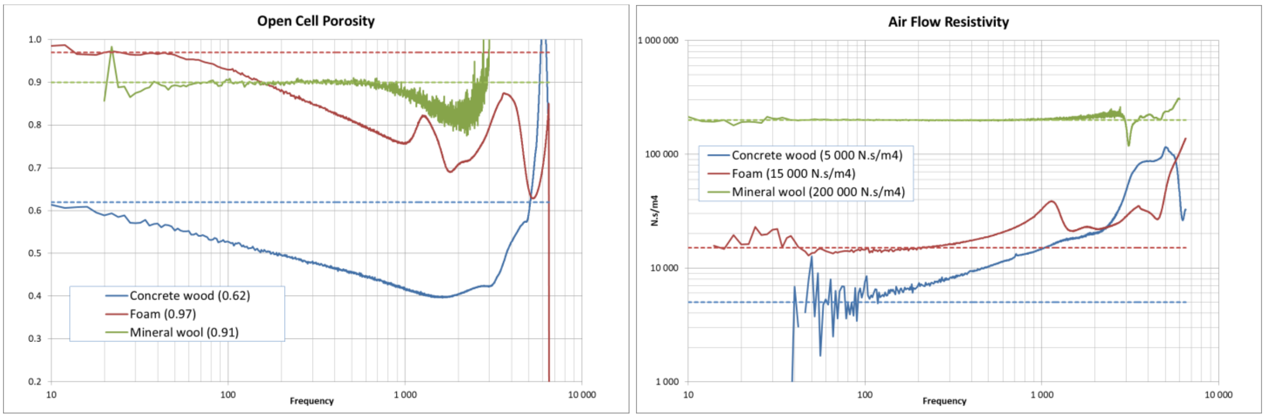

Figure 2: Example of open porosity and static air flow resistivity estimation. Dotted lines correspond to final parameter estimation.

In the presentation, we will show that the proposed method allows the analytical estimation of the complete set of poro-elastic fluid equivalent parameters with only one compact device. All parameters are estimated from the same sample, and with the same mounting condition, thus providing the method with increased accuracy.

4 References

[1] R. Panneton and X. Olny, "*Acoustical determination of the parameters governing viscous dissipation in porous media"* , J. Acoust. Soc. Am. 119. 2027-2040 (2006),
[2] X. Olny and R. Panneton, "*Acoustical determination of the parameters governing thermal dissipation in porous media"* , J. Acoust. Soc. Am. 123. 814-824 (2008),
[3] M. Niskanen, J.-P. Groby, A. Duclos, O. Dazel, J. C. Le Roux, N. Poulain, T. Huttunen, and T. Lahivaara, "*Deterministic and statistical characterization of rigid frame porous materials from impedance tube measurements"*, J. Acoust. Soc. Am., **142**: 2407-2418, 2017.
[4] J.C. Le Roux, J.P. Dalmont,"A New Impedance Sensor for Industrial Applications", *Acoustics 2012, Nantes, France* (2012)
[5] D. Lafarge, P. Lemarinier, J.-F. Allard and V. Tarnov, "*Dynamic compressibility of air in porous structures at audible frequencies*", J. Acoust. Soc. Am. 102. 1995-2006 (1997),
[6] F. Fohr, E. Portier, "*Conduit comprenant au moins une terminaison anéchoique…",* French patent FR 1771310 (2017).