10ème Congrès Français d'Acoustique
Lyon, 12-16 Avril 2010

Measurement of mechanical properties of porous materials using an ironless electrodynamic transducer

Nicolas DAUCHEZ[1], Olivier DOUTRES[2], Jean-Michel GENEVAUX[2], Guy LEMARQUAND[2], Sylvain MEZIL[2]
[1]Supméca, 3, rue Fernand Hainaut, F-93407 Saint Ouen cedex, nicolas.dauchez@supmeca.fr
[2]Laboratoire d'Acoustique de l'Université du Maine, Av. O. Messiaen F-72085 Le Mans cedex 9

A new set-up to measure the complex Young's modulus of porous materials is presented. It is an extension of the classic quasistatic method in compression towards high frequencies. It is based on the use of a specific highly linear loudspeaker as actuator and sensor. Results are obtained up to 500 Hz for a sound absorbing polymer foam.

1 Introduction

A new method for measuring viscoelastic properties of sound absorbing materials is presented. This method is derived from the quasistatic method [1,2] using a loudspeaker as actuator and sensor. Previous results carried out with a traditional electrodynamic loudspeaker were limited to 100 Hz because of transducer nonlinearities [3,4]. In this paper, viscoelastic properties are determined up to 500 Hz due to the design of a specific loudspeaker devoid of the main nonlinearities.

2 Experimental set-up

The proposed set-up is presented in Fig. 1. The porous sample is compressed in the top cavity using a specific electrodynamic transducer. The use of a cavity allows to carry out measurements in ambient conditions: it avoids a lateral airflow which can induce an overestimation of the porous material loss factor [5,6,7]. In opposition to the electrodynamic shaker used in the quasistatic method [1,2], the use of a loudspeaker as an actuator allows to excite the porous sample in the relevant frequency range for noise control applications. Indeed, such transducers are originally designed to radiate in the audible frequency range.

In the proposed method, the viscoelastic properties of the frame are derived from the mechanical impedance of the porous sample by inverse method using the Biot's model. This impedance is estimated from the measurement of the transducer electrical impedance and a model of its electro-mechanic behaviour [3,4]. The method requires the 4 steps (Fig. 2). The experimental set-up is thus considerably simplified but it requires in exchange a transducer as linear as possible to fit the Thiele and Small model [8].

Thereto, the transducer presented in Fig. 1 is made of a voice-coil motor such as those used in traditional electrodynamic loudspeakers but with major improvements [9]:

- the magnetic structure is ironless and is designed to vanish the major electrical nonlinearities,
- the viscoelastic suspension is replaced by two ferrofluid seals which help avoiding nonlinearities in the motion of the piston.

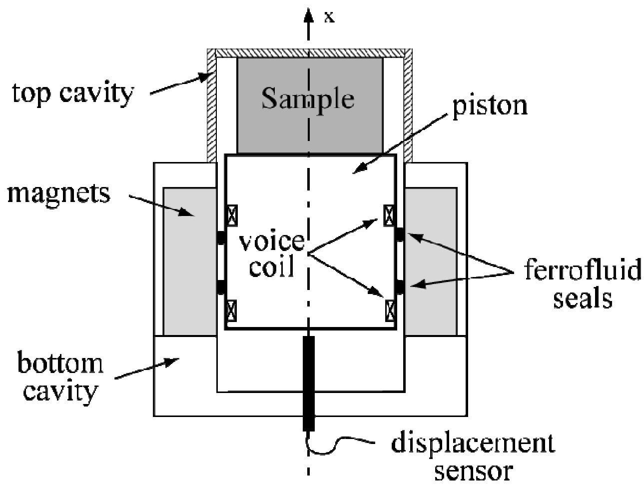

Figure 1: Experimental set-up.

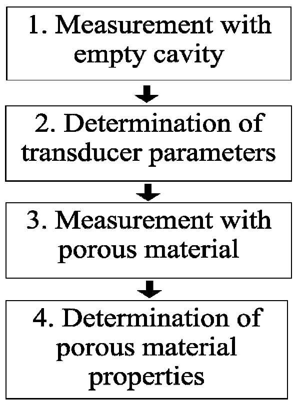

Figure 2: The 4 steps of the method.

3 Results

The method has been applied to one polymer foam. Results obtained with this method are presented in Fig. 3. Results are given up to 1000 Hz (square with errorbars) and are compared to the results given by the classical compression quasistatic method (circle) up to 100 Hz.

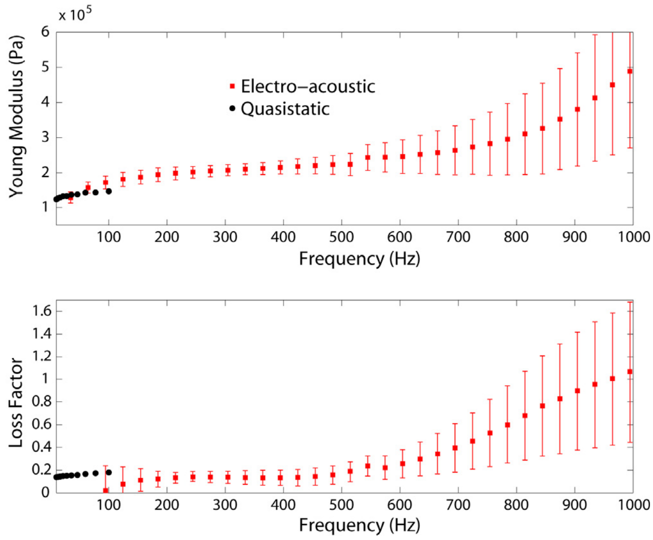

Figure 3: Measured viscoelastic properties of a foam sample by quasistatic (circle) and electro-acoustic (square with errobars) methods.

Results are satisfactory with the new electroacoustic method up to 500 Hz. Note that contrary to the previous test bench using a traditional electrodynamic loudspeaker [3], the uncertainties is the lower around the frequency resonance of the transducer, 350 Hz in this case. This shows the benefit to use ironless magnetic parts together with ferrofluid seals.

4 Conclusion

A new device to determine the viscoelastic properties of porous materials has been presented: it is based on an electrodynamic transducer used both as source and sensor. The setup is thus simplified compared to a classical compression quasistatic method. This setup is based on a linear transducer that has been optimized to allow a static compression of 10 mm, what cannot be performed with a classical shaker or loudspeakers. The transducer has also been designed so that the moving part behaves as a rigid solid body in an extended frequency range.

Results given by this method are in good agreement with classical method and are valid for frequencies up to 500 Hz. The air-pumping effect is also prevented by the use of a cavity what avoid the overestimation of the loss factor. The method could be extended in the higher frequency range by optimizing the mass of the moving piston and the sizes of the cavities.

For a more detailed description of the set-up, please refer to [10].

Acknowledgements

The authors are grateful to the C.N.R.S., Région Pays de la Loire and the European Commission (CREDO project - Contract no.: 030814) for their financial support, and to B. Merit for its contribution to design the magnetic part of the transducer.

References

[1] Dauchez N., Etchessahar M., Sahraoui S., On measurement of mechanical properties of sound absorbing materials, 2nd Biot conference on Poromechanics, 2002

[2] Mariez E., Saharoui S., Elastic constants of polyurethane foam's skeleton for Biot model, Internoise, Liverpool, 951–954, 1996

[3] Doutres O., Dauchez N., Genevaux J.M., Lemarquand G., On the use of a loudspeaker for measuring the viscoelastic properties of sound absorbing materials, J. Acoust. Soc. Am., 124 (6), EL335-EL340, 2008

[4] Doutres O., Dauchez N., Genevaux J.M., Lemarquand G., A new set-up for measuring the mechanical properties of porous materials, proceeding of Acoustics 08, Paris, 2008

[5] Tarnow V., Dynamic measurements of the elastic constants of glass wool, J. Acoust. Soc. Am. 118(6), 3672-3678, 2005

[6] Pritz T., Transfert function method for investigating the complex modulus of acoustic materials: spring-like specimen, J. Sound Vib. 72(3), 317-341, 1980

[7] Jaouen L., Renault A., Deverge M., Elastic and damping characterizations of acoustical porous materials, Appl. Acoust. 69, 1129–1140, 2008

[8] Small R.H., Closed-box loudspeakers systems, part 1: analysis, J. Audio Eng. Soc. 20, 798-808, 1972

[9] Lemarquand G., Ironless Loudspeakers, IEEE Trans. Mag., 43 (8), 3371-3374, 2007

[10] Doutres O., Dauchez N., Genevaux J.M., Lemarquand G., S. Mézil, Ironless transducer for measuring the mechanical properties of porous materials, submitted to Review of Scientific Instruments, 2010