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SOUND ABSORPTION OF CORRUGATED CARDBOARD SAMPLES WITH A SIMPLE IMPEDANCE TUBE

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Abstract: *The normal sound absorption coefficient of cardboard samples by using the standing wave ratio method is measured. An impedance tube with a simple design is employed. A Labview application is managing the acquisition of sound pressure in tube close to the samples, is processing the data and finally the graph of the normal sound absorbing coefficient versus frequency is shown on the screen. A set of cardboard circular samples are proposed for evaluation. The compact cardboard structure is the material for a set of low absorption samples measured with the simple impedance tube. A second set of corrugated cardboard samples is proposed. The sound absorption for these samples is very good because of the layer of air present in the cardboard structure. The paper is presenting an inexpensive material, offering a good sound absorbing structure for a relative large frequency band for quick usage and the micro-perforations are obtained by drilling.*

Keywords: *sound absorption coefficient, corrugated cardboard samples, microperforations, standing wave ratio method.*

1. INTRODUCTION

Sound absorption coefficient (α) [6], [11], taking values between 0 and 1, is used to evaluate the sound absorption efficiency of small samples of the sound absorbing materials. The sound absorption coefficient can be measured by using an impedance tube. The tube manufactured at a low cost like the one shown in figure 1, with a circular cross section is used for the experiment. The inner air is excited by sinusoidal plane waves by using a loudspeaker at one end of the tube. At the opposite end, a complex impedance of a sound absorbing material sample is to be evaluated. The microphone is sliding in the tube in order to measure the sound pressure of the standing waves generated into the tube. Alternative maximum sound pressure $p_{\max}$ (antinode) and minimum sound pressure $p_{\min}$ (node) are distributed along the tube length. A pair of adjacent node and antinode will be used to determine the magnitude impedance and the sample sound absorption coefficient.

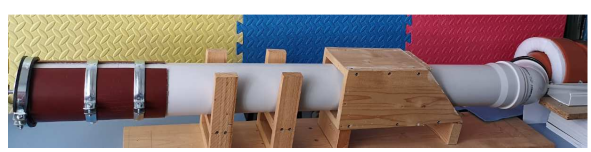


Fig. 1. The simple impedance tube - overview

The standing wave ratio (SWR) value is important for the sound absorption coefficient and the mechanical impedance derivation of a tested material. SWR does not provide phase information being a scalar quantity and is defined [1], [6], [9], [10] as the ratio of the maximum pressure amplitude and the minimum pressure amplitude of two adjacent extremes along the tube, closer to the material. The normal to the surface sound absorption coefficient is calculated based on the SWR [6].

In the paper the sound absorption coefficient of compact cardboard and corrugated cardboard samples is evaluated by using the standing wave ratio method [11] implemented on the simple impedance tube.

2. THE SIMPLE IMPEDANCE TUBE AND THE ACQUISITION SYSTEM

The Impedance tube is based on a plastic tube of 99.2 mm inner diameter and the wall thickness of 5.4 mm.

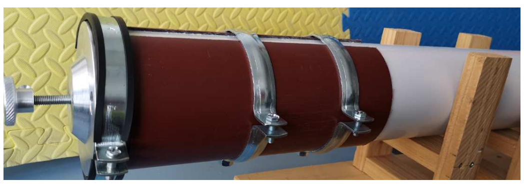


Fig. 2. Screw for the rigid termination displacement and the air layer thickness setting

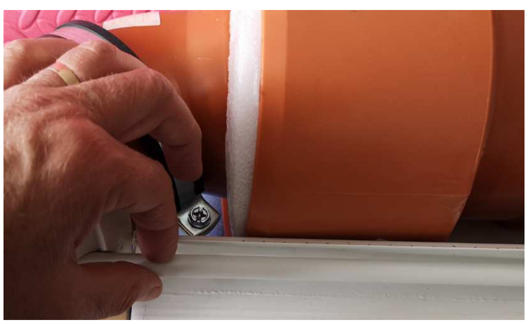


Fig. 3. Microphone support (white plastic tube) displacement realized by hand

Fig. 4. The NI signal conditioning unit and the power amplifier

The tube [6] has a translatable rigid termination (Fig. 2) at one side and a loudspeaker on the other side. Inside the tube a prepolarized free-field microphone BSWA is sliding (Fig. 3) in order to evaluate the sound pressure of the standing wave generated in the tube. The acquisition system is based on the National Instruments dynamic acquisition board PCI 4451 with simultaneous sampling on the input channels.

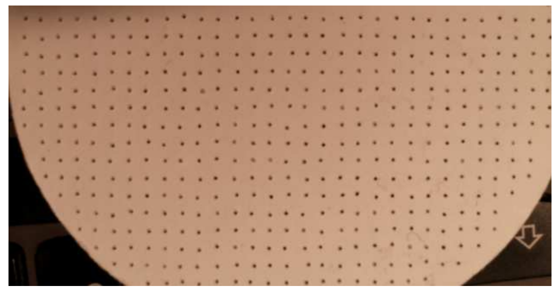


Fig. 5. Sample 2M, compact cardboard, thickness 2.2 mm

One output channel is generating the excitation signal for the loudspeaker, amplified by a Brüel & Kjær Type 2706 Power Amplifier (Fig. 4). The sound pressure along the tube is evaluated by using a MPA416 1/4" microphone with ICP preamplifier. A signal conditioning bloc, type BNC-2140 (NI) is interfacing the acquisition board (one side) and the microphone and the power amplifier (on the other side, Fig. 4).

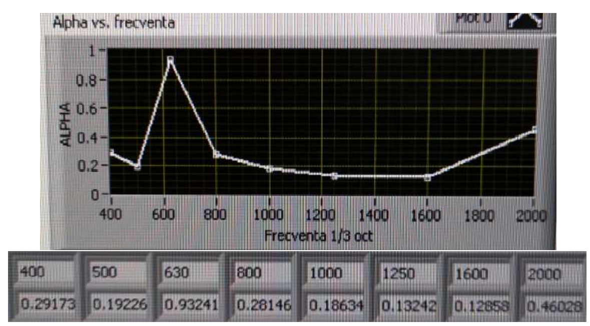


Fig. 6. Alpha vs. frequency for compact cardboard sample, one peak at low frequency

The distance between the loudspeaker and the material sample is L=1m. The tube diameter is D=0.0992 m. The lower sound frequency is

$f_l \geq 356$ Hz from relation $f_l \geq 250/(L-3D)$ [6], [11].

For excitation, sine waves or pure tones are used. The frequency of the signal generated by the speaker at one end is starting from 400 Hz and ending at 2000Hz is from one central frequency of a third octave to the next one.

The measurement of the maximum pressure, minimum pressure and the distance from the sample to the first minimum, or the distance between two adjacent extremes are allowed by moving the microphone support (Fig. 3) through the tube.

The Labview application, roughly presented in [6], is driving the signal generation at the loudspeaker output channel and the pressure measurement of the standing wave at one of the input channel of the acquisition board. A prepolarized free-field microphone BSWA 1/4" with ICP preamplifier is used.

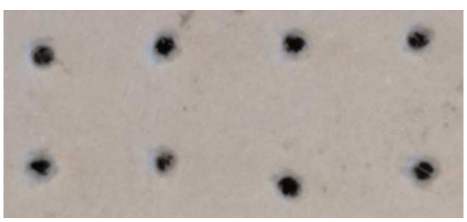


Fig.7. Close-up of micro-perforations of cardboard sample 2M

3. COMPACT CARDBOARD SAMPLES

For the compact cardboard samples the sound absorbing coefficient is in many cases relatively low with a high peak at a specific frequency in the frequency span of the manufactured impedance tube.

Table 1

t [mm]	Φ [mm]	b [mm]	Dair[mm]
2.2	0.8	6	30

The peak is located in function of the geometry of the micro-perforations and the length of the air layer between the sample and the rigid termination.

In Figure 5, the sample 2M made from cardboard of a cover of address agenda is shown. The parameters are presented in Table 1, where t is the thickness, Φ the perforation diameter, b is the perforation spacing, Dair is the thickness of the layer of air and M specifies the matrix arrangement for the perforations.

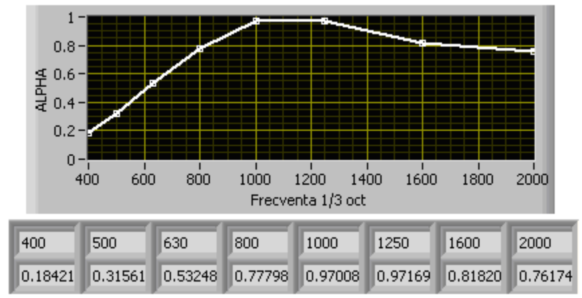


Fig. 8. t=0.85, Φ=0.5, b=2, Dair=30

A print screen of the Labview application with the sound absorption variation in the third octave frequency interval is shown in Figure 6. In Figure 7 a close-up of the micro-perforations made by drilling of sample 2M is presented.

Several other measurements were done and the samples parameters are available in Table 2.

Table 2

Cardboard samples

t [mm]	Φ [mm]	b [mm]	Dair [mm]
2.2	0.5	3	30
0.81	0.5	3	30
0.85	0.5	2	30
0.83	0.8	6	30

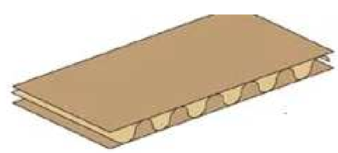
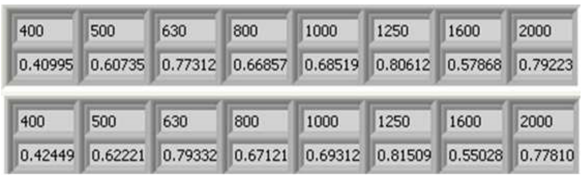


Fig. 9. Single wall corrugated cardboard sheet

A very good sound absorption coefficient we get for the sample manufactured from compact cardboard t=0.85, Φ=0.5, b=2 and the air thickness Dair=30, (Fig 8).

4. CORRUGATED CARDBOARD SAMPLES

Samples from single wall corrugated cardboard sheet (Fig. 9) are manufactured and measured in the sequel. It is a corrugated fiberboard carton made by gluing a sheet of fluted corrugated material between two flat sheets of linerboard. Seems to be E-Flute where flute thickness is about 1.5 mm. Generally this is used for light applications such as pizza boxes, mailers, shoe boxes [14].



400	500	630	800	1000	1250	1600	2000
0.40995	0.60735	0.77312	0.66857	0.68519	0.80612	0.57868	0.79223
400	500	630	800	1000	1250	1600	2000
0.42449	0.62221	0.79332	0.67121	0.69312	0.81509	0.55028	0.77810

Fig. 10. Alpha versus frequency for both faces of the Corr_t5 sample

Table 3

List of corrugated cardboard samples

t [mm]	Φ [mm]	b [mm]	Dair [mm]
5, Corr_t5	0.7	3, M	30
1.4, Corr_07	0.7	3, M	30
1.4	0.8	6, M	30
1.4	0.7	3, M	30
1.4	0.8	6, T	30

In Table 3 are listed several corrugated samples which were manufactured and measured.

The first corrugated cardboard sample is the thickest one: t=5mm, Φ=0.7, b=3mm, Dair=30mm (noted Corr_t5). In Figure 10 the variation of sound absorption coefficient can be observed. A set of samples of thinner corrugated cardboard, with t=1.4mm (Table 3) was manufactured by drilling, as well.

A very promising sound absorbing coefficient variation has been measured for the Corr_07 sample visualized in Figure 11, where both sides of the sample are shown. A first peak is visible in Figure 12 at about 600Hz and from 1000Hz to 2000Hz the absorption coefficient is almost one.

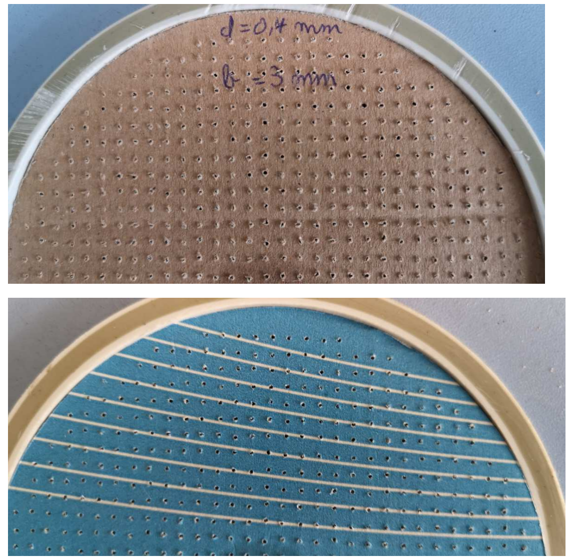


Fig. 11. Single wall corrugated cardboard sample, both sides, Corr_07 sample: Φ=0.7, b=3mm

the absorption resulted similar for the 1000-2000 frequency span excepting the first peak for lower frequency. After the sample was pressed between other samples, the burr of the perforations is modifying the perforation geometry and hence the sound absorption is changed.

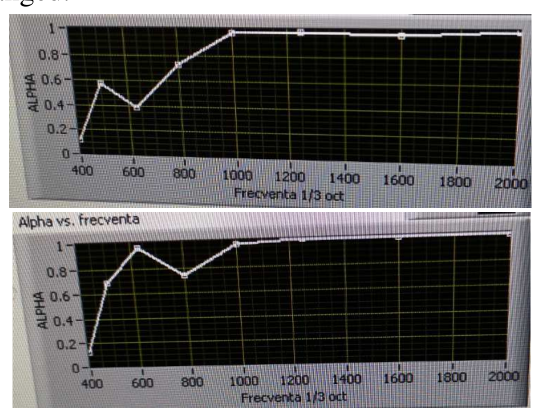
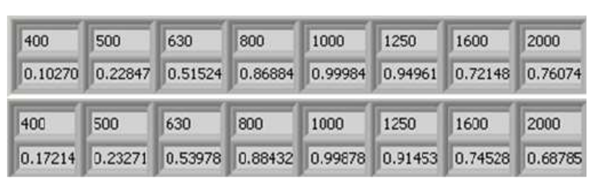


Fig. 12. Alpha vs. frequency, Corr_07 sample, both faces, 1/3 octave, 400Hz-2000Hz

The sound power absorption coefficient for the modified sample is presented numerically in Figure 13.



400	500	630	800	1000	1250	1600	2000
0.10270	0.22847	0.51524	0.86884	0.99984	0.94961	0.72148	0.76074
400	500	630	800	1000	1250	1600	2000
0.17214	0.23271	0.53978	0.88432	0.99878	0.91453	0.74528	0.68785

Fig. 13. Alpha versus frequency, Φ=0.7, b=3, Corr_07 modified burr

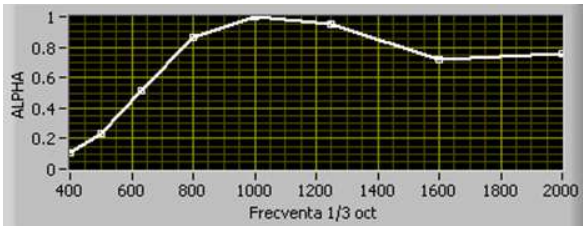


Fig. 14. Alpha versus frequency graph, Corr_07 sample, modified burr

The associated graph of Alpha values on eight frequency measurement points for one sample side, is shown in Figure 14.

5. CONCLUSIONS

The sound absorption coefficient measurement of some compact cardboard and corrugated cardboard samples by using the standing wave ratio method implemented on a simple impedance tube is presented.

The sound absorption coefficient is evaluated at 1/3 octave frequency span from 400Hz to 2000Hz. This is by no means an exhaustive plan for measurements of sound absorption on cardboard.

The purpose of the paper is to report some good absorbing samples with an inexpensive material, rapidly manufactured by using drilling for the microperforations and for quick usage. For a cardboard sample Corr_t5 (t=5mm, Dair=30mm, d=0.7, b=3mm) the absorption coefficient is higher than 0.8 from 800 Hz to 1800Hz.

A corrugated cardboard sample t=1.4, Φ=0.7, b=3 has Alpha coefficient almost 1 from 1000Hz to 2000Hz. The variability in time of the microperforations is observed because the structure is fragile to contact or pressure from vicinity and slight changeable in time.

The microperforation burr present on one sample side is deformed in time diminishing the opening area. The impedance tube is manufactured completely in our laboratory, the sound pressure acquisition system is calibrated (CAL200 Larson Davis) and comparisons with commercial instruments are ongoing.

The sound pressure variation in the vicinity of the sample measured with the movable microphone is trusty observing on the screen the acquired signal with the maxim and minim pressure amplitude while the microphone is translated.

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Coeficientului de absorbţie acustică a cartonului de ambalaj microperforat măsurat cu un tub de impedanţă simplu

Rezumat*:* In articol sunt prezentate proprietăţile fonoabsorbante deosebite ale unor mostre confecţionate din carton de ambalaj (două feţe exterioare şi o suprafaţă ondulată între ele). Microperforaţiile practicate în carton sunt realizate prin burghiere la diametre submilimetrice. Măsurarea coeficientului de absorbţie acustică se realizează cu un tub de impedanţă realizat in laborator, un sistem de achiţie bazat pe o placă National Instruments şi o aplicaţie Labview. S-au măsurat valori ale coeficientului de absorbţie acustică aproape de unu pe o bandă largă de frecvenţa (1000Hz-2000Hz) şi spaţiere 1/3 octave. Proprietăţile fonoabsorbante sunt uşor modificate prin contactul bavurilor rezultate din burghiere cu alte suprafeţe. Lucrarea propune o structură fonoabsorbantă uşor de realizat cu costuri reduse şi cu valori înalte ale coeficientului de absorbţie într-o bandă relativ largă de frecvenţă.

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