ACOUSTIC CHARACTERISTICS OF MATERIALS BUILT-UP FROM RECYCLING WOOD

Antonella Bevilacqua
Università di Parma

Giuseppe Ciaburro
Faculty of Engineering and Informatics, Pegaso University

Merli Elena
Next Technology Tecnotessile Società Nazionale di Ricerca r.l.

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Iannace Gino

University of Campania Luigi Vanvitelli, Italy

gino.iannace@unicampania.it

Amadasi Giovanni

SCS-ControlSys_Vibro-Acoustic, 35011 Padova, Italy

Bevilacqua Antonella

University of Parma, Italy

Canesi Ilaria

Next Technology Tecnotessile Società Nazionale di Ricerca r l., Prato Italy

Ciaburro Giuseppe

University of Campania Luigi Vanvitelli, Italy

Merli Elena

Next Technology Tecnotessile Società Nazionale di Ricerca r l., Prato Italy

Spinelli Daniele

Next Technology Tecnotessile Società Nazionale di Ricerca r l., Prato Italy

Trematerra Amelia

University of Campania Luigi Vanvitelli, Italy

Wood is a material that is often recycled after its primary usage for creating furniture or other objects of interior design. The working process regarding how it is recycled consists mainly of the trituration of the pieces in order to be mixed with other additives. In this way, a new material can be reused and potentially employed for acoustics. This paper deals with the acoustic measurements of small samples obtained from recycled wood. The impedance tube has been used for this purpose to obtain the absorption coefficients at normal incidence. From the first set of measurements, some assemblies have been studied to improve the acoustic quality of absorption, that is obtained with the creation of holes and cavity on the surface of the samples, in line with the concept of resonant cavities. An innovative material provided with an alternative geometry has been obtained with very performant acoustic properties.

Keywords: impedance tube, absorption coefficients, recycled wood, reused assemblies.

1. Introduction

In recent decades, attention has been paid to the creation of products obtained from recycling dismissed objects or from the use of vegetable fibres. These latest ones are usually discarded from the agricultural supply chain and can be a valid substitute for unprofitable agricultural crops. In this way it is possible to create supply chains that allow the agricultural sector to become the main support for economy. In a wide view, this process allows an increase of income against the depopulation of rural areas. The materials from vegetal origins can be used once dried and shredded, as absorbing panels in the field of acoustics instead of the high-carbon emission produced by polyester. Wood is the most popular material subject to be recycled after its primary usage. Its recycling process consists of the trituration of pieces in order to be mixed with other additives to create another material that can be employed in different fields other than interior design, in acoustics for example [1, 2].

This paper deals with the acoustic measurements carried out with the impedance tube on small samples obtained from recycled wood in order to test and obtain the absorption coefficients at normal incidence. From the first set of measurements, some assemblies have been particularly studied to improve the acoustic quality of absorption and holes and cavities have been created for this purpose, in line with the principles of resonant cavities. In this way, an innovative material provided with an alternative geometry has been obtained with high performance acoustic properties on absorption [3-5]. In this way it is possible to obtain a new material from waste ones. The use of these new materials allows for a reduction in waste and allows us to reduce the exploitation of trees and plants. Furthermore, these materials at the end of their useful life can be disposed of in the environment without causing damage.

2. Working process of recycling materials

The primary fibres used to create the new materials are the following:

- chips from cotton plants;
- chips from corn plant;
- long hemp fibres;
- short wood fibres (e.g. birch);
- short poly lactic acid (PLA) fibres.

Each assembly is a multilayer panel composed as follows:

- Outer layers made of cotton or corn chips with the addition of PLA fibre,
- Inner layers made of hemp or wood fibres with the addition of PLA fibre.

Each layer was created separately and then ultimately assembled together. The phase 1 to obtain the outer layers consists of mixing cotton or corn shavings together with PLA fibres in a box with compressed air. Phase 2 consists of pressing the still mixed material at high temperature of 145°C for 30 minutes. In phase 3 the thickness of the layer was determined by interposing shims of known dimensions between the two heating plates, as shown in Figure 1.

(a) (b)

Figure 1: Machinery used during the fabrication process of the recycled wood: cardina (a), thermos-presser (b).

In a similar way, the inner layers of the assemblies were made of hemp fibres mixed with PLA fibres with compressed air process. In phase 2 this composite is placed managed to form a non-woven fabric. As common practice, this panel was later subjected to the heat press under same heating conditions (at 145°C for 30 minutes and interposing thicknesses of known dimensions). After the creation of each single panel, the four panels were stacked and heat-pressed at 145°C for 90 minutes, which is the process that was used to create the final panel, as it has been used for the acoustic measurements with the impedance tube. Figure 2 shows the composite panels as final product obtained after the compression process.

(a) (b)

Figure 2: Final product used for the acoustic measurements: recycle of hemp (a) and corn chips (b).

3. Methodology adopted for the acoustic measurements

The material samples used for the acoustic measurements are those made with recycled wood, as described in the previous section, consisting of cellulose, organic and plant-based wastes (i.e. corn, hemp, cotton).

Samples of 100 mm diameter were inserted into the impedance tube for measuring the quality of absorption and gathering the absorption coefficients. The sound signal generated by the loudspeaker travels in the tube as a plane wave such that only one incident angle is considered. The signal is reflected back in different ways by the specimen, based on the properties of material, that are recorded by two microphones placed before and after the sample, in accordance with the ISO 10534-2 [6]. A post-processing analysis allows the determination of the absorption coefficients attributed to the tested sample. The values of the absorption coefficients span between 0 and 1, whereas 0 means that the material is more reflecting, while 1 means that the material is totally absorbing the incident sound energy. The absorption coefficients are measured in the frequency domain, between 200 Hz and 2000 Hz. The distance between the measurement microphones is 5 cm. Figure 3 shows the impedance tube used for the acoustic measurements [7-10].

Figure 3: Impedance tube in use.

In summary, the test samples are given by the combination layers of the panels described in Table 1.

Table 1: Technical composition of single panels.

ID.	Description	Characteristics
C60PLA	60 g hemp fibre + 40 g PLA fibre.	Thickness: 0.6 cm Mass: 28.1 g Density: 0.21 g/cm^3
COT80PLA	80 g cotton chips + 20 g PLA fibre.	Thickness: 0.5 cm Mass: 25.4 g Density: 0.23 g/cm^3

K80PES	80 g hemp fibre + 20 g polyester fibre	Thickness: 0.5 cm Mass: 111 g Density: 0.20 g/cm^3

4. Results and discussions

The results obtained by the signal recorded in the impedance tube were elaborated in the frequency domain ranging from 125 Hz and 2000 Hz. The composition of the composite panels is described in Table 2.

Table 2. Layer combination for the creation of recycling lamellate panels.

ID.	Composition	Characteristics
A	- 1 layer of 80 g corn chips + 20 g PLA fibre. - 2 layers of 60 g hemp fibre + 40 g PLA fibre. - 1 layer of 80 g corn chips + 20 g PLA fibre.	Dimensions: 15×15×1 cm Mass: 81.1 g Density: 0.36 g/cm^3
B	- 1 layer of 80 g cotton chips + 20 g PLA fibre. - 2 layers of 60 g hemp fibre + 60 g PLA fibre. - 1 layer of 40 g cotton chips + 10 g PLA fibre.	Dimensions: 15×15×1.9 cm Mass: 100.2 g Density: 0.23 g/cm^3
C	- 1 layer of 160 g corn chips + 40 g PLA fibre. - 2 layers of 60 g hemp fibre + 40 g PLA fibre. - 1 layer of 80 g corn chips + 40 g PLA fibre.	Dimensions: 14×15×2.6 cm Mass: 111 g Density: 0.20 g/cm^3

The results of the tests are reported in Figure 4, where the highest values of absorption coefficients are found with specimen C between 800 Hz and 1600 Hz and with specimens A and B at 1800 Hz and 2000 Hz [11]. Compared to other absorbing panels, this performance is not related to class A or B, but it is still useful for low-medium level of absorption.

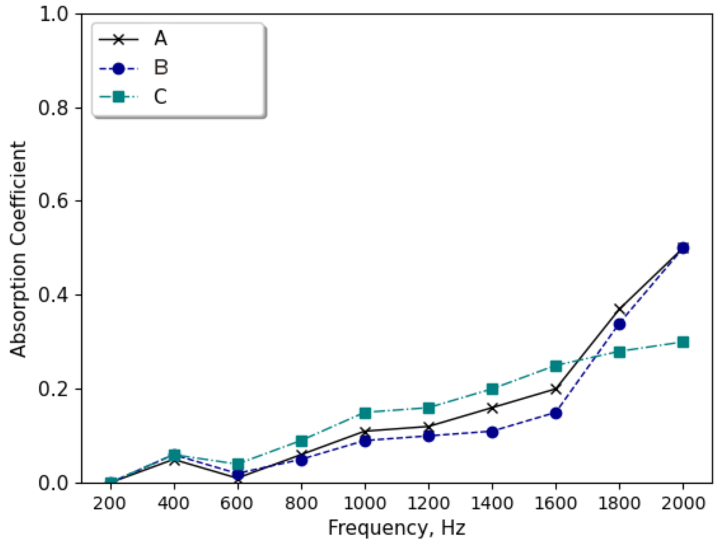

Figure 4: Measured results of absorption coefficients.

Conclusions

The amount of waste material from construction sites and other manufacturing process is huge. Another significant quantity derives from packaging and delivery. Many factories have already started to use the discarded material to build new ones based on innovative technique of assembly, that can be applied to the area of interior design with new furniture or simply by giving a further life to the material that is not useful anymore. The combination of corn, cotton and hemp fibres with PLA is the process that has been used for this research study. The assembly of all the recycling material has been subject to be hot-pressed in panels such that the authors were able to test the absorbing properties of these composite boards. The results show that some significant absorption is achieved at medium frequencies, to be equal to 0.2, with a pick at 2000 Hz that achieve up to 0.5. The idea of combining these single boards in a composite assembly is due to practical reasons, related to the stiffness of the product. Although the performance is not related to any class A or B, the performance results good to fit for low-medium level of absorption. These low frequency materials are not suitable for absorbing sound, but have the advantage that they can be processed easily. Thus, to increase low frequency acoustic absorption it is possible to drill holes in the material and obtain resonant systems, whose acoustic absorption depends on the diameter of the holes and the size of the cavity behind them [12-17]. It is known that by changing the thickness of the cavity behind the perforated panel it is possible to obtain a desired absorption coefficient value especially at low frequencies.

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