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STUDY ON THE SOUND ABSORPTION CHARACTERISTICS OF WOOD FROM SCOTS PINE

Pavlin Vitchev[1], Yonka Ivanova[2,4], Desislava Hristodorova[3]
[1]University of Forestry, e-mail: p_vitchev@ltu.bg
[2]Institute of Mechanics, Bulgarian Academy of Science, e-mail: yonka@imbm.bas.bg
[3]University of Forestry, e-mail: dhristodorova@yahoo.com
[4]Sofia University, Faculty of Physics

ABSTRACT

In this paper, the absorption properties of wood materials from Scots pine (Pinus Silvestrys L.), which are widely used in flooring and wall linings, have been experimentally studied. The frequency-dependent sound absorption coefficient (αp) was determined in octagonal frequency bands with an average geometric frequency of 100 Hz to 2000 Hz. The tests were carried out using an impedance tube, according to the requirements of BDS EN ISO 10534-1:2006. The obtained results are of a particular interest from both scientific and practical point of view, given that the sound absorption coefficient has a decisive impact on the reverberation time. The latter is the main acoustic parameter of a room depending on its intended purpose.

Key words: sound absorption, *Pinus silvestrys*, reverberation time.

INTRODUCTION

The room acoustics is significantly influenced by the acoustic characteristics of the materials used to build its interior. Wood and wood-based materials are among the materials that have been invariably used in the design of the interior of residential, administrative, sports and public buildings. The Scots pine (*Pinus Sylvestris* L.) wood is a material commonly used in the interior of the premises, both in flooring and wall cladding as well as in the production of various types of furniture. One of the fundamental properties of the wood and to a certain extent its disadvantage is its anisotropic structure and anisotropic physico-mechanical properties (Enchev, 1975; Blaskova, 2004). Taking this into account and in order to get a full picture of its structure and characteristics, each wood material has to be evaluated in three mutually perpendicular incisions – transverse, tangential and radial and in the respective possible directions of the wood fibers (Fig. 1).It is well known, for example, that the tensile strength across the fibers is up to 20 times less than the tensile strength in the direction of the fibers.

The anisotropic structure of the wooden material is responsible for differences in the acoustic characteristics in different directions of the material (Bucur, 2006).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).

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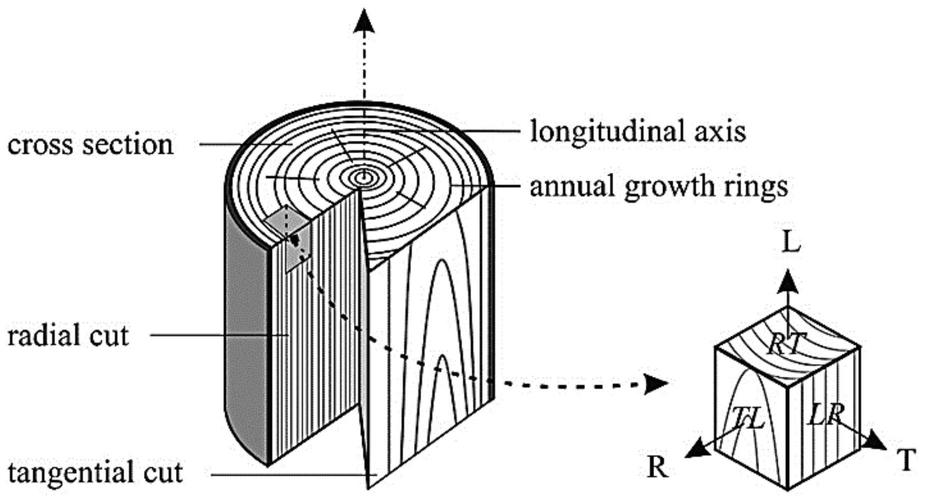


Figure 1: Wood cut sections and directions

It is well-known that the acoustic parameters depend on various characteristics of the wooden materials, such as: thickness, density, porosity, airflow resistance and last but not least on their place in the room (Seddeq, 2009; Arenas et al, 2010).

In regard to the interior acoustics, the main parameter which characterises the acoustic quality of a room is the reverberation time (R_T), which is determined by the Sabin's equation (Egan, 2007; Dinkovetal., 2016):

$$\boldsymbol{R_T = 0,164\frac{V}{\alpha.S}, s} \qquad (1)$$

where: V is a room volume, m^3;
S – the surface area of the room (floor, walls, ceiling, furniture), m^2;
α – sound absorption coefficient.

From the above-presented equation it is visible that the room acoustics is highly influenced by the sound absorption coefficient (α) of the surface material. This is equally important for the wood as a material used in building and architecture. Therefore, the absorption coefficient of different wood types has been an object of different research throughout the years.

The aim of the current study was to assess the sound absorption properties of Scots pine (*Pinus Silvestrys* L.) wood, taking into account its anisotropic structure and sound frequency. The experiments are carried in laboratory conditions in a Kundt's tube.

METHODOLOGY OF THE EXPERIMENT

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

Nine specimens, with diameter d = 90 mm and thickness s = 30 mm have been tested (Fig. 2). The specimens were divided in 3 groups (each of 3 specimen, n=3) as follow:

Group 1.1 – longitudinal/radial cut (*LR*) (Fig. 2a);

Group 1.2 – longitudinal/tangential cut (*LT*) (Fig. 2b);

Group 1.3 – radial/tangential cut (*RT*) (Fig. 2c).

a) Group 1.1

b) Group 1.2

c) Group 1.3

Figure 2: Specimens used:
a **– longitudinal/radial cut (*LR*);*b*** **– longitudinal/tangential cut (LT);** ***c*** **-radial/tangential cut(*RT*)**

Assessment of the sound absorption coefficient

The sound absorption coefficient has been measured in accordance with the interferometry method as described by Djoumaliisky (2013). Briefly, the experiments are carried out in a Kundt's tube. A control specimen, made of brass material, is located at the one end of the tube and at the other end, a loudspeaker, which generates a flat (sine) sound wave, is placed. The experiments were carried out in the frequency range from 100 to 2000 Hz. The wood samples are placed in front of the control specimen. 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 sound pressure level at the pressure minimum (node) and the pressure maximum (antinode) of the formed standing waves is measured by a moving microphone, located in the interferometer.

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).

For each of the tested specimen, three measurements at the peaks and falls of the standing waves at each resonant frequency have been performed. The results have been analyzed. 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, p_{max} (antinode) to the pressure minimum, p_{min} (node) is called the standing wave ratio SWR

$$SWR = \frac{p_{max}}{p_{min}}. \quad (2)$$

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

$$R_P = \left|\frac{SWR-1}{SWR+1}\right|^2 \quad (3)$$

The sound absorption coefficient α at a given resonance frequency is calculated by (Fahy, 2005; Djoumaliisky, 2012)

$$\alpha = 1 - R_p \quad (4)$$

$$\alpha = \frac{4SWR}{(SWR+1)^2} \quad (5)$$

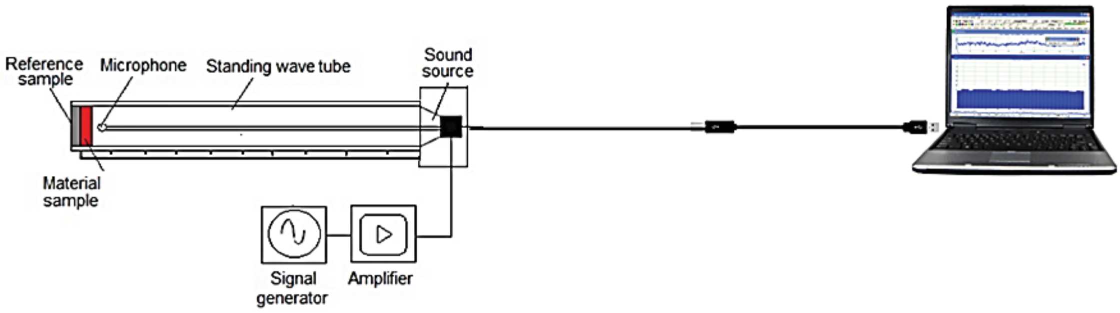


Figure 3: Scheme of the experimental equipment used for assessment of the absorption coefficient

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

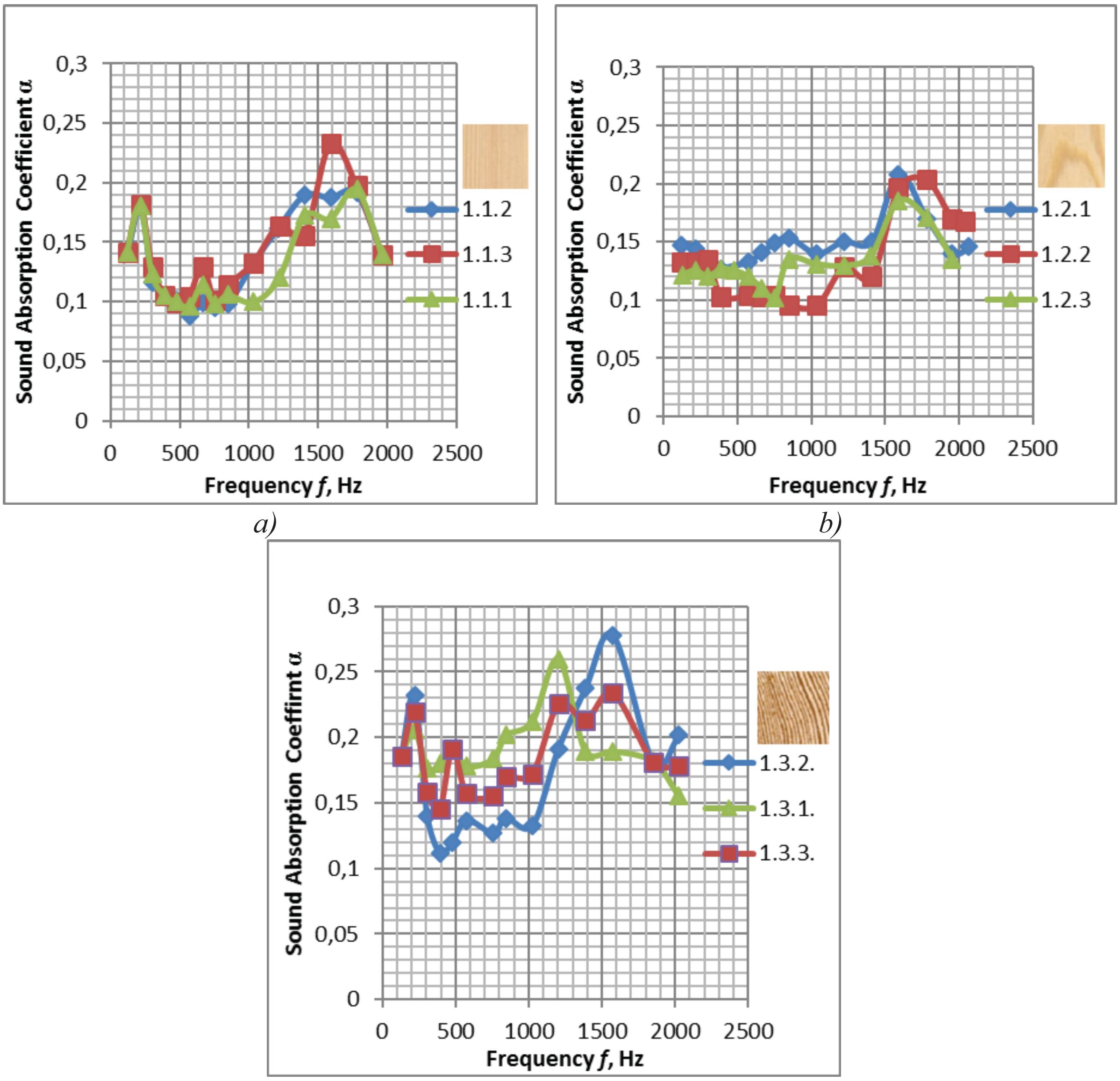
RESULTS

The results on the sound absorption properties of the Scots pine wood tested specimens, measured in the frequency range from 100 to 2000 Hz, are presented in Figure 4. For *LR* specimens (group 1.1.), depending on the frequency (*f*) of the sound energy, the sound absorption coefficient changes from 0,09 (at *f* = 600 Hz) to 0,24 (at *f* = 1600 Hz) (Fig. 4-a).

The highest values of the sound absorption coefficient are observed for the *RT* specimens

(group 1.3), which are from 0,15 (at *f* = 400 Hz) to 0,23 (at *f* = 1600 Hz) (Fig. 4-c).

In all three groups (1.1; 1.2; 1.3), peak (maximum) values of sound absorption coefficient (α) are observed at frequencies *f* = 216 Hz and *f* = 1600 Hz.



a) b)

c)

Figure 4: Changes in the sound absorption coefficient (α) depending on the frequency of the sound energy: *a* – longitudinal/radia lcut (*LR*); *b* – longitudinal/tangential lcut (LT); *c*– radial/tangential cut(*RT*)

In order to better visualize the influence of the anisotropic structure on the sound absorption properties of Scots pine wood, the changes in the sound absorption coefficients depending on the different wood cut: longitudinal/radial (*LR*) (group 1.1), longitudinal/tangential (*LT*) (group 1.2.) and radial/tangential (*RT*) (group 1.3) are summarised in Figure 5.

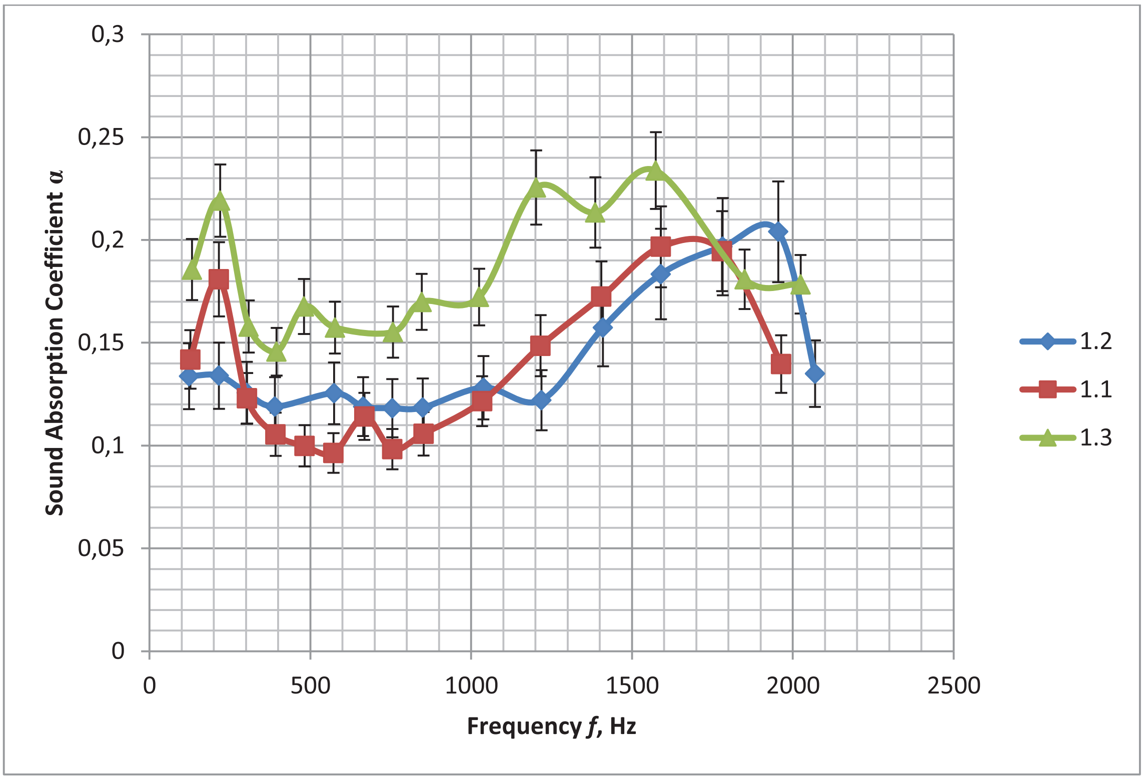


Figure5: Influence of the anisotropic structure of the Scots pine wood on the sound absorption coefficient measured in frequency range from 100 to 2000 Hz

From the results it is clearly visible that the specimens with radial/tangential cut (*RT*) (group 1.3) have the highest sound absorption properties. At frequency *f* = 1000 Hz the sound absorption coefficient values, measure for the three different groups are as follow: group 1.1 (*LR*) – α = 0,12; group 1.2 (*LT*) – α = 0,12; group 1.3 (*RT*) – α = 0,18. The peak values of the sound absorption coefficients (*α*) for all three groups fall in the frequency range from 1500 to 2000 Hz, as follow: group 1.1 (*LR*), *α*= 0,20 at *f* = 1600 Hz; group 1.2 (*LT*), *α*= 0,20 at *f* = 1950 Hz; group 1.3 (*RT*), *α*= 0,23 at *f* = 1600 Hz.

CONCLUSION

Under the conditions of this study and based on the obtained results, the following conclusions can be made:

- The results confirm the influence of the anisotropic structure of the wood on its sound absorption properties, measured by the sound absorption coefficient (α_p). The specimens with radial/tangential cut (*RT*) (group 1.3) show the highest value of the sound absorption coefficient, which when compared to the other two groups: longitudinal/radial (*LR*) and longitudinal/tangential (*LT*) is by 30% higher;
- Based on the results, it could be concluded that for the all three tested groups the highest sound absorption was observed in the lower limit of the average frequency range of human auditory field –1500÷2000 Hz (see Fig. 5);
- The observed higher standard deviations of the values of the sound absorption coefficient within the specimens from one group is normal, given the fact that the wood is natural material and the samples made out from the same stem could have different

physico-mechanical properties and respectively different acoustic characteristics.

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