THE ANALYSIS OF SOUND ABSORBING PERFORMANCES FOR COMPOSITE PLATES CONTAINING RECYCLED TEXTILE WASTES

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In this article we obtained some experimental results about soundproofing of three types of stratified composite materials made of: plate of short fiber fabricated from recovered textile which joins with: cork board; expanded polyethylene, laminated on one side with aluminum foil of 9μm thickness or extruded polystyrene. These materials used in the composite structure are analyzed in terms of the change in the absorption coefficient in the range of 100-3200 Hz. Experimental analyses are performed using an acoustic interferometer (Kundt tube) in order to classify absorbing materials submitted for testing.

Keywords: absorption coefficient, stratified composite materials, recycled textile waste, cork, expanded polyethylene, extruded polystyrene.

1. Introduction

It is known that the textile industry is not only a major consumer goods producer, but also, proportionally, a large producer of waste [1, 2], implicitly resulting materials from the manufacturing process, but which, reintroduced into a specific manufacturing process, become textile plates used in making multi-layered composite materials [3-5] that we study hereby in terms of sound-absorbing properties. The study of these absorption properties is found in other papers [6-8], where the material was composed especially of sawdust and rubber. It is noted a major interest in the use of recyclable materials in the making of composite materials [6, 9-12] that have been studied over time. Fiber insertions play an important part, which is why was studied their influence, both nationally and internationally, for wood or tea fiber [12, 13] and on textile fibers - bamboo, jute [14-17]. The authors of these study intend to use these newly made composite structures with preferential selectivity in certain fields of noise frequency by manifesting the acoustic properties of sound absorption with the ultimate goal of noise reduction in the production departments by encapsulating electric motors

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with these composite materials (e.g.: reducing noise produced by electric engines, thermal engines, compressors, etc.) [18-20].

2. Characteristic measures of sound absorbing materials

In order to characterize the sound absorbing properties of materials, it is necessary to specify quantitatively both the degree of transmission of acoustic waves on the separation surface between two media, and the degree of sound absorption [21, 22].

The sound absorption coefficient α $_i$ ***occurs if,*** at the surface of separation between the two media, there is a dissipation of acoustic energy, and then the amount of energy that is not reflected is considered to be absorbed [22, 23]:

$$\alpha_i = 1 - \frac{\Phi_r}{\Phi_i} \tag{1}$$

where: Φ_r - reflected acoustic energy flow; Φ_i - incident energy flow.

The average sound absorption coefficient can be calculated relative to the α_i absorption coefficient corresponding to S_i surface [22, 23], as follows:

$$\alpha_{med} = \frac{\sum \alpha_i S_i}{\sum \alpha_i} \tag{2}$$

Also, **the sound absorption coefficient, α,** can be defined as a ratio between the absorbed sound energy (E_a) by the medium through which the wave propagated and the incident wave energy (E_i) [22],

$$\alpha = \frac{E_a}{E_i} \tag{3}$$

or

$$\alpha = 1 - \frac{E_r}{E_i} \tag{4}$$

where E_r is the energy of the reflected wave.

Sound absorption equivalent area [23, 24] can be calculated using the formula:

$$A = \sum_{i=1}^{n} \alpha_i S_i \tag{5}$$

where: S_i stands for the surface *i* with / without sound-absorbing treatment;

α_i - the sound absorption coefficient of the surface S_i.

The overall noise reduction level ΔL is calculated [21-23] with the following formula:

$$\Delta L = 10 \lg \frac{A}{A_0} \quad (6)$$

where: A - stands for the equivalent surface of acoustic sound absorption after the application of the acoustic treatment;

A_0 - equivalent surface acoustic sound absorption without treatment.

3. The presentation of materials and the measurement system

Four plates of different materials are being studied, then they are combined two by two, the fabric layer plus one of the other materials, thus resulting three-layered composite materials, the measurements being made on the fabric layer.

a) Recovered textile+ cork b) Recovered textile+ polystyrene c) Recovered textile+ polyethylene

Fig. 1. Variants of multi-layered composite materials undergoing tests

The following types of materials are to be considered:

- Plates made from textile material obtained from recovered short fiber comprising 85% PNA (polyacrylonitrile) plus 15% PA (polyamide) or PE (polyester) fiber, recovered or the first use fiber, material thickness being 10 mm - **P 1**;
- Cork plate with material thickness of 3 mm **- P 2**;
- Extruded polystyrene plate of 7 mm thickness – **P3;**
- Plate of expanded polyethylene with closed cell spatial structure, covered on one side with aluminum foil with 9μm thickness, material thickness being 10 mm - **P 4.**

Out of the combination of these plates using a cold sticking polychloroprene glue, based on organic solvents, there are obtained the following layered composite material:

- *Case 1* is composed of: C 1 = P 1 + P 2; Fig. 1a);

- *Case 2* is composed of: C 2 = P 1 + P 3; Fig. 1b);
- *Case 3* is composed of: C 3 = P 1 + P 4; Fig. 1c).

Fig. 2. Acoustic interferometer, type 4206 A (Kundt tube)

In making experimental measurements the PULSE (Normal Incidence Absorption) analysis software allows the determination of α sound absorption coefficient and at the same time of the acoustic reflection coefficient, of the surface acoustic impedance and of the acoustic surface admittance of the material composite complex structures. The measuring method is used in accordance with SR EN ISO 10534-2: 2005 [24], in which are stipulated the necessary conditions for using the acoustic interferometer (the Kundt tube). The measurement system consist of: the type 4206 A acoustic interferometer, 2 Brüel & Kjaer microphones type 4187 with type 2670 embedded preamplifier, signal generator, power amplifier type 2716-C, PC with PULSE control and data acquisition software, named Type 7758 - acoustic material testing in tube (see Fig. 2).

The analysis of the acoustic characteristics for this type of acoustic interferometer is performed in the 100 Hz ÷ 3,2 kHz frequency range [24, 25].

4. Experimental results

Analyzing the experimental data obtained for the composite materials, a graph is drawn for all the samples of layered composite materials with a view to see the differences and variations of the sound absorption coefficient as a function of frequency. In all studied cases, the direct interaction surface of the acoustic waves consists of textile waste material (P1).

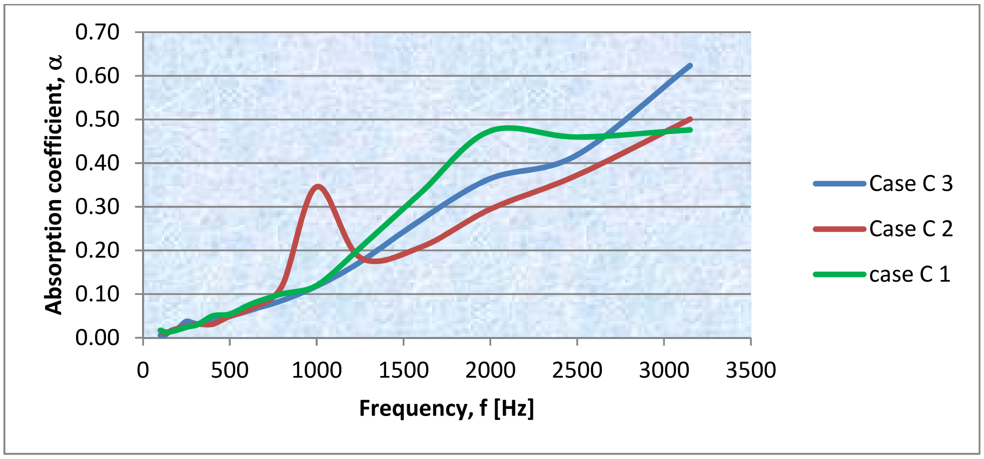

Fig. 3. The variation of sound absorption coefficient for the three cases of composite structures

Table 1

The average sound absorption coefficient α_{med}

The variant (the case)	Material structure	Sound absorption coefficient α_i			The average sound absorption α_m
		800 Hz	2000 Hz	3200 Hz	
C 1	Textile material + cork	0,100	0,474	0,539	0,371
C 2	Textile material + expanded polyethylene + Al foil	0,119	0,295	0,508	0,307
C 3	Textile material + extruded polystyrene	0,085	0,365	0,634	0,361

All materials do not develop sound absorbing properties up to 800 Hz frequency, in Case C 2 α_i growth is the slowest compared to the other two types of materials. There is noticed a directly proportional increase of the sound absorption coefficient relative to increasing frequency for all the analyzed cases (Fig. 3). Depending on the calculation of the average sound absorption coefficient on given frequency bands (Table 1), there can be made a classification in one of the A-E classes of absorption, as shown in Table 2.

Table 2

Absorption classes [16, 25]

Absorption coefficient α	Sound Absorption Class
0,90 – 1,00	A
0,80 – 0,85	B
0,60 – 0,75	C
0,30 – 0,55	D
0,15 – 0,25	E
0,00 – 0,10	Not classified

The value of the average sound absorption coefficient α_m is 0.371 for the composite material C 1, α_m is 0.307 for C 2, and α_m is 0.361 for C 3, thus making possible the inclusion of these composite layered materials in the D absorption class (see Table 2).

For C 1, there is a significant increase of the sound absorption coefficient variation in the range 1500 to 2500 Hz. Between 1250 - 3200 Hz there is a slight increase of the sound absorption coefficient for C 3 as compared to C 2.

Also, an important increase of the sound absorption coefficient is noted in for C 2 in the frequency range 800-1250 Hz (see Fig. 3).

The maximum values of the sound absorption coefficient obtained in the three cases are found at the maximum level of the measuring range, namely at 3200 Hz: 0.539 for case C 1; 0.508 for case C 2 and 0.634 corresponding to case C 3 (Table 2).

5. Conclusions

Analyzing the experimental results obtained for these types of layered composite materials there can be noticed that they have an absorption spectrum that can be classified for frequencies higher than 800 Hz, as can be seen in Fig. 3 and Table 2. This means that these combinations of materials do not have a substantial absorption effect in the low frequency range of up to 800 Hz.

In 1250-2500 Hz range of frequencies it is preferable to use composite C1 and at higher frequencies of 2700 Hz find the best reaction to the composite C 3.

Depending on the previously measured sound spectrum and on the narrower or wider rages in which the predominant frequencies which must be reduced are, the best variant of layered composite material can be chosen for a maximum absorption. Following the performed analyses, all the three layered composite materials have absorbing properties and a sound absorption characteristic correlated with frequency so that at the frequencies of 1000 Hz, 2000 Hz and 3200 Hz the composite structures C 2, C 1 and respectively C 3 to have a high absorption.

The sound-absorbing materials used in this study are produced from recyclable textile materials which have a low manufacturing cost, so that the obtained composite materials can be used efficiently at low costs. The utilization of these types of recyclable materials satisfies the fundamental requirements of worldwide sustainable resource use.

Finally, it can be concluded that by the use of some configurations of the mentioned materials can be obtained layered composite materials which have an increased effect of noise absorption from noise sources in certain frequency ranges, being of interest, useful and necessary for the soundproofing of the noise sources. Using the equations (5) and (6), depending on the absorption coefficient and the appropriate material surface, there can be easily estimated the equivalent sound absorption surface (A), respectively the overall noise reduction (ΔL) during the use of a particular soundproofing composite structure.

The checking of the effectiveness of these materials with multi-frequency absorbing properties in the case of the soundproofing of noise sources will be considered subsequently.

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