Extended Impedance Tube Measurements of Porous Absorbers

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Introduction

Samples of porous absorbers are commonly characterised by their absorption coefficient α and surface impedance $\underline{Z}_w$. For measurements, standard Kundt's tube or impedance tube method is used.

Alternatively, a pair of characteristic values, e.g. characteristic impedance $\underline{Z}_a$ and propagation constant $\underline{k}_a$ may be measured by extended tube measurement techniques. To know these parameters is advantageous as they provide information about the material rather than the sample. This renders the prediction of the properties of samples without measurements possible. Thus the design of silencers and other absorptive structures is more efficient.

Measurement techniques

A number of different measurement techniques are available. The choice of optimal method to use for a specific sample is subject to the sample properties, e.g. high or low attenuation. In what follows, five methods are outlined. These methods were implemented using a modular apparatus (Fig.1) and tested in a survey[1] on measurement techniques for characteristic values.

In the **two-thickness method**[2], the impedance tube is used in its conventional configuration as shown below, where the normal-incidence surface impedance is measured for the sample, and the same measurement is repeated for another sample of the same material, whose thickness is the double of the first. The normal surface impedance is measured through the measurement of the transfer function between the two microphones. Due to the fact, that surface impedance under this configuration is related to the characteristic pair in a well-known manner, we can get the two required figures out of the two measured surface impedances the other settings of the measurement like the sample thickness, microphone locations and environmental conditions.

Like the two-thickness method, the **two-cavity method**[3] depends on creating two different surface impedances for the sample and measuring them in the usual way, to extract then the characteristic values. However, this is done in this case not through varying thickness, but with the same sample with varying cavity depth behind.

In the **method proposed by Champoux and Stinson**[4], the information needed to obtain the characteristic value pair consists of only one surface impedance measurement plus another measurement of the transfer function along the sample. This is especially convenient for highly dissipative materials.

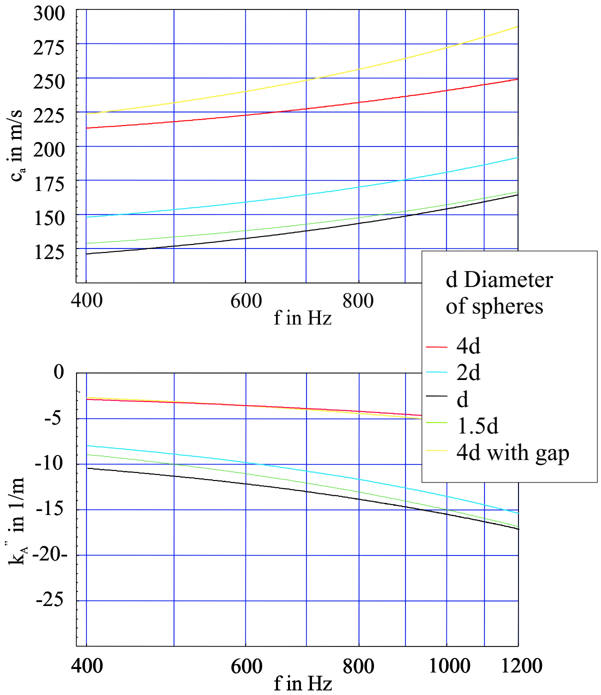

Figure 2: The characteristic wave number. Upper diagram: propagation speed $c_a^{'}$, lower diagram: attenuation $k_a^{''}$.

The **Iwase-Izume method**[5] is a special version of the Champoux-Stinson method, where the depth of the cavity behind the sample is reduced to zero and the microphones are brought directly to the sample surface for transfer function measurement.

The most versatile method is the **transfer-matrix method**[6]. The transfer matrix coefficients of the sample are determined through measuring the pressure at two points upstream and other two points downstream with the tube arbitrarily terminated. The measured transfer matrix of the absorber sample can be expressed as:

$$\begin{pmatrix} \underline{T}_{11} & \underline{T}_{12} \\ \underline{T}_{21} & \underline{T}_{22} \end{pmatrix} = \begin{pmatrix} \cos \underline{k}_a d_A & j\underline{Z}_A \sin \underline{k}_A d_A \\ \frac{j}{\underline{Z}_A} \sin \underline{k}_A d_A & \cos \underline{k}_a d_A \end{pmatrix}. \quad (1)$$

Thus characteristic impedance and the wave number can be calculated from the matrix elements $\underline{T}$.

Figs. 2 and 3 contain example results for a novel material made of sintered metal hollow spheres of different diameter and packing density.

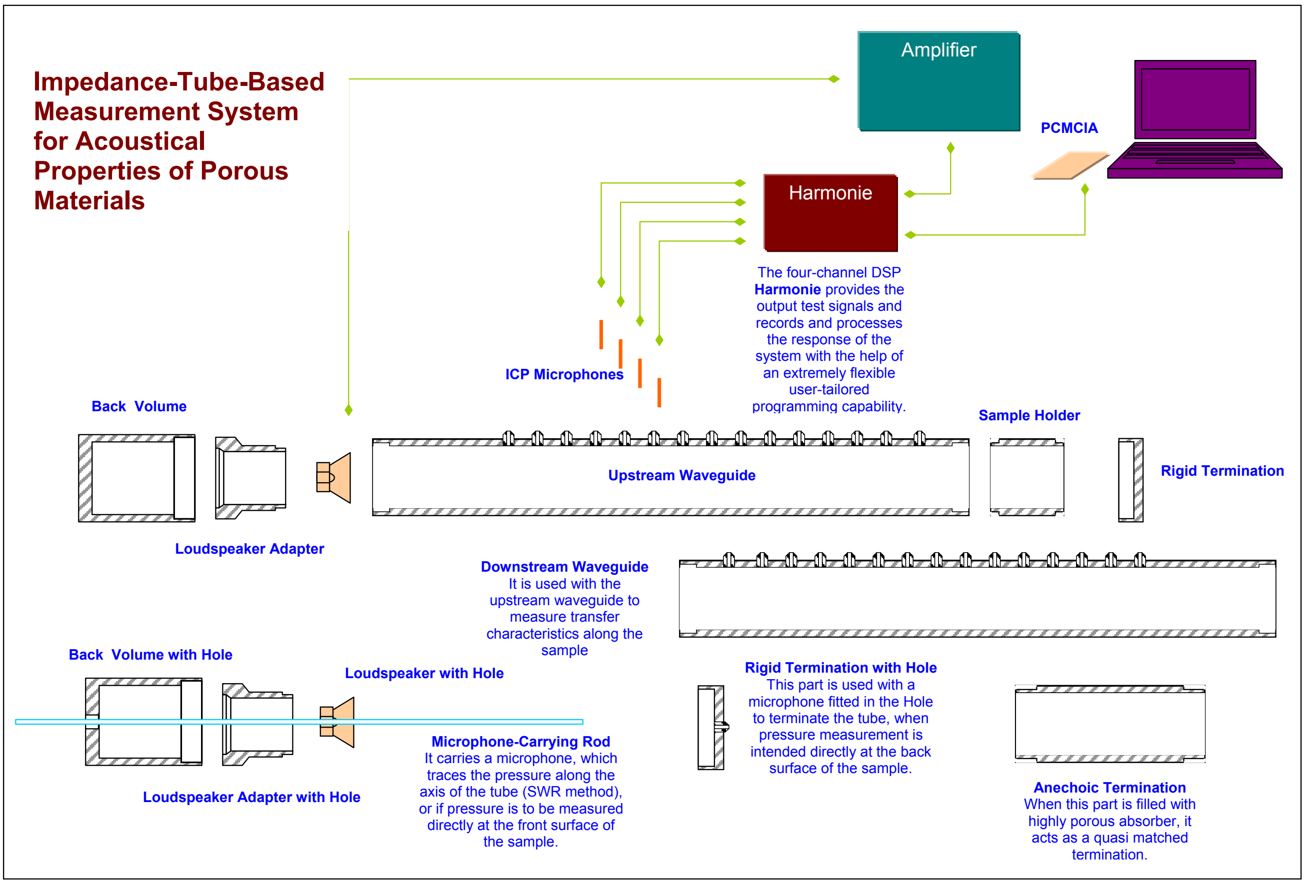

Figure 1: Modular apparatus for the implementation of several measurement techniques

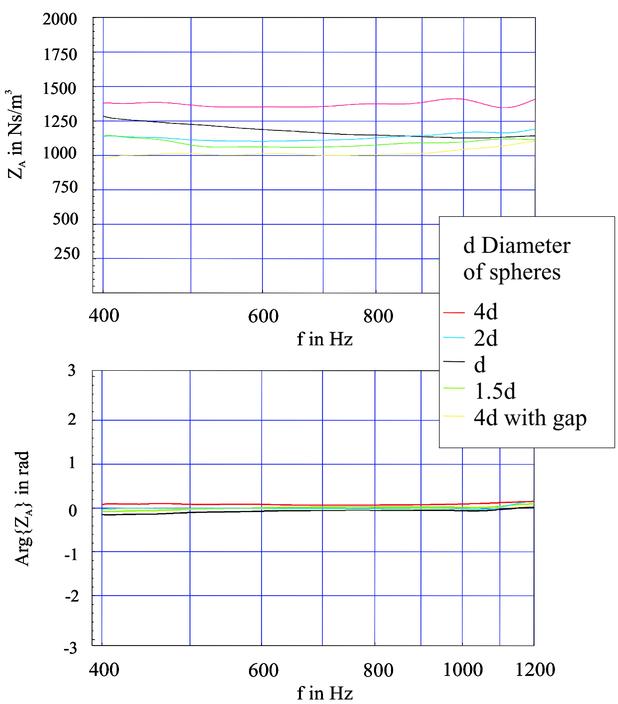

Figure 3: The characteristic impedance $\underline{Z}_A$. Upper diagram: Magnitude of $\underline{Z}_A$, lower diagram: Phase of $\underline{Z}_A$.

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