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THE INFLUENCE OF ARTIFICIAL AGING ON RESONANCE WOOD ON ITS PHYSICAL CHARACTERISTICS

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Abstract: *The paper presents the research on the physical and acoustic changes of the soundboard exposed to artificial aging. Thus, the spruce and maple wood samples were evaluated in terms of density, wood color and sound propagation speeds before and after exposure to ultraviolet radiation during two exposure cycles equivalent to one year of natural aging. The results showed that the effect of artificial aging is most evident on the color of the wood. The study is important for explaining the phenomena regarding the acoustic quality of old instruments.*

Keywords: *ageing, resonance wood, color of wood.*

INTRODUCTION

Wood is a very complex natural composite, which is based on an ultrastructure of the cell walls and an organization of the wood microstructure that differs from one wood species to another. The main wood substances, cellulose, hemicellulose and lignin, are packed into a composite matrix [1–3]. According to [4–6], the color of wood is affected by long-term aging, being particularly important for the imitation and restoration of old wooden instruments. The aging of wood has effects on both physical and mechanical properties, as a result of the changes that occur in the chemical composition of lignin, cellulose and hemicellulose. These changes, produced slowly and in the presence of vibrations, lead to the acoustic improvement of stringed musical instruments [7–10]. The purpose of the study was to determine the physical and acoustic changes that occur in wooden resonance boards with different anatomical structures.

1. MATERIALES AND METHODS

a. Materials

Samples of resonance wood used for the construction of violins were analyzed. Thus, 12 samples were prepared as flat plates with a thickness of 4 mm and a length of 240 mm, a width of 80 mm, six of them made of spruce wood and other six from maple wood. The samples were grouped into 2 classes of anatomical wood quality: class A characterized by a regular anatomical structure of annual rings in spruce wood and a wavy fiber structure in maple wood, respectively class D characterized by wider annual rings in spruce wood and straight fiber in maple wood (Figure 1). The anatomical features of resonance spruce are described by [9] and characterized the resonance spruce used for violins construction. The samples were coded according to the following principle: The first letter represents the species (M-spruce (Romanian language Molid) P-Maple (Romanian language Paltin)), the next letter represents the quality class (A and D), the next group of letters represents the treatment to which the samples were subjected (UV-ultraviolet exposure) and the number represents how many samples are in the same category. Table 1 shows the physical characteristics of the samples taken in the study.

a) b)

Figure 1: Wood samples: a) resonance spruce; b) resonance maple

Table1. **The physical characteristics of the species**

Code of sample	Type of wood species	Moisture content (%)	Mass m(g)	Density (g/m^3)
MA UV 1	Species class A (Picea Abies)	7.5	37.08	0.483
MA UV 2		8.0	39.10	0.509
MA UV 3		7.7	33.43	0.435
MD UV	Species class D	7.7	30.50	0.397

1	(Picea Abies)			
MD UV 2		7.7	34.80	0.453
MD UV 3		7.5	34.04	0.443
PA UV 1	Species class A (Acer Pseudoplatanus)	6.7	53.48	0.696
PA UV 2		7	54.22	0.706
PA UV 3		7.4	52.38	0.682
PD UV 1	Species class D (Acer Pseudoplatanus)	7.4	47.65	0.620
PD UV 2		6.7	48.57	0.632
PD UV 3		5.7	46.07	0.600

b. Methods

i. Determination of wood color

The color of the wood is affected by the physical characteristics and surface roughness. For color quantification, the CIELab chromatic space was chosen, described by the following coordinates: L* represents the brightness measured in percentage (%); a* represents the degree of red, if the indicated value is positive (+) or the degree of green, if the indicated value is negative (-); and b* represents the degree of yellowness if the indicated value is positive (+) or the degree of blueness if the indicated value is negative (-). The color was measured on each sample in 3 points (center, and symmetrical to the center at 40 mm) according to Figure 2.

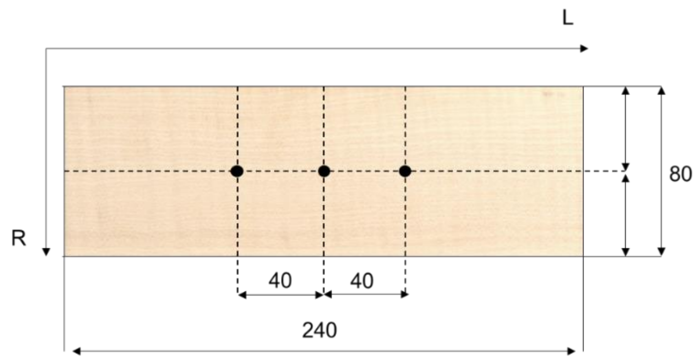
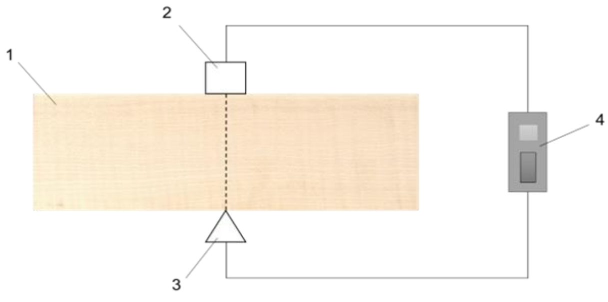


Figure 2: The principle of measuring the color of wood on the studied samples

ii. Determination of sound propagation speeds

The determination of the sound propagation speeds in wood in the longitudinal and radial direction was carried out according to the scheme in Figure 3. The wood sample (1) is fixed between the two transducers (2-transmitter and 3-receiver) of the ultrasound device that transmits the flow of ultrasound through the investigated material, and through the receiver captures the signal. Both the input and output signals are analyzed and compared in relation to time by means of the microcontroller incorporated in the LUCCHIMETTER portable ultrasound device, Cremona Italy (4).



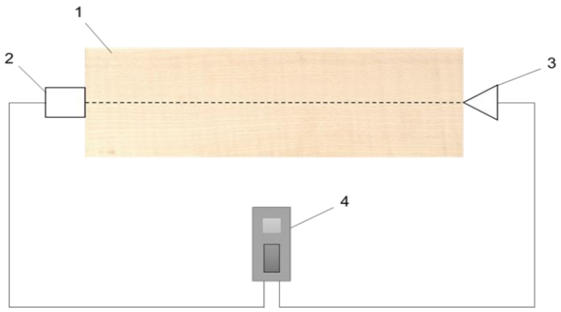


Figure 3: Scheme for measuring the speed of sound propagation: a) radial; b) longitudinal. Legend: 1 – sample; 2 – transmitter; 3 – receiver; 4 - LUCCHIMETTER portable ultrasound device

Connections are made through wiring that is protected against electromagnetic interference. The receiver is covered with an elastic surface to achieve a perfect contact between the transducer and the sample. An important parameter that intervenes in the correct measurement of the propagation speed is the humidity of the wood. Depending on its value, a correction factor is introduced in the device software to determine the correct propagation speed. Also during the measurement phase, the size (distance) between the transducers is entered into the software of the device in order to be able to calculate the speed, as a distance/time ratio - in m/s. These parameters were measured both before and after the application of the artificial aging treatment.

iii. Artificial aging of the samples

In the case of experimental tests, it is very important to keep the working conditions constant in order to be able to compare the obtained results. Thus, a photocatalytic reactor equipped with 3 tubes F 18W/T8 (Philips) placed circularly inside it was used for the static photo-degradation processes of the samples. A similar procedure was also approached in the studies [10–12]. Each tube emits UV radiation with wavelengths between 340-400 nm with $\lambda_{max} = 365\ nm$. For each of the three lamps there is a switch, and for checking the samples there is a door to be observed as can be seen in Figure 4.

Figure 4: Photocatalytic reactor used for aging

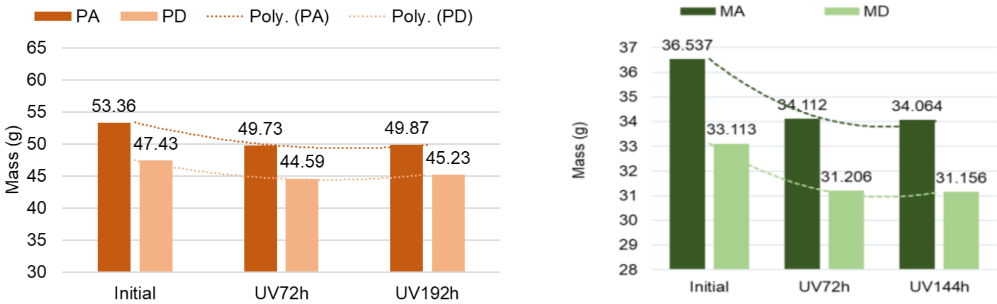
Thus, the spruce samples were successively exposed for 72 hours in 2 stages, measuring after each stage the color of the wood, the propagation speeds, the mass and the humidity. For the maple samples, the exposure was carried out in the same way, they were subjected to treatment for 72h in the first stage and 120h in the 2nd stage.

2. RESULTS AND DISCUSSION

1.1. The influence of artificial aging on the color of wood

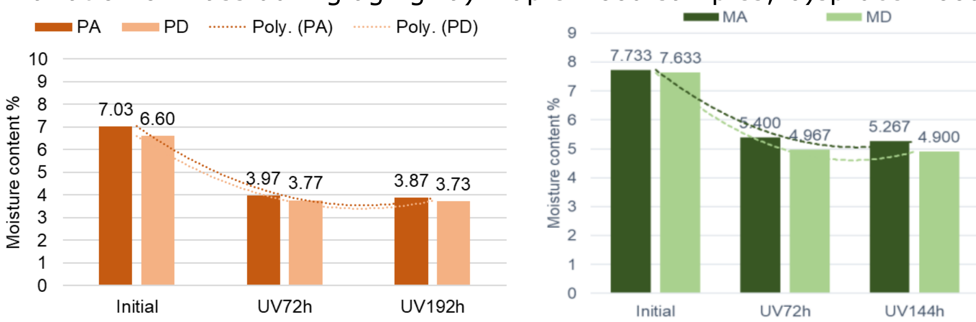
As a result of the artificial aging tests, changes can be observed in the case of all parameters measured in both maple and spruce according to the following figures. After making the necessary graphs and calculations, the following observations can be made: in the case of maple wood in the first phase the mass decreased by 6.8% in the case of quality class A and by 5.99% in the case of class D. In the 2nd stage the mass increased by 0.28% (class A) and by 1.44% (class D); in the case of spruce wood, the mass decreased in the first stage by 6.63% (class A) and by 5.57% (class D), in the 2nd stage it continued to decrease by 0.14% (class A) and by 0.16% (class D); the major decrease occurred for both species in the first stage where the quality classes were similar, with class A having a greater decrease. In the 2nd stage the maple wood had a minor increase in mass while the spruce wood continued to decrease as can be seen in Figure 5. The moisture content decreased in both stages, for quality class A but also for D in the case of both species as can be seen in Figure 6.

The moisture content of maple wood decreased in the first stage by 43.6% (class A) and by 42.92% (class D), while in the 2nd stage the decreases were significantly lower: 2.52% (class A) and 0.88% (class D). In the case of the spruce samples, although the decrease was not as great as in the maple wood in the first stage, 30.17% (class A) and 34.93% (class D), it was significant and it can be seen that both species had a similar reaction after treatment. In the second stage the difference was 2.46% (class A) and 1.13% (class D).



a) b)

Figure 5: Variation of mass during aging: a) maple wood samples; b)spruce wood samples



a) b)

Figure 6: Variation of moisture content: a)maple wood samples; b)spruce wood samples

Regarding the modification of wood color, maple wood had a decrease in brightness of 3.43% (class A) and 4.76% (class D) in the first stage, while in the 2nd stage the difference was 1.59% (class A) and 1.61 % (class D). In spruce wood, in the first stage the brightness decreased by 4.41% (class A) and 4.35% (class D), and in the 2nd stage by 2.09% (class A) and 2.55% (class D). The two species are anatomically different so it is normal to have differences in initial and final colors as shown in Figure 7 (a and b). In the case of the degree of redness, both species had increases, but greater changes can be observed in the case of spruce wood in Figure 7 (c and d). The maple samples, in the first stage, the degree of red increased by 4.71% (class A) and 27.03% (class D), and in the 2nd stage by 17.76% (class A) and 24.75% (class D).

Spruce samples, in the first stage, the degree of red increased by 27.26% (class A) and 19.92% (class D), and in the 2nd stage by 37.21% (class A) and 41.11% (class D). The maple samples, in the first stage, have increased yellowness by 12.65% (class A) and 18.63% (class D), and in the 2nd stage by 16.41% (class A) and 17.16% (class D) (Figure 7, e). Spruce samples, in the first stage have the degree of yellowness increased by 24.15% (class A) and 24.16% (class D), and in the 2nd stage by 16.15% (class A) and 15.28% (class D) as can be seen in Figure 7, f.

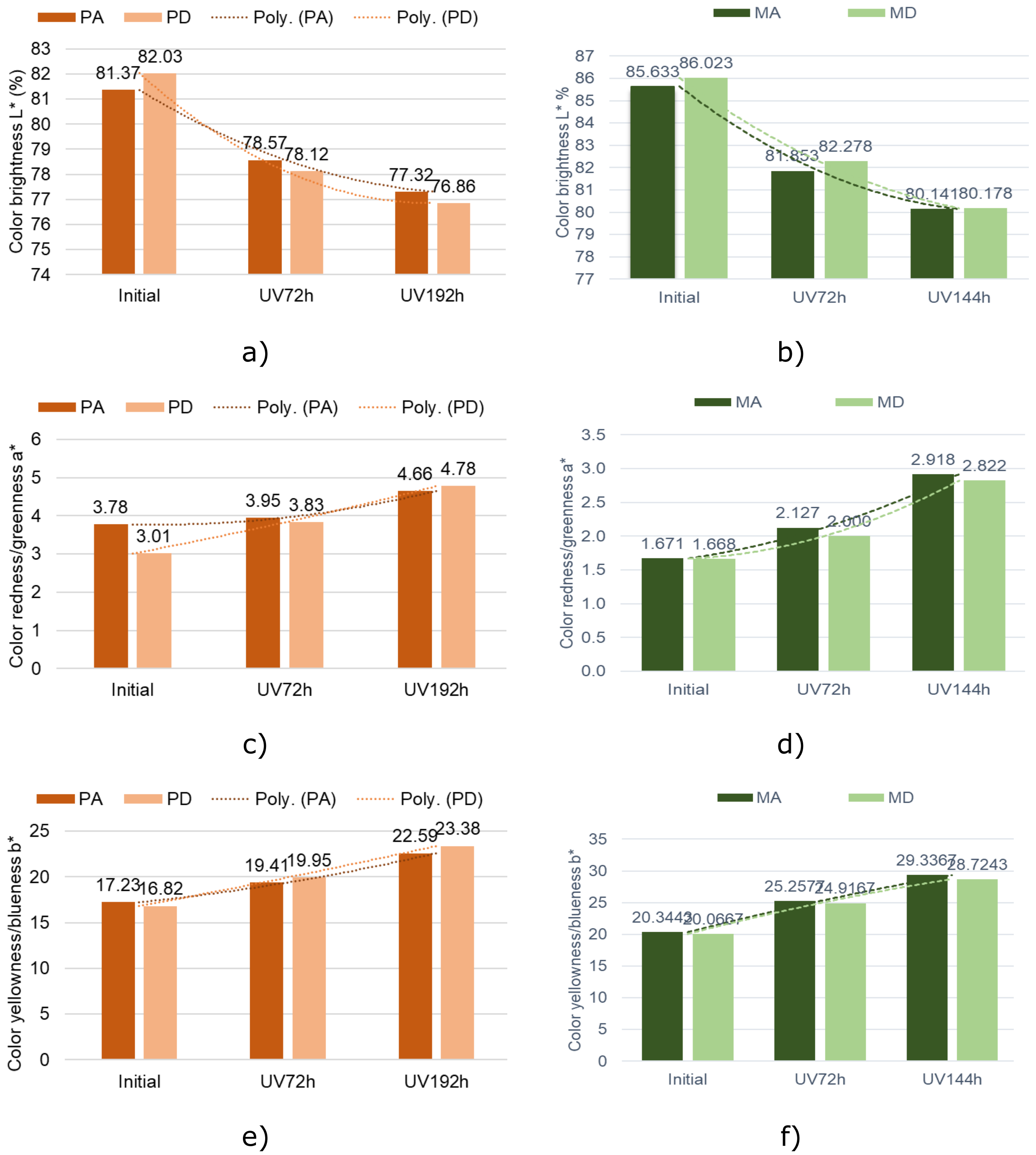


Figure 7: Variation of color parameters: a) color brightness of maple wood samples; b) color brightness of spruce wood samples; c) color redness of maple wood samples; d) color redness of spruce wood samples; e) color yellowness of maple wood samples; f) color yellowness of spruce wood samples

2.2. The influence of UV radiation on acoustic properties

Regarding the sound velocity in wood, it was noticed that the maple samples, in the first stage, have the longitudinal propagation speed increased by 1.71% (class A) and 2.31% (class D), and in the 2nd stage by 3.34% (class A) and 1.98% (class D) (Figure 8,a). The spruce samples, in the first stage, have the longitudinal propagation speed increased by 3.22%

(class A) and 3.15% (class D), and in the 2nd stage by 1.11% (class A) and 0.09% (class D) (Figure 8,b). The speed of sound propagation is an important parameter in the manufacture of musical instruments. Both species had increases as can be seen in Figure 8.

In case of radial propagation speed, the maple samples, in the first stage recorded an increases by 9.39% (class A) and 5.82% (class D), and in the 2nd stage by 0.53% (class A) and a decrease of 13.29% can be observed (class D) (Figure 8,c). Spruce samples, at the first stage, the radial propagation speed decreased by 0.54% (class A) and an increase of 3.61% (class D) can be observed, and in the 2nd stage a decrease by 0.71% (class A) and an increase of 3.53% (class D) (Figure 8,d).

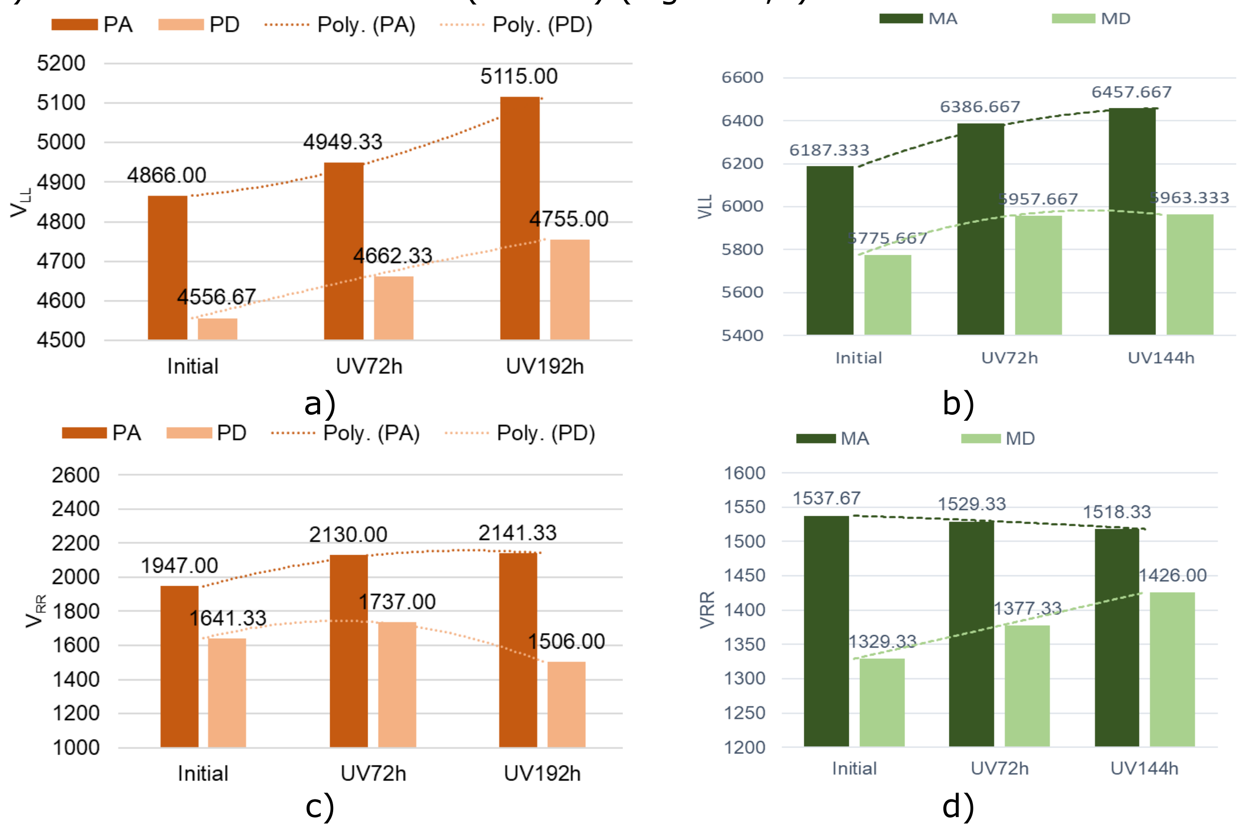


Figure 10: Variation of soun velocity in wood: a) longitudinal sound velocity in maple wood samples; b) longitudinal sound velocity in spruce wood samples; c) radial sound velocity in maple wood samples; d) radial sound velocity in spruce wood samples

3. CONCLUSION

In conclusion, it can be appreciated that the artificial aging of resonance wood shows the greatest surface degradation, manifested by changes in the color of the wood, in the first stage of exposure to UV radiation, followed by a decrease in the speed of change in physical parameters. In the following studies, the samples will continue to be subjected to artificial aging and will also be investigated from the point of view of modal analysis.

ACKNOWLEDGEMENT

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