Extension of frequency range of the eight-microphone method in normal-incidence sound absorption coefficient measurement

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1 Introduction

This study relates to a method for further increasing the upper limit frequency for measuring the normal-incidence sound absorption coefficient using eight microphones. With the conventional measurement method (so-called 2-microphone transfer function method [1]), the normal-incidence sound absorption coefficient can be measured when only the (0,0) mode can propagate in the impedance tube. By placing four microphones at 90 degree intervals on the same cross section and placing the tips of the microphones at the node of the radial (0,1) mode, it is possible to eliminate the influence of the circumferential (1,0) (2,0) (3,0) modes and the radial (0,1) mode. This makes it possible to measure the normal incident sound absorption coefficient up to a frequency band that is about three times higher than the conventional measurable upper limit frequency.

2 Method

The sound field inside the cylindrical tube with radius R, the acoustic modes generated in the cross-sectional direction inside the impedance tube are as shown in Figure 1. m and n represent the mode orders in the circumferential and radial directions of the impedance tube cross section respectively. λ_{mn} is a value of kR that satisfies the boundary condition equation 1 on the wall surface of the impedance tube.

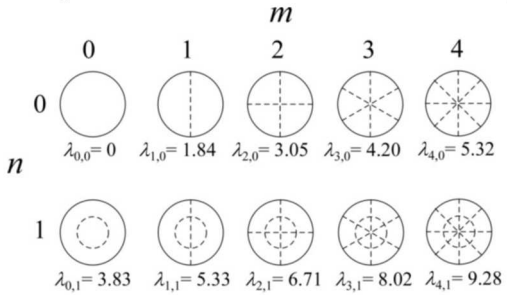

Figure 1 : Acoustic modes in the tube

$$\left.\frac{dJ_m(k_{r(m,n)}r)}{dr}\right|_{r=R} = 0. \qquad [1]$$

In the two-microphone transfer-function method, measurement is conducted under conditions where only the (0, 0) mode can propagate in the tube. Thus, the measurable frequency in the conventional method is below the cut-on frequency of the (1,0). As the frequency increases beyond that frequency, each high-order mode starts to propagate at its cut-on frequency. When these higher-order modes exist in the tube, the normal-incidence absorption coefficient cannot be measured by the two-microphone transfer-function method because of the complexity of the sound field.

The authors utilize the circumferential mode characteristics of the impedance tube to place four microphones on the same cross section at 90 degree intervals. By summing the sound pressure signals of the four microphones, the (1,0) (2,0) (3,0) modes are cancelled. Also, by placing the microphones at the nodal line of the radial (0,1) mode, the effects of this radial (0,1) mode is eliminated. This makes it possible to measure only the sound waves propagating in the axial direction of the impedance tube even within the frequency range in which the (1,0) (2,0) (3,0) and (0,1) modes propagate and enable to estimate normal-incidence absorption coefficient.

3 Measurement

Figure 2 shows an image of the impedance tube and microphone arrangement. The inner diameter of the impedance tube is 100 mm. Four microphones are placed at 90 degree intervals on two cross sections, and the tip of each microphone is adjusted to the nodal line of the (0,1) mode. Figure 3 shows a photograph of the actual impedance tube.

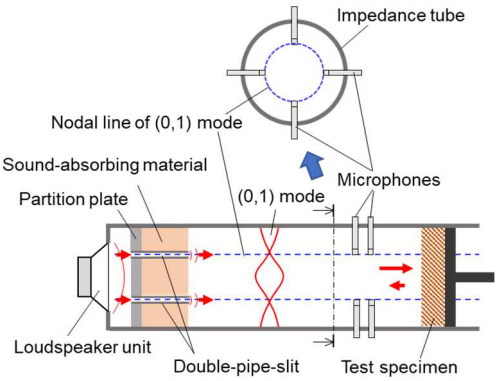

Figure 2

Figure 3

4 Results

Measured samples are Melamine foam with a thickness of 25 mm and urethane foam with a thickness 20mm. The measurement results are shown in Fig. 4. The red solid lines are the sound absorption coefficient measured by this development method (8 microphone method). The green solid lines are the sound absorption coefficient measured by the conventional method (2 microphone method) with an acoustic tube with a diameter of 40 mm.

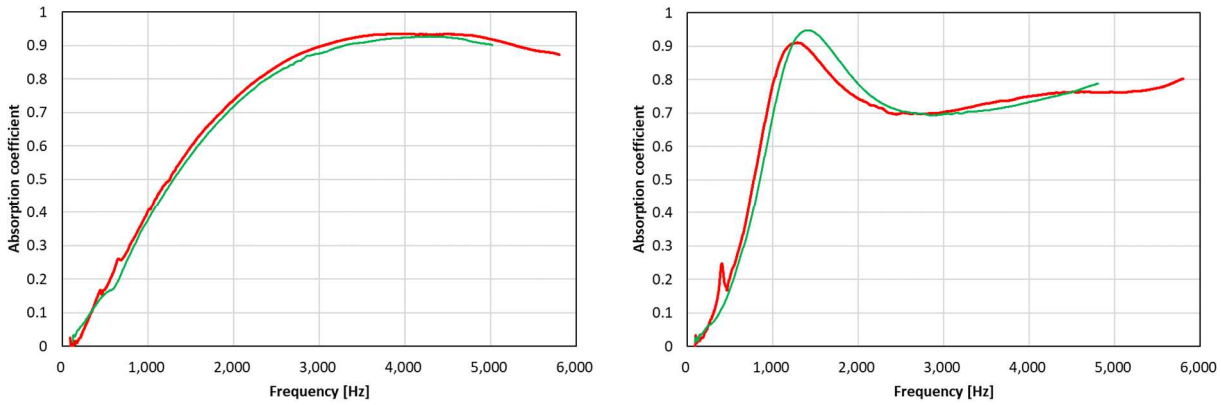

Figure 4 : Measurement results. Red line is φ100 tube 8-microphone method, green line is φ40 tube conventional 2-microphone method. Left – Melamine foam 25mm, right : urethane foam 20mm.

References

[1] ISO 10534-2, *Acoustics−Determination of sound absorption coefficient and impedance in impedance tubes −Part 2: Transfer-function method* (1998)

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[3] A. Sanada1, K. Iwata1 and H. Nakagawa, *Extension of the frequency range of normal-incidence sound absorption*
coefficient measurement in impedance tube using four or eight microphones, Acoustical Science and Technology, 39(5), 335-342 (2018).