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RESEARCHES CONCERNING THE ACOUSTIC PROPERTIES OF TONE WOOD USED ON MUSICAL INSTRUMENTS STRUCTURES

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ABSTRACT

The paper presents some aspects regarding to the connections of the features of wood and lingo-cellulose composites used for musical instruments manufacturing and the particulars of shape, structure and quality of instruments.

The paper is organized on three main units. The first unit presents the acoustic properties of wood regarding to: sound velocity in wood, specific acoustic impedance, acoustic damping, acoustic insulation, wood resonance. The second part of paper brings into focus the most important species of resonance wood from the point of view of the quality criteria of wood and materials based on wood used for musical instruments construction. The last part of study presents the experimental results obtained by the cyclic stresses applied to the plates of different guitars.

It is important to know the acoustic features of tone wood in correlation with the mechanical properties of wood (resistance to the cyclic stresses, the stiffness on the three main directions, density, the moisture content of wood) for the manufacture of qualitative musical instruments suitable for types of music and personal style of artists.

Keywords: resonance wood, acoustic quality, sound velocity in wood, cyclic stresses, fundamental frequency, amplitude, harmonic frequency

1. THE ROLES OF WOOD AND LIGNO CELLULOSE MATERIALS USED IN THE MUSICAL INSTRUMENTS STRUCTURES

Theoretically, the resonance is the vibration state of a solid or physic system when stressed by an exterior cyclic stress with a frequency more or less equal with fundamental frequency of the body or the system. From this point of view, wood, due to its intrinsic properties, has more harmonic frequencies, among which the natural frequency responsible for the tone colour and acoustic characteristic of the grade. Depending on the period of outer vibration, the resonance occurs every time the forced circular frequency passes in the vicinity of the fundamental frequency of wood [2]. The suitable wood for musical instruments manufacturing is picked out in accordance with the acoustic, physical and aesthetic properties of wood.

The main acoustic properties of tone wood are:

- *The sound velocity in wood* c_L relates to the longitudinal and transversal sound spreading speed in the solid (wood). Many studies have established the importance of longitudinal sound velocity compared to the transversal one, which is to 3-5 times smaller and the radial values are bigger than the tangential section [1]. The tests using the ultrasound method [7] revealed the following values of the sound velocity in wood for different species – figure 1. The higher the values of this parameter, the better the clarity of sounds. This acoustic parameter depends on the regularity of grain, density and moisture contents of wood.

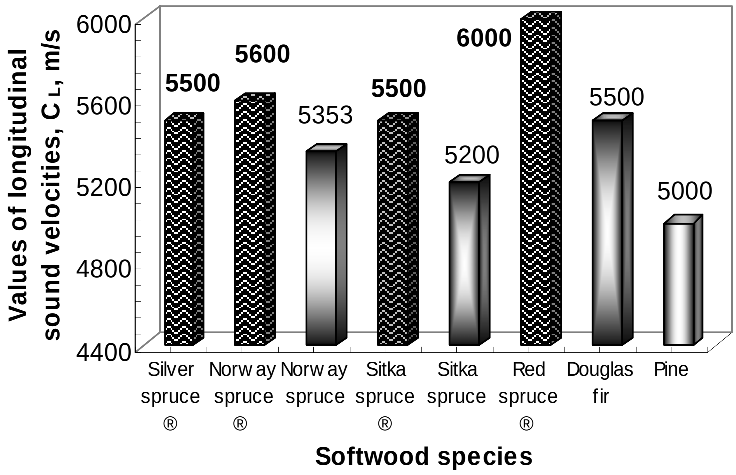

Figure 1. Average values of ultrasonic velocities (m/s) in different softwood species

- *The specific acoustic impedance (resistance)* R_a refers to the resistance of wood to the wave passage through its mass [3]. In the case of the tone wood, the values of acoustic impedance are low, which means lighter sounds.
- *The acoustic radiation K (the constant of acoustic radiation* – [8]) represents an important criterion to appreciate the resonance wood. The high values of this parameter indicate top quality of wood used for instrument manufacturing, the minimum being 10 $m^4/(N\ s^2)$, for a 10% moisture content [1].
- *The quality factor of the vibration damping Q* stands for the loss of vibration energy due to the internal friction which leads to the damping of sounds, after the forced vibrations have stopped. In the case of simple, even, continuous structure, the values of this parameter is high and proportional with sound velocity in wood. Table 1 provides the optimum values of the acoustical properties of resonance wood [1].

Table 1. The values of the main acoustic features of the resonance spruce

Types of acoustic properties	The limits values for carpathian spruce
Sound velocity in wood C_L [m/s]	4800-5700
Acoustic radiation K [$m^4/(kg\ s)$]	10.00 – 13.90
Internal friction δ	< 0.02
Quality factor Q	> 100 (105)
Specific acoustic impedance R_s [$N\ s/m^3$]	(2.16 -2.5) 10^6
Density ρ [kg/m^3]	400-500

2. THE QUALITY CRITERIA OF THE RESONANCE WOOD

There are many theories about the genetic morphological particularities, the growth conditions of resonance wood, the optimum period of time to harvest, the conversion pattern of round wood and the adequacy between wood properties and instrument types. Some researchers consider that the growth of tone wood is influenced by heredity and, more importantly, by the combined effect of numerous factors related to climate, soil, relief, environment and anthropology. It was established that these trees grow at relatively high altitudes (700-1200 m), in the alpine depressions or on the northern, partially-shaded, low-wind declivities. In our country, the resonance spruce used to grow mainly in the North of The Oriental Carpathian Mountains, the most famous being the Moldovita and Tomnatic forest areas.

Nowadays, due to the depletion of resonance spruce sources in the Romanian Carpathians, the research has been oriented towards reforestation to preserve the characteristics of this type of wood [1]. In these areas the soil is poor in minerals, clayey – sandy – limy, light acid, formed on volcanic layers. On the other hand, the specialists at the Columbia University of New York consider that the main influence is the constant climatic conditions during the growth period of wood (the annual average temperature ranges between 3.5 and 6^0 C).

The resonance spruce trees are distinguishable due to their cylindrical, narrow crown with thin branches, which give then a frail appearance. This type of crown retains only small quantities of snow, which assures increased resistance to breakage. Their roots produce abutments with stability function against the wind force. The analyses of the cross sections of wood at a height of 1.30 m from the soil, allowed the detection of two (and sometimes three) regions, based on the evennes and width of annual rings: the inner region – formed in the first part of the tree life, characterized by variation of annual rings width and the outer zone - full grown after 50 years of age, characterized by narrow and even annual rings width, which represents the resonance wood [1]. In the case of cut trees, the identification takes into account macroscopic aspects, such as: the regularity of annual rings width, range to 1-2(3) mm, the low proportion of latewood by reason of that the colour of wood is lighter (less than 20-35% of the annual rings width), thin medullar rays, low density (below 0.450g/cm^3), without resin pockets, the even white – whitish colour, silken lustre, striped grain, the suitable dimensions to radial conversion of round wood (diameter bigger than 500 mm). The conversion pattern, the trimming and dimensional grading, the stacking of the sawn timber, the storage and preservation, the air drying of the pieces are other factors which may affect the acoustic quality of tone wood. The timber is obtained by means of band saws for quarter sawing. In this end, the destination of timber products, the grade and the matching of pieces for stacking are established since the round wood conversion. The air drying period ranges between 5 (3) and 10 (12) years according to the quality of the musical instruments. Kiln drying - even the soft drying schedule – is avoided because of the occurrence of the internal tension and other microcellular phenomena which destroy the acoustic quality of resonance wood. After that, are obtained the ligno-cellulose plates (made from solid wood or plywood) with thicknesses range between 2.2…2.8 mm.

3. THE TESTS OF DIFFERENT TYPES OF PLATES

The experimental test consists in recording the transitory process, using the oscillograph. The samples were five different guitars, using the same type of strings (table 2).

Table 2. The physical features of the different strings of guitar

Composition	Mi 1 (329,2 Hz)	Si (246,9 Hz)	Sol (196 Hz)	Re (146,83 Hz)	La (110 Hz)	Mi (82,41 Hz)
Steel (diameter) Φ [mm]	0.25	0.35	0.30	0.30	0.30	0.40
CuAg (diameter) Φ [mm]	-	-	0.15	0.25	0.40	0.40
Mass m [g/cm]	0.00365	0.0075	0.019195	0.03425	0.0669875	0.0743275

The first step was to excite the free chords which were tensioned at the proper frequency. The frequency response was recorded with apparatus. The second step was to excite the strings which were fitted on samples. The transitory process was recorded graphically too. The aims of this experiment were on one hand to analyse the connection between the physical features of strings and the vibration behaviour, and on the other hand, the way in which the different structures of guitars can amplify or damp the vibration.

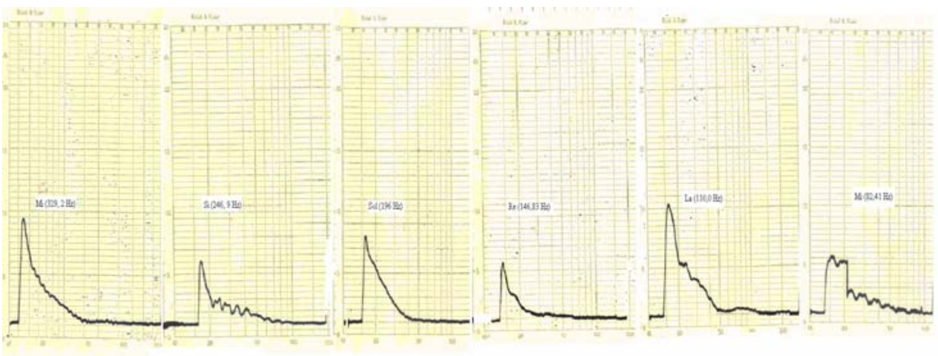

Figure 2. The transitory process for strings with different characteristics

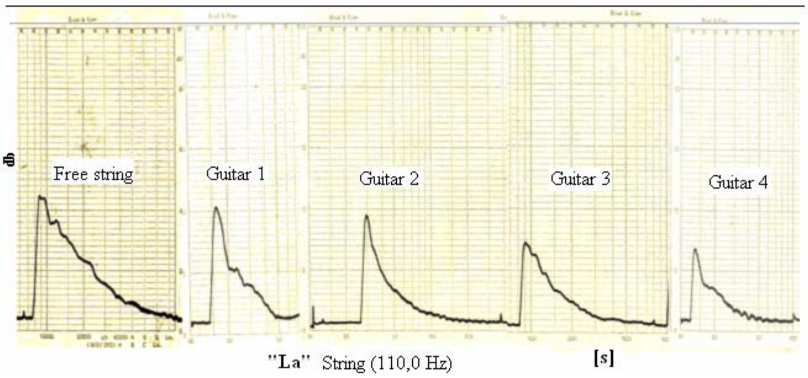

Figure 2. The transitory process of the "La" string for different types of guitars

4. DISCUSSION

The results bring the following: the strings made from one material (as steel –Mi 1, Si) disseminate the fundamental frequency and little harmonics at the high intensity during a short time. Contrary, the vibrations of strings with bigger mass have a long time to damp and many harmonics.
The material and structure type of guitars influence the transitory process and the intensity of sound.

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