Large scale impedance tubes

Walter Schneider[1], Michael Leistner[1], Frank Zickmantel[1], R. Tippkemper[2]
[1] *Fraunhofer-Institut für Bauphysik IBP, D-70569 Stuttgart, Germany, E-Mail: schneider@ibp.fhg.de*
[2] *Norsonic Tippkemper GmbH, D-59302 Oelde-Stromberg, Germany, E-Mail: tippkemper@norsonic.de*

Introduction

The measurement of the sound absorption coefficient and acoustic surface impedance at perpendicular sound incidence in an impedance tube belongs to the standardized [1, 2] tasks in the development and quality control of sound absorbers. There are cases, in which a large tube cross section is required. For instance, statistic accuracy can be increased by averaging over a larger surface when measurements of not completely homogeneous materials have to be performed. Other absorbers reach their effectiveness in the intended frequency range only with certain lateral dimensions such as for Compound Panel Resonators CPR [3]. Two examples of larger impedance tubes are presented in the following.

Tube with 0.2 x 0.2 m cross section

The defined frequency range of the impedance tube is limited at higher frequencies by the propagation of higher order modes. After [2] the upper limiting frequency f_u of tubes with square cross section and a flush mounted microphone arrangement is determined by

$$f_u < 0{,}5\frac{c_0}{d}, \qquad (1)$$

where d is the side length of the tube's cross section and c_0 the speed of sound. For d = 0.2 m an unsatisfactorily low upper frequency limit arises with $f_u < 850$ Hz. Figure 1 clarifies the situation for the one-dimensuinal case: The first mode in the tube's transverse direction, with its maxima of the sound pressure at the tube walls (x/d = 0 and x/d = 1), has a node at the center of the tube (x/d = 0.5). If the microphone is moved to that location, the first mode has no influence on the measurement result.

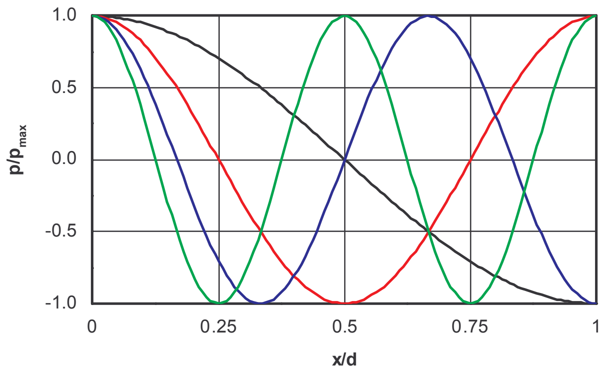

Figure 1: Sound pressure p as a function of position x in the impedance tube at the first higher order modes(-- 1. mode, -- 2. mode, -- 3. mode, -- 4. mode), onedimensional case.

Only the second mode is detected there, and thus f_u is doubled with respect to equation (1). A further increase of f_u can be achieved by an arrangement of 4 microphones, which are all placed at a distance of 0.25d from the tube walls (Figure 2), and whose signals are summed up. As shown in Figure 1, the respective contributions of the first and third mode add up to 0, whereas the second mode has nodes at these locations and does not supply a contribution. Only the forth mode has again an influence, which is not compensated. In this way f_u is quadrupled compared to equation (1), for d = 0.2 m to acceptable 3400 Hz. Figure 3 shows a realization of this tube design.

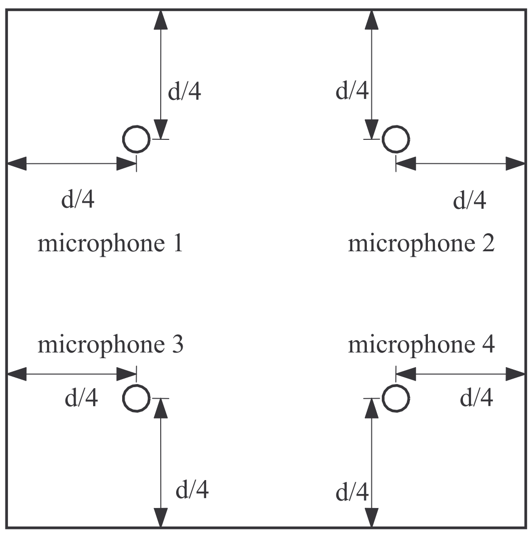

Figure 2: 4 microphone arrangement in the tube with square cross section for the increase of f_u.

Tube with 1.6 x 1.2 m cross section

For the development of modular type absorbers with single module sizes of 1.5 x 1.0 m an impedance tube with a rectangular cross section of 1.6 x 1.2 m was set up. The floor is the building foundation under the large anechoic chamber of the IBP, the walls are bricked from lime sandstones and the ceiling consists of concrete plates. Thus, it is possible to walk into the 8 m long tube for the installation of the samples (Figure 4). The rigid termination is formed by a 0.6 m thick concrete wall. An upper limiting frequency of 200 Hz results for a single microphone arrangement at the center. In Figure 5 absorption coefficient measurements at normal sound incidence are presented for the empty tube and for a Broadband Compact Absorber BCA according to [4]. A similar four microphone arrangement at the nodal points of the second mode in each direction allows increasing the upper frequency limit to 400 Hz.

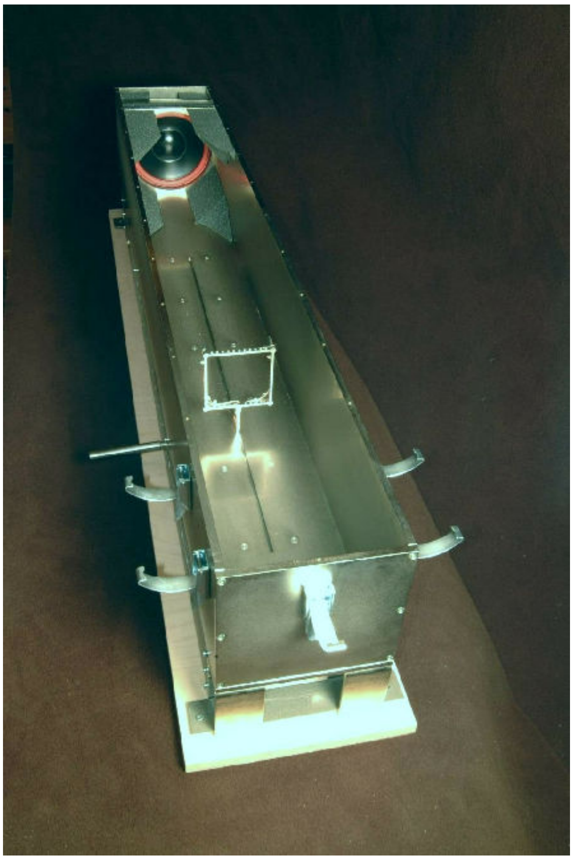

Figure 3: Sample of an impedance tube 0.2 x 0.2 m with 4 microphone arrangement.

Figure 4: View into the impedance tube with 1.6 x 1.2 m cross section.

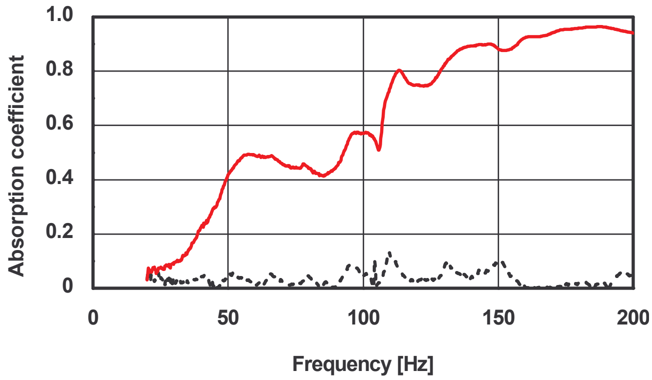

Figure 5: Absorption coefficient α_0 results in the impedance tube 1.6 x 1.2 m; (- - -) empty tube, (--) Broadband Compact Absorber BCA example.

Summary

Impedance tubes with large cross sections offer advantages for the investigation of laterally inhomogenous absorption materials and absorbers that need large lateral dimensions. The disadvantage of higher order modes propagating at low frequencies can be compensated to certain degrees by the employment of multi-microphone arrangements.

References

[1] ISO 10534-1: Determination of sound absorption coefficient and impedance in impedance tubes. Part 1: Method using standing wave ratio. December 1996

[2] ISO 10534-2: Determination of sound absorption coefficient and impedance in impedance tubes. Part 2: Transfer-function method. November 1998

[3] Fuchs, H.V.: Alternative fibreless absorbers – New tools and materials for noise control and acoustic comfort. ACUSTICA 87 (2001), 414 – 422

[4] Fuchs, H.V. et al.: Broadband compact absorbers for anechoic linings. In: CFA/DAGA 04, p. 272