ABSORBENT CHARACTERISTICS OF MATERIALS OBTAINED FROM INDUSTRIAL WASTES.

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ABSTRACT

In this communication we present measurements of the normal absorption coefficient performed on new materials made from industrial wastes. These materials are three conformed metal shavings and two textile agglomerates. We have also used two types of resonators to improve the absorbent characteristics of the tested materials at low frequencies. The results obtained are very interesting, because the absorption coefficient measured in some of the samples tested are similar (if not better) than that of actually used absorbent materials, but the final prize of our samples would be much lower if produced at industrial scale.

INTRODUCTION

Porous materials, such to as glass wool or foam, are generally used to attenuate noise. In addition to these well-known materials, new materials such as porous metal or ceramics have been developed [1], satisfy the need for porous material that can be used at high temperatures, can be exposed to high-speed air flow, and/or whose physical characteristics would remain unchanged when exposed to a chemical gas atmosphere.

The most fundamental acoustic property of the porous materials is their sound absorption coefficient, which may be measured by using transfer function method rather than the conventional standing wave ratio method.

Previous works have shown that the porous material itself must be considered as a medium in which the sound wave transmits, assuming that their surface is not locally reacting. In this last case, the porous material must be characterised by the characteristic impedance and the propagation constant, and not by the normal acoustic impedance. Even if the surface is assumed to be locally reacting, these properties are useful because the sound absorption coefficient and the acoustic impedance can be calculated from them. The characteristics of sound propagation through porous materials have been investigated by several researchers [2], but most notably by Zwikker and Kosten [3]. To utilize the theory in Ref 3, it is necessary to obtain certain parameters (flow resistance or structure factor), that are measuring by means non-acoustical experimental methods.

In this paper we measure the normal acoustic absorption coefficient of some conformer samples made by us from metallic and textile residual wastes by using the transfer function method. Also we study the influence on the absorption coefficient of two types of resonators placed on the frontal surface of our samples.

EXPERIMENTAL PROCEDURE

The experimental equipment used for all measurements presented here is an impedance tube type 4206 from Brüel & Kjær, which is shown in Figure 1. This apparatus has two tubes where the sample is placed, the large one (100 mm Ø) allows to measure in the range of frequencies from 100 Hz to 1600 Hz, and the small one (29 mm Ø) allows to measure in the range between 500 Hz and 6400 Hz. So, with both tubes we cover all the noise frequency range used in construction, from 100 Hz to 4000 Hz.

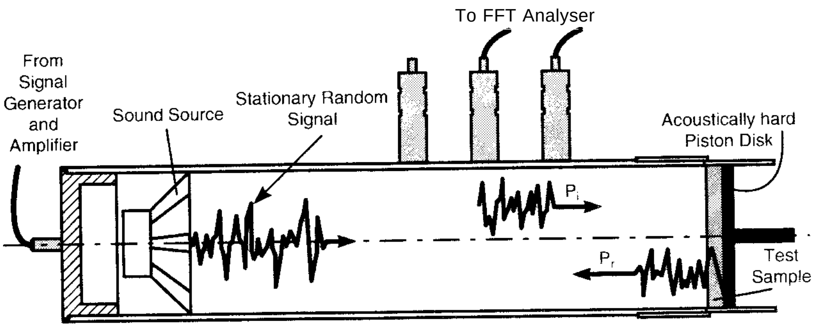

Figure 1: Experimental equipment used to measure the normal absorption coefficient.

In this work we present the experimental results from five types of materials: three metal shaving conformers, and two textile agglomerates. The samples were prepared in pairs according both diameters of the impedance tubes, some of their properties appear in Table I. The frontal surface of the samples was not flat, so the reference plane could not be established with precision, which prevents us to measure the impedance properly. The back surface of the textile samples where flat, but that of the metal shaving was rugose. To avoid the problems due to the existence of an air cavity behind the sample, we glue it to the movable piston at the end of the impedance tube by using double-faced adhesive tape. Also, just prior introducing the sample in the tube, its border was greased with vaseline to close any air gap between them and the tube wall. These two facts allow us to obtain a coherence of exactly 1.00. We have prepared a sample conformed by a front sheet of metal shaving and a back one of mineral wool.

Finally, we have also used two kinds of resonator with some of the samples. The first resonator is a metallic plaque of 1 mm thick, with round holes of 1.5 Ø distributed in a square array, with 3 mm of distance between the centre of adjacent holes. This plaque has a thin veil in its back surface. The second resonator is a metallic plaque of 1.5 mm thick with round holes of 4.5 mm Ø distributed in an hexagonal array, resulting in a 26% of holes in the surface.

Table I: Properties of the materials tested.

Samples	Density (Kg/m^3)	Thickness (mm)
Metal shaving conformer 1	278.5	23.5
Metal shaving conformer 2	278.6	22.4
Metal shaving conformer 3	278.1	22.9
Textile agglomerate 1	294.4	17.5
Textile agglomerate 2	352.3	21.5

To perform the measurement, a random sound signal is generated in the loudspeaker, and the transference function, H, between both microphones of the tube is measured using the fast Fourier´s transform (FFT) with two channels, and later processed by the computer using the PULSE 6.0 software.

The absorption coefficient, α, is obtained from the modulus of the reflection coefficient, $|R|$, of the following manner [4].

$$\alpha = 1 - |R|^2$$

$$R = |R| e^{j\phi_R} \qquad |R| = \sqrt{\frac{1 + |H|^2 - 2|H|\cos(\phi + ks)}{1 + |H|^2 - 2|H|\cos(\phi - ks)}}$$

where, k is the wave number, s is the space between both microphones and ϕ the phase.

After measuring each sample, it is verified by visual inspection the tested material, the coherence of the measurement and the possible variation of the weather conditions (pressure, temperature and humidity).

EXPERIMENTAL RESULTS

The normal absorption coefficients of the three samples of conformed metal shavings are shown in Figure 2(a), (b) and (c) versus the frequency in $^1/_3$ octave. From that figure, we observe that the three tested materials present a maximum of noise absorption (around 90%) for frequencies between 2000 Hz and 2500 Hz. Samples 1 and 2 present important resonance peaks for frequencies ranging from 3150 Hz to 4000 Hz. In conclusion, we observe that this material has good acoustic absorption characteristics at relatively low frequency.

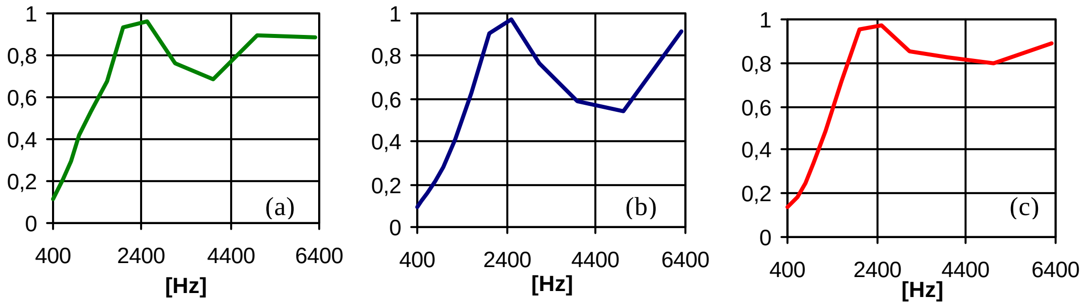

Figure 2. Normal absorption coefficient of metal shaving conformer samples 1 (a), 2 (b) and 3 (c) versus the frequency in $^1/_3$ octave.

If we place a sheet of mineral wool (23 mm thick) in the back surface of the metal shaving conformed sample 2, the acoustic absorption coefficient varies, as shown in Figure 3. For this multilayer material we obtain a nearly constant absorption coefficient (around 0.8) in the range of frequencies from 2000 Hz to 4000 Hz.

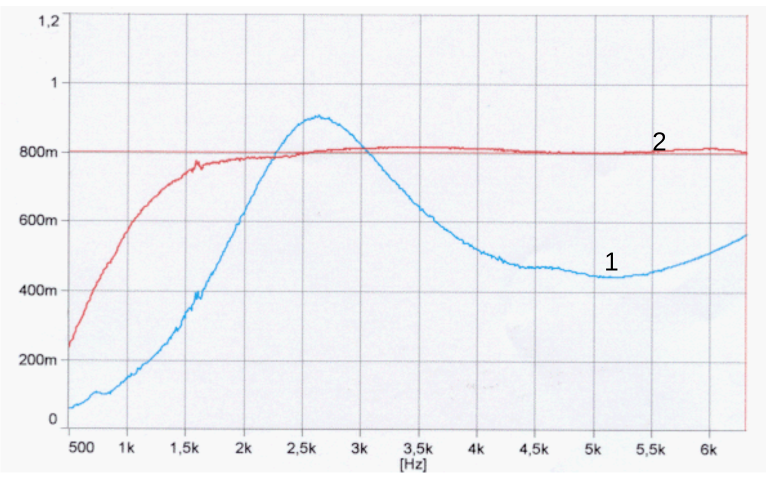

Figure 3. Comparison between the absorption coefficient of the metal shaving conformer (curve 1) and multilayer material (curve 2). See text for details.

In the other hand, the normal absorption coefficient for the two textile conformer samples made with industrial wastes, is presented in Figure 4. At low frequency the sound absorption of textile conformer 2 is bigger up to 2000 Hz, but from this frequency and up to 4800 Hz it is better absorber the textile conformer 1. The curve shape of this last sample is the typical one of the most used absorbent materials.

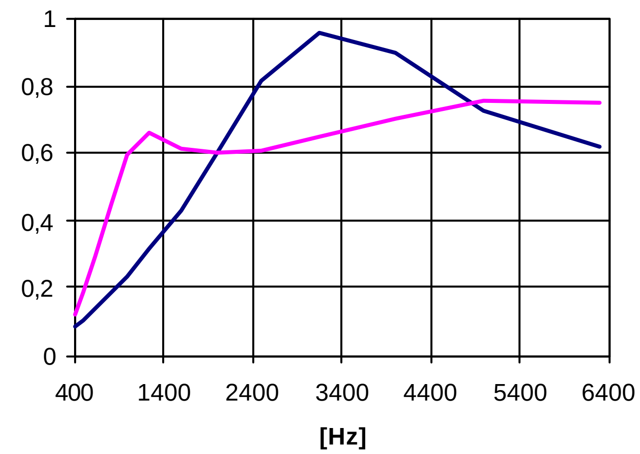

Figure 4. Normal absorption coefficient of textile agglomerate samples 1 (blue curve) and 2 (red curve) versus the frequency in $^{1}/_{3}$ octave.

Due to the fact that at low frequency the textile agglomerate 1 has poor absorption of sound, we have placed the multiperfored plaque (the first resonator described above) on its frontal side. To place that plaque we have used blue tack pieces asymmetrically distributed on the textile conformer, leaving a 4 mm depth air cavity between the textile sample and the first resonator. As observed in Figure 5, we have increased the absorption around a 20% at 800 Hz and around a 5% at 400 Hz. If we place the second resonator on this same sample, just like the first one, and leaving an air cavity of 4.5 mm in between, the increase of the absorption respecting the sample without any resonator is very high, around a 50% at 800 Hz.

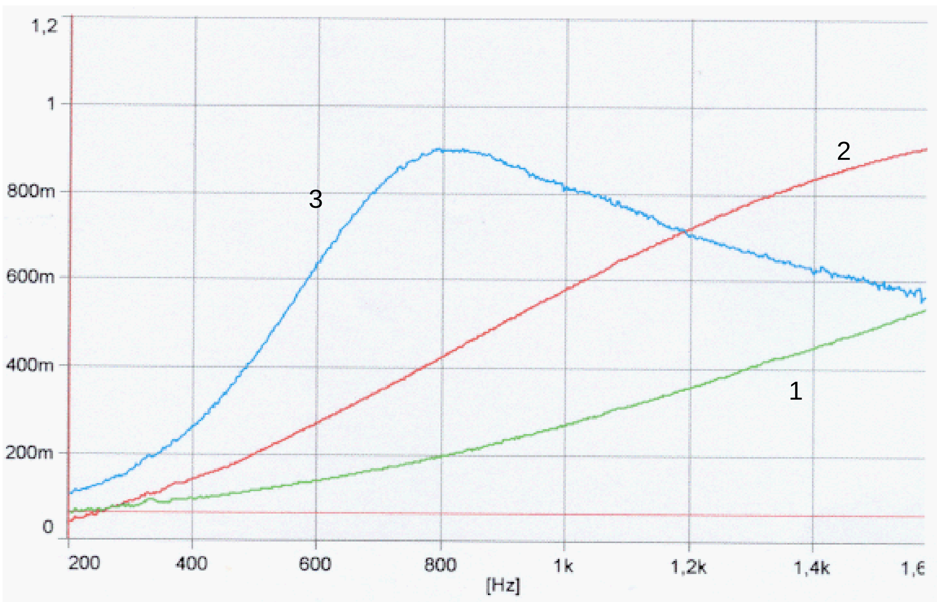

Figure 5. Normal absorption coefficient of the textile agglomerate 1 (green curve 1), that sample with the first resonator (red curve 2) and with the second resonator (blue curve 3). See text for details.

Also, we have placed the first resonator on the textile agglomerate 2 as before, and leaved an air cavity between the plaque and the textile sample of 6 mm depth. We have measured the normal absorption coefficient of this new multilayer sample with its back side just on the end of the impedance tube, and also leaving air cavities of 100 mm and 200 mm behind the sample. In Figure 6 we show the measured absorption curves for the plaque - 6 mm air - textile conformer (green curve), plaque - air - textile - 100 mm air depth (blue curve) and plaque - air - textile - 200 mm air depth (red curve). This Figure 6 shows that there is a displacement of the absorption peak toward low frequency as the air cavity depth behind increases. Although, when the air cavity behind the sample is 200 mm depth, some resonances appear around 800 Hz of frequency. This resonance was already present in the textile conformer 1 without resonator, but it was softer.

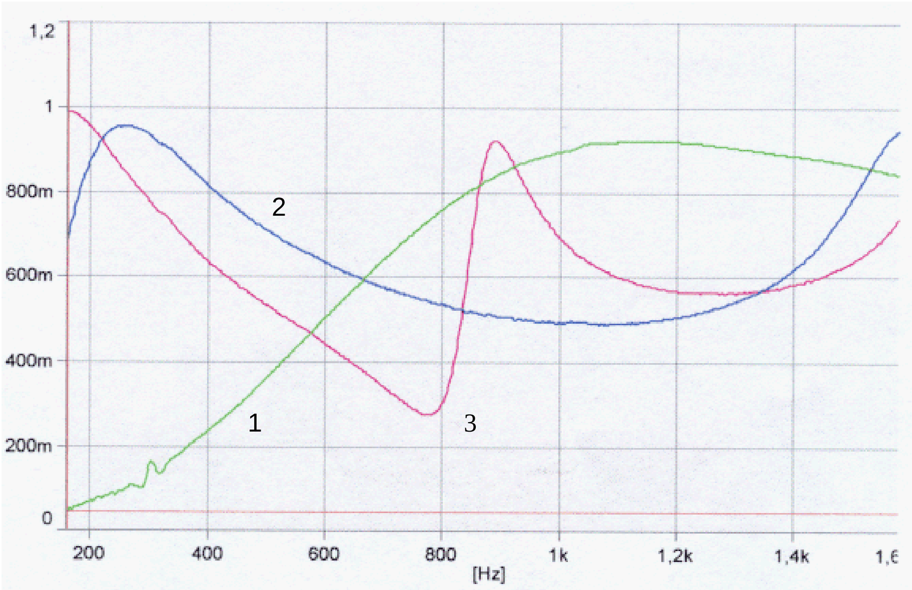

Figure 6. Influence of the air cavity depth behind the sample on the normal absorption coefficient of textile agglomerate 2 with first resonator. Green curve 1 without air cavity behind, blue curve 2 with 100 mm depth of air cavity behind and red curve 3 with double air cavity depth. See text for details.

CONCLUSIONS

The metal shaving conformer obtained from industrial waste presents very good sound absorber characteristics at low frequencies. The discrepancy between samples for high frequency absorption is not due to the experimental measurement, and we think it comes from the glue used to agglomerate the metal shavings. In any case more studies must be done in this sense to clarify that result.

The textile conformers made from textile waste by us present different absorption coefficients, and while one of them present high values for low frequency, the other one absorbs more for high frequency. In any case, these results are only an indication that it is interesting to follow studying this kind of samples to confirm this results and try to increase the absorption coefficient with new samples.

Finally, we have measured the influence of two kinds of multiperfored plaques as resonators placed on some of the tested samples. The results indicate that the absorption is increased at low frequency as expected.

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