The Test Principles of Biot Properties of Poro-Elastic Material and Its Engineering Validation

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As we well known, porous materials, because of its best absorption performance, have been widely used in the field of noise reduction. Its theoretical research is becoming more and more perfect, the most classic is Biot theory. The full poro-elastic Biot model for materials involves in the fluid and elastic properties. How to obtain these characteristic parameters correctly is the key for acoustic research. In this presentation we will introduce the basic test principle from the definition of Biot parameters and the applicable standards or methods. Finally, the correctness and practicability are verified by some engineering cases.

1 Introduction

In this presentation, I will explain how to obtain the parameters of bio model by experimental method from the following aspects:

- What about conventional porous materials in acoustics?
- Conventional theoretical models of porous materials.
- The definition of Biot parameters and related test standards and methods.
- Introduction of test equipment for Biot parameters.
- Engineering validation.

2 General information

2.1 The basic characteristics of porous materials

- Two phases: solid and fluid
- Elastic coupling
- Visco-inertial coupling
- Energy dissipation
  - viscous effect
  - thermal effect
  - structural damping

2.2 Macroscopic model

- 5-parameter Johnson-Champoux-Allard (JCA) model
- 6-parameter Johnson-Champoux-Allard-Lafarge (JCAL) Model
- 9-parameter Biot poro-elastic model

2.3 Biot parameters and related test standards and methods.

The popular parameters include: Open porosity, Static airflow resistivity, Tortuosity, Viscous characteristic length, Thermal characteristic length, Young’s modulus, Poisson’s ratio, Damping loss factor.

Parameters	*Definition*	*Standard*	*Method*
Porosity (ϕ)	$\phi = \frac{V_{fluid}}{V_{total}}$	N/A	Pressure/mass method
Bulk Density(ρ)	$\rho = \frac{m_s}{V_t}$	N/A	Pressure/mass method
Airflow Resistivity (σ)	$\sigma = \frac{\Delta P}{Q}\frac{A}{h}$	ISO 9053	Direct method

Tortuosity(α_∞)	$\alpha_\infty = \left(\frac{L'}{L}\right)^2$	N/A	Ultrasound method
Viscous characteristic length(Λ)	$\Lambda = 2\int_V v^2 dV \Big/ \int_S v^2 dS$	N/A	Ultrasound method
Thermal characteristic length(Λ')	$\Lambda' = 2\int_V dV \Big/ \int_S dS$	N/A	Ultrasound method
Young's modulus(E)		ISO 18437-5	Quasi-static compression test
Poisson's ratio(ν)		ISO 18437-5	Quasi-static compression test
Damping loss factor(η)		ISO 18437-5	Quasi-static compression test

Table 1 : Biot parameters and their test standards

2.4 Engineering validation

The comparison is given in figure 1. Very good agreement is observed.

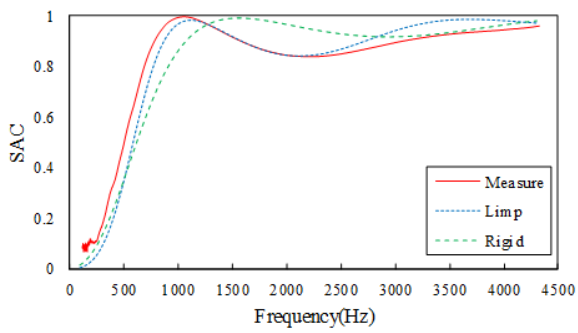

Figure 1 : The comparison between test and theoretical computation

References

[1] Allard J.F. & Atalla N., Propagation of sound in Porous media: Modelling Sound Absorbing Materials. 2e. John Wiley & Sons Ltd., 2009.

[2] INTERNATIONAL STANDARD, ISO 18437-5, Mechanical vibration and shock -- Characterization of the dynamic mechanical properties of visco-elastic materials -- Part 5: Poisson ratio based on comparison between measurements and finite element analysis, First edition, 2011.

[3] INTERNATIONAL STANDARD, ISO 9053-1, Acoustics – Determination of airflow resistance – Part 1: Static airflow method.

[4] Y. Salisssou and R. Panneton, "Pressure/mass method to measure open porosity of porous solids," J. Applied Physics 101, 124913, 1-7 (2007).

[5] J.-F. Allard, B. Castagnède, M. Henry, W. Lauriks, "Evaluation of tortuosity in acoustic porous materials saturated by air," Rev Sci. Instrum. 65, 754–755 (1994).

[6] Z.E.A. Fellah, S. Berger, W. Lauriks, C. Depollier, C. Aristégui, J.-Y. Chapelon, "Measuring the porosity and the tortuosity of porous materials via reflected waves at oblique incidence," J. Acoust. Soc. Am. 113, 2424-2433 (2003).

[7] N. Kino, "Ultrasonic measurements of the two characteristic lengths in fibrous materials," Applied Acoustics 68, 1427-1438, 2007.