STUDY ON THE INFLUENCE OF SOME FACTORS ON THE SOUND ABSORPTION CHARACTERISTICS OF WOOD FROM SCOTS PINE

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Abstract

The aim of the current study was to trace the variations in the frequency-dependent sound absorption coefficient of flooring and wall lining material, made out of Scots pine (Pinus Sylvestris L.) wood, depending on the thickness of the material and the type of the protective coating. The sound absorption has been assessed at the frequency range from 250 Hz to 2 kHz, on details with the following thickness: 20, 30 and 40 mm, and three different surface coatings: water-soluble lacquer (acrylic lacquer), polyurethane lacquer (two components) and hard wax oil for wood. The results obtained would be useful to determine the total equivalent sound absorption area of a room in order to provide the necessary acoustic characteristics. The tests were carried out using an impedance tube, according to the requirements of EN ISO 10534.

Key words: *sound absorption, Scots pine, equivalent sound absorption area, reverberation time.*

INTRODUCTION

Wood is a basic building material used for light frame constructions, beams, columns, etc. Further more solid wood materials and wood-based composites are considered as acoustic materials because of their ability to reduce the noise level and to absorb the sound.

It is well-known that the acoustic parameters of the wooden materials depend on different characteristics, like thickness, density, porosity, airflow resistance, as well as on their situation in the room (Seddeq, 2009; Arenas et al, 2010).

Many studies have been focused on the investigation of the acoustic behavior of wood and wood based bio-materials, aiming to ensure the necessary acoustic requirements along with resolving the problem of sound pollution (Wassilieff, 1996; Martellottaa et al., 2011; Smardzewski et al., 2013; Smardzewski et al., 2015; Amel et al., 2016; Negro et al., 2016; Daeipour et al, 2017). One of the main applications of wood is as an acoustic insulator in floors, ceilings and walls. Another important application is for sound absorbing materials. It is known that wooden-plated panels in front of an air cushion are used for absorbing low frequencies as well as wooden linings lead to a bright sound because of low frequency

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absorption (Bucur, 2006). Sound absorption and sound reflection efficiency are related to the type of wooden materials, the internal structure and properties (anisotropy, density, mechanical and elastic properties) as well as to surface treatments.

The aim of the present study was to investigate the changes in the sound absorption coefficient of flooring and wall lining material, made out of Scots pine (*Pinus Sylvestris* L.) wood in dependence of thickness and surface coatings.

The experiments are carried in laboratory conditions in a Kundt's tube.

MATERIALS AND METHODS

The materials used for the research are Scots pine (*Pinus Sylvestris* L.) wood samples with the following characteristics: density $\rho = 490$ kg.m^{-3}, moisture content $W = 12$ % and modulus of elasticity $E_{L(12\%)} = 10520.10^6$ N.m^{-2}. The characteristics of the used material have been determined in accordance with the following standards: BDS ISO 3131, BDS ISO 3130 and EN 310.

The methodology of the experiments included the following steps: (i) assessment of the influence of the thickness of the tested material on its sound absorption properties and (ii) assessment of the sound absorption properties of the tested material depending on the type of the surface coating material.

For the implementation of our first task – evaluation of the influence of the thickness of the tested material, nine specimens with a diameter of $d = 90$ mm and three different thicknesses (T): $T_1 = 20$ mm, $T_2 = 30$ mm and $T_3 = 40$ mm have been used. The data are presented in Table 1. All specimens are cut in the longitudinal direction of the tree. The used specimens with their coding are shown in Figure 1.

Table 1. Characteristics and coding of the specimens used for the evaluation of the influence of the thickness of the tested material on the sound absorption

Number	Thickness (T), mm	Code	Number	Thickness (T), mm	Code
1	$T_1 = 20$	1.20.1	6	$T_2 = 30$	1.30.3
2	$T_1 = 20$	1.20.2	7	$T_3 = 40$	1.40.1
3	$T_1 = 20$	1.20.3	8	$T_3 = 40$	1.40.2
4	$T_2 = 30$	1.30.1	9	$T_3 = 40$	1.40.3
5	$T_2 = 30$	1.30.2			

Figure 1. The tested specimens with different thickness

For our second task – evaluation of the influence of the coating material on the sound absorption coefficient, 12 specimens with diameter of *d* = 90 mm and thickness *T* = 30 mm have been prepared (Figure 2).

The samples have been divided into 4 groups: 1 – without coating; 2 – with hard wax oil (Levis, UK); 3 – with polyurethane lacquer (Orgachim, Bulgaria); 3 – with water soluble lacquer (Renner, Italy). The characteristics and coding of the test specimens are presented in Table 2.

Table 2. Characteristics and coding of the specimens used for the evaluation of the influence of the coating material on the sound absorption coefficient

No	Coating type	Code	No	Coating type	Code
1	Natural (no coating)	2.1	7	Polyurethane lacquer	4.1.PL
2	Natural (no coating)	2.2	8	Polyurethane lacquer	4.2.PL
3	Natural (no coating)	2.3	9	Polyurethane lacquer	4.3.PL
4	Hard wax oil	3.1.O	10	Water soluble lacquer	5.1.WSL
5	Hard wax oil	3.2.O	11	Water soluble lacquer	5.2.WSL
6	Hard wax oil	3.3.O	12	Water soluble lacquer	5.3.WSL

Figure 2. Specimens with different protective coatings

Measurements of the sound absorption coefficient

The experiments for the evaluation of the sound absorption levels are carried out in a Kundt’s tube, in laboratory conditions at constant temperature and pressure. The experiments have been performed in accordance with EN ISO 10534-1. The experimental design consists of impedance tube, made from Plexiglas, loudspeaker, sound generator Feel Tech FY2300 H, PC based Real Time Analyzer and Sound Level Meter System VT RTA-168, microphone ECM999 and Multi-Instrument Software. The experimental design is schematically presented in Figure 3 and described in details in the papers of Djoumaliisky, Ivanova et al., 2012 and Djoumaliisky, Ivanova et al., 2013.

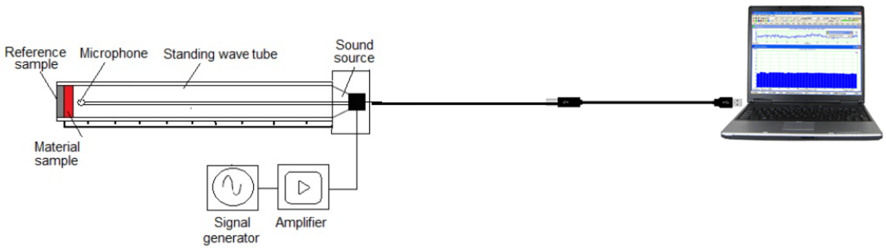


Figure 3. Scheme of the experimental equipment used for assessment of the absorption coefficient

The loudspeaker, which is located at one end of the tube is induced by signal generator, that generates sine waves in the frequency range from 100 to 2000 Hz. The waves propagate in the tube to the other end and are reflected at the hard termination end cap made from brass material. The wood samples are placed on a rigid end cap. The phase interference between the waves in the pipe which are incident upon and reflected from the test sample results in the formation of standing waves.

The pressure amplitudes at nodes and antinodes are measured with a microphone probe attached to a car which slides along a ruler. The ratio of the pressure maximum (antinode) to the pressure minimum (node) is called the standing wave ratio SWR

$$SWR = \frac{p_{max}}{p_{min}}. \quad (1)$$

This ratio is used to determine the sample's reflection coefficient amplitude R and absorption coefficient α. Sound power reflection coefficient R_p can be expressed by

$$R_P = \left|\frac{SWR - 1}{SWR + 1}\right|^2 \quad (2)$$

The sound absorption coefficient α at a given resonance frequency is calculated by (Fahy, 2005)

$$\alpha = 1 - R_p \quad (3)$$

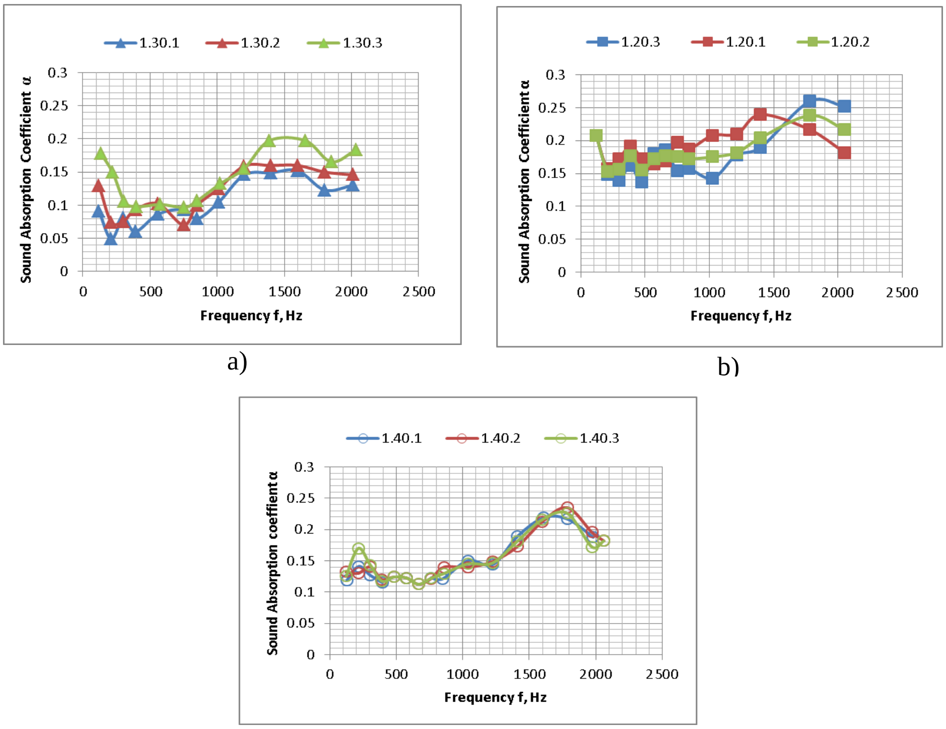
$$\alpha = \frac{4SWR}{(SWR + 1)^2} \quad (4)$$

Measurements in the frequency range are performed twice on each sample that is glued and hard adhered to the tube wall.

RESULTS AND DISCUSSION

Variation of sound absorption coefficient vs. frequency for different thicknesses of tested wood specimens from Scots pine

The dependence of the sound absorption coefficient on the frequency, measured for the tested specimens with different thicknesses is presented in Figure 4 (a, b, c). The specimens with the tickness of 20 mm, showed absorption in the frequency range from 1400 to 1600 Hz (Fig. 4 a), the one with the thickness of 30 mm, absorb from 1400 to 1800 Hz (Fig. 4 b) and the specimens with the thickness of 40 mm showed the highest values of the absorption coefficient in the frequency range of 1600 – 1700 Hz.



c)

Figure 4. Sound absorption properties of wood specimens from Scots pine with different thickness – 20 mm; b) – 30 mm; c) – 40 mm

The average values of the sound absorption coefficients for the experimental groups 1.20, 1.30 and 1.40 have been compared and presented in Figure 5. It is visible that the wood samples with lower thickness have better sound absorption than the one with higher thickness. It has to be noticed that the absorption curves show amplitude peaks and variable frequency position according to the considered thicknesses.

The specimens with T_1 = 20 mm have two absorption peaks: the first, observed at 120 Hz has an absorption coefficient α = 0.22; the second is observed around 1581 Hz and reaches a value of α = 0.25 (Fig. 5). In the frequency range from 200 to 1400 Hz the averaged value of sound absorption coefficient is α = 0.177.

The specimens with T_2 = 30 mm have also two peaks of absorption: the first peak is observed at 132 Hz (α = 0.13), the second peak - at 1656 Hz with a value α = 0.17. In frequency range from 200 to 1400 Hz the value of absorption coefficient slightly varies around α = 0.09.

For the specimens with T_3 = 40 mm, the value of the absorption coefficient varies around α = 0.13 in the frequency range of 100-1000 Hz. At this frequency range also two absorption peaks are observed: the first one is registered between 150 and 250 Hz and reached a low average value α = 0.15 and the second – about 1800 Hz and reached a value of α = 0.23.

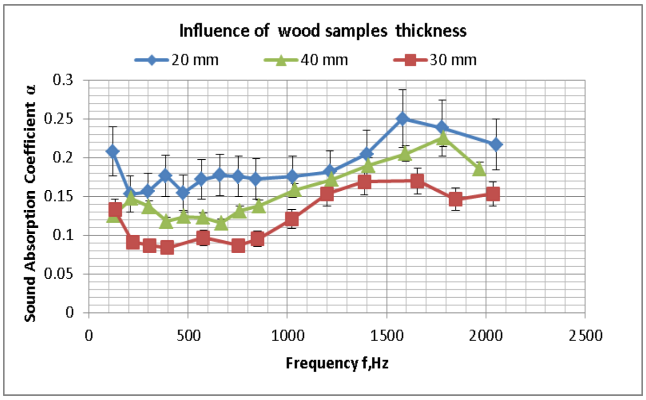


Figure 5. Comparison in the variation of the sound absorption coefficient vs frequency for wood specimens with T = 20, 30 and 40 mm

Assessment of the influence of the protective surface coatings on the sound absorption of wooden specimens from Scots pine

The experimental results of the influence of different surface coatings on the acoustic properties of the specimens are presented in Fig. 6, as follow: in Fig. 6a – uncoated (control) specimens; Fig. 6b – specimens with hard wax oil coating; Fig. 6c – specimens with polyurethane lacquer coating; Fig. 6d – specimens with water-soluble lacquer coating. From the results it is visible that the protective coatings decreased the dispersion of the measured sound pressures and sound absorption (Fig.6 b,c,d).

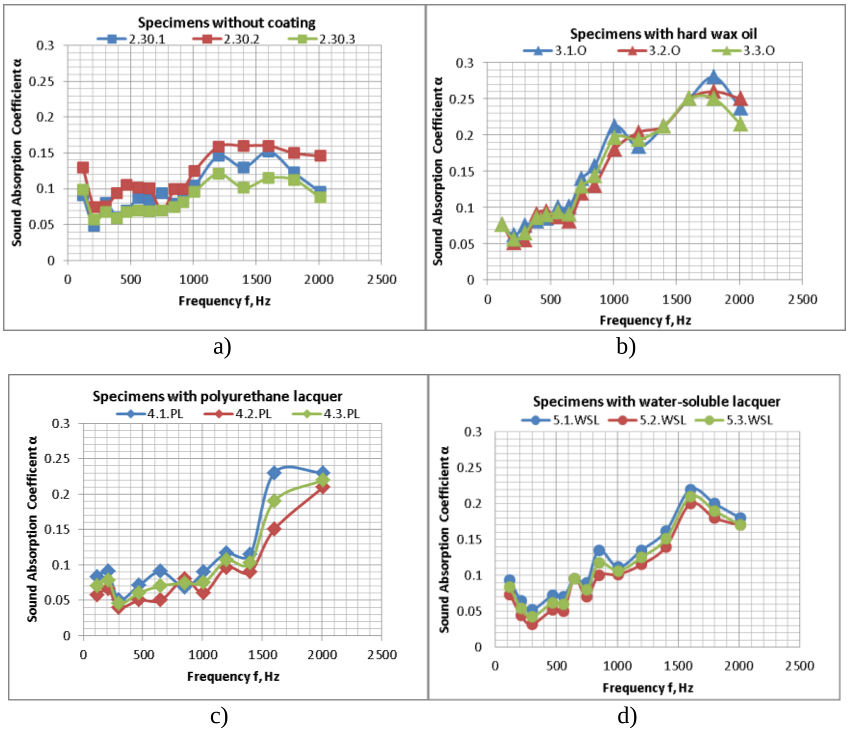


Figure 6. Changes in the sound absorption vs frequency for wood samples with and without protective coatings

The average values of the sound absorption, measured for the different groups, have been compared and the comparison is presented in Figure 7. It is visible that the specimens coating with hard wax oil showed better sound absorption properties – the maximum value is α = 0,25 at 1600 Hz, when compared to the other specimens. The sound absorption behavior of the specimens with lacquer (water-soluble and polyurethane) coatings, slightly differ at higher frequencies. It has to be noated, however, that the samples coated with water-soluble lacquer has better sound absorption in the frequency range of 500-1500 Hz, with a peak value of α = 0.22 at 1600 Hz.

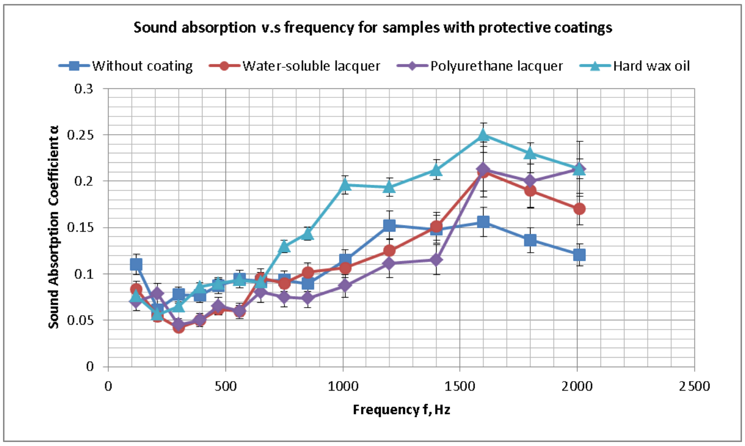


Figure 7. Comparison in the variation of the sound absorption coefficient vs frequency for wood specimens with different protective coatings

CONCLUSIONS

This paper presents results from experimental study, which investigated the influence of the thickness and the coating material on the sound absorption properties of specimens prepared from Scots pine (*Pinus Sylvestris* L.) wood, cut in longitudinal direction. The experiments were carried out in laboratory conditions with constant temperature and air pressure using the impedance tube method at a normal incidence. The moisture content of materials is constant.

Based on the results obtained under the conditions of this study, the following conclusions can be made:

• The sound absorption coefficient is influenced by the thickness of the specimens. When comparing the specimens with different thicknesses (20, 30, 40 mm), the best sound absorption properties are observed for specimens with T = 20 mm, for which the average value of sound absorption coefficient is α = 0.177.

• The absorption coefficient is easily influenced by the surface state and the presence of coatings. The coating reduces the dissipation of the results most probably due to the more homogeneous surface it provided. Our results show that the surface protective coatings (hard wax oil, water-soluble lacquer (acrylic lacquer), polyurethane lacquer) used in this study, improved the sound absorption properties of the tested specimens. Among the differently coated specimens, the best sound absorption properties in the frequency range of 600-2000 Hz showed those coated with hard wax oil. The peak value of the absorption coefficient is α = 0.25 at 1600 Hz. The specimens coated with water-soluble lacquer film showed better sound absorption abilities in the frequency region of 500-1500 Hz, with a peak value of $\alpha = 0.22$ at 1600 Hz, when compared to the samples coated with polyurethane lacquer.

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