Determination of angle-dependent absorption coefficients of porous materials based on the modal decomposition method

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This paper presents a way to measure the angle-dependent absorption coefficients of porous materials in a rectangular waveguide. An optimization of microphone locations is made to make the method robust against the measurement noise. It is further validated experimentally.

1 Introduction

Impedance tubes are commonly used to determine the absorption coefficients of porous materials at normal incidence. The angle-dependent absorption coefficients can not be measured easily therein since only plane waves can propagate in the working frequency range of the impedance tubes [1]. Existing setups to measure the angle-dependent absorption coefficients are based on methods such as in-situ method [2] and spatial Fourier-transform method [3], both of which have drawbacks. The in-situ method suffers from requirement of large sample size. The spatial Fourier-transform method suffers from unrealistic long waveguide. In this paper, we propose to use the modal decomposition method to obtain angle dependent properties in a setup of a moderate size.

2 Methodology

The acoustic field inside a rigid rectangular waveguide can be regarded as a weighted sum of all cut-on modes [4]. As a mode can be regarded as acoustic plane waves of an oblique angle, the absorption coefficients of the corresponding oblique angles can be calculated from that of the modes. The absorption coefficient of each mode can be calculated by the scattering matrix, which is calculated by measuring the acoustic pressure at a sufficient number of points in the field for a sufficient number of independent sound source locations. If N is the total number of cut-on modes at a frequency, theoretically, at least $2\,(N+1)$ points need to be measured in the field and at least $2\,(N+1)$ independent measurements need to be performed.

An optimization is performed on the microphone locations to improve the matrix inversion stability when calculating the scattering matrix [5]. Figure 1 shows the in-house designed waveguide with microphone locations optimized between 1000 Hz and 3000 Hz.

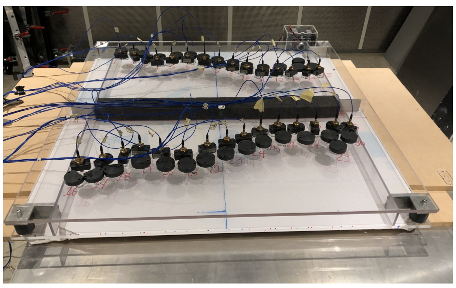
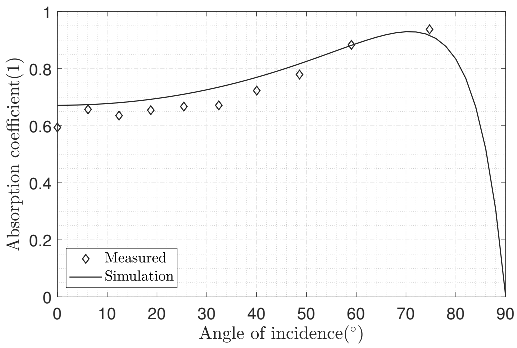


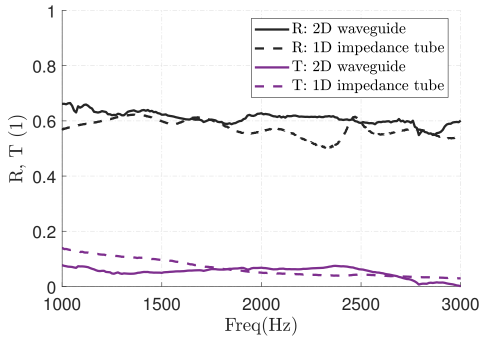
Figure 1: The waveguide designed and optimized between 1000 Hz and 3000 Hz

3 Results and discussion

A foam sample with known parameters is measured in the designed waveguide to validate the setup. In Figure 2 (left) a comparison is shown between the measurement from the designed waveguide and the simulation of the angle-dependent absorption coefficients at 2000 Hz. In Figure 2 (right) a comparison is shown between the measurement from the designed waveguide and that from an impedance tube of reflection and transmission coefficients at normal incidence.



(a)



(b)

Figure 2: (a) The angle-dependent absorption coefficients at 2000 Hz from simulation and from designed waveguide measurement (b) The reflection and transmission coefficients of a foam sample under normal incidence measured in the designed waveguide and in an impedance tube

4 Conclusions

In this work, it is shown that the modal decomposition method can be used to determine angle-dependent absorption coefficients of a porous sample. The method has been experimentally validated.

Acknowledgments

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References

[1] ISO. 10534-2: 2001. *Acoustics-Determination of sound absorption coefficient and impedance in impedance tubes-Part*, 2:10534–2, 2001.

[2] C Nocke. In-situ acoustic impedance measurement using a free-field transfer function method. *Applied Acoustics*, 59(3):253–264, 2000.

[3] Masayuki Tamura, Jean F Allard, and Denis Lafarge. Spatial fourier-transform method for measuring reflection coefficients at oblique incidence. ii. experimental results. *The Journal of the Acoustical Society of America*, 97(4):2255–2262, 1995.

[4] Mats Åbom. Modal decomposition in ducts based on transfer function measurements between microphone pairs. *Journal of Sound and Vibration*, 135(1):95–114, 1989.

[5] Ze Zhang, Hervé Denayer, Claus Claeys, Wim Desmet, and Elke Deckers. Angle-dependent reflection, transmission and absorption coefficients measurement using a 2d waveguide. *Applied Acoustics*, 177:107946, 2021.