MULTYLAYER ABSORBERS OF SILICA AEROGEL

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ABSTRACT: In former works [1, 2] the efficiency of a two-layer passive sound absorber by means of silica granular aerogel has been presented.
The aim of this work is to optimise the acoustical characteristics of these absorbers where the first two layers act as an impedance matcher and the third one as an absorber.
Experimental results on the acoustic properties of granular aerogels of diameters of 1 mm, 3 mm, and 80 µm, arranged in different orders and thicknesses are investigated, as well as variations and conditions.
This multilayer absorber could have potential applications in digital loudspeakers for rear radiation absorption where it has better results than rock woll, especially at low frequencies.

I –INTRODUCTION

Silica aerogels were invented by Kistler over sixty here ago and are traditionally defined as gels dried at a temperature and pressure higher than the critical point of the pore fluid. Through avoidance of capillary stress, this supercritical drying process largely replaces the original pore fluid with air with little associated shrinkage, resulting in the highly porous materials referred to as aerogels, soufflés of the materials world. Properties of aerogels have been widely studied using methods such as X-ray or neutron scattering, and their particular acoustical properties were described by Gronaueur and Fricke [3] and Nouailhas et al.[4], who analysed the characteristics of monolithic aerogel with high density. Nevertheless, their potential applications, although promising , have not yet led to industrial production, probably because of industrial and technical limitations.

The silica aerogels exist in a monolithic form, characterised by a micro-porosity, a very low volumetric mass (ρ<100 kg/m^3), and a sound velocities lower than in air. Sound velocities as low as 40 m/s have been measured up to [1]. In particular for this type of aerogel, the Biot theory has been applied [5, 6,] and seems to present a good agreement with experimental results.

Silica aerogels also exist in a granular form, with granulometry going from millimetres to a few tens of micrometers. They are characterised by a macro-porosity which is different from the monolithic form. Also in this case, their density and recorded propagation velocities are very low. In addition, their high absorption coefficients have already been tested and therefore is desirable to deeply investigate them on an experimental scale in order to optimise their efficiency. In the case of granules of very small size, their mechanical behaviour is intermediate between that of a gel and that of a "traditional " granular material: the more the volumetric mass and the diameters of the granules diminish, the more the sound propagation within the materials presents non linear phenomena.

II – THE MULTILAYER SYSTEM

Acoustic characterisation of a two-layer passive absorber, where the first layer is constituted by large granules and the second by small granules of silica aerogel, has already been carried out and it has been the object of former work and a patent [1, 2] . The system has been realised with two layers in order to have the first layer to act as an impedance matcher and the second as an absorber; in addition it has been shown that the diameters of granules influences the acoustic absorption: the larger diameters have a lower absorption coefficient than the smaller ones.

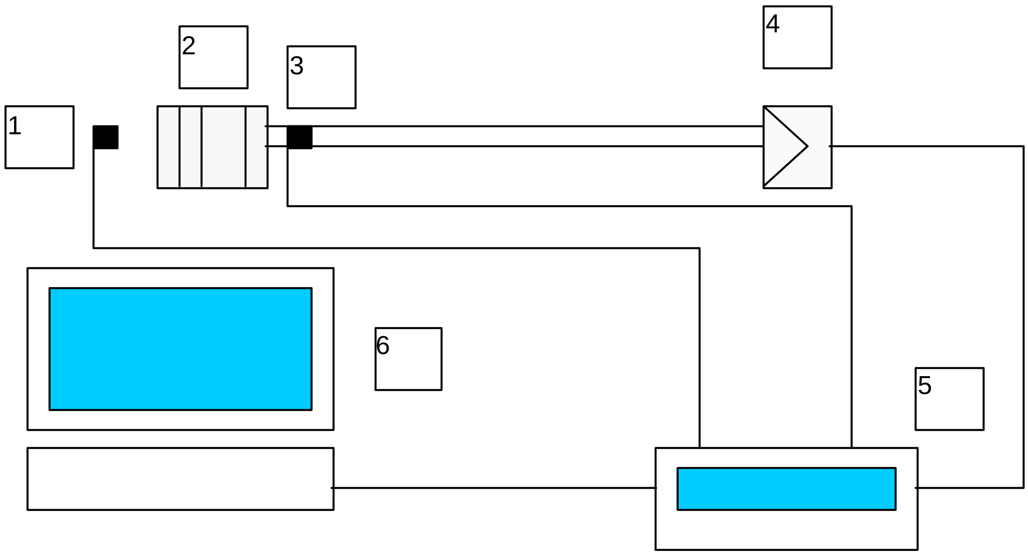
The main idea is to build an absorbing system where the reflection coefficient is minimised and the absorption coefficient is maximised. The perfect solution is a material whose surface impedance is equal to air impedance at the contact and whose impedance varies gradually with depth in order to be equal to the impedance of a highly absorbing material. This “gradient layer” can be approximated with a few layers of material of increasing impedance followed by the absorbing layer. This is an improvement of the two layers absorber presented by Forest et al. [1]. Since it is difficult to have a material with such a variation, it has been decided to approximate it with a two-layer system. As the granules of larger diameter present a low reflection coefficient [1] and the fine powder a high absorption coefficient, the multilayer is effectively an impedance matcher built with different granules diameters (3 mm and 1 mm), and the 80 μm granules as the absorber.

The goal of this work is to optimise a multilayer absorptive system of both two and three layers with granules of 1 mm, 3 mm and 80 μm having different thicknesses and arranged in various orders.

III – EXPERIMENTAL SET-UP

The simple experimental set-up has been built around the one used for TMTC impedance measurements [7]. In figure 1 the experimental chain is shown. It consists of a loudspeaker excited by a computer controlled signal connected to a cylindrical tube of 50 cm in length. The end of the tube is put inside the Plexiglas box which contains the different samples of silica aerogel granules. The acoustic signal has been measured with two Bruel and Kjaer 1/2 “ microphones, placed in proximity of the multilayer system (no. 2 of figure 1): one before (no. 3 of figure 1) and one after it (no. 1 of figure 1). The sampling frequency is set at 10 kHz, accuracy 12 bits, excitation signal chirp between 20 Hz and 3000 Hz. Length of the recorded signal 0.8192 s. Fourier transform of the time domain signal (frequency resolution 1.22 Hz) have been processed and experimental results corrected from the microphone differences.

A perspective drawing and a section of the plexiglas box containing the multilayer system (no. 2 of figure 1) are shown in figures 2 and 3 respectively.



1 : Microphone B & K ; **2** :Plexiglas box ; **3** : Microphone B & K ;

4 : Source ; **5** : Pre-amplifier ; **6** : PC

Figure 1 : Acquisition chain of the experimental set-up

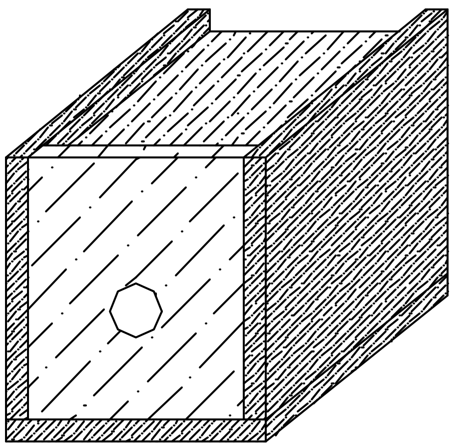


Figure 2: Plexiglas box containing the samples

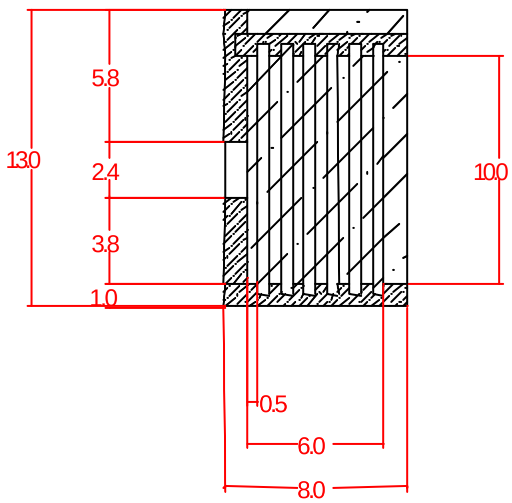


Figure 3: Details of the section of the Plexiglas box containing the samples (dimensions are in cm)

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IV EXPERIMENTAL RESULTS

Three different arrangements of the multilayer absorptive system have been tested. Case A is constituted by a first layer of granules 3 mm in diameter and 2 cm thick, a second layer of granules of 1 mm in diameter and 2 cm thick, and a third one of granules of 80 µm in diameter and 2 cm thick. The case B is constituted by first and second layers of granules of 1 mm in diameter and 2 cm thick, and a third one of granules of 80 µm in diameter and 2 cm thick. Case C is constituted by a first and a second layer of granules of 3 mm in diameter and 2 cm thick, and a third one of granules of 80 µm in diameter and 2 cm thick. Characteristics of the analysed cases are given in table 1.

Figures 4, 5 and 6 show the experimental results of attenuation in the frequency range 0 - 2500 Hz in the cases A, B and C respectively.

Case	**I Layer (2 cm)**	**II Layer (2 cm)**	**III Layer (3 cm)**
Case A	∅= 3 mm	∅= 1 mm	∅= 80 μ m
Case B	∅= 1 mm	∅= 1 mm	∅= 80 μ m
Case C	∅= 3 mm	∅= 3 mm	∅= 80 μ m

Table 1: Characteristics of the analysed case studies

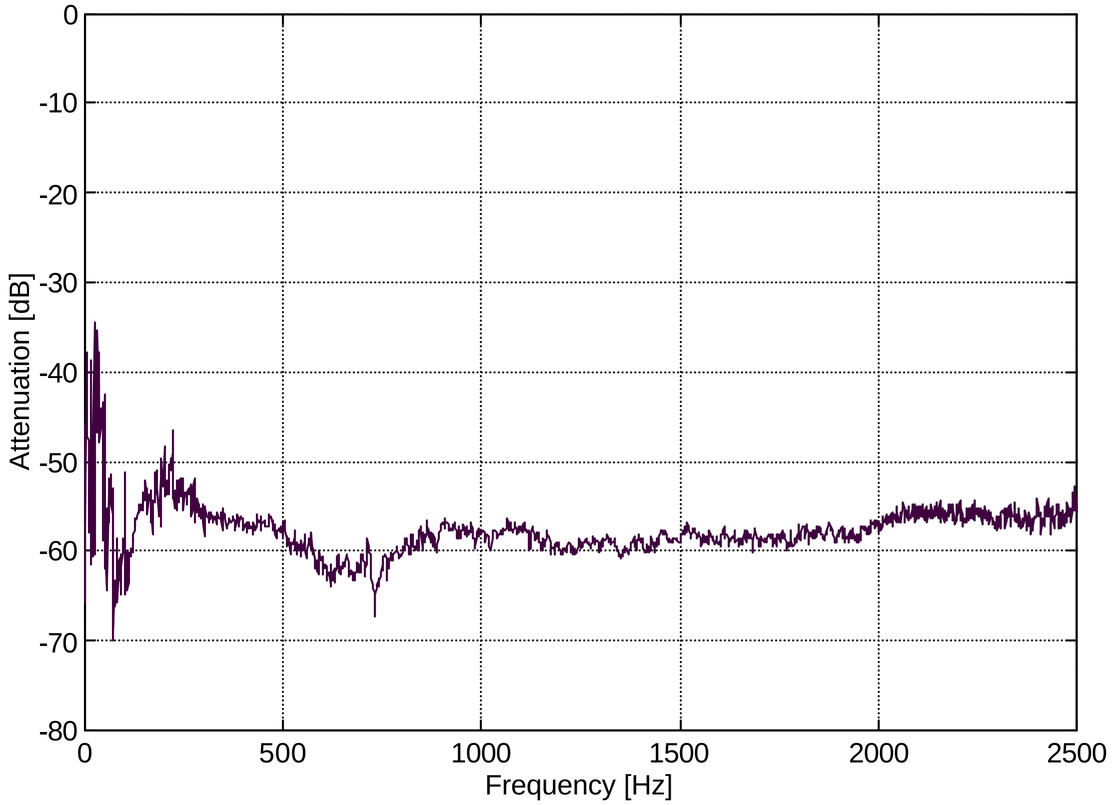
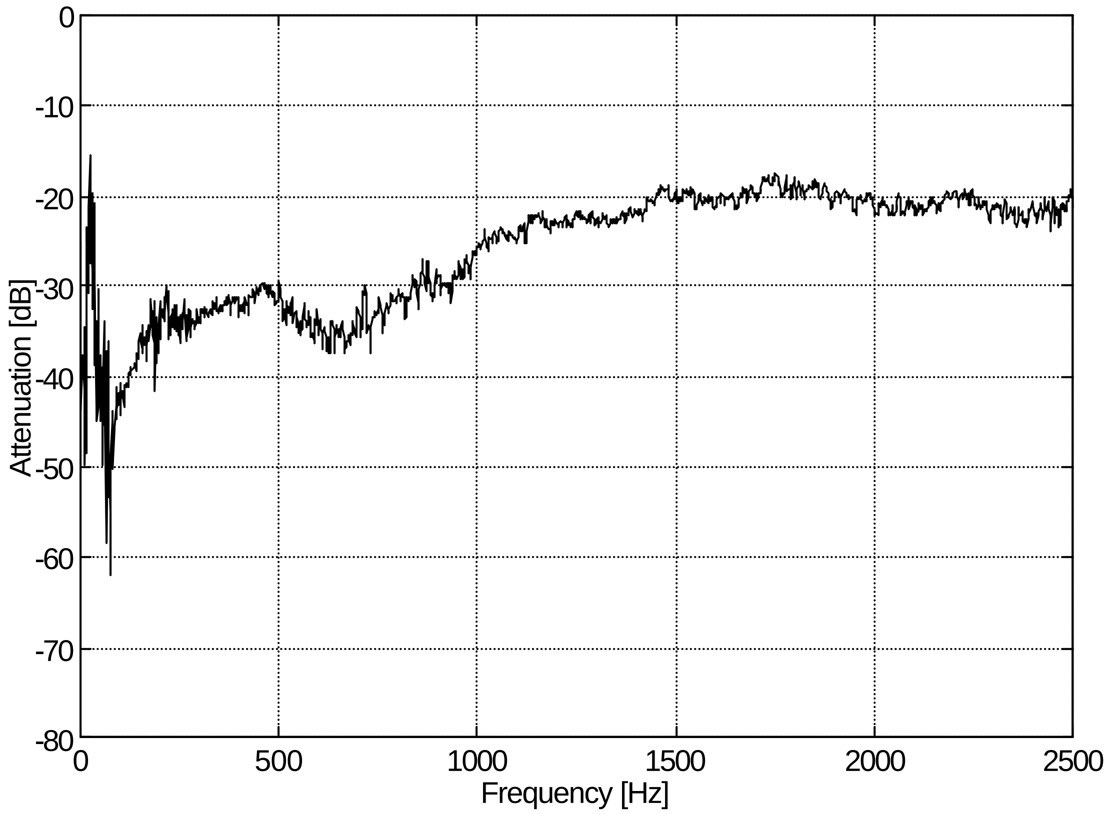


Figure 4 : Experimental results of attenuation versus frequency for case A



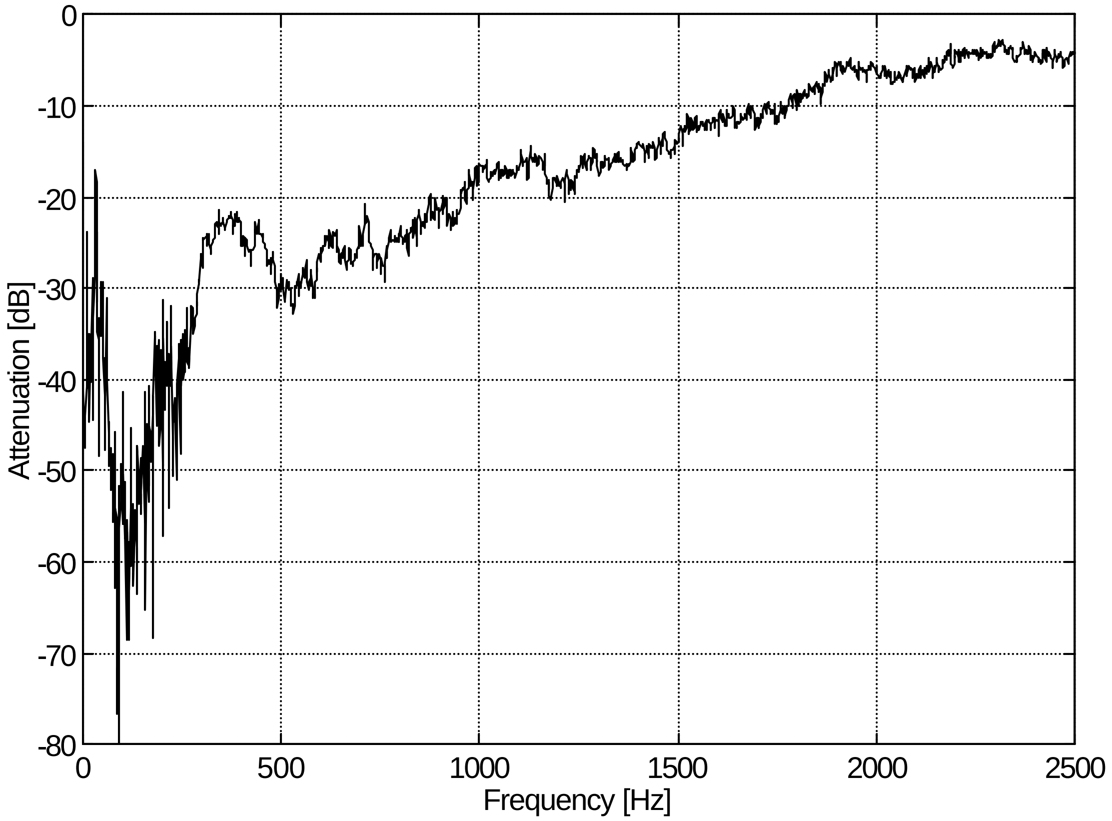


Figure 6 : Experimental results of attenuation versus frequency for case C

V DISCUSSION

The results for attenuation could be compared those for transmission loss but, it has to be kept in mind that the pressure measured inside the impedance tube is overestimated because of the non zero reflection function.

All the three cases analysed showed a maximum of attenuation at very low frequencies (below 100 Hz). Case A , after the first maximum of –70 dB, had a quite stable attenuation around the value of –60 dB. Case B, after the first maximum of –60 dB, had an attenuation around the value of –30 dB for the frequencies between 100 and 1000 Hz and a value around –20 dB for the frequencies between 1000 and 2500 Hz. Case C, after the first maximum of –80 dB, had an attenuation around the value of –25 dB for the frequencies between 100 and 1000 Hz and a value which decreased from –20 dB to –5dB, for the frequencies between 1000 and 2500 Hz. Therefore, case A has the higher and more stable values of attenuation.

VI CONCLUSIONS

Three multylayer absorptive systems made of silica aerogel granules have been experimentally compared. Even if the numerical results cannot be considered as an absolute one, attenuation results as a function of frequency of the different geometries show that the best arrangement is the one of case A, that is constituted by three layers with granules of decreasing diameter (a first 2 cm thick layer of granules of diameter 3 mm, a second 2 sm thick layer of granules of diameter 1 mm and a third 2 cm thick layer one of granules of diameter 80 μ m). Since the case A is constituted by three layers, it approximates better to the idea of "gradient material": it has the higher and more stable values of attenuation among the ones analysed.

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